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Economic analysis for the Renewable Heat Incentive for Ireland

Section 1:
Main Report
&
Section 2:
Additional Analysis for the RHI Business Case

for

Sustainable Energy Authority of Ireland (SEAI)

and

Department of Communications, Climate Action & Environment (DCCAE)

December 2017

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Introduction and structure of this report

This report is a study of potential design options for a Renewable Heat Incentive (RHI) for Ireland and was commissioned by the Department of Communications, Climate Action and Environment (DCCAE).

As part of Ireland's strategy to meet its obligations under the 2009 Renewable Energy Directive, the Government targets the delivery of 12% of final heating demand from renewable sources by 2020. While the deployment of renewable heating technologies has progressed significantly in recent years, reaching 6.5% of heat demand in 2015, recent analysis by the Sustainable Energy Authority of Ireland (SEAI) states that under the current set of policies the 2020 target will not be met.

In order to address this policy 'gap', a cross-governmental working group has recommended that an Exchequer-funded Renewable Heat Incentive (RHI) could be implemented. The Department of Communications, Climate Action and Environment (DCCAE) is leading the process to consult upon and design this policy.

The objective of this study was:

- to undertake an economic assessment of the cost of introducing a Renewable Heat Incentive with the objective of meeting Ireland's 2020 renewable heat target; and
- to develop a set of cost-effective design options for the Renewable Heat Incentive structured in such a way as to support investment in the efficiency and effective design, installation and operation of renewable heating technologies.

This report is divided into two sections, as follows.

Section 1: *Main report*. The main report describes the RHI design work undertaken to March 2017. An adjunct to the main report was produced following this, and delivered in September 2017, in which further design options for the RHI were considered, including variations in scheme eligibility and technology coverage.

Section 2: *Additional Analysis for the RHI Business Case*. In October to December 2017, further work was carried out as part of the development of the Draft Business Case for the RHI. This included the assessment of additional scenarios for the RHI, a comparison of the RHI with a grant-based approach, and an update to the main assumptions following a review of fuel prices and new information relating to the Renewable Electricity Support Scheme.

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Section 1: *Main report*

for

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Acronyms

AD	Anaerobic digestion
ASHP	Air source heat pump
CF	Counterfactual technology
CHP	Combined heat and power
CO_2-eq	Carbon dioxide equivalent
CPI	Consumer price index
EfW	Energy from waste
GHG	Greenhouse gas
GSHP	Ground source heat pump
HHL	High heat load
IRR	Internal rate of return
LHL	Low heat load
MHL	Medium heat load
MSW	Municipal solid waste
NPC	Net present cost
NPV	Net present value
RH	Renewable heat
RHI	Renewable heat incentive
RHT	Renewable heating technology
WSHP	Water source heat pump

1 Executive summary

This report is a study of potential design options for a Renewable Heat Incentive (RHI) for Ireland and was commissioned by the Department of Communications, Climate Action and Environment (DCCAE).

As part of Ireland's strategy to meet its obligations under the 2009 Renewable Energy Directive, the Government targets the delivery of 12% of final heating demand from renewable sources by 2020. While the deployment of renewable heating technologies has progressed significantly in recent years, reaching 6.5% of heat demand in 2015, recent analysis by the Sustainable Energy Authority of Ireland (SEAI) states that under the current set of policies the 2020 target will not be met. Given an estimated heat demand of 48.9 GWh in 2020, the 12% target equates to 5,870 GWh of renewable energy for heating.

In order to address this policy 'gap', a cross-governmental working group has recommended that an Exchequer-funded Renewable Heat Incentive (RHI) could be implemented. The Department of Communications, Climate Action and Environment (DCCAE) is leading the process to consult upon and design this policy.

The basic structure of the RHI is proposed to be a payment offered to producers of renewable heat on a 'per unit of energy produced' basis, with the payment intended to cover the additional cost of generating heat using a renewable technology as compared with a fossil fuel alternative, including the additional cost associated with perceived barriers.

DCCAE intends to hold a second public consultation on the RHI, focusing on the design options for the policy and requirements for implementation. This study is intended to provide the evidence base to inform the second public consultation. In particular, this work was commissioned in order to:

- Undertake an **economic assessment of the cost of introducing an RHI** with the objective of meeting Ireland's 2020 renewable heat target;
- Develop a **set of cost-effective design options for the RHI** structured in such a way as to support investment in the efficiency and effective design, installation and operation of renewable heating technologies.

The following renewable heating technologies were included in the economic assessment[1]:

- Biomass boiler
- Biomass combined heat and power (CHP)
- Biomass direct air heating
- Ground-source heat pump
- Air-source heat pump
- Water-source heat pump
- Deep geothermal
- Anaerobic digestion (AD) CHP[2]

[1] Descriptions of each renewable heating technology are provided in Appendix 1a
[2] AD CHP, AD boiler and biomethane were included in this study via the interface study 'Interface analysis and report for incorporation and alignment of data from biomethane study into RHI workstream'

- Anaerobic digestion (AD) boiler[2]
- Biomethane grid injection[2]
- Solar thermal

A desk-based assessment was carried out by Frontier Economics as part of this study, with the primary aim of identifying:

1. An initial longlist of design options for the RHI;
2. A list of assessment criteria against which the design options should be compared.

The assessment includes a literature review of evidence from RHI schemes in other countries, with a strong focus on the UK RHI scheme, along with a first-principles economic assessment of tariff design options. The full assessment[3] is available as an annex to this report.

In addition, stakeholders from a total of 26 different organisations were consulted as part of this study[4]. The consultations had three main objectives, namely to:

1. Collect the best available and up-to-date data on renewable heating technology costs and operational performance in the Irish context;
2. Gain insight on relevant technology constraints and non-cost barriers to deployment;
3. Provide initial feedback on proposed RHI design options.

We are grateful to the following stakeholders for participating in the consultation and providing much of the useful data and commentary contained in this report. However, the final responsibility for the details contained in the report lies with us, the authors.

- Ashgrove
- Bord Na Mona
- Codema
- Coillte
- Confederation of European Waste-to-Energy Plants Ireland (CEWEP Ireland)
- Cre
- Dept. of Agriculture
- Dept. of Environment – Northern Ireland
- Dept. of Environment – Republic of Ireland
- Dr Ger Devlin, University College Dublin
- Electricity Supply Board
- Environmental Protection Agency
- Gaelectric

[3] Frontier Economics, *Task 1 – Review of RHI Design Options: A report prepared for DCENR*, August 2016

[4] An additional stakeholder consultation was undertaken by Ricardo Energy & Environment, focusing on AD and biomethane technologies. The full list of organisations consulted is given in an Appendix.

- Gas Networks Ireland
- Geothermal Association of Ireland (GAI)
- GI Energy
- Glen Dimplex
- Green Energy Engineering
- Heat Pump Association of Ireland (HPA)
- Irish BioEnergy Association (IrBEA)
- Letterkenny IT
- Renewable Gas Forum – Irish Green Gas Ltd
- Sustainable Energy Authority of Ireland (SEAI)
- Teagasc
- Terawatt Ireland
- Tipperary Energy Agency

Following this process, the stakeholder views on the desirable outcomes of the RHI were used to produce the shortlist of assessment criteria summarised in Table 1-1.

Table 1-1: Summary of assessment criteria

Assessment criterion	Description
1. Incentivising an efficient level of investment to meet the target	Does the design option have the potential to meet the RES-H target, and would it result in the overall least cost mix of investment to reach the target?
2. Minimising costs to the Exchequer (and appropriately profiling overall costs)	Does the design option minimise costs, and find the right balance between lowest overall cost, and short term budget pressures?
3. Impact on CO_2	What impact would the design option have on CO_2 emissions?
4. Impact on particle emissions from biomass	What impact would the design option have on particle emissions from biomass?
5. Allocating risks efficiently	Does the design option allocate risk efficiently, such as between government and the sector?
6. Incentivising efficiency at the system specification, installation and operation stages	Does the design option promote efficient and effective design, installation and use of systems?
7. Impact on the diversity of the renewable heating technology mix	Would the design option lead to a diverse technology mix?
8. Complexity/clarity	Would the complexity of the design option deter investors?
9. Impact on the market/sustainability	What is the impact of the design option on the low-carbon heating sector in Ireland beyond 2020?

The outputs from the desk-based assessment were combined with stakeholder consultation feedback to develop a long list of RHI design options, as summarised in Table 1-2. This study considers the possible implications of each design option.

Table 1-2: Summary of design aspects

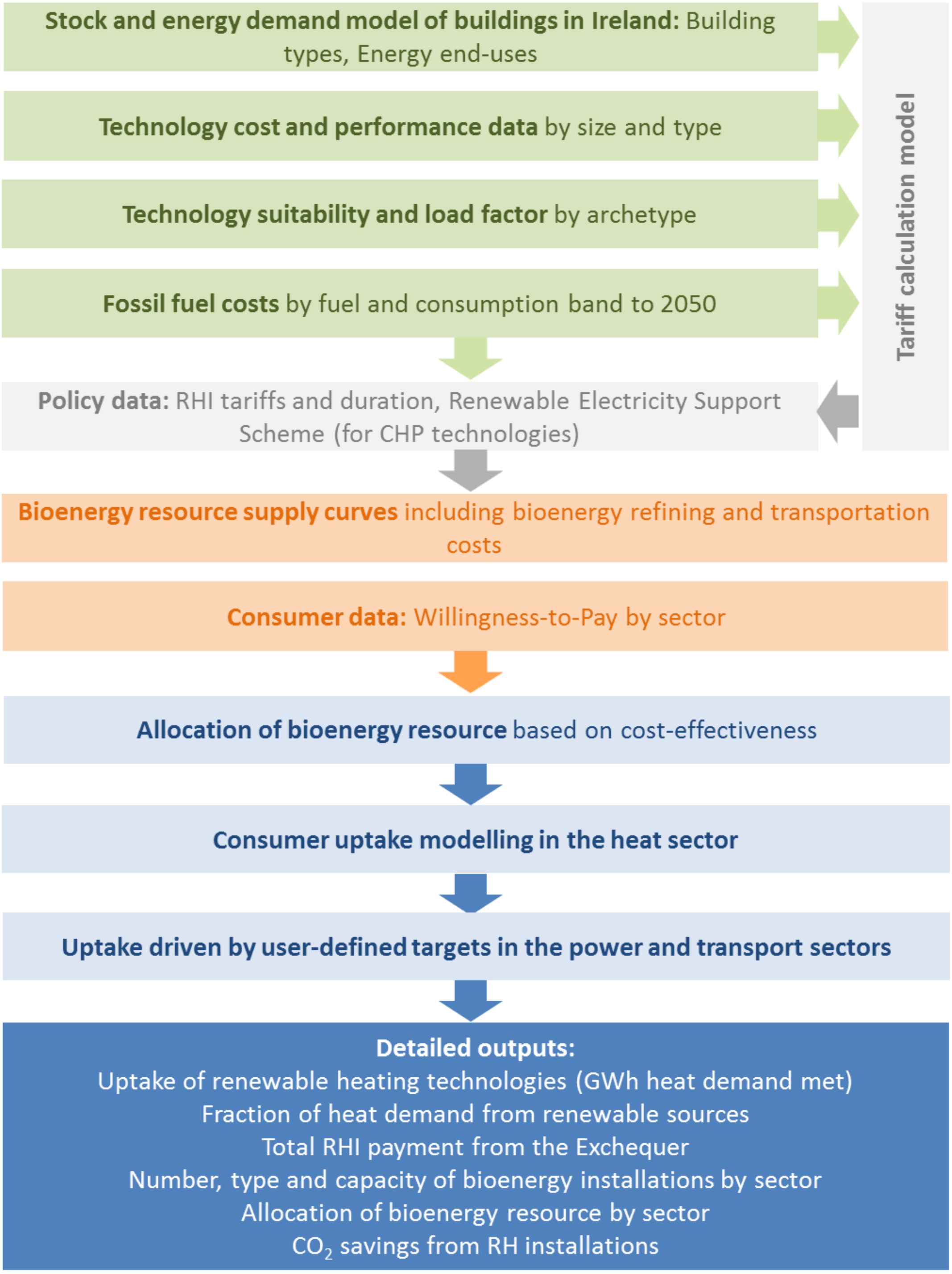
Design aspect	Options
1. Differentiation by technology	Whether a single tariff is offered for each technology or groups of technologies, or whether the same tariff is offered to all technologies
2. Differentiation by installation size	Whether the tariff is differentiated by installation size, such as on the basis of the installed capacity of the system or the annual heat generated
3. Minimum energy efficiency criteria for participant eligibility	Whether any minimum energy efficiency eligibility criteria for the building or heat use are included
4. Minimum biomass sustainability criteria for participant eligibility	Whether any minimum biomass sustainability criteria are included and if so, the stringency of the criteria
5. Maximum particulate and other emission levels for participant eligibility	Whether any maximum particulate matter and other emission limits are included and if so, the stringency of the limits implied
6. Location-based eligibility for biomass	Whether any constraints are placed on the location of biomass installations on the basis of the air quality impacts
7. Duration of support and profile of payments to participants	What duration of support the RHI is provided over and whether the profile of payments is flat or front-loaded
8. Payment based on metered or deemed heat	Whether the payments are based on metered or deemed heat use and whether this is differentiated by installation size
9. Systematic adjustment of tariffs	Whether any systematic adjustment of tariffs and/or budget management mechanisms are included in the scheme
10. Allowed rate of return	What rate of return is allowed for the scheme participants
11. Age of heating systems targeted for replacement	Whether the RHI is designed to target replacement of counterfactual heating systems at the end of life only or to also incentivise early replacement of systems
12. Implementation options	Whether the scheme is implemented via an online scheme only or if a paper-based option is also available; whether the scheme is administered by CER or by another third-party
13. Type of counterfactual heating systems targeted for replacement	Whether the RHI is designed to target replacement of all counterfactual technologies or only certain counterfactual technologies
14. ETS sector eligible for RHI	Whether the ETS sector is eligible for support in the RHI scheme

Methodology

The RHI tariff calculation is based on a detailed stock and energy demand model of buildings in Ireland. The total payment required for each archetype is determined as that required to cover the difference between the net present value of the renewable system and that of the existing fossil fuel counterfactual, accounting for the payment profile and the investor discount rate. The tariffs required by individual archetypes are divided, according to the RHI design option under consideration, into 'segments' differentiated by technology and size. Within each segment, a *reference installation* is identified, on which the tariff for that segment is based.

The uptake of RH technologies, under each RHI design scenario considered, is modelled using the BioHEAT model developed recently by Element Energy and the Sustainable Energy Authority of Ireland (SEAI). The uptake modelling process using BioHEAT is summarised in Figure 1-1.

Figure 1-1: High-level summary of RHI uptake modelling process using BioHEAT model



Based on the stakeholder consultation and desktop review, and following initial rounds of modelling and discussion with the project steering board, the shortlist of scenarios shown in Table 1-3 was agreed to assess the various design options and sensitivities. For each scenario, the design options were used to set the RHI tariffs and determine the eligibility of archetypes. These were then fed in to the uptake model. The full scenario definition is described in section 5.1. The key results of the scenarios are summarised in Table 1-4.

Table 1-3: Summary of shortlisted scenarios (the default options are shown in Table 5-1 in the main report)

Type	ID	Scenario name
RHI design scenarios	1	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
	2	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price
	3	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 9 c/kWh biomass price
	4	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 9 c/kWh biomass price
	5	Tariffs capped at biomass boiler tariffs
	6	Tariffs capped at 10 c/kWh
	7	Shorter duration (7 yrs)
	8	Higher IRR (12%)
	9	Lower IRR (6%)
	10	Shorter duration (7 yrs) and Higher IRR (12%) except for biomass-based techs for which retain 15 yr duration and 8% IRR
	11	High power sector biomass demand
	12	Include ETS sector - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price
	13	Include ETS sector - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
No RHI baseline cases	N1	No RHI - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
	N2	No RHI - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price

Table 1-4: Summary of key results of shortlisted scenarios

Type	ID	Scenario name	% renewable heat (fraction of heat from renewable sources)	Total cost to the Exchequer 2018-2034 (€ million, undiscounted)	Total CO_2 savings 2016-2034 ($MtCO_2$)
RHI design scenarios	1	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price	13.4%	1,622	21.5
	2	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price	12.1%	2,355	19.3
	3	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 9 c/kWh biomass price	18.0%	5,964	28.9
	4	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 9 c/kWh biomass price	12.1%	3,606	18.5
	5	Tariffs capped at biomass boiler tariffs	12.0%	1,188	18.9
	6	Tariffs capped at 10 c/kWh	12.0%	2,213	19.2
	7	Shorter duration (7 yrs)	12.8%	2,449	20.3
	8	Higher IRR (12%)	12.4%	3,310	19.9
	9	Lower IRR (6%)	12.0%	2,028	19.1
	10	Shorter duration (7 yrs) and Higher IRR (12%) except for biomass-based techs for which retain 15 yr duration and 8% IRR	13.3%	3,391	21.9
	11	High power sector biomass demand	11.4%	2,050	16.5
	12	Include ETS sector - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price	12.1%	2,512	19.6
	13	Include ETS sector - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price	13.4%	1,746	21.8
No RHI baseline cases	N1	No RHI - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price	9.9%	N/A	12.0
	N2	No RHI - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price	9.5%	N/A	11.3

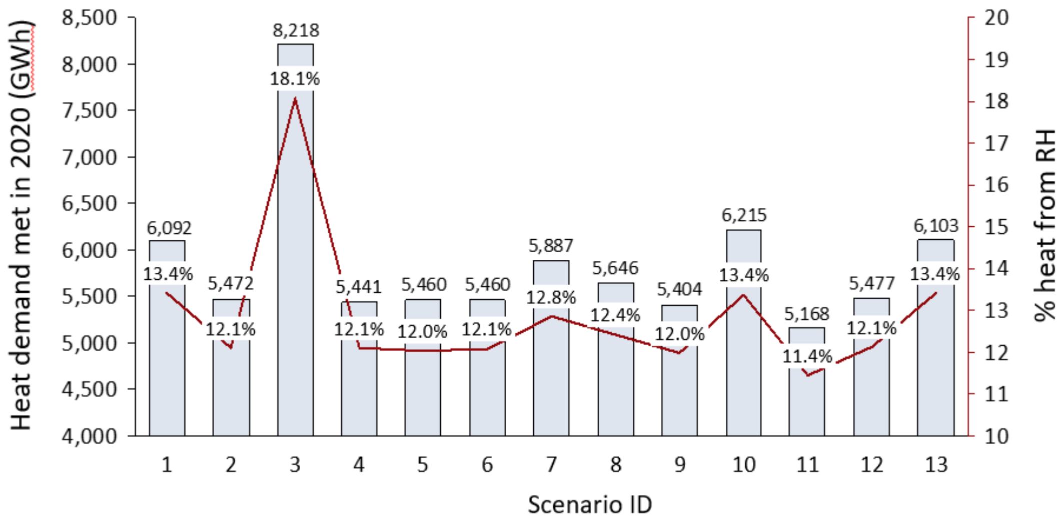
Key findings

The key findings of the economic analysis are summarised here, with reference to the assessment criteria listed in Table 1-1.

1. Incentivising an efficient level of investment to meet the target

- The heat demand met by RH technologies and the fraction of heat from renewable sources in 2020 is shown for all shortlisted scenarios in Figure 1-2.
- The availability of biomass is a key constraint on the potential uptake of biomass heating, and has an important impact on whether the 2020 RES-H target can be met. Under the central assumptions for biomass use in the power sector, biomass imports are needed in order to reach the target. The availability and price of imported biomass is controlled to a large extent by external factors (the global balance of supply and demand for biomass); however, any sustainability criteria included in the RHI will have an important impact on both the availability and price of imported biomass.
- When there is a high availability of imported biomass, the payback period, rather than the availability of biomass, limits the uptake of biomass technologies. In this case, the price of biomass fuel (and how this compares with the price applied in the calculation of the RHI tariffs) has a large impact on the uptake of biomass technologies.
- The duration of support and the IRR have a significant impact on the uptake of the technologies whose uptake is limited by the payback periods (i.e. less applicable to biomass technologies, which may be more limited by biomass fuel availability). Shortening the duration of support and/or increasing the IRR (as in Scenarios 7, 8 and 10) results in a higher tariff and correspondingly a lower payback period and hence higher uptake.
- Capping the tariffs (as in Scenarios 5 and 6) impacts the tariffs for the lower tiers (and hence the smallest installations) and for the most expensive technologies. However, given the relatively small contribution from these segments, and the ability for more cost-effective technologies to displace the less cost-effective technologies, capping the tariffs in this way has been found to have little impact on the ability to meet the 2020 target.
- We have also found that a lower uptake of biomass CHP in the power sector – which is dependent on the level of support the technology receives through the Renewable Electricity Support Scheme (RESS) as well as any support it may receive through the RHI – does not adversely impact on the ability to meet the RES-H target. This is because the biomass fuel not used in the biomass CHP installations is instead used to supply additional biomass boiler installations in the heat sector. This is found to (more than) compensate for the reduction in heat output from the biomass CHP. A series of sensitivities undertaken to test the impact of this case is described in section 5.7.2 in the main text.

Figure 1-2: Heat demand met by RH technologies and % heat from renewable sources in 2020 for all scenarios



2. Minimising costs to the Exchequer (and appropriately profiling overall costs)

- The total cost to the Exchequer of the shortlisted RHI scenarios is shown in Figure 1-3, and the annual cost to the Exchequer in 2020 is shown in Figure 1-4.
- Capping all the tariffs at the biomass boiler tariffs (as in Scenario 5) is found to lead to the lowest total costs to the Exchequer, whilst achieving the 2020 RES-H target. This partly reflects the fact that the most costly installations (including the smallest installations and, in particular, the solar thermal installations) are displaced by lower cost installations, but is largely due to the substantially reduced payments for biomass CHP in the power sector. The finding described above (and in section 5.7.2 in the main text), that a reduction in renewable heat production from biomass CHP is expected to be compensated by a corresponding increase in renewable heat output from biomass boilers, suggests that capping the tariffs at the biomass boiler tariffs may be a favourable option.
- The price of biomass used to set the tariffs also has a large impact on the Exchequer costs. When a low price of 5.5 c/kWh, reflecting the low estimate of the price of imported biomass, is used to derive the tariffs for biomass technologies (as in Scenario 1), the overall cost is substantially lower in the cases where a higher price is assumed. Using a higher estimate of the imported biomass price of 6.9 c/kWh (as in Scenario 2), or the price of the most costly domestic resource of 9 c/kWh (as in Scenarios 3 and 4), results in a substantially higher overall cost.
- Particularly high costs to the Exchequer are seen when high biomass tariffs are offered and low cost biomass imports are available as the target is far exceeded. A budget management mechanism, such as tariff degression could be used to constrain the uptake in this case, and hence limit the costs to the Exchequer.
- Increasing the IRR (as in Scenario 8 and 10) increases the total costs to the Exchequer, due both to the increase in the tariffs offered and to the increase in uptake of RH technologies. Decreasing the IRR (as in Scenario 9) leads to a reduction in the cost to the Exchequer; we find this can be achieved for a relatively small penalty in terms of uptake.

- Reducing the duration of support (as in Scenario 7) increases the uptake, particularly of the technologies with high upfront cost such as heat pumps and solar thermal. A reduced duration of support also leads to a relatively low total cost to the Exchequer since the effect of investor discounting is reduced. However, the impact on the annual Exchequer budget is a significant drawback, as the total payment is spread over fewer years.

Figure 1-3: Total costs to the Exchequer 2018-2034

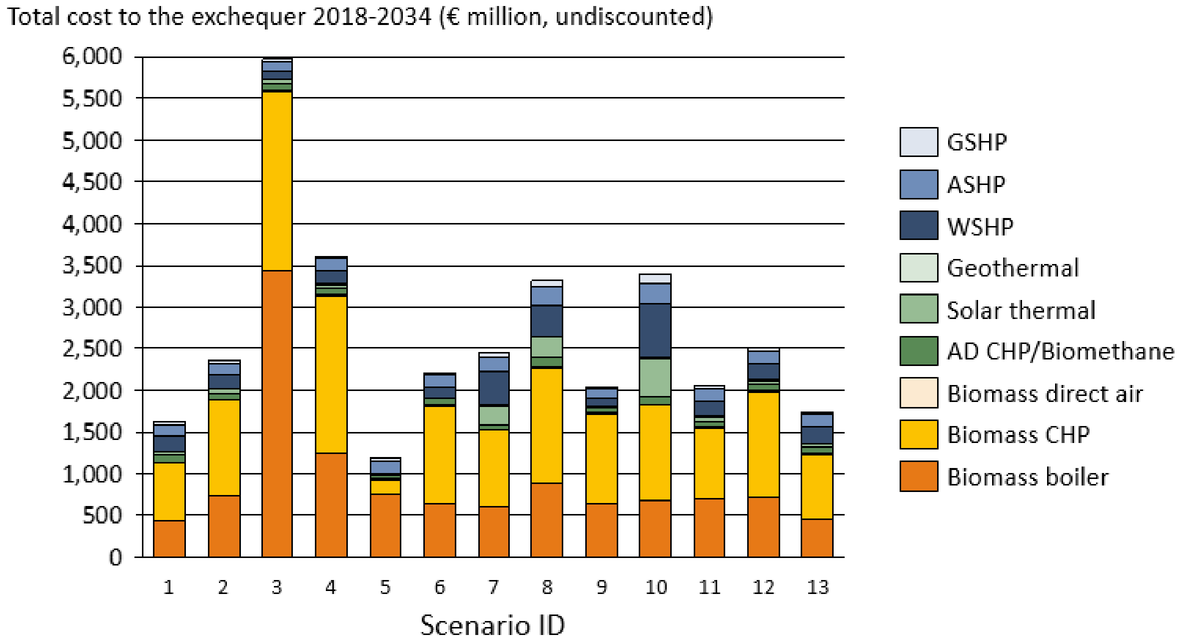
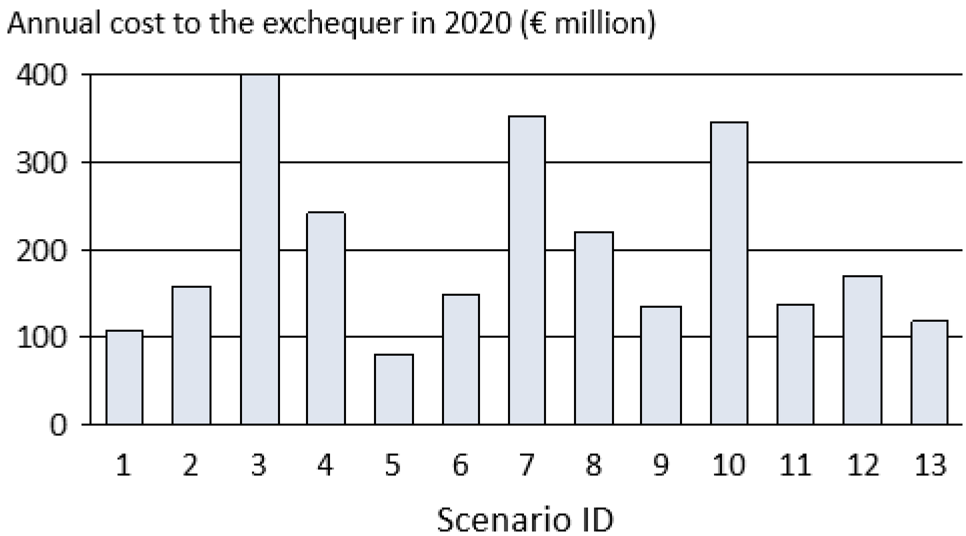


Figure 1-4: Annual cost to the Exchequer in 2020



3. Impact on CO_2

- In this study, we have considered both the life-cycle assessment (LCA) CO_2 emissions as well as emissions based on a 'zero-rating' for all biomass. The LCA emissions indicate how life-cycle emissions could vary between scenarios with differing levels of imported biomass and with differing levels of sustainability criteria. The 'zero-rating' method presents the carbon savings in accordance with the Renewable Energy Directive 2009 rules for calculating the greenhouse gas impact of biofuels, bioliquids and their fossil fuel comparators.

- The total CO_2 savings over the period 2016-2034 associated with the installations of RH technologies under the RHI to 2020 is shown for all scenarios, using the life-cycle biomass emissions approach, in Figure 1-5. A comparison of the annual CO_2 savings in 2020 due to all new installations over the period 2016-2020 is shown for all scenarios in Table 1-5.
- All scenarios considered in this study result in a positive CO_2 saving. The carbon savings are therefore strongly dependent on the overall level of uptake of RH technologies; beyond this, the mix of technologies has an impact on the overall CO_2 saving since certain technologies lead to greater savings on a per kWh basis than others.
- In Scenario 3, the uptake of RH technologies is very high, leading to the highest CO_2 savings of all scenarios studied, with the RES-H target exceeded and a renewable share of heat of 18.1% achieved by 2020. The uptake of RH technologies across the remaining scenarios is lower, and all achieve a share of renewable heating in the range 11.4%-13.4%. Scenarios 1, 10 and 13 have the highest uptake of RH after Scenario 3, and as a result the next highest CO_2 savings. Scenario 11 has the lowest uptake of RH, and the lowest carbon savings.
- The carbon intensity of heat pumps and geothermal installations is somewhat higher than that assumed for biomass imported under the more stringent sustainability criteria (as used in the "Strongly limited" biomass imports cases). As such, any scenarios that increase the uptake of non-biomass technologies (shorter duration of support and/or increased IRR) or reduce the uptake of biomass technologies (high power sector biomass demand) lead to a modest reduction in the CO_2 savings per kWh of heat produced.
- Whilst solar thermal has an assumed carbon intensity of zero, and hence lower than the biomass technologies, the uptake of solar thermal is relatively low in all cases, such that the impact on carbon savings is small.
- The breakdown of the CO_2 savings into ETS and non-ETS savings is presented and discussed for selected scenarios in the main text.

Figure 1-5: Total CO_2 savings 2016 – 2034 from RH technologies installed 2016-2020 using the life-cycle biomass emissions approach[5]

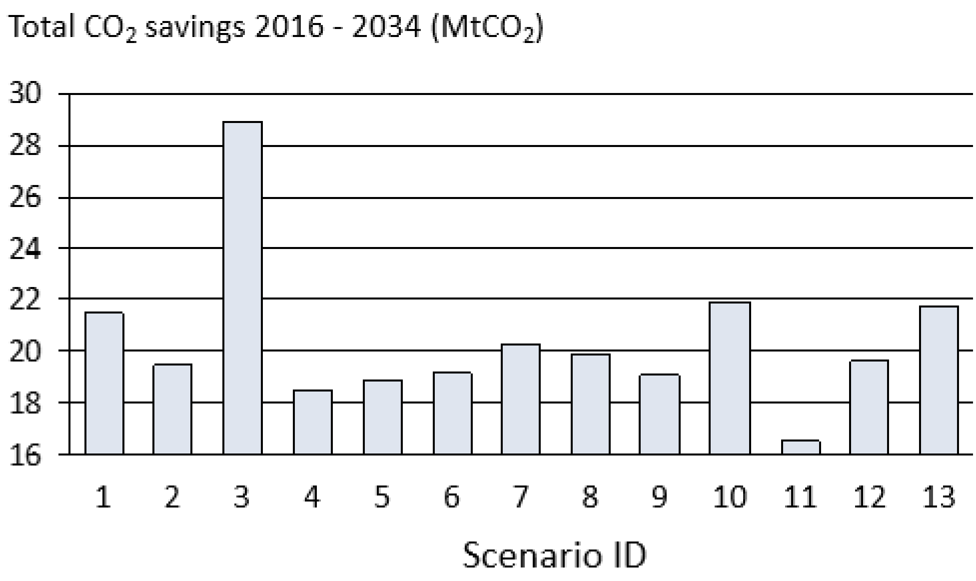


Table 1-5: Annual CO_2 savings in 2020 based on life-cycle assessment versus zero-rating method

Scenario ID	Annual CO_2 savings from renewable heat technologies installed 2016-2020 in 2020 ($ktCO_2$)		
	Based on life-cycle biomass emissions	Based on zero-rating of biomass emissions	Difference
1	1328	1496	11%
2	1185	1244	5%
3	1792	2151	17%
4	1123	1180	5%
5	1159	1216	5%
6	1178	1234	5%
7	1236	1292	4%
8	1219	1276	4%
9	1172	1229	5%
10	1351	1407	4%
11	1014	1068	5%
12	1200	1257	5%
13	1346	1516	11%
N1	730	784	7%
N2	689	716	4%

4. Impact on particle emissions from biomass

- The uptake of biomass technologies following the introduction of an RHI will lead to an increase in emissions of particulate matter (PM) and nitrogen oxides (NOx). Whilst some increase in such emissions is an unavoidable consequence of increased use of

[5] Note: The carbon savings include savings from both the heat and electricity components of the RH technologies installed

biomass, the magnitude of the increase will need to be managed through the use of appropriate technology and fuel to minimise the risk of exacerbating air quality issues.

- The difference in the increase in emissions of PM and NOx between the scenarios assessed here is controlled by the uptake of biomass technologies. The scenarios for which imported biomass availability is less strongly limited, and which therefore have a high uptake of biomass technologies, result in the highest increase in annual emissions of PM and NO_X. For all other scenarios, the increase in emissions from biomass are similar, as the use of biomass is limited to a similar extent in each case by the availability of imports.
- In the scenarios modelled, no location-based constraints for biomass technologies have been applied. Location constraints could be considered to limit the air quality impacts in particular areas, but this will need to be assessed on a local basis. Such constraints could reduce the uptake of biomass, leading to a lower overall uptake than that shown in the scenarios studied. However, but given that the biomass uptake is in most scenarios limited by the availability of domestic and imported biomass, this may not have a material impact.
- A biomass fuel suppliers list could be included as a requirement of the RHI to ensure high quality fuel is used and to help minimise emissions. Nonetheless, there is a risk that, once the RHI support ends, poor quality biomass fuel will be used unless the required regulations are also brought in outside of the RHI scheme. In addition, it is possible that maintenance and servicing will be reduced, leading to higher emissions, once the support period ends. This could be expected to be a particular issue for shorter support durations.

5. Incentivising efficiency at the system specification, installation and operation stages

- Minimum energy efficiency standards for the buildings and heat-using processes to be supplied by installations installed under the RHI will be a key component of a successful RHI design. This is supported by the negative publicity surrounding certain installations in the UK RHI, in which cases there is a widespread recognition that insufficient controls were in place to ensure that heat generated under the RHI was applied to useful purposes. The possible approaches to minimum efficiency standards are described in section 3.4.3.
- Whether payments under the RHI are calculated based on deemed or metered heat use has very important consequences in terms of the incentive for efficient use of heat. Allowing the option for smaller installations to have RHI payments based on deemed heat use could incentivise efficient use of heat in those installations, as heat use can be lowered without impacting the RHI revenue. However, the risk of non-use or under-use of the RH system in the case of payment based on deemed heat (particularly in large buildings and where the counterfactual system is left in place) means that this option is not expected to be suitable for large installations.
- However, payment based on metered heat has the disadvantage that it may in some cases incentivise the over-production of heat. This is a particular risk if the marginal price of generating an additional unit of heat is lower than the tariff offered for the unit of heat. We note that this situation could occur in certain cases, particularly for biomass-based heating, where a large fraction of the tariff offered corresponds to the repayment of the additional capital costs incurred (and not only additional ongoing fuel costs incurred). The risk of this outcome is greatest in the scenarios where a higher tariff is offered (such as scenarios 7 and 8). The impact of this outcome can be significantly

reduced by tiering the tariffs by heat output, such that the marginal payment per kWh decreases the more heat is produced (see section 3.5.7). However, tiering alone is not likely to be sufficient to disincentivise over-production of heat, and should be applied in conjunction with minimum efficiency standards and the other approaches to ensure efficient use of heat generated as described below. The most risk-averse option would be to cap the tariffs close to the expected fuel cost, with the cap being reviewed on a quarterly basis, for example. It should be noted that this is likely to under-incentivise certain installations, particularly those smaller in capacity.

- An alternative approach, which could help to mitigate the risk of inefficient use of heat but continue to promote use of an installed renewable heating system, combines the deemed and metered options. In this case, an annual 'cap' on the heat output for which payment can be claimed could be applied based on an assessment of deemed heat output. Within this approach, actual payment would still be based on metered heat use, but only up to a maximum amount as specified by the deemed heat output. This would limit the potential impact of inefficient use of heat, but also provide certainty over the amount of renewable heat actually generated by the RH system. Within this approach, there could be an option for the applicant to request (potentially at their own cost) a more in-depth energy audit capable of verifying the contributions of bespoke and/or recently-added heat uses. This approach is likely to increase the scheme complexity both for applicants and for the scheme implementing body, but may be considered preferable to minimise the risk of misuse of the scheme.
- The use of tiered tariffs (by absolute heat output) rather than banded tariffs (by installation size) also reduces the risk of installations being sized inappropriately in order to receive higher RHI tariffs. This helps to ensure that installations are specified and installed to an appropriate size and design to achieve high efficiency.
- A short duration of support carries the risk of inefficient use of heat (over-production) during the support period, as the tariffs are high (in many cases higher than the marginal cost of producing a unit of heat). Allocating RHI payments based on deemed heat use would mitigate this, but brings the risk described above of non-use or under-use of the RH system. Furthermore, once the RHI support comes to an end, the RH technology may no longer be used or may be used less efficiently. For these reasons, a shorter duration of support is not expected to incentivise efficiency at the operation stage to the same degree as a longer duration of support.

6. Allocating risks efficiently

- To manage the risks to both the Exchequer and the scheme participants, the tariffs should be adjusted systematically to reflect changing costs of both the RH technologies and the counterfactual technologies, as well as the changing price of fuel.
- The upfront costs of the RH technologies are likely to decrease following the introduction of an RHI as a growing market will drive competition and help to establish the supply chain within Ireland. Therefore, to prevent over-compensation, the tariffs may need to be decreased to new applicants over time.
- The fuel prices for the RH technologies and the counterfactual technologies they displace are likely to vary over time in an unpredictable manner. A mechanisms to adjust the tariffs offered, both for new applicants and during the support period, is likely to be required to ensure ongoing cost-effectiveness of the scheme. An important consideration in this regard is the appropriate allocation of risk between the investor and the Exchequer.

- An important question is therefore to which index the tariffs should be linked. Respondents to DCENR's 2015 public consultation expressed the view that any indexation to inflation should be based on CPI, as is currently the case for new installations in the UK RHI. There is a question as to whether CPI is the most suitable index to use for all technologies. For zero variable fuel cost technologies such as solar thermal, an on-going CPI linked payment may be too generous. However the deployment of solar thermal in Ireland is expected to be low relative to other renewable technologies.
- The price of biomass fuel is likely to be influenced by the implementation of the RHI, as the demand may increase more rapidly than supply, and the additional domestic resource is likely to carry a higher cost than that currently used. The risks associated with biomass fuel availability and price should be considered carefully and could merit a periodic review of the tariffs with specific reference to any change in biomass market prices.
- In addition, it is likely that budget management mechanisms (a budget cap and/or tariff degression) will be required to ensure the scheme is compatible with the total and annual Exchequer budget. Tariff degression could be used to control the uptake of individual RH technologies to manage the diversity of RH technologies.

7. Impact on the diversity of the renewable heating technology mix

- Differentiating the tariffs by technology is likely to increase the diversity of RH technologies by offering higher tariffs to more costly technologies, and tiered tariffs should encourage a more diverse range of installation sizes than non-tiered tariffs.
- When the tariffs are capped at 10 c/kWh, as in Scenario 6, the technology diversity is not significantly impacted; however, there is a reduction in the number of small installations for which costs are typically higher. When the tariffs are capped at the biomass tariffs, as in Scenario 5, the diversity of the technology mix is somewhat reduced, with solar thermal in particular seeing a much-reduced uptake.
- Increasing the IRR and/or decreasing the duration of support, as in Scenarios 7, 8 and 10, increases the diversity of the technology mix, as this tends to incentivise more strongly the uptake of the heat pump technologies and solar thermal which have high upfront costs.
- Despite the differentiation of the tariffs by technology leading to some diversity in the technology mix, biomass technologies dominate the uptake of RH technologies in all of the scenarios assessed. The uptake of biomass technologies is strongly impacted by the availability and price of imported biomass, which is likely to vary over time according to the dynamics of global biomass supply and demand. Therefore, it may be desirable to control the uptake of biomass technologies through systematic adjustment of the tariffs.

8. Complexity/clarity

- Differentiating the tariffs by RH technology increases the complexity of the scheme somewhat by increasing the number of different tariffs required. Tiering the tariffs has a similar impact, as this means that in many cases multiple tariffs will apply to a single applicant; this could make it more challenging for potential applicants to estimate the payments they would expect to receive. However, these concerns could be mitigated through the provision of an ‘RHI revenue calculator’ to allow potential applicants to estimate the payment they may expect to receive. As such, the additional complexity of these design options is not considered to be material.

- The inclusion of any eligibility criteria, including minimum energy efficiency criteria, biomass sustainability, limits on emissions of PM and NOx, location-based biomass constraints and technology/fuel supplier lists, adds complexity to the scheme. The cost associated with introducing any eligibility criteria and undertaking the required monitoring and evaluation, should be considered against the benefits the eligibility criteria would be expected to bring. The case for inclusion of these eligibility criteria is nonetheless strong, as has been set out above.
- Payments based on deemed heat use, as could be made an option for smaller installations, potentially adds complexity at the application stage, particularly if a new building energy assessment would need to be undertaken. On the other hand, payment based on metered heat output is likely to involve a higher ongoing administrative burden for both the scheme participants and the scheme administrators. In order to reduce the risk of misuse of the scheme it may be desirable to use a combination of these approaches, as described above, requiring metered heat output but including a default ‘cap’ based on deemed heat use (which could be lifted following a more detailed audit). This approach would add further complexity, but may be considered worthwhile to provide greater control over the application of the scheme.

9. Measures to ensure long-term market development

- Incentivising a diverse range of technologies across a range of sizes through the RHI is expected to improve the long-term sustainability of the market for RH by allowing the necessary skills and supply chain to be developed. This in turn is expected to lead to cost reductions through learning, reinforcing the competitiveness of RH versus conventional heating technologies.
- It is important to note that the provision of the RHI for a limited time period only risks adversely impacting the long-term sustainability of the domestic RH market in Ireland, to the extent that this causes a sharp reduction in demand for RH technologies following the closure of the scheme. In order to ensure the market can be sustained, a medium- and long-term plan for renewable heat should be developed with a view beyond 2020, in order to provide greater certainty to the sector.
- In addition, the availability, and hence the market price, of domestic biomass could be impacted by the introduction of an RHI, especially if stringent sustainability criteria are included which constrain the use of imported biomass. This issue could be exacerbated if confidence in the medium- and long-term (post-2020) market for biomass heating is low, as there will be less incentive to increase the production of domestic biomass given the long lead times required. The impact of an RHI on the price of domestic biomass would merit further consideration to ensure that existing users of biomass do not convert to fossil fuel based technologies due to a change in the differential price of biomass and conventional fuels.

Importance of regular review of the scheme design

The design options described in the key findings above aim to find a balance between incentivising a sufficient level of uptake to meet the RES-H target within the limited timeframe available, and the need to avoid perverse incentives for the over-production or inefficient use of heat.

Critical to maintaining the desired balance between these factors will be effective governance and regulation, including monitoring and auditing to ensure that all installations supported by the RHI are aligned with the scheme objectives. An important component of this will be the ability to review the design of the scheme at regular points, likely on a quarterly basis. This will help to ensure that any 'loopholes' identified in the scheme design and found to be leading to installations misaligned with the scheme objectives can rapidly be addressed.

Summary assessment of all scenarios

In Table 5-14, the evaluation of each of the 13 scenarios against the assessment criteria is summarised using a Harvey Ball scheme[6]. An 'empty' or all-white icon represents the lowest score against the relevant criterion; a 'full' or all-black icon represents the highest score. A high-level summary of the rationale for the scores is provided in the final column; the full evaluation of the scenarios against the assessment criteria is given in section 5.

We note that this reflects our own assessment of how the scenarios studied perform against the various criteria. While the assessment attempts to capture the feedback provided by the project steering group throughout the project, this is not intended to represent the views of DCCAE on the final design of the RHI.

Based on this assessment, and on feedback from the project steering board, we propose that Scenario 5 is most likely to meet the objectives of the policy in a cost-effective and sustainable way. As such, Scenario 5 is highlighted in the table as the preferred option. It should be noted, however, that the 2020 RES-H target is only just met in Scenario 5 and alternative scenarios, including Scenario 1, 3, 10 and 13, provide a higher likelihood of the target being met. These scenarios have substantial drawbacks, though, with Scenarios 3 and 10 resulting in significantly higher costs to the Exchequer, and Scenarios 1 and 13 performing less well in terms of sustainability (in terms of life-cycle carbon emissions from biomass).

Given the various advantages and drawbacks of the scenarios, it is likely that further scenarios combining the design options studied across multiple scenarios presented here will be of interest to DCCAE as the design of the RHI progresses.

[6] Harvey Balls are used as a visual communication to represent the performance of each scenario against each of the assessment criteria.

Table 1-6: Summary assessment of all scenarios against the assessment criteria

Assessment Criteria	S1: Limited imported biomass, tariff based on 5.5 c/kWh biomass price	S2: Strongly limited imported biomass, tariff based on 6.9 c/kWh biomass price	S3: Limited imported biomass, tariff based on 9 c/kWh biomass price	S4: Strongly limited imported biomass, tariff based on 9 c/kWh biomass price	S5: Tariffs capped at biomass boiler tariffs	S6: Tariffs capped at 10 c/kWh	S7: Shorter duration (7 yrs)	S8: Higher IRR (12%)	S9: Lower IRR (6%)
1. Incentivising an efficient level of investment to meet the target	●	◕	●	◕	◕	◕	●	◕	◕
2. Minimising costs to the Exchequer (and appropriately profiling overall costs)	◕	◑	◔	◔	●	◑	◔	◔	◕
3. Impact on CO_2	◕	◕	●	◕	◕	◕	◕	◕	◕
4. Impact on particle emissions from biomass	◔	◑	○	◑	◑	◑	◑	◑	◑
5. Allocating risks efficiently	◕	◕	◕	◕	◕	◕	◕	◕	◕
6. Incentivising efficiency at the system specification, installation and operation stages	◕	◕	◑	◑	◕	◕	◔	◕	◕
7. Impact on the diversity of the renewable heating technology mix	◔	◑	◔	◑	◔	◔	◕	◕	◑
8. Complexity/clarity	◑	◑	◑	◑	◑	◑	◑	◑	◑
9. Impact on the market/ sustainability	◕	◑	◕	◕	◑	◑	◑	◕	◑
Overall	◕	◕	◔	◑	●	◕	◑	◑	◕

Assessment Criteria	S10: Shorter duration and Higher IRR (except for biomass-based techs)	S11: High power sector biomass demand	S12: Include ETS - Strongly limited imported biomass, tariff based on 6.9 c/kWh biomass price	S13: Include ETS - Limited imported biomass, tariff based on 5.5 c/kWh biomass price	Comments
1. Incentivising an efficient level of investment to meet the target	●	◔	◕	●	The availability and cost of imported biomass have the largest influence on the uptake of RH technologies. A shorter duration and/or higher IRR increase the uptake of non-biomass technologies. Scenarios that exceed the target in the model would be expected to have the highest likelihood of meeting the target if implemented.
2. Minimising costs to the Exchequer (and appropriately profiling overall costs)	◔	◑	◑	◕	Biomass technologies dominate the uptake in all scenarios. Therefore, the price of biomass fuel used to set the tariffs has a large impact on the total cost to the Exchequer. Reducing the uptake of the most expensive technologies by capping all tariffs at the biomass boiler tariffs or at 10 c/kWh reduces the scheme cost. A short duration of support leads to high annual costs.
3. Impact on CO_2	●	◔	◕	◕	A high availability of biomass increases overall CO_2 savings as the uptake of RH technologies is large. However, importing biomass without stringent sustainability criteria reduces the CO_2 savings on a per kWh basis.
4. Impact on particle emissions from biomass	◑	◑	◑	◔	The availability and costs of imported biomass controls the uptake of biomass technologies and hence the emissions of PM and NOx. Abatement technologies (not modelled) could be used to restrict the emissions but would increase the tariffs required for biomass technologies and reduce uptake due to higher upfront costs.
5. Allocating risks efficiently	◕	◕	◕	◕	Systematic adjustment of the tariffs are included in all scenario (though not modelled here). Such mechanisms will help to ensure the ongoing cost-effectiveness of the scheme and allow risk to be allocated appropriately between the Exchequer and the scheme participants. Budget control mechanisms are likely to be required if low cost biomass imports are available.
6. Incentivising efficiency at the system specification, installation and operation stages	◔	◕	◕	◕	On-going payments differentiated by heat output, included in all scenarios, incentivise efficiency in design and operation. Higher tariffs, comparable to or higher than the fuel price, lead to a higher risk of over-production of heat (this is especially a risk for biomass heating). A short duration of support also means that, once the support period ends, there is a risk of the RH technologies not being maintained and the efficiency operation being reduced.
7. Impact on the diversity of the renewable heating technology mix	●	◑	◑	◔	Differentiating tariffs by technology and heat output increases diversity, as does incentivising non-biomass technologies via a shorter duration and/or increased IRR. Increasing the availability of imported biomass reduces diversity especially when the biomass tariffs are set based on the domestic biomass price.
8. Complexity/clarity	◑	◑	◑	◑	Differentiating the tariffs by technology increases the complexity of the scheme, as does tariff tiering. All scenarios include these design options. Inclusion of eligibility criteria also increases the complexity; scenarios are not differentiated by eligibility criteria.
9. Impact on the market/ sustainability	◑	◑	◑	◕	A greater availability of imported biomass will help to mitigate against biomass price rises. Offering tariffs based on a relatively high biomass fuel price is likely to help develop the domestic biomass market.
Overall	◑	◔	◕	◕	

2 Introduction

As part of Ireland's strategy to meet its obligations under the 2009 Renewable Energy Directive, the Government targets the delivery of 12% of final heating demand from renewable sources by 2020. While the deployment of renewable heating technologies has progressed significantly in recent years, reaching 6.5% of heat demand in 2015, recent analysis[7] by the Sustainable Energy Authority of Ireland (SEAI) states that under the current set of policies the 2020 target will not be met.

In order to address this policy 'gap', a cross-governmental working group has recommended[8] that an Exchequer-funded Renewable Heat Incentive (RHI) could be implemented. The Department of Communications, Climate Action and Environment (DCCAE) is leading the process to consult upon and design this policy.

The basic structure of the RHI is proposed to be a payment offered to producers of renewable heat on a 'per unit of energy produced' basis, with the payment intended to cover the additional cost of generating heat using a renewable technology as compared with a fossil fuel alternative, including the additional cost associated with perceived barriers.

DCCAE intends to hold a second public consultation on the RHI, focusing on the design options for the policy and requirements for implementation. This study is intended to provide the evidence base to inform the second public consultation. In particular, this work was commissioned in order to:

- Undertake an **economic assessment of the cost of introducing an RHI** with the objective of meeting Ireland's 2020 renewable heat target;
- Develop a **set of cost-effective design options for the RHI** structured in such a way as to support investment in the efficiency and effective design, installation and operation of renewable heating technologies.

The following renewable heating technologies were included in the economic assessment:

- Biomass boiler
- Biomass combined heat and power (CHP)
- Biomass direct air heating
- Ground-source heat pump
- Air-source heat pump
- Water-source heat pump
- Deep geothermal
- Anaerobic digestion (AD) CHP[9]
- Anaerobic digestion (AD) boiler
- Biomethane grid injection

[7] *Renewable Heat in Ireland to 2020*, Sustainable Energy Authority of Ireland (May 2015)
[8] *Draft Bioenergy Plan*, Department of Communications, Energy and Natural Resources (October 2014)
[9] AD CHP, AD boiler and biomethane were included in this study via the interface study 'Interface analysis and report for incorporation and alignment of data from biomethane study into RHI workstream'

- Solar thermal

It is important to note that a full impact assessment and cost-benefit analysis of the RHI is outside the scope of this study, and would be expected to follow DCCAE's decision on the precise design of the RHI scheme. Similarly, a detailed assessment of the governance structures required to administer the scheme and to ensure adequate monitoring and evaluation across the full supply chain has not been carried out as part of this work, and should be undertaken separately. The RHI design options will need to be carefully considered before implementation of the scheme and quarterly reviews will be required in order to ensure the long term sustainability of the RHI scheme.

In this report:

- Section 3 describes the full range of RHI design options studied, the possible implications of each option and a summary of the findings from a consultation of stakeholders on the list of options;
- Section 4 describes the approach taken to develop the RHI tariffs under each design option;
- Section 5 describes a detailed assessment of the shortlisted RHI design scenarios against the key assessment criteria.

The full set of tariffs and the results of the uptake modelling for each RHI design scenario are given in the Appendices.

3 Review of RHI design options and implications

3.1 Approach

Desk-based assessment

A desk-based assessment was carried out by Frontier Economics as part of this study, with the primary aim of identifying:

1. An initial longlist of design options for the RHI;
2. A list of assessment criteria against which the design options should be compared.

The assessment includes a literature review of evidence from RHI schemes in other countries, with a strong focus on the UK RHI scheme, along with a first-principles economic assessment of tariff design options. The full assessment[10] is available as an annex to this report.

Stakeholder consultation

Stakeholders from a total of 26 different organisations were consulted as part of this study. The consultations had three main objectives, namely to:

1. Collect the best available and up-to-date data on renewable heating technology costs and operational performance in the Irish context;
2. Gain insight on relevant technology constraints and non-cost barriers to deployment;
3. Provide initial feedback on proposed RHI design options.

We are grateful to the following stakeholders for participating in the consultation and providing much of the useful data and commentary contained in this report. As ever, the final responsibility for the details contained in the report lies with us, the authors.

- Ashgrove
- Bord Na Mona
- Codema
- Coillte
- Confederation of European Waste-to-Energy Plants Ireland (CEWEP Ireland)
- Cre
- Dept. of Agriculture
- Dept. of Environment – Northern Ireland
- Dept. of Environment – Republic of Ireland
- Dr Ger Devlin, University College Dublin
- Electricity Supply Board
- Environmental Protection Agency
- Gaelectric
- Gas Networks Ireland

[10] Frontier Economics, *Task 1 – Review of RHI Design Options: A report prepared for DCENR*, August 2016

- Geothermal Association of Ireland (GAI)
- GI Energy
- Glen Dimplex
- Green Energy Engineering
- Heat Pump Association of Ireland (HPA)
- Irish BioEnergy Association (IrBEA)
- Letterkenny IT
- Renewable Gas Forum – Irish Green Gas Ltd
- Sustainable Energy Authority of Ireland (SEAI)
- Teagasc
- Terawatt Ireland
- Tipperary Energy Agency

In the following section, the outputs from the desk-based assessment are combined with stakeholder consultation feedback to develop a longlist of RHI design options and to set out the pros and cons of each option.

Based on this process, and in partnership with the project steering board, a shortlist of design options were taken forward to be modelled and assessed in detail, as described in the later sections of this report.

3.2 Overview of RHI design options identified

We first give a brief overview of the RHI design options identified. The advantages and disadvantages of the design options are then discussed in more detail in Sections 3.3 to 3.7.

Figure 3-1: Summary of the design options

	Design aspect	Options			
1.	Differentiation by renewable technology	1. Single tariff across all technologies	2. Different tariff for certain groups of technologies	3. Separate tariff for each technology	
2.	Differentiation by installation size	1. No tariff banding by installation size	2. Tariff banding by installation size, no tiering	3. Tariff banding by installation size, with tiering based on percentage output	4. No tariff banding, tiering based on absolute kWh output
3.	Minimum energy efficiency criteria for participant eligibility	1. No minimum energy efficiency eligibility criteria	Include minimum energy efficiency eligibility criteria: 2. linked to an existing energy efficiency accreditation system	3. linked to a new energy efficiency accreditation system	
4.	Minimum criteria and/or tariff differentiation on biomass sustainability	1. No sustainability criteria beyond the minimum EU standards	2. Inclusion of sustainability criteria beyond the minimum EU standards	3. Differentiation of tariffs for biomass technologies based on the sustainability of the biomass fuel used	
5.	Minimum criteria and/or tariff differentiation on particulate matter and nitrogen oxides emissions from biomass	1. No emissions criteria beyond the minimum EU standards	2. Inclusion of emissions criteria beyond the minimum EU standards	3. Differentiation of tariffs for biomass technologies based on the emissions	
6.	Eligibility criteria for biomass by location	1. No eligibility criteria based on the location of the installation for biomass technologies	2. Inclusion of eligibility criteria based on the location of the installation for biomass technologies		
7.	Duration of support and profile of payments to scheme participants	Duration of support: 1. 20 years (same as UK Non-domestic RHI) 2. 15 years 3. 7 years (same as UK Domestic RHI) Profile of payments 1. On-going payments only – flat rate (same tariffs over duration of support) 2. On-going payments only – front loading (higher tariffs in the earlier years of support) 3. On-going payments and an upfront grant			
8.	Payment based on metered or deemed heat use	1. Payment based on metered heat use for all installations	2. Payment based on deemed heat use for all installations	3. Payment based on metered heat use for large installations and on deemed heat use for small installations*	
9.	Systematic adjustment to tariffs	1. No systematic adjustment of tariffs	2. Systematic adjustments of tariffs to reflect evolution of key input costs over time	a) 1 or 2 with no inclusion of budget management mechanisms	b) 1 or 2 with the inclusion of budget management mechanisms – degression and/or budget cap
10.	Allowed rate of return	1. 6% IRR	2. 8% IRR	3. 12% IRR	
11.	Age of technologies being targeted for replacement	1. Target replacement of technologies at the end of life only	2. Target replacement of technologies at the end of life or near the end of life	3. Target replacement of technologies not only at the end of life or near the end of life	
12.	Implementation options (online/paper-based)	1. Online system, with a paper option in exceptional circumstances	2. Online or paper options	a) 1 or 2, administered by CER	b) 1 or 2, administered by another third-party
13.	Counterfactual heating systems targeted for replacement	1. Target replacement of all counterfactual technologies	2. Target replacement only certain counterfactual technologies		
14.	Inclusion of the ETS sector	1. Exclude the ETS sector from the RHI scheme	2. Include the ETS sector in the RHI scheme		

* with the option for small installations to use metered heat output

3.2.1 Differentiation by renewable technology

State aid rules state that tariffs must be tied to a particular technology, such that it is not possible to offer a set of tariffs that are averaged over a number of different technologies. Since each technology has distinct cost characteristics, offering all technologies a tariff (or set of tariffs) based on a single technology is likely to mean that only the cheapest, most cost-effective technologies will be incentivised. While this may lead to a cost-effective outcome, there is a risk of over-reliance on a single technology; the relative merits of the cost of the policy on one hand, and the diversity of the renewable heat installations incentivised on the other, will need to be weighed against each other. Given the limited time to reach the target it is likely that several technology types will need to be incentivised such that a separate tariff for each technology may be required.

Design options:

1. A single tariff or set of tariffs across all technologies
2. Different tariffs for certain groups of technologies
3. A separate tariff for each technology

3.2.2 Differentiation by installation size

The upfront and ongoing costs of producing a unit of renewable heat vary with installation size, typically decreasing for larger installations. In order to ensure a sufficient incentive for smaller installations, without over incentivising larger installations, the tariffs may need to be differentiated by size.

Design options:

1. No tariff banding by installation size
2. Tariff banding by installation size, no tiering
3. Tariff banding by installation size, with tiering based on percentage output
4. No tariff banding, tiering based on absolute kWh output

3.2.3 Minimum energy efficiency criteria for participant eligibility

A risk of offering a tariff payable on every unit of heat produced is that it does not promote efficient use of heat, and in certain circumstances could incentivise over-production of heat. The RHI could be used to incentivise energy efficiency improvements by including minimum energy efficiency criteria for RHI eligibility.

Design options:

1. No minimum energy efficiency eligibility criteria
2. Include minimum energy efficiency eligibility criteria linked to an existing energy efficiency accreditation system
3. Include minimum energy efficiency eligibility criteria linked to a new energy efficiency accreditation system

3.2.4 Minimum criteria and/or tariff differentiation on biomass sustainability

In order to ensure biomass fuels used under the RHI are *sustainable* – in terms of their impact on carbon dioxide and other emissions, biodiversity, soil and watershed protection and other aspects – sustainability criteria could be included as a condition for RHI eligibility. Given that a key goal of the RHI is to reduce carbon dioxide emissions, it is particularly important that the policy is designed to promote a sustainable reduction in carbon emissions.

Design options:

1. No sustainability criteria beyond the minimum EU standards
2. Inclusion of sustainability criteria beyond the minimum EU standards
3. Differentiation of tariffs for biomass technologies based on the sustainability of the biomass fuel used

3.2.5 Minimum criteria and/or tariff differentiation on particulate matter and nitrogen oxides emissions from biomass

In order to minimise the impact of particulate matter and nitrogen oxides (NOx) emissions from biomass fuels used under the RHI, minimum criteria and/or tariff differentiation on such emissions could be included in the RHI.

Design options:

1. No emissions criteria beyond the minimum EU standards
2. Inclusion of emissions criteria beyond the minimum EU standards
3. Differentiation of tariffs for biomass technologies based on the emissions

3.2.6 Eligibility criteria for biomass by location

Emissions from biomass technologies can lead to local air quality issues, especially when several installations are located within a small geographical area. Certain locations may pose a higher risk for air quality issues for a variety of reasons. Therefore, biomass technologies may need to be restricted or banned in some locations.

Design options:

1. No eligibility criteria based on the location of the installation for biomass technologies
2. Inclusion of eligibility criteria based on the location of the installation for biomass technologies

3.2.7 Duration of support and profile of payments to scheme participants

The RHI tariffs are designed to cover all the additional costs required to operate the renewable heating technologies over their lifetime, relative to the counterfactual technology. However, a policy design choice is whether the duration of support should be equal to the lifetime of the technology, or shorter, and whether the profile of payment should be flat, or front-loaded towards the earlier years. These factors are likely to impact on the attractiveness of the offer to the consumer, but also on the way the technology is used throughout its lifetime.

Design options:

Duration of support

1. 20 years (same as UK Non-domestic RHI)
2. 15 years
3. 7 years (same as UK Domestic RHI)

Profile of payments

1. On-going payments only – flat rate (same tariffs over duration of support)
2. On-going payments only – front loading (higher tariffs in the earlier years of support)
3. On-going payments and an upfront grant

3.2.8 Payment based on metered or deemed heat use

RHI payments will be made, entirely or in part, on the basis of units of heat generated (i.e. per kWh). The payments could be determined based on metered heat output, or based on *deemed* heat output – that is, on predicted, modelled or verified historic heat output determined according to the type and size of building (or process) using the heat.

Design options:

1. Payment based on metered heat use for all installations
2. Payment based on deemed heat use for all installations
3. Payment based on metered heat use for large installations and on deemed heat use for small installations (with the option for small installations to use metered heat output)

3.2.9 Systematic adjustment to tariffs

Costs associated with both renewable heat and counterfactual technologies change over time, as the price of the technologies and fuels changes. These changes could be reflected in the tariffs via systematic adjustments. In addition, mechanisms for controlling the Exchequer budget – for example, reducing tariffs as the level of uptake increases – could be included.

Design options:

1. No systematic adjustment of tariffs
2. Systematic adjustments of tariffs to reflect evolution of key input costs over time
3. Option 1 or 2 with no inclusion of budget management mechanisms
4. Option 1 or 2 with the inclusion of budget management mechanisms – degression and/or budget cap

3.2.10 Allowed rate of return

The allowed internal rate of return (IRR) of the initial investment should reflect the cost of capital and the risks associated with deployment of the renewable heat technologies, whilst remaining cost-effective for the Exchequer. A range of IRRs were identified for assessment as described in section 3.5.5.

Design options:

1. 6% IRR
2. 8% IRR
3. 12% IRR

3.2.11 Age of technologies being targeted for replacement

The age of technologies being targeted for replacement has a large impact on the potential market size. To the extent that the RHI is intended to incentivise a substantial increase in the deployment of renewable heating to 2020, it may be necessary to incentivise the early replacement of fossil fuel technologies. However, this is likely to be less cost-effective, given that consumers may seek to be compensated for the residual value of the existing system in order to replace it with a new system.

Design options:

1. Target replacement of technologies at the end of life only
2. Target replacement of technologies at the end of life or near the end of life
3. Target replacement of technologies not only at the end of life or near the end of life

3.2.12 Implementation options (online/paper-based)

In order to deploy and manage the scheme in an efficient and effective way, the administrative burden and the costs of implementation need to be considered carefully. It will also be important to consider to pros and cons for allocating the responsibility for implementation to a particular organisation.

Design options:

1. Online system, with a paper option in exceptional circumstances
2. Online or paper options
3. Option 1 or 2, administered by CER
4. Option 1 or 2, administered by another third-party

3.2.13 Counterfactual heating systems targeted for replacement[11]

The counterfactual heating technologies are largely gas, oil and solid fuel heating. These technologies have different cost characteristics. A focus on cost-effectiveness may suggest only incentivising replacement of the most expensive counterfactual heating options;

[11] The counterfactual heating system refers to the non-renewable (i.e. fossil fuel) heating system most likely to be installed if the renewable heating system is not installed

however, a focus on meeting the 2020 RES-H target may suggest that replacement of all counterfactual technologies should be promoted. In order to incentivise replacement of all counterfactual technologies, the tariffs need to be high enough to allow the renewable heating technologies to compete with the lowest cost counterfactual technology.

Design options:

1. Target replacement of all counterfactual technologies
2. Target replacement only certain counterfactual technologies

3.2.14 Inclusion of the ETS sector

Inclusion of the EU Emissions Trading Scheme (ETS) sector (comprising largely energy-intensive industry) would increase the addressable market and help towards achieving the 2020 RES-H target. In addition, the administrative burden per unit of renewable heat is likely to be lower for the ETS sector, since each installation in the ETS sector would be expected to be large. However, as described in the following section, the second of the two main objectives of the RHI (the first being to meet the 2020 RES-H target) is to meet Ireland's 2020 non-ETS CO_2 emissions reduction target. Clearly, deployment of renewable heat in the ETS sector does not advance this second objective. The pros and cons of including the ETS sector should therefore be considered.

Design options:

1. Exclude the ETS sector from the RHI scheme
2. Include the ETS sector in the RHI scheme

3.3 Objectives of the RHI

3.3.1 Meeting the 2020 RES-H target

Since the publication of the 2009 Renewable Energy Directive (2009/28/EC), the EU has committed to reaching the target of 20% of all energy to come from renewable source by 2020. As its national contribution towards this objective, Ireland has a target of 16% of gross final consumption to come from renewables by 2020. This will be made up of contributions from renewable energy in all sectors; electricity (RES-E), transport (RES-T), and heating and cooling (RES-H).

Table 3-1: Ireland's RES-E, RES-T and RES-H targets for 2020

Energy Sector	Sector-level renewable energy target for 2020	Contribution to the 16% renewable energy target for 2020[12]
Electricity	40%	7%
Transport	10%	3%
Heating and cooling	12%	6%
Total	**-**	**16%**

Despite significant progress having been made in recent years, only 6.6% of Ireland's heat demand is currently met by renewable heating technologies. Recent analysis by the Sustainable Energy Authority of Ireland (SEAI) states that under the current set of policies the RES-H target will not be met by 2020. One of the overarching objectives of the RHI is to enable Ireland to reach its target to deliver 12% of its heat demand from renewable heating technologies by 2020. Given an estimated heat demand of 48.9 GWh in 2020, the 12% target equates to 5,870 GWh of renewable energy for heating.

In general, only a fraction of the heat generated by renewable heating technologies is eligible to count towards the target. Heat pumps and deep geothermal technologies require an electrical input such that their contribution to the renewable heating target is dependent on their Seasonal Performance Factor (SPF), the annual average coefficient of performance (COP). In practice, the portion that is renewable may be established on a site specific basis by metering both heat produced and electricity input. Heat pumps need to achieve a minimum SPF to be considered renewable. This value depends on the pan-EU average electricity generation efficiency. Following EU legislation[13], the UK RHI currently requires all heat pumps to meet a minimum design SPF of 2.5. Table 3-2 summarises our assumptions on the eligible renewable heat fraction of the RH technologies studied. The SPF values are based on the stakeholder consultation as described in section 4.2. The renewable contribution from heat pumps is based on the Renewable Energy Directive methodology that considers the delivered energy (Renewable energy contribution factor = 1-1/SPF)[14]. This is in contrast to the methodology used in the Energy Performance of Buildings Directive, the Energy Efficiency Directive, and the Dwelling Energy Assessment Procedure for BER calculations that uses the primary energy factor; assuming a harmonised primary energy

[12] Approximate, based on 2014 sector shares of total energy demand
[13] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D0114&from=EN
[14] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=en

factor for electricity of 2.5 (Renewable energy contribution factor = 1-2.5/SPF)[15,16]. The eligible renewable heat fraction of biomass heating is assumed to be 100%. Although a small amount of electrical input is required for auxiliary pumping purpose for solar thermal, this is very small, such that we also assume an eligible renewable heat fraction of 100%.

Table 3-2: Assumptions on renewable heat contribution by technology

Renewable heating technology	Assumed SPF	Renewable heat contribution
Biomass boiler	N/A	100%
Biomass CHP	N/A	100%
Biomass direct air	N/A	100%
AD CHP	N/A	100%
GSHP	5.1	80%
ASHP	3.5	71%
WSHP	5.0	80%
Deep geothermal	11.1	91%
Solar thermal	N/A	100%
AD CHP/Biomethane	N/A	100%

3.3.2 Reducing CO_2 emissions and meeting the 2020 non-ETS CO_2 emissions target

In addition to meeting the 2020 RES-H target, Ireland is committed to reducing CO_2 emissions. Ireland has adopted a target of a 20% reduction in GHG emissions compared to 2005 levels by 2020. Whilst renewable heating technologies typically result in lower carbon emissions than the counterfactual technologies, the exact saving depends on many factors such as the technology type, the efficiency and the carbon intensity of the renewable heating fuel. A number of stakeholders expressed concern regarding the focus of the RHI being solely on the deployment of renewable heat, and emphasised the importance of also considering the associated CO_2 savings. We have considered two mechanisms by which the design of the RHI could influence the carbon savings:

- Incentivising the renewable heating technologies with the lowest carbon intensity;
- Restricting the use of biomass with a high lifecycle carbon intensity (via sustainability criteria).

Higher carbon savings could be incentivised by reducing the RHI tariffs for high carbon intensity biomass (see below).

Carbon intensity of the renewable technologies

Renewable heating technologies are typically considered low carbon in comparison with fossil fuel heating. However, all the renewable heating technologies lead to some level of

[15] Building Regulations 2011, Technical Guidance Document L, Conservation of Fuel and Energy – Dwellings

[16] http://seai.ie/Your_Building/BER/BER_Assessors/Technical/HARP_Database/Information_for_Heating_Appliance_Manufacturers/HARP_Heat_Pump_Database_Submission_Notes.doc

carbon emissions, dependent upon a variety of factors, and it will be important to ensure the RHI scheme is designed to achieve the greatest reduction in carbon emissions possible. Biomass-based technologies can have very low carbon intensity; however, this is strongly dependent on the source of the biomass and the nature of its production. The carbon intensity of the heat pump and deep geothermal technologies is determined by the carbon intensity of the grid electricity used to power the compressor, as well as the heat pump efficiency; while these technologies could potentially be nearly-zero carbon in the presence of a decarbonised grid, carbon savings versus the fossil fuel counterfactual are currently strongly dependent on the efficiency achieved. Solar thermal is typically very low carbon as almost no fuel is required (other than a small amount of electricity used for pumping and other auxiliary purposes).

Renewable heating technology	Factors influencing carbon intensity
Biomass boiler Biomass CHP Biomass direct air	• Source of biomass (see below)
GSHP ASHP WSHP Deep geothermal	• Carbon intensity of grid electricity • Heat pump efficiency
Solar thermal	• Carbon intensity of grid electricity (for pumping and other auxiliary purposes)
AD CHP/Biomethane	• Feedstock (type and source – see below) • Refining and plant operation

Biomass sustainability criteria

Feedback from stakeholders and the literature review suggest that biomass sustainability will be a key concern given the limited domestic biomass resource in Ireland. Forestry in Ireland has existing checks and balances to promote environmental sustainability (e.g. felling licences). Imported biomass has to comply the requirements of the EU Timber Regulation, whereby it must be shown to be legally sourced. Forestry in Ireland must adhere to environmental guidelines through all stages of activity from afforestation to thinning and harvesting. These guidelines address environmental and biodiversity issues outside of life cycle GHG emissions. Through these mechanisms biodiversity and environmental concerns are addressed along the forest biomass supply chain. New integrated sustainability guidance and GHG savings thresholds are now proposed in the European Commission's proposed for a revised renewable energy Directive.

Biomass imported into Ireland must meet the EU Timber Requirements which ensure that the timber was legally harvested in the country of origin, but does not currently have to comply with environmental sustainability criteria and, if used for energy production, does not have to demonstrate minimum GHG savings. Solid and gaseous biomass (energy crops, domestic forestry, biomass wastes and residues, imported wood fuel etc.) used in the heat and power sectors in Ireland are currently not subject to mandatory requirements for life cycle GHG reduction.

Whilst the long-term goal is to establish a sustainable domestic biomass market, the domestic resource of biomass is limited (with around 4,200 GWh expected to be available in 2020) and it is likely that imported biomass will be required to play a role in reaching the RES-H 2020 target. Both the availability and the cost of imported biomass will depend strongly on the sustainability criteria included in the eligibility requirement for the RHI, as well as on the demand for bioenergy in other countries worldwide. One publication suggests that the global trade of biomass is likely to increase by a factor of about 80 by 2030 (from 2010 level)[17]. It is likely that Europe will be a net importer of biomass and Ireland will compete with other European countries for imported biomass. Therefore, Ireland's access to international imports is likely to be based on its willingness to pay along with any sustainability criteria imposed by Ireland. In addition, one stakeholder noted that there are in some cases currently challenges to importing wood (especially soft wood) due to pest control regulations.

The EU Renewable Energy Directive (RED) provides criteria for sustainability which cover all biofuels used in transport and all liquid biofuels used in all sectors, and requires that they are used as part of a national scheme. The RED does not include equivalent sustainability criteria for solid and gaseous biomass used in the heat and electricity sectors. The European Commission has published recommended sustainability requirements for solid and gaseous biomass set out in Communication SEC(2010)65-66 which includes a methodology for calculating the life-cycle GHG emissions of biomass. It is up to each Member State to determine whether or not to include such sustainability criteria when introducing subsidies for biomass. A few Member States have adopted some or all of the recommendations set out in the Communication, including the U.K., Denmark, Belgium and the Netherlands.

The following form the basis of the EU sustainability criteria[18]:

[17] Matzenberger et al., (2015) *Future perspectives of international bioenergy trade*
[18] https://ec.europa.eu/energy/sites/ener/files/documents/technical_memo_renewables.pdf

EU Renewable Energy Directive (EC 2009)

The EU Renewable Energy Directive includes the following key aspects of relevance to the sustainability of solid and gaseous biomass fuels:

1. **Biodiversity protection** – avoiding land use changes of certain types of land:
    a. **High biodiversity value** – primary forests, protected areas, highly biodiverse grasslands
    b. **Lands with high carbon stock** – wetlands, continuously forested areas, other forested areas
    c. **Peatlands**
2. **GHG emission savings** – At least 35% savings, increasing to 50% in 2017 (60% for new installations from 2017) compared to the EU's fossil energy mix (83.8 gCO_2/MJ).

The recast Renewable Energy Directive (EC 2016)[18]

The recast Renewable Energy Directive strengthens the existing criteria and extends them to cover biomass and biogas for heat and power. It includes the following new requirements relevant to solid and gaseous biomass for heating, cooling and electricity production:

1. A new sustainability criterion on forest biomass in introduced, in order to ensure that the production of wood fuel continues to be sustainable and that any LULUCF emissions are accounted for (in the country of biomass production).
2. The EU sustainability criteria are extended to cover solid biomass and biogas used in large heating, cooling and power plants (above 20 MW fuel capacity). This means that such plants are required to provide at least 80% GHG emissions savings compared to fossil fuels from 2021, and 85% savings from 2026.
3. Large-scale biomass electricity plants (above 20 MW) will need to use high efficiency combined heat and power technology (reaching efficiencies above

For imported biomass, the EU Renewable Energy Directive (RED) suggests criteria for biofuel sustainability and recommends that they are used as part of a national scheme, but these are currently not binding. Ireland could enforce these recommendations or choose to apply the same criteria as those in the UK RHI[19].

[19] DECC (2013), *Impact Assessment - RHI Tariff Review, Scheme Extensions and Budget Management*

UK biofuels sustainability criteria – 2015

The UK biofuels sustainability criteria expand on those in the EU Renewable Energy Directive (2009):

1. **Biodiversity protection** – specific land criteria, in order to ensure biodiversity and minimise negative environmental impacts
    a. The fuel must be **100% from legal sources** (legally harvested as defined in the EU Timber Regulation (EUTR))
    b. At least 70% of the fuel most come **from sustainable or deemed sustainable sources** (as defined in the Timber Standard for Heat & Electricity)
    c. For a forest to be labelled a ‘sustainable source’, its management has to fulfil a number of standards, such as: minimising the harm for the ecosystem; maintaining the forests’ productivity; maintaining the ecosystems’ health and vitality; maintaining biodiversity; complying with local and national requirements regarding labour and welfare as well as health and safety; and developing a regard for a variety of local factors related to the forest such as customs, dispute settlement and land tenure rights.
2. **GHG emission savings** – lifecycle greenhouse gas emissions threshold of 34.8 gCO_2/MJ of biomass heat produced or biomethane injected (125 gCO_2/kWh). Furthermore, there are plans to introduce a minimum greenhouse gas threshold of 60% relative to the EU-wide fossil fuel comparator (83.8gCO_2/MJ), and to apply the criteria to all biomass heat receiving RHI subsidies.

For each scenario modelled, the potential carbon savings are determined. In this study, we have considered both the life-cycle assessment (LCA) emissions as well as emissions based on a ‘zero-rating’ for all biomass. The LCA emissions indicate how life-cycle emissions could vary between scenarios with differing levels of imported biomass and with differing levels of sustainability criteria. The ‘zero-rating’ method presents the carbon savings in accordance with the Renewable Energy Directive 2009 rules for calculating the greenhouse gas impact of biofuels, bioliquids and their fossil fuel comparators.

The potential carbon savings (when considering LCA emissions) are highly dependent on the type of biomass used and the carbon intensity of any imported biomass. Typical carbon intensity values as provided in the UK Ofgem’s *Sustainability Self-reporting Guidance* (Ref. 20), based on LCA emissions are shown in Table 3-3. For Ireland’s domestic biomass the LCA carbon intensity (CO_2-eq) is estimated to be around 7.9-8.6 $kgCO_2$/MWh (2.2-2.4 $kgCO_2$/GJ)[21] compared with ≈200 $kgCO_2$/MWh for gas (and with supply chain emissions being of minor importance when the average transport distance is <100km[22]), implying a carbon emissions reduction of 96% versus gas. However, imported biomass is likely to have a higher CO_2-eq due to the variation in the source and method of production as well as the additional transportation required. Most solid biofuels currently imported to the EU are from Canada and the US (≈70%)[23]. One study finds that the transport of biomass from Canada to Europe increases the CO_2-eq by a factor of 5-10[24].

[20] Ofgem, *Sustainability Self-Reporting Guidance* (2017)
[21] Forest biomass supply chains in Ireland: A life cycle assessment of GHG emissions and primary energy balances – Murphy et al., 2014
[22] Forest biomass, carbon neutrality and climate change mitigation – Berndes et al., 2016
[23] Strategic Inter-Task Study: Monitoring Sustainability Certification of Bioenergy – IEA Bioenergy 2013
[24] An environmental impact assessment of exported wood pellets from Canada to Europe - Magelli et al., 2009

Table 3-3: Carbon intensity of biomass based on LCA

Biomass type	Carbon intensity, gCO_2/kWh
Wood chip (forest residues)	3.6
Wood chip (short rotation)	14
Wheat straw	7.2
Miscanthus	25

The carbon intensity of biomass is dependent on the distance and method of biomass transportation, and variations in the source and method of production (for example, whether the residue would otherwise be burned as a waste or left to decay in the forest[1,25]). Based on the range of values cited in the sources reviewed and on the most up-to-date supply curves for Ireland developed by SEAI[26], the following values of biomass carbon intensity are used to investigate the impact on CO_2 savings[27]:

1. ***Domestic*: 8 gCO_2/kWh**[21]
2. ***Strongly limited biomass imports:* ≤ 50 gCO_2/kWh**[25, 28]
3. ***Limited biomass imports:* >50 - ≤100 gCO_2/kWh**[24, 25, 28]
4. ***No limit on biomass imports: >100* gCO_2/kWh**[28]

The RHI design could include sustainability criteria (including maximum CO_2 intensity) and/or the tariffs could be differentiated by the CO_2 intensity of the biomass. The UK RHI scheme does not differentiate tariffs by CO_2 intensity of the biomass but includes the sustainability criteria described above. In the UK scheme, there are two options for demonstrating compliance with the sustainability criteria: (i) sourcing fuel from suppliers list on the Biomass Suppliers List (BSL) or (ii) self-reporting. To assist with self-reporting, a 'Solid and Gaseous Biomass Carbon Calculator'[29] has been made available. To ensure compliance with any sustainability criteria included in the RHI for Ireland, a similar approach could be used. The same Carbon Calculator tool could be applied; alternatively, other similar tools are available. For example, the EU FP6 project EFORWOOD has led to the development of 'ToSIA' (Tool for Sustainability Impact Assessment). ToSIA analyses the environmental, economic, and social impacts of changes in forestry-wood production chains, using a consistent framework from the forest to the end-of-life of final products. Like the Carbon Calculator, ToSIA could be used to develop and maintain an approved supplier list for imported biomass for the RHI and, potentially, to assist with self-reporting.

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[25] Comparison of Lifecycle Greenhouse Gas Emissions of Various Electricity Generation Sources – WNA, 2011

[26] SEAI/Ricardo Energy & Environment, *Bioenergy Supply in Ireland 2015 – 2035: An update of potential resource quantities and costs* (September 2016)

[27] For national accounting biomass carbon intensity is zero. A sensitivity on the carbon savings for LCA versus zero carbon rating for biomass is show in section 5.7

[28] Life Cycle Impacts of Biomass Electricity in 2020 – DECC, 2014

[29] See: https://www.ofgem.gov.uk/ofgem-publications/93896/b2c2rhiusermanualv71-pdf (Accessed November 2016)

Eligibility criterion for maximum biomass lifecycle carbon emissions

As part of the sustainability criteria, the RHI could include a maximum biomass lifecycle carbon emissions eligibility criterion. This could be the same as that currently applied in the UK RHI scheme; a lifecycle greenhouse gas emissions threshold of 34.8 gCO_2/MJ of biomass heat produced or biomethane injected (125 gCO_2/kWh). Article 26 of the recast Renewable Energy Directive[30] of November 2016 includes an enhanced requirement for biomass sustainability for heating, cooling and electricity production from biomass fuels of a minimum 80% GHG emission saving versus fossil fuels. However, this applies only to new installations from 2021, and does not apply to systems smaller than 20 MW for solid biomass fuels or systems smaller than 0.5 MW for gaseous biomass fuels, in order to "minimise the administrative burden" on those installations. The RHI in Ireland could nonetheless apply sustainability criteria in line with these proposals to ensure overall (i.e. global) CO_2 emissions savings are delivered.

