Assessment of the effectiveness and economic efficiency of selected support options for the Netherlands

D13 of WP4 from the RES-H Policy project

A Working Document prepared as part of the IEE project "Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)"

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The RES-H Policy project

The project "Policy development for improving RES-H/C penetration in European Member States (RES-H Policy)" aims at assisting Member State governments in preparing for the implementation of the forthcoming Directive on Renewables as far as aspects related to renewable heating and cooling (RES-H/C) are concerned. Member States are supported in setting up national sector specific 2020/2030 RES-H/C targets. Moreover the project initiates participatory National Policy Processes in which selected policy options to support RES-H/C are qualitatively and quantitatively assessed. Based on this assessment the project develops tailor made policy options and recommendations as to how to best design a support framework for increased RES-H/C penetration in national heating and cooling markets.

The target countries/regions of the project comprise Austria, Greece, Lithuania, The Netherlands, Poland and UK – countries that represent a variety in regard of the framework conditions for RES-H/C. On the European level the projects assesses options for coordinating and harmonising national policy approaches. This results in common design criteria for a general EU framework for RES-H/C policies and an overview of costs and benefits of different harmonised strategies.

This Working Document

This Working Document summarises the results of the assessment of the effectiveness and economic efficiency of different support instrument options to foster the market penetration of RES-H/C in the Netherlands. For two selected policy options related costs (mainly public transfer costs) and benefits (e.g. growth in RES-H/C capacities, avoided fuel costs, reduced GHG emissions) will be assessed. In addition it will be analysed how the different policy options will influence the development of different RES-H/C technologies. Moreover this working step covers an estimation of the transaction costs (in particular those resulting on the authorities' side) and the direct (gross) employment effect that can be linked to the two analysed support policy options. In addition, two separate research questions have been address in this working document: firstly one on cost optimisation for renewable heat in overall renewable mix and secondly renewable heat in industry is being addressed.

This Working Document is based on the description and qualitative assessment of selected support instrument options as described by Working Document D9. Similar documents have also been prepared relating to the other countries/regions targeted within this project.

1 Impacts of RES-H policies on capacities, emissions, costs

1.1 Modelling Methodology

Previous documents released in the RES-H Policy project have provided insights in the Dutch renewable heating and cooling sector: firstly, a report is available on the potential for renewable heating and cooling in the residential, service and industry sector (D6). Secondly, proposed policy support measures have been introduced in another report (D9). The current report (D13) presents in detail the results of the analysis, based on the underlying assumptions for the simulation modelling described in reports mentioned before. All documents have been compiled in co-operation with national stakeholders in the Netherlands, notably in a series of workshops, conducted in the period 2009 – 2011.

This chapter documents the outcomes of the exercises performed. Two demand sectors have been modelled:

- Space heating and hot water demand in the residential and service sector, using the Invert/EE-Lab modelling environment
- Industrial process heat using the Resolve-H/C model

Short descriptions of the modelling environment have been provided in Annex A: model descriptions.

Equally important for evaluating the modelling outcomes are the data assumptions that have been fed into the simulations. These have also been documented in the Annex sections (Annex B with three subsections).

1.2 Characteristics of investigated policies and scenarios

In Deliverable D9 of the RES-H Policy project it has been documented which policy instruments were most appropriate for the modelling exercise in the Netherlands. The choices have been made in interaction with Dutch stakeholders, among others the participants of the first two Dutch RES-H Policy workshops (The Hague, September 2009 and Amsterdam, May 2010).

> *Instrument 1: Subsidies (both in the residential sector (new and existing dwellings) and in industry.*
>
> *Instrument 2: Energy Performance Standard (EPN) in new dwellings*

More detail about the measures and the way in which they can be modelled is provided below.

Instrument 1: Subsidies

In the Netherlands, subsidies are implemented in the "Sustainable heat" subsidy scheme that allocates subsidies to techniques for sustainable heating and cooling. The scheme applies only to existing buildings and is available until the year 2011. It is not yet known what will happen to the scheme after 2011[1]

Next to the existing buildings, this scheme can also be applied to new buildings. It is also possible to apply the scheme outside the built environment, as for example in industry and agriculture.

Translation of policy scheme 1 to modelling environment

Modelling subsidies in INVERT is a relatively straightforward procedure. Also in the RESolve-H/C model for evaluating renewable heating and cooling in the industry sector is very well possible. The policy scheme is considered as an investment scheme, and subsidy levels will be introduced in the section on the modelling.

Instrument 2: Energy Performance Standard (EPN) in new dwellings

The Energy Performance Standard (in Dutch: *Energie Prestatie Normering*, EPN) was introduced in the year 1995. For the sector households the Energy Performance Standard calculates the overall energy performance of a new dwelling and its heating, ventilation, cooling and lighting equipment. The standard consists of a standardized method for the calculation of an Energy Performance Coefficient (EPC) for a new dwelling, which relates the reference energy use to the size of the house. The values of the constant factors in the equation which determine the reference figure are chosen in such a way that a new Dutch house of an average size and shape has an annual primary energy demand of 1000 cubic metres of natural gas equivalent, when its EPC would be 1.0. The maximum allowed EPC has been gradually tightened: from 1.4 in 1995 to 1.2 in 1998 to 1.0 in 2000 and 0.8 in 2006. The tightening by 25% around 2012 and 50% around 2015 could mean that the EPC for dwellings ultimately would become 0.4. The essential feature of this regulation is the freedom to choose any combination of measures that meet the required EPC.
After the introduction of the Energy Performance Standard the implementation of the following measures has been observed. Thermal insulation has improved and mainly condensing boilers with higher efficiency for hot water production and more advanced ventilation systems have been implemented in new houses. When the EPC will be tightened, RES-H options like solar thermal systems or heat pumps will become an important alternative for further energy savings.

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[1] See also the meeting report of the final conference in the Netherlands at http://www.ecn.nl/conferentie_hernieuwbare_warmte

In the period up to 2020 the modelling work in this chapter mainly focuses on the tightening of the EPC from 0.6 to 0.4, but after 2020 more renewables can be expected through increased and more severe regulation.

The current EPN also offers an opportunity for a mandatory share of renewable energy. Currently this option is not operational. The option of a mandatory share of energy from renewable sources is a real opportunity for new housing. However, this measure does not seem feasible for renovation of existing homes in the Netherlands, although examples in Germany indicate that this option is practicable (the case of Baden-Wuertemberg).

Translation of policy scheme 2 to modelling environment

Modelling the Energy Performance Standard (EPN) in INVERT is not possible in a direct way, but only in an indirect way. This indirect way is to assume the Energy Performance Coefficient (EPC) gradually to be tightened (from 0.8 in 2006 to 0.6 and 0.4 in the near future). Analyses have shown that these very low values for EPC can only be attained by adding renewable energy technologies . The essential feature, leaving the designer free in opting for any measure (be it an energy saving technology or an energy supply technology) remains intact. As the building stock in INVERT has not enough detail for evaluating such installation design choices, the EPN will be modelled as an obligation to use renewable energy technologies.

For industry, the modelled policy measure is an exploitation subsidy modelled with inputs from the UK Renewable Heat Incentive (RHI). In the course of the RES-H Policy project it has become clear that the Netherlands are considering the design of such policy, but because no tariffs have been available at the time of modelling the UK tariffs have been used. The simulations were run using the figures for levels of support provided in the UK Department of Energy and Climate Change document of March 2011 RHI available from www.decc.gov.uk/rhi

1.3 Variant without policy

In the modelling environments renewable heating and cooling has to compete with conventional energy in order to reach a certain penetration. The fuel prices are a very important determining factor in this competition: as can be seen in the annex section ‘Fuel price assumptions’ there is an important difference between the ‘low’ and the ‘high price scenario’. This difference becomes especially important in the period after 2010. It can be observed that for example the various heat pump technologies are cheaper per unit of heat generated than when generated using the conventional energy carriers. This is an indication that the growth for this technology might potentially be enormous. The potential is only constrained by the maximum allowed penetration: the potential. Some technologies (notably heat pumps) have potentials defined that allow high average annual growth rates. An example of a technology which is equally beneficial but has significantly less opportunities to grow is renewable district heating. Solar thermal is an option which has a relative bad starting position for competition with conventional energy carriers: even in the high price scenario the cost level of heat provided is simply too high above the conventional options.

The above narrative is illustrated by a model run of both price scenarios, which are presented in the figure below.

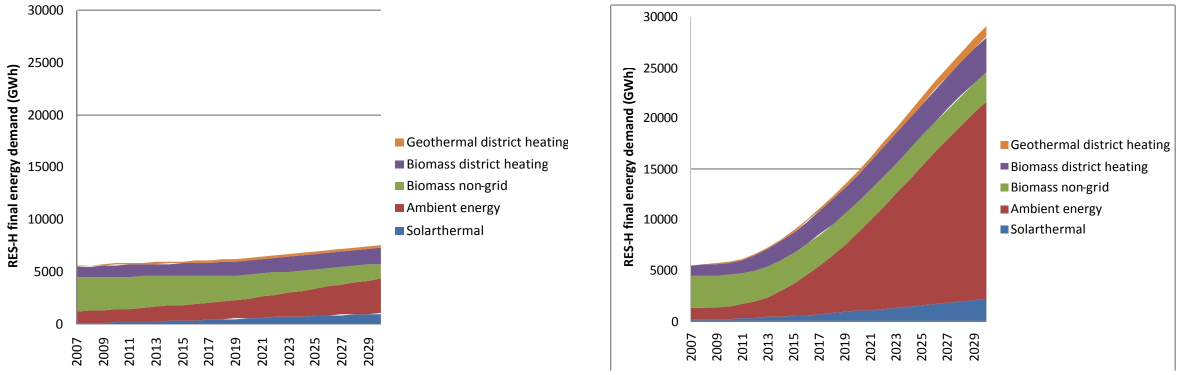

Figure 1: Development of RES-H in the building sector without policy support (left hand: low energy prices, right hand: high energy prices)

Below, tables are provided with the numerical values for both projections.

Table 1: Development of RES-H in the building sector without policy support (low energy prices)

	2010			2020			2030		
	Realisation		Share	Realisation		Share	Realisation		Share
	GWh	PJ	%	GWh	PJ	%	GWh	PJ	%
Solarthermal	246	0.9	4%	644	2.3	10%	1090	3.9	14%
Ambient energy	1244	4.5	21%	1862	6.7	29%	3332	12.0	44%
Biomass non-grid	3124	11.2	54%	2319	8.3	36%	1412	5.1	19%
Biomass district heating	1112	4.0	19%	1325	4.8	21%	1571	5.7	21%
Geothermal district heating	110	0.4	2%	207	0.7	3%	218	0.8	3%
RES-H total	5837	21.0	100%	6356	22.9	100%	7622	27.4	100%
Share RES-H	4%	4%		4%	4%		6%	6%	

Table 2: Development of RES-H in the building sector without policy support (high energy prices)

	2010			2020			2030		
	Realisation		Share	Realisation		Share	Realisation		Share
	GWh	PJ	%	GWh	PJ	%	GWh	PJ	%
Solar thermal	253	0.9	4%	1037	3.7	7%	2212	8.0	8%
Ambient energy	1278	4.6	22%	7784	28.0	52%	19506	70.2	67%
Biomass non-grid	3107	11.2	53%	3047	11.0	20%	2896	10.4	10%
Biomass district heating	1145	4.1	19%	2650	9.5	18%	3427	12.3	12%
Geothermal district heating	102	0.4	2%	371	1.3	2%	1125	4.1	4%
RES-H total	5885	21.2	100%	14889	53.6	100%	29167	105.0	100%
Share RES-H	4%	4%		11%	11%		23%	23%	

It is clear that heat pumps in the 'high price scenario' are benefiting enormously, even largely exceeding the potential as defined in previous analysis in the RES-H Policy project. The underlying reason for this very high potential is that the boiler replacement rate offers many opportunities to make people opt for a new heat pump instead of a gas (condensing) boiler which is the standard equipment in Dutch dwellings. If the model is being run with high fuel prices assumptions on the potentials are being overruled. In practise this is difficult to imagine, but the 'no policy' variants are relevant for indicating the range of technical possibilities. One of the conclusions from the above data is that the fuel price assumptions are extremely decisive in projecting the future of renewable heating options in the building sector. It can be observed that solar thermal penetrates strongly even at prices that are higher than fuel prices. Reason for this is the preference of the INVERT model for solar thermal systems in new buildings, but also that solar thermal system costs decrease over time.