The indicative range of carbon intensities for domestic and imported biomass above suggests, for example, that a threshold of 75 gCO_2/kWh would allow the use of a significant quantity of imported biomass, although there is some risk that a lower threshold such as this will constrain supply, and is likely to increase somewhat the average cost of biomass used. According to the evidence above, domestic biomass is unlikely to be affected by a maximum carbon intensity threshold.

There may be alternative approaches to requiring full biomass fuel chain GHG reporting (as in the U.K. RHI) that could be adopted. This could involve identifying the steps in individual supply chains which typically contribute the highest greenhouse gas emissions, and could potentially tip the life-cycle GHG emissions to a point where the fuel is not delivering sufficient savings over a fossil fuel alternative. For example, for woody and grassy biomass fuel chains it can often be the amount and type of fuel used in drying and processing steps which contribute the most to life-cycle emissions.

This alternative approach could involve identifying the 'high risk' supply chains and the 'high risk steps' within them, and setting some indicative thresholds for fuel/material use, or, a GHG threshold. Applicants would be required to report on these steps and demonstrate that their practices are resulting in GHG emissions below the indicative thresholds. This approach would likely require a lower administrative burden on reporters and the administrator but give sufficient assurances that GHG savings were being delivered by biomass fuels supported under the RHI.

Tariff variation according to biomass sustainability criteria

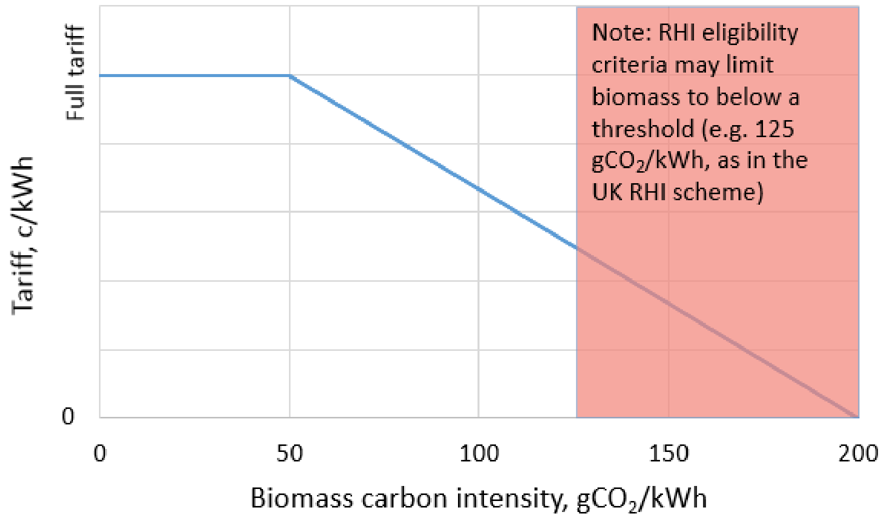
In addition to a maximum eligible lifecycle CO_2-eq, the use of biomass with the lowest possible CO_2-eq could be incentivised by varying the RHI tariff for biomass technologies according to the level of CO_2 savings which would be expected relative to the fossil fuel comparator.

One appropriate approach would be to reduce the biomass tariff in a simple linear way according to the estimated lifecycle CO_2-eq. The full tariff calculated could be offered to all installations using biomass with a lifecycle CO_2-eq below some lower threshold (e.g. 50 gCO_2/kWh), with the tariff decreasing linearly above that threshold such that the tariff would fall to zero for a lifecycle CO_2-eq equal to the fossil fuel comparator (≈200 gCO_2/kWh). Note that the maximum lifecycle CO_2-eq eligibility criterion may exclude part of this range from

[30] https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v7_1.pdf (Accessed March 2017)

receiving any tariff at all, as shown in Figure 3-2. The calculation of the applicable tariff could be determined using the same tool as is used to determine the eligibility threshold, such as the Carbon Calculator, ToSIA or similar tool.

Figure 3-2: Illustration of possible mechanism to differentiate biomass tariff by carbon intensity



Greenhouse gas emissions from biogas and biomethane

GHG emissions associated with production of biogas and biomethane include emissions associated with transport of the feedstock to the plant, operation of the plant (e.g. fugitive emissions from the anaerobic digestion plant) and for biomethane plant, energy used to operate upgrading systems and methane slippage from that equipment.

Where crops such as grass silage are used as a feedstock, there are also the emissions associated with their cultivation – principally emissions associated with the production of fertilisers applied to the crop, and nitrous oxide emissions from the soil caused by application of nitrogen in fertilisers or digestate, and CO_2 emissions from the application of urea fertiliser and certain types of limiting products.

Typical emissions associated with biogas and biomethane associated with biogas and biomethane production were provided by Ricardo Energy & Environment (based on results from Solid and Gaseous Biomass Carbon Calculator 2.0), and are shown in Table 8. For comparison emissions associated with natural gas when it is combusted are 204 gCO_2/kWh (on a lower heating value basis), so biomethane from the typical AD plants shown in Table 8 can offer GHG savings of between 43% and 69% compared to natural gas. The emissions per unit of heat produced from biogas depend on whether the biogas is combusted in a boiler or CHP plant, and in the case of CHP plant how much of the heat is used. The more of the heat that is produced by the CHP which goes to a useful use, the lower emissions per unit of heat and electricity from the CHP are. Typical emissions per unit of heat and electricity are shown in Table 9.

Table 3-4: Typical GHG Emissions for biogas and biomethane produced from Anaerobic Digestion[31]

Feedstock	Biogas	Biomethane
	gCO_2/kWh	gCO_2/kWh
Manure/slurry	24	63
Grass silage	77	117

Table 3-5: Emissions for heat and electricity production from biogas[32]

Feedstock	Boiler		CHP plant			
	High heat load		Medium heat load		High heat load	
	Biogas	Heat	Heat	Electricity	Heat	Electricity
	gCO_2/kWh	gCO_2/kWh	gCO_2/kWh	gCO_2/kWh	gCO_2/kWh	gCO_2/kWh
Manure	24	30	20	57	18	50
Silage	77	96	64	181	56	158

Emissions from AD plant using waste feedstocks are expected to have about the same emissions as plants using slurries[33]. Plant using a mixture of silage and slurries or wastes will have emissions that fall between the two values shown below, depending on the proportion of the biogas generated by each feedstock. For some of the archetype plants considered, silage feedstock accounts for the majority of biogas produced, so that emissions will be close to those for a plant using all grass silage. In others, slurry is the predominant feedstock with silage providing only about a third of the biogas generation potential so emissions for these will be closer to those for manure/slurry plant (at around 40 g CO_2/kWh biogas).

How the plant is operated can significantly affect emissions e.g. open storage of digestate could significantly increase emissions, and combustion of the off gases from the process of upgrading biogas to biomethane of biogas can reduce emissions (as the off gases contain small amounts of methane)[34]. Use of slurries and manures in AD can also lead to additional emissions reductions in the agricultural sector, as emissions from storing digestate are less than emissions from storing slurries and manures[35]. Use of wastes, can similarly deliver additional GHG savings in the waste sector, if the wastes would have otherwise been disposed of to landfills.

[31] Based on results from Solid and Gaseous Biomass Carbon Calculator 2.0 (build 36)
[32] Emissions per unit of heat and electricity produced from biogas CHP plant calculated using the methodology specified in the RED for allocation of emissions.
[33] Biogas and biomethane from waste feedstocks are not included in the solid and gaseous biomass carbon calculator. A comparison of results for manures and waste in the BioGrace GHG calculation tool for electricity, heat and cooling (version 3) shows that emissions are very similar.
[34] Based on results from BioGrace GHG calculation tool.
[35] JRC, 2015. Solid and gaseous bioenergy pathways: input values and GHG emissions

3.4 RHI eligibility

3.4.1 Inclusion of ETS sector

Given the short timeline for meeting the 2020 RES-H target, and the significant administrative burden associated with the RHI, it may be beneficial to encourage a smaller number of large renewable heat installations. A number of stakeholders consulted suggested that it would be preferable to encourage larger users to take up renewable heating as this may be the most cost-effective way of reaching the 2020 target. The ETS sector has a large economic potential that could be unlocked with an RHI or similar. However, a fraction of this is likely to be cost-effective even without an RHI given the economies of scale. In addition, uptake of Biomass CHP within the ETS sector is expected in the power sector as a result of the Renewable Electricity Support Scheme (RESS, the successor to REFIT) without the additional support of an RHI (see Section 5.3). Therefore, whilst the inclusion of the ETS sector in the RHI would increase the chances of reaching the target, there is a risk that the uptake would have occurred without an RHI, such that an RHI would represent an over-incentive.

In addition, a number of stakeholders argued that the scope of the RHI should be expanded to include the ETS sector to ensure competitiveness with other countries. It was suggested that the exclusion of the ETS sector could reduce competitiveness of Irish industry since ETS users are eligible for renewable heating in other EU countries, including Northern Ireland.

However, as described in detail above, one of the two key objectives of the RHI, along with meeting the 2020 RES-H target, is to contribute to the 2020 non-ETS sector CO_2 emissions reduction target. Inclusion of the ETS sector would be likely to reduce the contribution of the RHI to this second objective. The pros and cons of including the ETS sector in the RHI should therefore be considered.

3.4.2 Inclusion of Domestic sector

Earlier work on the potential for renewable heat to contribute to Ireland's 2020 targets has suggested that it will not be cost-effective to include the domestic sector in the scheme. For this reason, the domestic sector was excluded from the scope of this study, and we have not considered RHI design options including domestic users.

One stakeholder expressed concern that the scheme excludes domestic users despite being funded by the public purse, and that the scheme may be subject to public perception issues if it is seen only to be provided to businesses.

3.4.3 Minimum energy efficiency eligibility criteria

The RHI could be used not only to incentivise the uptake of renewable heating technologies but also to encourage improvements in energy efficiency by including minimum participant eligibility criteria. This would contribute towards the Government's obligations under the EU Energy Efficiency Directive Ireland's energy efficiency targets for 2020 and 2030. However, it should be noted that in some cases, switching to a renewable technology (e.g. switching to a biomass boiler from a gas boiler) can reduce the heating efficiency, leading to an increase in final energy demand.

The UK RHI includes energy efficiency requirements for the domestic sector only. This is due, in part, to a lack of standardised schemes that could be used to assess the energy efficiency in the non-domestic sectors. Ireland has an energy efficiency scheme, the Building Energy Rating (BER), which could form the basis of a minimum energy efficiency criterion for the domestic and commercial sectors. However, it is not suitable as a basis for a minimum efficiency criterion in industry or agriculture, where the heating demands include significant process heating and are hence much more varied, and cannot be captured in a highly standardised approach such as BER or EPC. In such cases, a more bespoke assessment is required.

One possible approach based on an already existing framework would be to link the RHI, for large industrial users, to SEAI's Excellence in Energy Efficiency Design (EXEED) scheme. EXEED is a new scheme developed by SEAI and is currently in the pilot stage. It involves ongoing support and management to ensure best practice and, given the bespoke assessment involved, is most cost-effective for large and/or energy-intensive installations. EXEED certifications last 3 to 5 years with annual reviews of the management and best practices.

Further research into the suitability of the BER and EXEED schemes for the RHI, along with the associated costs and administrative burden, is required.

For smaller users, and those with no significant process heating, a minimum efficiency criterion based on the BER scheme would be more cost-effective; indeed, given the administrative requirement, it would not be possible for EXEED to be applied across the board. Mandatory BER certification was introduced for new domestic buildings in 2007[36] in response to the EU Energy Performance in Buildings Directive, and was extended to new non-domestic buildings in 2008 and buildings offered for sale or letting in 2009. The assessment involves a site inspection where assessors review the performance specification of the equipment and determine the expected energy demands of the building under standard conditions. The assessment includes space heating, hot water, lighting and electricity for HVAC. The expected primary energy demand of the building is then compared to that of a notional building under the same standard conditions to determine the BER rating (A1-G). The assessment includes an advisory report on how the energy performance of the building could be improved. The key advantages of the BER scheme for this purpose are that it is a national scheme and so provides a standardised approach; that it is already well-established, with around 35% of buildings already have a BER certificate, and with 8,000-10,000 buildings currently assessed each year; that there would be the capacity to meet the additional demand for assessment the RHI may entail; and that it is a relatively cost-effective and straightforward process. We note that the inclusion of any minimum BER rating for RHI eligibility should take into consideration the BER rating of the building after installation of the renewable heating technology since the installation itself will (through the change in heating efficiency and fuel, and the associated impact on primary energy consumption) affect the BER rating of the building.

The majority of stakeholders consulted support the inclusion of a minimum energy efficiency criterion. It was suggested that measures to improve the energy performance of the fabric of the building should be considered before, or alongside, implementation of the renewable heating technology. A concern frequently raised was the possibility for the undesirable outcomes seen in certain cases in the UK RHI scheme, where renewable heating systems were installed in highly inefficient buildings, leading to high costs to the Exchequer, uncertainty over the net impact on carbon emissions and issues of poor public perception. One stakeholder, however, suggested that the inclusion of minimum energy efficiency criteria is unnecessary, not cost-effective for many users, and thus likely to reduce uptake of renewable heating. This stakeholder suggested that, in order to reach the 2020 targets,

[36] http://www.irishstatutebook.ie/eli/2006/si/666/made/en/print (Accessed November 2016)

the barriers to uptake should be kept to a minimum, and that additional eligibility criteria could be brought in after 2020.

We suggest that minimum energy efficiency standards will be a key component of a successful RHI design. This is supported by the negative publicity surrounding certain installations in the UK RHI, in which cases there is a widespread recognition that insufficient controls were in place to ensure that heat generated under the RHI was applied to useful purposes.

3.4.4 Location based eligibility criteria for biomass technologies

As described in section 3.6.4, biomass technologies lead to the emissions of relatively high levels of particulate matter and nitrogen oxides. As such, biomass installations have the potential to cause or exacerbate local air quality problems. It will therefore be particularly important to avoid locating biomass installations in areas with pre-existing air quality issues (due, for example, to existing sources of industrial emissions or high traffic flows).

However, air quality issues are typically highly localised, and distributed across rural, suburban and urban areas. As such, discussion with stakeholders and the project steering board have suggested that it will be most appropriate to assess the eligibility of biomass installations on a highly localised basis, according to an assessment of the local air quality. In the UK, DEFRA have a model for emissions in areas with different buildings and stack heights. The equivalent model does not yet exist for Ireland but could be developed. Given that the RHI is focused on commercial and industrial buildings, restricting locations could significantly limit the market. Balancing local air quality issues and uptake of biomass technologies will therefore require careful consideration.

3.4.5 Grandfathering

Some stakeholders mentioned the importance of existing renewable heat installations being eligible for the RHI, on the basis that it is important that existing RH installations are not scrapped in order to apply for the RHI. One stakeholder suggested, however, that the tariffs should account for the lower efficiency of current installations versus those installed at the time of the scheme's implementation. However, one stakeholder was concerned that existing RH installations might overwhelm the RHI budget if grandfathering is allowed. It was suggested that grandfathering should not be offered to any existing installations that have already received ReHeat funding. We note that the costs to the Exchequer presented in section 5 of this report do **not** include any allowance for grandfathering, which would be additional.

3.4.6 Minimum technology requirements

It is important that the RHI incentivises high quality installations that provide renewable heat in the most effective and efficient way. The minimum requirements will be technology specific; biomass boilers should be designed appropriately in order to minimise particulate matter and nitrogen oxide emissions[37], whereas heat pumps should be designed and installed in such a way that they demonstrate a high SPF to ensure they are producing renewable heat. It is also important that heat pumps are sized appropriately and are capable of meeting heat load requirements, as the appropriate sizing for heat pumps differs from that of the counterfactual technologies and heat pumps are unsuitable for less well insulated buildings. This could be achieved by including a list of eligible products and installers for the

[37] Study on Biomass Combustion Emissions – Irbea 2016

RHI. Including a list of eligible installers will help to manage the availability of skilled installers for each technology as the market grows in Ireland and the workforce adapts.

The EU Ecodesign standards will have an impact on smaller (<1 MW) installations. EU legislation and BER both require heat pumps to meet a minimum SPF of 2.5 to be considered renewable.[38,39] The UK RHI currently requires heat pumps to meet a minimum design SPF of 2.5 and biomass installations to have an emissions certificate (see section 3.3.2 for more details).

Many stakeholders are concerned about the quality of installations under an RHI and the impact on the consumer perception of the technologies, if the introduction of the RHI causes the demand for RH technologies to increase more quickly than the supply of skilled installers. This could lead to poor quality installations that do not achieve the expected efficiency and/or lifetime, increase the emissions, and give the technologies a bad reputation. These stakeholders support the proposal for a recommended list of products and installers to ensure high quality installations.

The proposals described above will be critical to the success of the RHI; however, it is also clear that they will require substantial administrative resources to undertake the required provision of information, monitoring and evaluation across the supply chain from producer to end-user. SEAI, as a member of the steering board for this work, has emphasised the level of work required to ensure adequate governance structures are in place at all levels before the RHI is launched, and that the timeline for implementation of the scheme should reflect this. They recommend that the detailed scheme design, including these components, is carried out as soon as possible.

3.4.7 Eligibility of heat uses for the RHI

There is some concern among stakeholders that renewable heat produced through the RHI will not always be used in the most efficient way, but will still receive payments. It is clearly important not to encourage inefficient use of heat. Minimum energy efficiency criteria, as described in section 3.2.3, will prevent some instances of inefficient heat use, but additional criteria may be required to prevent misuse of the scheme. In some circumstances, for example, the heat produced from a CHP unit is greater than the on-site heat demand, and there is a risk that the heat will not be usefully meeting any existing demand. Effective governance and regulation, including monitoring and auditing will be required to ensure that all heat supported under the RHI is being used for eligible purposes. It should be noted, however, that this will add a substantial administrative burden to the scheme, which should be properly accounted for in the impact assessment for the scheme. Further options that could help reduce inefficient heat use are described in section 3.5.3.

It will also be important to consider which heat uses should be eligible for the RHI. For example, an AD CHP plant typically uses a proportion of the heat produced in the AD process itself. Renewable heat might also be used for drying biomass to improve the biomass fuel quality or for drying digestate before it can be used as a fertiliser. These uses of the heat are not replacing any counterfactual (since the heat demand is associated with the renewable heating installation itself), and as such could be deemed ineligible. However, there is concern among some stakeholders that if these heat uses are not deemed eligible for the RHI, the economic case for these technologies will no longer be attractive, or that

[38] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D0114&from=EN
[39] seai.ie/Your_Building/BER/BER_Assessors/Technical/DEAP/DEAP_2009/DEAP_Version_3_2_0_Calculation_Excel_Version.xlsx

this could encourage the use of biomass with a high moisture content, resulting in lower efficiencies and higher emissions of PM and NOx. Accordingly, it will be necessary for the implementing body to assess the standards and requirements for the various technologies and site types in order to deem what constitutes eligible heat.

3.5 Setting the level of the tariff to promote the level of uptake and mix of technology types desired

3.5.1 Age of counterfactual technologies being targeted for replacement

Targeting only counterfactual technologies that are at the end of their useful life will strongly limit the potential uptake of RH technologies. Given the short timescale available to meet the 2020 RES-H target, some degree of early replacement of counterfactual technologies is likely to be required. In this case, the RHI tariffs need to be high enough to incentivise replacement of counterfactual technologies that still have useful lifetime remaining. Limiting the length of time over which the RHI is offered to new RH technologies (e.g. only accepting new applicants to the RHI until 2020) will act to bring forward the decision to convert to renewable heating for some, increasing the potential market size. However, this is likely to be strongly controlled by State Aid rules.

Most stakeholders agree that the RHI should not be limited to end-of-life replacement of the incumbent system as this would restrict the scheme and its impact too much. In many cases, stakeholders reported that the counterfactual heating system is typically kept in place to provide backup for the renewable heating technology. Under these circumstances, the age of the incumbent technology is likely to have less impact on the users' decision to install a renewable heating technology.

However, other stakeholders suggested that the focus should be on end-of-life replacement and new builds. It has also been suggested that not all technologies should be targeted for replacement; for example, the replacement of high efficiency boilers and existing renewable heating technologies might not be desirable. There is a concern that some counterfactual systems will be replaced systems that do not deliver any improvement in efficiency or emissions. The pros and cons of the options described above should be considered in conjunction with the analysis presented in this report which shows the likelihood of the RES-H target being met under various RHI designs.

3.5.2 Duration of support and profile of payments to scheme participants

Duration of support

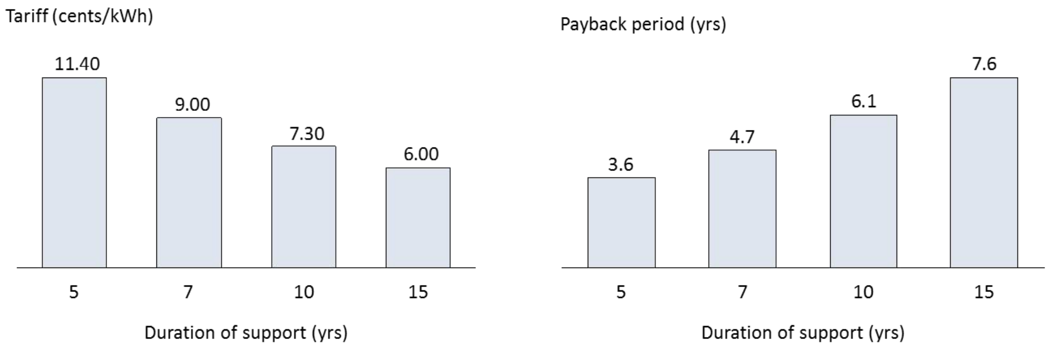
The non-domestic UK RHI scheme provides support over 20 years, reflecting the expected lifetime of the majority of the renewable technologies[40]. Providing support over the full lifetime of the renewable technologies has the key advantage of incentivising on-going, efficient use of the technologies. However, the long duration of support leads to long payback periods and is likely to significantly limit the uptake.

The tariffs (in cents/kWh) are set such that all the additional costs of the RH technology relative to the counterfactual technology over the lifetime of the RH technology are reimbursed over the duration of support of the RHI scheme. This means that when the

[40] We note that feedback from the Irish stakeholder consultation suggests the lifetime of renewable heating technologies is likely to be closer to 25 years.

duration of support is shorter the tariffs will be significantly higher. As a result, the payback period is shorter and the uptake is expected to be higher. However, the annual cost to the Exchequer will be significantly higher, albeit for a shorter period of time. An additional risk associated with a shorter duration of support is of the participant reverting back to the counterfactual technology once the support ends, if the ongoing costs of the renewable heating technology are larger than for an alternative, fossil-fuel option. Figure 3-3 presents an illustrative example of how the payback period varies with the duration of support, under the approach taken in this analysis.

Figure 3-3: Illustration of the impact on payback period of the duration of support



Many stakeholders suggested that a duration of support in the range 5 to 10 years is preferable, as a longer payback time than this would not appeal to most investors. Some stakeholders suggested that a longer support period of 15 to 20 years would be preferable to ensure ongoing use of the technologies, and to provide certainty in the supply chain for biomass suppliers.

Profile of payments

The RHI payments could be uniformly distributed over the duration of support, paid as a combination of an upfront and ongoing payments, or ‘front loaded’ such that the level of support is higher for an initial period and then falling to a lower level for the remaining duration of support. For example, for a 15 year duration of support, the payments could be paid through a higher tariff for the first 5 years followed by a lower tariff for the last 10 years.

Under all payment profiles the tariffs are calculated such that the net present value (NPV) of the payments over the full support period remains constant. The inclusion of an upfront payment, or the use of front loading, has the advantage of reducing the payback period and therefore likely increasing the uptake. However, both options also increase the annual cost to the Exchequer over the early years of the RHI. There is also a risk that the inclusion of upfront payments will result in poor quality installations in a ‘race to the bottom’. Furthermore, in some cases where front loading is applied, the higher tariff offered in the first period may be higher than the marginal cost of producing a unit of heat. In such case, this carried the risk of incentivising over-production of heat.

It should be noted that a focus on ongoing payments carries the risk that there will be little incentive for a contracted building developer, who will not be operating the site, to incur the higher cost of installing a renewable heating technology. This is a variation on the ‘split incentive’, where the long-term beneficiary of a decision to install a renewable heating technology is not the agent taking the decision of which heating system to install. An upfront payment suffers from a different issue in this case: while the developer may benefit from the upfront payment, the building occupant would not receive any payment towards any increase in ongoing costs that may be incurred.

The UK RHI offers only ongoing payments. As part of this decision, the expectation was that the RHI would stimulate the market to provide financing options to cover the upfront costs of the RH technology. However, evidence suggests that this has not been the case, with the upfront cost remaining the most frequently cited concern among potential investors[41].

Most stakeholders suggested that a mix of ongoing and upfront payments would be preferable to incentivise uptake along with promoting efficient lifetime operation. They think that without an upfront payment many will not go ahead with the installation given the high upfront costs of most of the renewable heating technologies. However, they agree that ongoing payments will be needed to ensure the installer continues to use the renewable heating technology where the ongoing costs are greater than for the counterfactual. It was also acknowledged that the upfront payment option may not be viable due to the impact on the annual Exchequer budget.

3.5.3 Payment based on metered or deemed heat use

As in the UK, ongoing RHI payments in Ireland will be paid on a per kWh basis. Therefore, in order to determine the payment required for each installation, the heat output needs to be either metered or deemed (where deemed heat output refers to heat output predicted or modelled according to the type and size of building or process using the heat, or based on verified historic data).

Whilst a requirement for metering potentially results in an additional upfront cost for users (where a heat meter needs to be installed) along with an ongoing administrative requirement, the use of deemed heat also creates an additional upfront cost (either to undertake an energy audit where required, or to verify historic metered data or an existing BER certificate, for example).

The advantages of payment based on deemed heat use are that energy efficiency is incentivised, and that the consumer knows in advance the level of RHI revenue they will receive each year. However, there is a risk that payments based on deemed heat use may result in payments being made despite the RH technology not being used (or only being used to generate some fraction of the heat demand being claimed for, with a fossil-fuel system used to generate the remainder). Stakeholder feedback suggests the counterfactual heating system is usually kept in place to provide back-up to the renewable heating installation, such that there is a risk the consumer will revert to using the counterfactual.

In addition to addressing the risk of the RH system not being used, payment based on metered heat has the advantage that it particularly incentivises uptake where heat consumption is likely to be large, improving the overall cost-effectiveness of the system. In addition, a requirement for metering would offer additional certainty over the quantity of renewable heat generated through the RHI (and the actual contribution to the RES-H target).

However, payment based on metered heat has the disadvantage that it may in some cases incentivise the over-production of heat. This is a particular risk when the marginal price of generating an additional unit of heat is lower than the tariff offered for the unit of heat. We note that this situation could occur in certain cases, particularly for biomass-based heating, where a large fraction of the tariff offered corresponds to the repayment of the additional capital costs incurred (and not only additional ongoing fuel costs incurred). We propose a range of options to minimise and manage this risk. The impact of this outcome can be significantly reduced by tiering the tariffs by heat output, such that the marginal payment per kWh decreases the more heat is produced (see section 3.5.7). Minimum efficiency

[41] Frontier Economics, *RHI Evaluation: Synthesis*, Report for DECC (2016)

standards will also play a key role in ensuring RH systems are only installed in buildings where there is a pre-existing and 'genuine' need for heat, where the risk of systems being used to generate large amounts of excess heat is reduced.

An alternative approach could combine the deemed and metered options. In this case, an annual 'cap' on the heat output for which payment can be claimed could be applied based on an assessment of deemed heat output. Within this approach, actual payment would still be based on metered heat use, but only up to a maximum amount as specified by the deemed heat output. This would limit the potential impact of inefficient use of heat, but also provide certainty over the amount of renewable heat actually generated by the RH system. An important remaining disadvantage of this approach is that it may fail to incentivise the installation of RH technologies where there is a genuinely high demand for heat above and beyond that captured by the calculation of deemed heat output (for example, if deemed heat output were based on historic data, for which the heat demand of some new, genuine heat-intensive process is not captured). This is an important drawback, as these cases have the potential to contribute large amounts of renewable heat towards the RES-H target. To address these cases, however, there could be an option for the applicant to request (potentially at their own cost) a more in-depth energy audit capable of verifying the contributions of bespoke and/or recently-added heat uses. This would leave open a route for these applicants to receive payment for their full heat demand, whilst allowing the scheme implementing body to retain the 'checks and balances' to minimise the inefficient use of heat. It should be noted that the combined 'metered with cap based on deemed heat output' approach outlined here increases the scheme complexity both for applicants and for the scheme implementing body. However, this approach may be considered preferable to minimise the risk of misuse of the scheme.

There is a general consensus amongst stakeholders that large installations should be required to provide metered heat data in order to claim payment, as they would typically have metering regardless of any requirement of the RHI. It was generally thought that deemed heat use could be a suitable optional alternative for small installations, for which the cost and hassle of metering could be more significant. Furthermore, while the heat generation for smaller users can be determined relatively easily through an energy assessment, use of certified product efficiency information and/or historical energy bills, this is more difficult for larger users or users with non-standard process heat uses. In the particular case where a secondary heating source or backup heat supply is required, it was considered important that payment should be made only on metered readings.

3.5.4 Systematic adjustment to tariffs

Tariff indexing

Over the lifetime of the scheme the RH technology costs (both upfront and ongoing) are likely to change, due to changes in fuel prices as well as component prices (due in part to the market growth which may be stimulated by the RHI). It will be important to have a mechanism through which the tariffs can be adjusted – both for new applicants and for during the period of support – to take account of these changes. Tariff adjustment has the advantage of reducing the risk to the Exchequer of over-payment, as well as the risk of under-incentivisation, but leads to greater uncertainty for both the consumer and the Exchequer. This can be particularly problematic for projects with a long lead-time as the RHI revenue will not be known until the installation is in place. The uncertainty this creates for the investor is likely to influence the decision of whether to proceed with the project.

An important question is to which index the tariffs should be linked. In the UK RHI, tariffs for all new installations are linked to the Consumer Price Index (CPI)[42]; alternative indices include industry-specific/technology-specific prices and/or fuel prices. Respondents to DCENR's 2015 public consultation expressed the view that any indexation to inflation should be based on CPI. There is a question as to whether CPI is the most suitable index to use for all technologies. For zero variable fuel cost technologies such as solar thermal, an on-going CPI linked payment may be too generous. However the deployment of solar thermal in Ireland is expected to be low relative to other renewable technologies.

Budget management mechanisms

In addition to indexing the tariffs, there may be a need for one or more 'budget management mechanisms'. Tariff degression, whereby the tariffs (for new applicants only) decrease when the uptake crosses a certain threshold (either overall or on a technology basis) could be used to control the uptake and associated costs to the Exchequer. The degression thresholds, and the percentage decrease of the tariffs, should be pre-determined to ensure clarity. In addition, a budget cap could be included. In this case, when the projected RHI payments reach the budget cap (either annually or overall) the scheme would close to all new applicants either temporarily or permanently. Both of the above mechanisms are currently used in the UK RHI.

Generally, stakeholders support tariff degression but are keen that some certainty could be provided in advance of an installation being commissioned to ensure the future returns for the investor. Without this, it is unlikely that many financing options will be available. The degression structure and timelines need to be transparent and publicised well in advance to minimise uncertainty about the level of support that an installation will have once completed.

3.5.5 Allowed rate of return

The internal rate of return (IRR) that participants can expect to gain from the RHI payments is likely to affect the uptake of RH technologies. The higher the IRR, the higher the RHI tariff and hence the lower the payback period of the installation. This may be particularly important for technologies with high upfront costs.

The IRR required by investors depends on both the cost of capital and the risks associated with the RH technologies, for many of which there is not a well-established market in Ireland. These factors in turn depend on the sector, size of installation (and hence the investment size and payback period) and technology type. The RH market is still relatively small and immature in Ireland for many of the technologies included in this study and as such there is a higher level of risk associated with RH technologies than the counterfactual technologies. The IRR needs to reflect these risks in order to incentivise the uptake of renewable heating technologies, develop the market and help build consumer confidence.

The tariffs for the UK non-domestic RHI scheme are based on a 12% IRR for all renewable heating technologies except solar thermal[43]. This is not differentiated by consumer sector. A value of 12% was chosen in the UK case to reflect the risks associated with the renewable heating technologies. A report on hurdle rates in the UK for a wide range of renewable electricity generation projects found a range of whole project hurdle rates (6.1%-15.7%)

[42] For installations with tariff start date before 1st April 2016, the UK RHI scheme links tariffs instead to the Retail Price Index (RPI).
[43] Frontier Economics, Task 1 – Review of RHI Design Options: A report prepared for DCENR, August 2016

based on stakeholder consultations, reports and bottom up calculations[44]. There rates are in line with a background calculation that was carried out as part of this study and found the cost of equity based on a biomass boiler in the Irish hotel sector would be in the range of 6.9-12.8%.

Since the introduction of the UK RHI, investor confidence in biomass boilers in the UK has increased and as a result investors are more willing to fund projects[45]. In addition, the cost of capital in Ireland, if the current low interest rate environment continues to prevail, is expected to be lower than it was in the UK when the RHI was launched. As such, a somewhat lower IRR could be considered acceptable to project developers.

It is important to emphasise here that the RHI tariffs derived in this report, as described in section 4, are based on the identification of *reference installations* for each of the technology-size segments defined by the stated set of design options. It is to these reference installations – in combination with all other assumptions made as described in section 4 – that the allowed rate of return is applied. In reality, variety in the heat load characteristics of individual installations and other factors will lead to a distribution of project IRRs both higher and lower than the value applied in the calculation of tariffs.

3.5.6 Differentiation by renewable technology

Differentiation of tariffs by renewable technology allows the distribution of costs for the different technologies to be accounted for. Given the range in both upfront and ongoing costs of the renewable heating technologies (see Appendix), differentiation by technology will be required to ensure a diverse mix of technologies are taken up as a result of the RHI. With no differentiation, it is likely that only the lowest cost technologies will be taken up and/or the lower cost technologies will be over-incentivised in order to ensure the higher cost technologies can be incentivised.

The majority of stakeholders support the inclusion of different tariffs for different technology types due to the different costs associated with each. It was suggested that this will be required in order to have the maximum impact towards reaching the target. However, others suggest further consideration of whether all technologies should be incentivised, especially those which are the least cost-effective or that have little potential to contribute significantly over the long term. Certain stakeholders suggest that the tariffs should be differentiated by technology to allow non-biomass technologies (which typically require higher tariffs) to be incentivised as they have a lesser impact on air quality and therefore warrant the additional cost to the Exchequer.

3.5.7 Differentiation by installation size

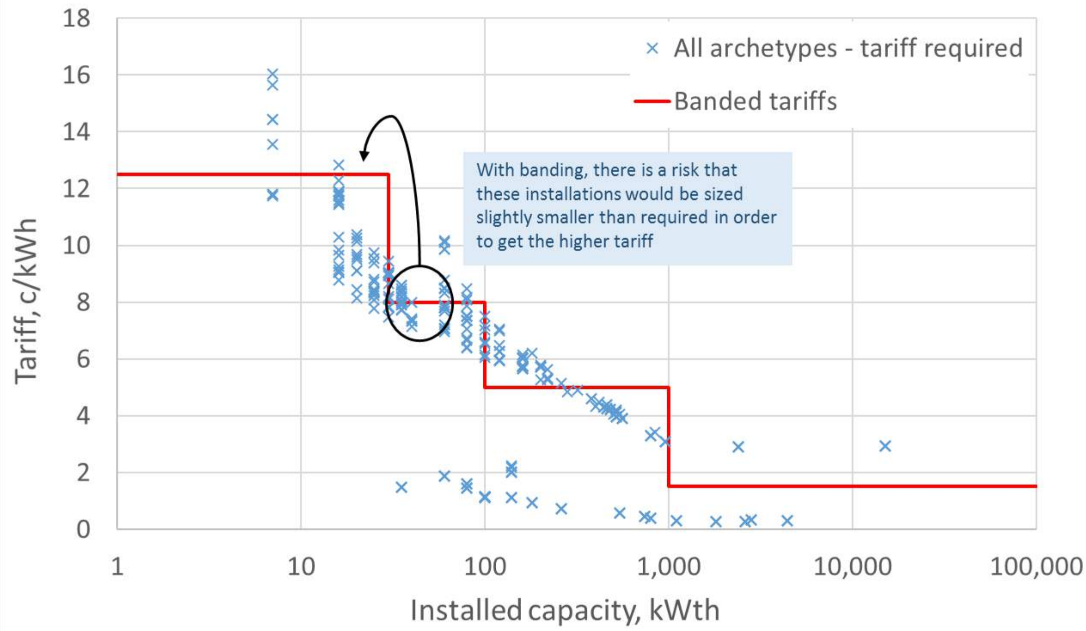
The cost of generating renewable heat typically depends on the size of the installation, as well as by technology. In order to reduce the risk of over- or under-incentivisation of installations, it is an option to differentiate by installation size to reflect the change in both upfront and ongoing costs with size.

In the UK RHI, the tariffs are banded by installation size (in terms of capacity, i.e. MW) with lower tariffs for larger installations. However, this banding structure has led many participants to opt for multiple smaller installations, with a capacity just below a tariff band threshold in order to receive a higher tariff. It is expected that this has resulted in additional (i.e. avoidable) costs to the Exchequer. The UK Government has recently proposed a

[44] NERA Ecomonic Consulting – Electricity Generation Costs and Hurdle Rates: Prepared for DECC, 2015
[45] DECC - Evaluation of the Renewable Heat Incentive, 2014

removal of the tariff bands for new biomass boilers in order to incentivise more appropriate sizing of installations.

Figure 3-4: Illustration of the incentive for under-sizing that can arise from tariff banding



An alternative approach is to 'tier' the tariffs based on the annual heat output (on a per kWh basis), such that larger heat users would receive a lower tariff per kWh on average, to reflect the economies of scale All participants would receive payment according to the tariff for Tier 1 up to the first threshold value; those with an annual heat output greater than that threshold would then continue to receive RHI payments but at a lower tariff, the tariff for Tier 2, and so on for all higher Tiers. The average payment per kWh (over a year) would therefore decrease with increasing heat output.

Since the tiering approach is based on heat output rather than installation capacity (i.e. on MWh not MW), tiering is more likely than banding to encourage appropriate system sizing whilst accounting for the tariff variation required with installation size.

3.5.8 Counterfactual heating systems targeted for replacement (gas, oil, solid)

Counterfactual heating systems (i.e. gas, oil, solid, or electric resistive heating) vary in cost. As such, it may be more cost-effective to target replacement of the most costly counterfactual heating systems (typically electric or oil heating) with renewable heating technologies. However, given the short time available to reach the 2020 RES-H target, the addressable market may need to be maximised by incentivising replacement of all counterfactual technologies. To incentivise replacement of all counterfactual heating systems, the RHI tariffs would need to be sufficient to cover the additional cost of the RH technology relative to the lowest cost counterfactual technology (which is currently gas heating).

A majority of stakeholders agreed that the RHI tariff should incentivise switching from gas as well as from oil and electric resistive heating, particularly given that more industrial and commercial users are now using gas due to the expansion of the gas network over the last few years.

3.6 Ensuring a sustainable RHI sector in Ireland

3.6.1 Ensuring a good understanding of the renewable heating technologies

There is some concern among stakeholders that the technologies may not be used correctly due to a lack of understanding of best practice. This is likely to be a greater problem for technologies for which the mode of operation is significantly different from the counterfactual, such as heat pumps in particular. Heat pumps, which are typically under-sized relative to boiler systems due to the higher capital costs, are intended to operate continuously to provide a constant temperature level, rather than operating for short bursts or ramped up and down. This mode of operation improves the efficiency as well as optimising the size of the system to achieve lower upfront costs. By providing users with information on the most effective use of the renewable heating technology (in addition to advice on selecting the best RH technology depending on the application) the efficiency will be maximised and the operational costs reduced. Stakeholders are concerned that if sufficient data is not provided, the technologies will not be used correctly, which could lead to poor public perception of renewable heating that may prevent further uptake of the technology. However, the administrative burden for providing such information along with setting of any additional standards should be taken into consideration. Where possible existing resources should be utilised, for example the best practice guides available from SEAI[46], in order to minimise the administrative burden.

3.6.2 Ensuring uptake does not lead to resource shortages

Many stakeholders are concerned that the RHI will lead to resource shortages in the short term. Given the limited biomass resource in Ireland it is possible that the introduction of the RHI will lead to an increase in the market price for biomass. The impact of this on existing biomass users, both in the heat sector and in other sectors, should be considered as some current users of biomass based heating technologies may convert to fossil fuel alternatives and hence reduce the net amount of renewable heating.

3.6.3 Impact on electricity grid

The RHI is likely to increase the uptake of both heat pumps and CHP systems (based on biomass and/or AD) as well as incentivising users of electric heating to switch to renewable heating alternatives. The impact of the RHI should therefore be considered in relation to the impact on the electricity grid, and in particular the distribution grid.

Current users of electric heating converting to any of the renewable heating technologies (including heat pumps) will reduce the electricity demand at peak times, whereas gas or oil users converting to heat pumps may increase the peak demand and change the demand profile (heating demand ramps up in the morning) testing the flexibility of the grid. CHP users will either use the electricity produced on-site, reducing demand on the electricity grid, or will export the electricity to the grid via a managed grid connection. The impact on the grid will therefore depend on the proportion of heat pumps and CHPs taken up as a result of the RHI, and the number of electric heating users that switch to RH technologies. In any case, it will be important to manage the transition to mitigate local constraints on the distribution grid. Demand-side response and (thermal and electric) storage technologies could play an important role in managing this transition.

[46] http://www.seai.ie/Renewables/Renewable_Energy_Library/

3.6.4 Impact on biomass emissions

As in the UK, the RHI is expected to significantly increase the number of biomass boilers in Ireland, and the deployment of biomass heating is likely to be required to meet the 2020 RES-H target; however, many stakeholders expressed concern over the environmental impacts of biomass technologies, and suggested that the RHI should be designed to minimise and manage those impacts.

The burning of biomass results in emissions of particulate matter (PM), oxides of nitrogen (NOx), oxides of carbon (COx), oxides of sulphur (SOx) and dioxins/furans[47]. PM and NOx are the most relevant for air quality issues and have been linked to impacts on both human health and the environment. Between 2010 and 2013 biomass combustion contributed ~10% of PM emissions across Ireland, an increase from just 5% in 2000[47].

Through the National Emissions Ceiling Directive (NECD), Ireland has binding limits on emissions of a range of pollutants, including PM and NOx, for 2020 and 2030. At present, and despite significant progress in recent years, the ceiling for NOx is being exceeded in Ireland, such that emissions must fall between now and 2020 (and 2030) for Ireland to avoid legal action and fines. Any emissions from new biomass plant installed through the RHI will be additional to the current levels, and will thus make it more challenging for Ireland to comply with the NECD.

It will therefore be critical to understand the impact of the RHI on emissions on PM, NOx and other pollutants, and hence on the overall cost (including the cost of additional abatement technology or reduction of emissions in other sectors, or through fines for non-compliance). We note that a recent publication by EnvEcon[48] applied a methodology to quantify the value of marginal damage caused by air pollution in Ireland, with the intention to assist government departments, agencies and others to incorporate this value into decision-making. The approach set out in that report, or similar, could be applied to assist the decision-making with respect to the design of the RHI. While a full analysis of this is outside the scope of this work, we have derived indicative estimates of the additional PM and NOx associated with each RHI scenario modelled in this study. These are presented as part of the full scenario results in the Appendices, and in the discussion in section 5.

The emissions associated with biomass technologies are influenced by a number of factors, including:

- Fuel type and quality
- Appliance design, type, operation and abatement technology
- Appliance installation

Fuel type and quality

To ensure the quality of biomass fuel (typically relating to the moisture content) a list of eligible suppliers of biomass could be maintained and applied to the RHI. Ireland has a Wood Fuel Quality Assurance scheme (WFQA) that guarantees the quality and reliability of the fuel. This scheme is currently voluntary for suppliers of biomass and has 16 registered suppliers in Ireland. However, it could be made a requirement of the RHI for all domestically produced biomass, as recommended in a recent report on biomass emissions[49]; although

[47] Irbea, *Study on Biomass Combustion Emissions*, 2016.
[48] EnvEcon (2015), *Marginal Damage Valuations for Air Pollutants in Ireland – 2015,* Dublin: EnvEcon Decision Support Series 2015/1.
[49] IrBEA (2016) *Study on Biomass Combustion Emissions*

some stakeholders question whether this scheme is robust enough. Alternatively, a more stringent scheme such as EN*plus* could be used; however, there are only two suppliers in Ireland currently providing fuel in compliance with this scheme. The UK RHI has a Biomass Suppliers List (BSL) that primarily ensures the sustainability of the biomass but also supports the use of high quality biomass fuels through the *Woodsure* scheme, which serves the same purpose as Ireland's WFQA scheme.

In addition, it is essential that users are provided with advice on the correct fuel type and moisture content for their installation. This should be provided as part of the overarching governance structure for the RHI which, as described in section 3.4.6, should include provision of information, monitoring and evaluation across the full supply chain from producer to end-user.

Appliance design, type, operation and abatement technology

The appliance design and operation, along with any abatement technologies included in the installation, influence the emissions associated with the biomass installation. It is important that the best available technologies leading to the lowest emissions are incentivised. Abatement technology is available for any biomass system; however, it is costly, raising both the capital cost and the operational costs. In order to ensure the use of abatement technologies, therefore, minimum standards should be applied.

Minimum standards for PM and NOx emissions could be implemented using an approved appliance list or 'type approval' system (as discussed in section 3.4.6). One stakeholder highlighted the need for very stringent limits as the real world conditions may lead to higher emissions than those seen in laboratory tests. The UK RHI requires all biomass installations to produce <30g of particulate matter and <150g of NOx per GJ of net thermal input[50]. This is implemented through an Emissions Certificate for biomass appliances.

Appliance installation

Correct sizing and installation of biomass appliances is vital to ensure high efficiencies are achieved and to minimise PM and NOx emissions. As discussed in section 3.4.6, this could be managed via a list of approved installers. The RHI applicants could be required to provide a certificate of competency in accordance with the manufacturers' installation requirements, indicating that their installation and commissioning of appliances is carried out by a suitably trained individual/organisation, as recommended in the IrBEA Emissions report[51].

[50] Ofgem, *Domestic Renewable Heat Incentive Reference Document Version 4.0* (October 2016)

[51] Irish Bioenergy Association (IrBEA), *Project Report for Biomass Combustion Emission Study* (December 2016)

3.7 Implementation of the scheme

3.7.1 Implementation options

The administrative burden and associated costs of implementing an RHI scheme in Ireland will be significant. As noted by SEAI, as a member of the steering board for this work, adequate governance structures will need to be in place at all levels before the RHI is launched. As described in the previous sections, this governance structure will need to cover information provision, legal aspects, monitoring and evaluation of the scheme as well as processing scheme applications and payment. In addition, an IT system will need to be developed. A detailed scheme design, including an assessment of the resources required to administer the final scheme, should be carried out as soon as possible. The effective governance required to ensure that any minimum eligibility criteria and standards (e.g. heat pump SPF, biomass regulations) included in the scheme design are achieved will result in a large administrative and financial burden.

There is a general preference among stakeholders for an electronic system to be implemented and administered by a third-party, although some would also like to see the option for paper applications. A paper-based option is likely to increase the administrative burden given that an electronic system would more quickly be able to identify incomplete or invalid applications.

It was also suggested that a close ongoing involvement in the administration of the scheme of those with a strong working technical knowledge of the renewable heating technologies will be required to ensure smooth operation of the scheme.

3.7.2 Pre-accreditation

Many stakeholders suggested that there is a need for a ‘pre-accreditation’ option – whereby developers planning a renewable heat project can submit the proposed project plan and effectively obtain in-principle confirmation of eligibility for the RHI – in order to provide more certainty for developers.

Stakeholders reported a wide range of timescales for procurement of renewable heating technologies, from just 1 week for smaller, ‘off-the-shelf’ installations, to up to 5 years for the largest and most complex installations. For most large projects the project development timescale is likely to be longer than one year. Under these circumstances, uncertainty over the eligibility for the RHI, or over the continuation of the support scheme, may lead the project to be deemed unviable. One stakeholder provided anecdotal evidence of two planned heat pump-based schemes in the UK which did not go ahead due to concerns over eligibility and the level of revenue the RHI would provide.

In the UK RHI, pre-accreditation is available only for large and complex installations, including geothermal installations, biogas installations and solid biomass installations above 200 kW_{th} in size.

3.7.3 Importance of regular review of the scheme design

The design options described above aim to find a balance between incentivising a sufficient level of uptake to meet the RES-H target within the limited timeframe available, and the need to avoid perverse incentives for the over-production or inefficient use of heat.

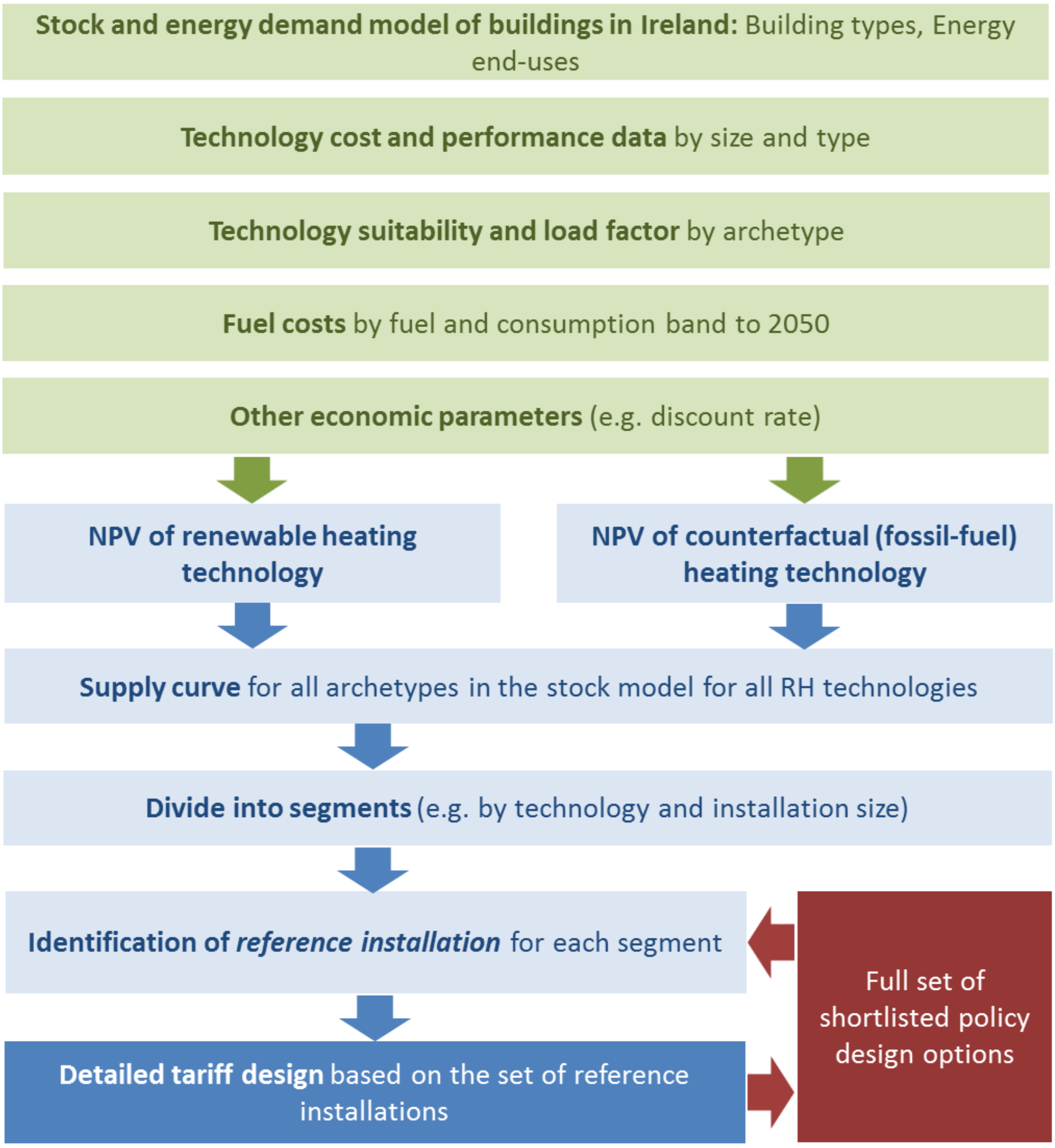
Critical to maintaining the desired balance between these factors will be effective governance and regulation, including monitoring and auditing to ensure that all installations supported by the RHI are aligned with the scheme objectives. An important component of this will be the ability to review the design of the scheme at regular points, likely on a quarterly basis. This will help to ensure that any 'loopholes' identified in the scheme design and found to be leading to installations misaligned with the scheme objectives can rapidly be addressed.

4 Detailed tariff design

4.1 Overview of tariff design process

Our approach to the design of tariffs for the RHI follows a bottom-up approach based on the detailed stock model of commercial, public and industrial building archetypes in Ireland developed through Element Energy's recent work for SEAI[52], as well as the Ireland-specific cost and performance data gathered through the stakeholder consultations. This approach is summarised in Figure 4-1, and described in detail below.

Figure 4-1: High-level summary of tariff calculation process



[52] Element Energy, *Unlocking the Energy Efficiency Opportunity*, Report for SEAI (2015)

4.2 Net present value calculations

The following nine renewable heating (RH) technologies are included in the scope of this study:

- Biomass boiler
- Biomass CHP
- Biomass direct air
- Ground source heat pump
- Air source heat pump (Air-to-Water; Air-to-Air is excluded from this analysis)
- Water source heat pump
- Deep geothermal
- Solar thermal
- AD CHP/Biomethane
- Energy-from-Waste

For each of the renewable heating technologies, with the exception of AD CHP/Biomethane and Energy-from-Waste, the tariff calculation is based on an assessment of the net present value (NPV) of ownership for each of the building archetypes in the stock model, assuming quarterly payments of the tariff. In the case of AD CHP/Biomethane, a set of representative installation archetypes were developed as part of a parallel, closely-related study[53] by Ricardo Energy & Environment. Detailed cost and performance data for these AD CHP/Biomethane archetypes were integrated into this work through an "interface" analysis[54] undertaken jointly by Element Energy and Ricardo Energy & Environment. The approach taken for Energy-from-Waste is described in section 4.5.

A number of data sets were used in order to determine the NPV for each renewable heating technology in each suitable archetype in the stock:

- Technology costs and performance
    - Capital cost
    - Operating cost
    - Additional and hidden costs
    - Thermal and electrical efficiency
    - Economic lifetime
- Technology suitability
    - Suitability for different heat uses (including space heating and hot water, low temperature process heating, high temperature process heating)
    - Suitable size range
- Fuel costs (to 2050)
- Commercial, public and industrial demand archetypes

[53] Ricardo Energy & Environment, *Report on AD CHP and biomethane* (Publication pending)
[54] Element Energy and Ricardo Energy & Environment, *Interface analysis and report for incorporation and alignment of data from biomethane study into RHI workstream, 2017*

    - Annual heating demand (by space heating and hot water, low temperature process heating, high temperature process heating)
    - Heating system load factor by technology
    - Annual electricity demand
- Other economic parameters
    - Discount rate (rate of return)

4.2.1 Technology costs and performance

Technology capital and operational costs. Technology capital and operating costs are based on data from the industry consultation. The data received was used to derive values for the capital and operating costs of each technology as a function of installation size, where relevant. The final cost dataset used is presented in Appendix 1. Technology costs for AD CHP and Biomethane were developed as part of a separate study by Ricardo Energy & Environment, and provided for use in this study[55].

Economic lifetime. The typical economic lifetime of each technology is also based on data from the industry consultation.

Additional and hidden costs. The calculation of total NPV used to derive the tariffs included an assessment of the additional and hidden costs summarised in Table 4-1. These were derived from a range of sources as described in the table.

[55] Ricardo Energy & Environment, *Report on AD CHP and biomethane* (Publication pending)

Table 4-1: Summary of additional and hidden costs applied

Additional or hidden cost	Notes	Cost assumption	Source of data
Metering	The additional capital cost of the heat meter	Cost varies with size (€4–6/kWth)	Stakeholder consultation
Biomass storage unit	The additional capital cost of the biomass fuel storage unit (for biomass only)	Cost varies with size	Stakeholder consultation
Space for biomass fuel storage unit	Compensation for loss of space used for the fuel storage unit (for biomass only)	Cost varies with sector; Public/Commercial: €488/kWth (€975/m^2) Industry: €163/kWth (€325/m^2)	Element Energy/NERA, *Achieving deployment of renewable heat* (2011)
Administration costs	Compensation for the additional administration time required for the renewable technology	Costs vary with sector and technology type	Element Energy/NERA, *Achieving deployment of renewable heat* (2011); Element Energy, *Energy efficiency investment pathways in Ireland,* for SEAI (2015)
Energy audit	Cost for having an energy audit carried out	Cost varies with building size: €0.67/m^2	Stakeholder consultation
Grid connection	Fee for grid connection (for CHPs only)	Cost varies with size[56]: €200k–€1m	Ricardo Energy & Environment study on cost of biogas and biomethane, for SEAI (2016)
Retrofit of emitters	Additional capex and installation costs for installing radiators where required (or replacing existing radiators with large area radiators or underfloor heating for heat pumps)	€625/kWth *(not required for new buildings)*	Stakeholder consultation; Frontier Economics/Element Energy, *Pathways to high penetration of heat pumps*, Report for CCC (2013)
Decommissioning the counterfactual	The cost of removing the counterfactual technology	Marginal cost: €12/kWth if applicable: *most stakeholders suggested that the counterfactual would be left in place as a back-up so this cost is not included in the tariff calculation*	Stakeholder consultation

4.2.2 Technology suitability

In the tariff calculation and uptake modelling, we make a number of assumptions on the suitability of each of the renewable heating technologies for certain circumstances and/or end-uses. For example, biomass CHP is not typically suitable for application in a building with a small annual energy demand of, say, 5 MWh, since biomass CHP systems are typically large (hundreds of kW or larger), and the system would be greatly over-sized. Unrealistic cases such as these are excluded from the analysis in order to ensure they do not skew the resulting tariff calculation. The suitability assumptions on which the tariff calculation and uptake modelling is based are described further below.

It is important to note, however, that the suitability assumptions are distinct from the *eligibility* criteria described in section 3.4 and 'unsuitable' cases are not necessarily ineligible for the RHI. To continue the example above, we do not propose to explicitly exclude the use of biomass CHP in buildings with small annual energy demand – it is simply that we do not expect such installations to be typical. Prior to implementation of the scheme, the implementing body will need to decide on standards and suitability for each RH technology.

Technology size

In the tariff calculation, we assume that each heating technology is available in a number of distinct unit sizes, and that each has an assumed minimum and/or a maximum size (see Table 4-2). This limits the suitability of certain technologies for particular archetypes with very high or very low heating demands. For example, Deep geothermal installations are not suitable for small energy users due to the assumed minimum size of a Deep geothermal installation of ≈200 kW, where the minimum size is a result of the high cost of drilling the borehole.

Heat uses

The stock model of buildings and industry in Ireland underpinning the tariff calculation includes the heat demand for each archetype for three end-uses:

- Space heating and hot water
- Low temperature process heat
- High temperature process heat

Not all RH technologies are deemed suitable to provide heat for all end-uses. All the RH technologies are able to contribute fully or partially towards the space heating and hot water demand. Feedback from the stakeholder consultation suggests only a fraction of the space heating and hot water demand is typically met by solar thermal installations, typically in the range 40-80%. In addition, stakeholders indicated that some of the technologies can also contribute towards low temperature process heating. Biomass boilers are deemed suitable provide up to 100% of the low temperature process heating demand whereas heat pumps are deemed suitable to provide up to ≈35% (an estimate based on an assumption of low temperature process heat at 200°C and a heat pump flow temperature of 70°C). Biomass direct air heating[57] can provide up to 100% of space heating and low temperature process heating for some industry demands. However, given that this is a niche technology that will

[56] The grid connection fee will also depend on the pre-existing strength and the available capacity of the grid at the location, however, it was beyond the scope of this project to include this is the modelling.

[57] Biomass direct air heating refers to the case where biomass is combusted to heat air which is circulated directly around a room or building or into an industrial process, rather than being used to heat water to be circulated for space heating or hot water provision.

not be suitable for most buildings, biomass direct air is therefore limited in suitability to 10% of the heating demand in the industry sector. None of the technologies are deemed suitable to provide high temperature process heat as this is likely to have very specific requirements. The data assumptions are given in full in Table 4-2.

Thermal efficiency of the building

Heat pumps are less suitable for very thermally inefficient buildings as they may be unable to provide enough heat at peak periods to reach the required levels of comfort. For this reason, in the model we consider heat pumps only in buildings with an existing BER rating E1 and above. This assumption is distinct from the energy efficiency eligibility requirements for the RHI, which, if included, will apply across all of the technologies.

Table 4-2: Summary of technology suitability assumptions used in tariff calculation

	Assumed min size, kW	Assumed max size, kW	Suitable heat uses	Suitable building thermal efficiency[58]
Biomass boiler	7	No maximum	Space and hot water, low temperature process	Suitable for all buildings
Biomass CHP	100	No maximum	Space and hot water	Suitable for all buildings
Biomass direct air	7	No maximum	Space and hot water	Suitable for all buildings
GSHP	3	2,000	Space and hot water, low temperature process (35%*)	Not suitable for BER rating E2-G
ASHP	3	2,000	Space and hot water, low temperature process (35%*)	Not suitable for BER rating E2-G
WSHP	3	10,000	Space and hot water, low temperature process (35%*)	Not suitable for BER rating E2-G
AD CHP	3	No maximum	Space and hot water	Suitable for all buildings
Solar thermal	3	1,000	50% of space and hot water demand (based on stakeholder consultation)	Suitable for all buildings
Deep geothermal	200	No maximum	Space and hot water	Suitable for all buildings

4.2.3 Commercial, public and industrial demand archetypes

Element Energy has previously developed with SEAI[59] a detailed stock and energy model of commercial and public buildings and industry in Ireland. This consists of more than 300 archetypes described by:

- Sub-sector (commercial, public, industry)

[58] Heat pumps are not suitable for low thermal efficiency buildings (e.g. BER rating E2-G) as they are unable to provide a sufficient level of comfort. Whilst they can be applied in buildings with moderate energy efficiency (e.g. BER rating C-E1), they may not be able to achieve the seasonal performance factors used to calculate the tariffs.
[59] Element Energy, *Unlocking the Energy Efficiency Opportunity*, Report for SEAI (2015)

- Size
- HVAC type
- Heating system
- Thermal condition

The stock model includes a breakdown of the heating demand into space heating and hot water, low temperature industrial processes and high temperature industrial processes. This stock and energy model forms a key part of the NPV calculation and tariff design.

4.2.4 Fuel prices

The fuel price assumptions used in the tariff design are presented in Appendix 1b. Retail fuel prices in 2016 are based on the values in SEAI's *Fuel Cost Comparison*[60] from July 2016. The fuel prices are applied in terms of the annual fuel consumption 'bands' as provided in the *Fuel Cost Comparison*, to reflect the lower average price paid by larger consumers. We have made an allowance for night rate electricity for heat pumps, assumed for the purposes of this analysis to be 20%[61].

The biomass purchase prices assumed in the tariff design are stated within each scenario as defined in section 5.1. These were chosen to represent different price points on the biomass resource supply curve for Ireland, based on the most up-to-date supply curves developed by SEAI in the recent study *Bioenergy Supply in Ireland 2015 – 2035*[62]. In addition, we have applied an annual fuel consumption banding for biomass analogous to that for gas and electricity in the *Fuel Cost Comparison*, to reflect the lower average price expected to be paid by larger consumers. We have implemented this to align with the banding for natural gas, such that the biomass purchase price defined in the scenario is applied to the second consumption band (278–2,778 MWh/yr), with the biomass price for the other bands varying in line with the prices for the different bands for natural gas.

Fuel prices have been projected forward to 2050. In order to do this, fuel prices were disaggregated into a component exclusive of the carbon price/tax, and a component representing the carbon price/tax. The component exclusive of the carbon price/tax was projected forward according to the UK Department of Energy and Climate Change's *Fossil fuel price projections*[63] (using the gas wholesale price to project both gas and electricity prices). The carbon price/tax component was projected forward according to the projected shadow price of carbon as set out in the Public Spending Code[64] for the case of electricity, and according to the larger of the current level of the carbon tax in Ireland (€20 per tonne) and the same projected shadow price of carbon for the case of gas, oil and solid fuel. The resulting fuel price projections are presented in Appendix 1b.

Electricity export prices, relevant for gas-fired CHP counterfactual technologies, were based on the average System Marginal Price over the full two-year period from 1st January 2014 to 1st January 2016, taken from *Single Electricity Market Operator* (SEMO) data. Electricity export prices for AD CHP and biomass CHP are defined separately, assuming eligibility for the upcoming Renewable Electricity Support Scheme (RESS), i.e. the successor to REFIT 3. The support levels for the RESS are currently under development. For the purposes of

[60] SEAI, *Fuel Cost Comparison* (July 2016)
[61] This value is based on Element Energy data from heat pump field trials in the UK.
[62] SEAI/Ricardo Energy & Environment, *Bioenergy Supply in Ireland 2015 – 2035: An update of potential resource quantities and costs* (September 2016)
[63] Department of Energy and Climate Change, *Fossil fuel price projections: 2015* (November 2015)
[64] http://publicspendingcode.per.gov.ie/wp-content/uploads/2015/09/E5.pdf (Accessed March 2017)

this analysis, we have assumed a fixed support level of 14 c/kWh in 2016 for both AD CHP and biomass CHP technologies, approximately in line with the support levels in REFIT 3. The electricity export prices are projected forward according to the same procedure as for the electricity retail prices; however, we assume that the Renewable Electricity Support Scheme support level received by any given AD CHP or biomass CHP installation remains fixed in real terms over the installation lifetime, even if the support level offered to new installations changes over time.

4.2.5 Counterfactual heating system and difference in NPV

The NPV was also determined for a counterfactual technology for each archetype. For the heat-only technologies the counterfactual technology was taken as a gas boiler. For biomass CHP the counterfactual was taken as gas CHP. For AD CHP the counterfactual was assumed to be a gas boiler, based on stakeholder feedback collected by Ricardo Energy & Environment through the interface work. For biomethane the counterfactual was set at the wholesale gas price.

The age of heating technologies being targeted for replacement has a large impact on the potential market size. To the extent that the RHI is intended to incentivise a substantial increase in the deployment of renewable heating to 2020, it may be necessary to incentivise the early replacement of fossil fuel technologies. However, this is likely to be less cost-effective, given that consumers may seek to be compensated for the residual value of the existing system in order to replace it with a new system. In the absence of an RHI, the typical time period between decisions to replace a heating system, the 'decision frequency', is of the order of 15 years. However, in the presence of an RHI, the decision frequency is likely to be substantially increased; particularly if the RHI is only offered for a short, fixed period. For example, it may be expected that consumers who have just installed a new (non-renewable) heating system (e.g. in 2016) would be unlikely to install another by 2020. Following preliminary analysis and in agreement with the project steering board, the modelling presented in this report makes the assumption of a decision frequency of 5 years[65]. This implies that over the period 2018-2020 (the RHI is expected to be implemented in late 2017 at the earliest) those consumers who have installed a new heating system since 2012 would not consider installing a new RH system, but consumers who last installed a heating system before that date would consider this option. In line with this assumption, we include the remaining value of the counterfactual technology as appropriate.

The difference in the NPV for the renewable heating technology and the counterfactual technology defines the present value which must be represented by the total RHI payment. Accounting for the other relevant tariff design options, including the duration of support, profile of payment and the allowed rate of return, the required tariff is then determined for each individual building archetype-technology combination.

[65] As part of the project, a number of sensitivities were run. In agreement with the steering committee, a 5 year decision frequency was selected.

4.3 Reference archetypes and tariff calculation

As described in the previous section, the tariff required to ensure that the total NPV of the renewable heating option is equal to the total NPV of the counterfactual heating option is calculated for each building archetype-technology combination.

The tariffs calculated for each building archetype-technology combination are then allocated to ‘segments’ based on technology category and the relevant ‘tier’ based on the eligible annual heat demand. For example, the tariffs calculated for biomass boilers for archetypes with heat demand less than 10 MWh/yr are allocated to one segment, the tariffs calculated for biomass boilers for archetypes with heat demand 10-30 MWh/yr to another segment, and so on.

For each technology and tier segment, the *reference archetype* is then identified. The reference archetype is defined as that in which the median unit of heat demand (based on the heat demand across the entire Irish building stock) falls when all archetypes within the segment are ordered from the archetype requiring the highest tariff to that requiring the lowest tariff. This is illustrated in Figure 4-2 (note that the reference archetypes do not always fall near the middle of the segment, since what determines where the reference archetype is the actual occurrence of each archetype across the Irish building stock and hence within which archetype the median unit of heat demand falls). The reference archetypes are simply used to calculate the tariff by technology and annual heat output. The calculated tariffs are then applied to all archetypes within each segment. Following this, only the technology type and the annual heat output need to be known to find the payment required for any given installation.

The tariff required for the reference archetype is, from then on, taken as the tariff to be applied to any installation insofar as the corresponding segment applies to that installation. In the tiering approach, all installations receive payment according to the tariff for Tier 1 up to either the total heat output of the installation or the threshold value marking the upper end of Tier 1 (whichever is the smallest); those with a heat output greater than the threshold marking the upper end of Tier 1 receive additional payment according to the tariff for Tier 2, up to either the total heat output of the installation or the threshold value marking the upper end of Tier 2 (whichever is the smallest); and so on for all higher tiers. The effective overall tariff for each installation (expressed as a single value in c/kWh) is therefore equal to the sum of marginal payments for each tier divided by the total eligible heat output.

Figure 4-2: Example of tariffs for individual and reference archetypes (dashed red lines denote boundary between tiers)[66]

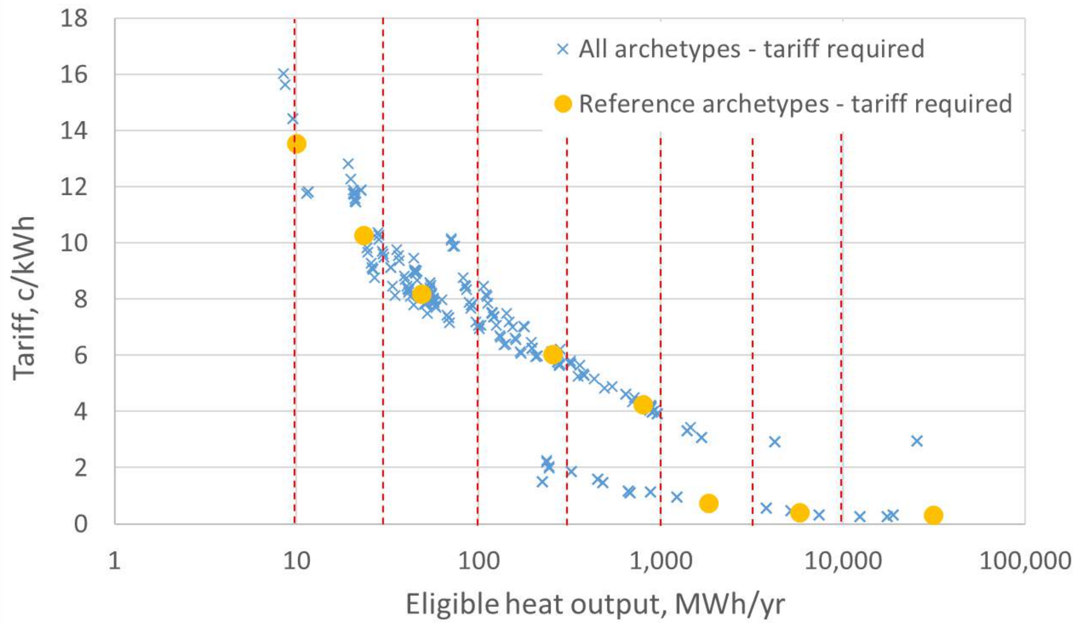
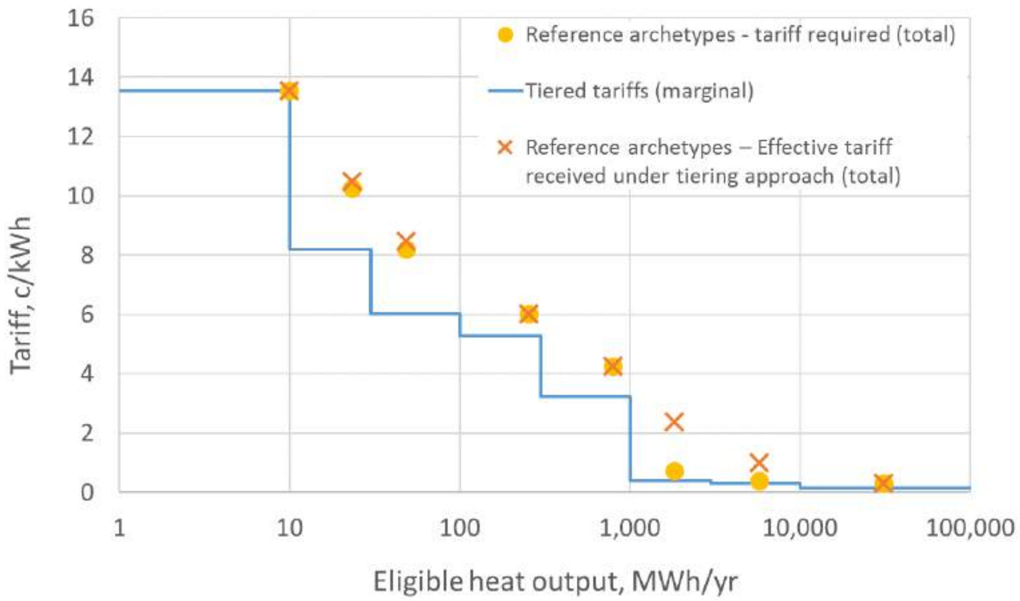


Figure 4-3: Example of tiered tariffs and tariffs for reference archetypes



66 A log scale was used to determine the segment size due to the near-exponential trend of the decrease in tariffs with eligible heat output as illustrated, for example, by Figure 4-2.

4.4 AD CHP, AD boiler and biomethane grid injection

The tariffs for AD CHP, AD boiler and biomethane grid injection were determined as part of the 'interface' study[67] undertaken jointly between Element Energy and Ricardo Energy & Environment. This analysis made use of a set of representative installation archetypes developed by Ricardo Energy & Environment in a separate study.[68] The installation archetypes relate to a range of AD and biomethane system types, differentiated by size, type of feedstock and heat load, as summarised in Table 4-3. The detailed cost and performance data for AD CHP, AD boiler and biomethane grid injection, and the associated data collection method, is presented in the final report for the Ricardo Energy & Environment study. The tariff design and uptake modelling methodology for these technologies is described in detail in section 5.4.

Table 4-3: AD CHP, boiler and biomethane archetype parameters

Technology type	Size	Feedstock type	Heat load
AD CHP	• Small (<500 kW biogas) • Medium (500-3,000 kW biogas) • Large (≥3,000 kW biogas)	• Farm fed (dairy slurry, grass silage, livestock manure) • Waste fed (source-separated food waste, contaminated food waste, sludges from industry waste)	• Low (0-20%) • Medium (40-60%) • High (60-80%)
AD boiler	• Small (<500 kW biogas) • Medium (≥500 kW biogas)	• Animal slurry and whey • Mixture of waste materials	• Low (60%) • Medium (80%) • High (85%)
Biomethane grid injection	• Medium (<3,000 kW biogas) • Large (≥3,000 kW biogas)	• Farm fed (cattle slurry, grass silage, maize) • Waste fed (all food waste, mixture of waste materials) • Sewage sludge (waste water treatment primary sludge)	• Constant (100%)

4.5 Energy-from-waste

Several energy-from-waste plants are in operation in Ireland; however, these currently produce electricity only, and the 'waste' heat is not typically captured. The heat generated by these plants could – with some efficiency penalty on electricity generation – be recovered and used on nearby industrial sites or to serve district heating systems. We have considered whether the RHI could incentivise the useful extraction of heat from existing energy from waste plants that currently produce electricity only.

The effective cost of producing heat energy in this way is based on the electrical efficiency penalty of extracting the waste heat. The 'Z-factor' is defined as the ratio of the heat usefully

[67] Element Energy and Ricardo Energy & Environment, *Interface analysis and report for incorporation and alignment of data from biomethane study into RHI workstream, 2017*
[68] Ricardo Energy & Environment, *Report on AD CHP and biomethane* (Publication pending)

extracted to the electricity foregone. A Z-factor of 6-10 is typical for energy-from-waste plants. Here we assume a Z-factor of 7.1[69]

The effective cost of extracting heat can then be estimated from the value of the electricity foregone to the EfW plant operator. In Ireland, the biodegradable fraction of industrial and municipal waste was eligible for the REFIT 3 tariff (8.5 c/kWh for biomass combustion). Assuming, as an illustrative example, that the electricity could be exported at 8.5 c/kWh, the effective cost of heat is taken as:

$$Cost\ of\ heat\ energy = \frac{Wholesale\ price\ of\ electricity}{Z\ factor}$$

The effective cost of heat energy is therefore 1.2 c/kWh. We note that this is less than the typical marginal cost of producing heat from a gas boiler (the cost of a unit of gas is in the range 3-6 c/kWh[70]).

In addition, under the REFIT 3 scheme, the applicable tariff would increase to 12 c/kWh if the heat produced was used to supply a suitable heat load such that the EfW plant was eligible for the high efficiency (HE) CHP tariff[71]. Under these circumstances the cost of heat would be negative as the additional tariff received for the electricity (per kWe) would more than cover the electricity foregone to extract useful heat. The tariff differential between solid biomass combustion and HE CHP should therefore be sufficient to drive the search for a suitable heat load.

However, despite the low (or negative) marginal cost of supplying useful heat as described above, the use of heat from energy-from-waste typically requires a large capital investment, as there is not usually sufficient on-site or local heat demand. As such, use of the heat from an energy-from-waste plant is likely to require the development of a heat network.

The business case for a heat network rests on the potential heat network developer (whether a private sector or public sector body, or a joint venture) having sufficient confidence in long term heat sale revenues to justify the large upfront cost of the network infrastructure. The economic viability of a heat network is highly location-specific, and requires a high local heat density (among other factors) to generate sufficient revenue from the capital investment. For example, it is estimated that more than 75% of Dublin City has heat demand densities suitable for district heating[72]. A heat network in Dublin has been planned for a number of years and many parts of the network are already in place, with new buildings in the area ready to connect once the heat network is ready to supply heat. A number of smaller heat networks are already in operation in Ireland but many barriers still exist. In addition to the high capital costs and complexity of the project development, there are risks associated with customers not connecting to the heat network, particularly given that heat networks are not prevalent in Ireland. A further barrier is the lack of guidelines, regulations and policies for heat networks in Ireland[72]. The potential for the development of heat networks in Ireland, and the barriers to deployment, are discussed in detail in a study carried out by AECOM for SEAI to meet the requirements of Article 14 of the Energy Efficiency Directive[73].

[69] Lincoln City Council, *Lincoln Energy from Waste & District Heating Study* (2011)
[70] SEAI, *Fuel Cost Comparison: Commercial/Industrial fuels* (October 2016)
[71] Providing the primary energy savings are at least 10% for plants ≥ 1 MWe and are positive for for plants < 1 MWe
[72] Codema and BioXL, *A Guide to District Heating in Ireland*, on behalf of IrBEA (2016)
[73] AECOM, *Cost Benefit Analysis of the potential for High-Efficiency Cogeneration and Efficient District Heating & Cooling in Ireland,* for SEAI (2015)

Given the highly location-specific economics of heat networks, we suggest that an RHI-type incentive is not, in isolation, an appropriate mechanism to address the barrier to the capture of waste heat from energy-from-waste plants. An alternative form of incentive is likely to be required such as, for example, site-specific capital grants or low-cost financing. A recent and relevant example of such a scheme was announced in 2015 by the UK Government's Heat Networks Delivery Unit. The Heat Network Investment Project[74] aims to provide £320m of capital support specifically to incentivise the delivery of low carbon heat networks in the UK. Support will be granted following a competitive case-by-case assessment of applications, which must describe in detail the proposed heat network project, the reason support is required and the economic, environmental and social benefits the project would bring.

[74] https://hnip.salixfinance.co.uk/ (Accessed November 2016)

5 Detailed assessment of optimal design and uptake modelling

5.1 Shortlisted scenarios

5.1.1 Default options

For each RHI policy design option, a 'default' or preferred value was assigned through discussion with the project steering committee, following earlier rounds of analysis and incorporating the feedback from stakeholders. The default values for each design option are given in Table 5-1. In the shortlisted scenarios, alternative policy design options are studied by modifying one or a small number of the values, otherwise retaining the default values.

Table 5-1: Summary of default options for shortlisted scenarios

Design option	Default value	Varies between scenarios
1. Differentiation by technology	Differentiation by all technology types	Yes
2. Differentiation by installation size	Tiering by annual heat output	No
3. Minimum energy efficiency criteria for participant eligibility	Yes	No
4. Minimum biomass sustainability criteria for participant eligibility	Yes - sensitivities on imported biomass availability and price	Yes
5. Maximum particulate and other emission levels for participant eligibility	Yes (not modelled)	No
6. Location-based eligibility for biomass	No	No
7. Duration of support and profile of payments to participants	15 years, no front loading	Yes
8. Payment based on metered or deemed heat	Metered heat for large users, metered or deemed for small	No
9. Systematic adjustment of tariffs	Yes (not modelled)	No
10. Allowed rate of return	8%	Yes
11. Age of heating systems targeted for replacement	Include early replacement (5 year decision frequency applied)	No
12. Implementation options	Not modelled	No
13. Type of counterfactual heating systems targeted for replacement	All types	No
14. ETS sector eligible for RHI	No	Yes

In the default case, it is assumed that stringent sustainability criteria are imposed such that imported biomass is limited to 1.5 TWh/yr at a cost of 6.9 c/kWh[75]; referred to as strongly limited imported biomass. A sensitivity with less stringent sustainability criteria, such that imported biomass is limited to 5 TWh/yr at a cost of 5.5 c/kWh[76] is also modelled; referred to as limited imported biomass. It should be noted that both the price and availability of imported biomass are purely illustrative here. In reality, they will depend on the global market along with any sustainability criteria that are imposed. The availability values used in this study are intentionally fairly conservative with a recent publication suggesting that the availability of imported biomass to the UK, and by correlation to Ireland, may be somewhat higher than the values used here[77]. The costs are based on those used in the UK RHI reformed and refocussed scheme. Whilst lower cost imported biomass may be available, as suggested by references 77 and 78, the effect of sustainability criteria on the price of imported biomass is uncertain[78]. The imported biomass prices were chosen to ensure the majority of the domestic biomass resource is taken up before imported biomass.

5.1.2 Definition of scenarios

In order to assess the various design options and sensitivities, 13 scenarios were designed (see Table 5-11). For each scenario, the design options were used to set the RHI tariffs and determine the eligibility of archetypes. These were then fed in to the uptake model.

[75] Based on upper biomass price in the UK RHI reformed and refocussed scheme to ensure domestic wood pellets, wood chips and PCRW are taken up before imported biomass.
[76] Based on the central price in the UK RHI reformed and refocussed scheme to ensure domestic wood pellets and wood chips are taken up before imported biomass.
[77] Ricardo Energy and Environment, *Biomass Feedstock Availability: Final Report*, on behalf of BEIS (2017)
[78] The Research Agency for the Forestry Commission, *Carbon impacts of biomass consumed in the EU: quantitative assessment* (2015)

Table 5-2: Key for scenario ID and name

Type	ID	Scenario name
RHI design scenarios	1	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
	2	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price
	3	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 9 c/kWh biomass price
	4	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 9 c/kWh biomass price
	5	Tariffs capped at biomass boiler tariffs
	6	Tariffs capped at 10 c/kWh
	7	Shorter duration (7 yrs)
	8	Higher IRR (12%)
	9	Lower IRR (6%)
	10	Shorter duration (7 yrs) and Higher IRR (12%) except for biomass-based techs for which retain 15 yr duration and 8% IRR
	11	High power sector biomass demand
	12	Include ETS sector - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price
	13	Include ETS sector - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
No RHI baseline cases	N1	No RHI - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
	N2	No RHI - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price

Table 5-3: Full scenario definitions with design options and sensitivities

ID	RHI offered	RHI design aspect					Sensitivities		
		1	4	7	10	14	Minimum biomass sustainability criteria		Power sector biomass demand
		Differentiation by renewable technology	Minimum biomass sustainability criteria	Duration of support and profile of payments	Allowed rate of return	ETS sector eligible for RHI	Availability and price of biomass imports	Biomass price used to calculate tariffs	
1	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	8%	No	Limited import: 5 TWh/yr at 5.5 c/kWh	5.5 c/kWh	Central
2	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	8%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
3	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	8%	No	Limited import: 5 TWh/yr at 5.5 c/kWh	9.0 c/kWh	Central
4	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	8%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	9.0 c/kWh	Central
5	Yes	Yes (tiered, capped)	Yes (see right)	15 yrs, no front loading	8%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
6	Yes	Yes (tiered, capped)	Yes (see right)	15 yrs, no front loading	8%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
7	Yes	Yes (tiered)	Yes (see right)	7 yrs, no front loading	8%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
8	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	12%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
9	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	6%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
10	Yes	Yes (tiered)	Yes (see right)	15 yrs biomass based, rest 7 yrs	8% biomass-based, rest 12%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
11	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	8%	No	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	High
12	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	8%	Yes	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	6.9 c/kWh	Central
13	Yes	Yes (tiered)	Yes (see right)	15 yrs, no front loading	8%	Yes	Limited import: 5 TWh/yr at 5.5 c/kWh	5.5 c/kWh	Central
N1	No	N/A	N/A	N/A	N/A	N/A	Limited import: 5 TWh/yr at 5.5 c/kWh	N/A	Central
N2	No	N/A	N/A	N/A	N/A	N/A	Strongly limited: 1.5 TWh/yr at 6.9 c/kWh	N/A	Central

5.2 Uptake modelling using *BioHEAT*

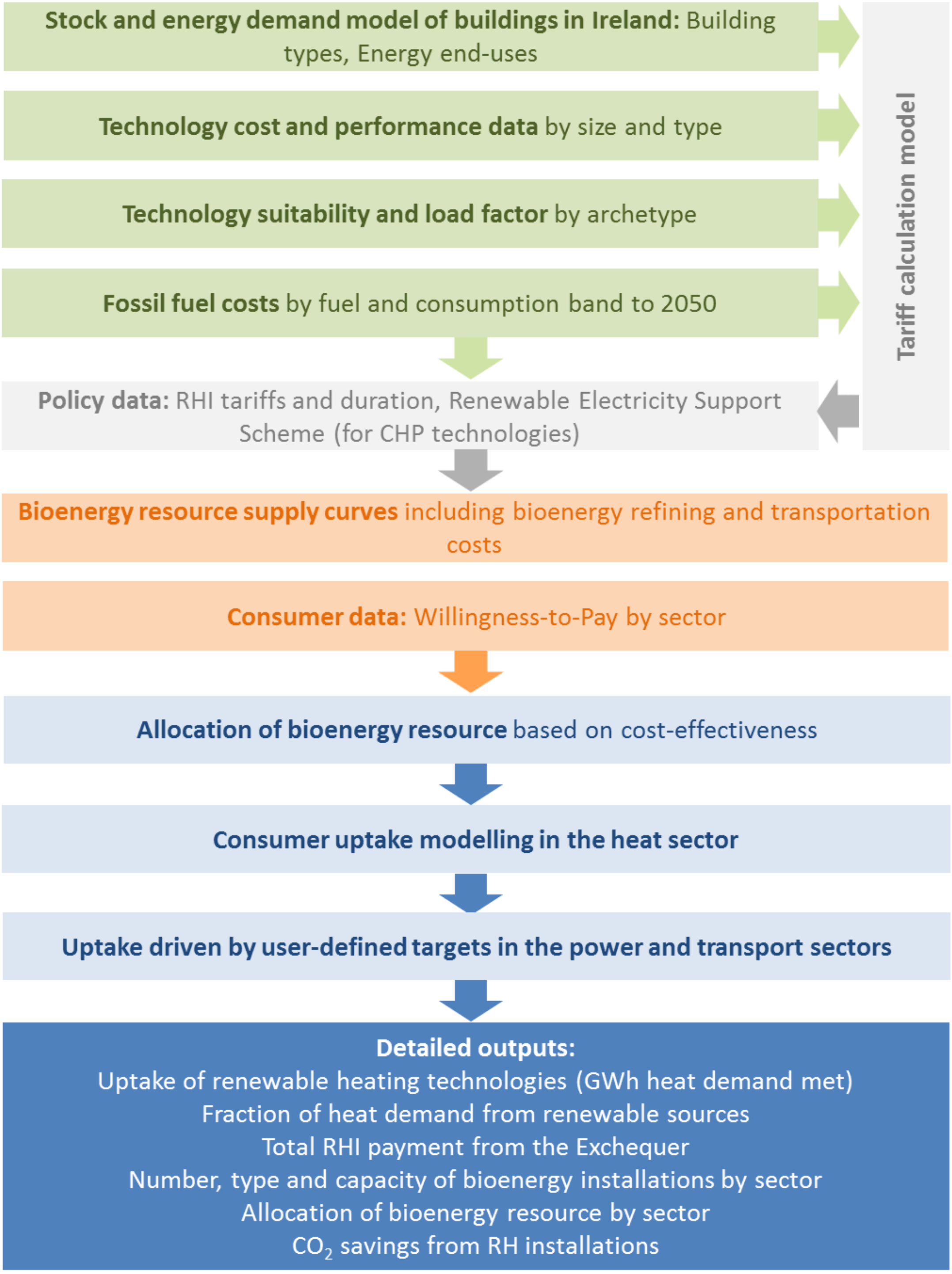
The uptake of RHTs under different RHI design options is assessed using the BioHEAT model recently developed by Element Energy for SEAI. This uses the same stock and energy demand model for buildings in Ireland as is used in the tariff calculation model, along with the same technology costs and performance data. In addition, the BioHEAT model contains a variety of policy interventions and key user inputs, including the RHI tariffs and duration of support (as set by the design options) and assumptions on the future Renewable Electricity Support Scheme (i.e. the successor to REFIT 3) for AD CHP and biomass CHP. The model allows these policies to be applied and combined as required.

The BioHEAT model also contains the most up-to-date bioenergy resource supply curves for Ireland developed by SEAI in the recent study *Bioenergy Supply in Ireland 2015 – 2035*[79]. The resource curves are supplemented by detailed data on bioenergy refining and transportation costs, developed by Element Energy and SEAI. The allocation of bioenergy resource in BioHEAT is based on cost-effectiveness, with realistic consumer uptake modelling for the heat sector based on Willingness-to-Pay data collected through recent surveys of consumers in Ireland, and uptake driven by user-defined targets in the power and transport sectors.

The model outputs include a full breakdown of the number, type and capacity of bioenergy installations by sector; allocation of bioenergy resource by sector; the fraction of heat demand from renewable sources (versus the 12% RES-H target); the total RHI payment from the Exchequer and the CO_2 savings.

[79] SEAI/Ricardo Energy & Environment, *Bioenergy Supply in Ireland 2015 – 2035: An update of potential resource quantities and costs* (September 2016)

Figure 5-1: High-level summary of RHI uptake modelling process using BioHEAT model



5.3 Uptake of biomass CHP in the power sector

Biomass is used in the power sector in co-firing and for biomass CHP and hence the power sector and the heat sector compete to some extent for the domestic biomass resource. The demand for biomass in the power sector to 2020 (and beyond) is somewhat uncertain. It is possible that the Edenderry power plant, which currently co-fires with 30% biomass, will increase its co-firing fraction. In addition, the two ESB peat plants at Lough Ree and West Offaly may start to co-fire with biomass beyond 2019. Furthermore, the Irish government has targeted 150 MWe of high efficiency biomass CHP plants to be installed by 2020 as a result of the REFIT3 scheme[80].

We note that, while the target of 150 MWe of biomass CHP to 2020 remains, there is growing acknowledgement that this target may not be met. The likelihood of this outcome was increased following the announcement in late 2016 that the planned 42.5 MW biomass CHP plant in County Mayo was to be put into liquidation[81]. As such, we have studied a sensitivity on the uptake of biomass CHP in the power sector, as described below.

In the central case, it is assumed that no additional biomass is used for co-firing by 2020 (but Edenderry continues to co-fire at 30%). For co-firing, it is assumed that 20% of the biomass is domestic and 80% is imported whereas for biomass CHP the biomass is assumed to be 100% domestic. In the central case, we assume that new biomass CHP plants come online limited only by the availability of biomass to the power sector. This results in 93 MWe of new biomass CHP installed in the power sector by 2020 – this is less than the 150 MWe target since the heat sector competes for the available (and limited) biomass resource.

In an alternative scenario, 'High biomass demand in the power sector' (see section 5.1), it is assumed that Edenderry increases co-firing to 50% from 2016, and both ESB peat plants start to co-fire with 30% biomass from 2020. The assumption on uptake of biomass CHP in the power sector remains unchanged.

It is important to note that the deployment of new biomass CHP in the power sector is dependent on the Renewable Electricity Support Scheme (RESS) being sufficient to incentivise uptake of the technology, likely including several large projects on the tens of MWe scale. Since an analysis of the RESS is outside the scope of this study, we have not studied in detail the RESS tariff structure which would be required to incentivise the targeted level of demand.

However, using the BioHEAT model, a sensitivity has been studied to examine the impact of a more limited level of uptake of new biomass CHP in the power sector. Initially a sensitivity was run with the uptake of biomass CHP in the power sector is constrained not only by the availability of biomass, but also to a level found to be cost-effective under an assumption of the RESS tariff available along with the RHI tariff. Based on the indicative level of support received by biomass CHP in the previous REFIT3 scheme, we constrained uptake of biomass CHP in the power sector to units with a levelised cost of electricity (LCOE) of 12 cents/kWh, once the RHI has also been applied. Under these conditions the uptake of biomass CHP in the power sector remained constant (at 93 MWe), indicating that the combination of the RESS tariff and the RHI tariff is sufficient to render the full 93 MWe cost-

[80] Department of Communications, Energy and Natural Resources (DCENR), *Renewable Energy Feed in Tariff: A Competition for Electricity Generation from Biomass Technologies 2010-2015, REFIT3* (Updated July 2013)

[81] http://www.irishtimes.com/business/energy-and-resources/liquidator-appointed-to-mayo-renewable-power-as-rescue-plan-fails-1.2887942 (Accessed March 2017)

effective. We note that the provision of both the RESS and RHI tariffs to biomass CHP represents a large combined level of incentive. In order to study the impact on the ability to meet the target of a lower uptake of biomass CHP in the power sector, a further sensitivity was studied wherein the RESS tariff was reduced by 5 c/kWh for biomass CHP in the power sector (i.e. from 12 to 7 cents/kWh). This led to a modest reduction in the uptake of Biomass CHP in the power sector to 79 MWe. The results of these sensitivities, including the impact on the overall RH target, are described in more detail in section 5.7.

5.4 Uptake of AD CHP, AD boiler and biomethane grid injection

As discussed in section 4.4, the tariffs for AD CHP, AD boiler and biomethane grid injection were determined using the same methods as for the other renewable heating technologies, with the only difference being that distinct archetypes were developed for these technologies by Ricardo Energy & Environment in a separate study[82]. Distinct archetypes were used for AD CHP, AD boiler and biomethane since these technologies are not expected to be deployed in the type of commercial and public premises in which the other RH technologies are likely to be deployed to replace existing fossil-fuel heating systems. Instead, they are likely to be deployed in the agriculture sector. The archetypes developed for these technologies were incorporated into this project via the interface study[83] undertaken jointly by Element Energy and Ricardo Energy & Environment.

Given that AD CHP and AD boiler plant are expected primarily in an agricultural context, an important source of uncertainty is the available on-site heat load. The heat from AD is not 'dispatchable', meaning that it cannot be turned on and off on a frequent basis in the same way most other heating systems can. The available on-site heat load will determine the load factor of the plant and the 'useful' proportion of heat generated, and will have an important bearing on the cost-effectiveness of generating renewable heat through these technologies. An important consideration in selecting the final scheme tariffs will be the need to provide a tariff sufficient to incentivise uptake of the desired type and number of installations, while not encouraging inefficient use of heat generated.

For each archetype for AD CHP and AD boiler, therefore, three cases were studied relating to the level of on-site heat demand, as shown in Table 5-4. Low (LHL), Medium (MHL) and High (HHL) heat load cases were studied, and the RHI tariff required calculated for each case. For biomethane grid injection, an operational load factor of 100% is assumed.

[82] Ricardo Energy & Environment, *Report on AD CHP and biomethane* (Publication pending)
[83] Element Energy and Ricardo Energy & Environment, *Interface analysis and report for incorporation and alignment of data from biomethane study into RHI workstream, 2017*

Table 5-4: Heat load factors by archetype for AD CHP and AD boiler

System ID	Heat load factor		
	LHL	MHL	HHL
Boiler A	60%	80%	85%
Boiler B	60%	80%	85%
CHP A	15%	40%	80%
CHP B	10%	40%	80%
CHP C	15%	40%	80%
CHP D	15%	40%	80%
CHP E	10%	40%	80%
CHP F	20%	50%	80%
CHP G	20%	50%	80%
CHP H	20%	60%	80%
CHP I	20%	50%	80%
CHP J	20%	40%	60%

It is important to note that the RHI tariffs presented here assume ongoing support for AD CHP through the Renewable Electricity Support Scheme (i.e. the successor to REFIT 3), in addition to the RHI tariffs given here. For the purposes of this analysis, we assume an indicative, flat level of support for renewable electricity of AD CHP of 14 c/kWh electricity exported in 2016, approximately in line with the level offered through REFIT3. The support level is projected forward according to the same procedure as for the electricity retail prices as described in section 4.2.4; however, we assume that the Renewable Electricity Support Scheme support level received by any given AD CHP installation remains fixed in real terms over the installation lifetime, even if the support level offered to new installations changes over time. The electricity exported is assumed to be 100% of the electricity produced.

In addition, it is assumed that the heat to the digester is an eligible heat use, such that this is included in the estimates of the on-site heat load. We note that, in the UK RHI scheme, heat used in the pasteurisation and drying of the digestate has been deemed an eligible heat use[84]; however, the recent consultation document on reforms to the UK RHI included proposals to end support for heat input to the digester[85]. The definition of eligible heat uses in general, and in the particular case of AD, will be an important consideration. In the case that heat input to the digester was not deemed eligible, somewhat higher levels of support than those presented here would likely be required.

[84] Ofgem, *Non-domestic Renewable Heat Incentive (RHI) Guidance Volume One: Eligibility and How to Apply (Version 8)* (November 2016)
[85] Department of Energy and Climate Change, *The Renewable Heat Incentive: A reformed and refocused scheme: Proposed reforms to the existing Domestic and Non-Domestic Renewable Heat Incentive schemes*, URN: 16D/012 (March 2016)

In order to align the AD and biomethane tariff calculation methodology with the other technologies considered in this assessment, the metering, additional and hidden costs were set as for the other technologies.

The RHI tariffs required for each archetype for each set of design options were then determined. Table 5-5 to Table 5-7 present the tariffs for Scenario 2 (see section 5.1). It can be seen that a wide range of tariffs are required to incentivise the range of archetypes, reflecting the variation in cost-effectiveness across different feedstock types, heat load levels and installation sizes, and whether the plant is entirely new or whether part of the required infrastructure already exists.

Table 5-5: AD boiler tariffs by system design (Scenario 2)

System ID	Feedstock	Capacity, kWth	Heat load	Heat output, MWh/yr	Tariff required, c/kWh
Boiler A	Farm - slurry and waste	48	Low	215	4.23
			Medium	287	3.16
			High	305	2.60
Boiler B	Waste – mixture of waste material	1,285	Low	5,256	0.00
			Medium	7,008	0.00
			High	7,446	0.00

Table 5-6: AD CHP tariffs by system design (Scenario 2)

System ID	Feedstock	Capacity, kWth	Heat load	Heat output, MWh/yr	Tariff, c/kWh
CHP A	Farm – slurry	100	Low	131	202.56
			Medium	350	72.78
			High	701	33.22
CHP B	Farm – slurry and silage	100	Low	88	33.93
			Medium	350	4.25
			High	701	0.00
CHP C	Farm – slurry	196	Low	258	19.01
			Medium	688	3.16
			High	1,376	0.00
CHP D	Farm – slurry and silage	512	Low	672	32.24
			Medium	1,792	8.13
			High	3,585	1.79
CHP E	Farm – silage and slurry	500	Low	438	147.21
			Medium	1,752	32.05
			High	3,504	13.75
CHP F	Farm – source-separated food waste, agri-food waste and grass silage	527	Low	923	59.42
			Medium	2,308	20.86
			High	3,693	10.99
CHP G	Farm – livestock manure, food waste and food process wastes	500	Low	876	0.00
			Medium	2,190	0.00
			High	3,504	0.00
CHP H	Waste – mixture of waste materials	500	Low	876	0.00
			Medium	2,628	0.00
			High	3,504	0.00
CHP I	Farm & Waste Fed – grass, slurry and food waste or sludges from industrial source	1,500	Low	2,628	19.12
			Medium	6,570	4.74
			High	10,512	0.92
CHP J	Waste Fed – all food waste	3,000	Low	5,256	0.00
			Medium	10,512	0.00
			High	15,768	0.00

Table 5-7: Biomethane tariffs by system design (Scenario 2)

System ID	Feedstock	Comments	Capacity, kW biogas	Biomethane produced, MWh/yr	Tariff required, c/kWh
BM A	Farm - silage (60%) and slurry (40%)	Biogas from several individual AD plant (five assumed) is transported by low pressure pipeline to a centralised upgrading and injection point	1,115	9,084	5.54
BM B	Waste Fed - MSW food waste	Plant capable of taking contained source separated food waste from MSW and commercial waste collections	1,746	14,529	6.75
BM C	Waste Fed - MSW food waste	Plant capable of taking contained source separated food waste from MSW and commercial waste collections	6,199	50,502	0.42
BM D	Waste Fed - food processing wastes	Plant taking less contaminated food wastes, typically with higher biogas yields	6,265	51,039	1.40
BM E	Farm - maize and food waste	Farm-based plants taking energy crops and waste	6,747	54,966	6.23
BM F	Farm - silage and slurry	Farm-based plant based on silage and slurry	6,341	51,655	2.59
BM G	Farm - silage and slurry	Similar plant to BM F but biomethane is compressed and taken by road to a central injection point	6,341	51,655	3.17
BM H	Wastewater treatment primary sludge	Existing wastewater treatment plant; only costs included are those for upgrading to biomethane and injection	4,385	35,726	0.00

As for all the other renewable heating technologies studied, tiered tariffs for AD CHP, AD boilers and biomethane are based on the tariff required for a reference installation of the appropriate technology and size. The range of archetypes studied for AD CHP, boiler and biomethane grid injection have widely differing levels of deployment potential, due to the availability of feedstock and, in the case of BM H, the number of existing wastewater treatment plant. Furthermore, the low cost-effectiveness, and associated high required tariffs, of some of the archetypes (particularly those in the range 30-200 c/kWh in Table 7) means it is unlikely to be desirable to design the tariffs to incentivise those types of plant. This includes all low heat load installations along with the purely slurry-based AD CHP installations.

As such, we have, in collaboration with Ricardo Energy & Environment, identified the reference installations corresponding to the types of AD and biomethane plant the RHI could be designed to incentivise, balancing the requirement for cost-effectiveness against the desire to ensure sufficient uptake of AD technologies, as described below. However, we have presented here the required tariffs for each of the individual archetypes (for Scenario 2) in order to demonstrate the tariff levels that would be required to incentivise additional types of plant to be deployed (by setting higher tariffs) or to further constrain the types of plant which would be incentivised (by setting lower tariffs). For example, if there is a desire to incentivise the use of higher cost feedstocks in order to utilise a particular resource, such as grass silage, the tariffs would need to be increased accordingly.

Using the individual tariffs and based on stakeholder feedback, reference installations were selected as described below.

AD boiler: reference installation selection and tariff tiering

The low heat load installations are excluded as reference installations, as it is not deemed desirable to incentivise these as there is no efficient use of the heat generated. Instead, installations where a higher fraction of heat is used on-site should be incentivised. However, it is expected that situations with a high heat load will be limited. Therefore, installations with medium heat loads are deemed to be the most likely desirable outcome, and the reference installations are selected from the 'MHL' installations.

The key reason for the difference in cost between Boiler A and Boiler B is the different feedstock, rather than the different size. The waste-fed system would expect to receive a gate fee, whereas the system fed by farm slurry and waste mixture would not. However, Boiler A is also representative of smaller installations which could be expected. The tier threshold for Tier 1 is therefore based on Boiler A, but with sufficient 'headroom' to incentivise a somewhat larger installation of this type within this tier.

Taking the reference installation and tiering considerations together the following tiers and reference installations were selected for AD boilers. These are set out in full in Table 5-8.

- Tier 1 (0-2.4 GWh): Boiler A with MHL is the representative case at this scale. The threshold is selected based on a maximum expected capacity of ~200 kW.
- Tier 2 (>2.4 GWh): Boiler B with MHL is representative of larger installations. No tariff required is required for this archetype in Scenario 2, so no further payment is required within this tier.

AD CHP: reference installation selection and tariff tiering

We emphasise here that the analysis for AD CHP already includes a tariff from the Renewable Electricity Support Scheme for electricity generated (of 14 c/kWh in the base year 2016). The tariffs derived here for the RHI are those we find are required in addition to the renewable electricity support.

Archetypes that are mainly waste-fed, including some mixture of waste with slurry (CHP G, CHP H and CHP J) are found to be the lowest cost, with no RHI tariff required beyond the renewable electricity support. This raises the question of why such systems have not already been deployed. The separate study[86] by Ricardo Energy & Environment highlights a range of non-financial barriers to the deployment of AD CHP systems which could explain this observation. In addition, a consultation carried out by Ricardo Energy & Environment as part of the above study suggests that investors in AD CHP may require a somewhat higher project IRR than that use to derive the tariffs in Scenario 2, at 8%. An IRR in the range 12-

[86] Ricardo Energy & Environment, *Report on AD CHP and biomethane* (Publication pending)

15% was typically cited in the consultation, due to the complexity of AD CHP plants (particularly of the large type described here by CHP J) and the relative immaturity of the technology. We note that Scenario 8 examines the case of a higher IRR of 12%.

Slurry- and silage-based systems (CHP A, CHP B, CHP C, CHP D, CHP E and CHP F) are included to understand the cost of maximising use of slurry and silage resource for AD CHP. These are generally higher cost, as shown in Table 5-6. In comparison with tariffs derived for other renewable heating technologies, AD CHP archetypes with required tariffs (in Scenario 2) greater than approximately 15 c/kWh can be seen to be relatively cost-ineffective.

It is expected that the farm-based installations would rarely achieve the high heat load level (HHL) so, as for AD boilers, the medium heat load (MHL) is generally taken as the more appropriate benchmark.

Taking these points together the following tiers and reference installations were selected for AD CHP:

- Tier 1 (0-2.4 GWh): Archetype CHP D with MHL is deemed the highest cost type of system at this scale that it would be desirable to incentivise, to ensure a significant fraction of the silage and slurry (i.e. non-waste) potential can be taken up. As such, this is selected as the reference installation for this tier. Archetypes CHP A and CHP E with MHL are deemed too high cost to be desirable to incentivise. Archetypes CHP B and CHP C are lower cost than CHP D, and so will be incentivised by the tariff derived. The threshold for this tier is based on allowing a small amount of headroom for the appropriate system types.
- Tier 2 (2.4-7.2 GWh): Archetype CHP I with MHL is deemed the highest cost system desirable to incentivise at this larger scale, as archetype CHP F with MHL is deemed too high cost. Archetypes CHP G, CHP H and CHP J require no tariff beyond the renewable electricity support. Again, the threshold is set to allow a small amount of headroom.
- Tier 3 (>7.2 GWh): Only archetype CHP I with HHL is deemed desirable at this scale for same reasons as given in Tier 2. For archetype CHP I no tariff is required beyond the payment for Tiers 1-2.

Biomethane: reference installation selection and tariff tiering

Archetype BM H is the special case of an existing wastewater sludge plant, for which it would be significantly more cost-effective to retrofit to enable biomethane grid injection compared with the other archetypes studied here. However, this would be limited to existing wastewater sludge plants and as such has limited potential. Therefore, this archetype is not deemed appropriate as a reference installation as it is proposed that the RHI should incentivise a wider range of plant types to contribute to renewable heating targets.

Archetype BM E is of low relevance due to the limited availability of farm-based food waste and maize feedstock resource and as such is not appropriate as a reference installation. Waste-fed systems (archetypes BM B, BM C and BM D) tend to have lower costs than silage- and slurry-fed systems of a similar size, mainly due to the difference in resource cost, as waste-fed systems would expect to receive gate fees. However, the resource potential of MSW food waste and food processing waste is relatively limited compared with the resource of silage and slurry, and stakeholder feedback suggests that the RHI should be designed to incentivise some level of uptake of this resource (i.e. archetype BM F or BM G).

There are some economies of scale in the biogas to biomethane upgrading step, which accounts for some of the differences in cost-effectiveness with installation size (such as between archetypes BM B and BM C). This suggests that some degree of tiering is appropriate. We note that archetype BM A represents a case where the biogas output of several (here it is assumed five) small AD plants would be delivered to a central grid injection point, so for the purposes of the tariff tiering the annual biomethane capacity of this archetype should be treated as the output of five of the individual AD plants (54.5 GWh rather than 10.9 GWh). Stakeholder feedback suggests that there will not be many biomethane plants larger than the archetypes shown here, in the case of Ireland (due mainly to the typical size of the agricultural facilities). However, to determine the thresholds for the tiers, some ‘headroom’ to account for some variation in the size of installations versus the sizing of archetypes is assumed here.

Taking the reference installation and tiering considerations together the following tiers and reference installations were selected for biomethane:

- Tier 1 (0-30 GWh/yr): Archetype BM B is selected as the reference installation as it is the only type representative of installations with an output of <30 MWh/yr (since BM A involves the delivery of the biogas output of five individual AD plant to a central injection point, as described above).
- Tier 2 (30-60 GWh): Archetype BM A is selected as the reference installation as it has the highest required tariff of the remaining archetypes deemed desirable to incentivise (once we have removed BM E for the reason above).
- Tier 3 (>60 GWh): Of the larger archetypes that are desirable to incentivise (including archetypes BM C, BM D and BM F) no further payment beyond the 60 MWh in Tiers 1 and 2 is required. Archetype BM F is selected as the reference installation as this requires the highest tariff of those deemed desirable to incentivise at this scale. However, we note that since this installation requires no further payment beyond tiers 1 and 2, the same results are seen when archetypes BM C or BM D are selected as the reference for tier 3).

Table 5-8: AD boiler, AD CHP and biomethane tariff structure and reference archetypes

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Reference archetype
Anaerobic digestion boiler	1	N/A	≤2,400	Boiler A - MHL
	2	>2,400	N/A	Boiler B - MHL
Anaerobic digestion CHP	1	N/A	≤2,400	CHP D - MHL
	2	>2,400	≤7,200	CHP I - MHL
	3	>7,200	N/A	CHP I - HHL
Biomethane grid injection	1	N/A	≤30,000	BM B
	2	>30,000	≤60,000	BM A
	3	>60,000	N/A	BM F

For each of the shortlisted scenarios, the tiered tariffs for AD boiler, AD CHP and biomethane were calculated following the design options as applied to derive the tariffs for the other technologies (see Appendix 2 for tariffs).

The development of scenarios for the deployment of AD and biomethane was within the scope of the study undertaken by Ricardo Energy & Environment, and was determined based on a combination of stakeholder consultation and their own analysis. The deployment scenarios are presented in Table 5-9. For all scenarios studied here, the uptake of AD and biomethane was taken as the Central deployment scenario. We note that, in reality, the uptake of AD and biomethane would (like all other technologies) depend on the level of the RHI tariffs offered along with tariffs offered for renewable electricity through the Renewable Electricity Support Scheme; however, this impact was not modelled here.

Table 5-9: Deployment scenarios for AD CHP, AD boilers and biomethane grid injection

System ID	Low deployment			Central deployment			High deployment		
	LHL	MHL	HHL	LHL	MHL	HHL	LHL	MHL	HHL
Boiler A	-	-	2	-	-	3	-	-	3
Boiler B	-	1	-	-	-	1	-	-	1
CHP A	-	-	-	-	-	-	-	-	-
CHP B	-	-	2	-	-	2	-	-	1
CHP C	-	-	1	-	-	1	-	-	1
CHP D	-	-	1	-	-	1	-	-	1
CHP E	-	-	-	-	-	-	-	-	-
CHP F	-	-	-	-	-	-	-	-	-
CHP G	-	-	2	-	-	4	-	-	4
CHP H	-	-	2	-	-	4	-	-	4
CHP I	-	1	-	-	-	1	-	-	1
CHP J	-	-	1	-	-	1	-	-	-
BM A	-			-			-		
BM B	-			-			1		
BM C	-			-			-		
BM D	-			-			1		
BM E	-			-			-		
BM F	-			-			-		
BM G	-			-			-		
BM H	-			1			1		
Number of plants	**13**			**19**			**19**		
Total heat, GWh/yr	**50**			**104**			**150**		

5.5 Assessment criteria

In the following sections, the scenarios are assessed in relation to the assessment criteria described in Table 5-10. The assessment criteria were developed through the literature review and stakeholder consultation process described in section 3.1.

Table 5-10: Summary of assessment criteria

Assessment criterion	Description
1. Incentivising an efficiency level of investment to meet the target	Does the design option have the potential to meet the target levels of uptake, and it would result in the overall least cost mix of investment to reach the target?
2. Minimising costs to the Exchequer (and appropriately profiling overall costs)	Does the design option minimise costs, and find the right balance between lowest overall cost and short term budget pressures?
3. Impact on CO_2	What impact would the design option have on CO_2 emissions?
4. Impact on particle emissions from biomass	What impact would the design option have on particle emissions from biomass?
5. Allocating risks efficiently	Does the design option allocate risk efficiently, such as between government and the sector?
6. Incentivising efficiency at the system specification, installation and operation stages	Does the design option promote efficient and effective design, installation and use of systems?
7. Impact on the diversity of the renewable heating technology mix	Would the design option lead to a diverse technology mix?
8. Complexity/clarity	Would the complexity of the design option deter investors?
9. Impact on the market/sustainability	What is the impact of the design option on the low-carbon heating sector in Ireland beyond 2020?

5.6 Summary of key outputs

A summary of the key outputs for each of the shortlisted scenarios, presented again for convenience in Table 5-11, is given in Table 5-12. A more extensive set of outputs for each scenario is included in Appendix 2.

Table 5-11: Description of scenarios

Type	ID	Scenario name
RHI design scenarios	1	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
	2	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price
	3	All central design options, Limited imported biomass (5 TWh/yr), tariff based on 9 c/kWh biomass price
	4	All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 9 c/kWh biomass price
	5	Tariffs capped at biomass boiler tariffs
	6	Tariffs capped at 10 c/kWh
	7	Shorter duration (7 yrs)
	8	Higher IRR (12%)
	9	Lower IRR (6%)
	10	Shorter duration (7 yrs) and Higher IRR (12%) except for biomass-based techs for which retain 15 yr duration and 8% IRR
	11	High power sector biomass demand
	12	Include ETS sector - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price
	13	Include ETS sector - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
No RHI baseline cases	N1	No RHI - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price
	N2	No RHI - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price

Table 5-12: Summary table of model outputs

ID	RHI offered	Annual heat output from all RH techs in 2020 (GWh)	Annual heat output from RH techs installed 2016-2020 in 2020 (GWh)	% RH (fraction of all heat from renewable sources)	Total cost to the Exchequer 2018-2034 (€ million, undiscounted)	Cost to the Exchequer in 2020 (€ million)	Annual CO_2 savings from RH techs installed 2016-2020 in 2020 ($ktCO_2$)[87]	Total CO_2 savings 2016-2034 (MtCO2)	Biomass fuel used in the heat sector in 2020 (GWh)	Biomass fuel used in the power sector in 2020 (GWh)	Total cost to the Exchequer of additional CO_2 savings 2016-2034[88] (€/tCO_2, undiscounted)
1	Yes	6,092	3,141	13.4%	1,622	109	1,328	21.5	4,281	2,525	171
2	Yes	5,472	2,521	12.1%	2,355	157	1,185	19.3	3,572	2,525	294
3	Yes	8,218	5,267	18.0%	5,964	398	1,792	28.9	7,072	2,525	351
4	Yes	5,441	2,490	12.1%	3,606	240	1,123	18.5	3,572	2,525	499
5	Yes	5,422	2,471	12.0%	1,188	79	1,159	18.9	3,572	2,525	157
6	Yes	5,460	2,509	12.0%	2,213	148	1,178	19.2	3,572	2,525	281
7	Yes	5,887	2,936	12.8%	2,449	350	1,236	20.3	3,572	2,525	273
8	Yes	5,646	2,695	12.4%	3,310	221	1,219	19.9	3,572	2,525	385
9	Yes	5,404	2,453	12.0%	2,028	135	1,172	19.1	3,572	2,525	261
10	Yes	6,215	3,264	13.3%	3,391	345	1,351	21.9	3,572	2,525	319
11	Yes	5,168	2,217	11.4%	2,050	137	1,014	16.5	3,341	2,756	390
12	Yes	5,477	2,526	12.1%	2,512	167	1,200	19.6	3,572	2,525	301
13	Yes	6,103	3,152	13.4%	1,746	117	1,346	21.8	4,317	2,525	178
N1	No	4,374	1,323	9.9%	N/A	N/A	730	12.0	2,680	2,525	N/A
N2	No	4,196	1,145	9.5%	N/A	N/A	689	11.3	2,465	2,525	N/A

[87] Including savings from both the heat and electricity components of the RH technologies installed
[88] relative to the corresponding No RHI case

5.7 Assessment of the scenarios against each criterion

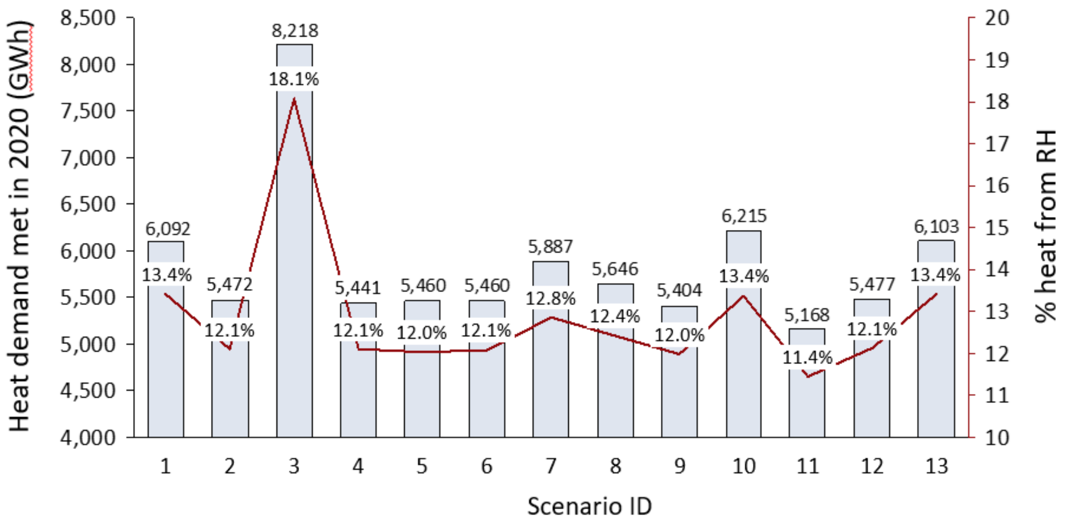
5.7.1 Incentivising an efficient level of investment to meet the target

Without an RHI, the renewable share of heat depends to some extent on the availability and price of imported biomass. In the 'No RHI - Strongly limited imported biomass' case (Scenario 2), the renewable share reaches 9.5%, implying a gap to the target of 12% of 2.5% (approximately 1,220 GWh). In the 'No RHI - Limited imported biomass' case a renewable share of 9.9% is achieved, implying a gap of 2.1% (approximately 1,030 GWh). However, it should be noted that these values include a significant uptake of biomass boilers in the ETS sector and biomass CHP in the power sector in the absence of an RHI (as discussed in Section 5.3).

The availability of biomass has a very large impact on the uptake of RH technologies and hence whether the 2020 RES-H target (12% of heat from renewable sources) can be met. Under the central assumptions for biomass use in the power sector, imported biomass is required in the heat sector in order to reach the 2020 target. The availability and price of imported biomass is dependent upon the balance of supply and demand on the international market, and therefore to some extent external to the decisions taken in relation to Ireland's RHI; however, any sustainability criteria included in the RHI will have an important impact on both the availability and the price of imported biomass.

When sustainability criteria are implemented such that imported biomass is limited to 1.5 TWh/yr, the RES-H target can still be met under the default design options (see Figure 5-2 – Scenario 2). However, when the biomass resource available to the heat sector is decreased due to increased demand for biomass in the power sector (Scenario 11), the uptake of biomass technologies in the heat sector is decreased and the RES-H target is missed. When less stringent sustainability criteria are applied such that the imported biomass availability increases to 5 TWh/yr, the RES-H target is exceeded, with RH providing 13.4% of the heat demand in 2020 (Scenario 1). Under these circumstances, the payback period limits the uptake of biomass technologies, rather than the availability of biomass fuel, and hence the price of biomass used to calculate the tariffs has a large impact on the uptake of biomass technologies. When the biomass technology tariffs are set based on the maximum domestic biomass price (9 c/kWh), but imported biomass is available at 5.5 c/kWh (Scenario 3), there is a very large increase in the uptake of biomass technologies compared with the case where the tariffs are set using the imported biomass price of 5.5 c/kWh (Scenario 1) and the target is far exceeded reaching 18.1% in 2020.

Figure 5-2: Heat demand met by RH technologies and % heat from renewable sources in 2020 for all scenarios



Including the ETS sector in the RHI scheme has little impact on the renewable heat contribution in 2020, in the scenarios studied here. The reasons for this finding are that:

- A substantial amount (of the order of 500 GWh in Scenario 2) of uptake of Biomass boiler occurs in the ETS sector in the absence of an RHI. This is because it is found to be cost-effective for a substantial fraction of the ETS heating demand even without an RHI. In line with this, the tariff offered to the ETS installations (which would be expected to have a very large annual heat output and hence receive the majority of payment under the highest tiers) in the presence of an RHI is small, such that it does not 'unlock' a significant amount of additional potential.
- Biomass availability is already limiting in the Strongly limited imported biomass case (Scenario 2) and so including the ETS sector (Scenario 12) does not increase the uptake. There is enough demand in the Non-ETS sector to exhaust the biomass supply in the Strongly limited imported biomass case already, such that including the ETS can only displace the Non-ETS uptake. We note that biomass availability is not limiting for the corresponding Limited imported biomass case (Scenarios 1 and 13); in this case, the above factors 1 and 2 are responsible.

One potential advantage of including the ETS sector, however, is that the number of installations required to reach the target is lowered, reducing the administrative burden of the scheme. However, this effect is found to be small in the scenarios studied here. On the other hand, the inclusion of the ETS sector shifts some of the carbon savings from non-ETS to ETS and hence reduces the non-ETS carbon savings, as described in Section 5.7.3.

The duration of support and the IRR applied to calculate the tariffs have a significant impact on the uptake of the technologies whose uptake is limited by the payback periods (that is, excluding biomass technologies, which are generally limited by biomass fuel availability). Shortening the duration of support and/or increasing the IRR results in a higher tariff and correspondingly a lower payback period and higher uptake of those technologies. This is shown in Figure 5-3 and Figure 5-4, where the latter focuses on non-biomass technologies.

Reducing the duration of support (Scenario 7) or increasing the IRR (Scenario 8) increases the overall uptake due to increased uptake of non-biomass technologies. Furthermore, while the use of biomass does not change significantly overall due to the limited biomass fuel resource, the proportions of the different biomass technologies vary slightly as the tariffs change, with a higher uptake of biomass CHP for the shorter duration and higher IRR.

Combining a reduced duration of support with a higher IRR for the non-biomass technologies (Scenario 10) results in the highest uptake of all scenarios in which imported biomass is strongly limited, with 6,224 GWh of heat demand met by RH technologies and the RES-H target being exceeded by 1.4%.

Figure 5-3: Heat demand met in 2020 by technology for selected scenarios – all technologies

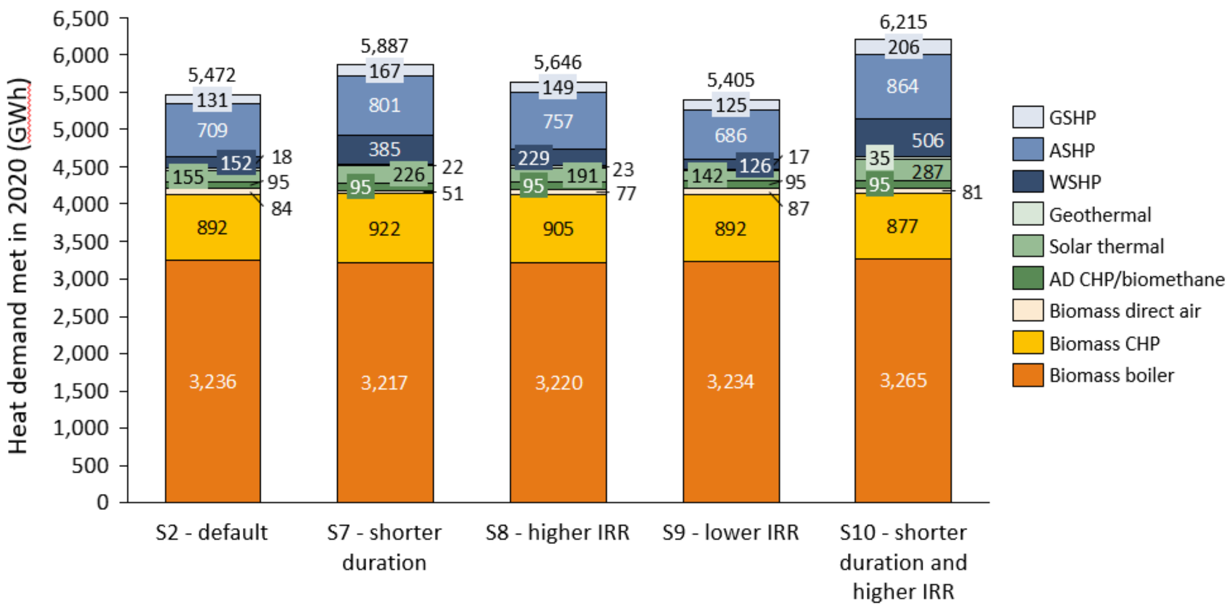
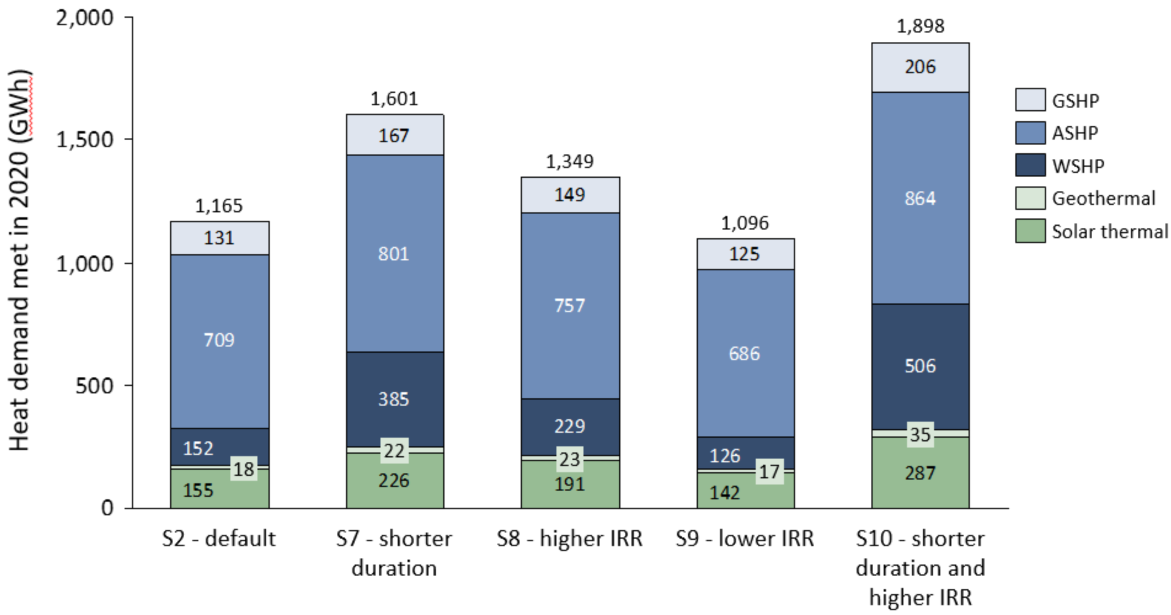


Figure 5-4: Heat demand met in 2020 by technology for selected scenarios – non-biomass technologies

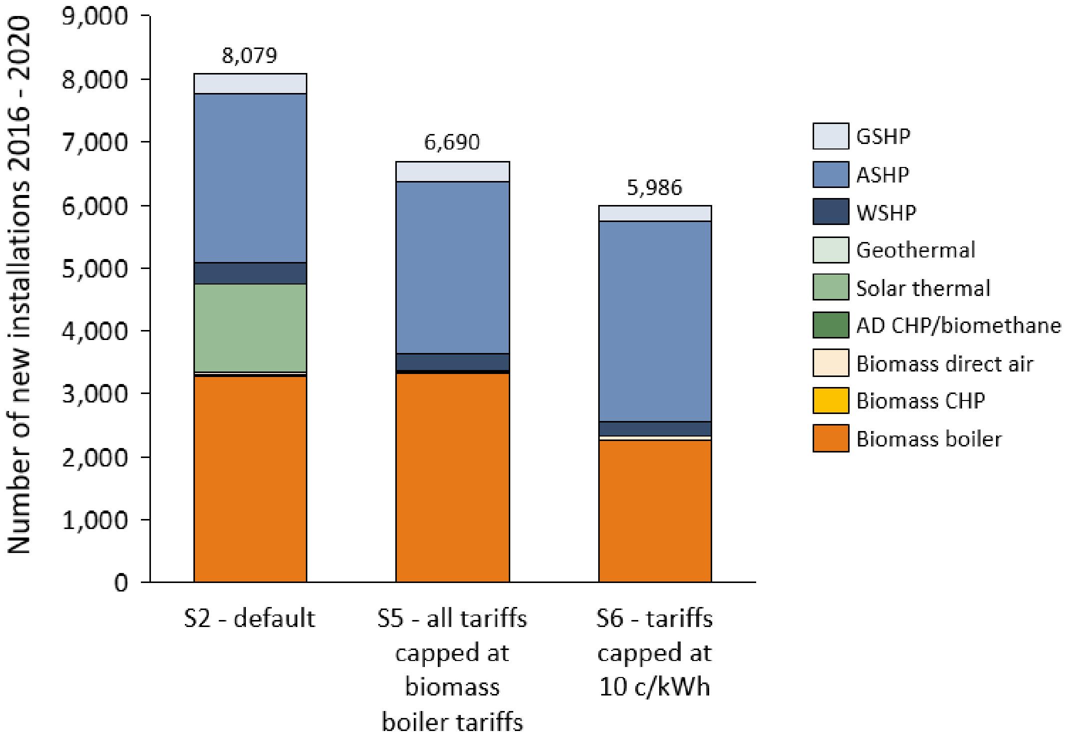


Capping the tariffs at 10 c/kWh (Scenario 6) only impacts the tariffs for certain tiers and/or technologies, and typically only for the lower tiers. This means that the capping has little impact on the larger installations for most technologies, and therefore has very little impact on the total heat demand met for RH technologies in 2020. In this scenario, the RES-H target is still met, which a renewable share of heating of 12.1%. The smallest installations are, however, significantly reduced in uptake, meaning that the total number of installations decreases by approximately 25% versus Scenario 2. This is presented in Figure 5-5. This could be seen as advantageous as a reduced number of installations is likely to reduce the administrative burden of the scheme; however, this could be seen as a reduction in the diversity of the installations incentivised.

When the tariffs for all RH technologies are capped at the level of the tiered biomass tariffs (Scenario 5), the technologies requiring higher tariffs (mainly solar thermal, WSHP and biomass CHP) are taken up in lower numbers; in the case of solar thermal, there is a reduction almost to zero uptake. On the other hand, the technologies requiring tariffs similar to or lower than the tariffs for biomass boilers, whose tariffs are therefore unaffected (including GSHP, ASHP, biomass boilers, biomass direct air heating and deep geothermal), experience a small increase in uptake as they displace the technologies whose uptake is reduced. As in Scenario 6, capping the tariffs predominantly affects the smallest installations such that the number of installations is reduced by 26% versus Scenario 2. This can be seen in Figure 5-5.

Overall, this leads to a small decrease in uptake of RH technologies from 5,431 GWh heat demand met versus 5,481 GWh in Scenario 2, but the RES-H target is still met with the renewable share of heating equal to 12.0%.

Figure 5-5: Number of installations by technology for selected scenarios



5.7.2 Minimising costs to the Exchequer (and appropriately profiling overall costs)

The total cost of the RHI to the Exchequer over the period 2018-2034, and the annual cost to the Exchequer in 2020, are shown for each scenario in Figure 5-6 and Figure 5-7 respectively. These costs reflect the RHI payments to the scheme participants but do not include the cost of administering the scheme[89]. The administrative costs are likely to be similar across the scenarios but may be expected to be somewhat higher for scenarios that involve a large number of installations.

Figure 5-6: Total costs to the Exchequer 2018-2034

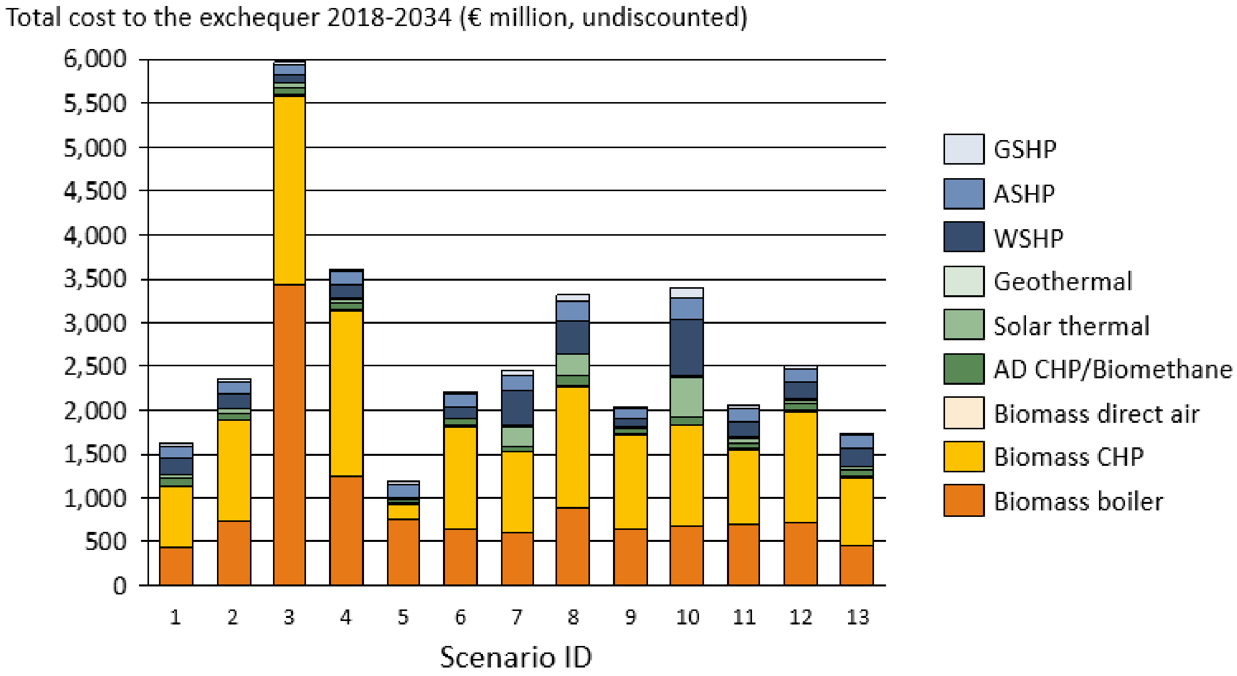
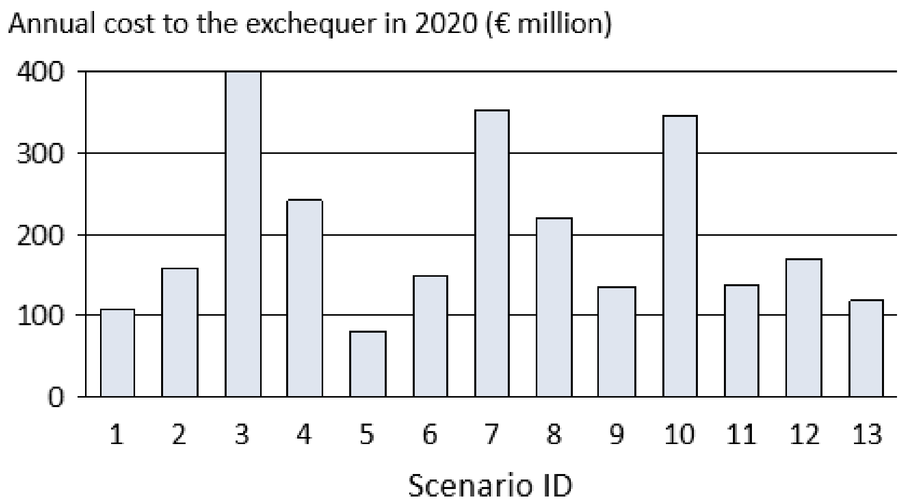


Figure 5-7: Annual cost to the Exchequer in 2020



Capping all tariffs at the biomass boiler tariffs (Scenario 5) leads to the lowest cost to the Exchequer (both annually and in total), whilst achieving the 2020 RES-H target. This is partly due to the displacement of the higher cost technologies by lower cost technologies. However, the bulk of the reduction in cost is due to the reduction in the Biomass CHP tariff. Biomass CHP, which forms a large part of the Exchequer cost, is largely taken up in the power sector. The tariff offered to biomass CHP users in the power sector in Scenario 5 is

89 In addition, the costs presented here do not include any payment to existing renewable heat installations through a 'grandfathering' process as described in section 3.4.5.

set equal to that of the highest tier, at 1.67 c/kWh, as these are expected to be relatively large installations. This tariff is significantly lower than that in all other scenarios (for example, compare this with 9.61 cents/kWh in Scenario 2). As such, the total costs to the Exchequer are significantly reduced.

Providing a lower RHI tariff for biomass CHP carries some risk of reducing the uptake of biomass CHP in the power sector, but this is strongly dependent on the level of support offered for the technology through the Renewable Electricity Support Scheme. In order to study the potential impact of reduced uptake of biomass CHP in the power sector, a set of sensitivities on this were studied by constraining the uptake of biomass CHP in the power sector to the cost-effective potential under two different levels of incentive. The results of these sensitivities are presented below (at the end of section 5.7.2).

Our analysis suggests a substantial amount of heating from Biomass boilers could be deployed in the ETS sector without the need for an RHI, such that an RHI would represent an over-incentive. However, as can be seen in Figure 5-6, the largest cost penalty in the case where the ETS is included (i.e. in Scenario 12 versus Scenario 2) is associated with the uptake of additional Biomass CHP in the ETS sector, rather than with the uptake of additional Biomass boilers. This is mainly because the tariff for Biomass CHP is substantially larger than the tariff for Biomass boiler for large installations (i.e. higher tiers). An alternative option (not presented here) would be to include the ETS sector, but to cap tariffs to the biomass boiler tariffs as in Scenario 5. This may be expected to carry the benefits of including the ETS sector – that is, that the RH target could be achieved through a smaller number of relatively cost-effective installations – without the negative impact seen in Scenario 12 resulting from large additional payments to Biomass CHP installations.

The second lowest Exchequer costs among the scenarios presented in Figure 5-6 are found in Scenario 1, closely followed by Scenario 13. This is due to the availability in those scenarios of low cost (5.5 c/kWh) imported biomass, which is used to set the tariffs for all biomass technologies. Since the majority of the uptake of RH technologies is in the form of biomass boilers and biomass CHP, this reduces the cost of the scheme significantly. In both of these scenarios the 2020 RES-H target is exceeded. However, the key drawback of these scenarios is that they rely on low cost imports, the availability of which is to some extent controlled by external factors, and also likely to be dependent on the application of weaker biomass sustainability criteria.

Scenario 3 results in very high costs to the Exchequer due to the high tariffs for the biomass technologies and the high uptake of these technologies. In this case, a budget management mechanism, such as tariff degression could be used to constrain the level of uptake to a level closer to the RES-H target and hence limit the costs to the Exchequer. Scenario 4 also carries high Exchequer costs due to the high biomass tariffs, but due to the limited availability of biomass the uptake is no larger than for Scenario 2.

Increasing the IRR from 8% (Scenario 2) to 12% (Scenario 8) increases the total costs to the Exchequer due to the increase in the tariffs offered and the associated increase in uptake of RH technologies. On the other hand, decreasing the IRR to 6% (Scenario 9) decreases the cost (relative to 8%) for a small decrease in uptake. Reducing the duration of support (Scenario 7) increases the uptake substantially versus Scenario 2, while the total cost to the Exchequer is not increased significantly. This is due to the fact that, with a shorter duration of support, the required net present value of the payment to the investor can be achieved using a smaller total payment in undiscounted terms (or discounted at a lower rate than the investor IRR). However, the annual payments for the shorter duration payment scheme are substantially larger, since the payment is spread over a small number of years (meaning that the tariffs paid during the support period are higher); this could prove not to be compatible with the Exchequer annual budget for the scheme.

Combining a short duration of support with a high IRR for non-biomass technologies (Scenario 10) results in a high total cost to the Exchequer, as the most costly technologies are strongly incentivised, as well as a high annual cost to the Exchequer, for the same reason and due to the fact payment is spread over a smaller number of years. In addition, the number of installations is large, due mainly to the large number of small solar thermal and heat pump installations taken up. This is likely to increase the administrative burden and associated costs of the scheme.

Sensitivities on Biomass CHP uptake in the power sector

As described above, providing a lower RHI tariff for biomass CHP (such as in Scenario 5) carries some risk of reducing the uptake of biomass CHP in the power sector. Since this is strongly dependent on the level of support offered for the technology through the Renewable Electricity Support Scheme, it is not a question which can be addressed entirely within the scope of this project. However, in order to study the impact of reduced uptake of Biomass CHP in the power sector on the ability to meet the RH target, a series of sensitivities were run for Scenarios 2, 12 and N2 in which Biomass CHP uptake in the power sector was constrained to the cost-effective potential under different assumptions on the level of incentives offered.

Sensitivity A: RESS tariff for Biomass CHP at a level in line with the REFIT3 tariff

In the first set of sensitivities, the uptake of Biomass CHP in the power sector is constrained not only by the availability of biomass (as in Scenarios 2 and 12), but also to a level found to be cost-effective following application the RHI tariff calculated for Biomass CHP in Scenarios 2 and 12 (that is, 9.61 cents/kWh of heat produced) and an indicative RESS tariff. Based on the level of support received by large Biomass CHP in the previous REFIT3 scheme, we assumed a RESS tariff of 12 cents/kWh of electricity produced. The uptake of Biomass CHP was then constrained to those cases with a levelised cost of electricity (LCOE) of up to 12 cents/kWh of electricity produced, after the RHI has been applied. Under these assumptions, it was found that the uptake of Biomass CHP in the power sector remained constant (at 93 MWe), indicating that the combination of the RESS tariff and the RHI tariff at these levels is sufficient to render the full 93 MWe cost-effective.

Therefore, the results of this first set of sensitivities is identical to Scenarios 2 and 12, and we do not present the results separately.

Sensitivity B: Reduced level of RESS tariff for Biomass CHP

Given that the details of the RESS tariffs have not been finalised, and given concerns that the envisioned level of uptake of Biomass CHP to 2020 may not materialise, a further set of sensitivities to Scenarios 2, 12 and N2 was studied wherein the combined incentive offered to Biomass CHP was reduced by 5 cents/kWh of electricity produced, through a reduction in the RESS from 12 to 7 cents/kWh. The constrained scenarios are referred to as Scenarios 2b, 12b and N2b.

The results of these scenarios are summarised in the figures and tables below (full outputs are included in Appendix 2). It can be seen that this reduction in the level of incentive offered reduces the uptake of Biomass CHP in the power sector from 93 MWe to 79 MWe.

However, in both Scenario 2b and Scenario 12b the reduction of biomass use in the power sector relative to Scenario 2 and Scenario 12 respectively (due to reduced uptake of

Biomass CHP in the power sector) is fully compensated by additional use of biomass in the heat sector such that the biomass use remains constant (Figure 5-8 and Figure 5-9). Furthermore, the reduced uptake of Biomass CHP in the power sector results in a slightly *higher* overall % RH, as the additional biomass used in the heat sector is predominantly used in Biomass boilers rather than Biomass CHP, such that some of the renewable contribution is shifted from electricity production to heat production.

Figure 5-8: Heat demand met in 2020 by technology for Scenarios 2 and 2b

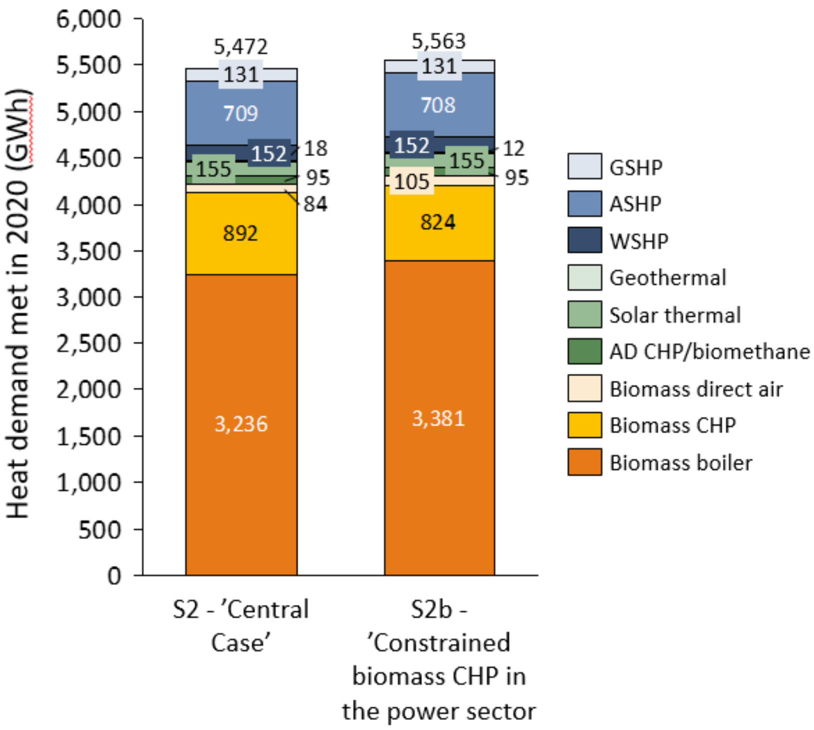
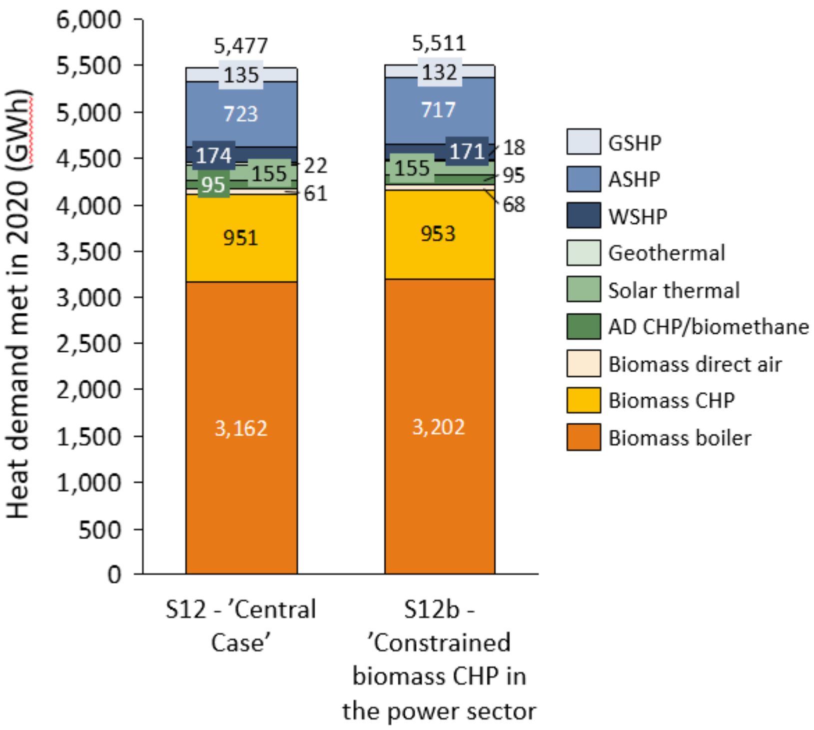


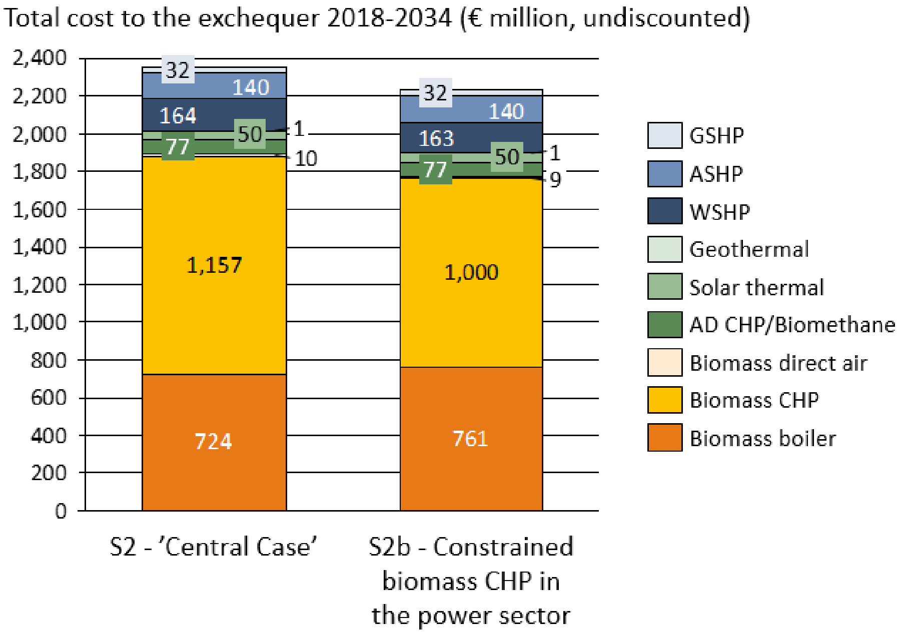
Figure 5-9: Heat demand met in 2020 by technology for Scenarios 12 and 12b



In Scenario N2 (no RHI), the biomass availability is not limiting and the uptake of biomass technologies is instead limited by the payback period. When the uptake of Biomass CHP in the power sector is reduced (Scenario N2b), the uptake of biomass technologies in the heat sector does not fully compensate and slightly less biomass is used overall. However, as more biomass goes to the heat sector rather than the power sector, the % RH increases slightly.

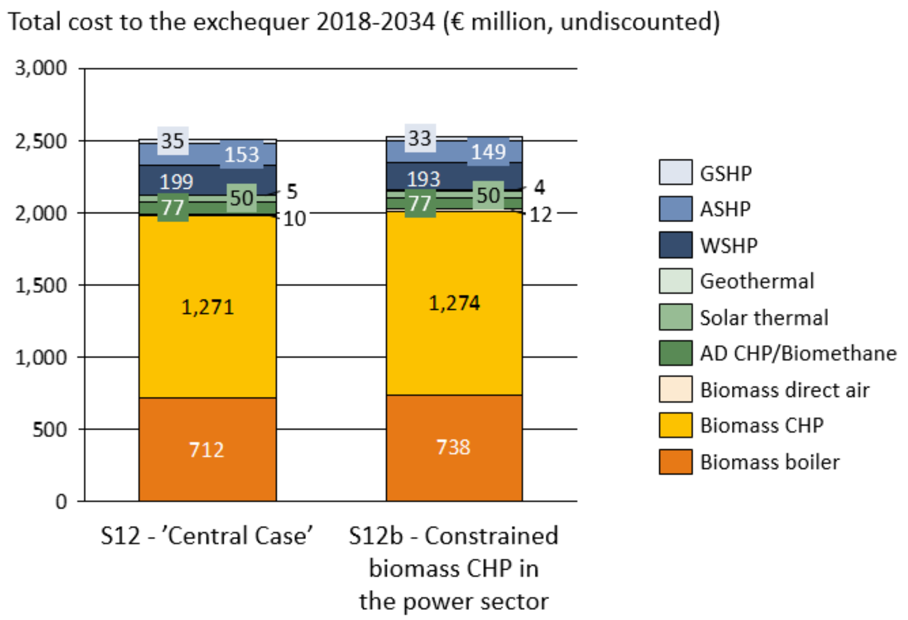
In Scenario 2b, the total cost to the Exchequer is somewhat lower than in Scenario 2 (Figure 5-10). This is mainly a result of the reduced cost of support for Biomass CHP in the power sector. The increase in uptake of Biomass boilers in Scenario 2b versus Scenario 2 results in an increase in the cost of support for Biomass boilers, however, this increase is substantially less than the decrease in the cost of Biomass CHP support, since the tariff for large Biomass boilers is significantly lower than for Biomass CHP. This leads to an overall cost saving. Over the entire scheme (2018-2035), the total Exchequer cost is €2,239 million in Scenario 2b versus €2,361 million in Scenario 2, representing a saving of €122 million.

Figure 5-10: Total cost to the exchequer for Scenarios 2 and 2b



In Scenario 12b, the annual Exchequer cost in 2020 is very similar to that in Scenario 12 (Figure 5-11). This is because, unlike in Scenario 2b, the reduction in Biomass CHP in the power sector is largely replaced by uptake of Biomass CHP in the heat sector, with only a small increase in uptake of Biomass boilers. This reflects the fact that in Scenario 12b, the ETS sector is eligible for the RHI (which is not the case in Scenario 2), and Biomass CHP (with the RHI) is found to be the most attractive option for the ETS users.

Figure 5-11: Total cost to the exchequer for Scenarios 12 and 12b



Overall, in summary, there is little change in % RH seen when the uptake of Biomass CHP in the power sector is constrained such that the uptake of Biomass CHP in the power sector is reduced from 93 MWe to 79 MWe. The reason for this is that the biomass that becomes available due to this reduction is used instead in the heat sector, where uptake is otherwise limited by biomass availability. This is a positive result which suggests that the performance against the RES-H target is relatively robust against a lower-than-expected uptake of Biomass CHP.

Given the high tariff required for Biomass CHP, a reduction in the uptake of Biomass CHP in the power sector reduces the cost to the Exchequer of the RHI. Given that a reduction in the uptake of Biomass CHP is likely to result in an increase in the uptake of Biomass boilers, contributing a similar or greater amount of renewable heat at a lower cost, the case for inclusion of Biomass CHP should be considered carefully.

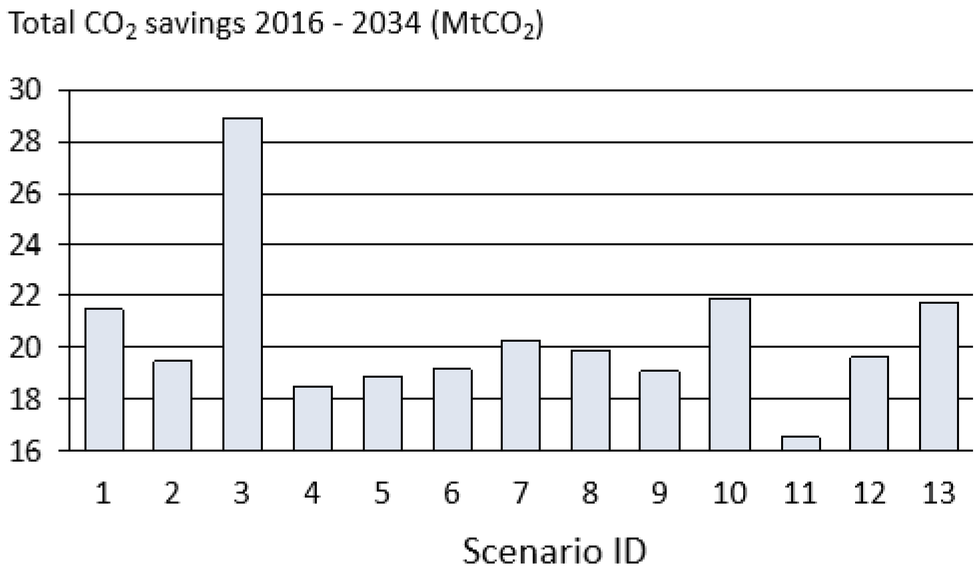
5.7.3 Impact on CO_2 emissions

All scenarios considered in this study result in a positive CO_2 saving, since all the renewable heating technologies included have a lower carbon intensity than the counterfactual fossil fuel-based technologies. The carbon savings are therefore strongly dependent on the overall level of uptake of RH technologies; beyond this, the mix of technologies has an impact on the overall CO_2 saving since certain technologies lead to greater savings on a per kWh basis than others.

Figure 5-12 presents the total CO_2 savings (using the life-cycle biomass emissions approach) over the period 2016-2034 due to RH technologies installed over the period 2016-2020 (note that this excludes installations prior to 2016, which nonetheless contribute to the heat demand met by RH technologies in Figure 5-2 and others). Note that a comparison of the CO_2 emissions savings using the life-cycle biomass emissions approach and the zero-rating approach is presented further below. In addition, we present below the breakdown of CO_2 savings in the zero-rating approach into ETS and Non-ETS CO_2 savings.

In Scenario 3, the uptake of RH technologies is very high, leading to the highest CO_2 savings of all scenarios studied, with the 2020 RES-H target exceeded by 6.1%. The uptake of RH technologies across the remaining scenarios is lower, and all achieve a share of renewable heating in the range 11.4%-13.4%. Scenarios 1, 10 and 13 have the highest uptake of RH after Scenario 3, and also the next highest CO_2 savings. Scenario 11 has the lowest uptake of RH, and the lowest carbon savings.

Figure 5-12: Total CO_2 savings 2016-2034 from RH technologies installed 2016-2020 using the life-cycle biomass emissions approach[90]



Differences in CO_2 savings for similar levels of uptake are due to the variation in the carbon intensities of the RH technologies taken up. These differences are most easily observed by comparing the CO_2 saving per kWh of renewable heat produced for each scenario, as in Figure 5-14.

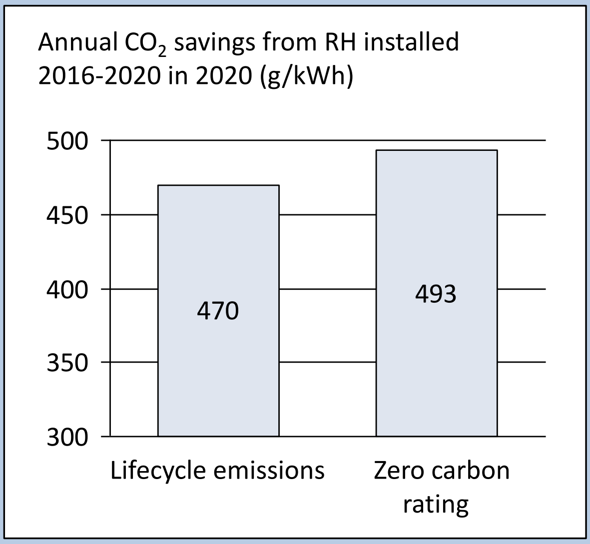
As discussed in section 3.3 the carbon intensity for heat pumps and deep geothermal installations depends on the carbon intensity of grid electricity and the efficiency of the heat pump. For the heat pumps, the assumed efficiency in the range 350-510%, and an assumed carbon intensity of grid electricity of 452 gCO_2/kWh, leads to a carbon intensity of heat produced in the range 89-129 gCO_2/kWh. This is higher than the 30 gCO_2/kWh assumed for biomass imported under the stringent sustainability criteria (in the “Strongly limited” biomass imports cases) assumed in Scenario 2 and others. As such, any scenarios that increase the uptake of non-biomass technologies (shorter duration of support and/or increased IRR) or reduce the uptake of biomass technologies (high power sector biomass demand) lead to a modest reduction in the CO_2 savings per kWh of heat produced. Whilst solar thermal has an assumed carbon intensity of zero, and hence lower than the biomass technologies, the uptake of solar thermal is low in all cases such that the impact on carbon savings is small.

[90] Note: The carbon savings include savings from both the heat and electricity components of the RH technologies installed

Life-cycle assessment (LCA) versus zero-rating for biomass

The results in the main text present the CO_2 emissions savings using the life-cycle biomass emissions, as described in section 3.3.2, in order to fully assess the impact of various design options on the RHI. Here, the CO_2 emissions are also considered using the 'zero-rating' method in accordance with the Renewable Energy Directive. In the zero-rating case all biomass is assigned a carbon intensity of zero, regardless of its origin. The CO_2 savings are therefore higher when the 'zero-rating' method than using the life-cycle biomass emissions method, as illustrated below.

Figure 5-13: Annual CO_2 savings per kWh in 2020 for Scenario 2 based on life-cycle assessment versus 'zero-rating' method



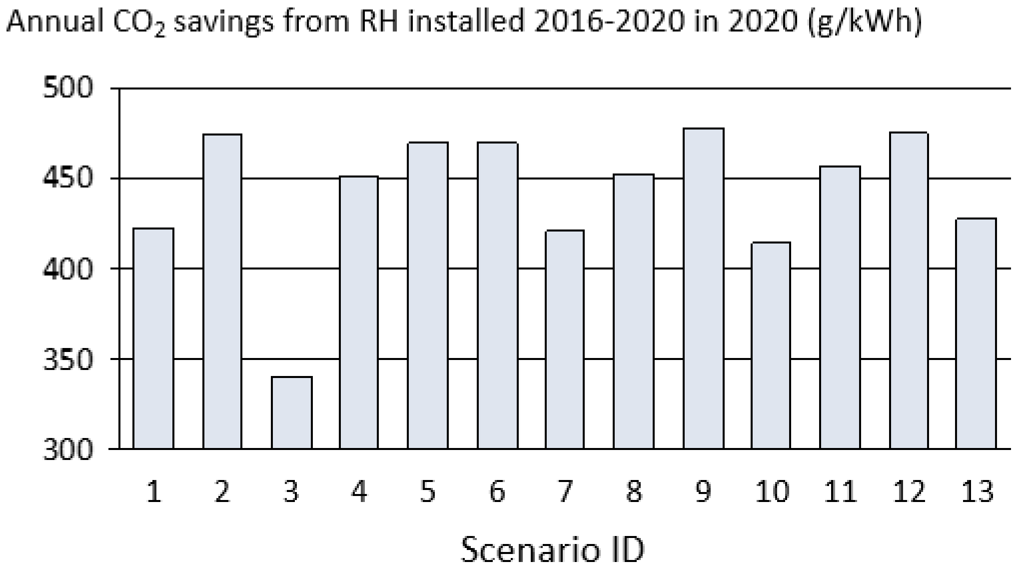
For scenarios using a larger amount of imported biomass with less stringent sustainability criteria (Scenarios 1, 3 and 13) the difference in savings between the two methods is significantly higher than for the cases using a smaller amount of imported biomass with more stringent sustainability criteria, as shown in Table 5-13.

Table 5-13: Annual CO_2 savings in 2020 based on life-cycle assessment versus zero-rating method

Scenario ID	Annual CO_2 savings from renewable heat technologies installed 2016-2020 in 2020 ($ktCO_2$)		
	Based on life-cycle biomass emissions	Based on zero-rating of biomass emissions	Difference
1	1328	1496	11%
2	1185	1244	5%
3	1792	2151	17%
4	1123	1180	5%
5	1159	1216	5%
6	1178	1234	5%
7	1236	1292	4%
8	1219	1276	4%
9	1172	1229	5%
10	1351	1407	4%
11	1014	1068	5%

12	1200	1257	5%
13	1346	1516	11%
N1	730	784	7%
N2	689	716	4%

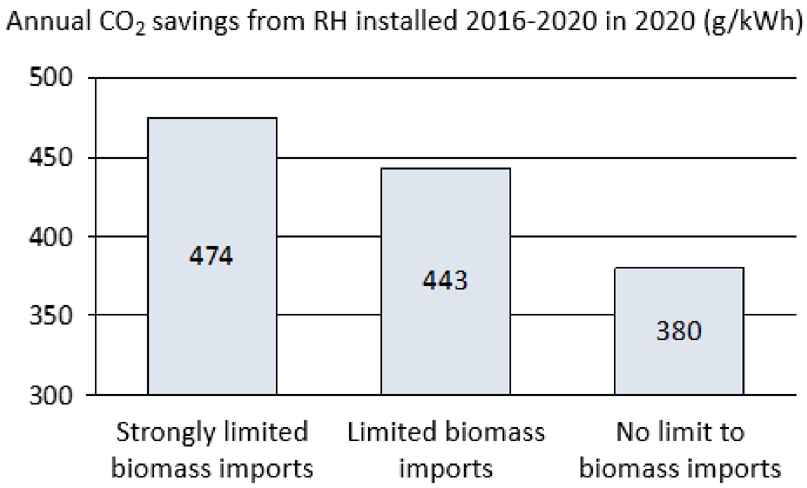
Figure 5-14: Annual CO_2 savings per kWh of heat demand supplied by renewable heat technologies, using the life-cycle biomass emissions approach[90]



Focusing on the biomass technologies, the biomass sustainability criteria applied has a large impact on the CO_2 saving per kWh of renewable heat produced. For scenarios with less stringent sustainability criteria for imported biomass (the "Limited" biomass imports cases), which includes Scenarios 1, 3 and 13, the CO_2 savings per kWh are significantly reduced. This is due to the carbon intensity of the imported biomass being higher than for scenarios with the more stringent sustainability criteria (see section 3.3.2). Here we assume an average value of 30 gCO_2/kWh for biomass imported in accordance with the more stringent sustainability criteria ("Strongly limited" biomass imports) and 70 gCO_2/kWh for biomass imported under less stringent sustainability criteria ("Limited" biomass imports).

As described in section 3.3.2, application of no biomass sustainability criteria risks leading to the use of biomass with a high lifecycle carbon intensity, potentially as high as 150 gCO_2/kWh as an upper limit estimate. A scenario with no sustainability criteria was not included in this analysis, as this was not deemed a viable option by the project steering board. However, to illustrate the potential impact of including no sustainability criteria, the sensitivity of the CO_2 savings to the biomass carbon intensity is shown for Scenario 2 for all cases in Figure 5-15.