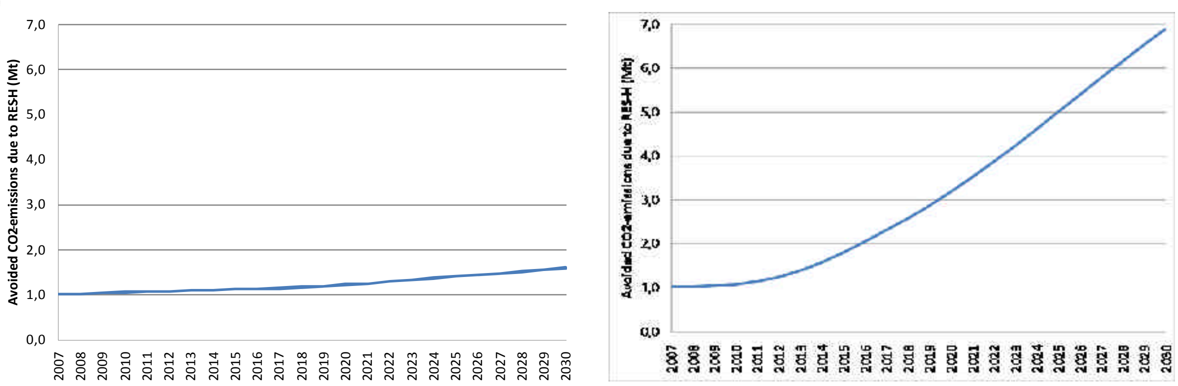

Figure 2: Avoided CO2-emission [Mt] due to RES-H in the building sector without policy support (left hand: low energy prices, right hand: high energy prices)

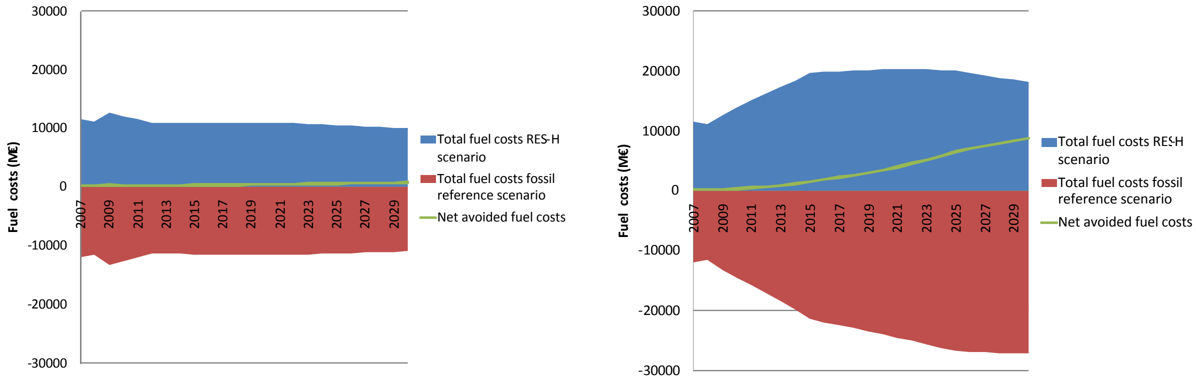

Figure 3: Fuel costs (left hand: low energy prices, right hand: high energy prices)

In the graphs above, the red area reflects the costs of a fossil fuel reference scenario, meaning the situation in which the whole demand is being met by just fossil energy technologies (assuming the energy carrier mix of 2007). The blue area reflects the fuel costs of the calculated scenario. Electricity costs for heat pumps are included in the blue area.

A financial summary of the above scenarios is provided in the tables below.

Table 3: Associated costs for policy, avoided fuel and avoided CO_2-emissions without policy support (low energy prices) in the building sector

	2010	2020	2030
Total renewable heat [PJ]	21	23	27
Policy costs [MEUR]	0	0	0
Avoided fuel costs [MEUR]	366	505	775
Avoided CO2-emissions [Mt]	1.1	1.2	1.6

Table 4: Associated costs for policy, avoided fuel and avoided CO_2-emissions without policy support (high energy prices) in the building sector

	2010	2020	2030
Total renewable heat [PJ]	21	54	105
Policy costs [MEUR]	0	0	0
Avoided fuel costs [MEUR]	455	3560	8882
Avoided CO2-emissions [Mt]	1.1	3.2	6.9

From the overview tables it can be concluded that in the high fuel price scenario the cumulative expenses for fuel are considerable. Two parameters drive this: firstly, the high penetration in this variant, secondly the relative high level of the fuel price. The policy costs are zero since no policy has been modelled in this scenario.

Based on the model runs above, it can be concluded that the high price variant does not require additional policy, as autonomous development is largely sufficient for reaching the targets.

The ‘no policy’ variants for industry show comparable results as for the building sector: very important differences occur for the two fuel price scenarios, which is illustrated by the graphs on the next pages.

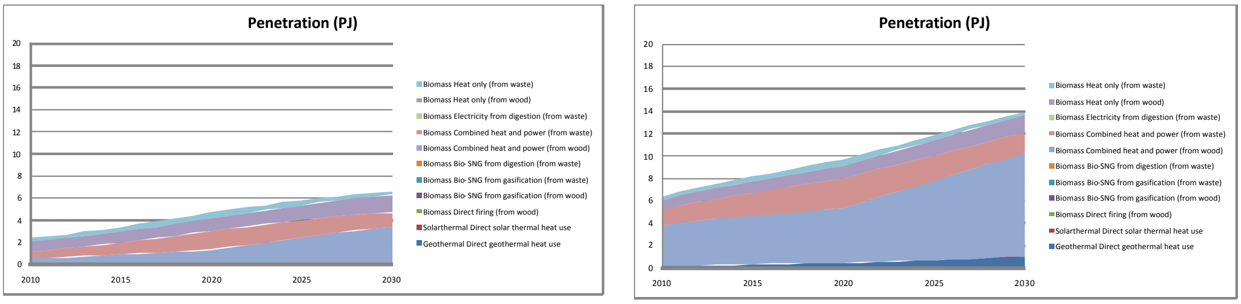

Figure 4: Development of RES-H in the industry sector without policy support (left hand: low energy prices, right hand: high energy prices)

The most important contribution comes from biomass CHP fuelled with wood. This modelling variant has no policy costs associated, but fuel expenses are displayed below, as well as the avoided CO$_2$-emissions.