Figure 5-15: Sensitivity of imported biomass carbon intensity on annual CO_2 savings, using the life-cycle biomass emissions approach



ETS versus non-ETS carbon savings

The total CO_2 savings are made up of a combination of savings in the ETS sector and savings in the non-ETS sector. It is useful to present the breakdown of the CO_2 savings into ETS and non-ETS components in order to understand the likely contribution of the RHI towards the non-ETS emissions reduction target. Here, the ETS and non-ETS components of the CO_2 savings are presented, based on the zero-rating method for biomass, in line with current national accounting under the Renewable Energy Directive.

It is important to note that emissions from grid electricity will accrue to the ETS sector. This means that an increase or reduction in electricity consumption in the non-ETS sector (for example in a non-ETS commercial organisation or a residential building) will impact the level of ETS emissions. As such, a switch away from electric heating to biomass-based heating in a non-ETS commercial property, for example, leads to a reduction in ETS CO_2 emissions due to the reduction in electricity consumption (and an increase in non-ETS emissions due to an increase in biomass consumption in the non-ETS sector, although these emissions will be assumed zero under the zero-rating of biomass). Similarly, a switch from gas heating to electric heating using a heat pump in a non-ETS commercial property, for example, leads to an increase in ETS CO_2 emissions due to the increase in electricity consumption, and a reduction in non-ETS emissions due to the reduction in gas consumption outside the ETS sector.

This means that the ETS savings result both from a reduction in the consumption of all fossil fuels and electricity in the ETS sector, as large industrial users switch to renewable heating technologies, and from switching to and from electric heating (whether renewable or non-renewable) in the non-ETS sector. This explains, in part, why ETS emissions savings make up a majority of the total savings, as shown in Figure 5-16.

Figure 5-16: CO_2 savings shown in terms of ETS and non-ETS components

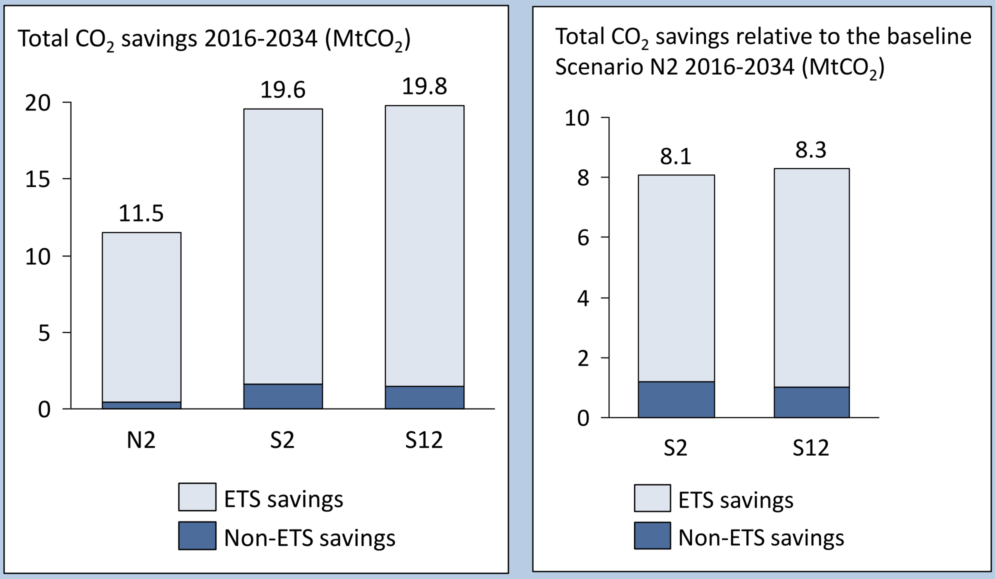
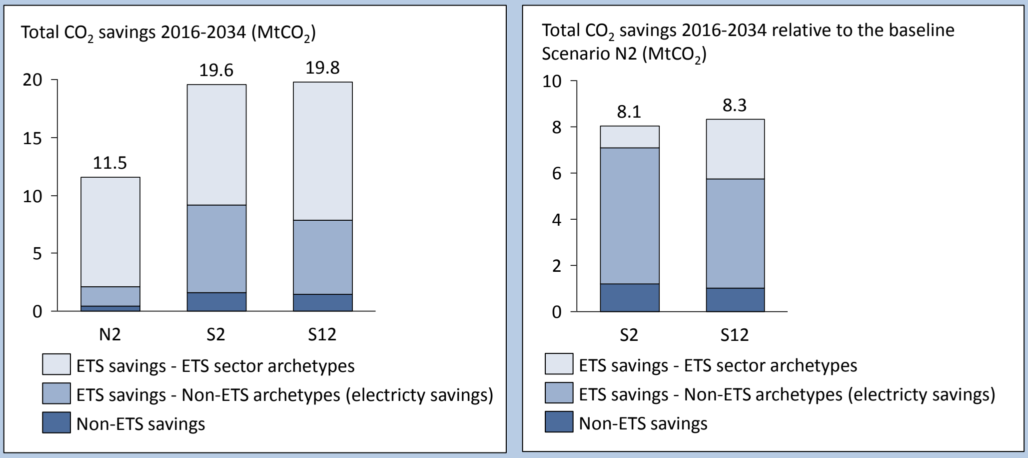


Figure 5-16 shows that a significant amount of ETS savings occur in the 'No RHI' case, Scenario N2. As shown in Figure 5-17, this reflects the fact that the most cost-effective opportunities for biomass-based renewable heating are found in the large ETS industrial facilities. When the RHI is offered to the non-ETS sector only (Scenario 2), the majority of the additional ETS savings are due to non-ETS archetypes (i.e. non-ETS organisations) switching from electric heating to renewable heating. A majority of the uptake of biomass in the non-ETS sector involves a switch from electric heating since the economic case for the switch from (relatively costly) electric heating to renewable heating is strong, and electric heating is widespread in the Irish non-domestic sector. When the RHI is offered to both non-ETS and ETS (Scenario 12), the share of ETS and non-ETS savings changes only slightly, while the share of ETS savings relating to electricity savings in non-ETS archetypes increases substantially. This is because although there is a substantial shift in the use of biomass for heating from non-ETS archetypes (in Scenario 2) to ETS archetypes (in Scenario 12), much of the emissions savings associated with the uptake of biomass heating in the non-ETS archetypes are anyway accounted for as ETS savings, given the predominance of electric heating among the non-ETS archetypes taking up the RHI.

Figure 5-17: Further breakdown of CO_2 savings by category



5.7.4 Impact on particle emissions from biomass

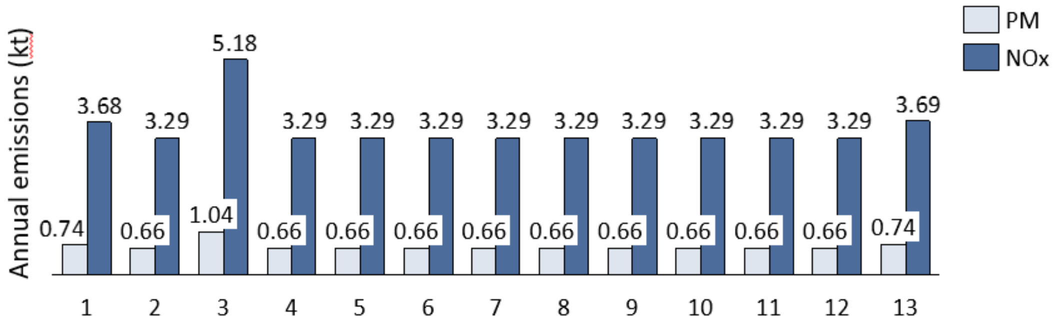
The uptake of biomass technologies following the introduction of an RHI will lead to an increase in emissions of particulate matter (PM) and nitrogen oxides (NOx). Whilst some increase in such emissions is an unavoidable consequence of increase use of biomass, the magnitude of the increase needs to be managed through the use of appropriate technology and fuel to minimise the risk of exacerbating air quality issues.

The difference in the increase in emissions of PM and NOx between the scenarios assessed here is controlled by the uptake of biomass technologies. The scenarios for which imported biomass availability is less strongly limited (Scenarios 1, 3, and 13), and which therefore have a high uptake of biomass technologies, result in the highest increase in annual emissions of PM and NOx. For all other scenarios, the increase in emissions from biomass are similar, as the use of biomass is limited to the same extent in each case by the availability of imports. The scenario with high biomass demand in the power sector (Scenario 11) has a similar increase in the level of PM and NOx emissions, since the increase in use of biomass in the power sector is matched by the decrease in the use of biomass in the heat sector.

In the scenarios modelled, no location-based constraints for biomass technologies have been applied. Location constraints could be considered to limit the air quality impacts in particular areas, but this will need to be assessed on a local basis. Such constraints could reduce the uptake of biomass, leading to a lower overall uptake than that shown in the scenarios studied, but given that the biomass uptake is in most cases limited by the availability of domestic and imported biomass, this may not have a material impact.

As described in section 3.6.4, a biomass fuel suppliers list could be included as a requirement of the RHI to ensure high quality fuel is used and to help minimise emissions. Nonetheless, there is a risk that once the RHI support ends poor quality biomass fuel will be used, unless regulations are also brought in outside of the RHI scheme. In addition, it is possible that maintenance and servicing will be reduced, leading to higher emissions, once the support ends. This could be expected to be a particular issue for shorter support durations.

Figure 5-18: Indicative annual PM_{10} and NOx emissions (all installations in heat and power sector)



5.7.5 Incentivising efficiency at the system specification, installation and operation stages

Minimum energy efficiency standards for the buildings and heat-using processes to be supplied by installations installed under the RHI will be a key component of a successful RHI design. This is supported by the negative publicity surrounding certain installations in the UK RHI, in which cases there is a widespread recognition that insufficient controls were in place to ensure that heat generated under the RHI was applied to useful purposes. The possible approaches to minimum efficiency standards are described in section 3.4.3.

Whether payments under the RHI are calculated based on deemed or metered heat use has very important consequences in terms of the incentive for efficient use of heat. Allowing the option for smaller installations to have RHI payments based on deemed heat use could incentivise efficient use of heat in those installations, as heat use can be lowered without impacting the RHI revenue. However, the risk of non-use or under-use of the RH system in the case of payment based on deemed heat (particularly in large buildings and where the counterfactual system is left in place) means that this option is not expected to be suitable for large installations.

However, payment based on metered heat has the disadvantage that it may in some cases incentivise the over-production of heat. This is a particular risk when the marginal price of generating an additional unit of heat is lower than the tariff offered for the unit of heat. We note that this situation could occur in certain cases, particularly for biomass-based heating, where a large fraction of the tariff offered corresponds to the repayment of the additional capital costs incurred (and not only additional ongoing fuel costs incurred). The risk of this outcome is greatest in the scenarios where a higher tariff is offered (such as scenarios 7 and 8). The impact of this outcome can be significantly reduced by tiering the tariffs by heat output, such that the marginal payment per kWh decreases the more heat is produced (see section 3.5.7). However, tiering alone is not likely to be sufficient to disincentivise over-production of heat, and should be applied in conjunction with minimum efficiency standards and the other approaches to ensure efficiency described below. The most risk-averse option would be to cap the tariffs close to the expected fuel cost, with the cap being reviewed on a quarterly basis, for example. It should be noted that this is likely to under-incentivise certain installations, particularly those smaller in capacity.

An alternative approach, which could reduce the negative impacts of inefficient use of heat but continue to promote use of an installed renewable heating system, combines the deemed and metered options. In this case, an annual 'cap' on the heat output for which payment can be claimed could be applied based on an assessment of deemed heat output. Within this approach, actual payment would still be based on metered heat use, but only up to a maximum amount as specified by the deemed heat output. This would limit the potential impact of inefficient use of heat, but also provide certainty over the amount of renewable heat actually generated by the RH system. Within this approach, there could be an option for the applicant to request (potentially at their own cost) a more in-depth energy audit capable of verifying the contributions of bespoke and/or recently-added heat uses. This approach is likely to increase the scheme complexity both for applicants and for the scheme implementing body, but may be considered preferable to minimise the risk of misuse of the scheme.

The use of tiered tariffs (by absolute heat output) rather than banded tariffs (by installation size) also reduces the risk of installations being sized inappropriately in order to receive higher RHI tariffs. This helps to ensure that installations are specified and installed to an appropriate size and design to achieve high efficiency.

A short duration of support carries the risk of inefficient use of heat (over-production) during the support period, as the tariffs are high (in many cases higher than the marginal cost of producing a unit of heat). Allocating RHI payments based on deemed heat use would mitigate this, but brings the risk described above of non-use or under-use of the RH system. Furthermore, once the RHI support comes to an end, the RH technology may no longer be used or may be used less efficiently. For these reasons, a shorter duration of support is not expected to incentivise efficiency at the operation stage to the same degree as a longer duration of support.

5.7.6 Allocating risks efficiently

To manage the risks to both the Exchequer and the scheme participants, as well as to ensure ongoing cost-effectiveness of the scheme, the tariffs should be adjusted systematically to reflect the changing costs of both the RH technologies and the counterfactual technologies, as well as the fuel prices. It will be important to consider whether the government is better placed than investors to manage input cost risks. A scheme design with no mechanism to adjust tariffs, both to new applicants and during the period of support, is not likely to be capable of allocating risks efficiently.

The upfront costs of the RH technologies are likely to decrease following the introduction of an RHI as a growing market will drive competition and help to establish the supply chain within Ireland. Therefore, to prevent over compensation, the tariffs may need to be decreased to new applicants over time. In addition, the fuel prices for the RH technologies and the counterfactual technologies are likely to vary over time in an unpredictable manner. However, an index linked directly to fuel prices is likely to lead to high cost uncertainty for the Exchequer, given the associated volatility. It may nonetheless be important to retain some flexibility in this regard in the case of biomass. The price of biomass is likely to be influenced by the implementation of the RHI, as the demand may increase more rapidly than supply, and the additional domestic resource is likely to carry a higher cost than that currently used. Due to this additional issue specific to biomass, the risks associated with biomass fuel availability and price should be considered carefully and managed by a frequent review of the tariffs offered to biomass technologies.

Respondents to DCENR's 2015 public consultation expressed the view that any indexation to inflation should be based on CPI, as is currently the case for new installations in the UK RHI. There is a question as to whether CPI is the most suitable index to use for all technologies, as solar thermal (in particular) entails little to no variable ongoing cost, and as such an on-going CPI linked payment may be deemed too generous. However, the deployment of solar thermal is expected to be low relative to other renewable technologies.

In addition, it is likely that budget management mechanisms will be required to ensure the scheme is compatible with the total and annual Exchequer budget. For example, in the case that imported biomass is available at low cost, the uptake of biomass technologies may be very large (especially if the biomass tariffs are calculated using the domestic biomass price). Whilst exceeding the 2020 RES-H target is desirable, the associated costs may not be acceptable. A budget cap and/or tariff degression (based on the level of uptake) could be used to prevent excessive costs to the Exchequer. Furthermore, tariff degression could be used to control the uptake of individual RH technologies to manage the diversity of the technology mix.

5.7.7 Impact on the diversity of the renewable heating technology mix

Differentiating the tariffs by technology increases the diversity of RH technologies, since the more costly technologies are incentivised, whereas tiered tariffs lead to a diverse range of installation sizes. When the tariffs are capped at 10 c/kWh as in Scenario 6, the technology diversity is not significantly impacted but there is a reduction in the number of small installations. When the tariffs are capped at the biomass tariffs as in Scenario 5, the diversity is somewhat reduced, with solar thermal and biomass CHP (in the heat sector) seeing a much-reduced uptake.

Increasing the IRR and/or decreasing the duration of support as in Scenarios 7, 8 and 10 increases the diversity of the technology mix, and this tends to incentivise more strongly the uptake of the heat pump and solar thermal technologies which have high upfront costs.

Despite the differentiation of the tariffs by technology leading to some diversity in the technology mix, however, biomass technologies dominate the uptake of RH technologies in all of the scenarios assessed. The uptake of biomass technologies is strongly impacted by the availability and price of imported biomass, which is likely to vary over time according to the dynamics of global biomass supply and demand. Therefore, the uptake of biomass technologies may need to be controlled by systematic adjustment of the tariffs and/or by including restrictions on the location of biomass technologies.

5.7.8 Complexity/clarity

Differentiating the tariffs by RH technology increases the complexity of the scheme by increasing the number of different tariffs required. Tiering the tariffs has a similar impact, and also means that multiple tariffs may apply to a single applicant, which could potentially make it more challenging for potential applicants to estimate the payments they would expect to receive. However, an 'RHI revenue calculator' could be provided to help applicants determine their potential revenue, and the associated complexity is not deemed to be a material drawback of differentiation by technology or the use of tiering.

The inclusion of any eligibility criteria, including minimum energy efficiency criteria, biomass sustainability, limits on emissions of PM and NOx, location-based biomass constraints and technology/fuel supplier lists, adds complexity to the scheme. The cost associated with introducing any eligibility criteria (especially if this means that a new scheme or process would need to be established) and undertaking the required monitoring and evaluation, should be considered against the benefits the eligibility criteria would be expected to bring.

Payments based on deemed heat use, as could be made an option for smaller installations, potentially adds complexity at the application stage, particularly if a new building energy assessment would need to be undertaken. On the other hand, payment based on metered heat output is likely to involve a higher ongoing administrative burden for both the scheme participants and the scheme administrators. Regardless of the method of determining the payments, ongoing checks will be required; either to ensure the RH technologies are being used or to check the heat meters are installed and operated correctly.

5.7.9 Impact on the market/sustainability

Incentivising a diverse range of technologies across a range of sizes through the RHI is expected to improve the long-term sustainability of the market for RH by allowing the necessary skills and supply chain to be developed. This in turn is expected to lead to cost reductions through learning, reinforcing the competitiveness of RH versus conventional heating technologies. It is important to note that the provision of the RHI for a limited time period only risks adversely impacting the long-term sustainability of the domestic RH market in Ireland, to the extent that this causes a sharp reduction in demand for RH technologies following the closure of the scheme. In order to ensure the market can be sustained, a medium- and long-term plan for renewable heat should be developed with a view beyond 2020, in order to provide greater certainty to the sector.

In addition, the availability, and hence the market price, of domestic biomass could be impacted by the introduction of an RHI, especially if stringent sustainability criteria are included which constrain the use of imported biomass. This issue could be exacerbated if confidence in the medium- and long-term (post-2020) market for biomass heating is low, as there will be less incentive to increase the production of domestic biomass given the long lead times required. The impact of an RHI on the price of domestic biomass would merit further consideration to ensure that existing users of biomass do not convert to fossil fuel based technologies due to a change in the differential price of biomass and conventional fuels.

5.8 Summary assessment of all scenarios

In Table 5-14, each of the 13 scenarios is evaluated against the assessment criteria using a Harvey Ball scheme. An ‘empty’ or all-white icon represents the lowest score against the relevant criterion; a ‘full’ or all-black icon represents the highest score. A high-level summary of the rationale for the scores is provided in the final column; the full evaluation of the scenarios against the assessment criteria is given in the text above.

We note that this reflects our own assessment of how the scenarios studied perform against the various criteria. While the assessment attempts to capture the feedback provided by the project steering group throughout the project, this is not intended to represent the views of DCCAE on the final design of the RHI.

Based on this assessment, and on feedback from the project steering board, we propose that Scenario 5 is most likely to meet the objectives of the policy in a cost-effective and sustainable way. As such, Scenario 5 is highlighted in the table as the preferred option. It should be noted, however, that the 2020 RES-H target is only just met in Scenario 5 and alternative scenarios, including Scenario 1, 3, 10 and 13, provide a higher likelihood of the target being met. These scenarios have substantial drawbacks, though, with Scenarios 3 and 10 resulting in significantly higher costs to the Exchequer, and Scenarios 1 and 13 performing less well in terms of sustainability (in terms of life-cycle carbon emissions from biomass).

Given the various advantages and drawbacks of the scenarios, it is likely that further scenarios combining the design options studied across multiple scenarios presented here will be of interest to DCCAE as the design of the RHI progresses.

Table 5-14: Summary assessment of all scenarios against the assessment criteria

Assessment Criteria	S1: Limited imported biomass, tariff based on 5.5 c/kWh biomass price	S2: Strongly limited imported biomass, tariff based on 6.9 c/kWh biomass price	S3: Limited imported biomass, tariff based on 9 c/kWh biomass price	S4: Strongly limited imported biomass, tariff based on 9 c/kWh biomass price	S5: Tariffs capped at biomass boiler tariffs	S6: Tariffs capped at 10 c/kWh	S7: Shorter duration (7 yrs)	S8: Higher IRR (12%)	S9: Lower IRR (6%)
1. Incentivising an efficient level of investment to meet the target	●	◕	●	◕	◕	◕	●	◕	◕
2. Minimising costs to the Exchequer (and appropriately profiling overall costs)	◕	◑	◔	◔	●	◑	◔	◔	◕
3. Impact on CO_2	◕	◕	●	◕	◕	◕	◕	◕	◕
4. Impact on particle emissions from biomass	◔	◑	○	◑	◑	◑	◑	◑	◑
5. Allocating risks efficiently	◕	◕	◕	◕	◕	◕	◕	◕	◕
6. Incentivising efficiency at the system specification, installation and operation stages	◕	◕	◑	◑	◕	◕	◔	◕	◕
7. Impact on the diversity of the renewable heating technology mix	◔	◑	◔	◑	◔	◔	◕	◕	◑
8. Complexity/clarity	◑	◑	◑	◑	◑	◑	◑	◑	◑
9. Impact on the market/ sustainability	◕	◑	◕	◕	◑	◑	◑	◕	◑
Overall	◕	◕	◔	◑	●	◕	◑	◑	◕

Assessment Criteria	S10: Shorter duration and Higher IRR (except for biomass-based techs)	S11: High power sector biomass demand	S12: Include ETS - Strongly limited imported biomass, tariff based on 6.9 c/kWh biomass price	S13: Include ETS - Limited imported biomass, tariff based on 5.5 c/kWh biomass price	Comments
1. Incentivising an efficient level of investment to meet the target	●	◔	◕	●	The availability and cost of imported biomass have the largest influence on the uptake of RH technologies. A shorter duration and/or higher IRR increase the uptake of non-biomass technologies. Scenarios that exceed the target in the model would be expected to have the highest likelihood of meeting the target if implemented.
2. Minimising costs to the Exchequer (and appropriately profiling overall costs)	◔	◑	◑	◕	Biomass technologies dominate the uptake in all scenarios. Therefore, the price of biomass fuel used to set the tariffs has a large impact on the total cost to the Exchequer. Reducing the uptake of the most expensive technologies by capping all tariffs at the biomass boiler tariffs or at 10 c/kWh reduces the scheme cost. A short duration of support leads to high annual costs.
3. Impact on CO_2	●	◔	◕	◕	A high availability of biomass increases overall CO_2 savings as the uptake of RH technologies is large. However, importing biomass without stringent sustainability criteria reduces the CO_2 savings on a per kWh basis.
4. Impact on particle emissions from biomass	◑	◑	◑	◔	The availability and costs of imported biomass controls the uptake of biomass technologies and hence the emissions of PM and NOx. Abatement technologies (not modelled) could be used to restrict the emissions but would increase the tariffs required for biomass technologies and reduce uptake due to higher upfront costs.
5. Allocating risks efficiently	◕	◕	◕	◕	Systematic adjustment of the tariffs are included in all scenario (though not modelled here). Such mechanisms will help to ensure the ongoing cost-effectiveness of the scheme and allow risk to be allocated appropriately between the Exchequer and the scheme participants. Budget control mechanisms are likely to be required if low cost biomass imports are available.
6. Incentivising efficiency at the system specification, installation and operation stages	◔	◕	◕	◕	On-going payments differentiated by heat output, included in all scenarios, incentivise efficiency in design and operation. Higher tariffs, comparable to or higher than the fuel price, lead to a higher risk of over-production of heat (this is especially a risk for biomass heating). A short duration of support also means that, once the support period ends, there is a risk of the RH technologies not being maintained and the efficiency operation being reduced.
7. Impact on the diversity of the renewable heating technology mix	●	◑	◑	◔	Differentiating tariffs by technology and heat output increases diversity, as does incentivising non-biomass technologies via a shorter duration and/or increased IRR. Increasing the availability of imported biomass reduces diversity especially when the biomass tariffs are set based on the domestic biomass price.
8. Complexity/clarity	◑	◑	◑	◑	Differentiating the tariffs by technology increases the complexity of the scheme, as does tariff tiering. All scenarios include these design options. Inclusion of eligibility criteria also increases the complexity; scenarios are not differentiated by eligibility criteria.
9. Impact on the market/ sustainability	◑	◑	◑	◕	A greater availability of imported biomass will help to mitigate against biomass price rises. Offering tariffs based on a relatively high biomass fuel price is likely to help develop the domestic biomass market.
Overall	◑	◔	◕	◕	

6 Appendix 1: Input data

Appendix 1a: Technology costs and performance data

Biomass boiler

Biomass boilers are similar to conventional gas and oil boilers but are fuelled by biomass; typically, wood chips or wood pellets although energy crops can also be used. Biomass boilers are technically suitable for space heating, hot water and low temperature industrial processes where hot water or steam is required.

Table 6-1: Biomass boiler cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€320/kW for >1 MW to €981/kW for 7 kW (varies by size, see below)
	Operating cost	€13/kW/yr to €34/kW/yr (varies by size, see below)
	Relevant additional and hidden costs (where applied)	• Heat metering • Space for fuel storage unit • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	7 kW and larger
	Load factor	20-82% (varies by sector and end-use, see below)
	Efficiency	83-84% (varies by size, see below)
	Lifetime	25 years
Suitability	Suitable heat uses	Space and hot water, low temperature process
	Suitable building thermal efficiency	Suitable for all buildings

Figure 6-1: Biomass boiler capital cost including installation and fuel storage unit but excluding additional and hidden costs

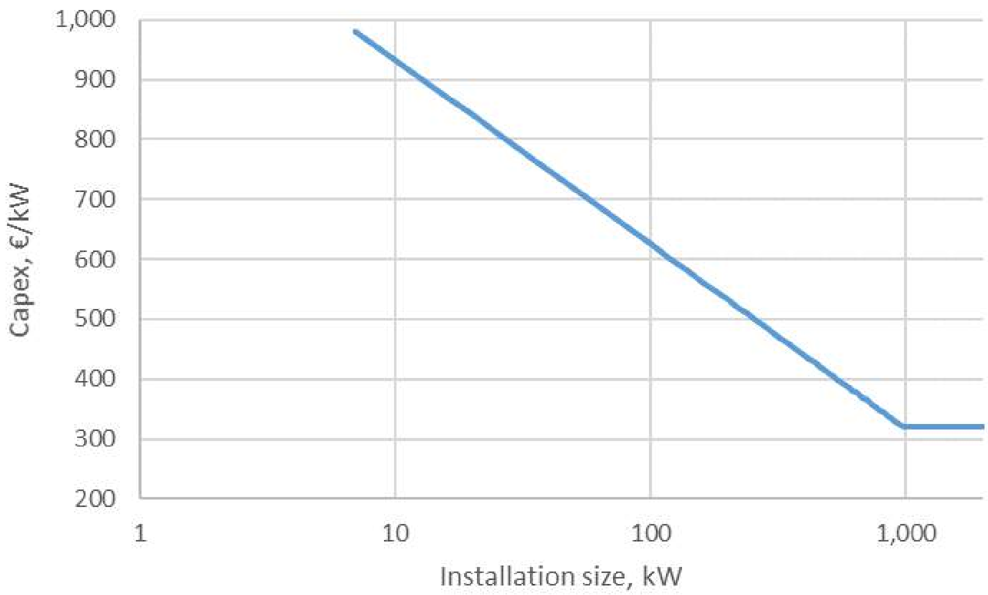


Table 6-2: Biomass boiler cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Efficiency
7	981	34	83%
30	787	28	83%
100	625	23	83%
300	478	18	83%
1000	320	13	83%
3000	320	13	84%

Table 6-3: Biomass boiler load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	20%
Commercial	Space heating and hot water	20%
Industry	Space heating and hot water	20%
Industry	Low temperature process heat	82%

Biomass CHP

Biomass CHP units combust biomass (typically wood pellets or wood chips) to produce both useful heat and electricity. Biomass CHP units are suitable for space heating and hot water.

Table 6-4: Biomass CHP cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€2411/kW for >10 MW to €3305/kW for 100 kW (varies by size, see below)
	Operating cost	€100/kW/yr to €132/kW/yr (varies by size, see below)
	Relevant additional and hidden costs (where applied)	• Heat metering • Biomass storage unit • Space for fuel storage unit • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	100 kW and larger
	Load factor	60%
	Efficiency	50% (Thermal), 29% (Electrical)
	Lifetime	25 years
Suitability	Suitable heat uses	Space and hot water
	Suitable building thermal efficiency	Suitable for all buildings

Figure 6-2: Biomass CHP capital cost including installation but excluding additional and hidden costs

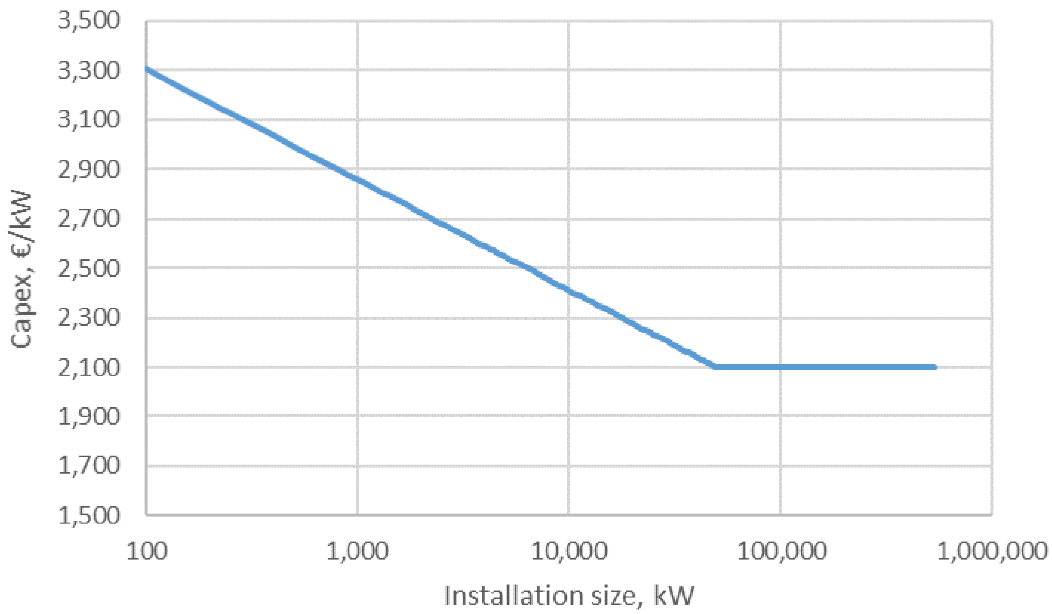


Table 6-5: Biomass CHP cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Thermal Efficiency	Electrical Efficiency
100	3305	132	50%	29%
300	3091	125	50%	29%
1000	2858	116	50%	29%
3000	2645	109	50%	29%
10000	2411	100	50%	29%

Table 6-6: Biomass CHP load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	60%
Commercial	Space heating and hot water	60%
Industry	Space heating and hot water	60%

Biomass direct air

Biomass direct air heating refers to the case where biomass is combusted to heat air which is circulated directly around a room or building or into an industrial process, rather than being used to heat water to be circulated for space heating or hot water provision.

Table 6-7: Biomass direct air cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€525/kW
	Operating cost	€13/kW/yr
	Relevant additional and hidden costs (where applied)	• Heat metering • Biomass storage unit • Space for fuel storage unit • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	7 kW and larger
	Load factor	20-82% (varies by end-use, see below)
	Efficiency	83-84% (varies by size, see below)
	Lifetime	25 years
Suitability	Suitable heat uses	Space heating
	Suitable building thermal efficiency	Niche; for modelling purposes assumed suitable for 10% of space heating demand in large commercial and industrial sector

Table 6-8: Biomass direct air cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Efficiency
7	N/A	N/A	83%
30	N/A	N/A	83%
100	N/A	N/A	83%
300	N/A	N/A	83%
1000	N/A	N/A	83%
3000	N/A	N/A	84%

Table 6-9: Biomass direct air load factor

Sector	Heat use	Load factor
Industry	Space heating and hot water	20%
Industry	Low temperature process heat	82%

Ground-source heat pump

Ground source heat pumps extract heat from the ground by circulating a fluid through pipe buried in trenches or borehole, using a refrigeration cycle to move the heat from the cooler side (the ground) to the warmer side (the building). Ground-source heat pumps can be used to provide both space heating and hot water.

Table 6-10: GSHP cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€1297/kW for >100 kW to €3466/kW for 3 kW (varies by size, see below)
	Operating cost	€8/kW/yr to €11/kW/yr (varies by size, see below)
	Relevant additional and hidden costs (where applied)	• Heat metering • Retrofit of emitters (not for new builds) • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	3 kW to 2 MW
	Load factor	35-82% (varies by sector and end-use, see below)
	Efficiency	510%
	Lifetime	25 years
Suitability	Suitable heat uses	Space and hot water, 35% of low temperature process
	Suitable locations	All locations potentially suitable
	Space requirements	Need ground space
	Suitable building thermal efficiency	Not suitable for BER rating E2-G

Figure 6-3: GSHP capital cost including installation but excluding additional and hidden costs

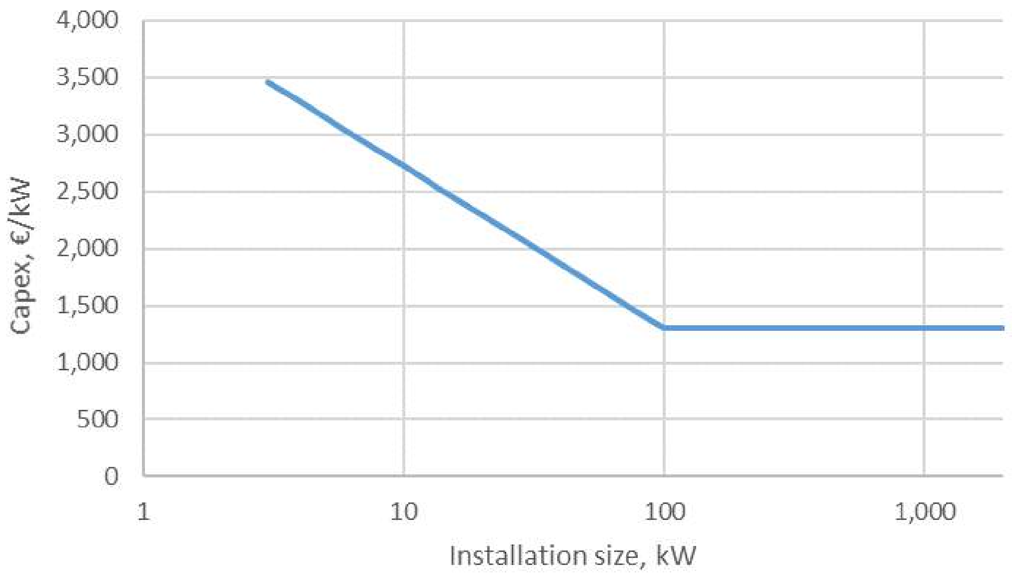


Table 6-11: GSHP cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Thermal Efficiency
3	3466	11	510%
30	2042	9	510%
100	1297	8	510%
300	1297	8	510%
1000	1297	8	510%

Table 6-12: GSHP load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	35%
Commercial	Space heating and hot water	35%
Industry	Space heating and hot water	35%
Industry	Low temperature process heat	82%

Air-source heat pump

Air source heat pumps (here meaning air-to-water heat pumps) extract heat from the ambient air, using a refrigeration cycle to move the heat from the cooler side (the outside air) to the warmer side (the building). Air-source heat pumps can be used to provide both space heating and hot water.

Table 6-13: ASHP cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€479/kW for >300 kW to €1408/kW for 3 kW (varies by size, see below)
	Operating cost	€3/kW/yr to €32/kW/yr (varies by size, see below)
	Relevant additional and hidden costs (where applied)	• Heat metering • Retrofit of emitters (not for new builds) • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	3 kW to 2 MW
	Load factor	35-82% (varies by sector and end-use, see below)
	Efficiency	350%
	Lifetime	20 years
Suitability	Suitable heat uses	Space and hot water, 35% of low temperature process
	Suitable locations	All locations potentially suitable
	Space requirements	No specific requirements
	Suitable building thermal efficiency	Not suitable for BER rating E2-G

Figure 6-4: ASHP capital cost including installation but excluding additional and hidden costs

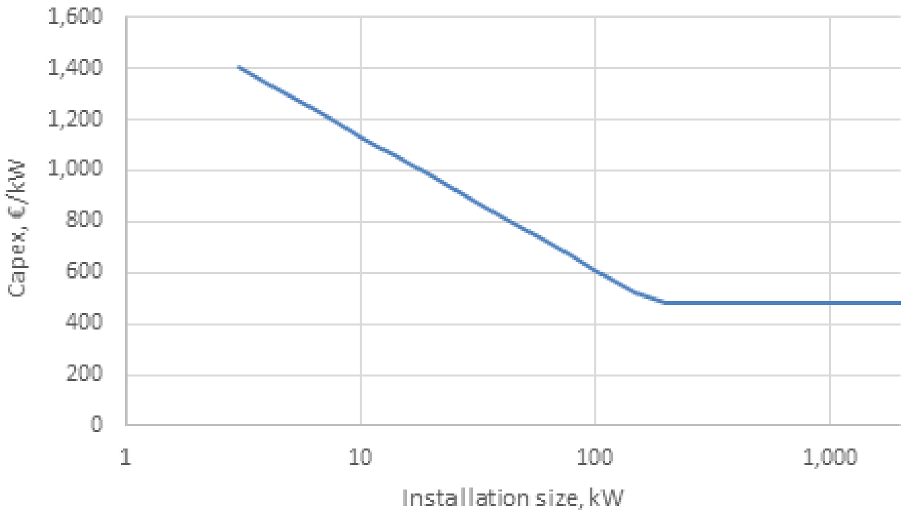


Table 6-14: ASHP cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Thermal Efficiency
3	1408	32	350%
30	885	6	350%
100	612	3	350%
300	479	3	350%
1000	479	3	350%

Table 6-15: ASHP load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	35%
Commercial	Space heating and hot water	35%
Industry	Space heating and hot water	35%
Industry	Low temperature process heat	82%

Water-source heat pump

Water-source heat pumps extract heat from a body of water, such as a river, lake or sea, using a refrigeration cycle to move the heat from the cooler side (the water body) to the warmer side (the building). Water-source heat pumps can be used to provide both space heating and hot water.

Table 6-16: WSHP cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€1786/kW for >300 kW to €2777/kW for 3 kW (varies by size, see below)
	Operating cost	€56/kW/yr
	Relevant additional and hidden costs (where applied)	• Heat metering • Retrofit of emitters (not for new builds) • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	3 kW to 10 MW
	Load factor	35-82% (varies by sector and end-use, see below)
	Efficiency	500%
	Lifetime	25 years
Suitability	Suitable heat uses	Space and hot water, 35% of low temperature process
	Suitable locations	All locations potentially suitable
	Space requirements	Need space to extract water (either water body or groundwater)
	Suitable building thermal efficiency	Not suitable for BER rating E2-G

Figure 6-5: WSHP capital cost including installation but excluding additional and hidden costs

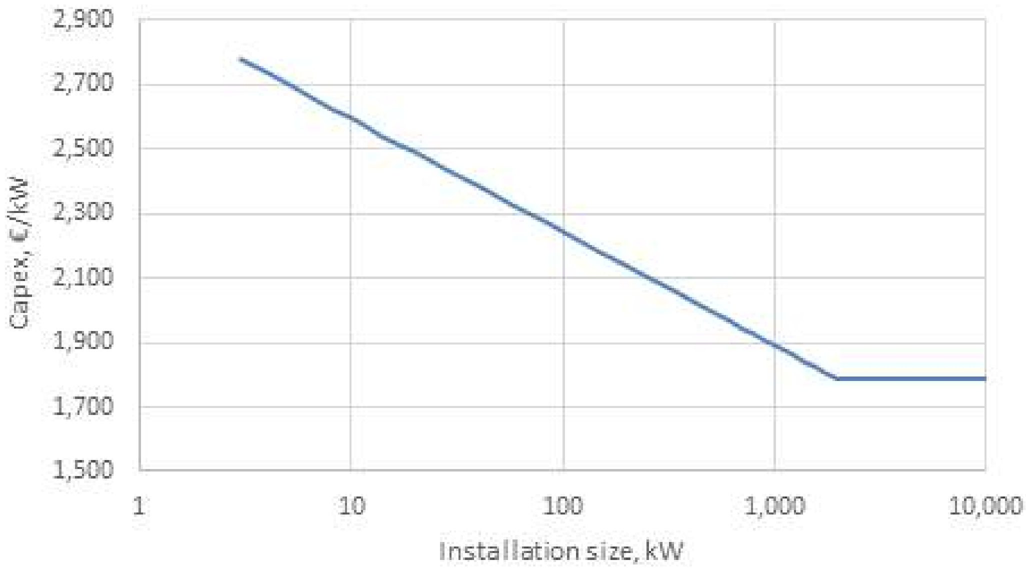


Table 6-17: WSHP cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Thermal Efficiency
3	2777	56	500%
30	2426	56	500%
100	2242	56	500%
300	2075	56	500%
1000	1891	56	500%
3000	1786	56	500%
10000	1786	56	500%

Table 6-18: WSHP load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	35%
Commercial	Space heating and hot water	35%
Industry	Space heating and hot water	35%
Industry	Low temperature process heat	82%

Deep geothermal

In deep geothermal, water is pumped down into hot rocks where it is heated before being brought back to the surface. The temperatures obtained can be high enough that a heat pump is not required to reach temperatures compatible with space heating and hot water.

Table 6-19: Deep geothermal cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€2890/kW for >200 kW
	Operating cost	€11/kW/yr
	Relevant additional and hidden costs (where applied)	• Heat metering • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	200 kW and larger
	Load factor	70%
	Efficiency	1100%
	Lifetime	25 years
Suitability	Suitable heat uses	Space and hot water
	Suitable locations	All locations potentially suitable
	Space requirements	Need ground space
	Suitable building thermal efficiency	Suitable for all buildings

Figure 6-6: Deep geothermal capital cost including installation but excluding additional and hidden costs

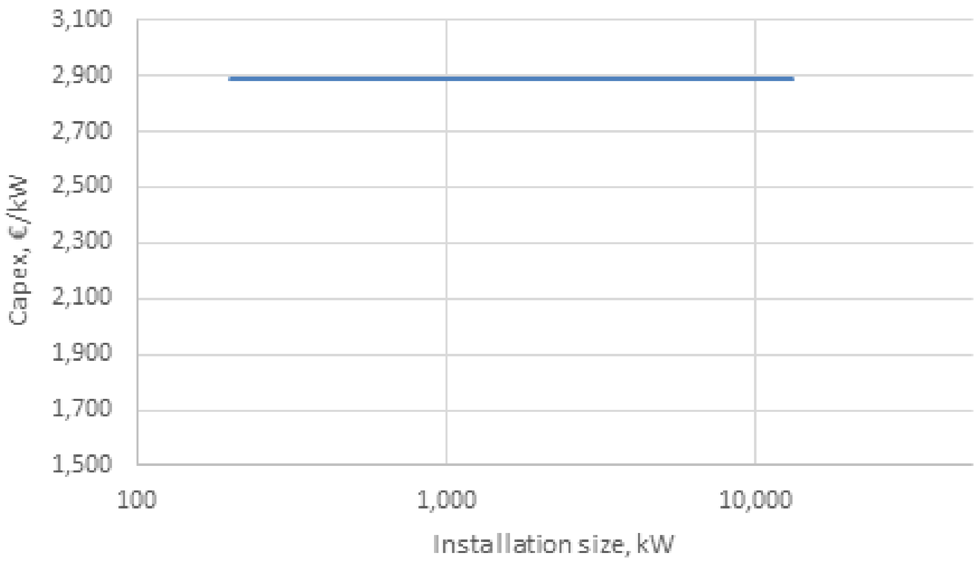


Table 6-20: Deep geothermal cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Thermal Efficiency
>200	2890	11	1100%

Table 6-21: Deep geothermal load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	70%
Commercial	Space heating and hot water	70%
Industry	Space heating and hot water	70%

Solar thermal

Solar thermal systems use heat from the sun's radiation to produce warm or hot water, which can be used for both space heating and hot water. A conventional boiler or immersion heater can be used to increase the temperature of the water if required.

Table 6-22: Solar thermal cost, performance and suitability assumptions

Category	Item	Assumption
Cost	Capital cost	€549/kW for 1 MW to €1464/kW for 3 kW (varies by size, see below)
	Operating cost	€8/kW/yr
	Relevant additional and hidden costs (where applied)	• Heat metering • Admin costs • Energy audit • Decommissioning the counterfactual
Technical parameters	Typical size	3 kW to 1MW
	Load factor	6%
	Efficiency	100%
	Lifetime	25 years
Suitability	Suitable heat uses	Space and hot water
	Suitable locations	All locations potentially suitable
	Space requirements	Need roof space – suitable orientation
	Suitable building thermal efficiency	Suitable for all buildings

Figure 6-7: Solar thermal capital cost including installation but excluding additional and hidden costs

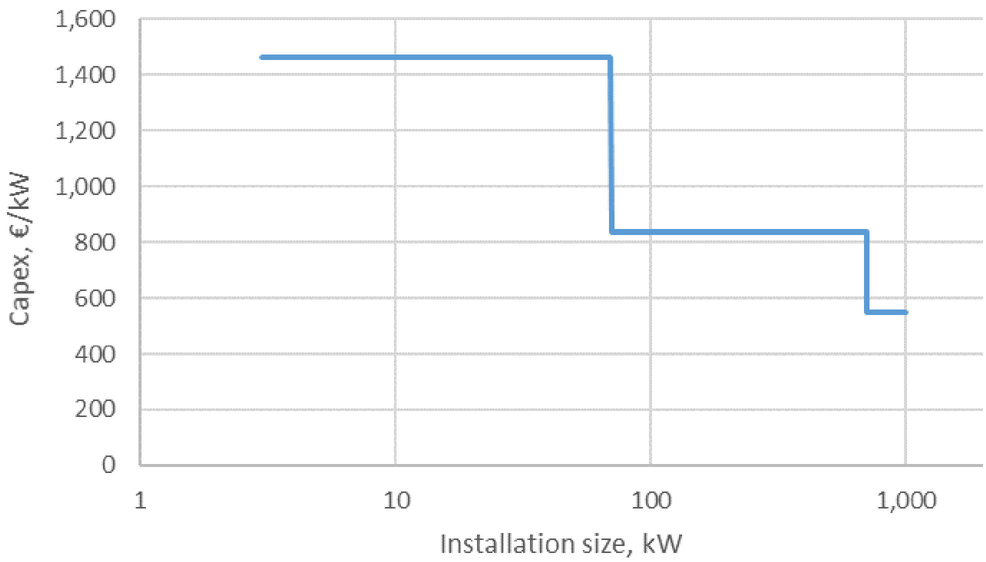


Table 6-23: Solar thermal cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Thermal Efficiency
3	1464	8	100%
10	1464	8	100%
30	1464	8	100%
100	839	8	100%
300	839	8	100%
1000	549	8	100%

Table 6-24: Solar thermal load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	6%
Commercial	Space heating and hot water	6%
Industry	Space heating and hot water	6%

Counterfactual technologies

Table 6-25: Gas boiler cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Efficiency
7	215	6.5	90%
30	182	5.5	90%
100	155	4.7	90%
300	130	3.9	90%
1000	103	3.1	90%
3000	78	2.3	90%

Table 6-26: Oil boiler cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Efficiency
7	128	3.8	80%
30	117	3.5	80%
100	107	3.2	80%
300	98	2.9	80%
1000	89	2.7	80%
3000	80	2.4	80%

Table 6-27: Electric heating cost and performance

Size, kW	Capex, €/kW	Opex, €/kW	Efficiency
7	374	1	100%
30	334	1	100%
100	301	1	100%
300	271	1	100%
1000	238	1	100%
3000	208	1	100%

Table 6-28: Counterfactual load factor

Sector	Heat use	Load factor
Public	Space heating and hot water	20%
Commercial	Space heating and hot water	20%
Industry	Space heating and hot water	20%
Industry	Low temperature process heat	82%

Appendix 1b: Fuel costs

Table 6-29: Fuel price assumptions (fossil fuels)

Year	Fuel price, €/kWh					
	Gas				Solid	Oil
	Up to 278 MWh/yr	278–2,778 MWh/yr	2,778–27,778 MWh/yr	More than 27,778 MWh/yr		
2016	0.063	0.048	0.041	0.033	0.016	0.051
2017	0.064	0.048	0.041	0.033	0.016	0.053
2018	0.064	0.048	0.042	0.033	0.017	0.054
2019	0.065	0.049	0.042	0.033	0.017	0.056
2020	0.068	0.051	0.044	0.035	0.017	0.060
2021	0.072	0.054	0.046	0.037	0.018	0.065
2022	0.076	0.057	0.048	0.038	0.018	0.069
2023	0.079	0.059	0.051	0.040	0.019	0.074
2024	0.083	0.062	0.053	0.042	0.020	0.079
2025	0.087	0.065	0.056	0.044	0.021	0.084
2026	0.089	0.067	0.058	0.046	0.022	0.084
2027	0.090	0.068	0.058	0.046	0.023	0.085
2028	0.090	0.068	0.059	0.047	0.024	0.086
2029	0.091	0.069	0.059	0.047	0.025	0.086
2030	0.091	0.069	0.060	0.048	0.026	0.087
2031	0.092	0.070	0.060	0.048	0.026	0.087
2032	0.092	0.070	0.060	0.049	0.027	0.088
2033	0.093	0.070	0.061	0.049	0.028	0.088
2034	0.093	0.071	0.061	0.049	0.028	0.089
2035	0.093	0.071	0.062	0.050	0.029	0.089
2036	0.093	0.071	0.062	0.050	0.029	0.089
2037	0.093	0.071	0.062	0.050	0.029	0.089
2038	0.093	0.071	0.062	0.050	0.029	0.089
2039	0.093	0.071	0.062	0.050	0.029	0.089
2040	0.093	0.071	0.062	0.050	0.029	0.089
2041	0.093	0.071	0.062	0.050	0.029	0.089
2042	0.093	0.071	0.062	0.050	0.029	0.089
2043	0.093	0.071	0.062	0.050	0.029	0.089
2044	0.093	0.071	0.062	0.050	0.029	0.089
2045	0.093	0.071	0.062	0.050	0.029	0.089
2046	0.093	0.071	0.062	0.050	0.029	0.089
2047	0.093	0.071	0.062	0.050	0.029	0.089
2048	0.093	0.071	0.062	0.050	0.029	0.089
2049	0.093	0.071	0.062	0.050	0.029	0.089
2050	0.093	0.071	0.062	0.050	0.029	0.089

Table 6-30: Fuel price assumptions (electricity)

Year	Fuel price, €/kWh								
	Electricity purchase price							Electricity export price	
	Up to 20 MWh/yr	20–500 MWh/yr	500–2,000 MWh/yr	2,000-20,000 MWh/yr	20,000–70,000 MWh/yr	More than 70,000 MWh/yr	Night rate	Grid export	Renewable Electricity Support Scheme
2016	0.227	0.182	0.148	0.119	0.102	0.092	0.072	0.054	0.140
2017	0.232	0.185	0.152	0.121	0.104	0.095	0.074	0.055	0.140
2018	0.234	0.187	0.153	0.123	0.106	0.096	0.075	0.055	0.141
2019	0.236	0.189	0.155	0.124	0.107	0.097	0.076	0.056	0.141
2020	0.250	0.200	0.164	0.132	0.114	0.103	0.081	0.059	0.150
2021	0.264	0.212	0.174	0.139	0.120	0.109	0.086	0.062	0.158
2022	0.279	0.223	0.183	0.147	0.127	0.115	0.091	0.065	0.166
2023	0.293	0.234	0.192	0.155	0.134	0.121	0.096	0.069	0.175
2024	0.307	0.246	0.202	0.162	0.140	0.127	0.101	0.072	0.183
2025	0.321	0.257	0.211	0.170	0.147	0.133	0.106	0.075	0.191
2026	0.329	0.263	0.217	0.174	0.151	0.137	0.109	0.077	0.195
2027	0.330	0.265	0.218	0.175	0.152	0.138	0.110	0.077	0.195
2028	0.331	0.266	0.219	0.177	0.153	0.139	0.111	0.077	0.195
2029	0.333	0.268	0.221	0.178	0.154	0.141	0.112	0.077	0.196
2030	0.334	0.268	0.221	0.179	0.155	0.142	0.113	0.077	0.196
2031	0.334	0.269	0.222	0.180	0.156	0.142	0.114	0.077	0.196
2032	0.335	0.270	0.223	0.181	0.157	0.143	0.115	0.077	0.196
2033	0.336	0.271	0.224	0.182	0.158	0.144	0.116	0.077	0.196
2034	0.337	0.272	0.225	0.182	0.159	0.145	0.117	0.077	0.196
2035	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2036	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2037	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2038	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2039	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2040	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2041	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2042	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2043	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2044	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2045	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2046	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2047	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2048	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2049	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196
2050	0.338	0.273	0.225	0.183	0.160	0.146	0.117	0.077	0.196

7 Appendix 2: Detailed tariffs and results by Scenario

Scenario 1 – All central design options, Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price

Tariffs

Table 7-1: Tariffs for Scenario 1

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	13.17
	2	>10	≤30	8.59
	3	>30	≤100	6.06
	4	>100	≤300	5.27
	5	>300	≤1,000	3.32
	6	>1,000	≤3,000	0.52
	7	>3,000	≤10,000	0.42
	8	≥10,000	N/A	0.00
Biomass CHP	1	N/A	N/A	5.98
Biomass Direct Air	1	N/A	≤300	4.84
	2	>300	≤1,000	4.49
	3	>1,000	≤3,000	4.22
	4	>3,000	≤10,000	0.76
	5	≥10,000	N/A	0.00
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	10.64
	4	>100	≤300	10.64
	5	>300	N/A	10.50
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	22.66
	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-1: Total heat demand met by RH technologies in 2020 in Scenario 1

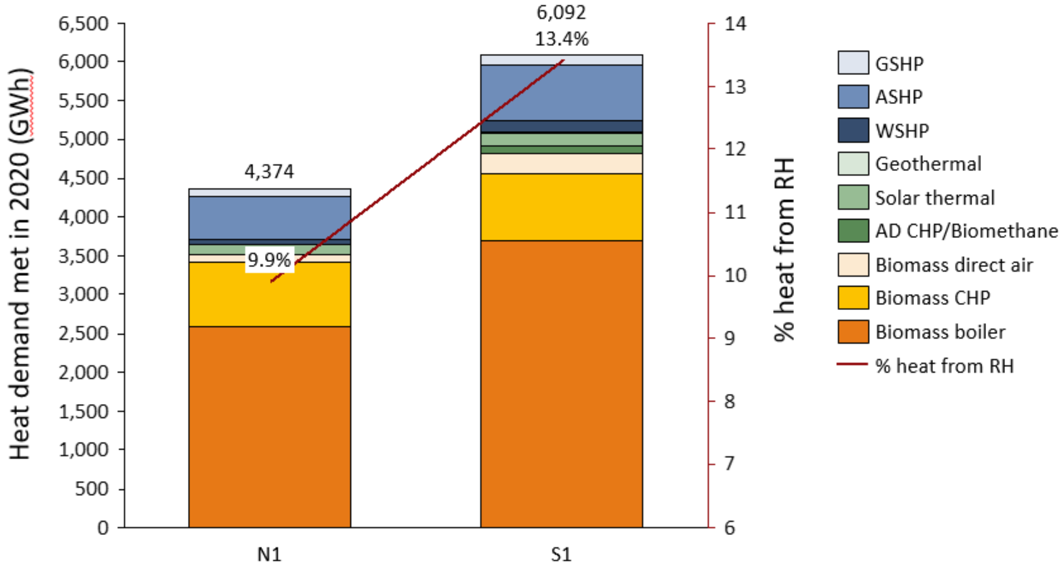


Table 7-2: Total heat demand met by RH technologies in 2020 in Scenario 1

GWh	2015	2020 Scenario N1	2020 Scenario 1
GSHP	99	103	132
ASHP	530	563	718
WSHP	50	51	155
Deep geothermal	0	5	15
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	105	267
Biomass CHP	84	827	868
Biomass boiler	2048	2580	3689
Total	**2951**	**4374**	**6092**
% heat from RH	**6.6%**	**9.9%**	**13.4%**

Figure 7-2: Annual RHI payments made in Scenario 1

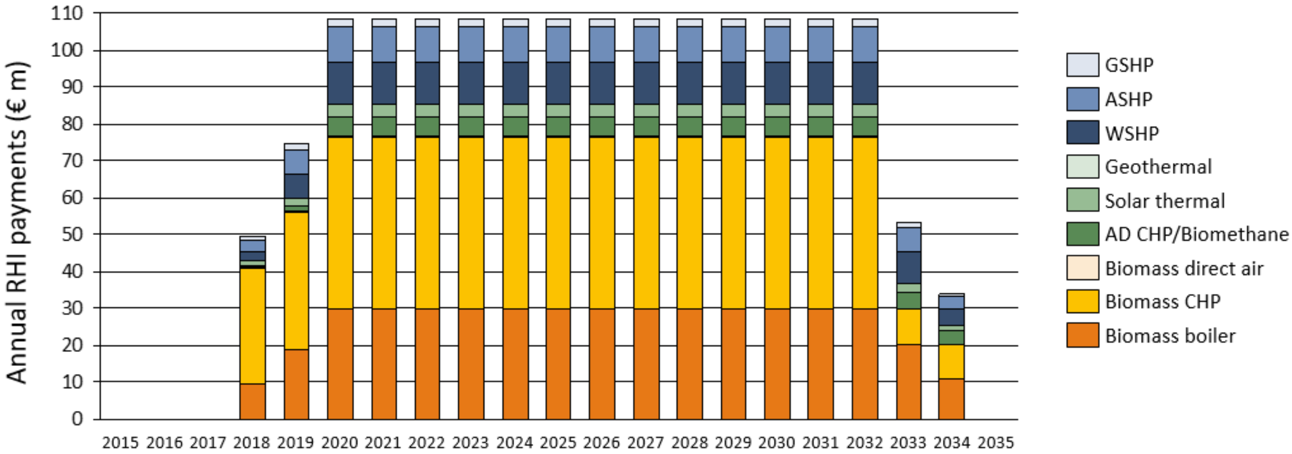


Table 7-3: Annual RHI payments made in Scenario 1

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.7	1.4	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ASHP	3.2	6.5	9.9	9.9	9.9	9.9	9.9	9.9	9.9
WSHP	2.5	6.5	11.2	11.2	11.2	11.2	11.2	11.2	11.2
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Biomass CHP	31.4	37.3	46.5	46.5	46.5	46.5	46.5	46.5	46.5
Biomass boiler	9.5	18.8	29.8	29.8	29.8	29.8	29.8	29.8	29.8
Total	**49.4**	**74.4**	**108.5**	**108.5**	**108.5**	**108.5**	**108.5**	**108.5**	**108.5**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.2	2.2	2.2	2.2	2.2	2.2	1.4	0.7	0.0
ASHP	9.9	9.9	9.9	9.9	9.9	9.9	6.7	3.4	0.0
WSHP	11.2	11.2	11.2	11.2	11.2	11.2	8.7	4.7	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.1	0.0
Biomass CHP	46.5	46.5	46.5	46.5	46.5	46.5	9.4	9.2	0.0
Biomass boiler	29.8	29.8	29.8	29.8	29.8	29.8	20.3	10.9	0.0
Total	**108.5**	**108.5**	**108.5**	**108.5**	**108.5**	**108.5**	**53.4**	**34.1**	**0.0**

Table 7-4: Cumulative RHI payments made in Scenario 1

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	7	9	11	13	15	17
ASHP	3	10	20	29	39	49	59	69	79
WSHP	3	9	20	31	43	54	65	76	87
Deep geothermal	0	0	0	0	0	0	0	0	1
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	0	1	1	2	2	2	3	3
Biomass CHP	31	69	115	162	208	255	301	348	394
Biomass boiler	10	28	58	88	118	147	177	207	237
Total	**49**	**124**	**232**	**341**	**449**	**558**	**666**	**775**	**883**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	19	22	24	26	28	30	32	32	32
ASHP	89	99	109	119	128	138	145	149	149
WSHP	99	110	121	132	143	155	163	168	168
Deep geothermal	1	1	1	1	1	1	1	1	1
Solar thermal	30	33	37	40	43	47	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	4	4	4	5	5	6	6	6	6
Biomass CHP	441	488	534	581	627	674	683	692	692
Biomass boiler	266	296	326	356	386	415	436	446	446
Total	**992**	**1,101**	**1,209**	**1,318**	**1,426**	**1,535**	**1,588**	**1,622**	**1,622**

Table 7-5: Number of new installations 2016-2020 by technology and sector in Scenario 1 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2070	69	685	0	**2824**
Biomass CHP	10	0	2	0	**12**
Biomass direct air	0	0	66	0	**66**
ASHP	2573	168	103	0	**2844**
GSHP	295	0	25	0	**320**
WSHP	277	49	12	0	**338**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1393**
AD CHP/ Biomethane	0	0	0	19	**19**
Total	**6545**	**360**	**892**	**19**	**7817**

Figure 7-3: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 1

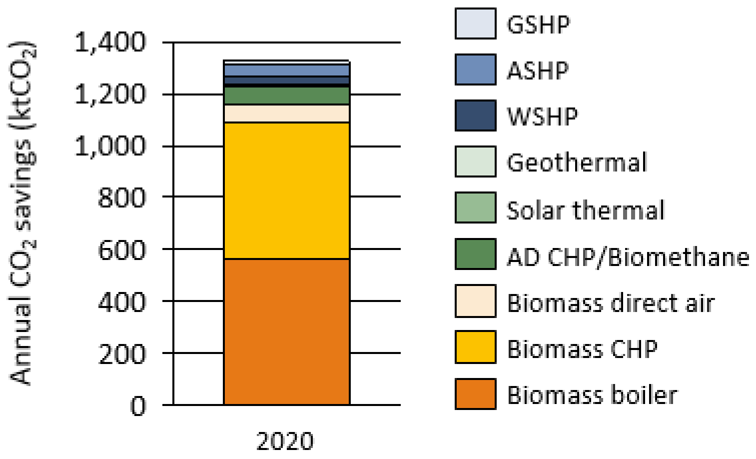
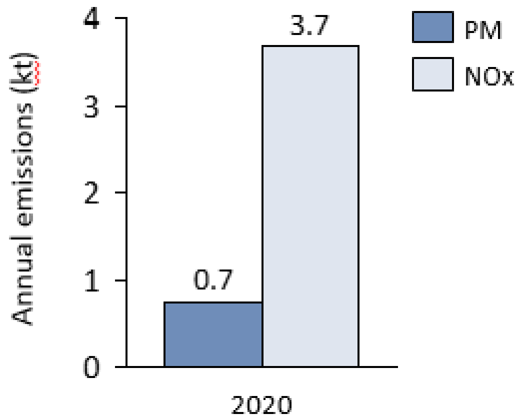


Table 7-6: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 1

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	11.7
ASHP	52.2
WSHP	26.2
Deep geothermal	5.3
Solar thermal	6.7
AD CHP/ Biomethane	67.3
Biomass direct air	72.8
Biomass CHP	524.5
Biomass boiler	561.6
Total	**1328.4**

Table 7-7: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 1



Scenario 2 – All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price

Tariffs

Table 7-8: Tariffs for Scenario 2

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	16.15
	2	>10	≤30	11.57
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Biomass CHP	1	N/A	N/A	9.61
Biomass Direct Air	1	N/A	≤300	7.03
	2	>300	≤1,000	6.67
	3	>1,000	≤3,000	6.41
	4	>3,000	≤10,000	2.59
	5	≥10,000	N/A	0.99
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	10.64
	4	>100	≤300	10.64
	5	>300	N/A	10.50
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	22.66
	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-4: Total heat demand met by RH technologies in 2020 in Scenario 2

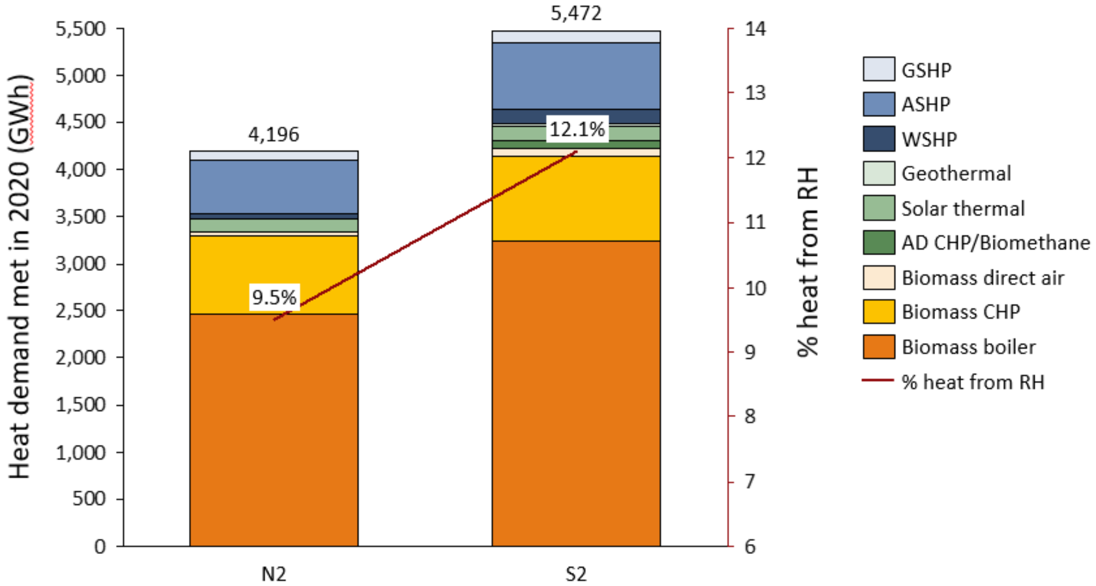


Table 7-9: Total heat demand met by RH technologies in 2020 in Scenario 2

GWh	2015	2020 Scenario N2	2020 Scenario 2
GSHP	99	103	131
ASHP	530	563	709
WSHP	50	51	152
Deep geothermal	0	7	18
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	84
Biomass CHP	84	827	892
Biomass boiler	2048	2467	3236
Total	**2951**	**4196**	**5472**
% heat from RH	**6.6%**	**9.5%**	**12.1%**

Figure 7-5: Annual RHI payments made in Scenario 2

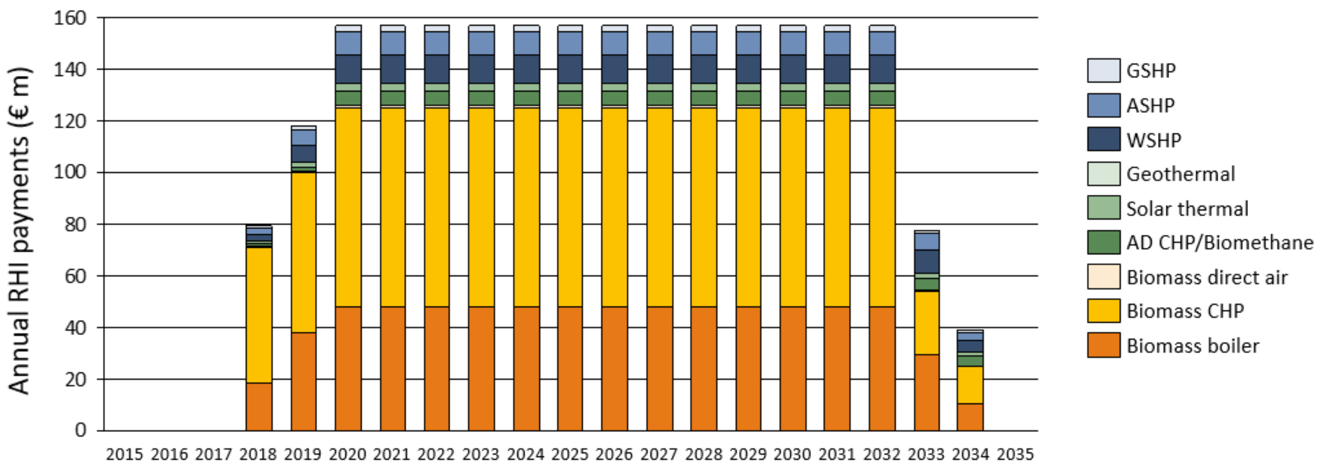


Table 7-10: Annual RHI payments made in Scenario 2

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.7	1.4	2.1	2.1	2.1	2.1	2.1	2.1	2.1
ASHP	2.9	6.1	9.4	9.4	9.4	9.4	9.4	9.4	9.4
WSHP	2.3	6.3	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.2	0.4	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Biomass CHP	52.5	62.2	77.1	77.1	77.1	77.1	77.1	77.1	77.1
Biomass boiler	18.8	38.1	48.3	48.3	48.3	48.3	48.3	48.3	48.3
Total	**79.4**	**118.1**	**157.0**	**157.0**	**157.0**	**157.0**	**157.0**	**157.0**	**157.0**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.1	2.1	2.1	2.1	2.1	2.1	1.4	0.7	0.0
ASHP	9.4	9.4	9.4	9.4	9.4	9.4	6.4	3.2	0.0
WSHP	10.9	10.9	10.9	10.9	10.9	10.9	8.6	4.7	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.2	0.0
Biomass CHP	77.1	77.1	77.1	77.1	77.1	77.1	24.7	14.9	0.0
Biomass boiler	48.3	48.3	48.3	48.3	48.3	48.3	29.5	10.2	0.0
Total	**157.0**	**157.0**	**157.0**	**157.0**	**157.0**	**157.0**	**77.7**	**39.0**	**0.0**

Table 7-11: Cumulative RHI payments made in Scenario 2

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	6	9	11	13	15	17
ASHP	3	9	18	28	37	46	56	65	75
WSHP	2	9	20	31	41	52	63	74	85
Deep geothermal	0	0	0	0	0	0	0	0	1
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	1	2	3	3	4	5	5
Biomass CHP	52	115	192	269	346	423	500	578	655
Biomass boiler	19	57	105	153	202	250	298	346	395
Total	**79**	**197**	**354**	**511**	**669**	**826**	**983**	**1,140**	**1,297**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	19	21	23	26	28	30	31	32	32
ASHP	84	93	103	112	121	131	137	140	140
WSHP	96	107	118	129	140	151	160	164	164
Deep geothermal	1	1	1	1	1	1	1	1	1
Solar thermal	30	33	37	40	43	46	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	6	7	7	8	9	9	10	10	10
Biomass CHP	732	809	886	963	1,040	1,118	1,142	1,157	1,157
Biomass boiler	443	491	539	588	636	684	714	724	724
Total	**1,454**	**1,611**	**1,768**	**1,925**	**2,082**	**2,239**	**2,316**	**2,355**	**2,355**

Table 7-12: Number of new installations 2016-2020 by technology and sector in Scenario 2 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2547	114	616	0	**3277**
Biomass CHP	16	0	3	0	**18**
Biomass direct air	0	0	41	0	**41**
ASHP	2422	161	94	0	**2677**
GSHP	294	0	24	0	**319**
WSHP	273	48	12	0	**333**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1393**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**6873**	**396**	**791**	**19**	**8079**

Figure 7-6: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 2

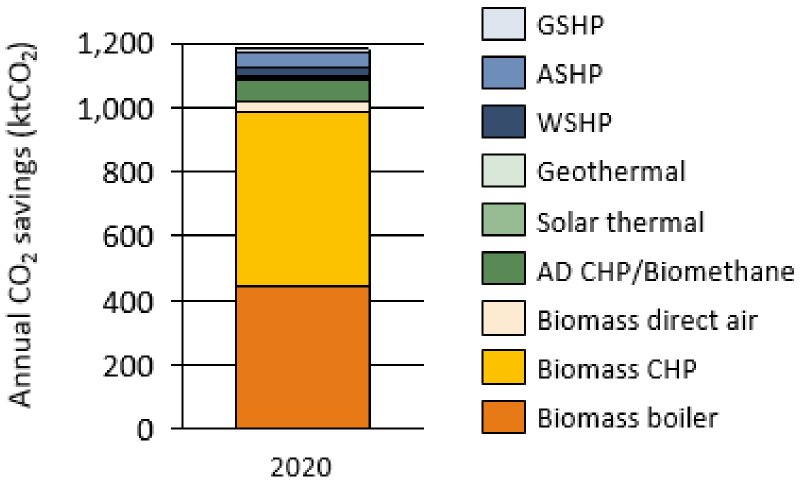
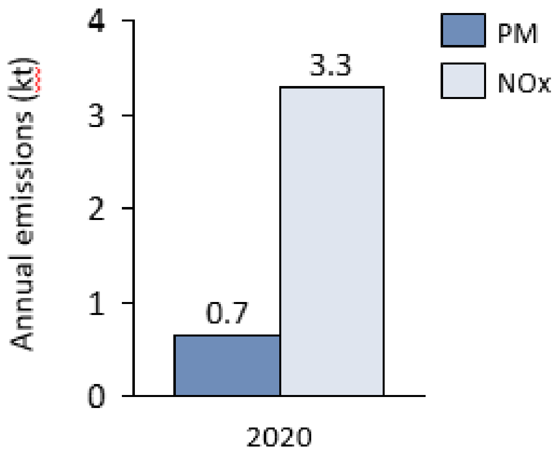


Table 7-13: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 2

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	11.6
ASHP	49.3
WSHP	25.7
Deep geothermal	6.4
Solar thermal	6.7
AD CHP/ biomethane	67.3
Biomass direct air	30.8
Biomass CHP	540.4
Biomass boiler	447.3
Total	**1185.4**

Table 7-14: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 2



Scenario 3 - All central design options, Limited imported biomass (5 TWh/yr), tariff based on 9 c/kWh biomass price

Tariffs

Table 7-15: Tariffs for Scenario 3

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	20.62
	2	>10	≤30	16.04
	3	>30	≤100	13.45
	4	>100	≤300	9.79
	5	>300	≤1,000	8.79
	6	>1,000	≤3,000	5.15
	7	>3,000	≤10,000	4.99
	8	≥10,000	N/A	4.33
Biomass CHP	1	N/A	N/A	15.06
Biomass Direct Air	1	N/A	≤300	10.31
	2	>300	≤1,000	9.95
	3	>1,000	≤3,000	9.69
	4	>3,000	≤10,000	5.33
	5	≥10,000	N/A	3.52
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	10.64
	4	>100	≤300	10.64
	5	>300	N/A	10.50
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	22.66
	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-7: Total heat demand met by RH technologies in 2020 in Scenario 3

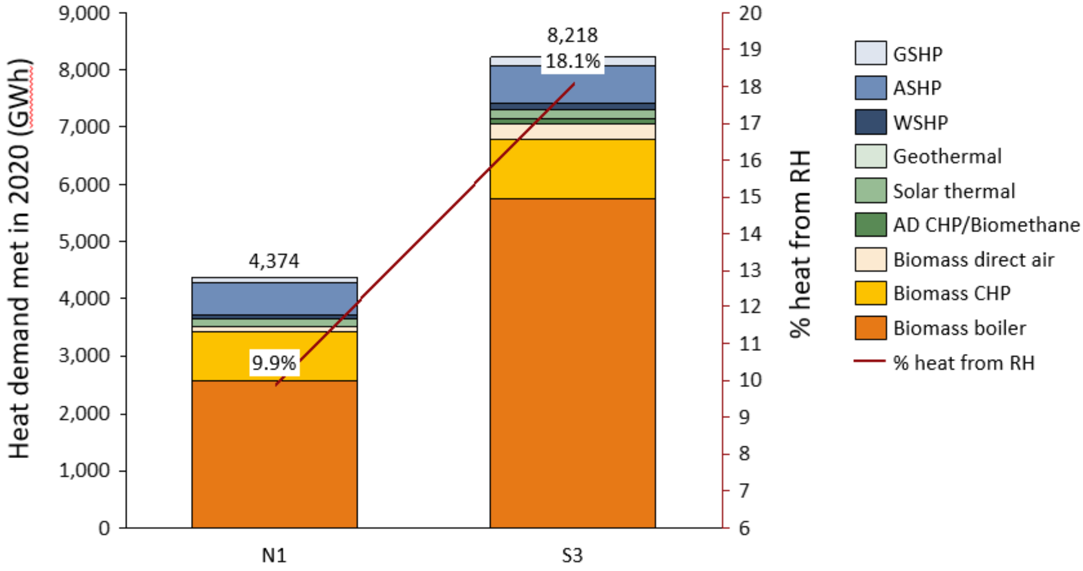


Table 7-16: Total heat demand met by RH technologies in 2020 in Scenario 3

GWh	2015	2020 Scenario N1	2020 Scenario 3
GSHP	99	103	130
ASHP	530	563	667
WSHP	50	51	115
Deep geothermal	0	5	13
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	105	240
Biomass CHP	84	827	1037
Biomass boiler	2048	2580	5766
Total	**2951**	**4374**	**8218**
% heat from RH	**6.6%**	**9.9%**	**18.1%**

Figure 7-8: Annual RHI payments made in Scenario 3

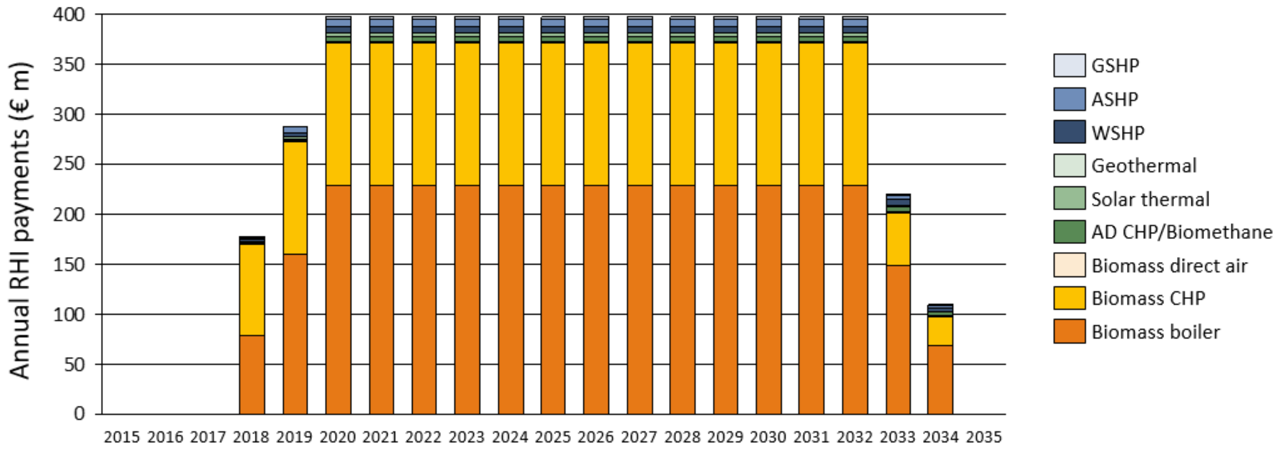


Table 7-17: Annual RHI payments made in Scenario 3

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.7	1.4	2.1	2.1	2.1	2.1	2.1	2.1	2.1
ASHP	2.5	4.8	7.3	7.3	7.3	7.3	7.3	7.3	7.3
WSHP	2.0	4.3	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.4	0.8	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Biomass CHP	90.1	113.1	142.9	142.9	142.9	142.9	142.9	142.9	142.9
Biomass boiler	79.6	160.4	228.6	228.6	228.6	228.6	228.6	228.6	228.6
Total	**177.3**	**288.3**	**397.6**	**397.6**	**397.6**	**397.6**	**397.6**	**397.6**	**397.6**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.1	2.1	2.1	2.1	2.1	2.1	1.3	0.7	0.0
ASHP	7.3	7.3	7.3	7.3	7.3	7.3	4.9	2.5	0.0
WSHP	7.0	7.0	7.0	7.0	7.0	7.0	5.0	2.7	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	1.2	1.2	1.2	1.2	1.2	1.2	0.8	0.4	0.0
Biomass CHP	142.9	142.9	142.9	142.9	142.9	142.9	52.7	29.8	0.0
Biomass boiler	228.6	228.6	228.6	228.6	228.6	228.6	149.0	68.3	0.0
Total	**397.6**	**397.6**	**397.6**	**397.6**	**397.6**	**397.6**	**220.3**	**109.3**	**0.0**

Table 7-18: Cumulative RHI payments made in Scenario 3

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	6	8	10	12	14	17
ASHP	2	7	15	22	29	37	44	51	58
WSHP	2	6	13	20	27	34	41	48	55
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	2	4	5	6	7	8	9
Biomass CHP	90	203	346	489	632	775	918	1,060	1,203
Biomass boiler	80	240	469	697	926	1,155	1,383	1,612	1,841
Total	**177**	**466**	**863**	**1,261**	**1,658**	**2,056**	**2,454**	**2,851**	**3,249**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	19	21	23	25	27	29	30	31	31
ASHP	66	73	80	88	95	102	107	110	110
WSHP	62	69	76	83	90	97	102	105	105
Deep geothermal	0	1	1	1	1	1	1	1	1
Solar thermal	30	33	37	40	43	46	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	11	12	13	14	15	16	17	18	18
Biomass CHP	1,346	1,489	1,632	1,775	1,918	2,061	2,113	2,143	2,143
Biomass boiler	2,069	2,298	2,526	2,755	2,984	3,212	3,361	3,430	3,430
Total	**3,646**	**4,044**	**4,442**	**4,839**	**5,237**	**5,635**	**5,855**	**5,964**	**5,964**

Table 7-19: Number of new installations 2016-2020 by technology and sector in Scenario 3 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	4982	716	1234	0	**6932**
Biomass CHP	86	65	5	0	**156**
Biomass direct air	0	0	60	0	**60**
ASHP	2167	93	80	0	**2340**
GSHP	292	0	24	0	**316**
WSHP	273	35	11	0	**318**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1392**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**9120**	**981**	**1414**	**19**	**11535**

Figure 7-9: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 3

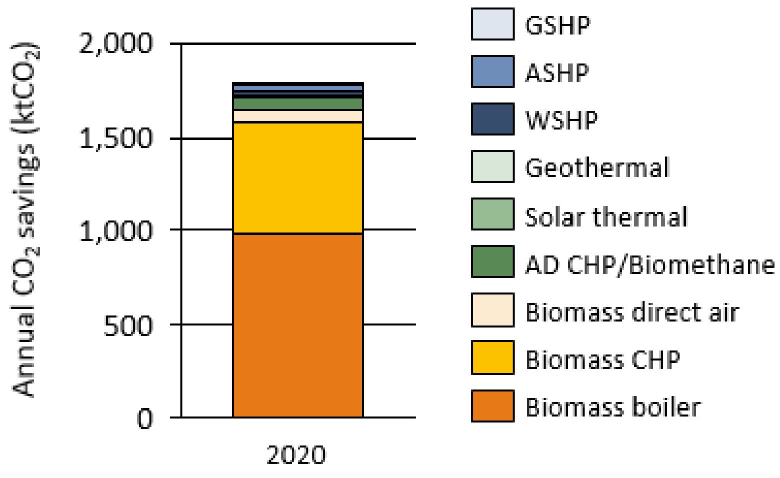
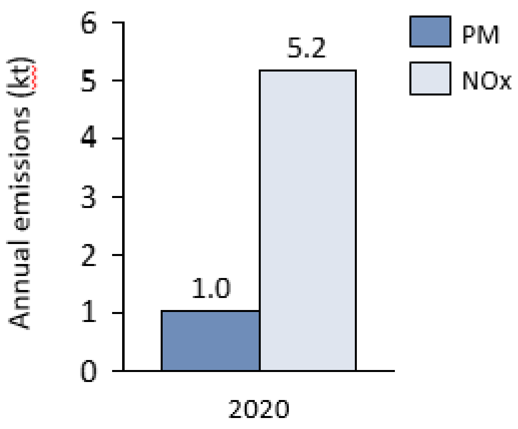


Table 7-20: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 3

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	11.1
ASHP	40.0
WSHP	17.4
Deep geothermal	4.9
Solar thermal	6.7
AD CHP/ biomethane	67.3
Biomass direct air	65.6
Biomass CHP	598.9
Biomass boiler	980.1
Total	**1792.0**

Table 7-21: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 3



Scenario 4 - All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 9 c/kWh biomass price

Tariffs

Table 7-22: Tariffs for Scenario 4

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	20.62
	2	>10	≤30	16.04
	3	>30	≤100	13.45
	4	>100	≤300	9.79
	5	>300	≤1,000	8.79
	6	>1,000	≤3,000	5.15
	7	>3,000	≤10,000	4.99
	8	≥10,000	N/A	4.33
Biomass CHP	1	N/A	N/A	15.06
Biomass Direct Air	1	N/A	≤300	10.31
	2	>300	≤1,000	9.95
	3	>1,000	≤3,000	9.69
	4	>3,000	≤10,000	5.33
	5	≥10,000	N/A	3.52
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	10.64
	4	>100	≤300	10.64
	5	>300	N/A	10.50
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	22.66
	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-10: Total heat demand met by RH technologies in 2020 in Scenario 4

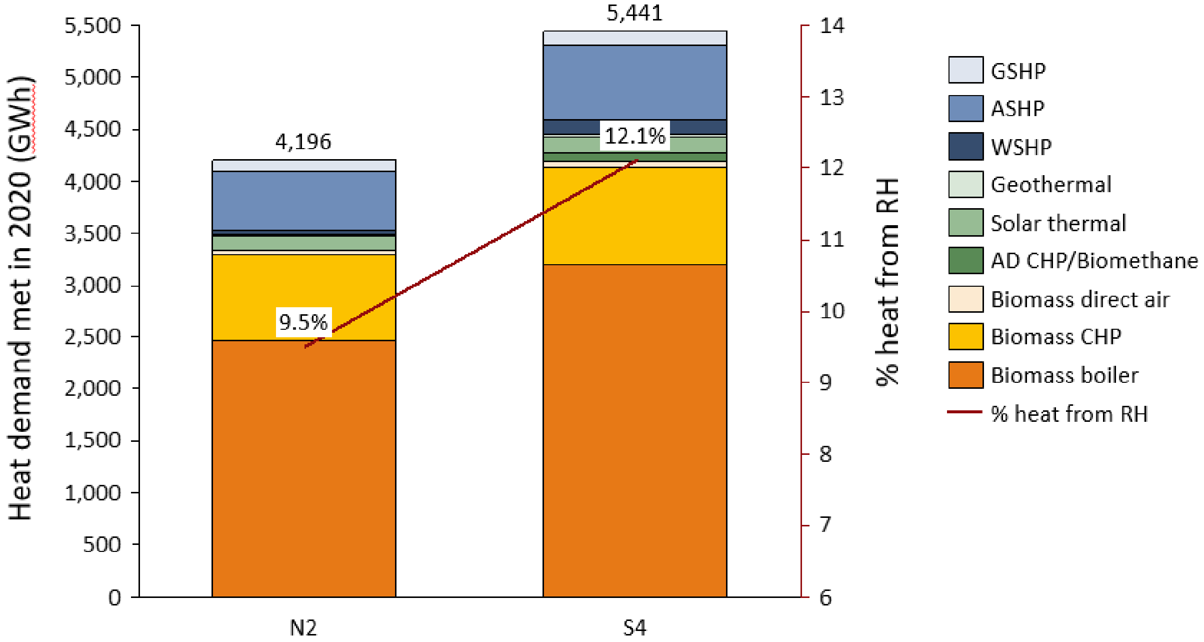


Table 7-23: Total heat demand met by RH technologies in 2020 in Scenario 4

GWh	2015	2020 Scenario N2	2020 Scenario 4
GSHP	99	103	135
ASHP	530	563	710
WSHP	50	51	143
Deep geothermal	0	7	22
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	51
Biomass CHP	84	827	933
Biomass boiler	2048	2467	3198
Total	**2951**	**4196**	**5441**
% heat from RH	**6.6%**	**9.5%**	**12.1%**

Figure 7-11: Annual RHI payments made in Scenario 4

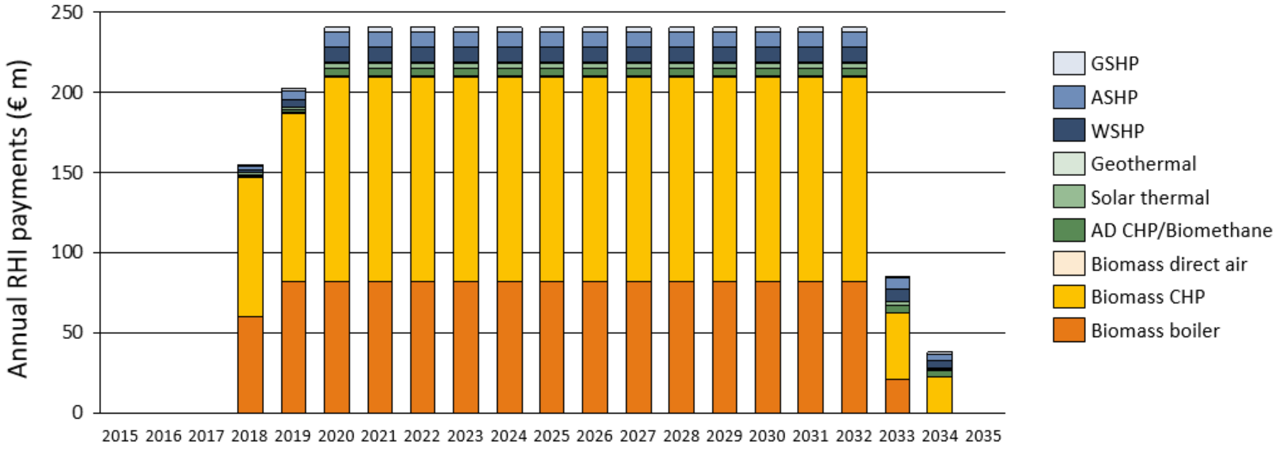


Table 7-24: Annual RHI payments made in Scenario 4

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.7	1.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
ASHP	2.6	5.2	9.5	9.5	9.5	9.5	9.5	9.5	9.5
WSHP	2.1	4.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.4	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Biomass CHP	86.5	104.9	127.3	127.3	127.3	127.3	127.3	127.3	127.3
Biomass boiler	60.6	81.9	81.9	81.9	81.9	81.9	81.9	81.9	81.9
Total	**154.8**	**202.5**	**240.4**	**240.4**	**240.4**	**240.4**	**240.4**	**240.4**	**240.4**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.4	2.4	2.4	2.4	2.4	2.4	1.6	1.0	0.0
ASHP	9.5	9.5	9.5	9.5	9.5	9.5	6.9	4.3	0.0
WSHP	10.0	10.0	10.0	10.0	10.0	10.0	7.9	5.1	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.8	0.8	0.8	0.8	0.8	0.8	0.4	0.0	0.0
Biomass CHP	127.3	127.3	127.3	127.3	127.3	127.3	40.8	22.4	0.0
Biomass boiler	81.9	81.9	81.9	81.9	81.9	81.9	21.2	0.0	0.0
Total	**240.4**	**240.4**	**240.4**	**240.4**	**240.4**	**240.4**	**85.5**	**37.9**	**0.0**

Table 7-25: Cumulative RHI payments made in Scenario 4

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	7	9	12	14	16	19
ASHP	3	8	17	27	36	46	55	65	74
WSHP	2	7	17	27	37	47	57	67	77
Deep geothermal	0	0	0	0	0	0	0	1	1
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	2	3	4	4	5	6	7
Biomass CHP	87	191	319	446	573	701	828	955	1,082
Biomass boiler	61	142	224	306	388	470	552	634	716
Total	**155**	**357**	**598**	**838**	**1,078**	**1,319**	**1,559**	**1,800**	**2,040**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	21	23	26	28	31	33	35	36	36
ASHP	84	94	103	113	122	132	139	143	143
WSHP	87	96	106	116	126	136	144	149	149
Deep geothermal	1	1	1	1	1	1	1	1	1
Solar thermal	30	33	37	40	43	47	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	7	8	9	10	11	11	12	12	12
Biomass CHP	1,210	1,337	1,464	1,592	1,719	1,846	1,887	1,909	1,909
Biomass boiler	797	879	961	1,043	1,125	1,207	1,228	1,228	1,228
Total	**2,280**	**2,521**	**2,761**	**3,001**	**3,242**	**3,482**	**3,568**	**3,606**	**3,606**

Table 7-26: Number of new installations 2016-2020 by technology and sector in Scenario 4 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2697	306	589	0	**3592**
Biomass CHP	28	17	3	0	**48**
Biomass direct air	0	0	27	0	**27**
ASHP	2681	135	106	0	**2922**
GSHP	322	0	29	0	**351**
WSHP	303	42	13	0	**358**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1323	73	0	0	**1396**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**7354**	**573**	**768**	**19**	**8715**

Figure 7-12: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 4

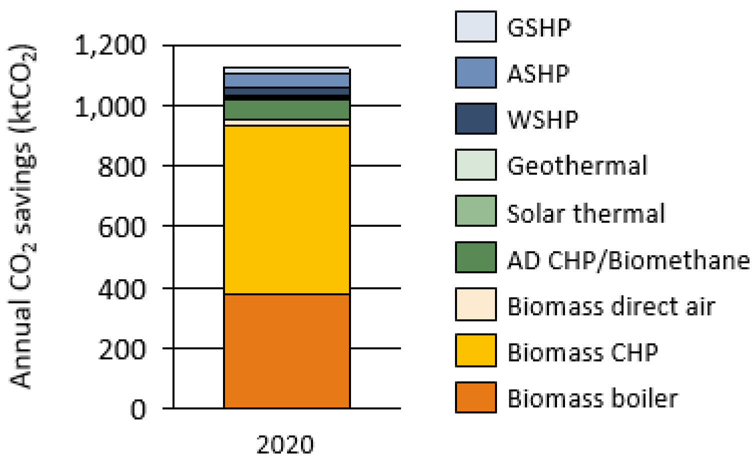
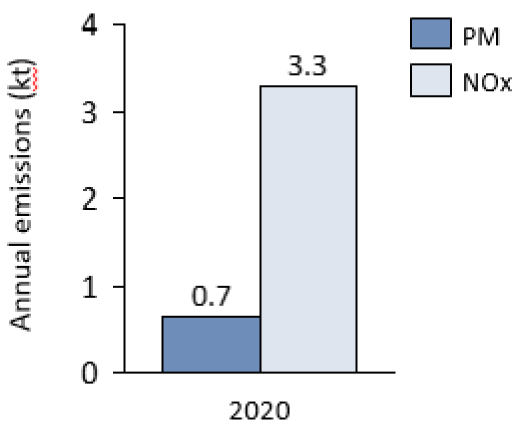


Table 7-27: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 4

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	12.9
ASHP	51.1
WSHP	24.3
Deep geothermal	7.7
Solar thermal	6.7
AD CHP/ biomethane	67.3
Biomass direct air	18.7
Biomass CHP	559.5
Biomass boiler	375.0
Total	**1123.3**

Table 7-28: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 4



Scenario 5 - Tariffs capped at biomass boiler tariffs

Tariffs

Table 7-29: Tariffs for Scenario 5

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	16.15
	2	>10	≤30	11.57
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Biomass CHP	1	N/A	≤10	9.61
	2	>10	≤30	9.61
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Biomass Direct Air	1	N/A	≤10	7.03
	2	>10	≤30	7.03
	3	>30	≤100	7.03
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	0.99
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	≤1,000	4.69
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	≤1,000	3.85
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
	1	N/A	≤10	1.39

Deep geothermal	2	>10	≤30	1.39
	3	>30	≤100	1.39
	4	>100	≤300	1.39
	5	>300	≤1,000	1.39
	6	>1,000	≤3,000	1.39
	7	>3,000	≤10,000	1.39
	8	≥10,000	N/A	1.39
Solar thermal	1	N/A	≤10	16.15
	2	>10	≤30	11.57
	3	>30	≤100	8.97
	4	>100	≤300	5.41
	5	>300	≤1,000	0.02
	6	>1,000	≤3,000	0.02
	7	>3,000	≤10,000	0.02
	8	≥10,000	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤10	3.16
	2	>10	≤30	3.16
	3	>30	≤100	3.16
	4	>100	≤300	3.16
	5	>300	≤1,000	3.16
	6	>1,000	≤2,400	2.37
	7	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤10	8.13
	2	>10	≤30	8.13
	3	>30	≤100	8.13
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤2,400	2.37
	7	>2,400	≤3,000	2.37
	8	>3,000	≤7,200	2.25
	9	>7,200	≤10,000	0.00
	10	>10,000	N/A	0.00
Biomethane grid injection	1	N/A	≤10	6.75
	2	>10	≤30	6.75
	3	>30	≤100	6.75
	4	>100	≤300	6.75
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	>10,000	≤30,000	1.67
	9	>30,000	≤60,000	1.67
	10	>60,000	N/A	0.00

Results

Figure 7-13: Total heat demand met by RH technologies in 2020 in Scenario 5

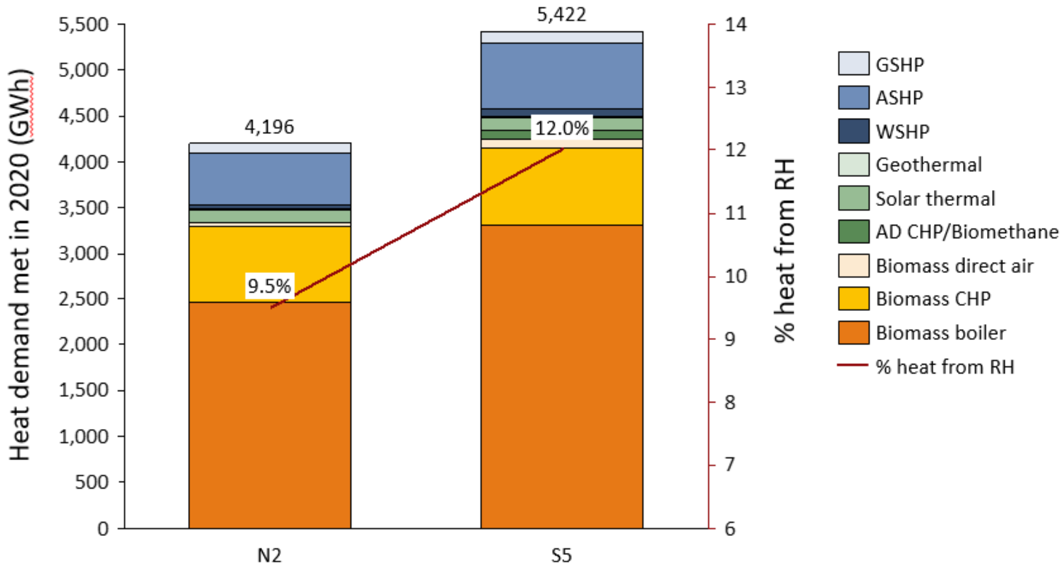


Table 7-30: Total heat demand met by RH technologies in 2020 in Scenario 5

GWh	2015	2020 Scenario N2	2020 Scenario 5
GSHP	99	103	133
ASHP	530	563	719
WSHP	50	51	69
Deep geothermal	0	7	24
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	85
Biomass CHP	84	827	848
Biomass boiler	2048	2467	3310
Total	**2951**	**4196**	**5422**
% heat from RH	**6.6%**	**9.5%**	**12.0%**

Figure 7-14: Annual RHI payments made in Scenario 5

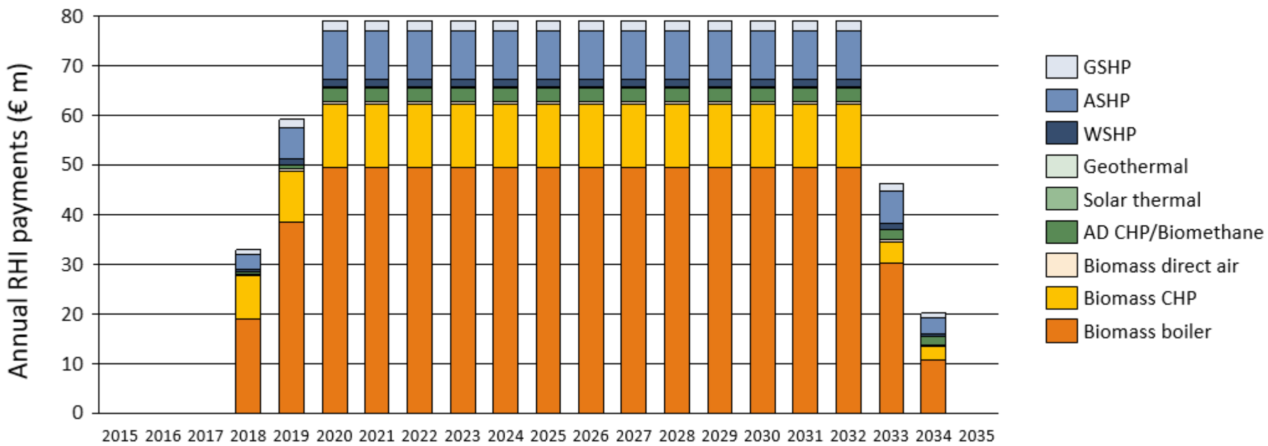


Table 7-31: Annual RHI payments made in Scenario 5

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.8	1.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ASHP	3.1	6.4	9.7	9.7	9.7	9.7	9.7	9.7	9.7
WSHP	0.6	1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Deep geothermal	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.5	0.8	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Biomass direct air	0.2	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Biomass CHP	8.6	10.2	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Biomass boiler	19.1	38.6	49.5	49.5	49.5	49.5	49.5	49.5	49.5
Total	**32.8**	**59.1**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.2	2.2	2.2	2.2	2.2	2.2	1.4	0.7	0.0
ASHP	9.7	9.7	9.7	9.7	9.7	9.7	6.7	3.3	0.0
WSHP	1.7	1.7	1.7	1.7	1.7	1.7	1.1	0.6	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	2.5	2.5	2.5	2.5	2.5	2.5	2.0	1.7	0.0
Biomass direct air	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.2	0.0
Biomass CHP	12.7	12.7	12.7	12.7	12.7	12.7	4.1	2.5	0.0
Biomass boiler	49.5	49.5	49.5	49.5	49.5	49.5	30.4	10.9	0.0
Total	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**46.3**	**20.1**	**0.0**

Table 7-32: Cumulative RHI payments made in Scenario 5

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	7	9	11	13	15	18
ASHP	3	9	19	29	39	48	58	68	78
WSHP	1	2	3	5	7	8	10	12	13
Deep geothermal	0	0	0	0	1	1	1	1	1
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	1	4	6	9	11	14	16	19
Biomass direct air	0	1	1	2	3	3	4	5	5
Biomass CHP	9	19	32	44	57	70	82	95	108
Biomass boiler	19	58	107	157	206	256	305	355	405
Total	**33**	**92**	**171**	**250**	**330**	**409**	**488**	**567**	**647**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	20	22	24	27	29	31	32	33	33
ASHP	87	97	107	117	126	136	143	146	146
WSHP	15	17	18	20	22	23	24	25	25
Deep geothermal	1	1	2	2	2	2	2	2	2
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	22	24	27	29	32	34	36	38	38
Biomass direct air	6	6	7	8	8	9	9	10	10
Biomass CHP	121	133	146	159	172	184	188	191	191
Biomass boiler	454	504	553	603	652	702	732	743	743
Total	**726**	**805**	**884**	**963**	**1,043**	**1,122**	**1,168**	**1,188**	**1,188**

Table 7-33: Number of new installations 2016-2020 by technology and sector in Scenario 5 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2576	114	620	0	**3310**
Biomass CHP	0	0	1	0	**1**
Biomass direct air	0	0	42	0	**42**
ASHP	2430	192	96	0	**2718**
GSHP	303	0	25	0	**328**
WSHP	244	14	5	0	**263**
Deep geothermal	0	0	0	1	**1**
Solar thermal	0	8	0	0	**8**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**5553**	**328**	**789**	**19**	**6690**

Figure 7-15: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 5

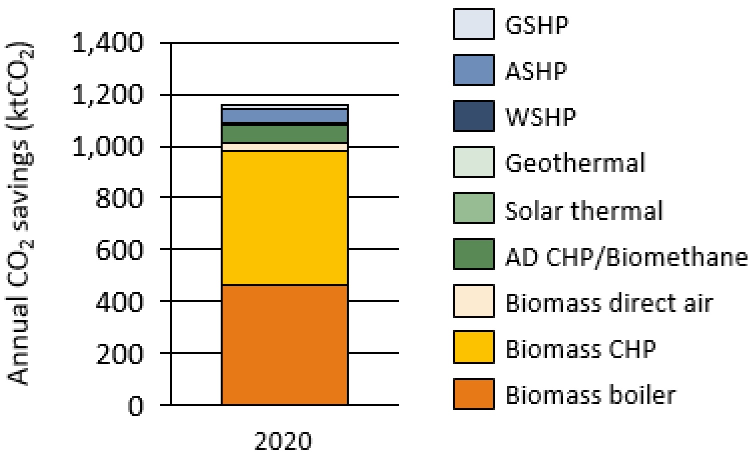
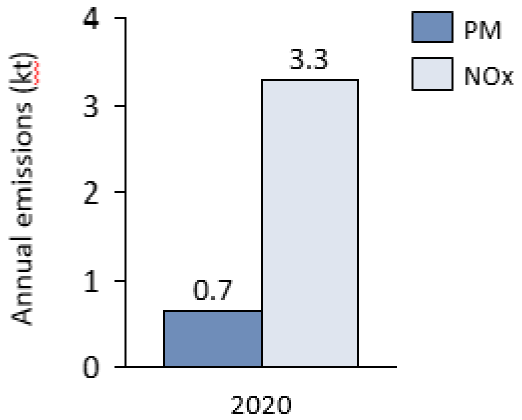


Table 7-34: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 5

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	12.1
ASHP	51.1
WSHP	6.8
Deep geothermal	8.4
Solar thermal	0.0
AD CHP/ biomethane	67.3
Biomass direct air	30.9
Biomass CHP	514.9
Biomass boiler	467.9
Total	**1159.5**

Table 7-35: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 5



Scenario 6 - Tariffs capped at 10 c/kWh

Tariffs

Table 7-36: Tariffs for Scenario 6

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	10.00
	2	>10	≤30	10.00
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Biomass CHP	1	N/A	N/A	9.61
Biomass Direct Air	1	N/A	≤300	7.03
	2	>300	≤1,000	6.67
	3	>1,000	≤3,000	6.41
	4	>3,000	≤10,000	2.59
	5	≥10,000	N/A	0.99
Ground-source heat pump	1	N/A	≤10	10.00
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.00
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	10.00
	2	>10	≤30	10.00
	3	>30	≤100	10.00
	4	>100	≤300	10.00
	5	>300	N/A	10.00
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	10.00

	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-16: Total heat demand met by RH technologies in 2020 in Scenario 6

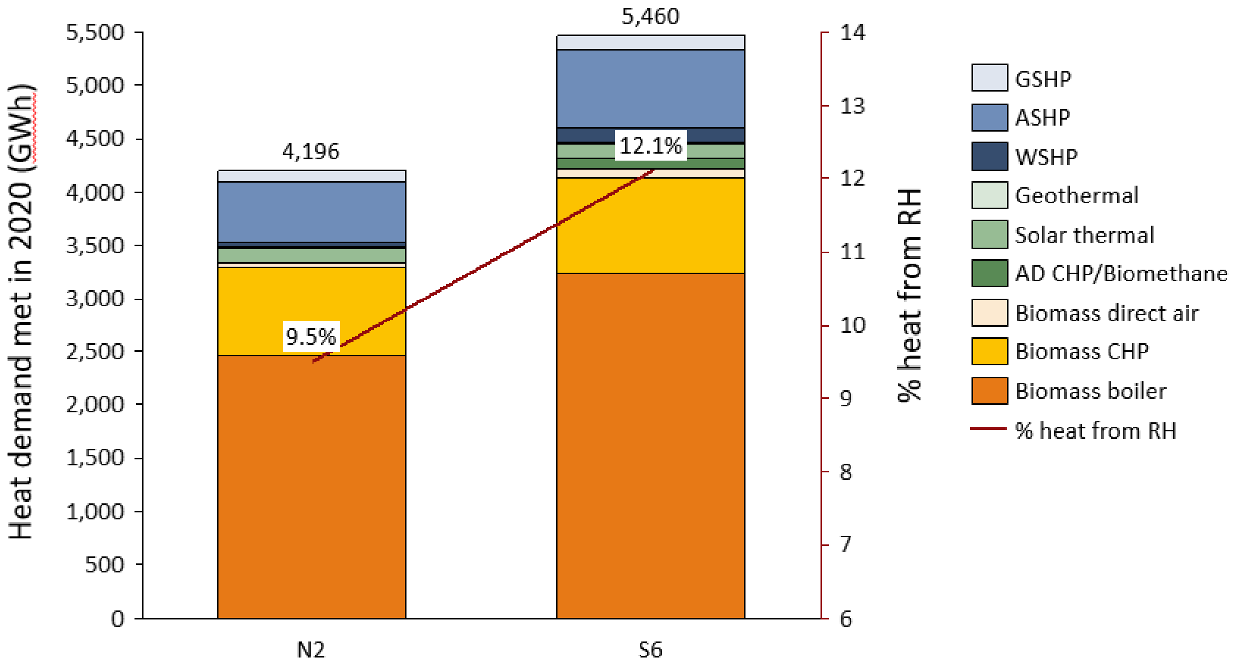


Table 7-37: Total heat demand met by RH technologies in 2020 in Scenario 6

GWh	2015	2020 Scenario N2	2020 Scenario 6
GSHP	99	103	128
ASHP	530	563	728
WSHP	50	51	139
Deep geothermal	0	7	18
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	84
Biomass CHP	84	827	894
Biomass boiler	2048	2467	3234
Total	**2951**	**4196**	**5460**
% heat from RH	**6.6%**	**9.5%**	**12.1%**

Figure 7-17: Annual RHI payments made in Scenario 6

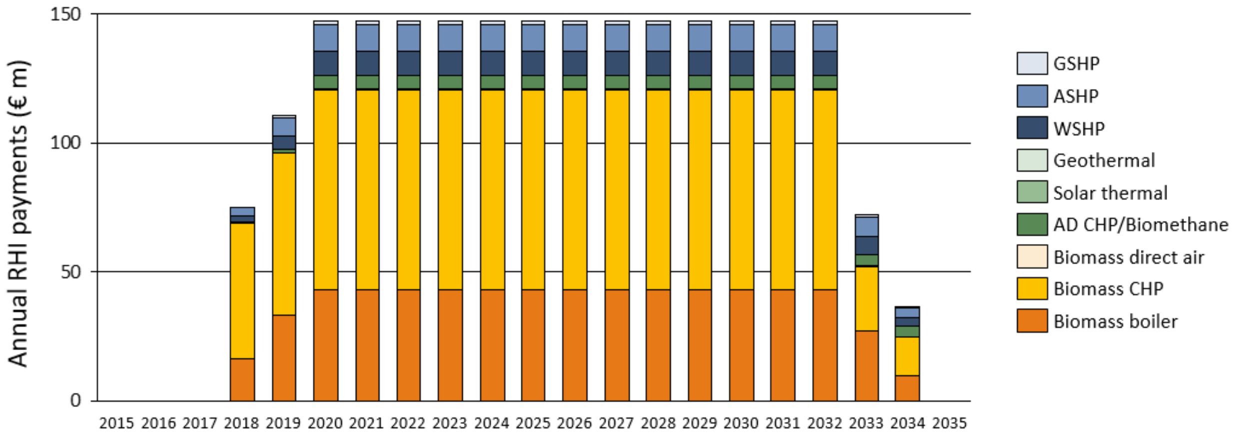


Table 7-38: Annual RHI payments made in Scenario 6

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.6	1.2	1.8	1.8	1.8	1.8	1.8	1.8	1.8
ASHP	3.3	6.8	10.4	10.4	10.4	10.4	10.4	10.4	10.4
WSHP	1.7	5.2	8.9	8.9	8.9	8.9	8.9	8.9	8.9
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.2	0.4	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Biomass CHP	52.6	62.3	77.3	77.3	77.3	77.3	77.3	77.3	77.3
Biomass boiler	16.1	33.5	43.3	43.3	43.3	43.3	43.3	43.3	43.3
Total	**75.3**	**110.8**	**147.5**	**147.5**	**147.5**	**147.5**	**147.5**	**147.5**	**147.5**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	1.8	1.8	1.8	1.8	1.8	1.8	1.2	0.6	0.0
ASHP	10.4	10.4	10.4	10.4	10.4	10.4	7.0	3.6	0.0
WSHP	8.9	8.9	8.9	8.9	8.9	8.9	7.2	3.7	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.2	0.0
Biomass CHP	77.3	77.3	77.3	77.3	77.3	77.3	24.7	14.9	0.0
Biomass boiler	43.3	43.3	43.3	43.3	43.3	43.3	27.2	9.8	0.0
Total	**147.5**	**147.5**	**147.5**	**147.5**	**147.5**	**147.5**	**72.2**	**36.8**	**0.0**

Table 7-39: Cumulative RHI payments made in Scenario 6

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	5	7	9	11	12	14
ASHP	3	10	21	31	41	52	62	73	83
WSHP	2	7	16	25	34	43	51	60	69
Deep geothermal	0	0	0	0	0	0	0	0	1
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	1	2	3	3	4	5	5
Biomass CHP	53	115	192	270	347	424	501	579	656
Biomass boiler	16	50	93	136	179	223	266	309	352
Total	**75**	**186**	**334**	**481**	**629**	**776**	**924**	**1,071**	**1,219**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	16	18	19	21	23	25	26	27	27
ASHP	93	104	114	124	135	145	152	156	156
WSHP	78	87	96	105	114	123	130	134	134
Deep geothermal	1	1	1	1	1	1	1	1	1
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	6	7	7	8	9	9	10	10	10
Biomass CHP	733	810	888	965	1,042	1,120	1,144	1,159	1,159
Biomass boiler	396	439	482	526	569	612	639	649	649
Total	**1,366**	**1,514**	**1,661**	**1,809**	**1,957**	**2,104**	**2,176**	**2,213**	**2,213**

Table 7-40: Number of new installations 2016-2020 by technology and sector in Scenario 6 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	1601	64	591	0	**2255**
Biomass CHP	16	0	3	0	**19**
Biomass direct air	0	0	42	0	**42**
ASHP	2906	174	98	0	**3178**
GSHP	221	0	25	0	**245**
WSHP	178	36	10	0	**223**
Deep geothermal	0	0	1	0	**1**
Solar thermal	0	4	0	0	**4**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**4921**	**278**	**769**	**19**	**5986**

Figure 7-18: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 6

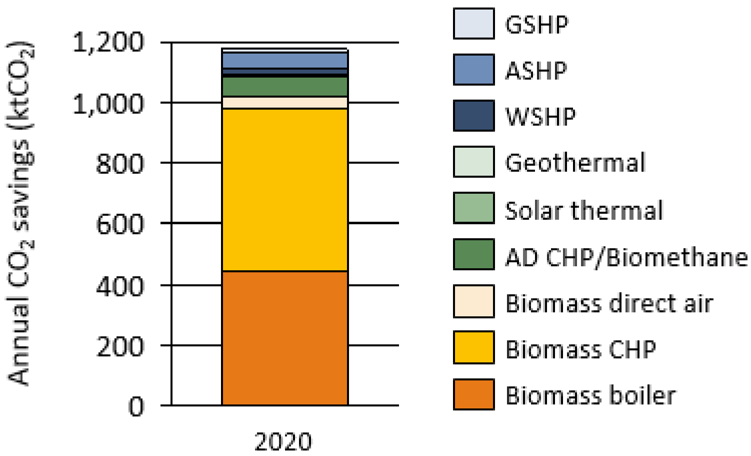
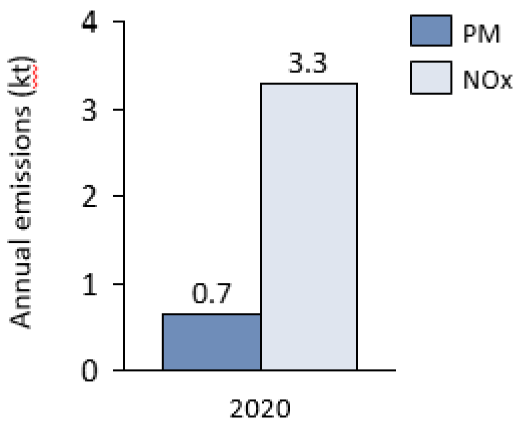


Table 7-41: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 6

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	10.6
ASHP	55.1
WSHP	22.2
Deep geothermal	6.4
Solar thermal	0.0
AD CHP	67.3
Biomass direct air	30.8
Biomass CHP	541.1
Biomass boiler	444.1
Total	**1177.6**

Table 7-42: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 6



Scenario 7 - Shorter duration (7 yrs)

Tariffs

Table 7-43: Tariffs for Scenario 7

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	26.55
	2	>10	≤30	19.02
	3	>30	≤100	14.77
	4	>100	≤300	11.47
	5	>300	≤1,000	9.13
	6	>1,000	≤3,000	3.90
	7	>3,000	≤10,000	3.70
	8	≥10,000	N/A	2.74
Biomass CHP	1	N/A	N/A	15.80
Biomass Direct Air	1	N/A	≤300	11.55
	2	>300	≤1,000	10.97
	3	>1,000	≤3,000	10.53
	4	>3,000	≤10,000	4.25
	5	≥10,000	N/A	1.63
Ground-source heat pump	1	N/A	≤10	25.00
	2	>10	≤30	14.75
	3	>30	≤100	8.87
	4	>100	≤300	8.87
	5	>300	N/A	7.71
Air-source heat pump	1	N/A	≤10	17.27
	2	>10	≤30	9.74
	3	>30	≤100	7.14
	4	>100	≤300	7.14
	5	>300	N/A	6.33
Water-source heat pump	1	N/A	≤10	24.97
	2	>10	≤30	18.21
	3	>30	≤100	17.49
	4	>100	≤300	17.49
	5	>300	N/A	17.27
Deep geothermal	1	N/A	N/A	2.29
Solar thermal	1	N/A	≤30	37.26
	2	>30	≤100	14.74
	3	>100	≤300	8.89
	4	>300	N/A	0.04
Anaerobic digestion boiler	1	N/A	≤2,400	5.19
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	13.36
	2	>2,400	≤7,200	4.58
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	11.10
	2	>30,000	≤60,000	6.64
	3	>60,000	N/A	0.00

Results

Figure 7-19: Total heat demand met by RH technologies in 2020 in Scenario 7

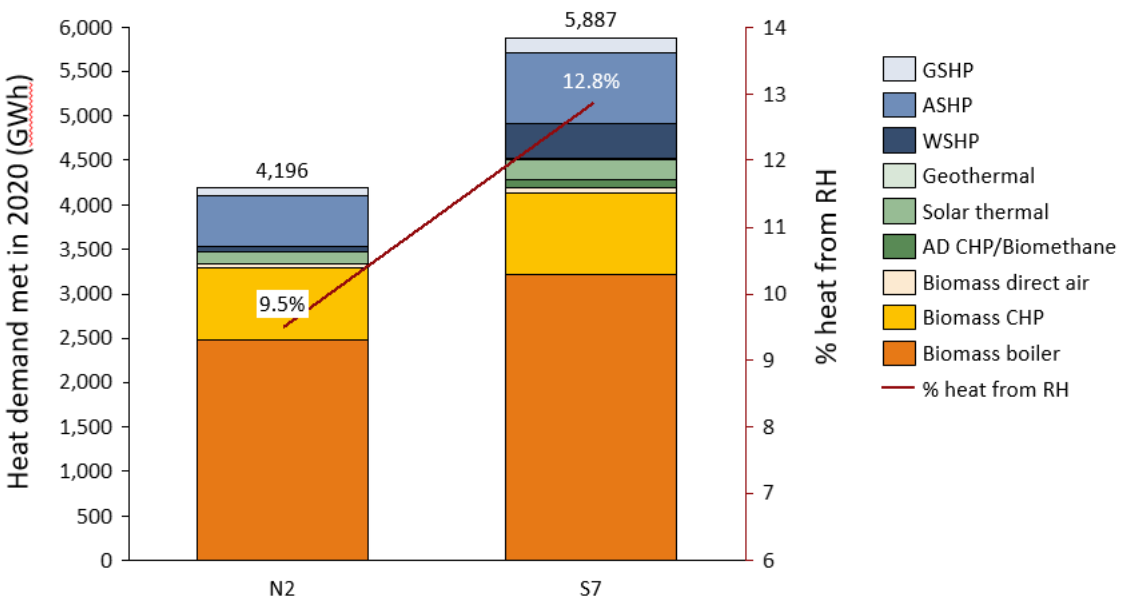


Table 7-44: Total heat demand met by RH technologies in 2020 in Scenario 7

GWh	2015	2020 Scenario N2	2020 Scenario 7
GSHP	99	103	167
ASHP	530	563	801
WSHP	50	51	385
Deep geothermal	0	7	22
Solar thermal	140	140	226
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	51
Biomass CHP	84	827	922
Biomass boiler	2048	2467	3217
Total	**2951**	**4196**	**5887**
% heat from RH	**6.6%**	**9.5%**	**12.8%**

Figure 7-20: Annual RHI payments made in Scenario 7

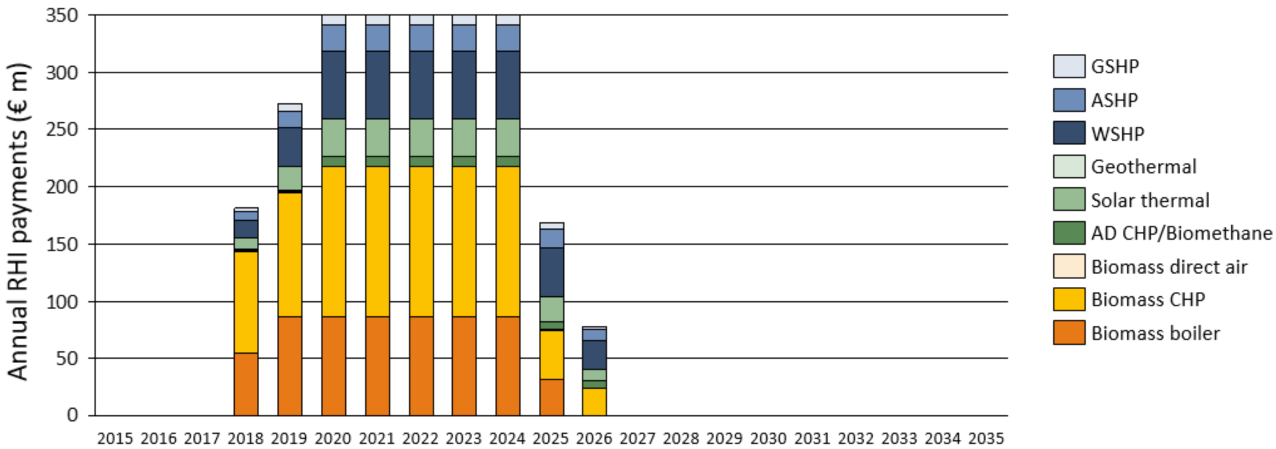


Table 7-45: Annual RHI payments made in Scenario 7

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	2.6	5.0	8.1	8.1	8.1	8.1	8.1	5.6	3.2
ASHP	7.5	14.2	23.4	23.4	23.4	23.4	23.4	15.9	9.2
WSHP	15.3	34.4	59.1	59.1	59.1	59.1	59.1	43.8	24.7
Deep geothermal	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.1	0.1
Solar thermal	10.6	21.2	32.0	32.0	32.0	32.0	32.0	21.5	10.8
AD CHP/ biomethane	1.2	2.1	8.5	8.5	8.5	8.5	8.5	7.2	6.4
Biomass direct air	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.0
Biomass CHP	88.7	108.0	131.6	131.6	131.6	131.6	131.6	42.9	23.5
Biomass boiler	55.0	86.2	86.2	86.2	86.2	86.2	86.2	31.3	0.0
Total	**181.3**	**271.9**	**349.9**	**349.9**	**349.9**	**349.9**	**349.9**	**168.6**	**78.0**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 7-46: Cumulative RHI payments made in Scenario 7

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	3	8	16	24	32	40	48	54	57
ASHP	8	22	45	69	92	115	139	155	164
WSHP	15	50	109	168	227	286	345	389	414
Deep geothermal	0	0	0	0	1	1	1	1	1
Solar thermal	11	32	64	96	128	160	192	214	224
AD CHP/ biomethane	1	3	12	20	29	37	46	53	59
Biomass direct air	0	1	2	2	3	4	5	5	5
Biomass CHP	89	197	328	460	591	723	855	897	921
Biomass boiler	55	141	227	314	400	486	572	604	604
Total	**181**	**453**	**803**	**1,153**	**1,503**	**1,853**	**2,203**	**2,371**	**2,449**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	57	57	57	57	57	57	57	57	57
ASHP	164	164	164	164	164	164	164	164	164
WSHP	414	414	414	414	414	414	414	414	414
Deep geothermal	1	1	1	1	1	1	1	1	1
Solar thermal	224	224	224	224	224	224	224	224	224
AD CHP	59	59	59	59	59	59	59	59	59
Biomass direct air	5	5	5	5	5	5	5	5	5
Biomass CHP	921	921	921	921	921	921	921	921	921
Biomass boiler	604	604	604	604	604	604	604	604	604
Total	**2,449**	**2,449**	**2,449**	**2,449**	**2,449**	**2,449**	**2,449**	**2,449**	**2,449**

Table 7-47: Number of new installations 2016-2020 by technology and sector in Scenario 7 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2815	325	644	0	**3784**
Biomass CHP	27	8	3	0	**38**
Biomass direct air	0	0	24	0	**24**
ASHP	3634	290	129	0	**4053**
GSHP	965	0	41	0	**1006**
WSHP	1081	392	38	0	**1511**
Deep geothermal	0	0	1	0	**1**
Solar thermal	6989	583	0	0	**7573**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**15510**	**1598**	**881**	**19**	**18008**

Figure 7-21: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 7

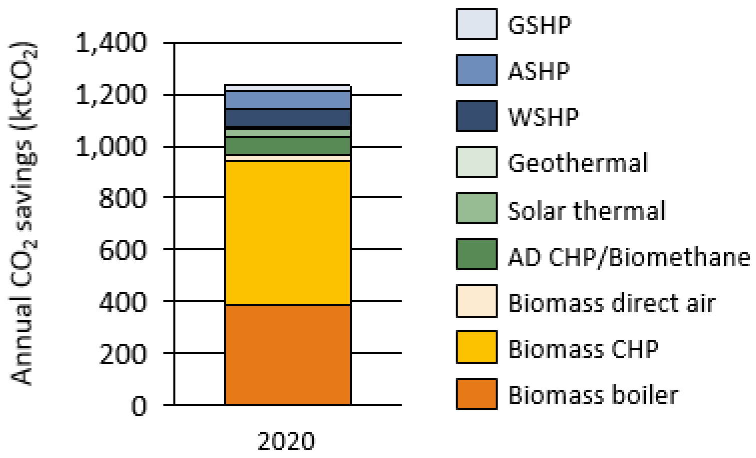
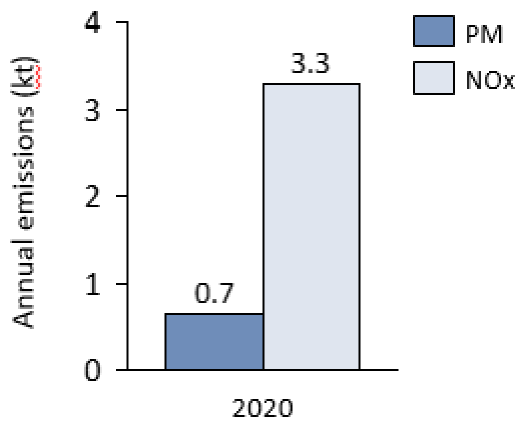


Table 7-48: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 7

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	23.1
ASHP	65.1
WSHP	72.3
Deep geothermal	7.9
Solar thermal	36.8
AD CHP/ biomethane	67.3
Biomass direct air	18.7
Biomass CHP	555.1
Biomass boiler	389.5
Total	**1235.9**

Table 7-49: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 7



Scenario 8 - Higher IRR (12%)

Tariffs

Table 7-50: Tariffs for Scenario 8

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	18.84
	2	>10	≤30	13.16
	3	>30	≤100	10.07
	4	>100	≤300	8.10
	5	>300	≤1,000	6.31
	6	>1,000	≤3,000	2.65
	7	>3,000	≤10,000	2.52
	8	≥10,000	N/A	1.86
Biomass CHP	1	N/A	N/A	11.13
Biomass Direct Air	1	N/A	≤300	8.16
	2	>300	≤1,000	7.71
	3	>1,000	≤3,000	7.36
	4	>3,000	≤10,000	2.94
	5	≥10,000	N/A	1.09
Ground-source heat pump	1	N/A	≤10	20.63
	2	>10	≤30	12.58
	3	>30	≤100	7.75
	4	>100	≤300	7.75
	5	>300	N/A	6.82
Air-source heat pump	1	N/A	≤10	13.45
	2	>10	≤30	7.81
	3	>30	≤100	5.66
	4	>100	≤300	5.66
	5	>300	N/A	5.01
Water-source heat pump	1	N/A	≤10	19.86
	2	>10	≤30	14.65
	3	>30	≤100	13.53
	4	>100	≤300	13.53
	5	>300	N/A	13.31

Deep geothermal	1	N/A	N/A	3.09
Solar thermal	1	N/A	≤30	31.37
	2	>30	≤100	14.38
	3	>100	≤300	9.05
	4	>300	N/A	1.73
Anaerobic digestion boiler	1	N/A	≤2,400	5.32
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	13.54
	2	>2,400	≤7,200	6.51
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	9.06
	2	>30,000	≤60,000	2.43
	3	>60,000	N/A	0.00

Results

Figure 7-22: Total heat demand met by RH technologies in 2020 in Scenario 8

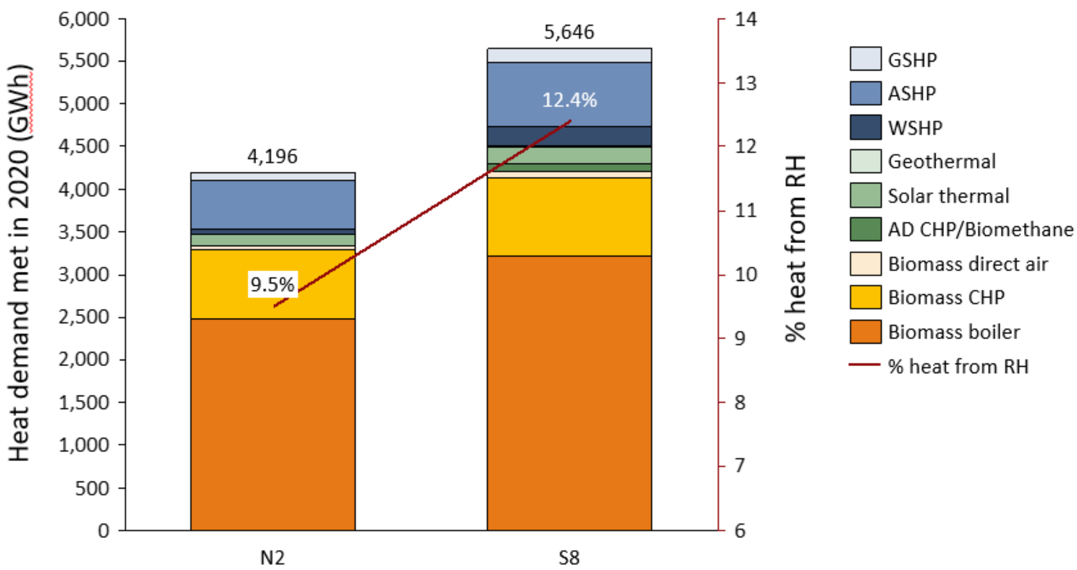


Table 7-51: Total heat demand met by RH technologies in 2020 in Scenario 8

GWh	2015	2020 Scenario N2	2020 Scenario 8
GSHP	99	103	149
ASHP	530	563	757
WSHP	50	51	229
Deep geothermal	0	7	23
Solar thermal	140	140	191
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	77
Biomass CHP	84	827	905
Biomass boiler	2048	2467	3220
Total	**2951**	**4196**	5646
% heat from RH	**6.6%**	**9.5%**	**12.4%**

Figure 7-23: Annual RHI payments made in Scenario 8

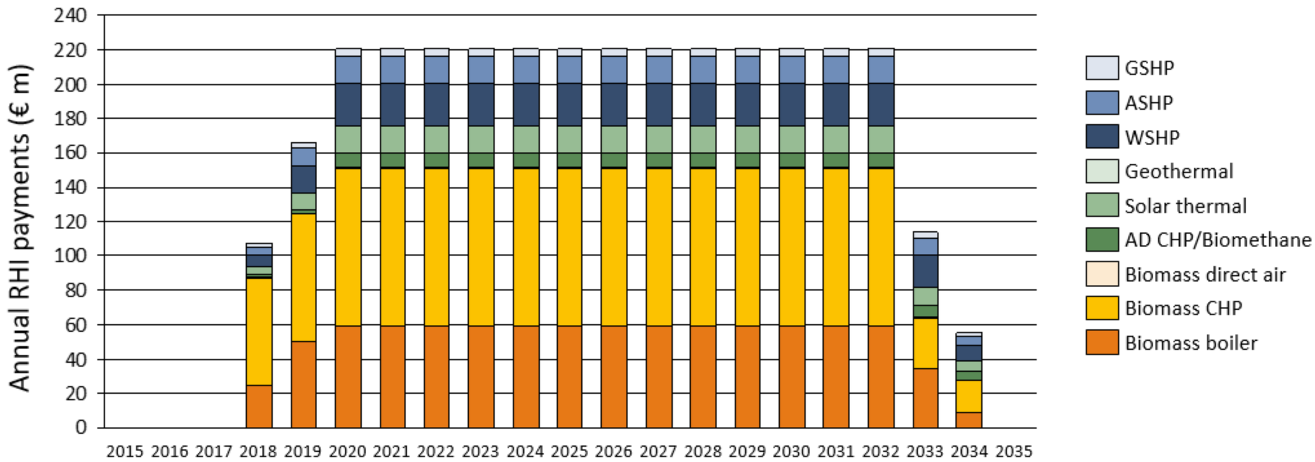


Table 7-52: Annual RHI payments made in Scenario 8

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.7	3.2	5.0	5.0	5.0	5.0	5.0	5.0	5.0
ASHP	5.3	10.3	15.3	15.3	15.3	15.3	15.3	15.3	15.3
WSHP	6.3	15.4	24.5	24.5	24.5	24.5	24.5	24.5	24.5
Deep geothermal	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Solar thermal	4.9	9.7	15.9	15.9	15.9	15.9	15.9	15.9	15.9
AD CHP/ biomethane	1.4	2.3	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Biomass direct air	0.2	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Biomass CHP	62.5	74.2	92.1	92.1	92.1	92.1	92.1	92.1	92.1
Biomass boiler	24.8	49.9	59.0	59.0	59.0	59.0	59.0	59.0	59.0
Total	**107.1**	**165.6**	**220.7**	**220.7**	**220.7**	**220.7**	**220.7**	**220.7**	**220.7**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	5.0	5.0	5.0	5.0	5.0	5.0	3.3	1.7	0.0
ASHP	15.3	15.3	15.3	15.3	15.3	15.3	10.1	5.0	0.0
WSHP	24.5	24.5	24.5	24.5	24.5	24.5	18.3	9.1	0.0
Deep geothermal	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.0
Solar thermal	15.9	15.9	15.9	15.9	15.9	15.9	10.9	6.1	0.0
AD CHP/ biomethane	8.0	8.0	8.0	8.0	8.0	8.0	6.6	5.8	0.0
Biomass direct air	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.2	0.0
Biomass CHP	92.1	92.1	92.1	92.1	92.1	92.1	29.7	18.0	0.0
Biomass boiler	59.0	59.0	59.0	59.0	59.0	59.0	34.1	9.1	0.0
Total	**220.7**	**220.7**	**220.7**	**220.7**	**220.7**	**220.7**	**113.6**	**55.0**	**0.0**

Table 7-53: Cumulative RHI payments made in Scenario 8

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	2	5	10	15	20	25	30	35	40
ASHP	5	16	31	46	62	77	92	108	123
WSHP	6	22	46	71	95	120	144	169	193
Deep geothermal	0	0	1	1	1	1	2	2	2
Solar thermal	5	15	31	46	62	78	94	110	126
AD CHP/ biomethane	1	4	12	20	28	36	44	52	60
Biomass direct air	0	1	1	2	2	3	4	4	5
Biomass CHP	62	137	229	321	413	505	597	689	782
Biomass boiler	25	75	134	193	252	311	370	429	488
Total	**107**	**273**	**493**	**714**	**935**	**1,155**	**1,376**	**1,597**	**1,817**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	45	49	54	59	64	69	73	74	74
ASHP	138	154	169	184	200	215	225	230	230
WSHP	218	242	267	291	316	340	359	368	368
Deep geothermal	3	3	3	3	4	4	4	4	4
Solar thermal	141	157	173	189	205	221	232	238	238
AD CHP/ biomethane	68	76	84	92	100	108	115	121	121
Biomass direct air	5	6	7	7	8	8	9	9	9
Biomass CHP	874	966	1,058	1,150	1,242	1,334	1,364	1,382	1,382
Biomass boiler	547	606	664	723	782	841	876	885	885
Total	**2,038**	**2,259**	**2,479**	**2,700**	**2,921**	**3,141**	**3,255**	**3,310**	**3,310**

Table 7-54: Number of new installations 2016-2020 by technology and sector in Scenario 8 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2865	171	721	0	**3756**
Biomass CHP	22	0	3	0	**25**
Biomass direct air	0	0	34	0	**34**
ASHP	2835	258	101	0	**3193**
GSHP	587	0	34	0	**621**
WSHP	549	233	20	0	**802**
Deep geothermal	0	0	1	0	**1**
Solar thermal	4052	420	3	0	**4476**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**10909**	**1082**	**917**	**19**	**12928**

Figure 7-24: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 8

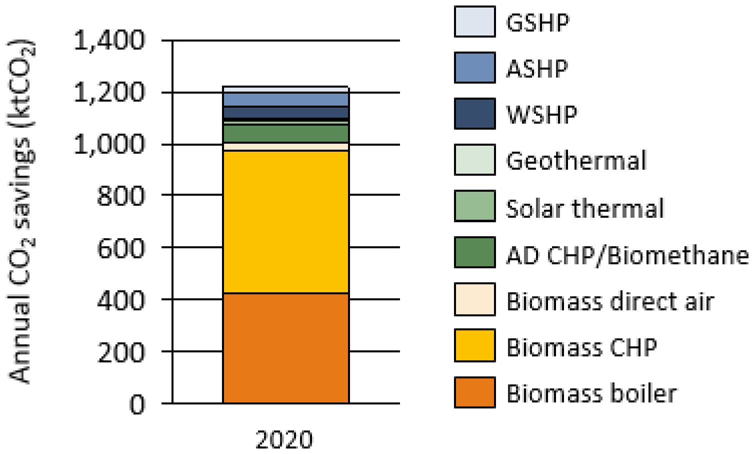
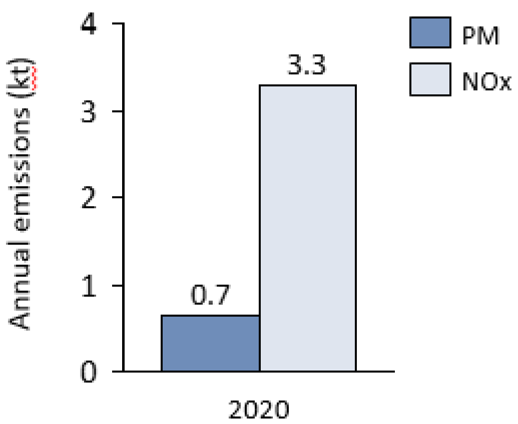


Table 7-55: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 8

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	17.3
ASHP	56.4
WSHP	43.2
Deep geothermal	7.6
Solar thermal	22.6
AD CHP/ biomethane	67.3
Biomass direct air	28.6
Biomass CHP	546.8
Biomass boiler	429.5
Total	**1219.5**

Table 7-56: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 8



Scenario 9 - Lower IRR (6%)

Tariffs

Table 7-57: Tariffs for Scenario 9

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	14.93
	2	>10	≤30	10.94
	3	>30	≤100	8.43
	4	>100	≤300	6.49
	5	>300	≤1,000	5.21
	6	>1,000	≤3,000	2.25
	7	>3,000	≤10,000	2.12
	8	≥10,000	N/A	1.58
Biomass CHP	1	N/A	N/A	8.91
Biomass Direct Air	1	N/A	≤300	6.51
	2	>300	≤1,000	6.20
	3	>1,000	≤3,000	5.97
	4	>3,000	≤10,000	2.42
	5	≥10,000	N/A	0.94
Ground-source heat pump	1	N/A	≤10	12.54
	2	>10	≤30	7.18
	3	>30	≤100	4.21
	4	>100	≤300	4.21
	5	>300	N/A	3.62
Air-source heat pump	1	N/A	≤10	9.10
	2	>10	≤30	5.02
	3	>30	≤100	3.71
	4	>100	≤300	3.71
	5	>300	N/A	3.29
Water-source heat pump	1	N/A	≤10	12.91
	2	>10	≤30	9.32
	3	>30	≤100	9.25
	4	>100	≤300	9.25
	5	>300	N/A	9.16
Deep geothermal	1	N/A	N/A	0.48
Solar thermal	1	N/A	≤30	18.34
	2	>30	≤100	6.20
	3	>100	≤300	3.54
	4	>300	N/A	0.00
Anaerobic digestion boiler	1	N/A	≤2,400	2.13
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	5.55
	2	>2,400	≤7,200	1.01
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	5.66
	2	>30,000	≤60,000	4.81
	3	>60,000	N/A	0.00

Results

Figure 7-25: Total heat demand met by RH technologies in 2020 in Scenario 9

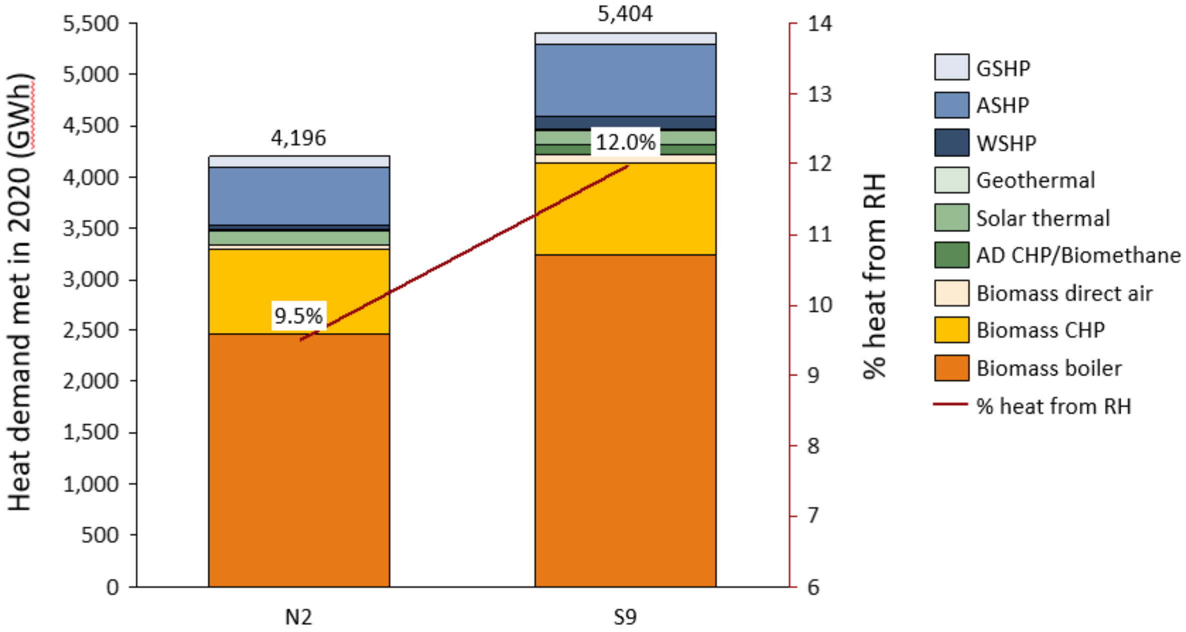


Table 7-58: Total heat demand met by RH technologies in 2020 in Scenario 9

GWh	2015	2020 Scenario N2	2020 Scenario 9
GSHP	99	103	125
ASHP	530	563	686
WSHP	50	51	126
Deep geothermal	0	7	17
Solar thermal	140	140	142
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	87
Biomass CHP	84	827	892
Biomass boiler	2048	2467	3234
Total	**2951**	**4196**	**5404**
% heat from RH	**6.6%**	**9.5%**	**12.0%**

Figure 7-26: Annual RHI payments made in Scenario 9

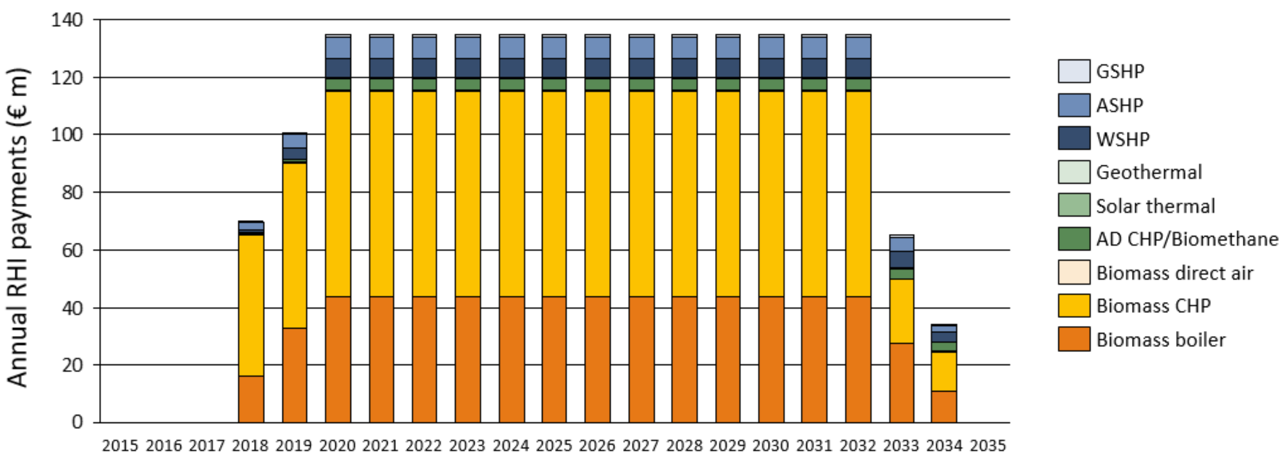


Table 7-59: Annual RHI payments made in Scenario 9

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.4	0.8	1.3	1.3	1.3	1.3	1.3	1.3	1.3
ASHP	2.2	4.7	7.0	7.0	7.0	7.0	7.0	7.0	7.0
WSHP	1.2	3.9	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3
AD CHP/ biomethane	0.5	0.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Biomass direct air	0.2	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Biomass CHP	48.9	57.8	71.5	71.5	71.5	71.5	71.5	71.5	71.5
Biomass boiler	16.4	32.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5
Total	**69.9**	**101.0**	**135.2**	**135.2**	**135.2**	**135.2**	**135.2**	**135.2**	**135.2**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	1.3	1.3	1.3	1.3	1.3	1.3	0.9	0.5	0.0
ASHP	7.0	7.0	7.0	7.0	7.0	7.0	4.8	2.3	0.0
WSHP	7.1	7.1	7.1	7.1	7.1	7.1	5.8	3.2	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.0
AD CHP/ biomethane	3.8	3.8	3.8	3.8	3.8	3.8	3.3	3.0	0.0
Biomass direct air	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.2	0.0
Biomass CHP	71.5	71.5	71.5	71.5	71.5	71.5	22.6	13.7	0.0
Biomass boiler	43.5	43.5	43.5	43.5	43.5	43.5	27.1	11.0	0.0
Total	**135.2**	**135.2**	**135.2**	**135.2**	**135.2**	**135.2**	**65.3**	**34.2**	**0.0**

Table 7-60: Cumulative RHI payments made in Scenario 9

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0	1	3	4	5	6	8	9	10
ASHP	2	7	14	21	28	35	42	49	56
WSHP	1	5	12	19	26	33	40	47	55
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	1	1	2	2	2	3
AD CHP/ biomethane	0	1	5	9	13	16	20	24	28
Biomass direct air	0	1	1	2	3	3	4	5	5
Biomass CHP	49	107	178	250	321	393	464	536	607
Biomass boiler	16	49	92	136	179	223	266	310	353
Total	**70**	**171**	**306**	**441**	**577**	**712**	**847**	**982**	**1,117**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	12	13	14	16	17	18	19	20	20
ASHP	63	70	77	84	91	98	103	106	106
WSHP	62	69	76	83	90	97	103	106	106
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	3	3	4	4	4	5	5	5	5
AD CHP/ biomethane	32	35	39	43	47	51	54	57	57
Biomass direct air	6	7	7	8	9	9	10	10	10
Biomass CHP	679	750	822	893	964	1,036	1,059	1,072	1,072
Biomass boiler	397	440	484	527	571	614	641	652	652
Total	**1,253**	**1,388**	**1,523**	**1,658**	**1,793**	**1,929**	**1,994**	**2,028**	**2,028**

Table 7-61: Number of new installations 2016-2020 by technology and sector in Scenario 9 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2422	90	556	0	**3068**
Biomass CHP	10	0	3	0	**13**
Biomass direct air	0	0	45	0	**45**
ASHP	2256	98	91	0	**2445**
GSHP	191	0	21	0	**212**
WSHP	183	31	9	0	**223**
Deep geothermal	0	0	1	0	**1**
Solar thermal	154	56	0	0	**210**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**5217**	**275**	**726**	**19**	**6238**

Figure 7-27: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 9

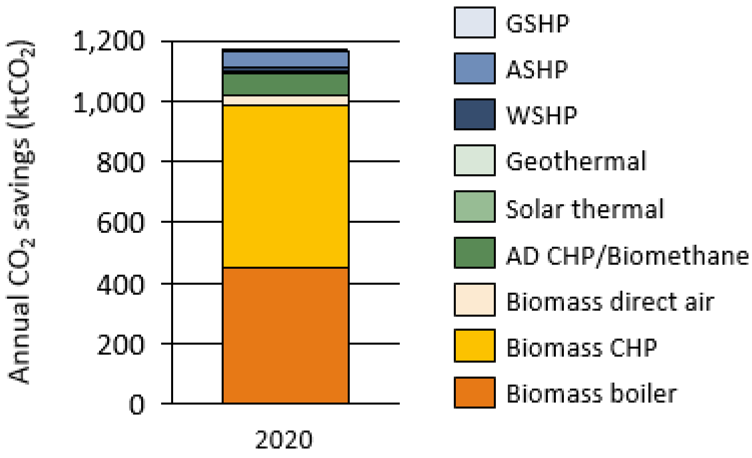
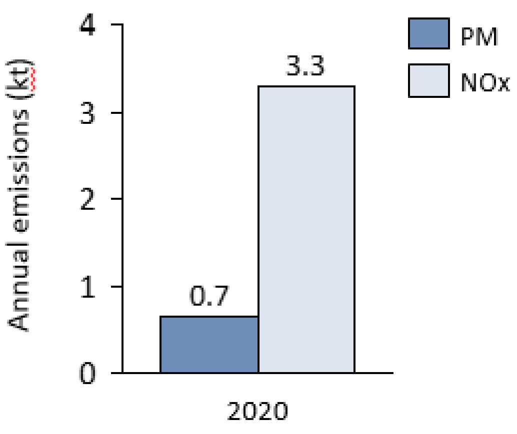


Table 7-62: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 9

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	9.3
ASHP	45.9
WSHP	19.5
Deep geothermal	6.1
Solar thermal	0.9
AD CHP/ biomethane	67.3
Biomass direct air	31.8
Biomass CHP	539.8
Biomass boiler	451.6
Total	**1172.2**

Table 7-63: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 9



Scenario 10 - Shorter duration (7 yrs) and Higher IRR (12%) except for biomass-based techs for which retain 15 yr duration and 8% IRR

Tariffs

Table 7-64: Tariffs for Scenario 10

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	16.15
	2	>10	≤30	11.57
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Biomass CHP	1	N/A	N/A	9.61
Biomass Direct Air	1	N/A	≤300	7.03
	2	>300	≤1,000	6.67
	3	>1,000	≤3,000	6.41
	4	>3,000	≤10,000	2.59
	5	≥10,000	N/A	0.99
Ground-source heat pump	1	N/A	≤10	30.78
	2	>10	≤30	18.77
	3	>30	≤100	11.57
	4	>100	≤300	11.57
	5	>300	N/A	10.18
Air-source heat pump	1	N/A	≤10	20.08
	2	>10	≤30	11.65
	3	>30	≤100	8.44
	4	>100	≤300	8.44
	5	>300	N/A	7.48
Water-source heat pump	1	N/A	≤10	29.64
	2	>10	≤30	21.86
	3	>30	≤100	20.19
	4	>100	≤300	20.19
	5	>300	N/A	19.86
Deep geothermal	1	N/A	N/A	4.61
Solar thermal	1	N/A	≤30	46.81
	2	>30	≤100	21.46
	3	>100	≤300	13.51
	4	>300	N/A	2.58
Anaerobic digestion boiler	1	N/A	≤2,400	7.93
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	20.21
	2	>2,400	≤7,200	9.72
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	13.53
	2	>30,000	≤60,000	3.63
	3	>60,000	N/A	0.00

Results

Figure 7-28: Total heat demand met by RH technologies in 2020 in Scenario 10

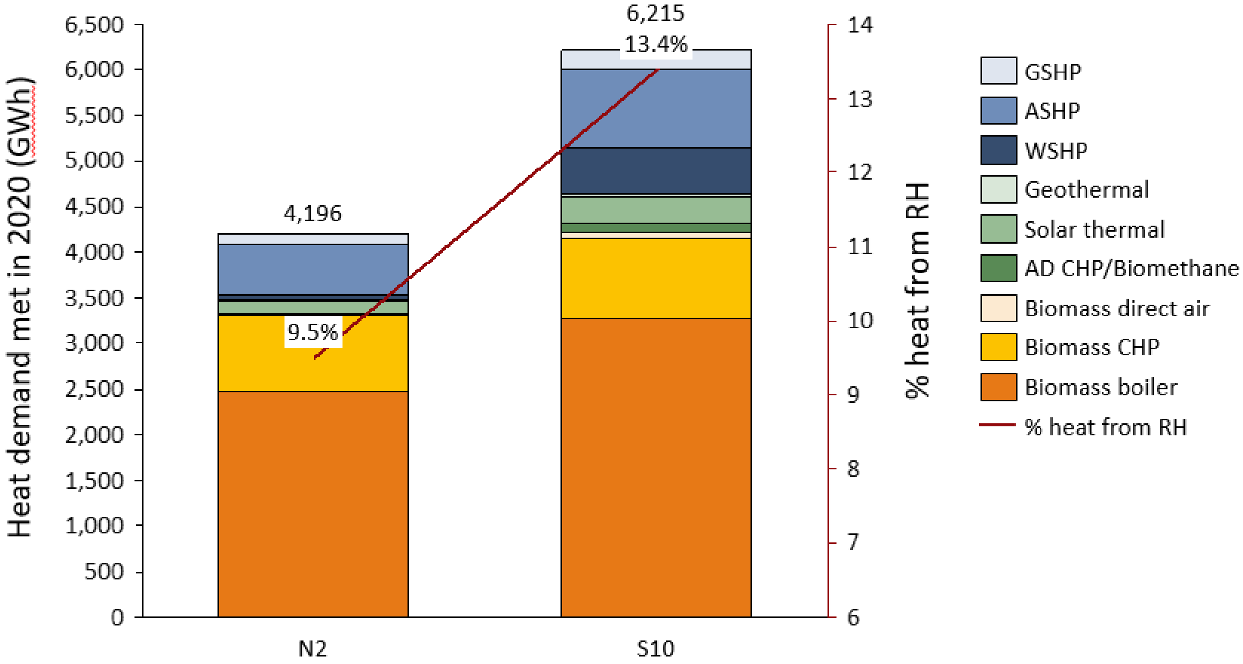


Table 7-65: Total heat demand met by RH technologies in 2020 in Scenario 10

GWh	2015	2020 Scenario N2	2020 Scenario 10
GSHP	99	103	206
ASHP	530	563	864
WSHP	50	51	506
Deep geothermal	0	7	35
Solar thermal	140	140	287
AD CHP/ biomethane	0	0	95104
Biomass direct air	0	38	81
Biomass CHP	84	827	877
Biomass boiler	2048	2467	3265
Total	**2951**	**4196**	**6215**
% heat from RH	**6.6%**	**9.5%**	**13.4%**

Figure 7-29: Annual RHI payments made in Scenario 10

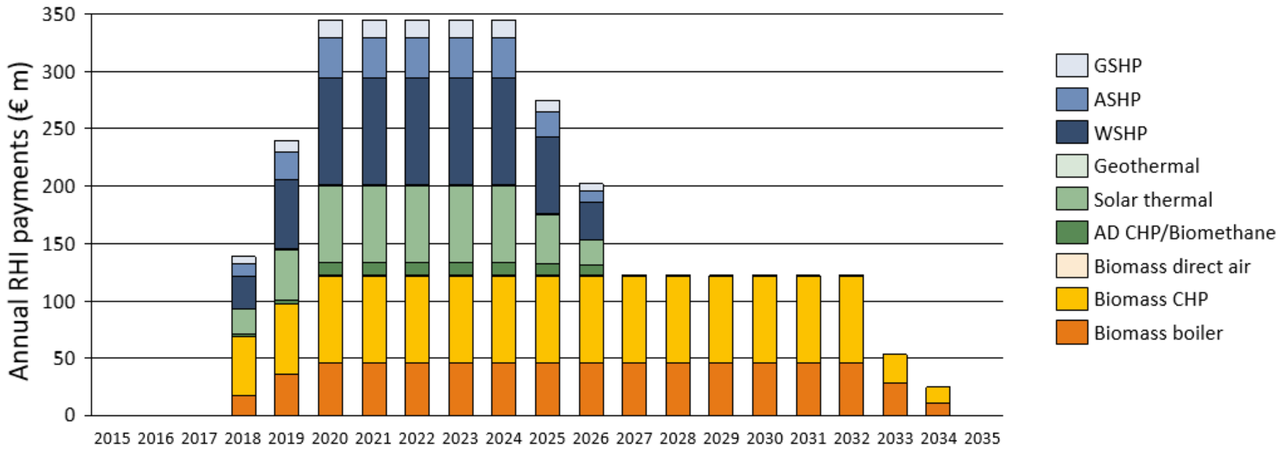


Table 7-66: Annual RHI payments made in Scenario 10

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	5.5	10.8	16.2	16.2	16.2	16.2	16.2	10.7	5.4
ASHP	11.8	23.3	33.9	33.9	33.9	33.9	33.9	22.1	10.6
WSHP	27.6	61.3	93.6	93.6	93.6	93.6	93.6	66.0	32.4
Deep geothermal	0.2	0.6	1.0	1.0	1.0	1.0	1.0	0.8	0.4
Solar thermal	22.4	43.9	66.2	66.2	66.2	66.2	66.2	43.8	22.3
AD CHP/ biomethane	2.1	3.4	12.0	12.0	12.0	12.0	12.0	9.9	8.6
Biomass direct air	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Biomass CHP	51.1	60.8	75.7	75.7	75.7	75.7	75.7	75.7	75.7
Biomass boiler	17.5	35.9	45.9	45.9	45.9	45.9	45.9	45.9	45.9
Total	**138.3**	**240.1**	**344.9**	**344.9**	**344.9**	**344.9**	**344.9**	**275.3**	**201.8**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.1	0.0
Biomass CHP	75.7	75.7	75.7	75.7	75.7	75.7	24.7	14.9	0.0
Biomass boiler	45.9	45.9	45.9	45.9	45.9	45.9	28.5	10.0	0.0
Total	**122.1**	**122.1**	**122.1**	**122.1**	**122.1**	**122.1**	**53.4**	**25.1**	**0.0**

Table 7-67: Cumulative RHI payments made in Scenario 10

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	5	16	32	49	65	81	97	108	113
ASHP	12	35	69	103	137	171	204	227	237
WSHP	28	89	183	276	370	463	557	623	655
Deep geothermal	0	1	2	3	4	5	6	6	7
Solar thermal	22	66	132	199	265	331	397	441	463
AD CHP/ biomethane	2	5	17	29	41	53	65	75	84
Biomass direct air	0	0	1	1	2	2	3	3	3
Biomass CHP	51	112	188	263	339	415	490	566	642
Biomass boiler	17	53	99	145	191	237	283	329	375
Total	**138**	**378**	**723**	**1,068**	**1,413**	**1,758**	**2,103**	**2,378**	**2,580**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	113	113	113	113	113	113	113	113	113
ASHP	237	237	237	237	237	237	237	237	237
WSHP	655	655	655	655	655	655	655	655	655
Deep geothermal	7	7	7	7	7	7	7	7	7
Solar thermal	463	463	463	463	463	463	463	463	463
AD CHP/ biomethane	84	84	84	84	84	84	84	84	84
Biomass direct air	4	4	5	5	5	6	6	6	6
Biomass CHP	717	793	869	945	1,020	1,096	1,121	1,136	1,136
Biomass boiler	421	467	513	559	605	651	679	689	689
Total	**2,702**	**2,824**	**2,946**	**3,068**	**3,190**	**3,312**	**3,366**	**3,391**	**3,391**

Table 7-68: Number of new installations 2016-2020 by technology and sector in Scenario 10 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	1881	104	594	0	**2579**
Biomass CHP	16	0	2	0	**18**
Biomass direct air	0	0	30	0	**30**
ASHP	4190	557	154	0	**4901**
GSHP	1473	0	50	0	**1523**
WSHP	1528	944	53	0	**2526**
Deep geothermal	0	0	1	0	**1**
Solar thermal	10177	1435	16	0	**11628**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**19265**	**3041**	**900**	**19**	**23225**

Figure 7-30: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 10

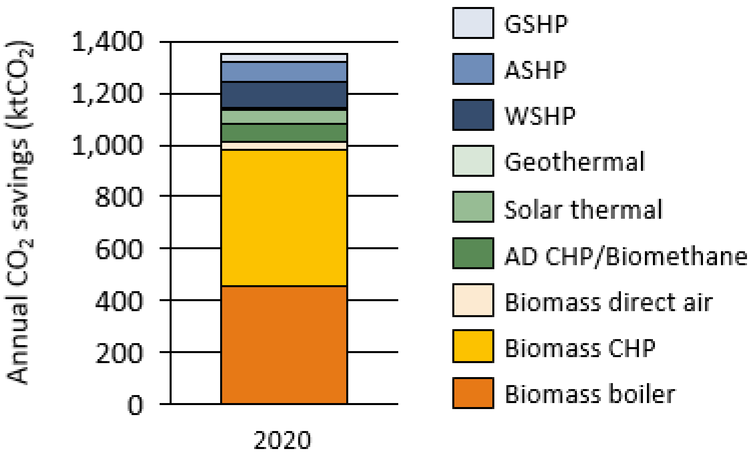
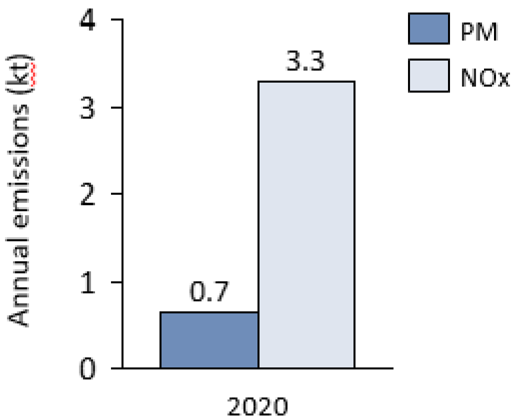


Table 7-69: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 10

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	32.1
ASHP	74.5
WSHP	95.6
Deep geothermal	10.8
Solar thermal	57.5
AD CHP/ biomethane	67.3
Biomass direct air	29.9
Biomass CHP	532.1
Biomass boiler	450.7
Total	**1350.7**

Table 7-70: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 10



Scenario 11 - High power sector biomass demand

Tariffs

Table 7-71: Tariffs for Scenario 11

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	16.15
	2	>10	≤30	11.57
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Biomass CHP	1	N/A	N/A	9.61
Biomass Direct Air	1	N/A	≤300	7.03
	2	>300	≤1,000	6.67
	3	>1,000	≤3,000	6.41
	4	>3,000	≤10,000	2.59
	5	≥10,000	N/A	0.99
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	10.64
	4	>100	≤300	10.64
	5	>300	N/A	10.50
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	22.66
	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-31: Total heat demand met by RH technologies in 2020 in Scenario 11

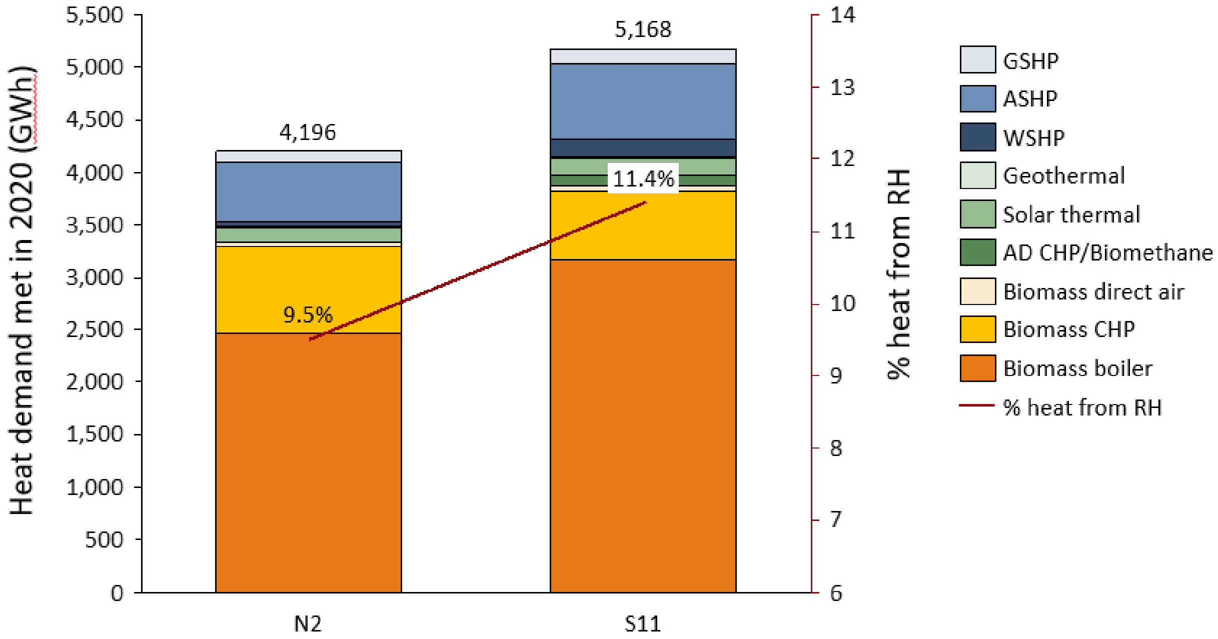


Table 7-72: Total heat demand met by RH technologies in 2020 in Scenario 11

GWh	2015	2020 Scenario N2	2020 Scenario 11
GSHP	99	103	131
ASHP	530	563	715
WSHP	50	51	169
Deep geothermal	0	7	21
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	65
Biomass CHP	84	827	657
Biomass boiler	2048	2467	3159
Total	**2951**	**4196**	**5168**
% heat from RH	**6.6%**	**9.5%**	**11.4%**