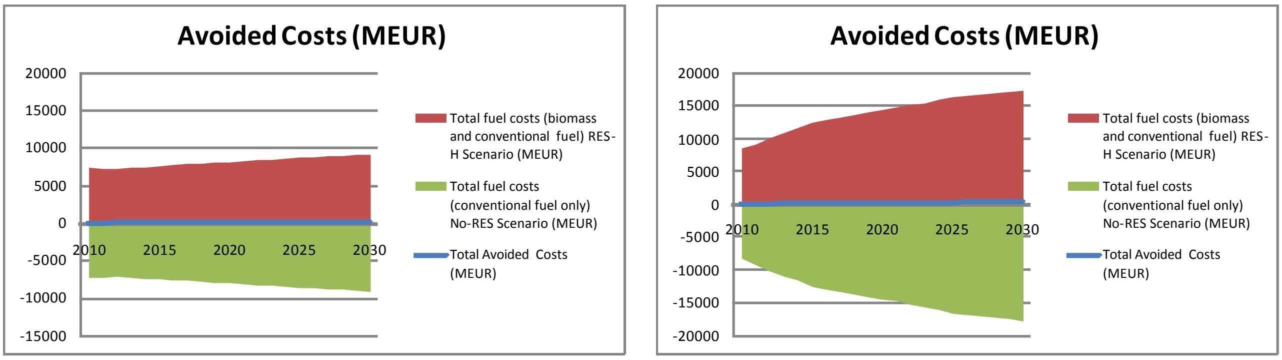

Figure 5: Avoided costs in the industry sector without policy support (left hand: low energy prices, right hand: high energy prices)

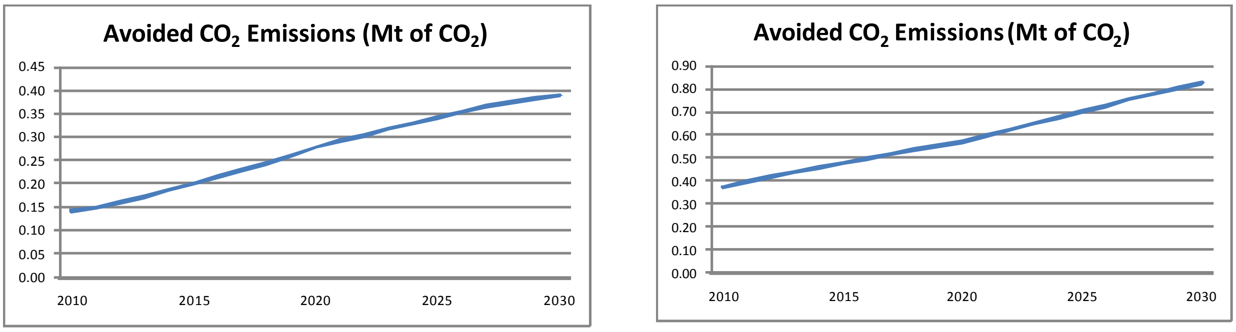

Figure 6: Avoided CO_2-emissions in the industry sector without policy support (left hand: low energy prices, right hand: high energy prices)

The fact that fuel price assumptions are highly determining the modelling outcomes also is valid for the industry sector, as can be concluded from the graphs above. Technologies that are penetration most strongly are the biomass-based CHP options (both wood and waste). Also biomass heat-only penetrates significantly. This technology in principle is assumed to be cheaper, but is does not benefit from the income through electricity sales, which especially in the 'high price' variant is attractive. From the non-biomass options, only deep geothermal penetrates significantly. The policy costs are zero since no policy has been modelled in this scenario.

Based on the model runs above, it can be concluded that the high price variant does not require additional policy, as autonomous development is largely sufficient for reaching the targets. In this respect the industry sector behaves identical to the building sector.

1.4 Policy set 1: subsidies

Policy set 1 is based on investment subsidies for RES-H technologies. As a starting point for the scenario that will be presented in the following graphs, the following values have been selected for the modelling:

Technology	Investment subsidy
Biomass non-grid boiler	40%
UHR systems	40%
Heat pump air/water	40%
Heat pump brine/water	40%

Biomass district heating	40%
Geothermal district heating	10%
Solar thermal systems	40%

Technology	Investment subsidy
Wood log	25%
Wood chips	30%
Wood pellets	30%
Heat pump air/water	10%
Heat pump brine/water	25%
Biomass district heating	35%
Solarthermal system, DHW	35%
Solarthermal system, Combi	45%

It is assumed that the policies become operational starting in 2011.

For industry the subsidy levels have been defined at 25% of the investment for all technologies.

1.4.1 Growth in RES-H/C capacities

This section shows the results for the investment subsidy.

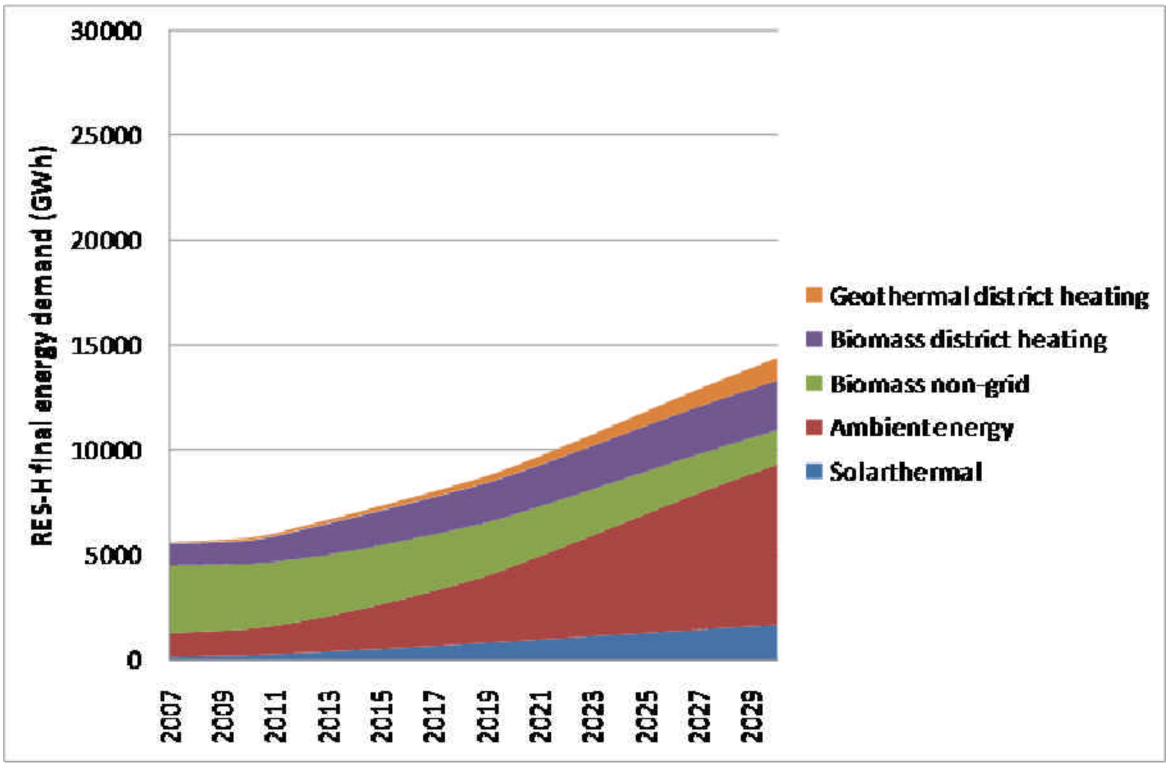

Figure 7: Development of RES-H in the building sector under policy set 1 (investment grant; low energy prices only)