Figure 7-32: Annual RHI payments made in Scenario 11

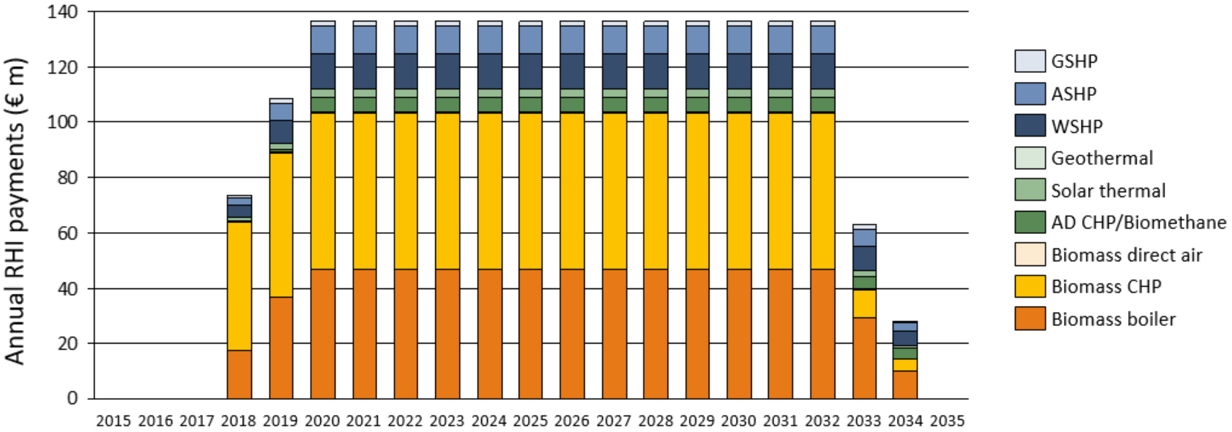


Table 7-73: Annual RHI payments made in Scenario 11

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.7	1.4	2.1	2.1	2.1	2.1	2.1	2.1	2.1
ASHP	3.2	6.4	9.6	9.6	9.6	9.6	9.6	9.6	9.6
WSHP	4.1	8.0	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.2	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Biomass CHP	46.3	52.1	56.5	56.5	56.5	56.5	56.5	56.5	56.5
Biomass boiler	17.5	36.8	46.6	46.6	46.6	46.6	46.6	46.6	46.6
Total	**73.8**	**108.6**	**136.7**	**136.7**	**136.7**	**136.7**	**136.7**	**136.7**	**136.7**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.1	2.1	2.1	2.1	2.1	2.1	1.4	0.7	0.0
ASHP	9.6	9.6	9.6	9.6	9.6	9.6	6.4	3.2	0.0
WSHP	12.7	12.7	12.7	12.7	12.7	12.7	8.6	4.7	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.2	0.0
Biomass CHP	56.5	56.5	56.5	56.5	56.5	56.5	10.3	4.4	0.0
Biomass boiler	46.6	46.6	46.6	46.6	46.6	46.6	29.1	9.8	0.0
Total	**136.7**	**136.7**	**136.7**	**136.7**	**136.7**	**136.7**	**62.9**	**28.1**	**0.0**

Table 7-74: Cumulative RHI payments made in Scenario 11

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	6	9	11	13	15	17
ASHP	3	10	19	29	38	48	57	67	77
WSHP	4	12	25	38	50	63	76	88	101
Deep geothermal	0	0	0	0	0	0	0	1	1
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	1	2	2	3	3	4	5
Biomass CHP	46	98	155	211	268	325	381	438	494
Biomass boiler	17	54	101	147	194	241	287	334	380
Total	**74**	**182**	**319**	**456**	**592**	**729**	**866**	**1,002**	**1,139**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	19	22	24	26	28	30	31	32	32
ASHP	86	96	105	115	124	134	140	144	144
WSHP	114	126	139	152	164	177	186	190	190
Deep geothermal	1	1	1	1	1	1	1	1	1
Solar thermal	30	33	37	40	43	46	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	5	6	6	7	7	8	8	9	9
Biomass CHP	551	607	664	720	777	833	844	848	848
Biomass boiler	427	473	520	567	613	660	689	699	699
Total	**1,276**	**1,412**	**1,549**	**1,686**	**1,822**	**1,959**	**2,022**	**2,050**	**2,050**

Table 7-75: Number of new installations 2016-2020 by technology and sector in Scenario 11 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2547	114	566	0	**3227**
Biomass CHP	16	0	1	0	**17**
Biomass direct air	0	0	39	0	**39**
ASHP	2422	161	106	0	**2689**
GSHP	294	0	25	0	**319**
WSHP	273	48	13	0	**334**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1393**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**6873**	**396**	**751**	**19**	**8038**

Figure 7-33: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 11

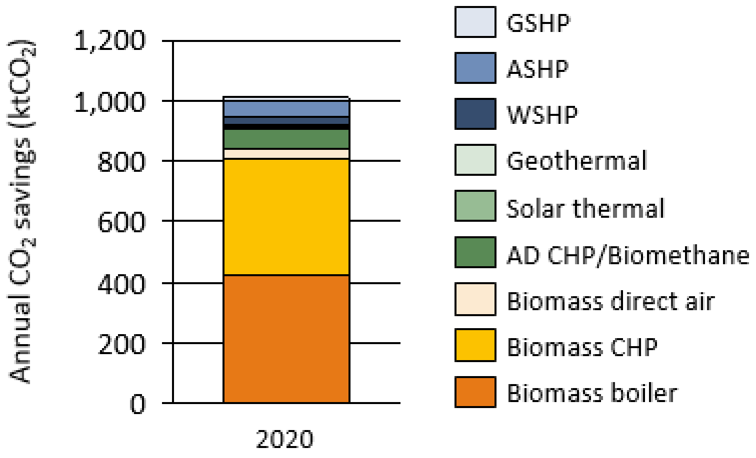
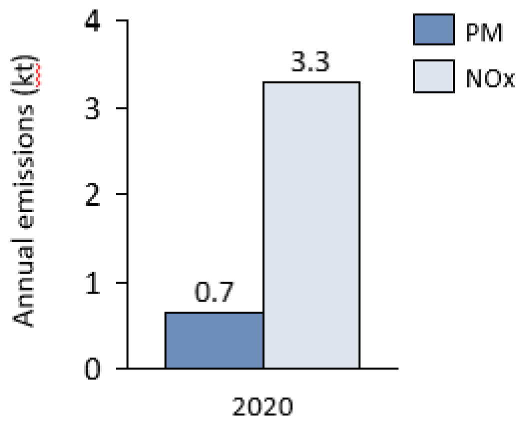


Table 7-76: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 11

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	11.6
ASHP	51.2
WSHP	29.4
Deep geothermal	7.4
Solar thermal	6.7
AD CHP/ biomethane	67.3
Biomass direct air	25.8
Biomass CHP	389.9
Biomass boiler	424.2
Total	**1013.6**

Table 7-77: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 11



Scenario 12 - Include ETS sector - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price

Tariffs

Table 7-78: Tariffs for Scenario 12

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	16.15
	2	>10	≤30	11.57
	3	>30	≤100	8.98
	4	>100	≤300	6.98
	5	>300	≤1,000	5.56
	6	>1,000	≤3,000	2.37
	7	>3,000	≤10,000	2.25
	8	≥10,000	N/A	1.67
Biomass CHP	1	N/A	N/A	9.61
Biomass Direct Air	1	N/A	≤300	7.03
	2	>300	≤1,000	6.67
	3	>1,000	≤3,000	6.41
	4	>3,000	≤10,000	2.59
	5	≥10,000	N/A	0.99
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	10.64
	4	>100	≤300	10.64
	5	>300	N/A	10.50
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	22.66
	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-34: Total heat demand met by RH technologies in 2020 in Scenario 12

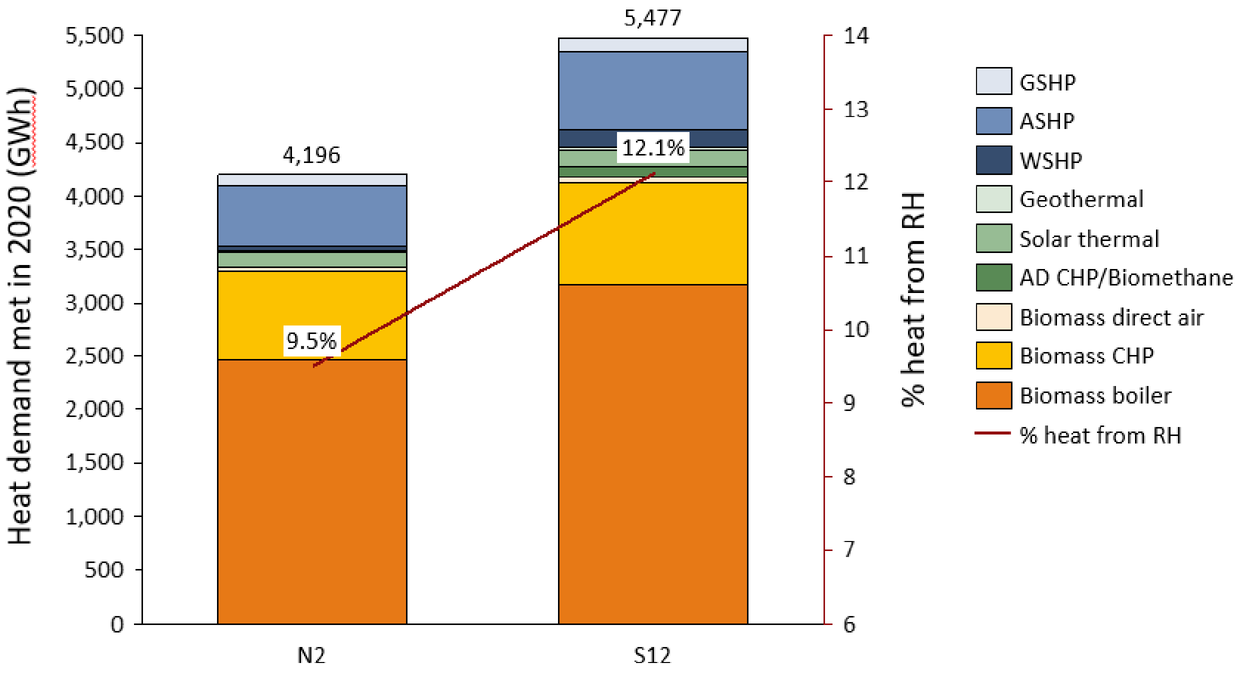


Table 7-79: Total heat demand met by RH technologies in 2020 in Scenario 12

GWh	2015	2020 Scenario N2	2020 Scenario 12
GSHP	99	103	135
ASHP	530	563	723
WSHP	50	51	174
Deep geothermal	0	7	22
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	61
Biomass CHP	84	827	951
Biomass boiler	2048	2467	3162
Total	**2951**	**4196**	**5477**
% heat from RH	**6.6%**	**9.5%**	**12.1%**

Figure 7-35: Annual RHI payments made in Scenario 12

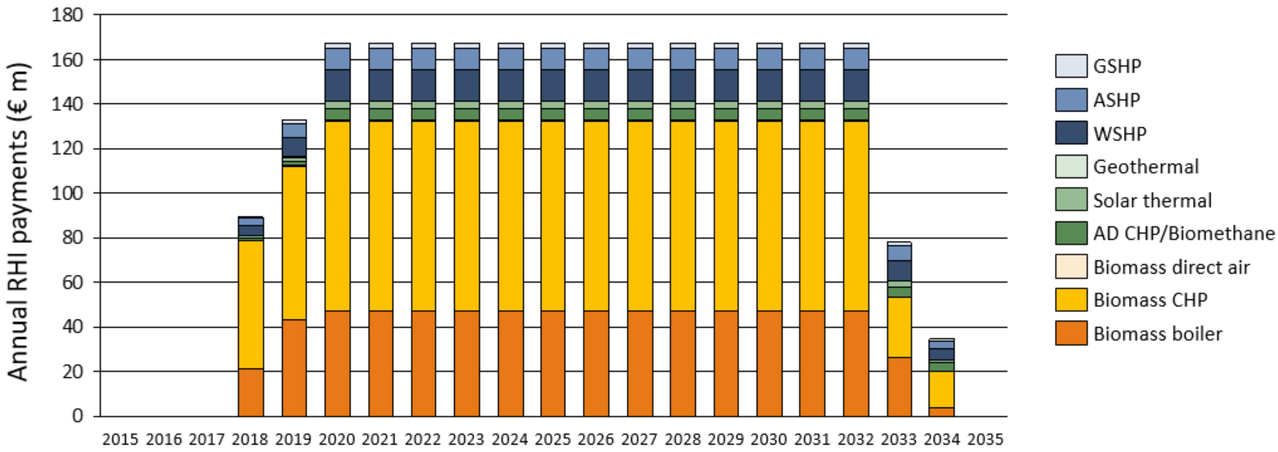


Table 7-80: Annual RHI payments made in Scenario 12

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.8	1.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4
ASHP	3.3	6.6	10.2	10.2	10.2	10.2	10.2	10.2	10.2
WSHP	4.2	8.3	13.2	13.2	13.2	13.2	13.2	13.2	13.2
Deep geothermal	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.2	0.5	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Biomass CHP	57.6	68.7	84.7	84.7	84.7	84.7	84.7	84.7	84.7
Biomass boiler	21.3	43.6	47.5	47.5	47.5	47.5	47.5	47.5	47.5
Total	**89.4**	**132.8**	**167.5**	**167.5**	**167.5**	**167.5**	**167.5**	**167.5**	**167.5**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.4	2.4	2.4	2.4	2.4	2.4	1.6	0.9	0.0
ASHP	10.2	10.2	10.2	10.2	10.2	10.2	6.9	3.6	0.0
WSHP	13.2	13.2	13.2	13.2	13.2	13.2	9.0	5.0	0.0
Deep geothermal	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.2	0.0
Biomass CHP	84.7	84.7	84.7	84.7	84.7	84.7	27.1	16.0	0.0
Biomass boiler	47.5	47.5	47.5	47.5	47.5	47.5	26.2	3.9	0.0
Total	**167.5**	**167.5**	**167.5**	**167.5**	**167.5**	**167.5**	**78.1**	**34.7**	**0.0**

Table 7-81: Cumulative RHI payments made in Scenario 12

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	5	7	9	12	14	16	19
ASHP	3	10	20	30	41	51	61	71	82
WSHP	4	12	26	39	52	65	79	92	105
Deep geothermal	0	0	1	1	1	2	2	2	2
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	1	2	3	3	4	5	5
Biomass CHP	58	126	211	296	380	465	550	635	719
Biomass boiler	21	65	112	160	207	255	302	350	397
Total	**89**	**222**	**390**	**557**	**725**	**892**	**1,060**	**1,227**	**1,394**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	21	24	26	28	31	33	35	35	35
ASHP	92	102	112	122	133	143	150	153	153
WSHP	118	132	145	158	171	185	194	199	199
Deep geothermal	3	3	3	4	4	4	5	5	5
Solar thermal	30	33	37	40	43	46	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	6	7	7	8	9	9	10	10	10
Biomass CHP	804	889	973	1,058	1,143	1,228	1,255	1,271	1,271
Biomass boiler	445	492	540	587	635	682	708	712	712
Total	**1,562**	**1,729**	**1,897**	**2,064**	**2,232**	**2,399**	**2,477**	**2,512**	**2,512**

Table 7-82: Number of new installations 2016-2020 by technology and sector in Scenario 12 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2547	114	521	0	**3183**
Biomass CHP	16	0	1	0	**17**
Biomass direct air	0	0	37	0	**37**
ASHP	2422	161	116	0	**2699**
GSHP	294	0	30	0	**324**
WSHP	273	48	15	0	**336**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1393**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**6873**	**396**	**721**	**19**	**8008**

Figure 7-36: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 12

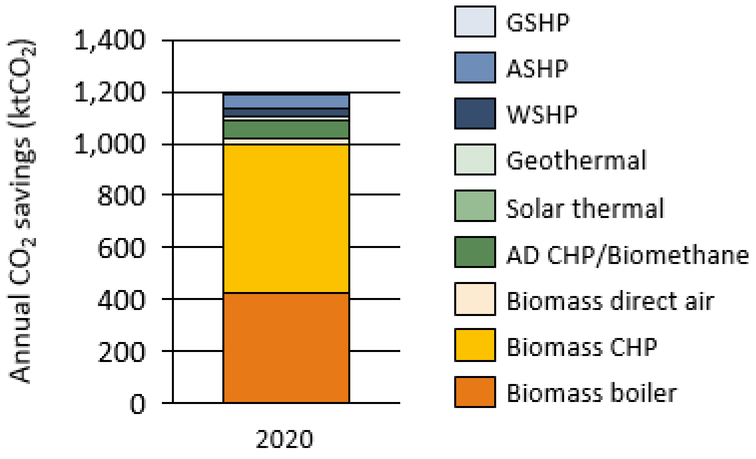
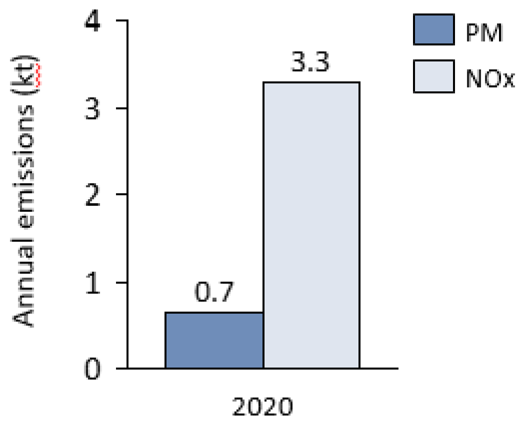


Table 7-83: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 12

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	12.9
ASHP	52.9
WSHP	31.1
Deep geothermal	7.9
Solar thermal	6.7
AD CHP/ biomethane	67.3
Biomass direct air	22.9
Biomass CHP	569.2
Biomass boiler	429.4
Total	**1200.3**

Table 7-84: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 12



Scenario 13 - Include ETS sector - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price

Tariffs

Table 7-85: Tariffs for Scenario 13

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	13.17
	2	>10	≤30	8.59
	3	>30	≤100	6.06
	4	>100	≤300	5.27
	5	>300	≤1,000	3.32
	6	>1,000	≤3,000	0.52
	7	>3,000	≤10,000	0.42
	8	≥10,000	N/A	0.00
Biomass CHP	1	N/A	N/A	5.98
Biomass Direct Air	1	N/A	≤300	4.84
	2	>300	≤1,000	4.49
	3	>1,000	≤3,000	4.22
	4	>3,000	≤10,000	0.76
	5	≥10,000	N/A	0.00
Ground-source heat pump	1	N/A	≤10	15.21
	2	>10	≤30	8.97
	3	>30	≤100	5.39
	4	>100	≤300	5.39
	5	>300	N/A	4.69
Air-source heat pump	1	N/A	≤10	10.50
	2	>10	≤30	5.92
	3	>30	≤100	4.34
	4	>100	≤300	4.34
	5	>300	N/A	3.85
Water-source heat pump	1	N/A	≤10	15.19
	2	>10	≤30	11.07
	3	>30	≤100	10.64
	4	>100	≤300	10.64
	5	>300	N/A	10.50
Deep geothermal	1	N/A	N/A	1.39
Solar thermal	1	N/A	≤30	22.66
	2	>30	≤100	8.97
	3	>100	≤300	5.41
	4	>300	N/A	0.02
Anaerobic digestion boiler	1	N/A	≤2,400	3.16
	2	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤2,400	8.13
	2	>2,400	≤7,200	2.79
	3	>7,200	N/A	0.00
Biomethane grid injection	1	N/A	≤30,000	6.75
	2	>30,000	≤60,000	4.04
	3	>60,000	N/A	0.00

Results

Figure 7-37: Total heat demand met by RH technologies in 2020 in Scenario 13

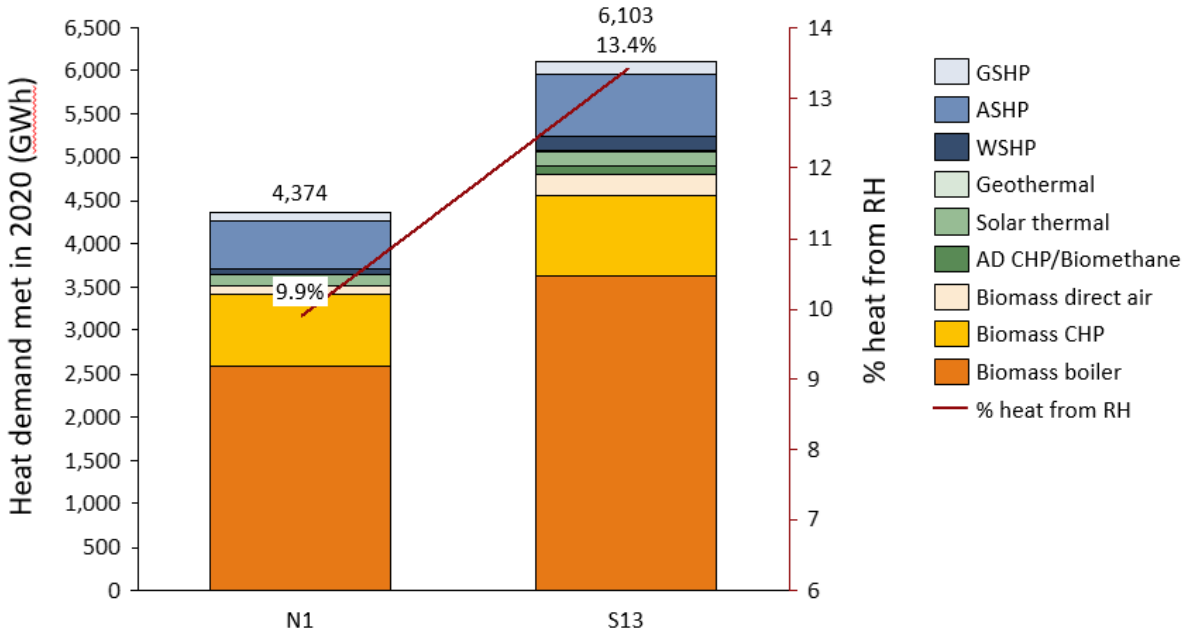


Table 7-86: Total heat demand met by RH technologies in 2020 in Scenario 13

GWh	2015	2020 Scenario N1	2020 Scenario 13
GSHP	99	103	133
ASHP	530	563	726
WSHP	50	51	170
Deep geothermal	0	5	17
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	105	252
Biomass CHP	84	827	936
Biomass boiler	2048	2580	3619
Total	**2951**	**4374**	**6103**
% heat from RH	**6.6%**	**9.9%**	**13.4%**

Figure 7-38: Annual RHI payments made in Scenario 13

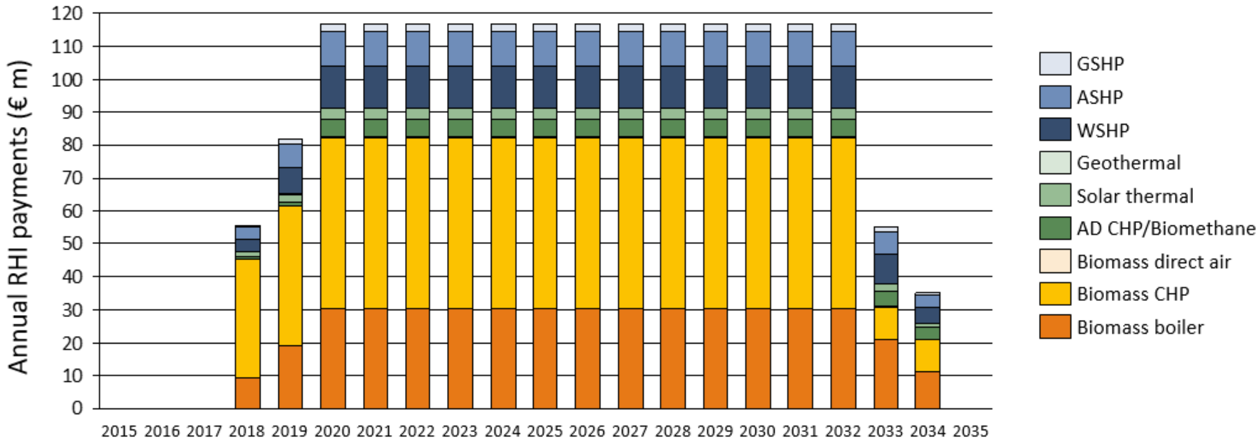


Table 7-87: Annual RHI payments made in Scenario 13

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.8	1.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ASHP	3.5	7.0	10.5	10.5	10.5	10.5	10.5	10.5	10.5
WSHP	3.9	8.0	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Deep geothermal	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Biomass CHP	35.9	42.3	51.9	51.9	51.9	51.9	51.9	51.9	51.9
Biomass boiler	9.5	19.1	30.3	30.3	30.3	30.3	30.3	30.3	30.3
Total	**55.7**	**81.7**	**116.8**	**116.8**	**116.8**	**116.8**	**116.8**	**116.8**	**116.8**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.2	2.2	2.2	2.2	2.2	2.2	1.5	0.7	0.0
ASHP	10.5	10.5	10.5	10.5	10.5	10.5	7.0	3.5	0.0
WSHP	12.8	12.8	12.8	12.8	12.8	12.8	8.8	4.7	0.0
Deep geothermal	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.1	0.0
Biomass CHP	51.9	51.9	51.9	51.9	51.9	51.9	10.2	9.6	0.0
Biomass boiler	30.3	30.3	30.3	30.3	30.3	30.3	20.8	11.2	0.0
Total	**116.8**	**116.8**	**116.8**	**116.8**	**116.8**	**116.8**	**55.3**	**35.1**	**0.0**

Table 7-88: Cumulative RHI payments made in Scenario 13

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	5	7	9	11	14	16	18
ASHP	4	10	21	31	42	52	63	73	84
WSHP	4	12	25	37	50	63	76	89	101
Deep geothermal	0	0	0	1	1	1	1	2	2
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	0	1	1	2	2	2	3	3
Biomass CHP	36	78	130	182	234	286	338	389	441
Biomass boiler	10	29	59	89	119	150	180	210	241
Total	**56**	**137**	**254**	**371**	**488**	**605**	**721**	**838**	**955**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	20	22	25	27	29	31	33	34	34
ASHP	94	105	115	126	136	147	154	157	157
WSHP	114	127	140	152	165	178	187	192	192
Deep geothermal	2	2	3	3	3	3	4	4	4
Solar thermal	30	33	37	40	43	47	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	4	4	4	5	5	6	6	6	6
Biomass CHP	493	545	597	649	701	752	763	772	772
Biomass boiler	271	301	331	362	392	422	443	454	454
Total	**1,072**	**1,188**	**1,305**	**1,422**	**1,539**	**1,656**	**1,711**	**1,746**	**1,746**

Table 7-89: Number of new installations 2016-2020 by technology and sector in Scenario 13 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2070	69	675	0	**2815**
Biomass CHP	10	0	1	0	**11**
Biomass direct air	0	0	64	0	**64**
ASHP	2573	168	112	0	**2853**
GSHP	295	0	25	0	**321**
WSHP	277	49	13	0	**339**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1393**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**6545**	**360**	**891**	**19**	**7816**

Figure 7-39: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 13

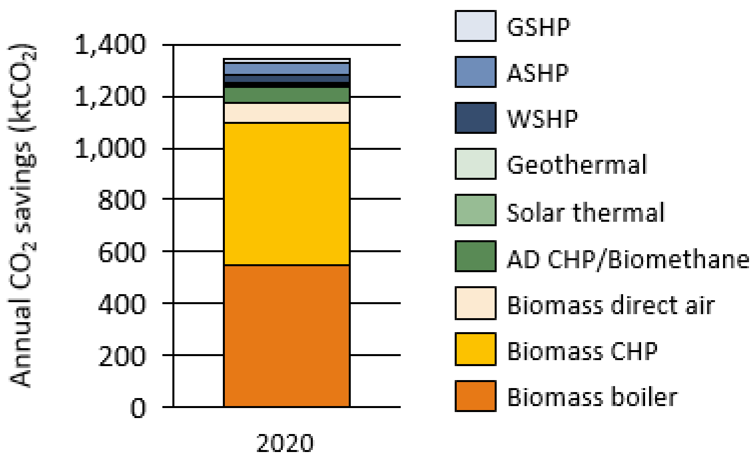
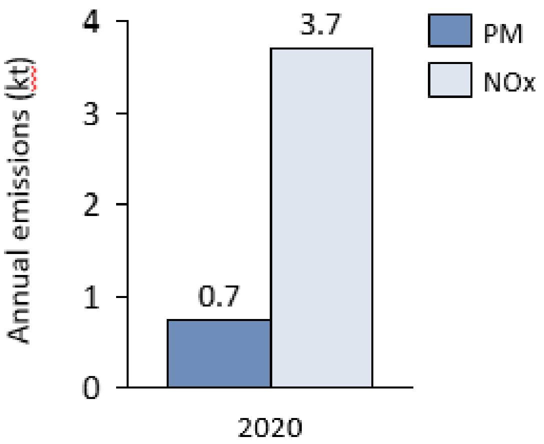


Table 7-90: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 13

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	12.1
ASHP	53.9
WSHP	29.8
Deep geothermal	6.2
Solar thermal	6.7
AD CHP/ biomethane	67.3
Biomass direct air	68.9
Biomass CHP	557.1
Biomass boiler	544.2
Total	**1346.3**

Table 7-91: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 13



Scenario N1 - No RHI - Limited imported biomass (5 TWh/yr), tariff based on 5.5 c/kWh biomass price

Tariffs

No RHI tariffs were applied in this scenario.

Results

Figure 7-40: Total heat demand met by RH technologies in 2020 in Scenario N1

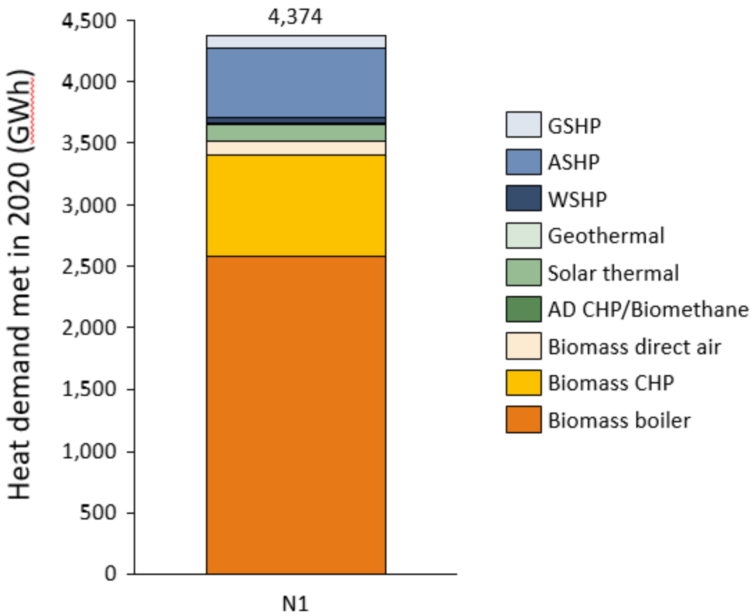


Table 7-92: Total heat demand met by RH technologies in 2020 in Scenario N1

GWh	2015	2020 Scenario N1
GSHP	99	103
ASHP	530	563
WSHP	50	51
Deep geothermal	0	5
Solar thermal	140	140
AD CHP/ biomethane	0	0
Biomass direct air	0	105
Biomass CHP	84	827
Biomass boiler	2048	2580
Total	**2951**	**4374**
% heat from RH	**6.6%**	**9.9%**

Table 7-93: Number of new installations 2016-2020 by technology and sector in Scenario N1 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	0	0	136	0	**136**
Biomass CHP	0	0	0	0	**0**
Biomass direct air	0	0	26	0	**26**
ASHP	169	4	31	0	**204**
GSHP	9	0	3	0	**12**
WSHP	0	0	0	0	**0**
Deep geothermal	0	0	1	0	**1**
Solar thermal	0	0	0	0	**0**
AD CHP/ biomethane	0	0	0	0	**0**
Total	**177**	**4**	**197**	**0**	**379**

Figure 7-41: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario N1

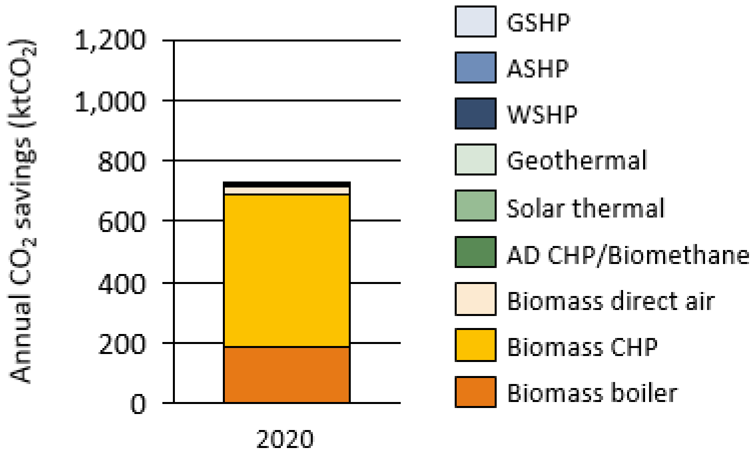
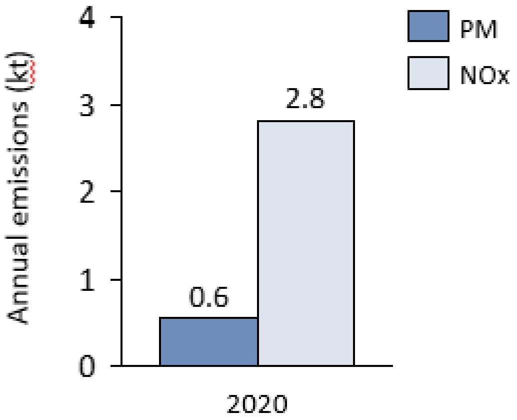


Table 7-94: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario N1

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	1.3
ASHP	10.6
WSHP	0.2
Deep geothermal	2.0
Solar thermal	0.0
AD CHP/ biomethane	0.0
Biomass direct air	29.0
Biomass CHP	502.1
Biomass boiler	184.7
Total	**730.0**

Table 7-95: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario N1



Scenario N2 - No RHI - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price

Tariffs

No RHI tariffs were applied in this scenario.

Results

Figure 7-42: Total heat demand met by RH technologies in 2020 in Scenario N2

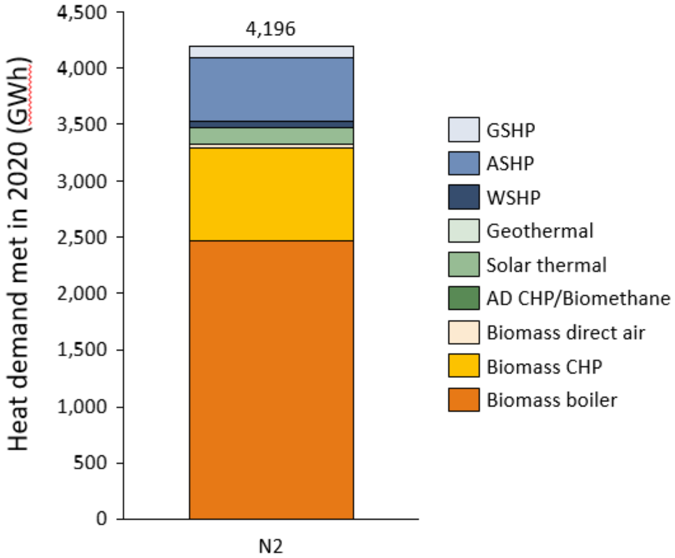


Table 7-96: Total heat demand met by RH technologies in 2020 in Scenario N2

Heat demand met in 2020 (GWh)	2015 Baseline	Scenario N2
GSHP	99	103
ASHP	530	563
WSHP	50	51
Deep geothermal	0	7
Solar thermal	140	140
AD CHP/ biomethane	0	0
Biomass direct air	0	38
Biomass CHP	84	827
Biomass boiler	2048	2467
Total	**2951**	**4196**
% heat from RH	**6.6%**	**9.5%**

Table 7-97: Number of new installations 2016-2020 by technology and sector in Scenario N2 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	0	0	122	0	**122**
Biomass CHP	0	0	0	0	**0**
Biomass direct air	0	0	14	0	**14**
ASHP	169	4	32	0	**204**
GSHP	9	0	4	0	**12**
WSHP	0	0	0	0	**0**
Deep geothermal	0	0	1	0	**1**
Solar thermal	0	0	0	0	**0**
AD CHP/ biomethane	0	0	0	0	**0**
Total	**177**	**4**	**173**	**0**	**355**

Figure 7-43: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario N2

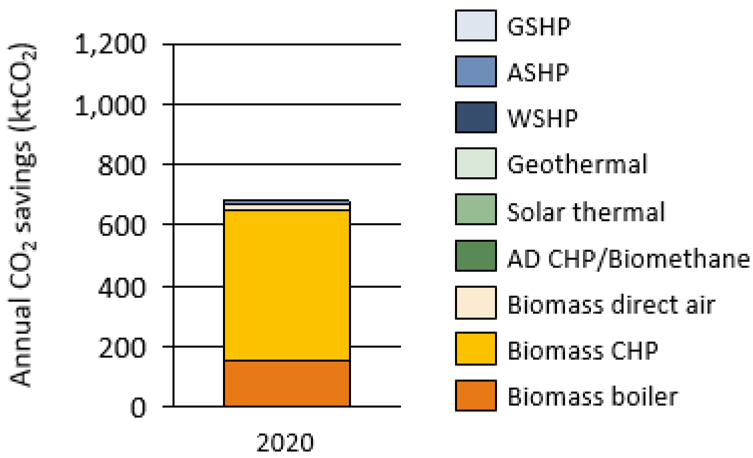
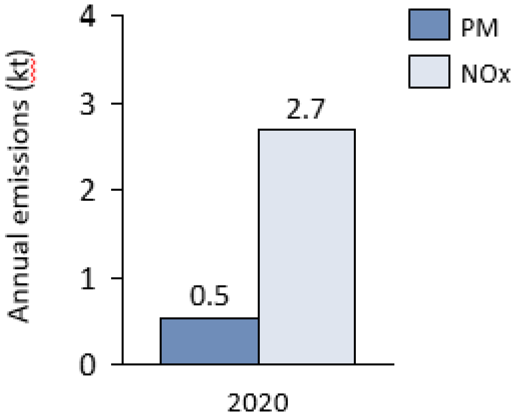


Table 7-98: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario N2

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	1.4
ASHP	10.8
WSHP	0.3
Deep geothermal	2.4
Solar thermal	0.0
AD CHP/ biomethane	0.0
Biomass direct air	13.6
Biomass CHP	502.3
Biomass boiler	151.1
Total	**681.9**

Table 7-99: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario N2



Scenario 2b – All central design options, Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price, Limited Biomass CHP in power sector

Results

Figure 7-44: Total heat demand met by RH technologies in 2020 in Scenario 2b (Low CHP)

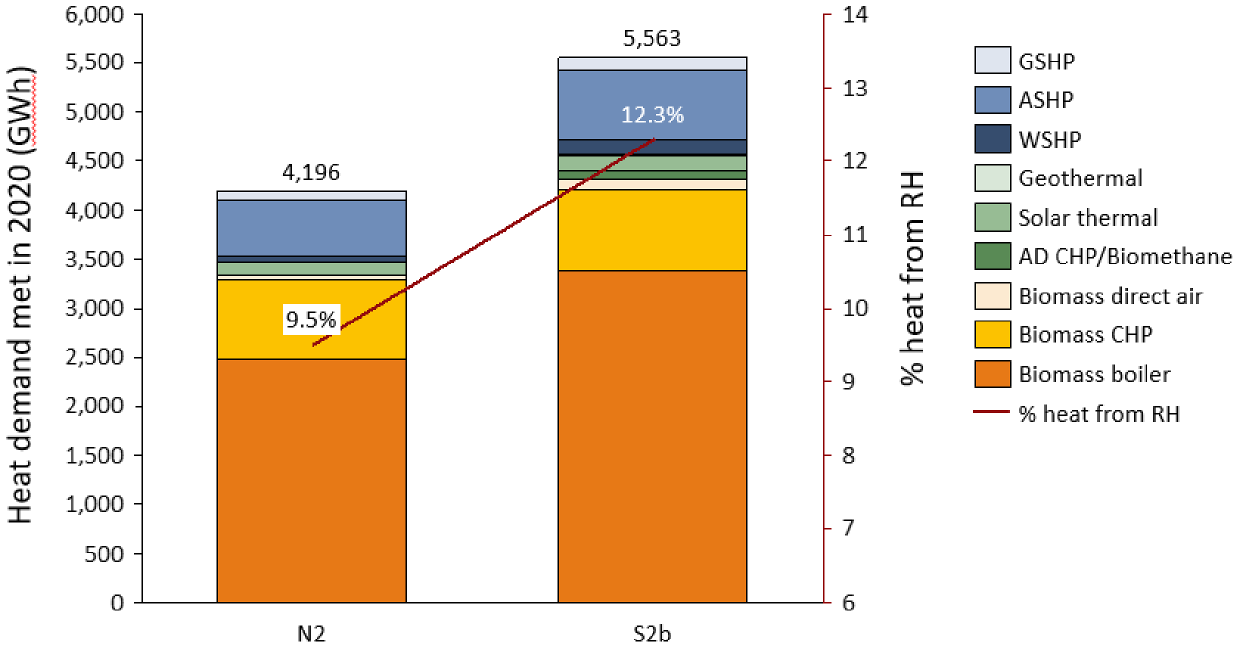


Table 7-100: Total heat demand met by RH technologies in 2020 in Scenario 2b

GWh	2015	2020 Scenario N2	2020 Scenario 2b
GSHP	99	103	131
ASHP	530	563	708
WSHP	50	51	152
Deep geothermal	0	7	12
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	105
Biomass CHP	84	827	824
Biomass boiler	2048	2467	3381
Total	**2951**	4196	5563
% heat from RH	**6.6%**	**9.5%**	**12.3%**

Figure 7-45: Annual RHI payments made in Scenario 2b (Low CHP)

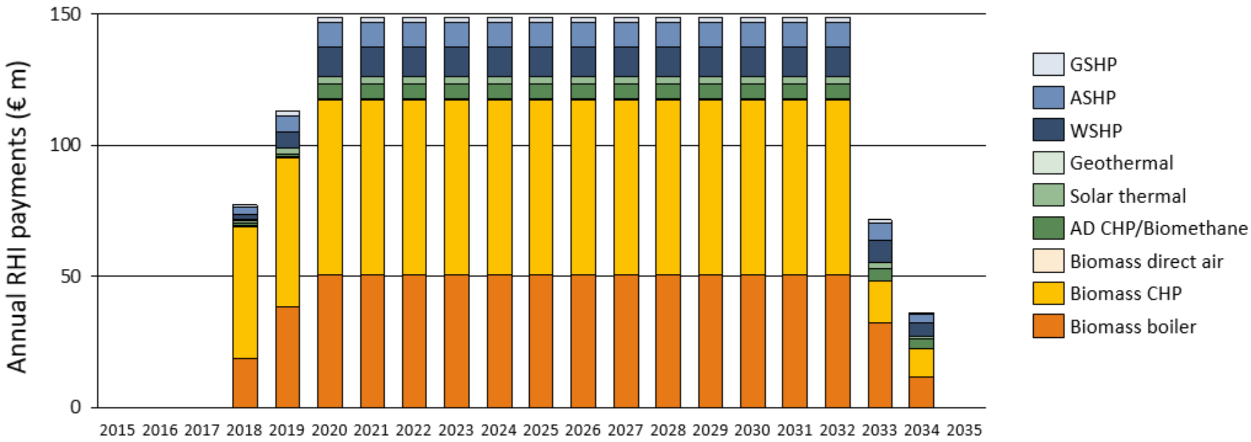


Table 7-101: Annual RHI payments made in Scenario 2b

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.7	1.4	2.1	2.1	2.1	2.1	2.1	2.1	2.1
ASHP	2.9	6.1	9.3	9.3	9.3	9.3	9.3	9.3	9.3
WSHP	2.3	6.2	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.6	5.6	5.6	5.6	5.6	5.6	5.6
Biomass direct air	0.2	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Biomass CHP	50.4	56.4	66.7	66.7	66.7	66.7	66.7	66.7	66.7
Biomass boiler	18.8	38.7	50.7	50.7	50.7	50.7	50.7	50.7	50.7
Total	**77.3**	**112.9**	**148.9**	**148.9**	**148.9**	**148.9**	**148.9**	**148.9**	**148.9**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.1	2.1	2.1	2.1	2.1	2.1	1.4	0.7	0.0
ASHP	9.3	9.3	9.3	9.3	9.3	9.3	6.4	3.2	0.0
WSHP	10.9	10.9	10.9	10.9	10.9	10.9	8.6	4.6	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.2	0.0
Biomass CHP	66.7	66.7	66.7	66.7	66.7	66.7	16.2	10.3	0.0
Biomass boiler	50.7	50.7	50.7	50.7	50.7	50.7	32.0	12.0	0.0
Total	**148.9**	**148.9**	**148.9**	**148.9**	**148.9**	**148.9**	**71.5**	**36.0**	**0.0**

Table 7-102: Cumulative RHI payments made in Scenario 2b

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	6	9	11	13	15	17
ASHP	3	9	18	28	37	46	56	65	74
WSHP	2	9	19	30	41	52	63	74	85
Deep geothermal	0	0	0	0	0	0	0	1	1
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	1	2	2	3	4	4	5
Biomass CHP	50	107	174	240	307	374	440	507	573
Biomass boiler	19	58	108	159	210	260	311	362	413
Total	**77**	**190**	**339**	**488**	**637**	**786**	**935**	**1,083**	**1,232**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	19	21	23	26	28	30	31	32	32
ASHP	84	93	102	112	121	130	137	140	140
WSHP	95	106	117	128	139	150	158	163	163
Deep geothermal	1	1	1	1	1	1	1	1	1
Solar thermal	30	33	37	40	43	46	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	5	6	7	7	8	8	9	9	9
Biomass CHP	640	707	773	840	907	973	990	1,000	1,000
Biomass boiler	463	514	565	615	666	717	749	761	761
Total	**1,381**	**1,530**	**1,679**	**1,828**	**1,977**	**2,125**	**2,197**	**2,233**	**2,233**

Table 7-103: Number of new installations 2016-2020 by technology and sector in Scenario 2b (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2564	114	676	0	**3354**
Biomass CHP	18	0	3	0	**21**
Biomass direct air	0	0	39	0	**39**
ASHP	2422	161	93	0	**2676**
GSHP	294	0	24	0	**319**
WSHP	273	48	12	0	**333**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1393**
AD CHP/ Biomethane	0	0	0	19	**19**
Total	**6891**	**396**	**849**	**19**	**8154**

Figure 7-46: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 2b

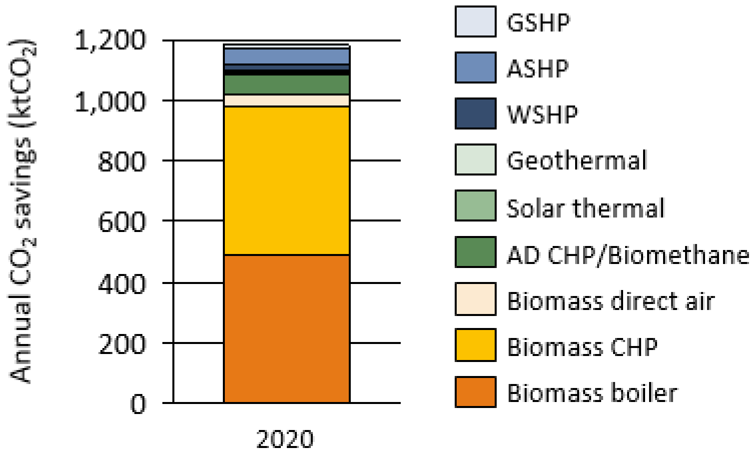
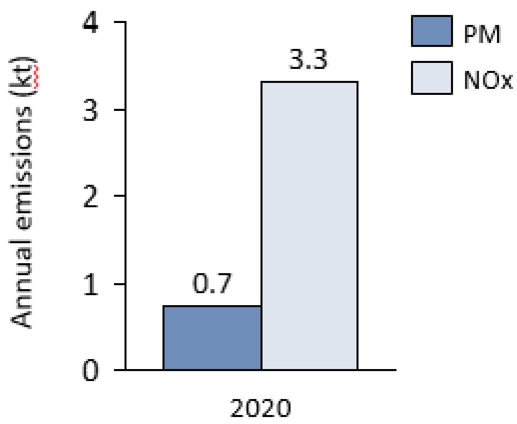


Table 7-104: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 2b

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	11.6
ASHP	49.2
WSHP	25.6
Deep geothermal	4.2
Solar thermal	6.7
AD CHP/ Biomethane	67.3
Biomass direct air	35.7
Biomass CHP	492.0
Biomass boiler	490.2
Total	**1182.6**

Table 7-105: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 2b



Scenario 12b - Include ETS sector - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price, Limited Biomass CHP in power sector

Results

Figure 7-47: Total heat demand met by RH technologies in 2020 in Scenario 12b (Low CHP)

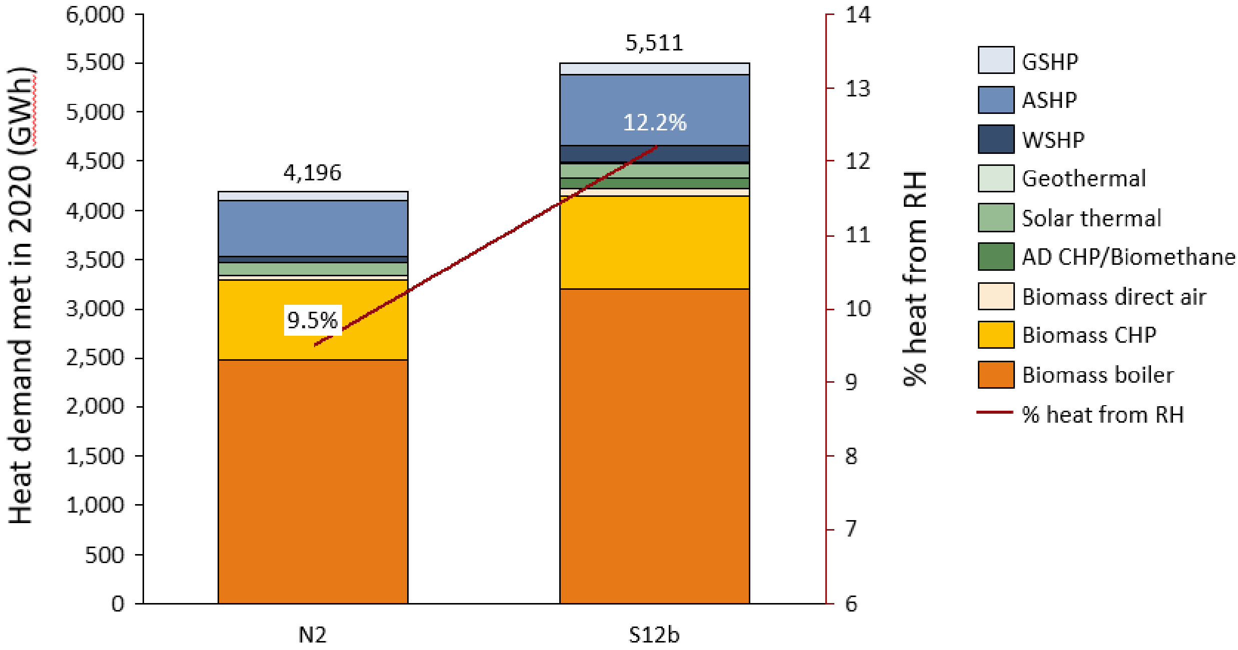


Table 7-106: Total heat demand met by RH technologies in 2020 in Scenario 12b

GWh	2015	2020 Scenario N2	2020 Scenario 12b
GSHP	99	103	132
ASHP	530	563	717
WSHP	50	51	171
Deep geothermal	0	7	18
Solar thermal	140	140	155
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	68
Biomass CHP	84	827	953
Biomass boiler	2048	2467	3202
Total	**2951**	**4196**	**5511**
% heat from RH	**6.6%**	**9.5%**	**12.2%**

Figure 7-48: Annual RHI payments made in Scenario 12b (Low CHP)

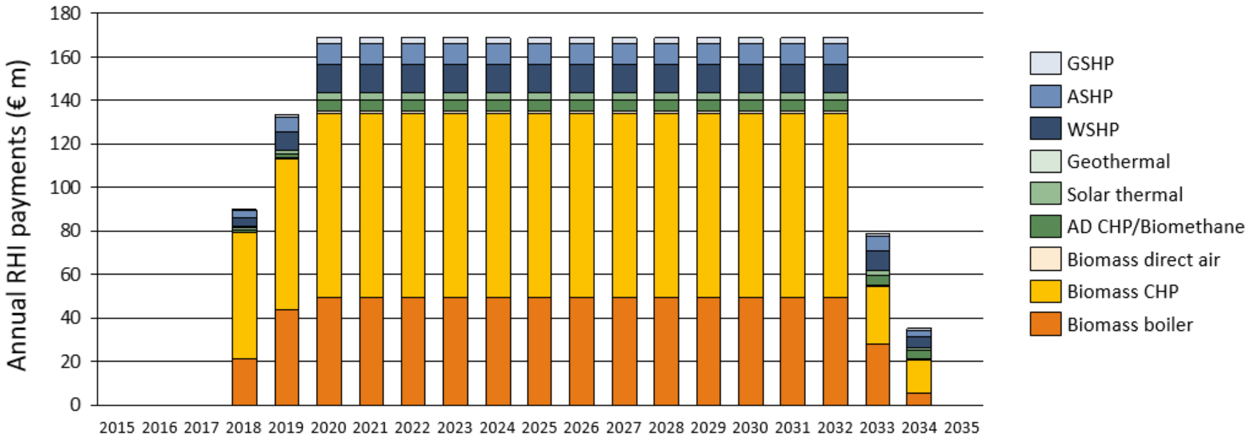


Table 7-107: Annual RHI payments made in Scenario 12b

Annual cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.8	1.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ASHP	3.3	6.6	10.0	10.0	10.0	10.0	10.0	10.0	10.0
WSHP	4.1	8.2	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Deep geothermal	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Solar thermal	1.1	2.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
AD CHP/ biomethane	0.8	1.3	5.2	5.2	5.2	5.2	5.2	5.2	5.2
Biomass direct air	0.3	0.5	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Biomass CHP	58.1	69.3	84.9	84.9	84.9	84.9	84.9	84.9	84.9
Biomass boiler	21.4	43.8	49.2	49.2	49.2	49.2	49.2	49.2	49.2
Total	**89.9**	**133.6**	**168.7**	**168.7**	**168.7**	**168.7**	**168.7**	**168.7**	**168.7**

Annual cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.2	2.2	2.2	2.2	2.2	2.2	1.5	0.7	0.0
ASHP	10.0	10.0	10.0	10.0	10.0	10.0	6.7	3.3	0.0
WSHP	12.9	12.9	12.9	12.9	12.9	12.9	8.8	4.7	0.0
Deep geothermal	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.0
Solar thermal	3.3	3.3	3.3	3.3	3.3	3.3	2.2	1.1	0.0
AD CHP/ biomethane	5.2	5.2	5.2	5.2	5.2	5.2	4.4	3.9	0.0
Biomass direct air	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0.3	0.0
Biomass CHP	84.9	84.9	84.9	84.9	84.9	84.9	26.8	15.6	0.0
Biomass boiler	49.2	49.2	49.2	49.2	49.2	49.2	27.8	5.4	0.0
Total	**168.7**	**168.7**	**168.7**	**168.7**	**168.7**	**168.7**	**78.8**	**35.1**	**0.0**

Table 7-108: Cumulative RHI payments made in Scenario 12b

Cumulative cost, €m	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	7	9	11	13	16	18
ASHP	3	10	20	30	40	50	60	70	80
WSHP	4	12	25	38	51	64	77	90	103
Deep geothermal	0	0	0	1	1	1	1	2	2
Solar thermal	1	3	7	10	13	17	20	23	27
AD CHP/ biomethane	1	2	7	12	18	23	28	33	38
Biomass direct air	0	1	2	2	3	4	5	6	6
Biomass CHP	58	127	212	297	382	467	552	637	722
Biomass boiler	21	65	114	164	213	262	311	360	409
Total	**90**	**223**	**392**	**561**	**729**	**898**	**1,067**	**1,235**	**1,404**

Cumulative cost, €m	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	20	22	24	27	29	31	32	33	33
ASHP	90	100	109	119	129	139	146	149	149
WSHP	115	128	141	154	167	180	189	193	193
Deep geothermal	2	2	3	3	3	3	4	4	4
Solar thermal	30	33	37	40	43	46	49	50	50
AD CHP/ biomethane	43	48	54	59	64	69	74	77	77
Biomass direct air	7	8	9	10	10	11	12	12	12
Biomass CHP	807	892	976	1,061	1,146	1,231	1,258	1,274	1,274
Biomass boiler	459	508	557	606	655	705	732	738	738
Total	**1,573**	**1,741**	**1,910**	**2,079**	**2,247**	**2,416**	**2,495**	**2,530**	**2,530**

Table 7-109: Number of new installations 2016-2020 by technology and sector in Scenario 12b (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2564	114	552	0	**3229**
Biomass CHP	18	0	2	0	**19**
Biomass direct air	0	0	39	0	**39**
ASHP	2422	161	106	0	**2689**
GSHP	294	0	25	0	**319**
WSHP	273	48	13	0	**334**
Deep geothermal	0	0	1	0	**1**
Solar thermal	1320	73	0	0	**1393**
AD CHP/ Biomethane	0	0	0	19	**19**
Total	**6891**	**396**	**737**	**19**	**8043**

Figure 7-49: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 12b

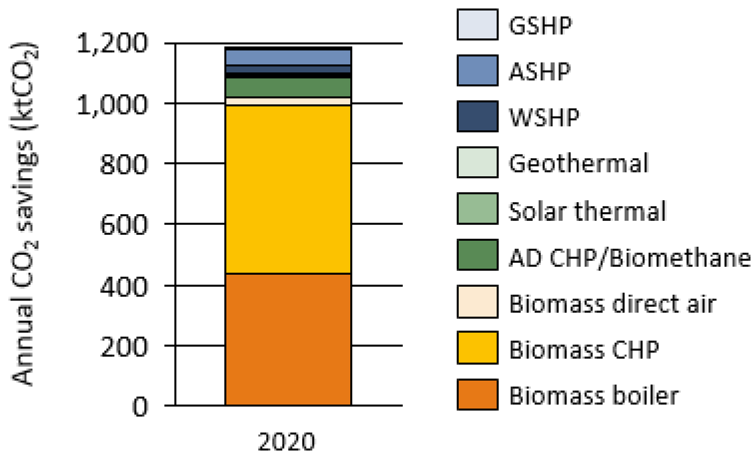
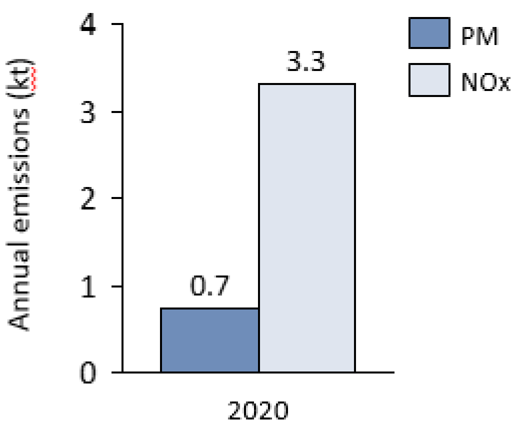


Table 7-110: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 12b

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	11.9
ASHP	50.9
WSHP	30.0
Deep geothermal	6.3
Solar thermal	6.7
AD CHP/ Biomethane	67.3
Biomass direct air	24.8
Biomass CHP	553.5
Biomass boiler	439.7
Total	**1191.1**

Table 7-111: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 12b



Scenario N2b - No RHI - Strongly limited imported biomass (1.5 TWh/yr), tariff based on 6.9 c/kWh biomass price, Limited Biomass CHP in power sector

Results

Figure 7-50: Total heat demand met by RH technologies in 2020 in Scenario N2b (Low CHP)

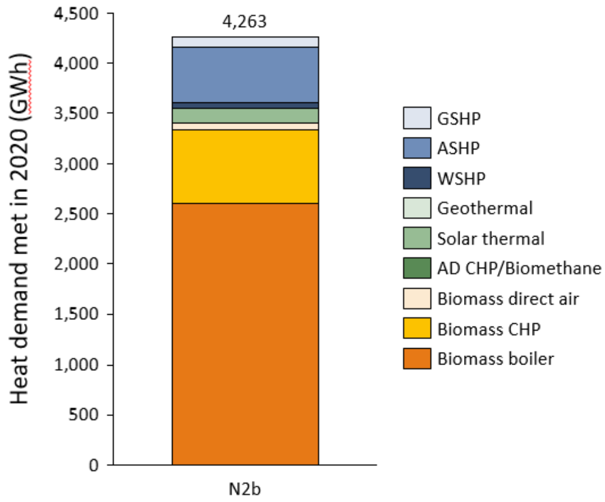


Table 7-112: Total heat demand met by RH technologies in 2020 in Scenario N2b

GWh	2015	2020 Scenario N2b
GSHP	99	102
ASHP	530	558
WSHP	50	51
Deep geothermal	0	3
Solar thermal	140	140
AD CHP/ biomethane	0	0
Biomass direct air	0	66
Biomass CHP	84	738
Biomass boiler	2048	2605
Total	**2951**	**4263**
% heat from RH	**6.6%**	**9.6%**

Table 7-113: Number of new installations 2016-2020 by technology and sector in Scenario N2b (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	0	0	141	0	**141**
Biomass CHP	0	0	1	0	**1**
Biomass direct air	0	0	25	0	**25**
ASHP	169	4	25	0	**197**
GSHP	9	0	3	0	**12**
WSHP	0	0	0	0	**0**
Deep geothermal	0	0	1	0	**1**
Solar thermal	0	0	0	0	**0**
AD CHP/ Biomethane	0	0	0	19	**19**
Total	**177**	**4**	**196**	**19**	**396**

Figure 7-51: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario N2b

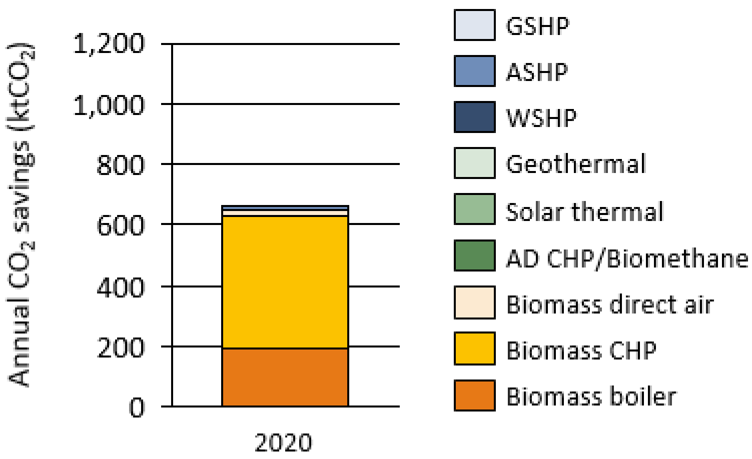
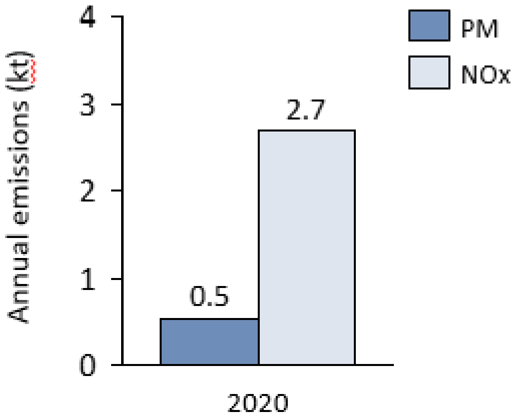


Table 7-114: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario N2b

Annual CO_2 savings ($ktCO_2$)	2020
GSHP	1.3
ASHP	9.2
WSHP	0.2
Deep geothermal	1.0
Solar thermal	0.0
AD CHP/ Biomethane	0.0
Biomass direct air	20.6
Biomass CHP	441.1
Biomass boiler	189.1
Total	**662.6**

Table 7-115: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario N2b



8 Appendix 3: Full list of stakeholders consulted

Element Energy stakeholder engagement

- Ashgrove
- Bord Na Mona
- Codema
- Coillte
- Confederation of European Waste-to-Energy Plants Ireland (CEWEP Ireland)
- Cre
- Dept. of Agriculture
- Dept. of Environment – Northern Ireland
- Dept. of Environment – Republic of Ireland
- Electricity Supply Board
- Environmental Protection Agency
- Gaelectric
- Gas Networks Ireland
- Geothermal Association of Ireland (GAI)
- GI Energy
- Glen Dimplex
- Green Energy Engineering
- Heat Pump Association of Ireland (HPA)
- Irish BioEnergy Association (IrBEA)
- Letterkenny IT
- Renewable Gas Forum – Irish Green Gas Ltd
- Sustainable Energy Authority of Ireland (SEAI)
- Teagasc
- Terawatt Ireland
- Tipperary Energy Agency
- University College Dublin

Ricardo Energy & Environment stakeholder engagement

- Ormonde Organics
- Fingleton White
- FLI Group
- NRGE Ltd
- Technology Centre for Biorefining and Bioenergy (TCBB)

- Calor
- Cré
- Farmgas
- Gas Networks Ireland
- Green Forty Development Ltd.
- Renewable Gas Forum Ireland (RGFI)
- Siemens
- Stream Bioenergy
- IrBea
- AbbVie Ireland NL B.V
- Commission for Energy Regulation
- International Energy Research Centre

elementenergy

Economic analysis for the Renewable Heat Incentive for Ireland

Adjunct to **Section 1**: *Main report*

for

Sustainable Energy Authority of Ireland (SEAI)

and

Department of Communications, Climate Action & Environment (DCCAE)

September 2017

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9 Introduction

Subsequent to the submission of the final RHI report by Element Energy to DCCAE in Quarter 2 2017, government deliberations on the specific proposals for the scheme have led to a number of additional questions. To examine the impact of these a number of amended scenarios are required. At present there are several specific questions outstanding:

- What would be the impact of including the ETS in the lead scenario?
- What would be the impact of limiting the tariff to Biomass boilers only?
- What would be the impact of removing the Renewable Electricity Support Scheme (RESS) support for Biomass CHP?
- What would be the impact of targeting the scheme at fossil-fuel heated buildings for part or all of the scheme?
- What would be the impact of supporting heat pumps through a grant scheme instead of the RHI?

Based on this list of key questions, five scenarios were constructed in partnership with SEAI, DCCAE and NTMA. This adjunct to the final RHI report describes the results of these additional scenarios.

10 Definition of scenarios

The five additional scenarios studied as part of this assignment are as follows:

Additional Scenario A1: "Scenario 5 with ETS included"

- Tariffs and biomass import availability/price as for Scenario 5
- Include ETS sector

Additional Scenario A2: "Focus on fossil fuel heated buildings in 1st phase (exclude ETS)"

- Tariffs and biomass import availability/price as for Scenario 5
- Exclude ETS sector
- Only Biomass boilers supported[91]
- Phased focus on fossil fuel heating
    - 2018/2019 (Year 1): Only buildings with non-electric counterfactual heating supported
    - 2019/2020 and 2020/2021 (Years 2 and 3): Buildings with all counterfactual fuel types supported
- Remove RESS for Biomass CHP
- Include 35% grant for ASHP, GSHP and WSHP (Commercial and Industry sector, not Residential)

Additional Scenario A3: "Focus on fossil fuel heated buildings for whole scheme (exclude ETS)"

- Tariffs and biomass import availability/price as for Scenario 5
- Exclude ETS sector

[91] AD CHP is also included in all scenarios according to the scenarios developed by Ricardo Energy & Environment presented in the Final report.

- Only Biomass boilers supported
- Phased focus on fossil fuel heating: Only buildings with non-electric counterfactual heating supported (Years 1, 2 and 3)
- Remove RESS for Biomass CHP
- Include 35% grant for ASHP, GSHP and WSHP (Commercial and Industry sector, not Residential)

Additional Scenario A4: "Focus on fossil fuel heated buildings in 1st phase (include ETS)"

- Tariffs and biomass import availability/price as for Scenario 5
- Include ETS sector
- Only Biomass boilers supported
- Phased focus on fossil fuel heating
    - 2018/2019 (Year 1): Only buildings with non-electric counterfactual heating supported
    - 2019/2020 and 2020/2021 (Years 2 and 3): Buildings with all counterfactual fuel types supported
- Remove RESS for Biomass CHP
- Include 35% grant for ASHP, GSHP and WSHP (Commercial and Industry sector, not Residential)

Additional Scenario A5: "Focus on fossil fuel heated buildings for whole scheme (include ETS)"

- Tariffs and biomass import availability/price as for Scenario 5
- Include ETS sector
- Only Biomass boilers supported
- Phased focus on fossil fuel heating: Only buildings with non-electric counterfactual heating supported (Years 1, 2 and 3)
- Remove RESS for Biomass CHP
- Include 35% grant for ASHP, GSHP and WSHP (Commercial and Industry sector, not Residential)

11 Results

The results of the five additional scenarios studied in this assignment are presented below. The results of the original Scenario 5 as presented in the final RHI report are reproduced here for comparison.

It should be noted that some of the additional scenarios studied should be compared with a different 'No RHI' baseline from Scenario 5, due to the removal of RESS support for Biomass CHP (in both the baseline 'No RHI' case and the RHI case). Scenario A1 takes the same 'No RHI' baseline as Scenario 5 (Scenario N2); Scenarios A2-A5 take a new 'No RHI' baseline (Scenario N3).

Figure 11-1: Summary outputs from the additional scenarios and comparison with Scenario 5

ID	RHI offered	Annual heat output from all RH techs in 2020 (GWh)	% RH (fraction of all heat from renewable sources)	RHI: Total cost to the Exchequer 2018-2034 (€ million, undiscounted)	RHI: Cost to the Exchequer in 2020 (€ million)	Grants for HPs: Total cost to the Exchequer 2018-2020 (€ million)	Annual CO2 savings from RH techs installed 2016-2020 in 2020 (ktCO2) (Based on lifecycle emissions)			Total CO2 savings 2016-2034 (MtCO2) (Based on lifecycle emissions)			Non-ETS fraction of total CO2 savings (%)
							ETS + Non-ETS	ETS only	Non-ETS only	ETS + Non-ETS	ETS only	Non-ETS only	
N2 (No RHI)	No	4,196	9.5%	N/A	N/A	N/A	689	661	28	11.3	10.8	0.5	4%
5	Yes	5,422	12.0%	1,188	79	0	1,092	968	125	17.8	15.8	2.0	11%
A1	Yes	5,423	12.1%	1,259	84	0	1,103	984	119	18.0	16.2	1.9	11%
N3 (No RHI, No RESS)	No	3,804	8.7%	N/A	N/A	N/A	305	288	18	4.9	4.6	0.3	6%
A2	Yes	5,157	11.5%	893	60	21	784	626	158	12.5	10.0	2.5	20%
A3	Yes	4,272	9.7%	467	31	8	452	267	185	7.2	4.3	2.9	40%
A4	Yes	5,289	11.8%	1,042	69	21	832	670	162	13.2	10.7	2.5	19%
A5	Yes	4,302	9.7%	477	32	9	459	293	166	7.3	4.7	2.6	36%

Scenario 5 (reproduced from Final report for comparison)

Figure 11-2: Total heat demand met by RH technologies in 2020 in Scenario 5

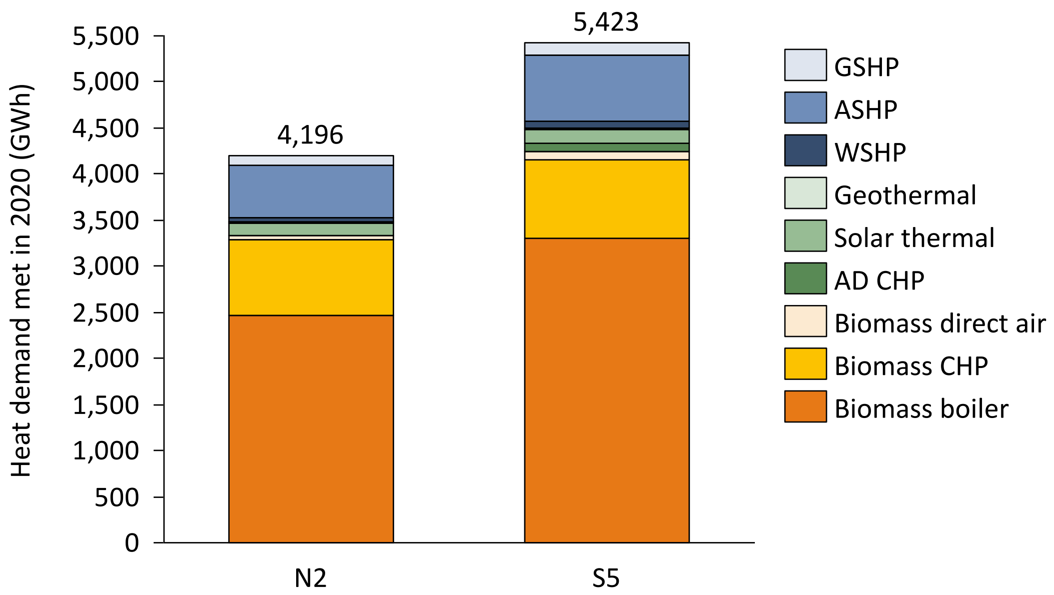


Table 11-1: Total heat demand met by RH technologies in 2020 in Scenario 5

GWh	2015	2020 Scenario N2	2020 Scenario 5
GSHP	99	103	133
ASHP	530	563	719
WSHP	50	51	69
Deep geothermal	0	7	24
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	85
Biomass CHP	84	827	848
Biomass boiler	2048	2467	3310
Total	**2951**	**4196**	**5422**
% heat from RH	**6.6%**	**9.5%**	**12.0%**

Figure 11-3: Annual RHI payments made in Scenario 5

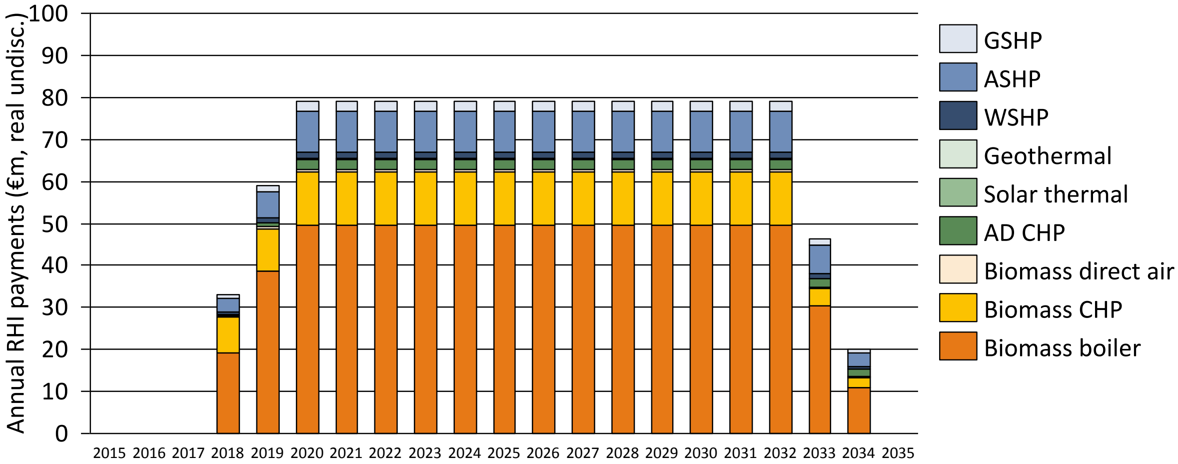


Table 11-2: Annual RHI payments made in Scenario 5

Annual cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.8	1.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ASHP	3.1	6.4	9.7	9.7	9.7	9.7	9.7	9.7	9.7
WSHP	0.6	1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Deep geothermal	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.5	0.8	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Biomass direct air	0.2	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Biomass CHP	8.6	10.2	12.7	12.7	12.7	12.7	12.7	12.7	12.7
Biomass boiler	19.1	38.6	49.5	49.5	49.5	49.5	49.5	49.5	49.5
Total	**32.8**	**59.1**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**

Annual cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.2	2.2	2.2	2.2	2.2	2.2	1.4	0.7	0.0
ASHP	9.7	9.7	9.7	9.7	9.7	9.7	6.7	3.3	0.0
WSHP	1.7	1.7	1.7	1.7	1.7	1.7	1.1	0.6	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	2.5	2.5	2.5	2.5	2.5	2.5	2.0	1.7	0.0
Biomass direct air	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.2	0.0
Biomass CHP	12.7	12.7	12.7	12.7	12.7	12.7	4.1	2.5	0.0
Biomass boiler	49.5	49.5	49.5	49.5	49.5	49.5	30.4	10.9	0.0
Total	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**79.2**	**46.3**	**20.1**	**0.0**

Table 11-3: Cumulative RHI payments made in Scenario 5

Cumulative cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	4	7	9	11	13	15	18
ASHP	3	9	19	29	39	48	58	68	78
WSHP	1	2	3	5	7	8	10	12	13
Deep geothermal	0	0	0	0	1	1	1	1	1
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	1	4	6	9	11	14	16	19
Biomass direct air	0	1	1	2	3	3	4	5	5
Biomass CHP	9	19	32	44	57	70	82	95	108
Biomass boiler	19	58	107	157	206	256	305	355	405
Total	**33**	**92**	**171**	**250**	**330**	**409**	**488**	**567**	**647**

Cumulative cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	20	22	24	27	29	31	32	33	33
ASHP	87	97	107	117	126	136	143	146	146
WSHP	15	17	18	20	22	23	24	25	25
Deep geothermal	1	1	2	2	2	2	2	2	2
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	22	24	27	29	32	34	36	38	38
Biomass direct air	6	6	7	8	8	9	9	10	10
Biomass CHP	121	133	146	159	172	184	188	191	191
Biomass boiler	454	504	553	603	652	702	732	743	743
Total	**726**	**805**	**884**	**963**	**1,043**	**1,122**	**1,168**	**1,188**	**1,188**

Table 11-4: Number of new installations 2016-2020 by technology and sector in Scenario 5 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2576	114	620	0	**3310**
Biomass CHP	0	0	1	0	**1**
Biomass direct air	0	0	42	0	**42**
ASHP	2430	192	96	0	**2718**
GSHP	303	0	25	0	**328**
WSHP	244	14	5	0	**263**
Deep geothermal	0	0	1	0	**1**
Solar thermal	0	8	0	0	**8**
AD CHP/ biomethane	0	0	0	19	**19**
Total	**5553**	**328**	**789**	**19**	**6690**

Figure 11-4: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 5 (based on lifecycle emissions)

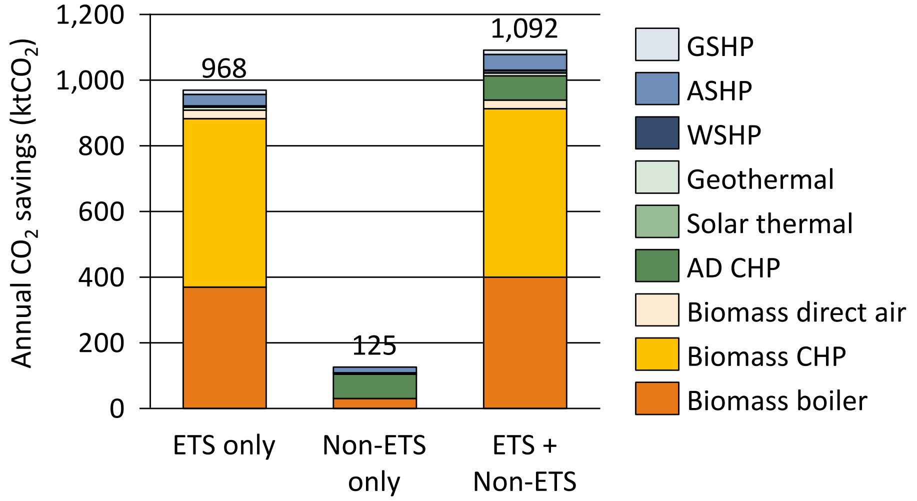
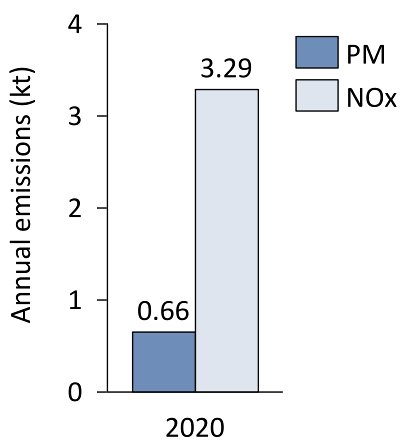


Table 11-5: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario 5 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11.5	0.6	12.1
ASHP	33.9	17.2	51.1
WSHP	6.4	0.4	6.8
Deep geothermal	6.7	1.6	8.4
Solar thermal	0.0	0.0	0.0
AD CHP/ biomethane	0.0	73.5	73.5
Biomass direct air	26.2	0.3	26.3
Biomass CHP	512.1	1.2	513.9
Biomass boiler	371.0	29.8	400.2
Total	**967.8**	**124.6**	**1,092.4**

Table 11-6: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario 5



Scenario A1

Figure 11-5: Total heat demand met by RH technologies in 2020 in Scenario A1

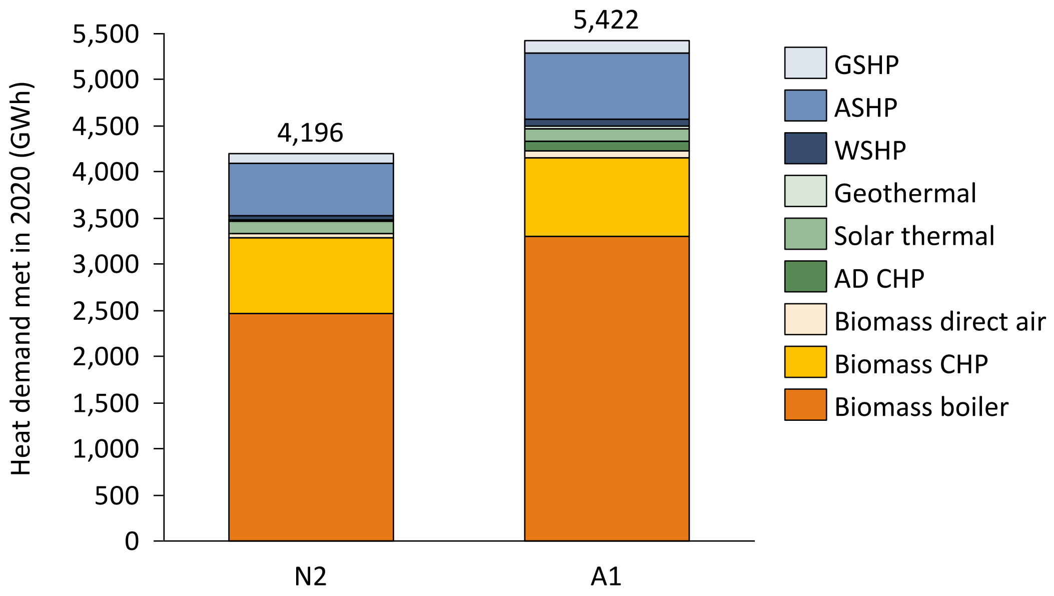


Table 11-7: Total heat demand met by RH technologies in 2020 in Scenario A1

GWh	2015	2020 Scenario N2	2020 Scenario A1
GSHP	99	103	133
ASHP	530	563	720
WSHP	50	51	69
Deep geothermal	0	7	30
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	38	78
Biomass CHP	84	827	859
Biomass boiler	2048	2467	3298
Total	**2951**	**4196**	**5423**
% heat from RH	**6.6%**	**9.5%**	**12.0%**

Figure 11-6: Annual RHI payments made in Scenario A1

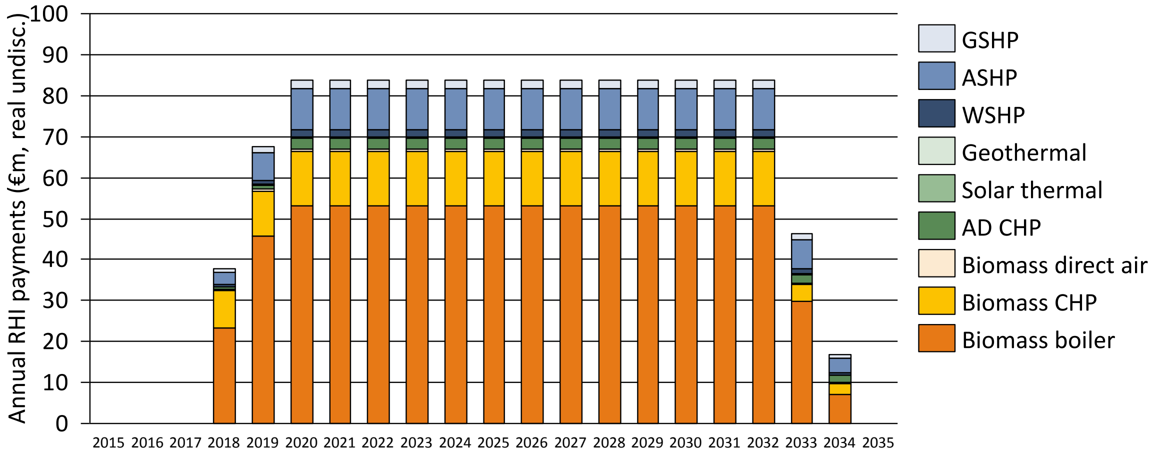


Table 11-8: Annual RHI payments made in Scenario A1

Annual cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.8	1.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2
ASHP	3.1	6.6	10.0	10.0	10.0	10.0	10.0	10.0	10.0
WSHP	0.6	1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Deep geothermal	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.5	0.8	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Biomass direct air	0.3	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Biomass CHP	9.2	10.8	13.3	13.3	13.3	13.3	13.3	13.3	13.3
Biomass boiler	23.2	45.8	53.0	53.0	53.0	53.0	53.0	53.0	53.0
Total	**37.8**	**67.3**	**83.9**	**83.9**	**83.9**	**83.9**	**83.9**	**83.9**	**83.9**

Annual cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	2.2	2.2	2.2	2.2	2.2	2.2	1.5	0.8	0.0
ASHP	10.0	10.0	10.0	10.0	10.0	10.0	6.9	3.4	0.0
WSHP	1.7	1.7	1.7	1.7	1.7	1.7	1.1	0.6	0.0
Deep geothermal	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	2.5	2.5	2.5	2.5	2.5	2.5	2.0	1.7	0.0
Biomass direct air	0.8	0.8	0.8	0.8	0.8	0.8	0.5	0.3	0.0
Biomass CHP	13.3	13.3	13.3	13.3	13.3	13.3	4.1	2.5	0.0
Biomass boiler	53.0	53.0	53.0	53.0	53.0	53.0	29.7	7.2	0.0
Total	**83.9**	**83.9**	**83.9**	**83.9**	**83.9**	**83.9**	**46.1**	**16.6**	**0.0**

Table 11-9: Cumulative RHI payments made in Scenario A1

Cumulative cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	5	7	9	11	13	16	18
ASHP	3	10	20	30	40	50	60	70	80
WSHP	1	2	3	5	7	8	10	12	13
Deep geothermal	0	0	1	1	2	2	2	3	3
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	1	4	6	9	11	14	16	19
Biomass direct air	0	1	2	3	3	4	5	6	7
Biomass CHP	9	20	33	47	60	73	86	100	113
Biomass boiler	23	69	122	175	228	281	334	387	440
Total	**38**	**105**	**189**	**273**	**357**	**441**	**525**	**609**	**693**

Cumulative cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	20	22	25	27	29	31	33	34	20
ASHP	90	100	110	120	129	139	146	150	90
WSHP	15	17	18	20	22	23	24	25	15
Deep geothermal	4	4	5	5	5	6	6	6	4
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	21	24	26	29	31	34	36	38	21
Biomass direct air	8	8	9	10	11	12	12	12	8
Biomass CHP	126	140	153	166	180	193	197	199	126
Biomass boiler	493	546	599	652	705	757	787	794	493
Total	**776**	**860**	**944**	**1,028**	**1,112**	**1,196**	**1,242**	**1,259**	**1,259**

Table 11-10: Number of new installations 2016-2020 by technology and sector in Scenario A1 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2576	114	607	0	3297
Biomass CHP	0	0	1	0	1
Biomass direct air	0	0	41	0	41
ASHP	2430	192	96	0	2718
GSHP	303	0	25	0	328
WSHP	244	14	6	0	263
Deep geothermal	0	0	1	0	1
Solar thermal	0	8	0	0	8
AD CHP/ biomethane	0	0	0	19	19
Total	**5553**	**328**	**777**	**19**	**6677**

Figure 11-7: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A1 (based on lifecycle emissions)

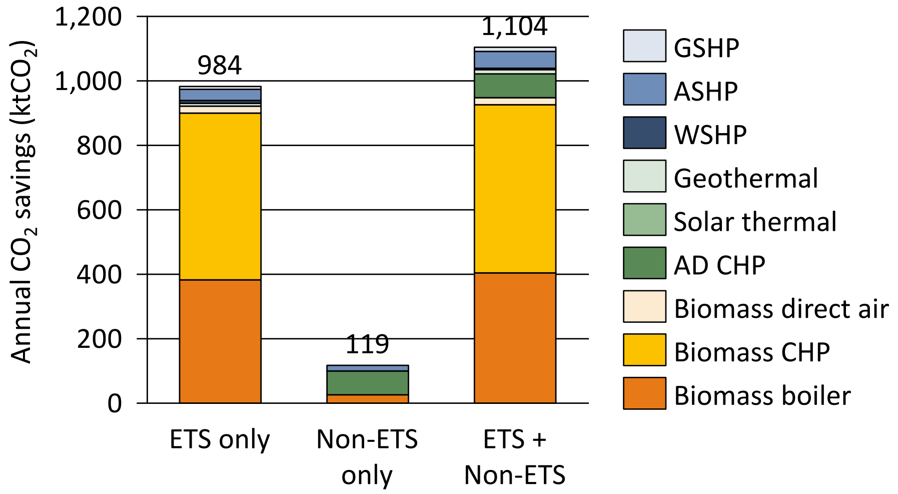
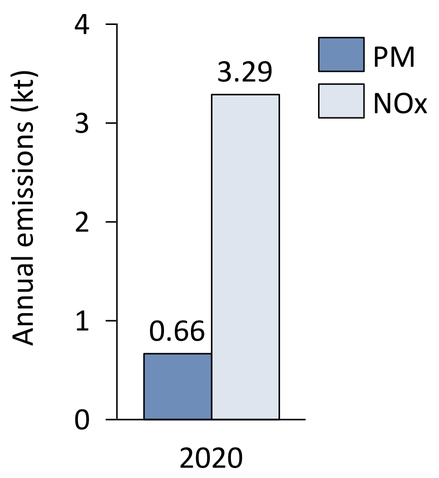


Table 11-11: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A1 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11.7	0.6	12.3
ASHP	33.8	17.2	51.0
WSHP	6.5	0.4	6.9
Deep geothermal	9.0	1.6	10.7
Solar thermal	0.0	0.0	0.0
AD CHP/ biomethane	0.0	73.5	73.5
Biomass direct air	23.6	0.6	24.0
Biomass CHP	517.6	1.2	519.6
Biomass boiler	382.0	24.1	405.5
Total	**984.2**	**119.2**	**1,103.4**

Table 11-12: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario A1



Scenario A2

Figure 11-8: Total heat demand met by RH technologies in 2020 in Scenario A2

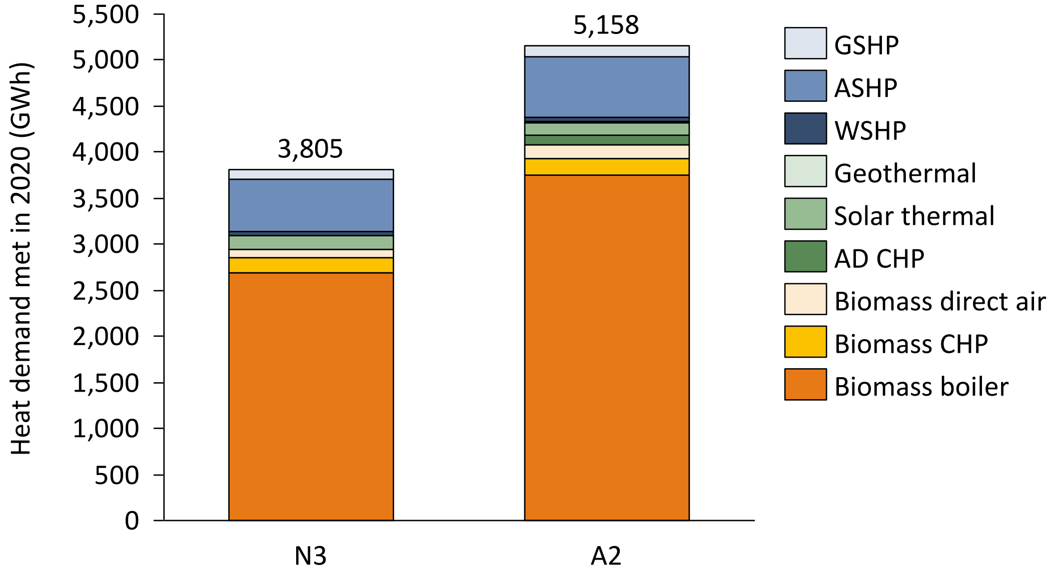


Table 11-13: Total heat demand met by RH technologies in 2020 in Scenario A2

GWh	2015	2020 Scenario N3	2020 Scenario A2
GSHP	99	102	127
ASHP	530	558	648
WSHP	50	51	55
Deep geothermal	0	3	10
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	93	153
Biomass CHP	84	165	174
Biomass boiler	2048	2693	3756
Total	**2951**	**3804**	**5157**
% heat from RH	**6.6%**	**8.7%**	**11.5%**

Figure 11-9: Annual RHI payments made in Scenario A2

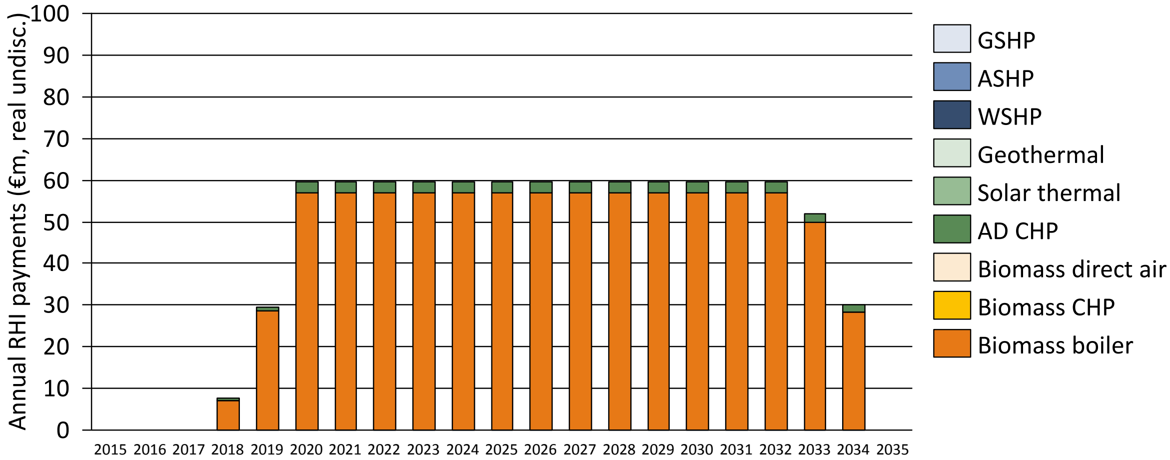


Table 11-14: Annual RHI payments made in Scenario A2

Annual cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.5	0.8	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	7.2	28.7	57.0	57.0	57.0	57.0	57.0	57.0	57.0
Total	**7.7**	**29.5**	**59.5**	**59.5**	**59.5**	**59.5**	**59.5**	**59.5**	**59.5**

Annual cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	2.5	2.5	2.5	2.5	2.5	2.5	2.0	1.7	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	57.0	57.0	57.0	57.0	57.0	57.0	49.8	28.3	0.0
Total	**59.5**	**59.5**	**59.5**	**59.5**	**59.5**	**59.5**	**51.8**	**30.0**	**0.0**

Table 11-15: Cumulative RHI payments made in Scenario A2

Cumulative cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	1	4	6	9	11	14	16	19
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	7	36	93	150	207	264	321	378	435
Total	**8**	**37**	**97**	**156**	**216**	**275**	**335**	**394**	**454**

Cumulative cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	22	24	27	29	32	34	36	38	38
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	492	549	606	663	720	777	827	855	855
Total	**514**	**573**	**633**	**692**	**752**	**811**	**863**	**893**	**893**

Table 11-16: Number of new installations 2016-2020 by technology and sector in Scenario A2 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2748	209	852	0	3809
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	47	0	47
ASHP	1742	13	83	0	1839
GSHP	109	0	26	0	135
WSHP	5	1	4	0	10
Deep geothermal	0	0	1	0	1
Solar thermal	0	0	0	0	0
AD CHP/ biomethane	0	0	0	19	19
Total	**4604**	**223**	**1014**	**19**	**5860**

Figure 11-10: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A2 (based on lifecycle emissions)

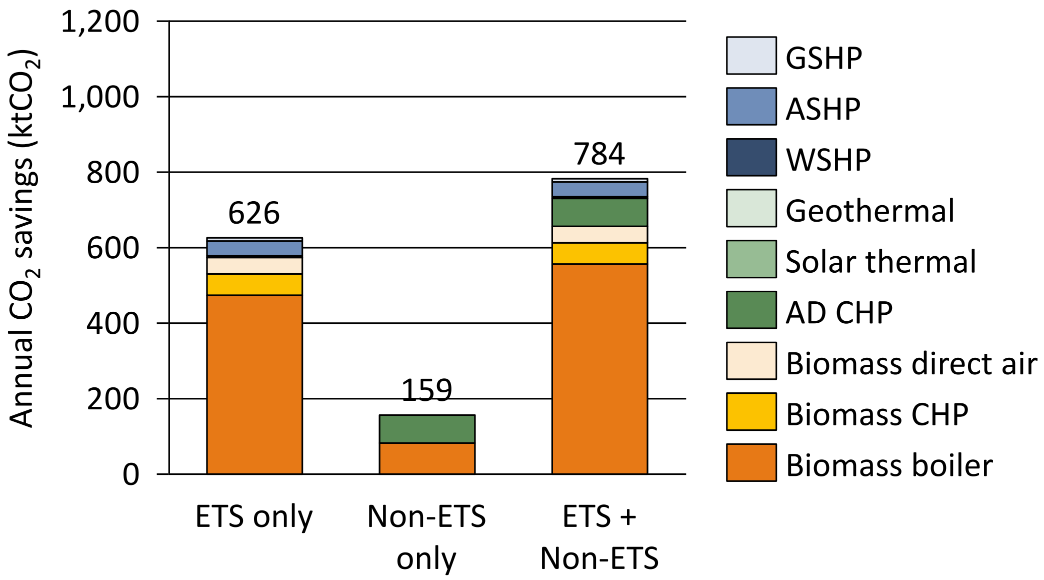
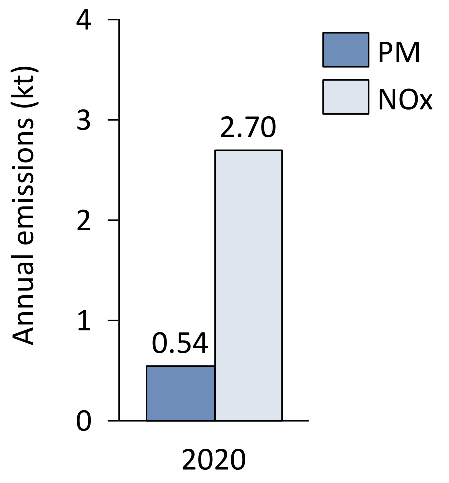


Table 11-17: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A2 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10.1	0.0	10.2
ASHP	37.6	0.5	38.1
WSHP	1.7	0.0	1.7
Deep geothermal	3.0	0.7	3.7
Solar thermal	0.0	0.0	0.0
AD CHP/ biomethane	0.0	73.5	73.5
Biomass direct air	43.3	0.6	43.5
Biomass CHP	56.0	0.1	56.4
Biomass boiler	474.0	83.1	557.1
Total	**625.8**	**158.5**	**784.3**

Table 11-18: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario A2



Scenario A3

Figure 11-11: Total heat demand met by RH technologies in 2020 in Scenario A3

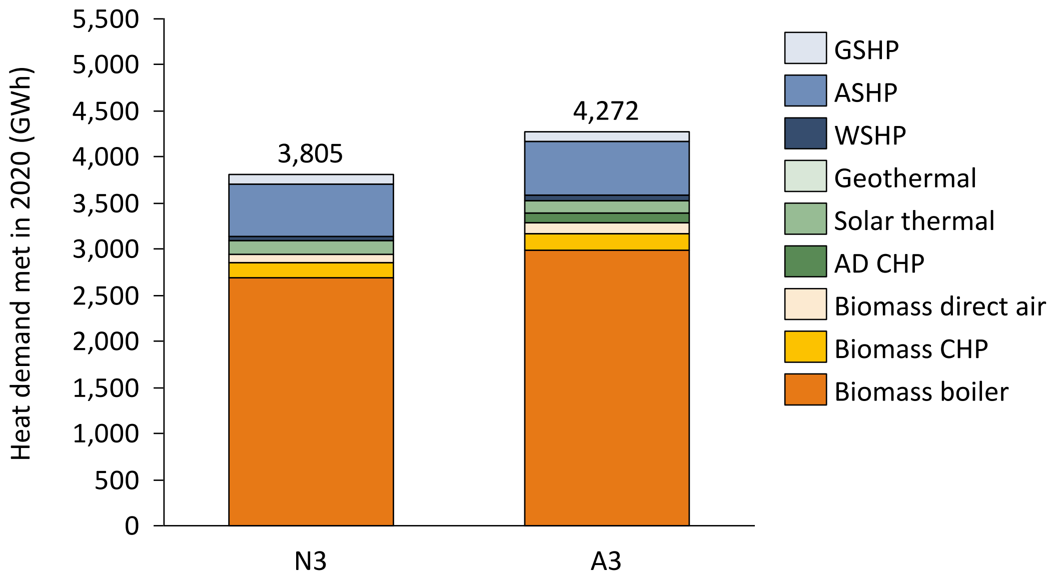


Table 11-19: Total heat demand met by RH technologies in 2020 in Scenario A3

GWh	2015	2020 Scenario N3	2020 Scenario A3
GSHP	99	102	109
ASHP	530	558	578
WSHP	50	51	52
Deep geothermal	0	3	5
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	93	129
Biomass CHP	84	165	169
Biomass boiler	2048	2693	2995
Total	**2951**	**3804**	**4272**
% heat from RH	**6.6%**	**8.7%**	**9.7%**

Figure 11-12: Annual RHI payments made in Scenario A3

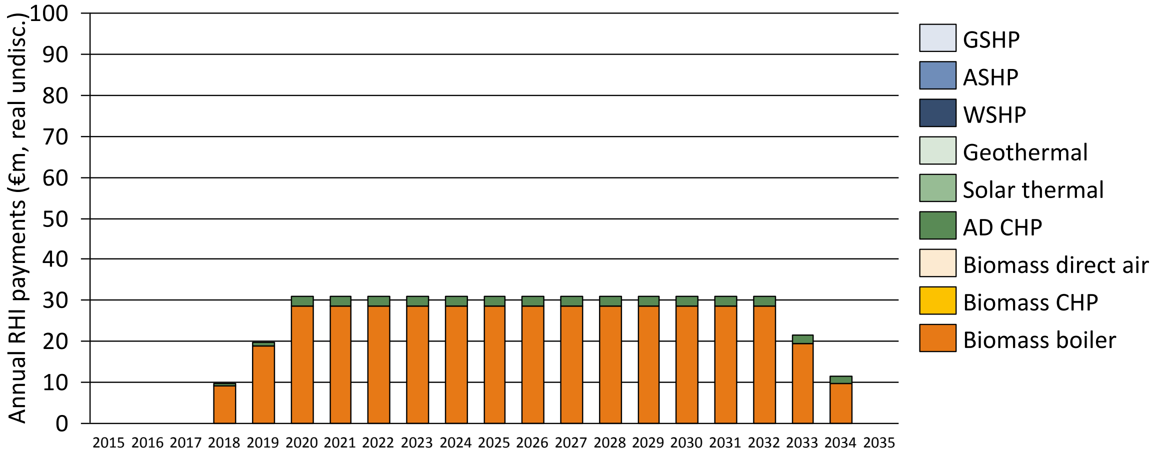


Table 11-20: Annual RHI payments made in Scenario A3

Annual cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.5	0.8	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	9.1	18.9	28.6	28.6	28.6	28.6	28.6	28.6	28.6
Total	**9.6**	**19.7**	**31.1**	**31.1**	**31.1**	**31.1**	**31.1**	**31.1**	**31.1**

Annual cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	2.5	2.5	2.5	2.5	2.5	2.5	2.0	1.7	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	28.6	28.6	28.6	28.6	28.6	28.6	19.5	9.7	0.0
Total	**31.1**	**31.1**	**31.1**	**31.1**	**31.1**	**31.1**	**21.5**	**11.4**	**0.0**

Table 11-21: Cumulative RHI payments made in Scenario A3

Cumulative cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	1	4	6	9	11	14	16	19
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	9	28	57	85	114	142	171	200	228
Total	**10**	**29**	**61**	**91**	**123**	**153**	**185**	**216**	**247**

Cumulative cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	22	24	27	29	32	34	36	38	38
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	257	285	314	343	371	400	419	429	429
Total	**279**	**309**	**341**	**372**	**403**	**434**	**455**	**467**	**467**

Table 11-22: Number of new installations 2016-2020 by technology and sector in Scenario A3 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	122	219	649	0	990
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	38	0	38
ASHP	759	7	30	0	795
GSHP	43	0	9	0	52
WSHP	2	0	1	0	3
Deep geothermal	0	0	1	0	1
Solar thermal	0	0	0	0	0
AD CHP/ biomethane	0	0	0	19	19
Total	**925**	**226**	**729**	**19**	**1900**

Figure 11-13: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A3 (based on lifecycle emissions)

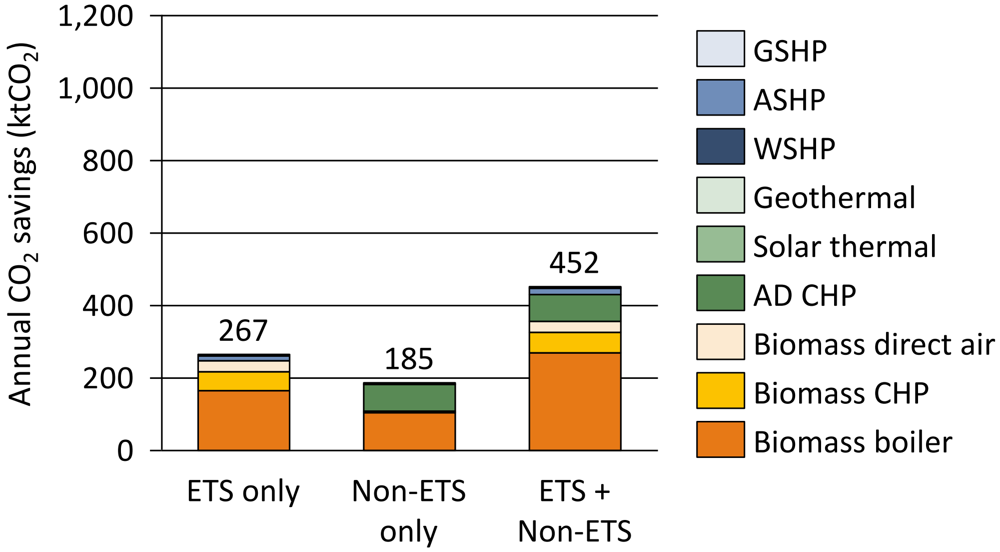
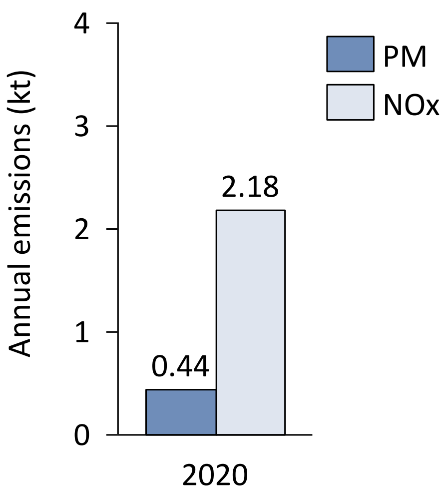


Table 11-23: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A3 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	3.7	0.0	3.7
ASHP	15.1	0.4	15.6
WSHP	0.5	0.0	0.5
Deep geothermal	1.3	0.3	1.6
Solar thermal	0.0	0.0	0.0
AD CHP/ biomethane	0.0	73.5	73.5
Biomass direct air	28.2	4.9	32.8
Biomass CHP	52.3	0.4	52.9
Biomass boiler	165.6	105.5	271.1
Total	**266.8**	**184.9**	**451.7**

Table 11-24: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario A3



Scenario A4

Figure 11-14: Total heat demand met by RH technologies in 2020 in Scenario A4

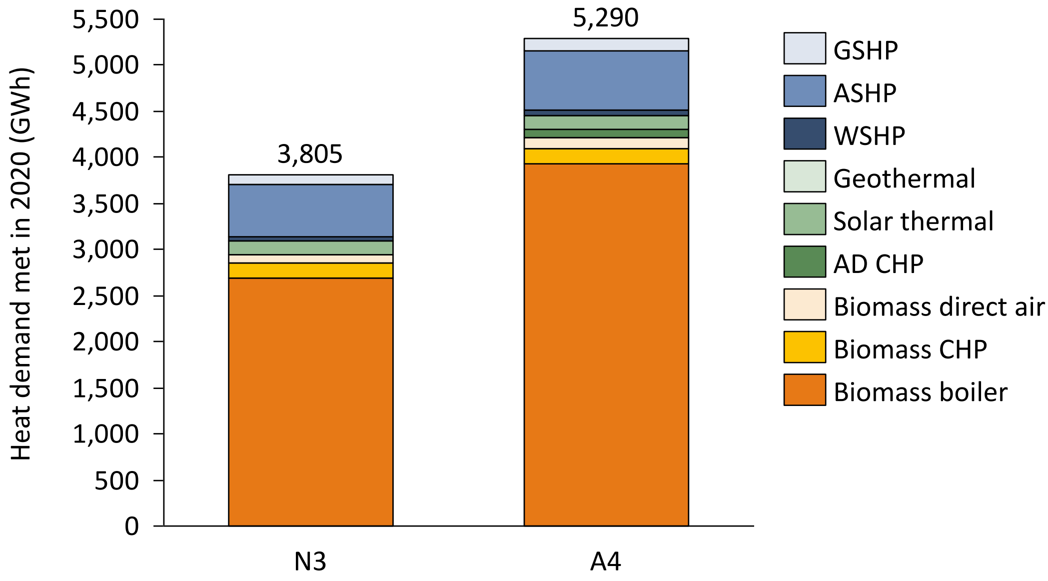


Table 11-25: Total heat demand met by RH technologies in 2020 in Scenario A4

GWh	2015	2020 Scenario N3	2020 Scenario A4
GSHP	99	102	127
ASHP	530	558	646
WSHP	50	51	56
Deep geothermal	0	3	12
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	93	118
Biomass CHP	84	165	172
Biomass boiler	2048	2693	3924
Total	**2951**	**3804**	**5289**
% heat from RH	**6.6%**	**8.7%**	**11.8%**

Figure 11-15: Annual RHI payments made in Scenario A4

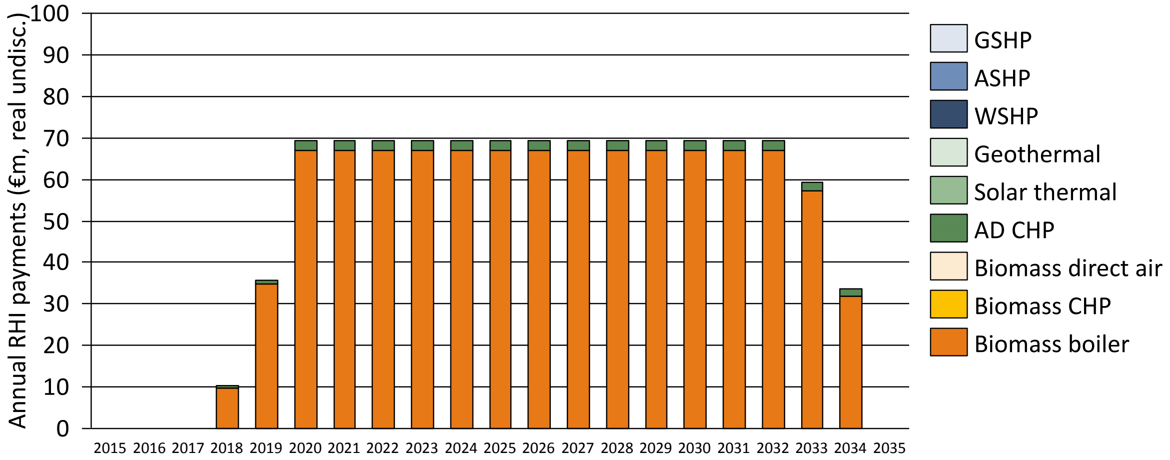


Table 11-26: Annual RHI payments made in Scenario A4

Annual cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.5	0.8	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	9.7	34.9	66.9	66.9	66.9	66.9	66.9	66.9	66.9
Total	**10.2**	**35.7**	**69.4**	**69.4**	**69.4**	**69.4**	**69.4**	**69.4**	**69.4**

Annual cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	2.5	2.5	2.5	2.5	2.5	2.5	2.0	1.7	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	66.9	66.9	66.9	66.9	66.9	66.9	57.2	32.0	0.0
Total	**69.4**	**69.4**	**69.4**	**69.4**	**69.4**	**69.4**	**59.2**	**33.7**	**0.0**

Table 11-27: Cumulative RHI payments made in Scenario A4

Cumulative cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	1	4	6	9	11	14	16	19
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	10	45	111	178	245	312	379	446	513
Total	**11**	**46**	**115**	**184**	**254**	**323**	**393**	**462**	**532**

Cumulative cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	22	24	27	29	32	34	36	38	38
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	580	647	714	781	848	915	972	1,004	1,004
Total	**602**	**671**	**741**	**810**	**880**	**949**	**1,008**	**1,042**	**1,042**

Table 11-28: Number of new installations 2016-2020 by technology and sector in Scenario A4 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2748	209	858	0	3815
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	42	0	42
ASHP	1742	13	83	0	1838
GSHP	109	0	26	0	135
WSHP	5	1	4	0	10
Deep geothermal	0	0	1	0	1
Solar thermal	0	0	0	0	0
AD CHP/ biomethane	0	0	0	19	19
Total	**4604**	**223**	**1014**	**19**	**5860**

Figure 11-16: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A4 (based on lifecycle emissions)

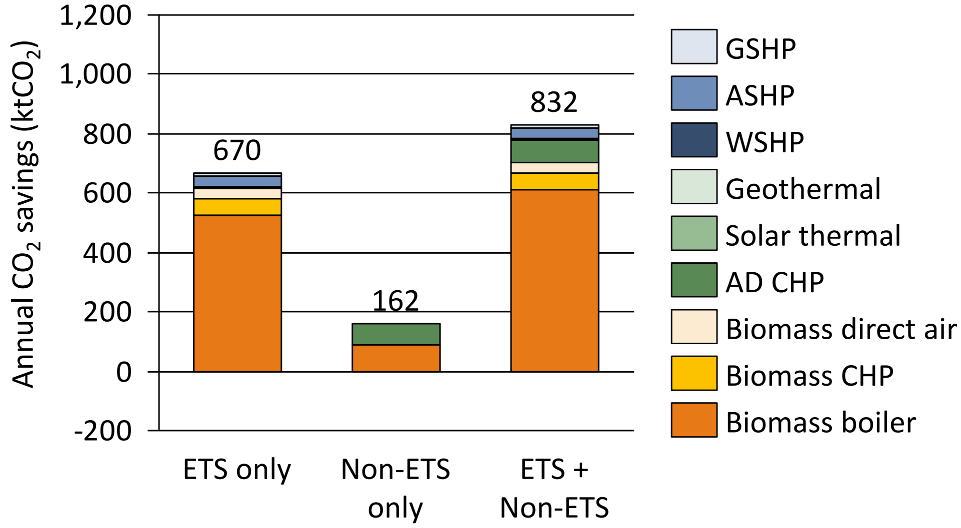
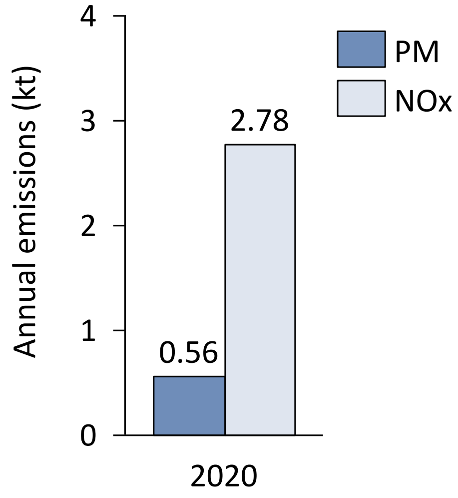


Table 11-29: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A4 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10.1	0.0	10.1
ASHP	37.1	0.5	37.6
WSHP	2.1	0.0	2.1
Deep geothermal	3.6	0.7	4.3
Solar thermal	0.0	0.0	0.0
AD CHP/ biomethane	0.0	73.5	73.5
Biomass direct air	37.1	-0.1	36.9
Biomass CHP	54.8	0.1	55.1
Biomass boiler	524.9	87.4	612.2
Total	**669.7**	**162.2**	**831.9**

Table 11-30: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario A4



Scenario A5

Figure 11-17: Total heat demand met by RH technologies in 2020 in Scenario A5

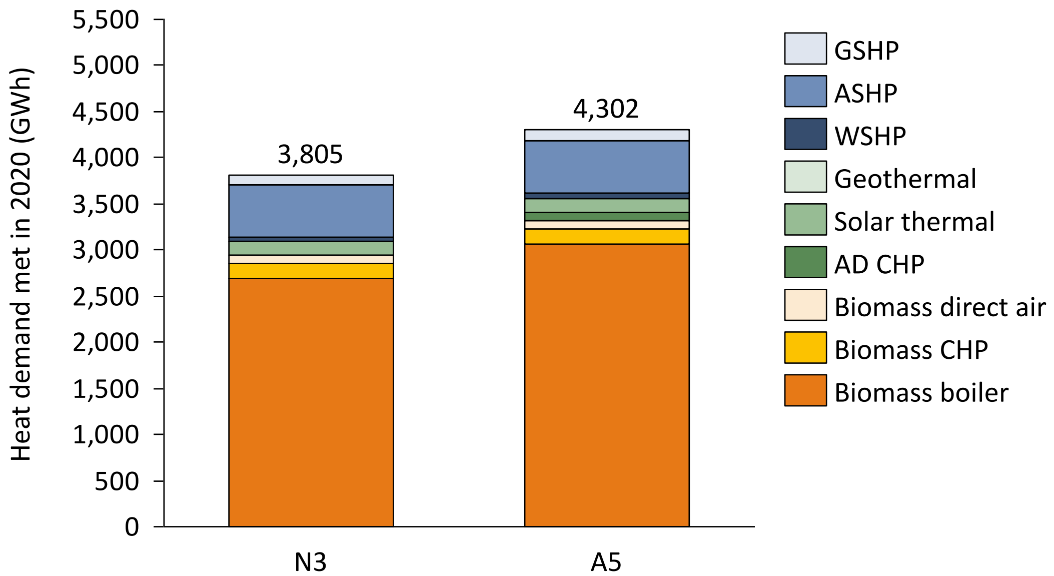


Table 11-31: Total heat demand met by RH technologies in 2020 in Scenario A5

GWh	2015	2020 Scenario N3	2020 Scenario A5
GSHP	99	102	110
ASHP	530	558	580
WSHP	50	51	52
Deep geothermal	0	3	5
Solar thermal	140	140	140
AD CHP/ biomethane	0	0	95
Biomass direct air	0	93	93
Biomass CHP	84	165	167
Biomass boiler	2048	2693	3060
Total	**2951**	**3804**	**4302**
% heat from RH	**6.6%**	**8.7%**	**9.7%**

Figure 11-18: Annual RHI payments made in Scenario A5

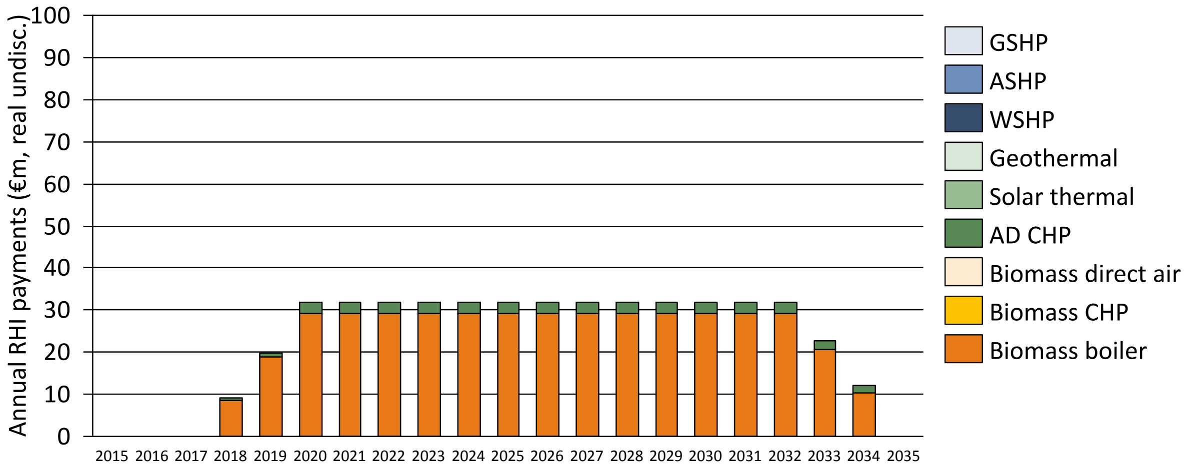


Table 11-32: Annual RHI payments made in Scenario A5

Annual cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	0.5	0.8	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	8.7	18.9	29.3	29.3	29.3	29.3	29.3	29.3	29.3
Total	**9.2**	**19.7**	**31.8**	**31.8**	**31.8**	**31.8**	**31.8**	**31.8**	**31.8**

Annual cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP/ biomethane	2.5	2.5	2.5	2.5	2.5	2.5	2.0	1.7	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	29.3	29.3	29.3	29.3	29.3	29.3	20.6	10.4	0.0
Total	**31.8**	**31.8**	**31.8**	**31.8**	**31.8**	**31.8**	**22.6**	**12.1**	**0.0**

Table 11-33: Cumulative RHI payments made in Scenario A5

Cumulative cost, €m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	1	1	4	6	9	11	14	16	19
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	9	28	57	86	115	145	174	203	233
Total	**10**	**29**	**61**	**92**	**124**	**156**	**188**	**219**	**252**

Cumulative cost, €m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD CHP/ biomethane	22	24	27	29	32	34	36	38	38
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	262	291	320	350	379	408	429	439	439
Total	**284**	**315**	**347**	**379**	**411**	**442**	**465**	**477**	**477**

Table 11-34: Number of new installations 2016-2020 by technology and sector in Scenario A5 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	122	219	528	0	869
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	35	0	35
ASHP	759	7	32	0	797
GSHP	43	0	10	0	54
WSHP	2	0	2	0	4
Deep geothermal	0	0	1	0	1
Solar thermal	0	0	0	0	0
AD CHP/ biomethane	0	0	0	19	19
Total	**925**	**226**	**609**	**19**	**1779**

Figure 11-19: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A5 (based on lifecycle emissions)

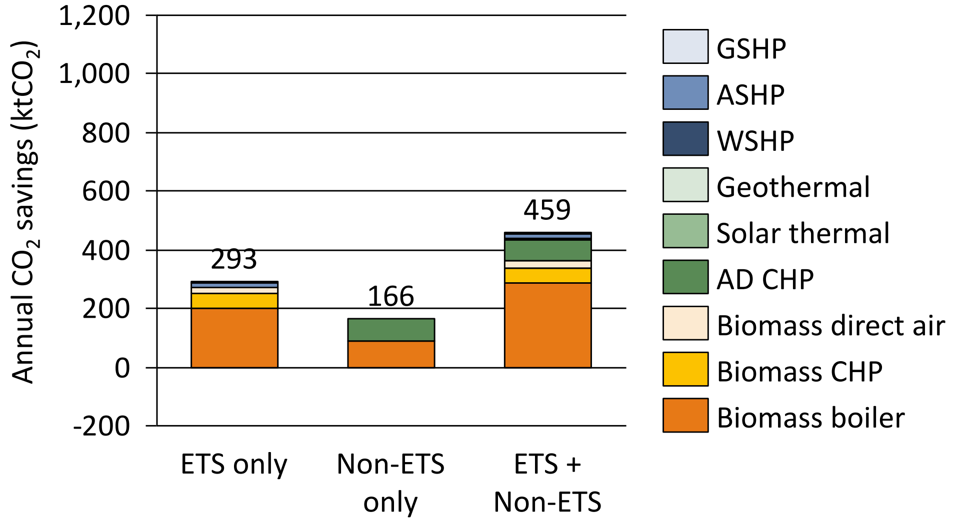
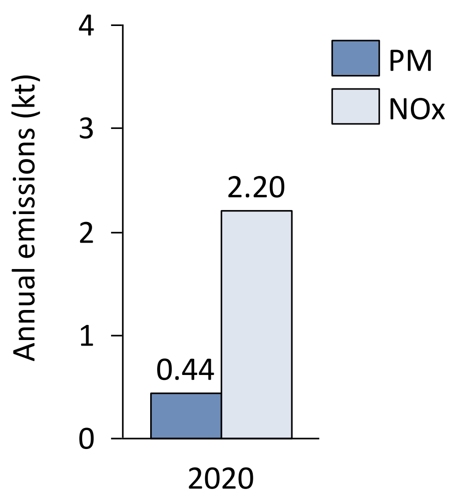


Table 11-35: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A5 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	4.0	0.0	4.0
ASHP	15.5	0.5	16.0
WSHP	0.6	0.0	0.6
Deep geothermal	1.3	0.4	1.8
Solar thermal	0.0	0.0	0.0
AD CHP/ biomethane	0.0	73.5	73.5
Biomass direct air	21.5	3.9	25.2
Biomass CHP	51.7	0.1	51.9
Biomass boiler	198.8	87.2	285.8
Total	**293.3**	**165.6**	**458.8**

Table 11-36: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario A5



elementenergy

Economic analysis for the Renewable Heat Incentive for Ireland

Section 2: *Additional Analysis for the RHI Business Case*

for

Sustainable Energy Authority of Ireland (SEAI)

and

Department of Communications, Climate Action & Environment (DCCAE)

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12 Summary of the additional analysis

12.1 Introduction

Subsequent to the submission of the final Renewable Heat Incentive (RHI) report by Element Energy to the Department of Communications, Climate Action and Environment (DCCAE) in Quarter 2 2017, review by the project steering group of the specific proposals for the scheme have led to a number of proposed additional scenarios for assessment.

The additional scenarios were chosen to explore the impact of varying several design aspects of the RHI, including the biomass import price assumed in the modelling; the level of support paid for the electrical output for Biomass and AD CHP (to align with the anticipated Renewable Electricity Support Scheme); the counterfactual heating systems targeted for replacement; and the list of technologies to be supported. The impact on the expected level of deployment of renewable heat and the associated policy cost of supporting renewable heating technologies through a grant scheme, instead of through ongoing support as in the Renewable Heat Incentive, was also studied.

During the time period that the main economic analysis was being finalised, there were significant changes in currency exchange rates and in the price of oil. Further additional relevant information also became available from the analysis for the Renewable Electricity Support Scheme.

The motivation for the definition of the additional scenarios and a summary of the findings are outlined below. Detailed results of the scenarios are presented in a later section.

12.2 Summary of findings

Update to fuel prices and level of RESS assumed

The opportunity was taken to update the fuel prices used in the analysis and explore the insights from the additional scenarios in more detail. The tariffs for the new scenarios are thereby based on the Sustainable Energy Authority of Ireland (SEAI) Fuel Cost Comparison July 2017[92]. In addition, a further study[93] on the Potential Biomass Prices in Ireland was undertaken and the results of this report were used to carry out updated economic analysis.

Finally, as additional relevant information also became available from the analysis for the Renewable Electricity Support Scheme, the level of RESS support assumed for Biomass CHP and AD CHP was updated in the modelling.

The preferred RHI scenario from the main report *An Economic Analysis of the Renewable Heat Incentive for Ireland* study, Scenario 5, was taken as the basis for two new scenarios. Based on the proposed modifications to the fuel prices and RESS support levels, two scenarios were constructed. **Scenario A5** was designed to reflect an assumption of an 8% IRR for investors, and **Scenario B5** an assumption of 12% IRR, with the scenarios otherwise identical. The full definition of the scenarios is provided in the next section.

Scenario A achieves a high level of deployment of renewable heating, with the fraction of heat from renewable sources reaching 12.8% in 2020. The associated cost of the RHI is determined as €707m (2015€, undiscounted) over the period 2018-2034, with an annual

[92] It should be noted that this accounts for the small difference between the tariffs derived for Biomass boilers in Scenario A5 in this document, and those derived for Biomass boilers in Scenario 1 in the Main RHI report.
[93] Ricardo Energy & Environment for SEAI, Potential Biomass Prices in Ireland, (2017)

cost in 2020 of €47m. In Scenario B, the higher tariff drives further uptake, with the share of renewable heating rising to 13.1% in 2020. This comes at a higher cost of €1,081m 2018-2034, with an annual cost of €72m in 2020. Note that the costs policy cost excludes the cost of administrative support of the scheme.

Impact of Grant support

The additional analysis undertaken included an examination of the impact of grant supports. A high level scenario, **Scenario C5**, was examined that offered grant support equivalent to 45% of the capital costs of the renewable technology for technologies installed at non-ETS sites in the commercial, agricultural, industrial and public sectors.

This scenario showed significant cost reductions as compared to a Renewable Heat Incentive only scenario, achieving a renewable share of heating of 12.1% for a total cost of €83m (2015€, undiscounted) over the period 2018-2034 (with the full cost incurred over the period 2018-2020 given the nature of the support i.e. a grant rather than an ongoing payment).

The favourable cost outcome in the grant scenario is primarily a function of the large number of biomass boilers that were taken up by buildings previously using electricity as a heating fuel, representing nearly half of the total new installed capacity of biomass boilers. Due to the high cost of electricity, biomass boilers – using lower cost fuel – deliver substantial ongoing fuel cost savings in these buildings. This is despite the substantially higher operation and maintenance cost associated with biomass boilers relative to electric heating, including the costs of fuel delivery, storage, loading and waste disposal, and the greater requirement for regular servicing. In such cases, an upfront grant approach is likely to be effective (note the similarity to the case of energy efficiency, where grants have been shown to deliver substantial uptake).

However, oil and gas boilers can also deliver significant ongoing savings in buildings currently heated by electricity, but these lower cost options have not been taken up in these buildings. This suggest that there are hidden costs and other barriers associated with the move from electricity to another fuel in buildings heated by electricity.

The modelling includes various elements of hidden cost, such as the cost of installing radiators, the time cost associated with researching and assessing the options, the administrative cost associated with managing fuel deliveries, waste disposal and boiler maintenance, and the cost of building and allocating space for a boiler house and fuel storage. However, other hidden costs and non-cost barriers may be expected to play a role, and quantifying these would require more detailed information than is currently available. These include the business disruption costs associated with a large heating system retrofit, the convenience premium sites attach to electricity as a heating fuel and the lack of engagement with energy savings. The type of decision faced by consumers in electrically heated buildings may also be a factor. For example, buildings with split heating and air conditioning units can make many small investment decisions based on the cost of replacing a single roof unit, whereas a move to a boiler requires a large one-off capital outlay, installation of a wet central heating system and ongoing management of fuel supply and boiler maintenance.

Based on these factors, the uptake rate in the 45% Grant scenario is deemed an unrealistic view of how the market may react to a grant instrument. This view is supported by the SEAI's prior experience administering a grant scheme for renewable heat. The ReHeat scheme, operational between 2007 and 2011, offered grants of up to 30% of eligible costs to the commercial and public sector for the installation of renewable heating technologies including biomass boilers, heat pumps and solar thermal. The ReHeat scheme as a whole led to the deployment of approximately 78 MW of biomass boilers. For comparison, Scenario C5 entails the uptake of more than 300 MW of biomass boilers over three years. The evidence from ReHeat also supports the view that fuel switching from electric heating to biomass heating is unlikely to be prevalent. Less than 10% of the biomass boilers installed through ReHeat were recorded as replacing an electric heating system, with the majority of installations either replacing oil heating or being recorded as a 'New' installation with no counterfactual system. This is substantially lower than the fraction of biomass boilers replacing electric heating in Scenario C5, found to be nearly 50% of the total installed capacity as noted above.

While there are a number of differences between ReHeat and the modelled scheme (including the level of the grant), the high level of uptake predicted in the Grant only scenario is therefore considered by the project team and steering board to be an unreliable outcome with a significant risk that the modelling results would not be realised in reality.

In view of this, sensitivities to the modelling were studied in order to understand the potential reasons for, and impact of, a lower than predicted uptake of the grant scheme. These focused on two of the key potential reasons identified for a difference between the modelled outcome and the experience of the ReHeat scheme: the impact of a low rate of fuel switching from electric heating to biomass due to additional barriers associated with that switch, and the sensitivity of the predicted uptake to the relative price of biomass and oil heating fuels. The findings of these sensitivities are described below.

Sensitivity of no fuel switching from electric heating

To account for the risk of uptake in the electric heating sector not materialising, a further scenario was examined and compared to an updated baseline. This scenario, **Scenario D6**, offered grant support equivalent to 30% of the capital costs of the renewable technology for technologies installed at non-ETS sites in commercial, agricultural, industrial and public sectors but under an assumption of no fuel switching in electrically-heated buildings (i.e. buildings that currently use electricity for heating would not switch to biomass heating). This scenario was defined to explore the uncertainty over whether buildings heated by electricity would in fact switch to biomass or other renewable fuel sources.

These assumptions result in insufficient uptake of renewable heat technologies to meet the 2020 target of 12% of heat from renewable sources, with a share of 10.8% renewable heating being reached by 2020.

Low oil price sensitivity

A further observation of the grant scenario assuming no fuel switch from electrical heating to biomass heating is that much of the uptake observed in this scenario is associated with sites currently using oil switching to biomass boilers. In these cases, biomass boilers are found to deliver ongoing cost savings with a viable payback period – albeit that the cost savings are substantially smaller than for the switch from electrical heating to biomass heating. This outcome is primarily dependent on the difference in oil and biomass fuel prices. Under the fuel price assumptions applied in the analysis, the running costs for oil and biomass are found to be very finely balanced, and in view of fuel price volatility there remains a substantial risk that the cost savings identified in the modelling for the switch from oil heating to biomass heating will not materialise. The scenario assumes a 5.5 c/kWh price for biomass from the low end of the range recommended by Ricardo Energy & Environment[94]

[94] Ricardo Energy & Environment for SEAI, Potential Biomass Prices in Ireland, (2017)

in the supporting analysis on biomass prices. Should the biomass price turn out to be higher, or should oil prices reduce from the present value, then biomass boilers will no longer deliver ongoing savings versus oil heating in the majority of cases.

Further, an implicit assumption of the modelling is that potential investors have full information of future ongoing costs for all technology options. In reality this is not the case, and investor expectations – and uncertainty – relating to how ongoing costs of renewable heat technologies may develop relative to the fossil fuel alternative will be incorporated into decision-making. In practice, these factors could lead to a low uptake of grant support or a reversion back to fossil fuel heating if the underlying cost drivers change, such as if biomass increases in price or fossil fuel prices reduce.

In order to quantify the potential impact of a lower oil price on uptake of biomass heating in a Grant only scheme, a sensitivity to Scenario D6 has been studied, **Scenario D6L**. To illustrate this risk in a transparent way, Scenario D6L assumes a reduced oil price of 5.1 cents/kWh over the whole study period, such that the oil price is below the biomass imports price assumed in the scenario, at 5.5 cents/kWh. The value of 5.1 cents/kWh, approximately 20% lower than the oil price for 2017 of 6.1 cents/kWh (as assumed in all other scenarios), was selected through a review of the historic SEAI Fuel Cost Comparison data, which suggested that the heating oil price was as much as 20% lower than in July 2017 as recently as January 2016.

In the low oil price sensitivity, Scenario D6L, the uptake of biomass heating is severely reduced, with the fraction of heat from renewable sources in 2020 as low as 9.1%. This highlights the risk of very low uptake of renewable heating in under a grant only scenario in the case that there is insufficient confidence in biomass prices being lower than fossil fuel prices, and remaining lower.

Combination of a Grant for heat pumps and an RHI for other RH technologies

In cases where the absence of ongoing cost savings (or the perceived risk of this from the consumer perspective) means that a grant-based scheme is unlikely to deliver substantial deployment of renewable heating, ongoing support through the Renewable Heat Incentive provides a mechanism to incentivise the switch from fossil fuel heating to biomass heating, and a mechanism through which the level of supported could (in principle) be adjusted in response to changes in observed fuel prices.

A “hybrid” scenario, **Scenario E6**, combining a grant for heat pump technologies and solar thermal (offered to sites currently using either electric or fossil fuel heating) with a Renewable Heat Incentive for all other renewable heating technologies (offered to fossil fuel heating sites only), was therefore constructed and included in the economic analysis. Under Scenario E6, the share of heat demand from renewable sources reaches 11.7% by 2020, with a total RHI policy cost of €317m (2015€, undiscounted) over the period 2018-2034, and total additional grant support of €21m over the same period (all incurred 2018-2020). The annual policy cost in 2020 is estimated to be €21m for the RHI component, and €9m for the grant component. The total capital investment in renewable heating technologies under Scenario F6 is €451m.

An additional hybrid scenario, **Scenario F6**, was also studied, in which the following additional modifications were made as compared with Scenario E6:

- List of technologies supported was revised to include: Biomass boilers, Biomass direct air, Biomass CHP, AD CHP and AD boilers (through ongoing RHI support); air-source, ground-source and water-source heat pumps (through grant support);

- RHI tiering structure was simplified by merging tiers 1-4 such that the first 300 MWh/yr of heat generated receive the same level of support in cents/kWh terms;
- Aligning the tariff for tiers 1-4 between the solid biomass technologies i.e. Biomass boilers, Biomass direct air and Biomass CHP.

It should be noted that, in Scenario F6, the exclusion of biomethane from the scheme is a result of the conclusion that, as described in Section 16, further work is required to finalise the design of the most suitable support scheme for biomethane.

Under Scenario F6, the share of heat demand from renewable sources reaches 11.7% by 2020 (the same as Scenario E6), with a total RHI policy cost of €311m (2015€, undiscounted) over the period 2018-2034, and total additional grant support of €18m over the same period (all incurred 2018-2020). The annual policy cost in 2020 is estimated to be €21m for the RHI component, and €6m for the grant component. The total capital investment in renewable heating technologies under Scenario F6 is €439m.

13 Definition of scenarios and comparison of results

Scenario definition

The following key assumptions are applied across the additional scenarios studied, unless otherwise stated:

- **Eligible technologies**:
  - **Scenarios A5, B5, C5, D6, D6L E6**: biomass boiler, biomass combined heat and power (CHP), biomass direct air, ground source heat pumps, air source heat pumps, water source heat pumps, deep geothermal, solar thermal, anaerobic digestion boiler, anaerobic digestion CHP, biomethane grid injection
  - **Scenario F6**: biomass boiler, biomass combined heat and power (CHP), biomass direct air, ground source heat pumps, air source heat pumps, water source heat pumps, anaerobic digestion boiler, anaerobic digestion CHP[95]
- **Eligible ETS/Non-ETS sectors**: Non-ETS sector only
- **Eligible economic sectors**: Commercial, Public, Industry, Agriculture
- **Eligible counterfactual heating systems**:
  - **Scenarios A5, B5, C5, D6, D6L**: All counterfactual systems eligible
  - **Scenarios E6, F6**: Fossil fuel counterfactual heating eligible for RHI support; all counterfactual systems eligible for Grant support
- **Availability of biomass imports assumed**: 1.5 TWh/yr
- **Renewable Electricity Support Scheme support level assumed**: 8 cents per kWh electricity generation for both Biomass CHP and anaerobic digestion CHP
- **Biomass import price assumed**: 5.5 c/kWh, based on analysis undertaken by Ricardo Energy & Environment for the Sustainable Energy Authority of Ireland (SEAI) in 2017[96].
- **IRR**: 8% and 12%

Table 13-1 summarises the variable assumptions across the scenarios. The additional scenarios are defined as follows:

- Scenario A5. Renewable heat incentive tariff based on an internal rate of return of 8%, offered to non-ETS sites in the commercial, agricultural, industrial and public sectors.
- Scenario B5. Renewable heat incentive tariff based on an internal rate of return of 12%, offered to non-ETS sites in the commercial, agricultural, industrial and public sectors.

[95] Scenario F6 does not include biomethane, a result of the conclusion that further work is required to finalise the design of the most suitable support scheme for biomethane. This is described further in Section 16.
[96] Ricardo Energy & Environment for SEAI, Potential Biomass Prices in Ireland, (2017)

- **Scenario C5**. Grant support equivalent to 45% of the capital costs of the renewable technology for technologies installed at non-ETS sites in commercial, agricultural, industrial and public sectors.
- **Scenario D6**. Grant support equivalent to 30% of the capital costs (otherwise as above), but under an assumption of no fuel switching in electrically-heated buildings. This scenario was defined to explore the uncertainty over whether buildings heated by electricity would in fact switch to biomass or other renewable fuel sources even if this is expected to deliver lifetime cost savings, given that they have not previously taken up the option to switch to oil or gas (which is also expected to deliver lifetime cost savings).
- **Scenario D6L**. As for Scenario D6, but with an assumption of a lower oil price, in order to test the impact on a grant only scenario of a change in fuel prices such that the oil price is lower than the imported biomass price.
- **Scenario E6**. Grant support for heat pump technologies and solar thermal (only) equivalent to 30% of the capital costs, in combination with a Renewable Heat Incentive (tariffs as in Scenario A5) offered to non-electrically-heated buildings only. Residential and ETS sites are not eligible to receive support through either the grant or RHI scheme. This scenario was defined to explore the impact of mitigating the risk of low uptake of grants at sites currently using fossil fuel heating sources. At such sites, a switch to biomass-based renewable heating is expected to lead to relatively marginal ongoing cost savings, if any, and any such savings may be perceived by potential investors as highly uncertain due to fuel price volatility. In practice, this could lead to a low uptake of grant support or a reversion back to fossil fuel heating if the underlying cost drivers change, such as if biomass increases in price or fossil fuel prices reduce. In such cases, ongoing support through the Renewable Heat Incentive provides greater confidence in the ongoing economic benefit for potential investors in biomass heating, and also a mechanism through which the level of support could (in principle) be adjusted in response to changes in observed fuel prices.
- **Scenario F6**. As for Scenario E6, but with the following modifications:
    - List of technologies supported was revised to include: Biomass boilers, Biomass direct air, Biomass CHP, AD CHP and AD boilers (through ongoing RHI support); air-source, ground-source and water-source heat pumps (through grant support);
    - RHI tiering structure was simplified by merging tiers 1-4 such that the first 300 MWh/yr of heat generated receive the same level of support in cents/kWh terms;
    - Aligning the tariff for tiers 1-4 between the solid biomass technologies i.e. Biomass boilers, Biomass direct air and Biomass CHP.

Table 13-1: Definition of additional scenarios (only variable assumptions shown)

ID	RHI tariff scenario	Allowed rate of return implied by tariffs	Technologies eligible for RHI	Counterfactual heating systems eligible for RHI	Grant offered (% of capex)	Technologies eligible for Grant	Counterfactual heating systems eligible for Grant	Fuel switching electric to biomass assumed to occur?	Oil price scenario
N5	None	None	None	None	None	None	None	Yes	Central
A5	A5	8%	Biomass boiler, Biomass CHP, Biomass direct air, GSHP, ASHP, WSHP, Deep geothermal, Solar thermal, AD boiler, AD CHP, Biomethane	All counterfactual heating systems	None	None	None	Yes	Central
B5	B5	12%	As for A5	All counterfactual heating systems	None	None	None	Yes	Central
C5	None	None	None	None	45%	Biomass boiler, Biomass CHP, Biomass direct air, GSHP, ASHP, WSHP, Deep geothermal, Solar thermal	All counterfactual heating systems	Yes	Central
N6	None	None	None	None	None	None	None	Yes	Central
D6	None	None	None	None	30%	Biomass boiler, Biomass CHP, Biomass direct air, GSHP, ASHP, WSHP, Deep geothermal, Solar thermal	All counterfactual heating systems	No	Central
D6L	None	None	None	None	30%	As for D6	All counterfactual heating systems	No	Low oil price
E6	A5	8%	Biomass boiler, Biomass CHP, Biomass direct air, Deep geothermal, AD boiler, AD CHP, Biomethane	Fossil fuel only (non-electric)	30%	GSHP, ASHP, WSHP, Solar thermal	All counterfactual heating systems	No	Central
F6	F6	8%	Biomass boiler, Biomass CHP, Biomass direct air, AD boiler, AD CHP	Fossil fuel only (non-electric)	30%	GSHP, ASHP, WSHP	All counterfactual heating systems	No	Central

Scenario results

A summary of the results of the scenarios is presented below. As a result of the difference in the assumption on fuel switching from electric heating to biomass heating across the scenarios studied, two different 'No RHI' baselines are presented. Scenarios A5, B5 and C5, for which it is assumed that fuel switching may occur, are compared against a 'No RHI' Scenario N5; Scenarios D6 and E6, for which it is assumed that no fuel switching will occur, are compared against a 'No RHI' Scenario N6.

It should be noted that Scenario D6L, the low oil price sensitivity to Scenario D6, is not strictly comparable with the No RHI Scenario N6 due to the different assumption on oil price. The purpose of Scenario D6L, however, as described above, is to illustrate the impact of a reduced oil price on uptake of biomass heating in a low oil price scenario (that is, it is intended to be compared with Scenario D6). The detailed results of the scenarios are presented in Section 15.

Table 13-2: Summary of results from the scenarios

ID	RHI offered	Annual heat output from all RH techs in 2020 (GWh)	% RH (fraction of all heat from renewable sources)	RHI: Total cost to the Exchequer 2018-2034 (2015€ million, undiscounted)	RHI: Cost to the Exchequer in 2020 (2015€ million)	Grant: Total cost to the Exchequer 2018-2034 (2015€ million, undiscounted)	Grant: Peak annual cost to the Exchequer 2018-2034 (2015€ million, undiscounted)	Annual CO2 savings from RH techs installed 2016-2020 in 2020 (ktCO2) (Based on lifecycle emissions)			Total CO2 savings 2016-2034 (MtCO2) (Based on lifecycle emissions)			Non-ETS fraction of total CO2 savings (%)
								ETS + Non-ETS	ETS only	Non-ETS only	ETS + Non-ETS	ETS only	Non-ETS only	
Fuel switch electric heating to biomass allowed														
Scenario N5 (No RHI)	No	4,224	9.6%	0	0	0	0	464	373	91	7.5	6.0	1.5	20%
Scenario A5	Yes	5,763	12.8%	707	47	0	0	973	736	237	15.8	11.9	3.9	24%
Scenario B5	Yes	5,917	13.1%	1,081	72	0	0	1,078	781	297	17.7	12.8	4.9	28%
Scenario C5 [Grant only (45%)]	No	5,476	12.1%	0	0	83	31	862	686	175	14.1	11.2	2.9	21%
Fuel switch electric heating to biomass NOT allowed														
Scenario N6 (No RHI)	No	3,935	8.9%	0	0	0	0	338	219	119	5.5	3.6	2.0	35%
Scenario D6 [Grant only (30%)]	No	4,856	10.8%	0	0	35	12	566	342	223	9.2	5.5	3.6	40%
Scenario D6L [Grant only (30%) - Low Oil Price]	No	4,064	9.1%	0	0	24	9	379	280	99	6.2	4.6	1.6	26%
Scenario E6 [30% Grant for HPs, RHI Scenario A for non-electric heating buildings only]	Yes	5,236	11.7%	317	21	21	9	686	378	307	11.1	6.1	5.0	45%
Scenario F6 [30% Grant for HPs, RHI Scenario A for non-electric heating buildings only - Tariff tiers merged and aligned; No Biomethane, Geothermal, Solar thermal]	Yes	5,233	11.7%	311	21	18	6	676	378	298	10.9	6.1	4.8	44%

14 Tariffs

The tiered RHI tariffs for Scenario A5, Scenario B5 and Scenario F6 are presented below. All currency values in this report are in 2015€. The RHI tariffs applied in Scenario E6 (for all technologies apart from the heat pump technologies) are equal to the tariffs for Scenario A5.

Scenario A5

Table 14-1: Tariffs for Scenario A5

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	12.54
	2	>10	≤30	7.96
	3	>30	≤100	5.77
	4	>100	≤300	5.05
	5	>300	≤1,000	3.02
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	≥10,000	N/A	0.37
Biomass CHP	1	N/A	≤10	5.52
	2	>10	≤30	5.52
	3	>30	≤100	5.52
	4	>100	≤300	5.05
	5	>300	≤1,000	3.02
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	≥10,000	N/A	0.37
Biomass Direct Air	1	N/A	≤10	4.54
	2	>10	≤30	4.54
	3	>30	≤100	4.54
	4	>100	≤300	4.54
	5	>300	≤1,000	3.02
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	≥10,000	N/A	0.37
Ground-source heat pump	1	N/A	≤10	12.54
	2	>10	≤30	7.96
	3	>30	≤100	4.87
	4	>100	≤300	4.87
	5	>300	≤1,000	3.02
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	≥10,000	N/A	0.37
Air-source heat pump	1	N/A	≤10	10.98
	2	>10	≤30	6.41
	3	>30	≤100	3.77
	4	>100	≤300	3.77
	5	>300	≤1,000	3.02
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	≥10,000	N/A	0.37
Water-source heat pump	1	N/A	≤10	12.54
	2	>10	≤30	7.96
	3	>30	≤100	5.77

	4	>100	≤300	5.05
	5	>300	≤1,000	3.02
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	≥10,000	N/A	0.37
Deep geothermal	1	N/A	≤10	1.36
	2	>10	≤30	1.36
	3	>30	≤100	1.36
	4	>100	≤300	1.36
	5	>300	≤1,000	1.36
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	≥10,000	N/A	0.37
Solar thermal	1	N/A	≤10	12.54
	2	>10	≤30	7.96
	3	>30	≤100	5.77
	4	>100	≤300	5.05
	5	>300	≤1,000	0.00
	6	>1,000	≤3,000	0.00
	7	>3,000	≤10,000	0.00
	8	≥10,000	N/A	0.00
Anaerobic digestion boiler	1	N/A	≤10	2.95
	2	>10	≤30	2.95
	3	>30	≤100	2.95
	4	>100	≤300	2.95
	5	>300	≤1,000	2.95
	6	>1,000	≤2,400	0.50
	7	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤10	12.54
	2	>10	≤30	7.96
	3	>30	≤100	5.77
	4	>100	≤300	5.05
	5	>300	≤1,000	3.02
	6	>1,000	≤2,400	0.50
	7	>2,400	≤3,000	0.50
	8	>3,000	≤7,200	0.50
	9	>7,200	≤10,000	0.00
	10	>10,000	N/A	0.00
Biomethane grid injection	1	N/A	≤10	6.75
	2	>10	≤30	6.75
	3	>30	≤100	5.77
	4	>100	≤300	5.05
	5	>300	≤1,000	3.02
	6	>1,000	≤3,000	0.50
	7	>3,000	≤10,000	0.50
	8	>10,000	≤30,000	0.37
	9	>30,000	≤60,000	0.37
	10	>60,000	N/A	0.37

Scenario B5

Table 14-2: Tariffs for Scenario B5

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler	1	N/A	≤10	15.42
	2	>10	≤30	9.75
	3	>30	≤100	7.13
	4	>100	≤300	6.26
	5	>300	≤1,000	3.94
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	≥10,000	N/A	0.63
Biomass CHP	1	N/A	≤10	7.30
	2	>10	≤30	7.30
	3	>30	≤100	7.13
	4	>100	≤300	6.26
	5	>300	≤1,000	3.94
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	≥10,000	N/A	0.63
Biomass Direct Air	1	N/A	≤10	5.83
	2	>10	≤30	5.83
	3	>30	≤100	5.83
	4	>100	≤300	5.83
	5	>300	≤1,000	3.94
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	≥10,000	N/A	0.63
Ground-source heat pump	1	N/A	≤10	15.42
	2	>10	≤30	9.75
	3	>30	≤100	7.13
	4	>100	≤300	6.26
	5	>300	≤1,000	3.94
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	≥10,000	N/A	0.63
Air-source heat pump	1	N/A	≤10	13.91
	2	>10	≤30	8.27
	3	>30	≤100	5.92
	4	>100	≤300	5.10
	5	>300	≤1,000	3.94
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	≥10,000	N/A	0.63
Water-source heat pump	1	N/A	≤10	15.42
	2	>10	≤30	9.75
	3	>30	≤100	7.13
	4	>100	≤300	6.26
	5	>300	≤1,000	3.94
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	≥10,000	N/A	0.63
Deep geothermal	1	N/A	≤10	3.84
	2	>10	≤30	3.84
	3	>30	≤100	3.84

	4	>100	≤300	3.84
	5	>300	≤1,000	3.84
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	≥10,000	N/A	0.63
Solar thermal	1	N/A	≤10	15.42
	2	>10	≤30	9.75
	3	>30	≤100	7.13
	4	>100	≤300	6.26
	5	>300	≤1,000	0.78
	6	>1,000	≤3,000	0.78
	7	>3,000	≤10,000	0.78
	8	≥10,000	N/A	0.63
Anaerobic digestion boiler	1	N/A	≤10	5.11
	2	>10	≤30	5.11
	3	>30	≤100	5.11
	4	>100	≤300	5.11
	5	>300	≤1,000	3.94
	6	>1,000	≤2,400	0.81
	7	>2,400	N/A	0.00
Anaerobic digestion CHP	1	N/A	≤10	15.42
	2	>10	≤30	9.75
	3	>30	≤100	7.13
	4	>100	≤300	6.26
	5	>300	≤1,000	3.94
	6	>1,000	≤2,400	0.81
	7	>2,400	≤3,000	0.81
	8	>3,000	≤7,200	0.81
	9	>7,200	≤10,000	0.81
	10	>10,000	N/A	0.00
Biomethane grid injection	1	N/A	≤10	9.06
	2	>10	≤30	9.06
	3	>30	≤100	7.13
	4	>100	≤300	6.26
	5	>300	≤1,000	3.94
	6	>1,000	≤3,000	0.81
	7	>3,000	≤10,000	0.81
	8	>10,000	≤30,000	0.63
	9	>30,000	≤60,000	0.33
	10	>60,000	N/A	0.33

Scenario F6

Table 14-3: Tariffs for Scenario F6

	Tier	Lower limit, MWh/yr	Upper limit, MWh/yr	Tariff, c/kWh
Biomass boiler, Biomass CHP, Biomass Direct Air	1	N/A	≤300	5.66
	2	>300	≤1,000	3.02
	3	>1,000	≤3,000	0.50
	4	>3,000	≤10,000	0.50
	5	≥10,000	N/A	0.37
Anaerobic digestion boiler, Anaerobic digestion CHP	1	N/A	≤300	2.95
	2	>300	≤1,000	2.95
	3	>1,000	≤2,400	0.50
	4	>2,400	N/A	0.00

15 Detailed scenario results

Scenario A5

Figure 15-1: Total heat demand met by RH technologies in 2020 in Scenario A5

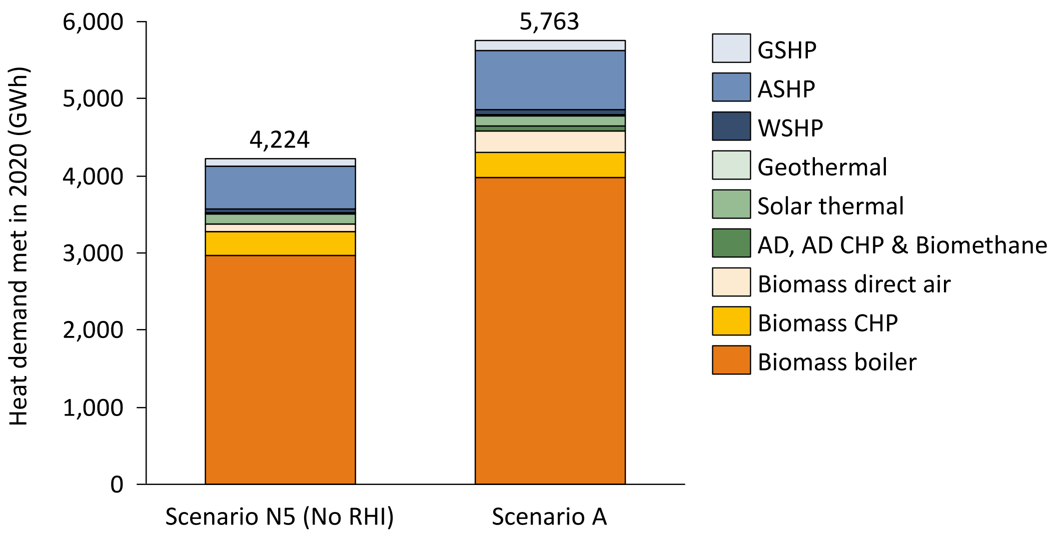


Table 15-1: Total heat demand met by RH technologies in 2020 in Scenario A5

GWh	2015	2020 Scenario N5	2020 Scenario A5
GSHP	99	101	131
ASHP	530	557	778
WSHP	50	50	57
Deep geothermal	0	4	14
Solar thermal	140	140	140
AD boiler	0	0	8
AD CHP	0	0	61
Biomass direct air	0	100	273
Biomass CHP	84	310	318
Biomass boiler	2048	2962	3984
Total	**2951**	4224	5763
% heat from RH	**6.6%**	**9.6%**	**12.8%**

Figure 15-2: Annual RHI payments made in Scenario A5

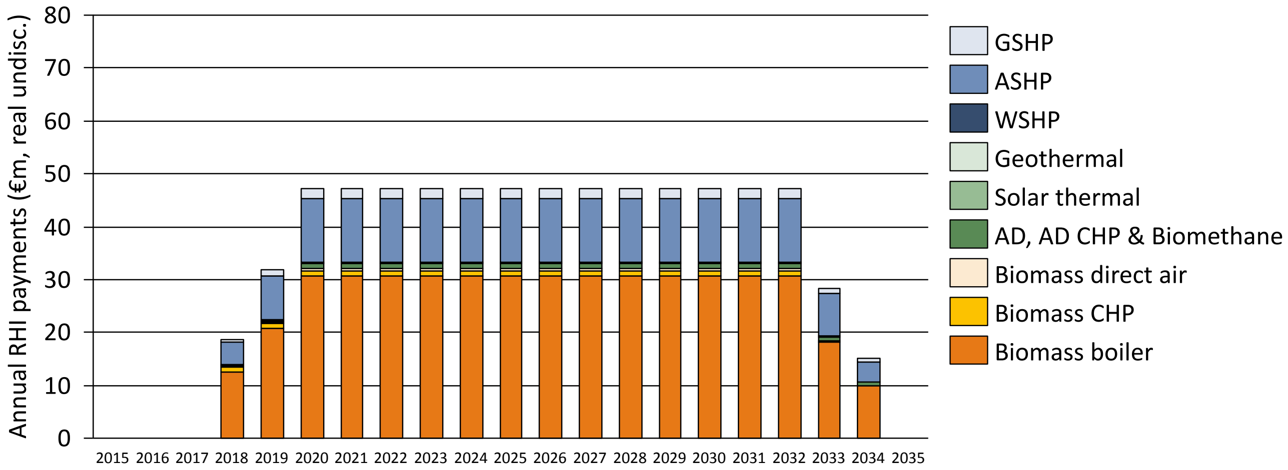


Table 15-2: Annual RHI payments made in Scenario A5

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.6	1.1	1.7	1.7	1.7	1.7	1.7	1.7	1.7
ASHP	4.2	8.3	12.1	12.1	12.1	12.1	12.1	12.1	12.1
WSHP	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AD CHP	0.2	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Biomethane	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Biomass direct air	0.1	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Biomass CHP	0.9	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Biomass boiler	12.6	20.8	30.7	30.7	30.7	30.7	30.7	30.7	30.7
Total	**18.7**	**31.8**	**47.1**	**47.1**	**47.1**	**47.1**	**47.1**	**47.1**	**47.1**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	1.7	1.7	1.7	1.7	1.7	1.7	1.1	0.6	0.0
ASHP	12.1	12.1	12.1	12.1	12.1	12.1	7.9	3.8	0.0
WSHP	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
AD CHP	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.4	0.0
Biomethane	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0
Biomass direct air	0.4	0.4	0.4	0.4	0.4	0.4	0.2	0.1	0.0
Biomass CHP	1.0	1.0	1.0	1.0	1.0	1.0	0.1	0.0	0.0
Biomass boiler	30.7	30.7	30.7	30.7	30.7	30.7	18.1	9.9	0.0
Total	**47.1**	**47.1**	**47.1**	**47.1**	**47.1**	**47.1**	**28.5**	**15.3**	**0.0**

Table 15-3: Cumulative RHI payments made in Scenario A5

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	2	3	5	7	9	10	12	14
ASHP	4	12	25	37	49	61	73	85	97
WSHP	0	0	1	1	1	2	2	2	2
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	1	2	3	3	4	5	5
Biomethane	0	0	0	0	1	1	1	1	1
Biomass direct air	0	0	1	1	2	2	2	3	3
Biomass CHP	1	2	3	4	5	6	7	7	8
Biomass boiler	13	33	64	95	125	156	187	217	248
Total	**19**	**51**	**98**	**145**	**192**	**239**	**286**	**333**	**380**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	16	17	19	21	23	24	25	26	26
ASHP	109	121	134	146	158	170	178	182	182
WSHP	3	3	3	4	4	4	5	5	5
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	1	1	1	1	1	1	1	1	1
AD CHP	6	7	7	8	9	9	10	10	10
Biomethane	1	2	2	2	2	2	2	3	3
Biomass direct air	3	4	4	4	5	5	5	6	6
Biomass CHP	9	10	11	12	13	14	14	14	14
Biomass boiler	279	310	340	371	402	432	450	460	460
Total	**428**	**475**	**522**	**569**	**616**	**663**	**692**	**707**	**707**

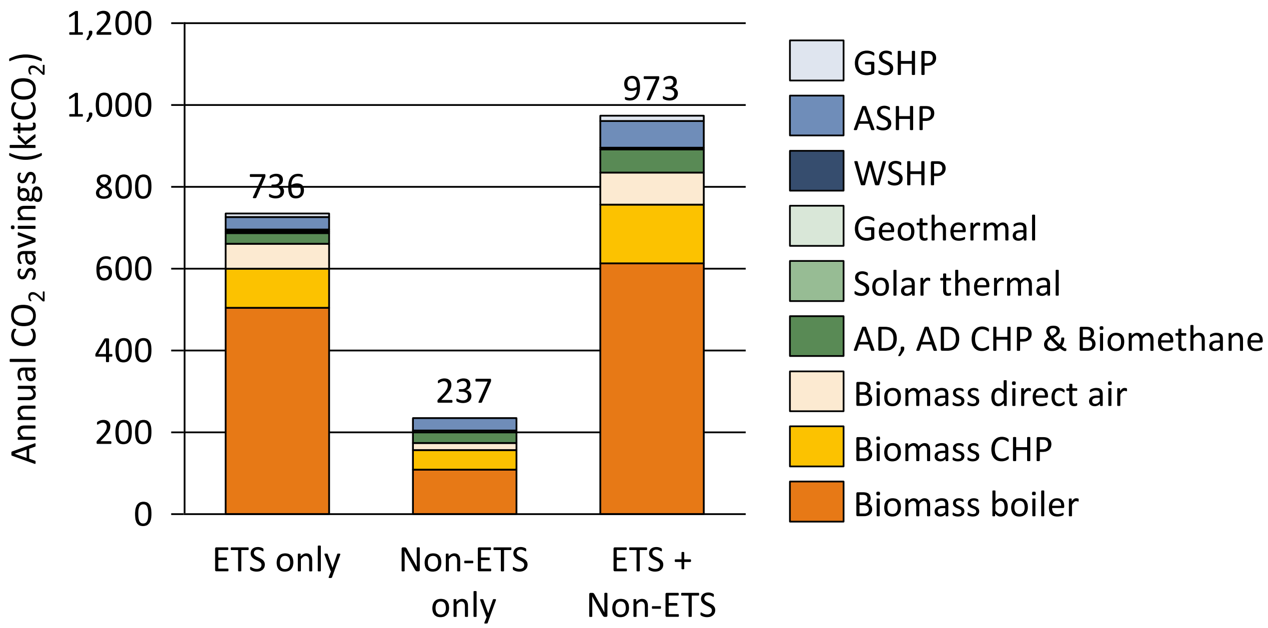
Table 15-4: Number of new installations 2016-2020 by technology and sector in Scenario A5 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2079	92	743	0	**2914**
Biomass CHP	1	0	1	0	**2**
Biomass direct air	0	0	72	0	**72**
ASHP	2970	279	108	0	**3357**
GSHP	242	0	26	0	**268**
WSHP	42	7	4	0	**53**
Deep geothermal	0	0	1	0	**1**
Solar thermal	0	0	0	0	**0**
AD boiler	0	0	0	4	**4**
AD CHP	0	0	0	14	**14**
Total	**5334**	**378**	**955**	**18**	**6685**

Table 15-5: Annual RHI support in 2020 per unit additional heat demand met by RH technologies 2015-2020 versus No RHI case in Scenario A5 (excluding Biomethane)

	Annual RHI support in 2020 (2015€m)	Additional heat demand met by RH 2015-2020 versus No RHI (GWh)	Annual RHI support in 2020 per unit additional heat demand versus No RHI (2015€ cents/kWh)[97]
GSHP	1.7	30	5.7
ASHP	12.1	221	5.5
WSHP	0.3	7	4.3
Deep geothermal	0.0	10	0.0
Solar thermal	0.0	0	0.0
AD boiler	0.1	8	1.3
AD CHP	0.7	61	1.1
Biomass direct air	0.4	173	0.2
Biomass CHP	1.0	8	12.5
Biomass boiler	30.7	1022	3.0
Total	**47.0**	**1539**	**3.1**

Figure 15-3: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A5 (based on lifecycle emissions)



[97] N.B. Annual RHI support in 2020 per unit additional heat demand versus No RHI can be larger than the tariff offered due to deadweight i.e. payment of RHI to installations which occurred in the No RHI case.