Table 5: Development of RES-H in the building sector under policy set 1 (investment grant; low energy prices)

	2010			2020			2030		
	Realisation		Share	Realisation		Share	Realisation		Share
	GWh	PJ	%	GWh	PJ	%	GWh	PJ	%
Solar thermal	247	0.9	4%	908	3.3	10%	1683	6.1	12%
Ambient energy	1249	4.5	22%	3552	12.8	39%	7632	27.5	53%
Biomass non-grid	3102	11.2	53%	2466	8.9	27%	1648	5.9	11%
Biomass district heating	1106	4.0	19%	1924	6.9	21%	2376	8.6	16%
Geothermal district heating	99	0.4	2%	359	1.3	4%	1089	3.9	8%
RES-H total	5803	20.9	100%	9210	33.2	100%	14429	51.9	100%
Share RES-H	4%	4%		7%	7%		11%	11%	

Table 6: Calculated average annual growth of RES-H in the building sector under policy set 1 (investment grant; low energy prices)

	Average annual growth	
	2010 - 2020	2020 - 2030
Solar thermal	14%	6%
Ambient energy	11%	8%
Biomass non-grid	-2%	-4%
Biomass district heating	6%	2%
Geothermal district heating	14%	12%
RES-H total	5%	5%

The associated costs are indicated below:

	2010	2020	2030
Total renewable heat [PJ]	21	33	52
Policy costs [MEUR]	20	327	391
Avoided fuel costs [MEUR]	366	831	1525
Avoided CO2-emissions [Mt]	1.1	1.8	3.0

This represents an increase in the RES-H share in the building sector in the low-price scenario from 4% (2010) to 7% (2020) and ultimately 11% (2030). In absolute terms the contribution from ambient heat through heat pumps is most important: it represents more than 53% of total RES-H by 2030. The calculated average annual growth rates are relatively large for all non-biomass options. Although in absolute terms the contribution from solar thermal and deep geothermal is not very large (less than 10% of total RES-H), the resulting growth rates up to 2020 are more than 10%, which indicate a reliable and steady growth. This is even more the case for deep geothermal, which continues this relatively strong growth after 2020. Policy costs are considerable in this scenario, but they are still less than the avoided fuel costs.

In industry the effect of subsidies is considerable in the low price scenario, but in the high price scenario the effect is much less. In the latter scenario the high fuel prices already result in high penetrations, and an investment subsidy can only in a limited way increase the penetration. It can be concluded that the added value of the investment subsidy is higher in the low price scenario. See pictures below.

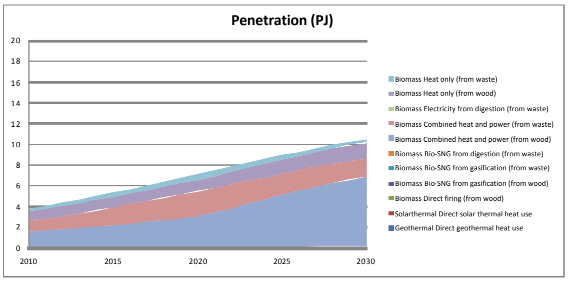

Figure 8: Development of RES-H in the industry sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

1.4.2 Costs

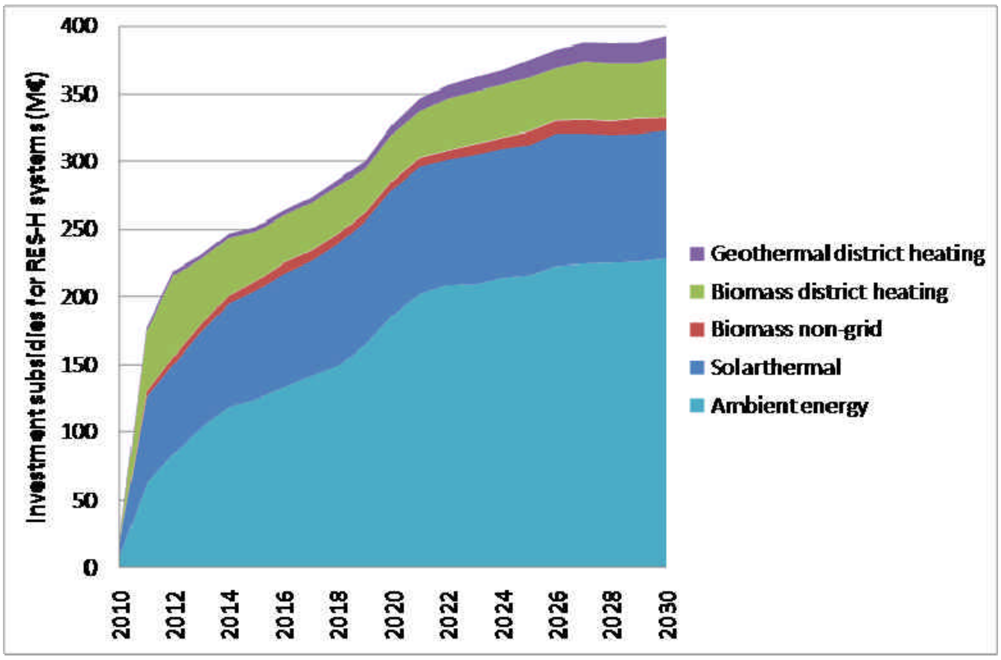

Figure 9: Public budget requirement in the building sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

Because the subsidies have been defined as a percentage of the investment costs, high penetrations for a technology result in high required budgets. From the figure above it becomes clear that heat pumps receive important amounts of funding. Public budgets increase to yearly 350-400 M€ in the low price scenario.

As mentioned before, in industry the effect of subsidies is considerable in the low price scenario, but in the high price scenario the effect is much less. Because in the high price scenario also other technologies penetrate, the cumulative investment subsidies are more important than in the low price scenario. It can be concluded that the added value of the investment subsidy is higher in the low price scenario, although it succeeds to mobilise non-biomass technologies such as deep geothermal. It may be concluded that technology-specific policy might be worthwhile: investment subsidies for deep geothermal and solar thermal, an no policy or other types of policy measures for biomass options. See graph below.

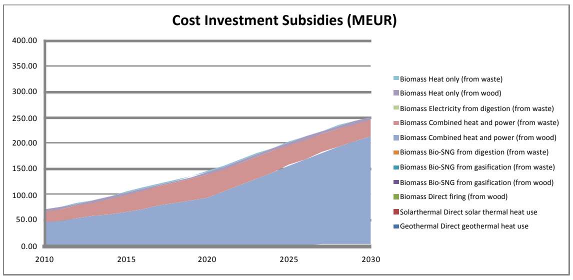

Figure 10: Public budget requirement in the industry sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

1.4.3 Avoided fuel costs

The following figures show the avoided fuel costs due to RES-H systems for the low price scenario. The blue area shows the total fuel costs that occur in the scenario that has been presented above. The red area shows the total fuel costs that would have occurred in the case that all RES-H systems would be provided by a fossil fuel mix (based on the mix of fossil fuels in the year 2007). The difference of the total fuel costs in the pure fossil reference scenario and in the scenario presented above represent the net avoided fuel costs. The net avoided fuel costs amount to approximately 1 billion euro per year in 2030, which surpass the public budget requirements presented before (350 to 400 MEUR per year).

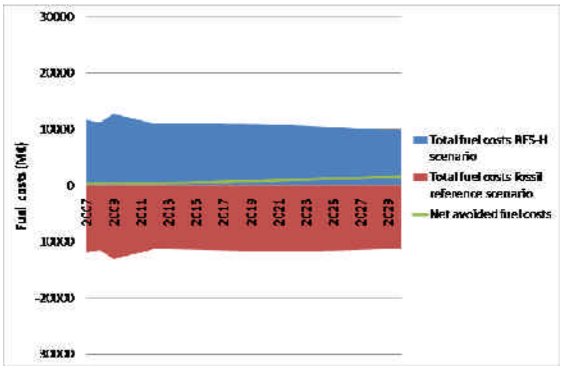

Figure 11: Avoided fuel costs in the building sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

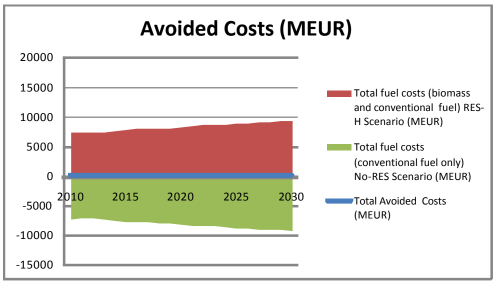

Figure 12: Avoided fuel costs in the industry sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

1.4.4 Reduction of GHG emissions

The following figures show the reduced GHG emissions. For the calculation of this indicator we assumed that in the fossil reference system all RES-H systems would be replaced by a fossil heating system mix (fossil energy mix from 2007).

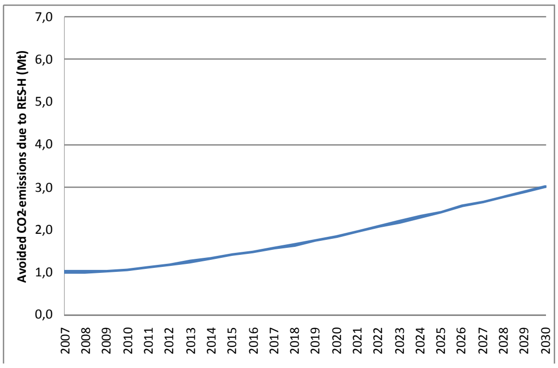

Figure 13: Reduced GHG emissions in the building sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

Starting with annual avoided CO_2-emission of 1.0 Mt through using renewable energy carriers in the housing sector in 2007, avoided emissions increase to 1.9 Mt (2020) and 3.0 Mt (2030) in the low price scenario.

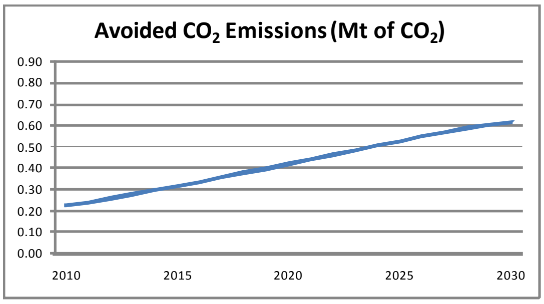

Figure 14: Reduced GHG emissions in the industry sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

1.5 Policy set 2: renewables obligation to represent tightened energy performance standard

In this policy set existing buildings do not have an obligation on renewables, only new buildings and buildings undergoing major renovations

Policy set 2 is based on a combination of investment subsidies for all buildings with an obligatory share of RES-H technologies or district heating for new and refurbished buildings if a new heating system is installed. As a starting point for the scenario that will be presented in the following graphs, the following values have been selected:

Technology	Investment subsidy
Biomass non-grid boiler	30%
UHR systems	30%
Heat pump air/water	30%
Heat pump brine/water	30%
Biomass district heating	30%
Geothermal district heating	10%
Solar thermal systems	20%

Year	Share of RES on final energy consumption	Compensation payment if target will not be reached (€/m²)
2011	10%	55
2015	20%	55
2020	30%	55
2025	30%	55
2030	30%	55

* note, that in our implementation the obligation can be fulfilled by the use of district heating as well, even though district heating is not considered to be a RES energy carrier.

Policies are expected to become operational in 2011.

For industry, the modelled policy measure is an exploitation subsidy modelled with inputs from the UK Renewable Heat Incentive (RHI). In the course of the RES-H Policy project it has become clear that the Netherlands are considering the design of such policy, but because no tariffs have been available at the time of modelling the UK tariffs have been used.