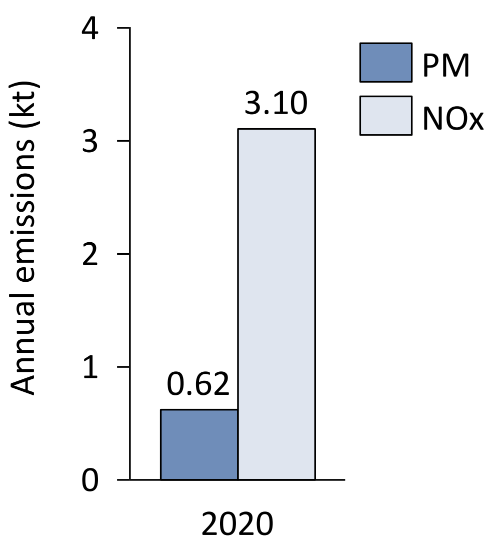
Table 15-6: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A5 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10	1	11
ASHP	32	33	65
WSHP	2	0	2
Deep geothermal	3	1	5
Solar thermal	0	0	0
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	9	9
Biomass direct air	59	19	78
Biomass CHP	97	46	143
Biomass boiler	504	110	615
Total	**736**	**237**	**973**

Table 15-7: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario A5 (based on 'point of use' emissions for biomass technologies)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10	1	11
ASHP	32	33	65
WSHP	2	0	2
Deep geothermal	3	1	5
Solar thermal	0	0	0
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	9	9
Biomass direct air	63	20	84
Biomass CHP	108	51	159
Biomass boiler	536	117	654
Total	**782**	**250**	**1,033**

Figure 15-4: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario A5



Scenario B5

Figure 15-5: Total heat demand met by RH technologies in 2020 in Scenario B5

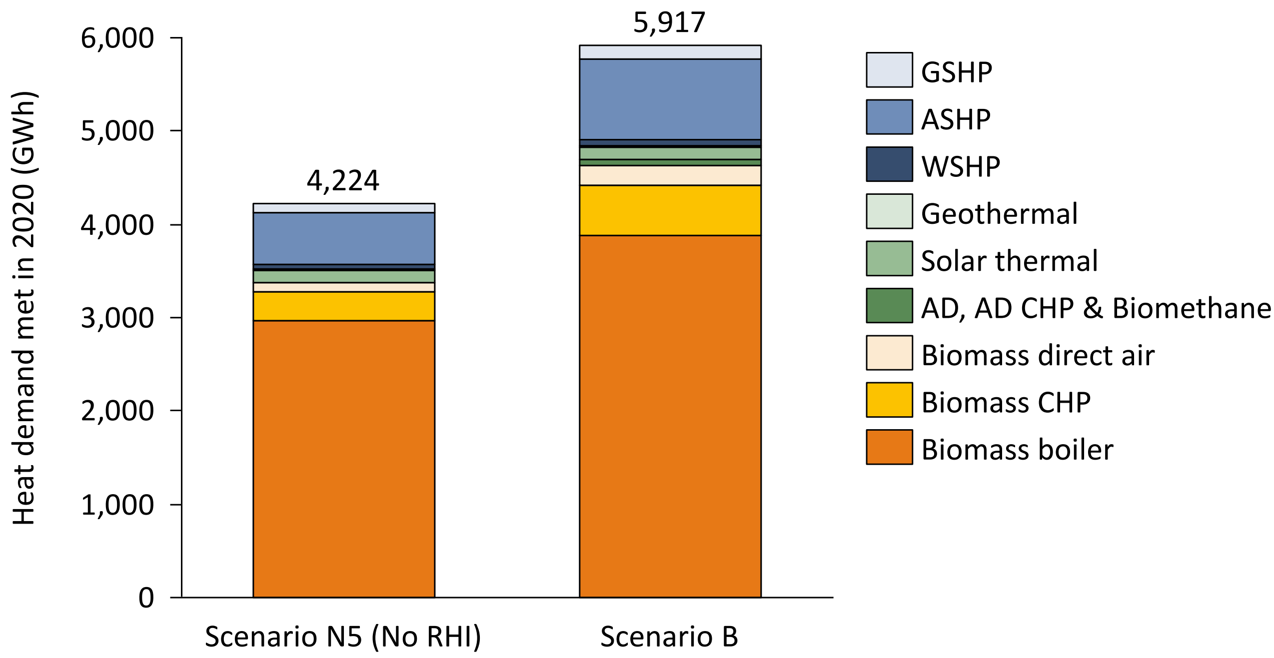


Table 15-8: Total heat demand met by RH technologies in 2020 in Scenario B5

GWh	2015	2020 Scenario N5	2020 Scenario B5
GSHP	99	101	142
ASHP	530	557	865
WSHP	50	50	63
Deep geothermal	0	4	14
Solar thermal	140	140	140
AD boiler	0	0	8
AD CHP	0	0	61
Biomass direct air	0	100	200
Biomass CHP	84	310	535
Biomass boiler	2048	2962	3887
Total	**2951**	4224	5917
% heat from RH	**6.6%**	**9.6%**	**13.1%**

Figure 15-6: Annual RHI payments made in Scenario B5

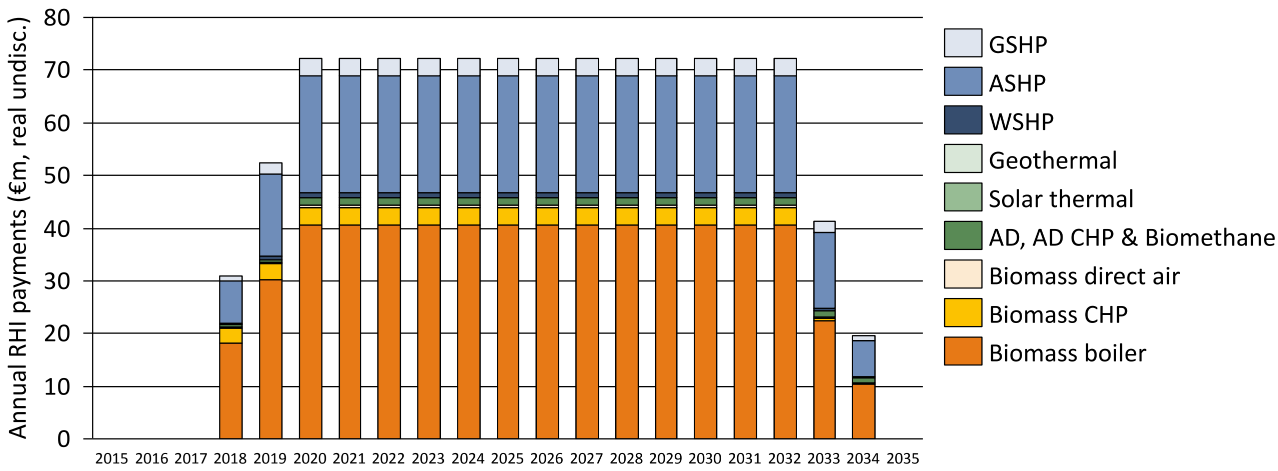


Table 15-9: Annual RHI payments made in Scenario B5

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.1	2.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
ASHP	8.0	15.6	22.3	22.3	22.3	22.3	22.3	22.3	22.3
WSHP	0.3	0.6	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Deep geothermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AD CHP	0.3	0.4	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Biomethane	0.0	0.0	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Biomass direct air	0.2	0.3	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Biomass CHP	2.9	3.2	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Biomass boiler	18.2	30.1	40.5	40.5	40.5	40.5	40.5	40.5	40.5
Total	**30.9**	**52.4**	**72.1**	**72.1**	**72.1**	**72.1**	**72.1**	**72.1**	**72.1**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	3.1	3.1	3.1	3.1	3.1	3.1	2.1	1.0	0.0
ASHP	22.3	22.3	22.3	22.3	22.3	22.3	14.3	6.7	0.0
WSHP	0.9	0.9	0.9	0.9	0.9	0.9	0.6	0.3	0.0
Deep geothermal	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
AD CHP	1.0	1.0	1.0	1.0	1.0	1.0	0.7	0.6	0.0
Biomethane	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.0
Biomass direct air	0.5	0.5	0.5	0.5	0.5	0.5	0.3	0.2	0.0
Biomass CHP	3.3	3.3	3.3	3.3	3.3	3.3	0.4	0.1	0.0
Biomass boiler	40.5	40.5	40.5	40.5	40.5	40.5	22.4	10.4	0.0
Total	**72.1**	**72.1**	**72.1**	**72.1**	**72.1**	**72.1**	**41.2**	**19.7**	**0.0**

Table 15-10: Cumulative RHI payments made in Scenario B5

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	3	6	10	13	16	19	22	25
ASHP	8	24	46	68	90	113	135	157	179
WSHP	0	1	2	3	4	5	6	7	7
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	0	0	0	0	0	0	1	1	1
AD CHP	0	1	2	3	4	5	6	7	8
Biomethane	0	0	0	1	1	1	1	2	2
Biomass direct air	0	0	1	1	2	2	3	3	4
Biomass CHP	3	6	9	13	16	19	23	26	29
Biomass boiler	18	48	89	129	170	210	251	292	332
Total	**31**	**83**	**155**	**228**	**300**	**372**	**444**	**516**	**588**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	28	32	35	38	41	44	46	47	47
ASHP	202	224	246	268	291	313	327	334	334
WSHP	8	9	10	11	12	13	14	14	14
Deep geothermal	0	1	1	1	1	1	1	1	1
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	1	1	1	1	1	1	1	2	2
AD CHP	9	10	11	12	13	14	14	15	15
Biomethane	2	2	3	3	3	3	4	4	4
Biomass direct air	4	5	5	6	6	7	7	7	7
Biomass CHP	33	36	39	42	46	49	49	49	49
Biomass boiler	373	413	454	494	535	575	598	608	608
Total	**660**	**732**	**804**	**876**	**948**	**1,021**	**1,062**	**1,081**	**1,081**

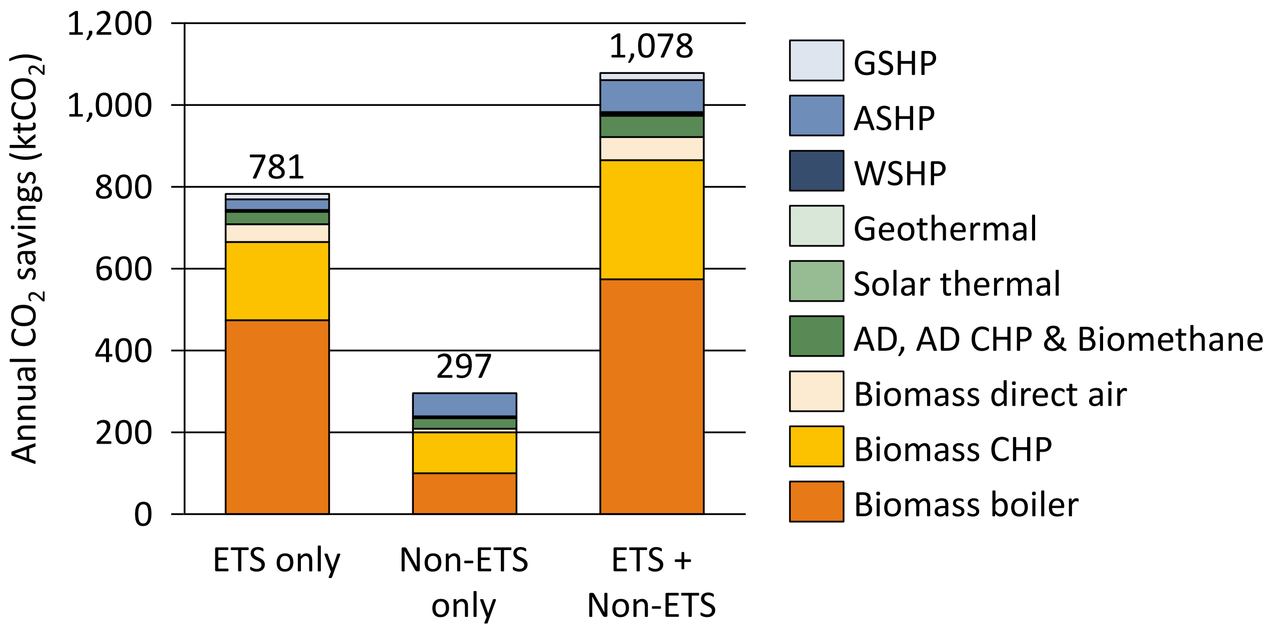
Table 15-11: Number of new installations 2016-2020 by technology and sector in Scenario B5 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2531	164	740	0	3435
Biomass CHP	5	0	1	0	6
Biomass direct air	0	0	60	0	60
ASHP	3845	528	134	0	4507
GSHP	380	0	31	0	411
WSHP	121	18	5	0	144
Deep geothermal	0	0	1	0	1
Solar thermal	0	8	0	0	8
AD boiler	0	0	0	4	4
AD CHP	0	0	0	14	14
Total	**6882**	**718**	**972**	**18**	**8590**

Table 15-12: Annual RHI support in 2020 per unit additional heat demand met by RH technologies 2015-2020 versus No RHI case in Scenario B5

	Annual RHI support in 2020 (2015€m)	Additional heat demand met by RH 2015-2020 versus No RHI (GWh)	Annual RHI support in 2020 per unit additional heat demand versus No RHI (2015€ cents/kWh)[98]
GSHP	3.1	41	7.6
ASHP	22.3	308	7.2
WSHP	0.9	13	6.9
Deep geothermal	0.1	10	1.0
Solar thermal	0.0	0	0.0
AD boiler	0.1	8	1.3
AD CHP	1.0	61	1.6
Biomass direct air	0.5	100	0.5
Biomass CHP	3.3	225	1.5
Biomass boiler	40.5	925	4.4
Total	**72.1**	**1693**	**4.3**

Figure 15-7: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario B5 (based on lifecycle emissions)



[98] N.B. Annual RHI support in 2020 per unit additional heat demand versus No RHI can be larger than the tariff offered due to deadweight i.e. payment of RHI to installations which occurred in the No RHI case.

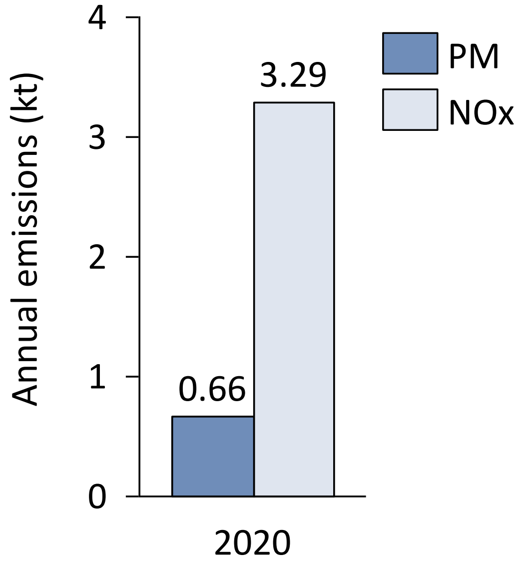
Table 15-13: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario B5 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	12	3	15
ASHP	24	56	80
WSHP	3	1	4
Deep geothermal	4	1	5
Solar thermal	0	0	0
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	9	9
Biomass direct air	44	11	54
Biomass CHP	193	98	292
Biomass boiler	473	101	574
Total	**781**	**297**	**1,078**

Table 15-14: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario B5 (based on 'point of use' emissions for biomass technologies)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	12	3	15
ASHP	24	56	80
WSHP	3	1	4
Deep geothermal	4	1	5
Solar thermal	0	0	0
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	9	9
Biomass direct air	47	12	58
Biomass CHP	204	103	307
Biomass boiler	506	108	614
Total	**828**	**310**	**1,137**

Figure 15-8: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario B5



Scenario C5

Figure 15-9: Total heat demand met by RH technologies in 2020 in Scenario C5

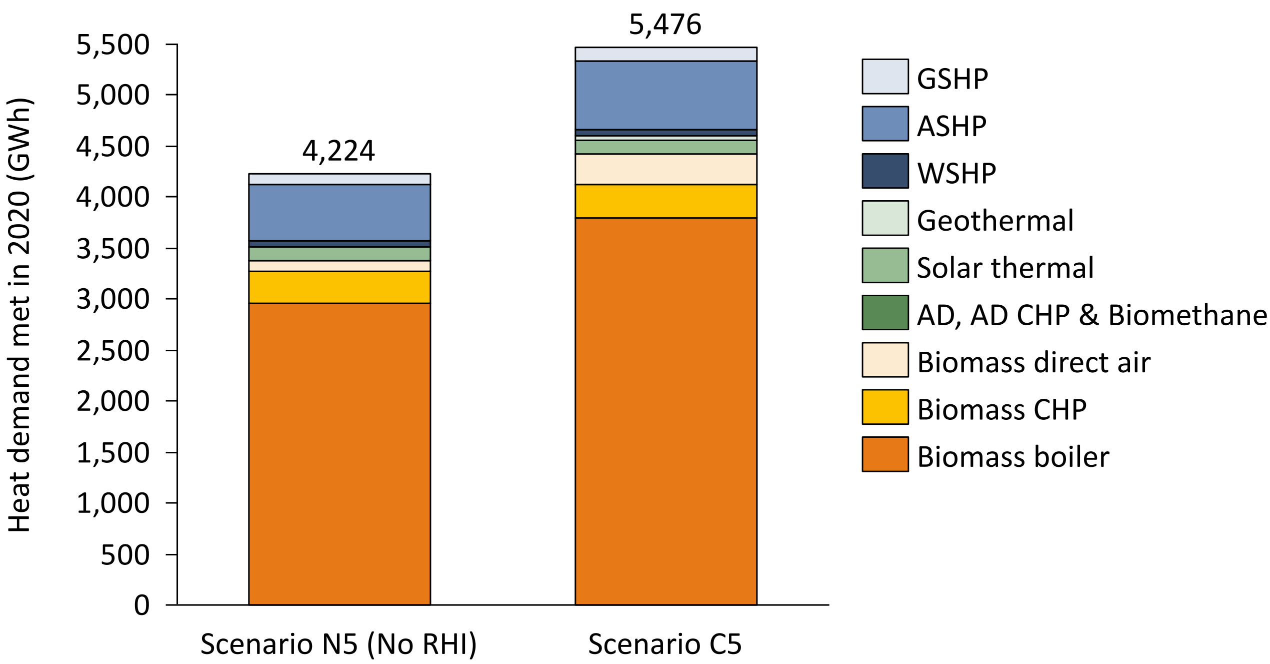


Table 15-15: Total heat demand met by RH technologies in 2020 in Scenario C5

GWh	2015	2020 Scenario N5	2020 Scenario C5
GSHP	99	101	133
ASHP	530	557	685
WSHP	50	50	58
Deep geothermal	0	4	39
Solar thermal	140	140	141
AD boiler	0	0	0
AD CHP	0	0	0
Biomass direct air	0	100	295
Biomass CHP	84	310	324
Biomass boiler	2048	2962	3800
Total	**2951**	**4224**	**5476**
% heat from RH	**6.6%**	**9.6%**	**12.1%**

Figure 15-10: Annual Grant payments made in Scenario C5

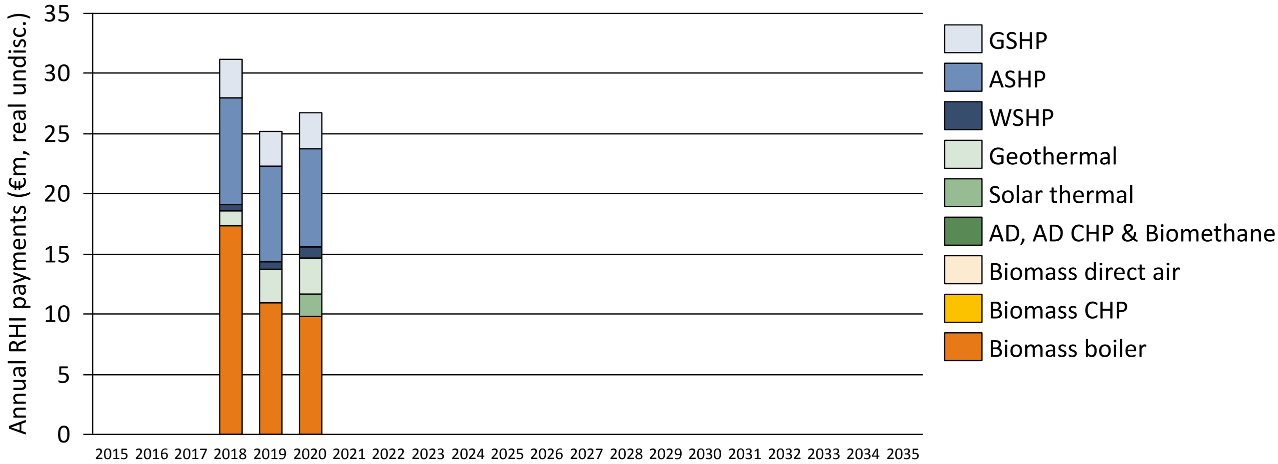


Table 15-16: Annual Grant payments made in Scenario C5

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	3.2	2.9	3.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	8.9	8.0	8.1	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.5	0.6	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	1.3	2.8	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	17.3	10.9	9.8	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	3.2	2.9	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	8.9	8.0	8.1	0.0	0.0	0.0	0.0	0.0	0.0
Total	**31.2**	**25.2**	**26.8**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 15-17: Cumulative Grant payments made in Scenario C5

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	3	6	9	9	9	9	9	9	9
ASHP	9	17	25	25	25	25	25	25	25
WSHP	0	1	2	2	2	2	2	2	2
Deep geothermal	1	4	7	7	7	7	7	7	7
Solar thermal	0	0	2	2	2	2	2	2	2
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	0	0	0	0	0	0	0
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	17	28	38	38	38	38	38	38	38
Biomass CHP	3	6	9	9	9	9	9	9	9
Biomass boiler	9	17	25	25	25	25	25	25	25
Total	**31**	**56**	**83**	**83**	**83**	**83**	**83**	**83**	**83**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	9	9	9	9	9	9	9	9	9
ASHP	25	25	25	25	25	25	25	25	25
WSHP	2	2	2	2	2	2	2	2	2
Deep geothermal	7	7	7	7	7	7	7	7	7
Solar thermal	2	2	2	2	2	2	2	2	2
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	0	0	0	0	0	0	0
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	38	38	38	38	38	38	38	38	38
Biomass CHP	9	9	9	9	9	9	9	9	9
Biomass boiler	25	25	25	25	25	25	25	25	25
Total	**83**	**83**	**83**	**83**	**83**	**83**	**83**	**83**	**83**

Table 15-18: Number of new installations 2016-2020 by technology and sector in Scenario C5 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	220	8	243	0	471
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	25	0	25
ASHP	922	20	25	0	967
GSHP	84	0	12	0	96
WSHP	8	0	3	0	11
Deep geothermal	0	0	0	0	0
Solar thermal	51	6	0	0	57
AD boiler	0	0	0	0	0
AD CHP	0	0	0	0	0
Total	**1285**	**34**	**308**	**0**	**1627**

Figure 15-11: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario C5 (based on lifecycle emissions)

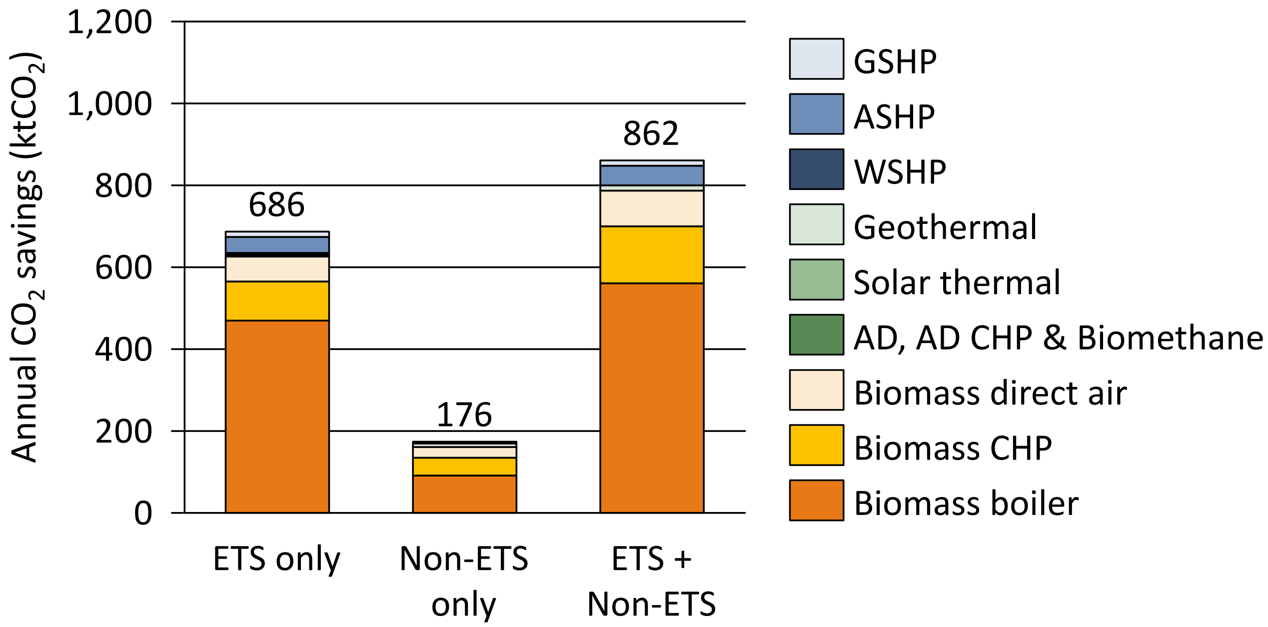


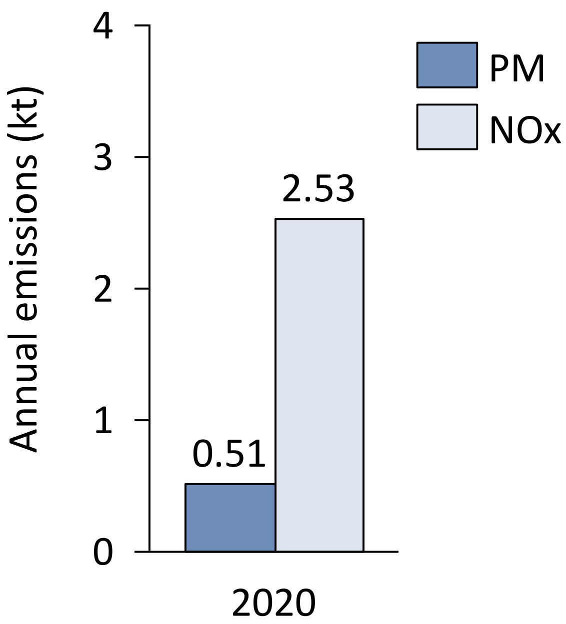
Table 15-19: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario C5 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11.9	0.5	12.4
ASHP	40.4	7.2	47.5
WSHP	1.9	0.6	2.5
Deep geothermal	6.8	6.3	13.1
Solar thermal	0.6	0.0	0.6
AD boiler	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0
Biomass direct air	60.1	25.5	85.2
Biomass CHP	95.3	44.8	140.4
Biomass boiler	469.0	91.1	560.2
Total	**685.9**	**176.0**	**861.9**

Table 15-20: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario C5 (based on 'point of use' emissions for biomass technologies)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11.9	0.5	12.4
ASHP	40.4	7.2	47.5
WSHP	1.9	0.6	2.5
Deep geothermal	6.8	6.3	13.1
Solar thermal	0.6	0.0	0.6
AD boiler	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0
Biomass direct air	62.8	26.7	89.5
Biomass CHP	105.4	50.0	155.4
Biomass boiler	490.4	95.3	585.7
Total	**720.2**	**186.5**	**906.8**

Figure 15-12: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario C5



Scenario D6

Figure 15-13: Total heat demand met by RH technologies in 2020 in Scenario D6

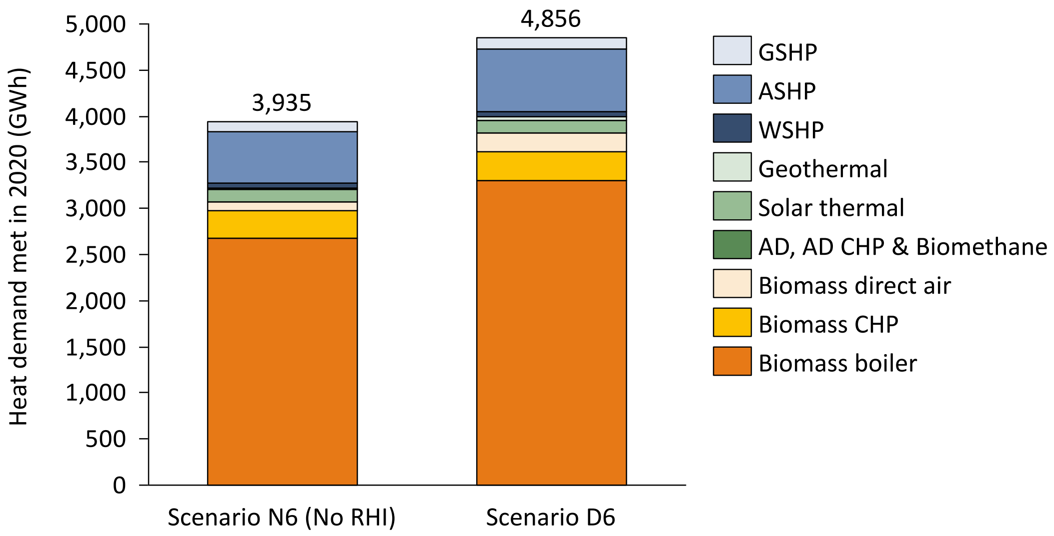


Table 15-21: Total heat demand met by RH technologies in 2020 in Scenario D6

GWh	2015	2020 Scenario N6	2020 Scenario D6
GSHP	99	103	129
ASHP	530	564	678
WSHP	50	51	56
Deep geothermal	0	8	32
Solar thermal	140	140	141
AD boiler	0	0	0
AD CHP	0	0	0
Biomass direct air	0	91	202
Biomass CHP	84	305	317
Biomass boiler	2048	2673	3300
Total	**2951**	**3935**	**4856**
% heat from RH	**6.6%**	**8.9%**	**10.8%**

Figure 15-14: Annual Grant payments made in Scenario D6

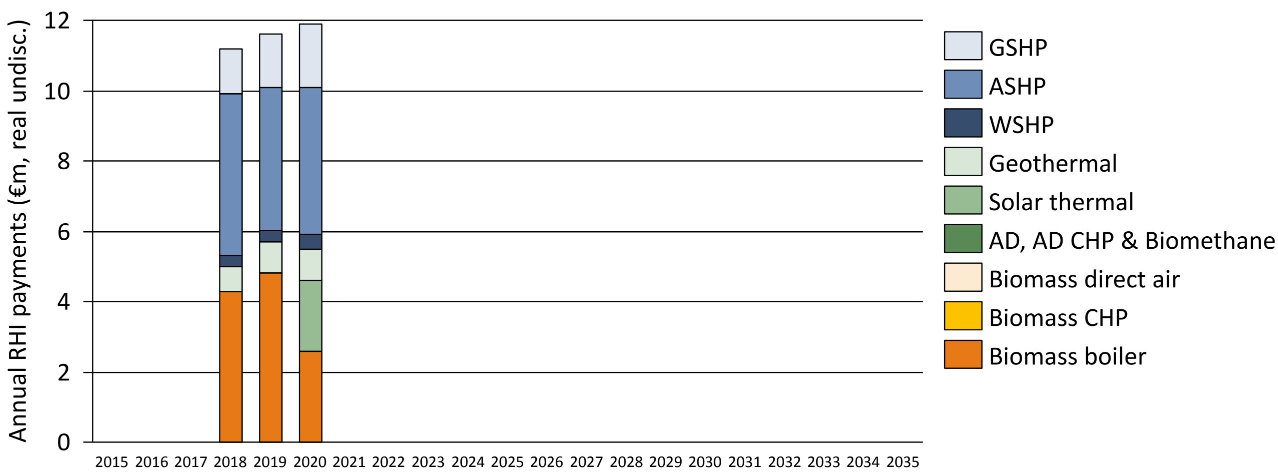


Table 15-22: Annual Grant payments made in Scenario D6

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.3	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	4.6	4.1	4.2	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.3	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.7	0.9	0.9	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	4.3	4.8	2.6	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	1.3	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	4.6	4.1	4.2	0.0	0.0	0.0	0.0	0.0	0.0
Total	**11.2**	**11.6**	**12.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 15-23: Cumulative Grant payments made in Scenario D6

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.3	2.9	4.7	4.7	4.7	4.7	4.7	4.7	4.7
ASHP	4.6	8.7	12.9	12.9	12.9	12.9	12.9	12.9	12.9
WSHP	0.3	0.6	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Deep geothermal	0.7	1.6	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Solar thermal	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	4.3	9.1	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Biomass CHP	1.3	2.9	4.7	4.7	4.7	4.7	4.7	4.7	4.7
Biomass boiler	4.6	8.7	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Total	**11.2**	**22.8**	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
ASHP	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
WSHP	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Deep geothermal	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Solar thermal	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Biomass CHP	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
Biomass boiler	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
Total	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**	**34.8**

Table 15-24: Number of new installations 2016-2020 by technology and sector in Scenario D6 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	0	0	189	0	189
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	62	0	62
ASHP	1523	46	117	0	1686
GSHP	73	0	33	0	106
WSHP	1	0	5	0	6
Deep geothermal	0	0	1	0	1
Solar thermal	154	17	1	0	172
AD boiler	0	0	0	0	0
AD CHP	0	0	0	0	0
Total	**1751**	**63**	**408**	**0**	**2222**

Figure 15-15: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario D6 (based on lifecycle emissions)

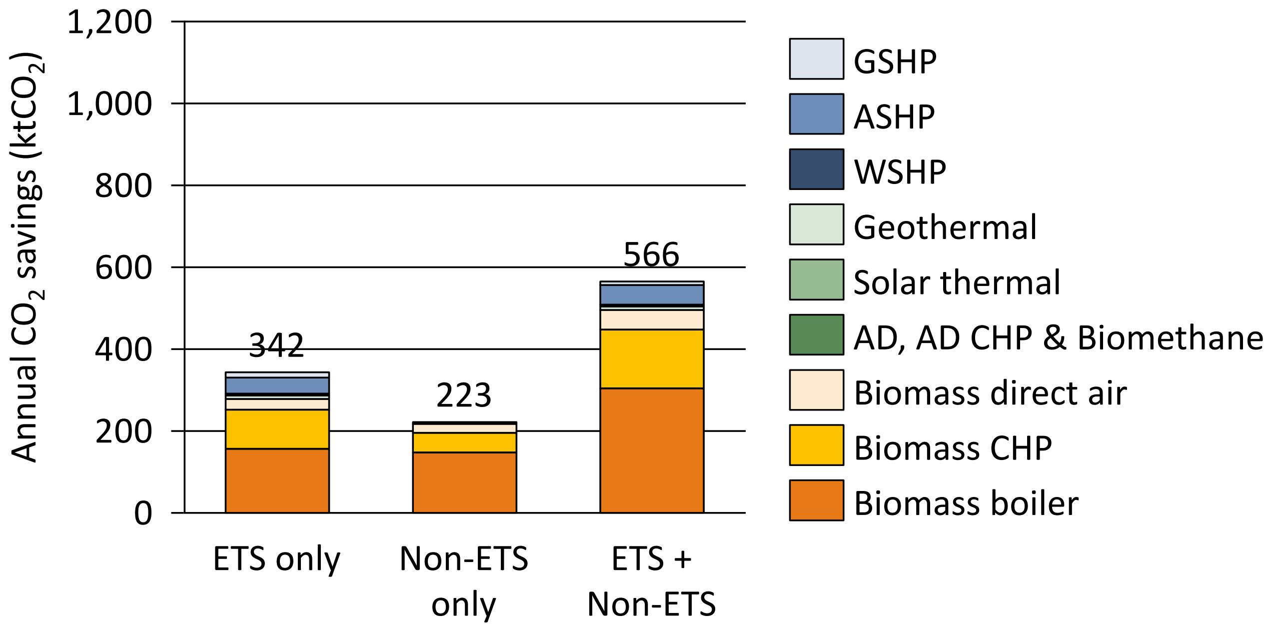


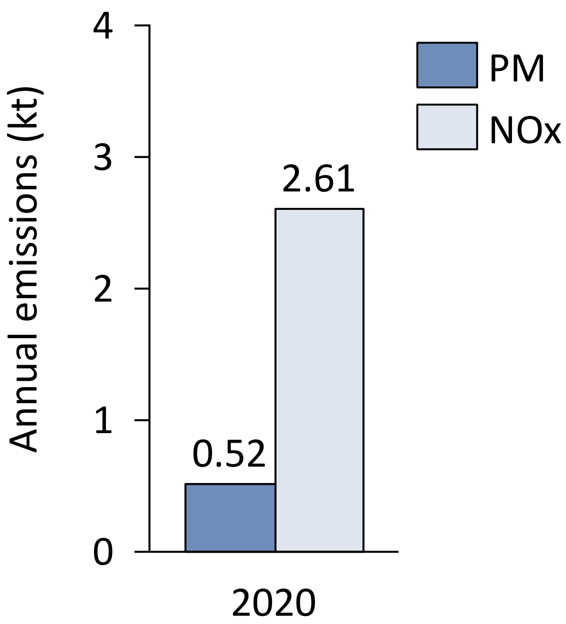
Table 15-25: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario D6 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10.6	0.2	10.8
ASHP	41.5	4.7	46.3
WSHP	1.9	0.3	2.2
Deep geothermal	10.4	1.7	12.1
Solar thermal	0.6	0.0	0.6
AD boiler	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0
Biomass direct air	26.3	20.1	46.1
Biomass CHP	93.7	48.0	142.1
Biomass boiler	157.1	148.4	305.3
Total	**342.1**	**223.4**	**565.6**

Table 15-26: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario D6 (based on 'point of use' emissions for biomass technologies)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10.6	0.2	10.8
ASHP	41.5	4.7	46.3
WSHP	1.9	0.3	2.2
Deep geothermal	10.4	1.7	12.1
Solar thermal	0.6	0.0	0.6
AD boiler	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0
Biomass direct air	28.8	22.0	50.8
Biomass CHP	103.9	53.3	157.2
Biomass boiler	172.1	162.6	334.6
Total	**369.9**	**244.8**	**614.7**

Figure 15-16: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario D6



Scenario D6L

Figure 15-17: Total heat demand met by RH technologies in 2020 in Scenario D6L (corresponding No RHI case not shown)

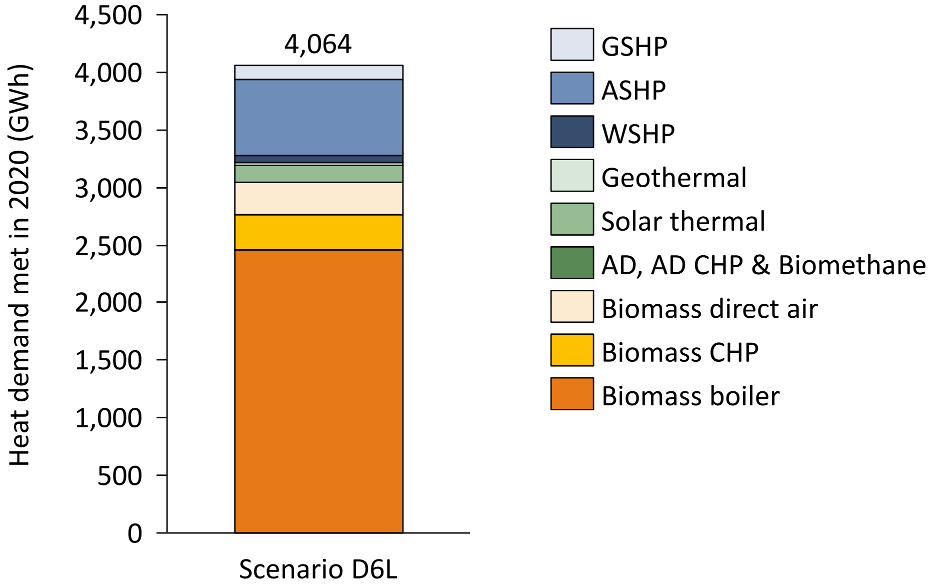


Table 15-27: Total heat demand met by RH technologies in 2020 in Scenario D6L

GWh	2015	2020 Scenario D6L
GSHP	99	128
ASHP	530	664
WSHP	50	55
Deep geothermal	0	26
Solar thermal	140	141
AD boiler	0	0
AD CHP	0	0
Biomass direct air	0	283
Biomass CHP	84	312
Biomass boiler	2048	2455
Total	**2951**	**4064**
% heat from RH	**6.6%**	**9.1%**

Figure 15-18: Annual Grant payments made in Scenario D6L

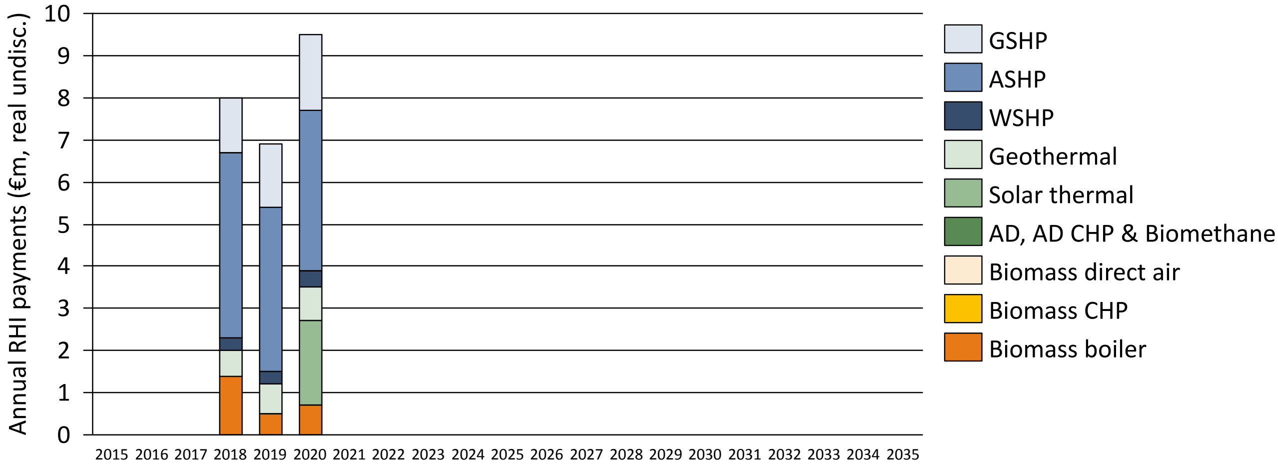


Table 15-28: Annual Grant payments made in Scenario D6L

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.3	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	4.4	3.9	3.8	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.3	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.6	0.7	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	1.4	0.5	0.7	0.0	0.0	0.0	0.0	0.0	0.0
Total	**7.9**	**6.8**	**9.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 15-29: Cumulative Grant payments made in Scenario D6L

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.3	2.8	4.6	4.6	4.6	4.6	4.6	4.6	4.6
ASHP	4.4	8.3	12.1	12.1	12.1	12.1	12.1	12.1	12.1
WSHP	0.3	0.5	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Deep geothermal	0.6	1.3	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Solar thermal	0.0	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	1.4	1.9	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Total	**7.9**	**14.8**	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
ASHP	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
WSHP	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Deep geothermal	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Solar thermal	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Total	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**	**24.2**

Table 15-30: Number of new installations 2016-2020 by technology and sector in Scenario D6L (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	0	0	73	0	73
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	82	0	82
ASHP	1520	16	107	0	1643
GSHP	73	0	32	0	105
WSHP	1	0	5	0	6
Deep geothermal	0	0	1	0	1
Solar thermal	154	17	1	0	172
AD boiler	0	0	0	0	0
AD CHP	0	0	0	0	0
Total	**1748**	**33**	**301**	**0**	**2082**

Figure 15-19: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario D6 (based on lifecycle emissions)

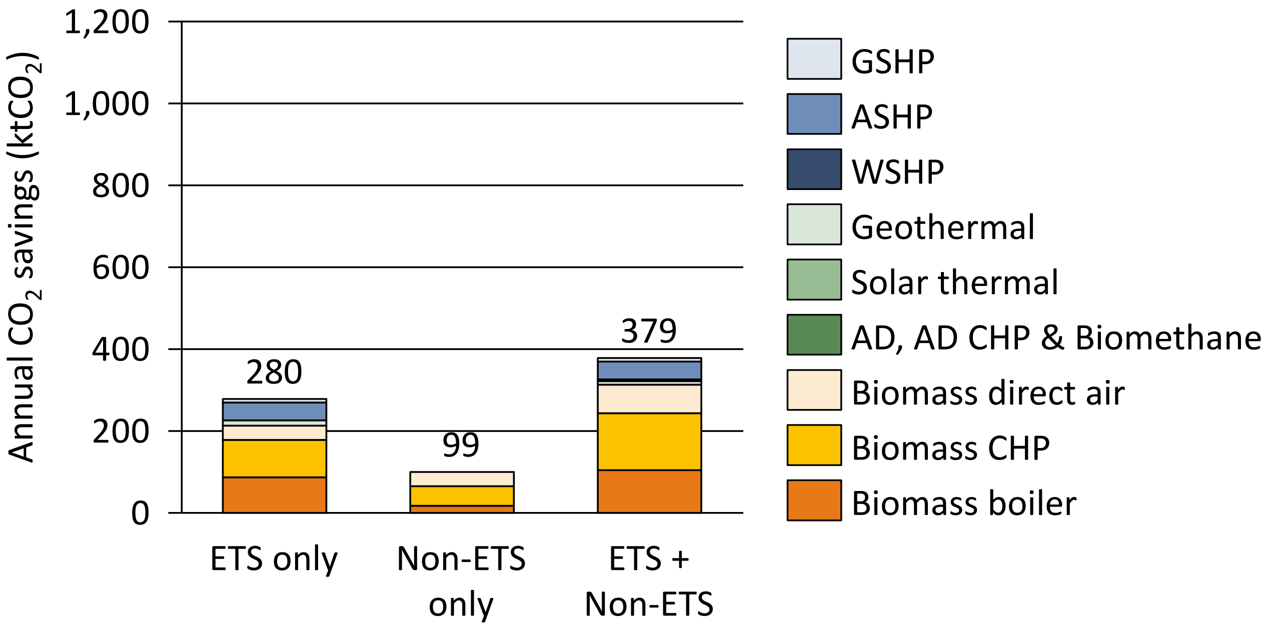


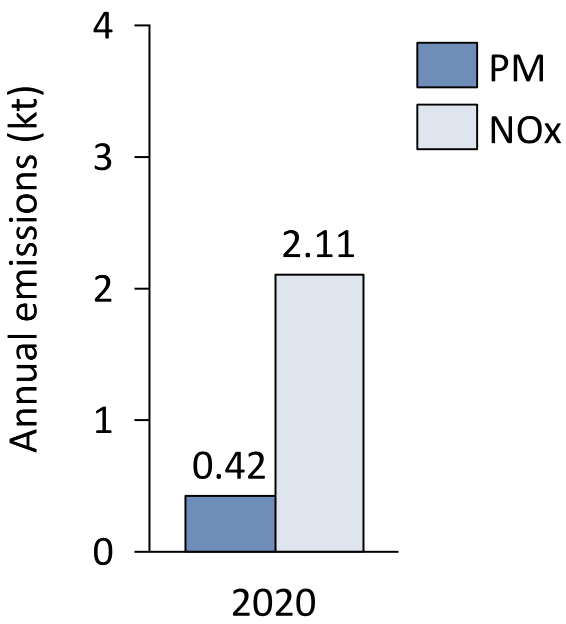
Table 15-31: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario D6L (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10.6	0.0	10.6
ASHP	43.4	0.2	43.6
WSHP	2.0	0.0	2.0
Deep geothermal	9.7	0.7	10.3
Solar thermal	0.6	0.0	0.6
AD boiler	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0
Biomass direct air	35.7	33.3	68.9
Biomass CHP	91.7	48.4	140.3
Biomass boiler	86.7	16.2	102.9
Total	**280.4**	**98.8**	**379.2**

Table 15-32: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario D6L (based on 'point of use' emissions for biomass technologies)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	10.6	0.0	10.6
ASHP	43.4	0.2	43.6
WSHP	2.0	0.0	2.0
Deep geothermal	9.7	0.7	10.3
Solar thermal	0.6	0.0	0.6
AD boiler	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0
Biomass direct air	37.0	34.5	71.5
Biomass CHP	101.3	53.7	155.0
Biomass boiler	90.0	16.8	106.8
Total	**294.6**	**105.9**	**400.5**

Figure 15-20: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario D6L



Scenario E6

Figure 15-21: Total heat demand met by RH technologies in 2020 in Scenario E6

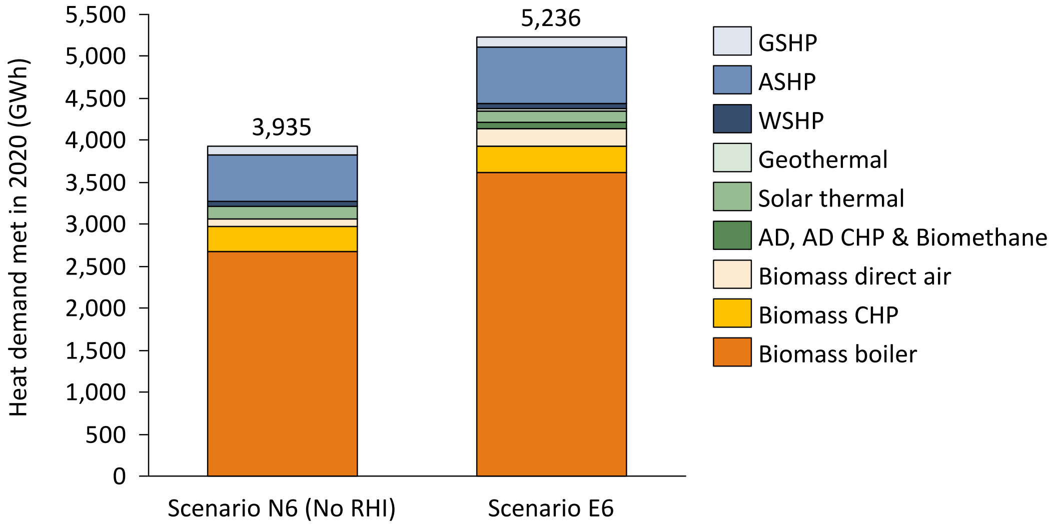


Table 15-33: Total heat demand met by RH technologies in 2020 in Scenario E6

GWh	2015	2020 Scenario N6	2020 Scenario E6
GSHP	99	103	129
ASHP	530	564	674
WSHP	50	51	56
Deep geothermal	0	8	21
Solar thermal	140	140	142
AD boiler	0	0	8
AD CHP	0	0	61
Biomass direct air	0	91	207
Biomass CHP	84	305	317
Biomass boiler	2048	2673	3620
Total	**2951**	**3935**	**5236**
% heat from RH	**6.6%**	**8.9%**	**11.7%**

Figure 15-22: Annual Grant + RHI payments made in Scenario E6

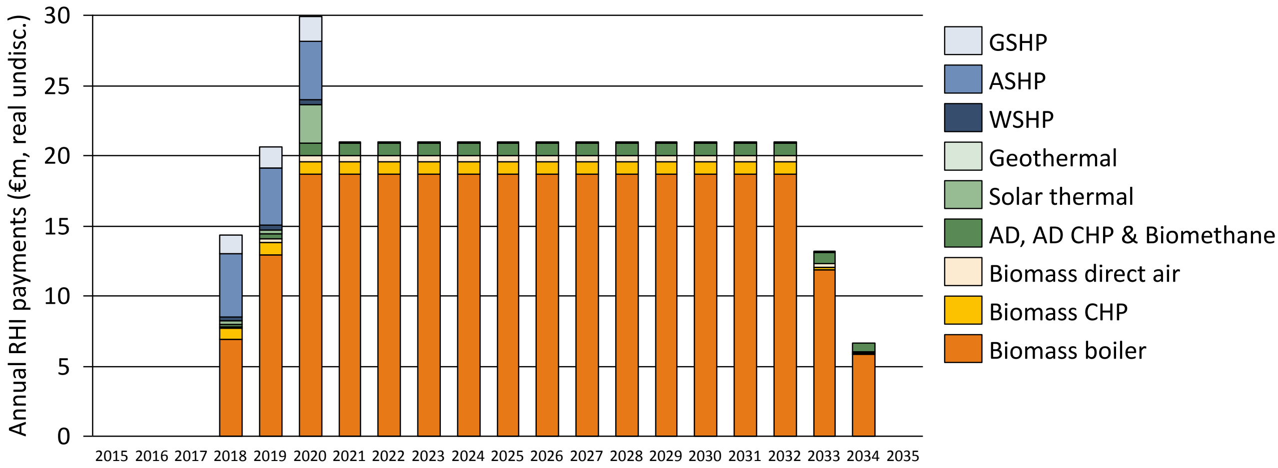


Table 15-34: Annual Grant payments made in Scenario E6

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.3	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	4.5	4.1	4.1	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.3	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.2	0.3	2.6	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**6.3**	**6.2**	**8.9**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 15-35: Annual RHI payments made in Scenario E6

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AD boiler	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AD CHP	0.2	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Biomethane	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Biomass direct air	0.1	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Biomass CHP	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Biomass boiler	6.9	12.9	18.7	18.7	18.7	18.7	18.7	18.7	18.7
Total	**8.0**	**14.5**	**21.1**	**21.1**	**21.1**	**21.1**	**21.1**	**21.1**	**21.1**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
AD boiler	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
AD CHP	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.4	0.0
Biomethane	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0
Biomass direct air	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.1	0.0
Biomass CHP	0.9	0.9	0.9	0.9	0.9	0.9	0.1	0.1	0.0
Biomass boiler	18.7	18.7	18.7	18.7	18.7	18.7	11.9	5.8	0.0
Total	**21.1**	**21.1**	**21.1**	**21.1**	**21.1**	**21.1**	**13.1**	**6.7**	**0.0**

Table 15-36: Cumulative Grant payments made in Scenario E6

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	3	5	5	5	5	5	5	5
ASHP	4	9	13	13	13	13	13	13	13
WSHP	0	1	1	1	1	1	1	1	1
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	3	3	3	3	3	3	3
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	0	0	0	0	0	0	0
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	0	0	0	0	0	0	0	0	0
Total	**6**	**13**	**21**	**21**	**21**	**21**	**21**	**21**	**21**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	5	5	5	5	5	5	5	5	5
ASHP	13	13	13	13	13	13	13	13	13
WSHP	1	1	1	1	1	1	1	1	1
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	3	3	3	3	3	3	3	3	3
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	0	0	0	0	0	0	0
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	0	0	0	0	0	0	0	0	0
Total	**21**	**21**	**21**	**21**	**21**	**21**	**21**	**21**	**21**

Table 15-37: Cumulative RHI payments made in Scenario E6

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	1	1
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	1	2	3	3	4	5	5
Biomethane	0	0	0	0	1	1	1	1	1
Biomass direct air	0	0	1	1	2	2	3	3	3
Biomass CHP	1	2	3	4	5	6	6	7	8
Biomass boiler	7	20	39	57	76	95	113	132	151
Total	**8**	**23**	**44**	**65**	**86**	**107**	**128**	**149**	**170**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	1	1	1	1	1	1	1	1	1
AD boiler	1	1	1	1	1	1	1	1	1
AD CHP	6	7	7	8	9	9	10	10	10
Biomethane	1	2	2	2	2	2	2	3	3
Biomass direct air	4	4	5	5	6	6	6	6	6
Biomass CHP	9	10	11	12	13	14	14	14	14
Biomass boiler	170	188	207	226	245	263	275	281	281
Total	**192**	**213**	**234**	**255**	**276**	**297**	**310**	**317**	**317**

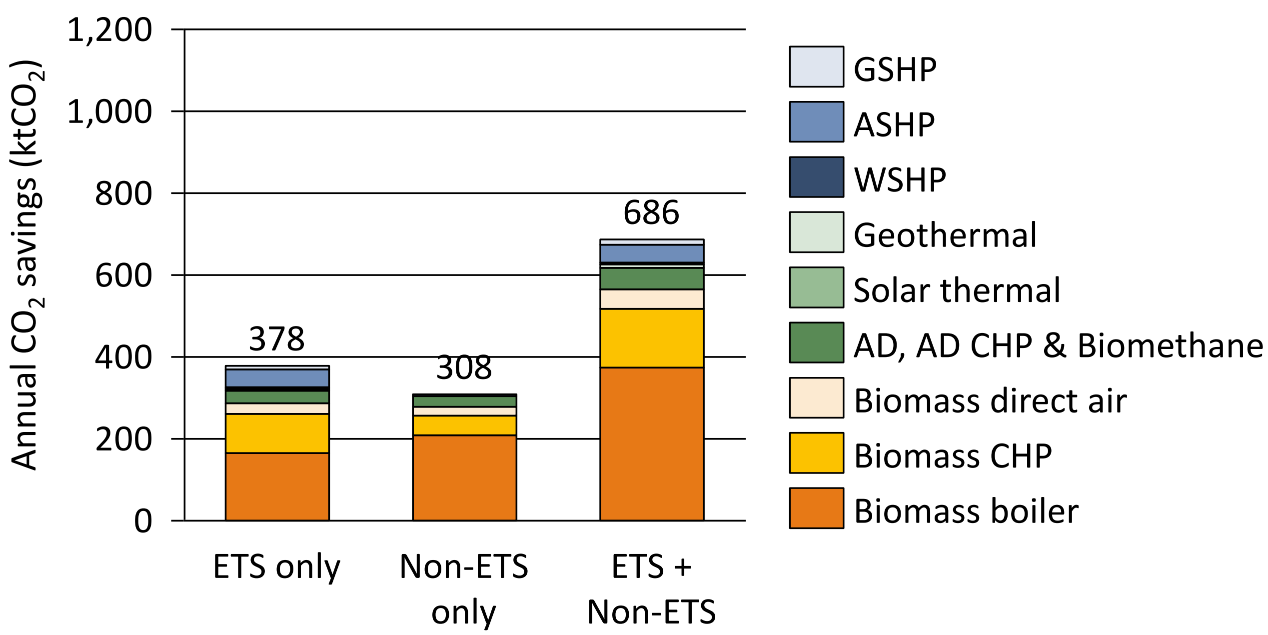
Table 15-38: Number of new installations 2016-2020 by technology and sector in Scenario E6 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2	93	528	0	623
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	58	0	58
ASHP	1522	31	116	0	1669
GSHP	73	0	33	0	106
WSHP	1	0	5	0	6
Deep geothermal	0	0	1	0	1
Solar thermal	154	60	1	0	215
AD boiler	0	0	0	4	4
AD CHP	0	0	0	14	14
Total	**1752**	**184**	**742**	**18**	**2696**

Table 15-39: Annual RHI support (excluding Grant support) in 2020 per unit additional heat demand met by RH technologies 2015-2020 versus No RHI case in Scenario E6 (excluding Biomethane)

	Annual RHI support in 2020 (2015€m)	Additional heat demand met by RH 2015-2020 versus No RHI (GWh)	Annual RHI support in 2020 per unit additional heat demand versus No RHI (2015€ cents/kWh)[99]
GSHP	0.0	26	0.0
ASHP	0.0	110	0.0
WSHP	0.0	5	0.0
Deep geothermal	0.0	13	0.0
Solar thermal	0.1	2	5.0
AD boiler	0.1	8	1.3
AD CHP	0.7	61	1.1
Biomass direct air	0.4	116	0.3
Biomass CHP	0.9	12	7.5
Biomass boiler	18.7	947	2.0
Total	**20.9**	**1301**	**1.6**

Figure 15-23: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario E6 (based on lifecycle emissions)



[99] N.B. Annual RHI support in 2020 per unit additional heat demand versus No RHI can be larger than the tariff offered due to deadweight i.e. payment of RHI to installations which occurred in the No RHI case.

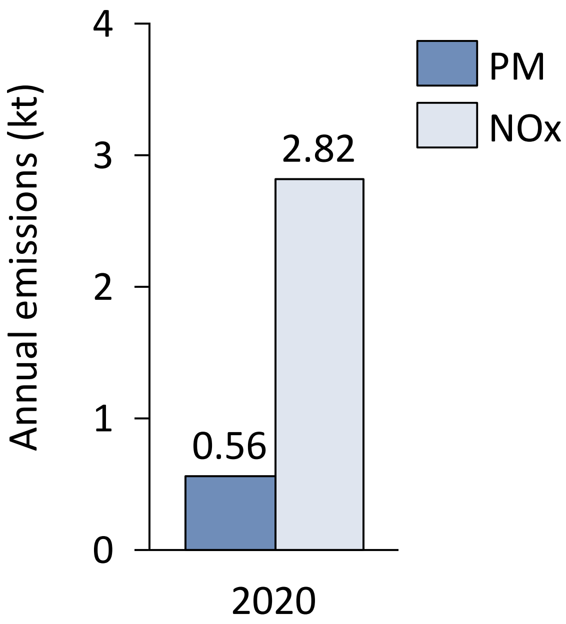
Table 15-40: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario E6 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11	0	11
ASHP	42	3	45
WSHP	2	0	2
Deep geothermal	7	1	8
Solar thermal	1	0	1
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	9	9
Biomass direct air	27	21	47
Biomass CHP	94	48	142
Biomass boiler	167	208	375
Total	**378**	**308**	**686**

Table 15-41: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario E6 (based on 'point of use' emissions for biomass technologies)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11	0	11
ASHP	42	3	45
WSHP	2	0	2
Deep geothermal	7	1	8
Solar thermal	1	0	1
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	9	9
Biomass direct air	30	23	53
Biomass CHP	104	53	157
Biomass boiler	184	230	414
Total	**409**	**337**	**746**

Figure 15-24: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario E6



Scenario F6

Figure 15-25: Total heat demand met by RH technologies in 2020 in Scenario F6

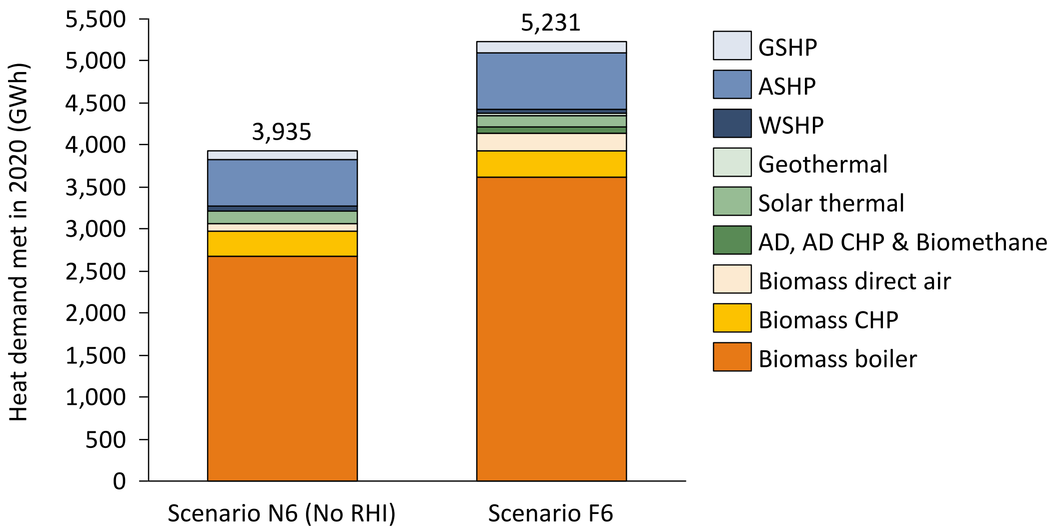


Table 15-42: Total heat demand met by RH technologies in 2020 in Scenario F6

GWh	2015	2020 Scenario N6	2020 Scenario F6
GSHP	99	103	128
ASHP	530	564	673
WSHP	50	51	56
Deep geothermal	0	8	21
Solar thermal	140	140	140
AD boiler	0	0	8
AD CHP	0	0	61
Biomass direct air	0	91	211
Biomass CHP	84	305	317
Biomass boiler	2048	2673	3616
Total	**2951**	**3935**	**5233**
% heat from RH	**6.6%**	**8.9%**	**11.7%**

Figure 15-26: Annual Grant + RHI payments made in Scenario F6

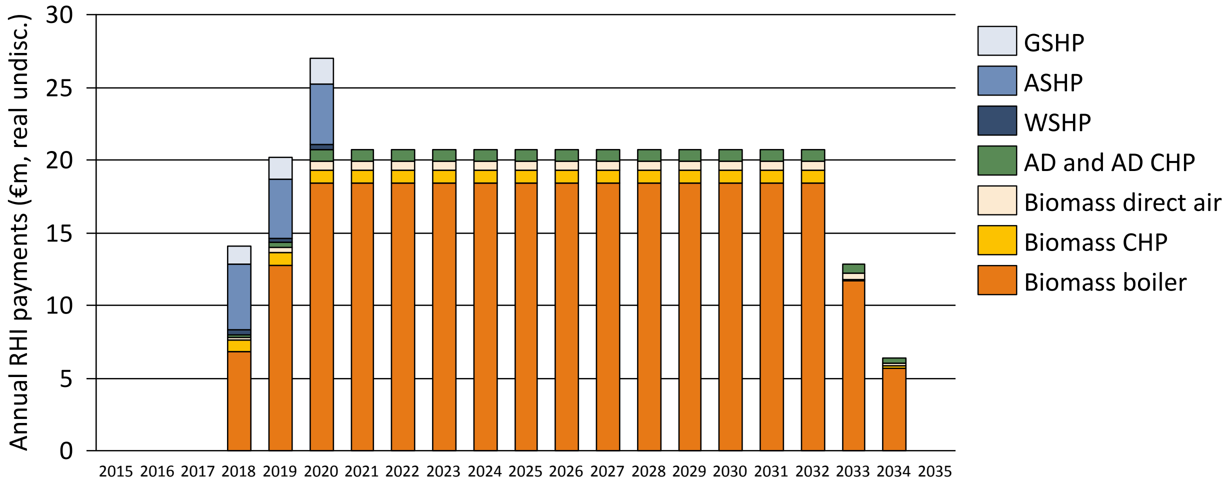


Table 15-43: Annual Grant payments made in Scenario F6

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1.3	1.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	4.5	4.1	4.1	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.3	0.3	0.4	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**6.1**	**5.9**	**6.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass CHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass boiler	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

Table 15-44: Annual RHI payments made in Scenario F6

Annual cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
AD CHP	0.2	0.3	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.2	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Biomass CHP	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Biomass boiler	6.8	12.7	18.4	18.4	18.4	18.4	18.4	18.4	18.4
Total	**8.0**	**14.3**	**20.7**	**20.7**	**20.7**	**20.7**	**20.7**	**20.7**	**20.7**

Annual cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
ASHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WSHP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deep geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solar thermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AD boiler	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0
AD CHP	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.4	0.0
Biomethane	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Biomass direct air	0.6	0.6	0.6	0.6	0.6	0.6	0.4	0.2	0.0
Biomass CHP	0.9	0.9	0.9	0.9	0.9	0.9	0.1	0.1	0.0
Biomass boiler	18.4	18.4	18.4	18.4	18.4	18.4	11.7	5.7	0.0
Total	**20.7**	**20.7**	**20.7**	**20.7**	**20.7**	**20.7**	**12.8**	**6.4**	**0.0**

Table 15-45: Cumulative Grant payments made in Scenario F6

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	1	3	5	5	5	5	5	5	5
ASHP	4	9	13	13	13	13	13	13	13
WSHP	0	1	1	1	1	1	1	1	1
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	0	0	0	0	0	0	0
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	0	0	0	0	0	0	0	0	0
Total	**6**	**12**	**18**	**18**	**18**	**18**	**18**	**18**	**18**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	5	5	5	5	5	5	5	5	5
ASHP	13	13	13	13	13	13	13	13	13
WSHP	1	1	1	1	1	1	1	1	1
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	0	0	0	0	0	0	0
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	0	0	0	0	0	0	0	0	0
Biomass CHP	0	0	0	0	0	0	0	0	0
Biomass boiler	0	0	0	0	0	0	0	0	0
Total	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**	**18**

Table 15-46: Cumulative RHI payments made in Scenario F6

Cumulative cost, 2015€m (real, undiscounted)	2018	2019	2020	2021	2022	2023	2024	2025	2026
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	0	0	0	0	0	0	0	0	0
AD CHP	0	0	1	2	3	3	4	5	5
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	0	1	1	2	2	3	4	4	5
Biomass CHP	1	2	3	4	5	6	6	7	8
Biomass boiler	7	19	38	56	75	93	112	130	148
Total	**8**	**22**	**43**	**64**	**84**	**105**	**126**	**147**	**167**

Cumulative cost, 2015€m (real, undiscounted)	2027	2028	2029	2030	2031	2032	2033	2034	2035
GSHP	0	0	0	0	0	0	0	0	0
ASHP	0	0	0	0	0	0	0	0	0
WSHP	0	0	0	0	0	0	0	0	0
Deep geothermal	0	0	0	0	0	0	0	0	0
Solar thermal	0	0	0	0	0	0	0	0	0
AD boiler	1	1	1	1	1	1	1	1	1
AD CHP	6	7	7	8	9	9	10	10	10
Biomethane	0	0	0	0	0	0	0	0	0
Biomass direct air	5	6	7	7	8	8	9	9	9
Biomass CHP	9	10	11	12	13	14	14	14	14
Biomass boiler	167	185	204	222	240	259	270	276	276
Total	**188**	**209**	**229**	**250**	**271**	**292**	**304**	**311**	**311**

Table 15-47: Number of new installations 2016-2020 by technology and sector in Scenario F6 (Biomass CHP in the power sector not included)

Number of installations	Commercial	Public	Industry	Agriculture	Total
Biomass boiler	2	51	521	0	574
Biomass CHP	0	0	0	0	0
Biomass direct air	0	0	62	0	62
ASHP	1522	31	115	0	1668
GSHP	73	0	33	0	106
WSHP	1	0	5	0	6
Deep geothermal	0	0	1	0	1
Solar thermal	0	0	0	0	0
AD boiler	0	0	0	4	4
AD CHP	0	0	0	14	14
Total	**1598**	**82**	**738**	**18**	**2436**

Table 15-48: Annual RHI support (excluding Grant support) in 2020 per unit additional heat demand met by RH technologies 2015-2020 versus No RHI case in Scenario F6

	Annual RHI support in 2020 (2015€m)	Additional heat demand met by RH 2015-2020 versus No RHI (GWh)	Annual RHI support in 2020 per unit additional heat demand versus No RHI (2015€ cents/kWh)[100]
GSHP	0.0	25	0.0
ASHP	0.0	109	0.0
WSHP	0.0	5	0.0
Deep geothermal	0.0	13	0.0
Solar thermal	0.0	0	0.0
AD boiler	0.1	8	1.3
AD CHP	0.7	61	1.1
Biomass direct air	0.6	120	0.5
Biomass CHP	0.9	12	7.5
Biomass boiler	18.4	943	2.0
Total	**20.7**	**1298**	**1.6**

[100] N.B. Annual RHI support in 2020 per unit additional heat demand versus No RHI can be larger than the tariff offered due to deadweight i.e. payment of RHI to installations which occurred in the No RHI case.

Figure 15-27: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario F6 (based on lifecycle emissions)

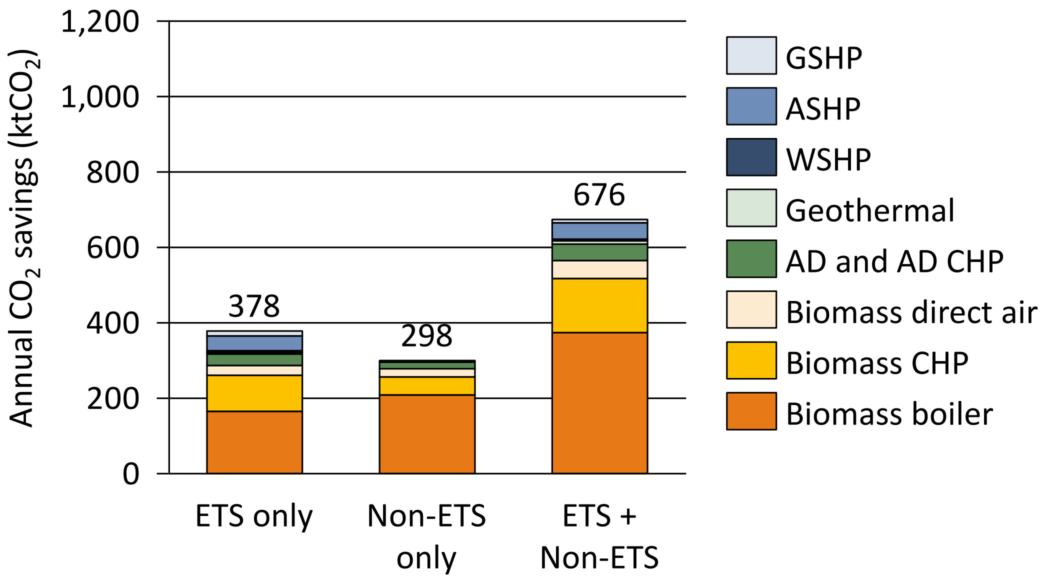


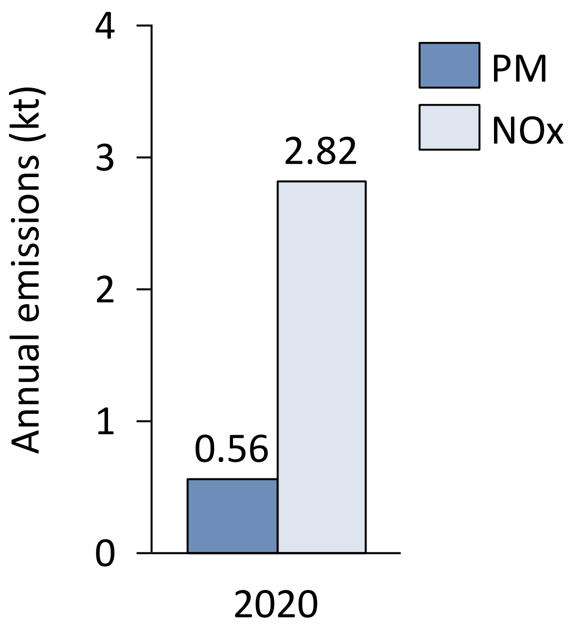
Table 15-49: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario F6 (based on lifecycle emissions)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11	0	11
ASHP	42	3	45
WSHP	2	0	2
Deep geothermal	7	1	8
Solar thermal	0	0	0
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	0	0
Biomass direct air	27	21	48
Biomass CHP	94	48	143
Biomass boiler	167	207	374
Total	**378**	**298**	**676**

Table 15-50: Annual CO_2 savings in 2020 due to installations 2016-2020 in Scenario F6 (based on 'point of use' emissions for biomass technologies)

Annual CO_2 savings ($ktCO_2$)	ETS only	Non-ETS only	ETS + Non-ETS
GSHP	11	0	11
ASHP	42	3	45
WSHP	2	0	2
Deep geothermal	7	1	8
Solar thermal	0	0	0
AD boiler	0	2	2
AD CHP	28	15	43
Biomethane	0	0	0
Biomass direct air	30	24	54
Biomass CHP	104	54	158
Biomass boiler	184	229	413
Total	**408**	**327**	**736**

Figure 15-28: Indicative annual PM_{10} and NOx emissions in 2020 in Scenario F6



16 Discussion on level of tariffs for Biomethane

The analysis undertaken to produce the deployment scenarios, and required tariffs, for AD boilers, AD CHP and Biomethane is described in the report *Interface analysis and report for incorporation and alignment of data from biomethane study into RHI workstream* produced by Element Energy and Ricardo Energy & Environment for SEAI in January 2017. In that study, the tariffs required to incentivise the deployment of these technologies were derived, aligning assumptions with the wider RHI analysis for other technologies wherever possible.

The tariffs presented for Biomethane in Section 14 have, as for the other technologies, been capped at the Biomass boiler tariffs. However, the impact of capping the tariffs for Biomethane has not been incorporated into the associated level of deployment of this technology. The reason for this is that, as described in the *Interface* report, the deployment scenarios were developed 'off-model' by Ricardo Energy & Environment assuming a sufficient level of incentivises for the relevant technologies.

As a result, there is a risk that application of the 'capped' tariffs presented in Section 14 will not lead to the level of deployment of Biomethane presented in this document. In order to allow a comparison with the 'capped' tariffs shown above, the 'uncapped' tariffs required to incentivise the Biomethane installations studied are presented in Table 5-7 below.

The 'Central' deployment scenario, assumed to be achieved in Scenario A5 and Scenario B5 in the results shown in Section 15, are presented in Table 5-9.

Tariff level for Biomethane

It is recognised that the approach of capping tariffs at the level of the tariff for Biomass boilers is likely to result in a reduced diversity of the heating technology mix. However, this approach is intended to ensure good value for money for the RHI scheme, and to incentivise only the least costly installations.

The rationale for capping the tariff level for Biomethane at the level of Biomass boilers is not fully comparable with the rationale for the other technologies, since the Biomethane technologies are not fully equivalent, producing methane for grid injection rather than producing heat directly, and because the associated installations are expected to be substantially larger than for most of the other technologies included in the RHI. It may therefore be appropriate to apply a different approach to this technology.

In view of this, a particular comment is made here on the level of the tariff implied in the 'capped' case presented in Section 14 above, and the level found to be required to incentivise the relevant Biomethane systems presented in Table 5-7 below.

The Biomethane system assumed to be deployed in Central scenario, as presented in Table 5-9, is 'BM H' i.e. a system based on an existing wastewater treatment plant. Since the only costs included are those for upgrading the existing plant to capture and inject biomethane, no tariff is found to be required for such a system in Scenario A5 (8% IRR) or in Scenario B5 (12% IRR). Deployment of such a system may therefore be compatible with the 'capped' tariffs in Section 14.

However, while the bioenergy resource assessment underpinning the RHI analysis identifies potential feedstocks for the production of biogas, farm scales in Ireland mean that biomethane injection for most farms is uneconomic without a higher level of support. Based on stakeholder consultation undertaken to date, it is deemed likely that in the early stages of market development the most technically viable pathway is that described by 'BM G'. In the BM G pathway, farm waste and grass silage is used in small AD units on individual farms, and the biogas is then collected, compressed and cleaned before being transported by road to a central injection point. Table 5-7 suggests that such an installation would require a tariff in the range 3.2 cents/kWh in Scenario A5 (8% IRR) and 3.6 cents/kWh in Scenario B5 (12% IRR). Comparison with the ‘capped’ tariffs in Section 14 above (noting that the annual biomethane production of such a system is 51,655 MWh/yr, meaning that the tariffs up to Tier 9 will be applicable) clearly suggests that the ‘capped’ tariffs will be insufficient to incentivise this system.

It is evident, therefore, that the final design of a suitable RHI scheme for biomethane should be based on a clear decision over the type(s) of biomethane installation the scheme is intended to incentivise. It is therefore concluded that further work is required to finalise the design of the RHI tariff for biomethane.

Table 16-1: Biomethane tariffs by system design in Scenario A5 and Scenario B5 (not capped at Biomass boiler tariffs)

System ID	Feedstock	Comments	Capacity, kW biogas	Biomethane produced, MWh/yr	Scenario A5: Tariff required, c/kWh	Scenario B5: Tariff required, c/kWh
BM A	Farm - silage (60%) and slurry (40%)	Biogas from several individual AD plant (five assumed) is transported by low pressure pipeline to a centralised upgrading and injection point	1,115	9,084	5.5	6.1
BM B	Waste Fed - MSW food waste	Plant capable of taking contained source separated food waste from MSW and commercial waste collections	1,746	14,529	6.8	9.1
BM C	Waste Fed - MSW food waste	Plant capable of taking contained source separated food waste from MSW and commercial waste collections	6,199	50,502	0.4	1.6
BM D	Waste Fed - food processing wastes	Plant taking less contaminated food wastes, typically with higher biogas yields	6,265	51,039	1.4	1.9
BM E	Farm - maize and food waste	Farm-based plants taking energy crops and waste	6,747	54,966	6.2	7.1
BM F	Farm - silage and slurry	Farm-based plant based on silage and slurry	6,341	51,655	2.6	3.0
BM G	Farm - silage and slurry	Similar plant to BM F but biomethane is compressed and taken by road to a central injection point	6,341	51,655	3.2	3.6
BM H	Wastewater treatment primary sludge	Existing wastewater treatment plant; only costs included are those for upgrading to biomethane and injection	4,385	35,727	0.0	0.0

Table 16-2: Deployment scenarios for AD CHP, AD boilers and biomethane grid injection in 2020[101]

System ID	Central deployment		
	LHL	MHL	HHL
Boiler A	-	-	3
Boiler B	-	-	1
CHP A	-	-	-
CHP B	-	-	2
CHP C	-	-	1
CHP D	-	-	1
CHP E	-	-	-
CHP F	-	-	-
CHP G	-	-	4
CHP H	-	-	4
CHP I	-	-	1
CHP J	-	-	1
BM A	-		
BM B	-		
BM C	-		
BM D	-		
BM E	-		
BM F	-		
BM G	-		
BM H	1		
Number of plants	**19**		
Total heat, GWh/yr	**96**		

[101] Taken from: Element Energy and Ricardo Energy & Environment, *Interface analysis and report for incorporation and alignment of data from biomethane study into RHI workstream*, Report for SEAI (January 2017)