The simulations were run using the figures for levels of support provided in the UK Department of Energy and Climate Change document of March 2011 RHI available from www.decc.gov.uk/rhi

Levels of support

Tariff name	**Eligible technology**	**Eligible sizes**	**Tariff rate (pence/ kWh)**	**Tariff duration (Years)**	**Support calculation**
Small biomass	Solid biomass; Municipal Solid Waste (incl. CHP)	Less than 200 kWth	Tier 1: **7.6**	20	Metering Tier 1 applies annually up to the Tier Break, Tier 2 above the Tier Break. The Tier Break is: installed capacity x 1,314 peak load hours, i.e.: **kWth x 1,314**
			Tier 2: **1.9**		
Medium biomass		200 kWth and above; less than 1,000 kWth	Tier 1: **4.7**		
			Tier 2: **1.9**		
Large biomass		1,000 kWth and above	**2.6**		Metering
Small ground source	Ground-source heat pumps; Water-source heat pumps; deep geothermal	Less than 100 kWth	**4.3**	20	Metering
Large ground source		100 kWth and above	**3**		
Solar thermal	Solar thermal	Less than 200 kWth	**8.5**	20	Metering
Biomethane	Biomethane injection and biogas combustion, except from landfill gas	Biomethane all scales, biogas combustion less than 200 kWth	**6.5**	20	Metering

1.5.1 Growth in RES-H/C capacities

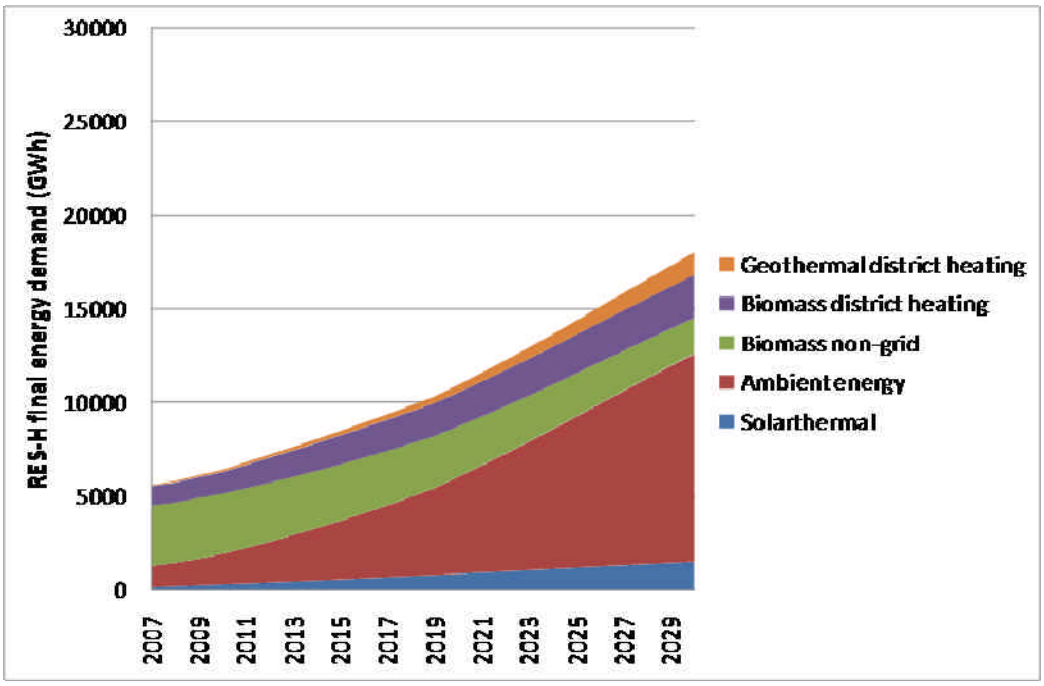

Figure 15: Development of RES-H in the building sector under policy set 2 (investment grant combined with an obligation; low energy prices only)

Table 7: Development of RES-H in the building sector under policy set 2 (investment grant combined with an obligation; low energy prices)

	2010			2020			2030		
	Realisation		Share	Realisation		Share	Realisation		Share
	GWh	PJ	%	GWh	PJ	%	GWh	PJ	%
Solar thermal	326	1.2	5%	894	3.2	8%	1537	5.5	9%
Ambient energy	1617	5.8	25%	5157	18.6	47%	11076	39.9	61%
Biomass non-grid	3222	11.6	50%	2688	9.7	25%	1888	6.8	10%
Biomass district heating	1140	4.1	18%	1805	6.5	16%	2312	8.3	13%
Geothermal district heating	110	0.4	2%	399	1.4	4%	1210	4.4	7%
RES-H total	6416	23.1	100%	10944	39.4	100%	18024	64.9	100%
Share RES-H	4%	4%		8%	8%		14%	14%	

This represents an increase in the RES-H share in the building sector in the low-price scenario from 4% (2010) to 8% (2020) and 14% (2030). In absolute terms, introducing the obligation means an increase with 3.6 TWh (13 PJ) compared to the grant-only case, which is fulfilled mostly by heat pumps. Solar thermal and biomass district heating reduce slightly their contributions compared to policy set 1 (the reason for this is less grants for all technologies (-10%), in case of solar thermal even -20% so cheaper technologies have higher shares). Ambient heat by 2030 represents 61% of all RES-H in policy set 2.

For industry the use of the RHI exploitation subsidy results in the exploitation of the full potential in both cases. This highlights the fact that when fuel prices are high, the additional effect of RHI is almost absent, and that overstimulation is a serious risk. From the data on the policy expenditures it can be seen that the cumulative expenses are lower in the high price scenario, but not completely absent. The regular review of tariffs as planned by the UK government is a crucial design criterion for the RHI, which is important for the Dutch government as well.

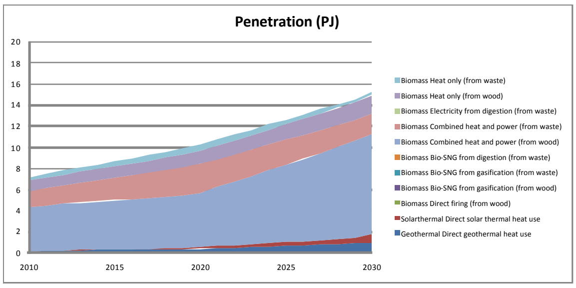

Figure 16: Development of RES-H in the industry sector under policy set 2 (only low energy prices, for high prices no policy variant has been modelled)

1.5.2 Public revenue due to penalties

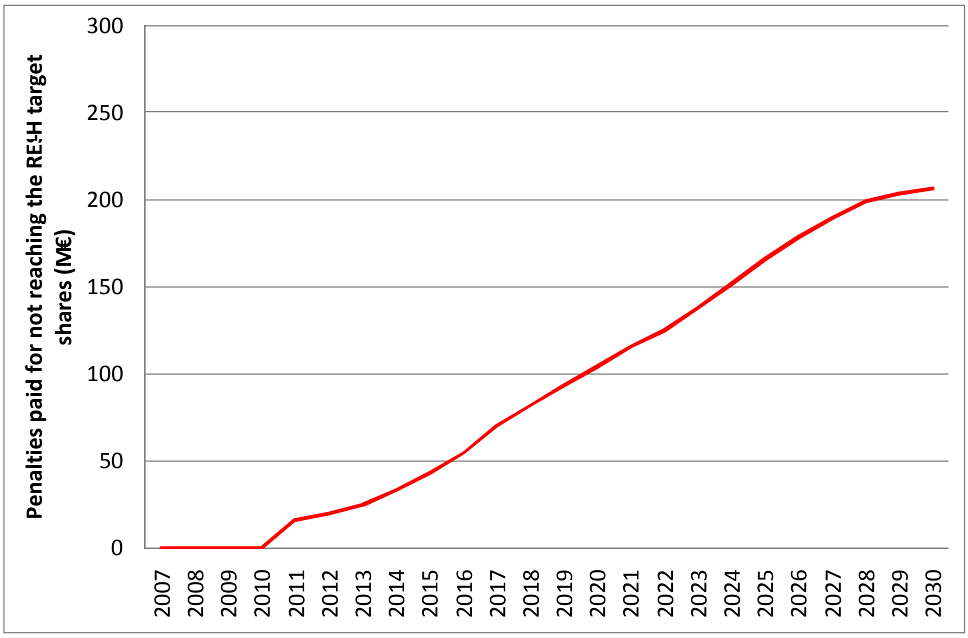

Figure 17: Public revenues in the building sector under policy set 2 (investment grant combined with an obligation; low energy prices only)

In the low-price scenario the yearly amount of penalties rises significantly up to 100 M€ until 2020 and then further increasing to more than 200 M€ in 2030. An overview of the financial results in this scenario are depicted in the table below.

	2010	2020	2030
Total renewable heat [PJ]	23	39	65
Policy costs [MEUR]	48	282	349
Public revenues from penalties (MEUR)	0	104	207
Avoided fuel costs [MEUR]	440	1080	2048
Avoided CO2-emissions [Mt]	1.2	2.2	3.8

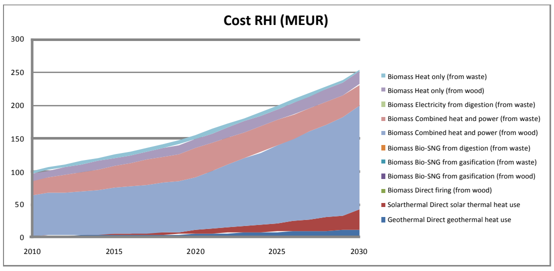

Figure 18: Public budget requirement in the industry sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

1.5.3 Avoided fuel costs

The following figures show the avoided fuel costs due to RES-H systems for the low price case for the second policy scheme. The blue area shows the total fuel costs that occur in the scenario. The red area shows the total fuel costs that would have occurred in the case that all RES-H systems would be provided by a fossil fuel mix (based on the mix of fossil fuels in the year 2007). The difference of the total fuel costs in the pure fossil reference scenario and in the scenario presented above represent the net avoided fuel costs. In the low price scenario, the net avoided fuel costs a approximately 2 billion euro per year by 2030.

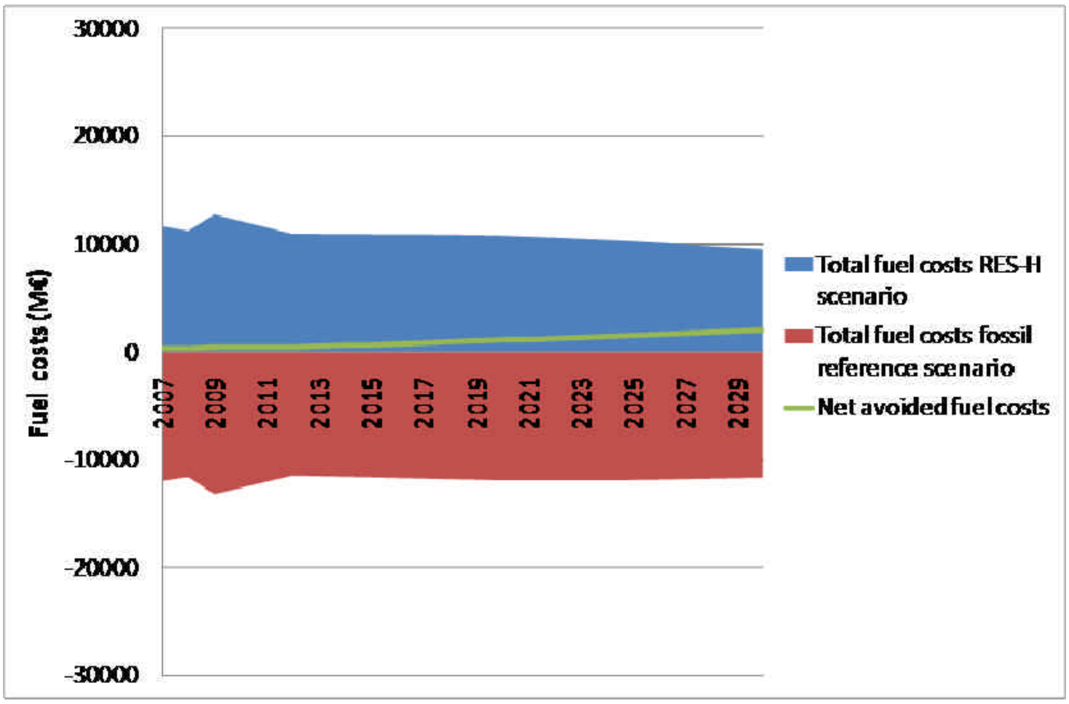

Figure 19: Avoided fuel costs in the building sector under policy set 2 (low energy prices only)

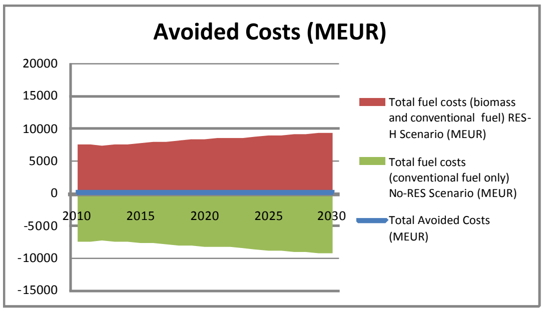

Figure 20: Avoided fuel costs in the industry sector under policy set 1 (only low energy prices, for high prices no policy variant has been modelled)

1.5.4 Reduction of GHG emissions

The following figures show the reduced GHG emissions. For the calculation of this indicator we assumed that in the fossil reference system all RES-H systems would be replaced by a fossil heating system mix (fossil energy mix from 2007).

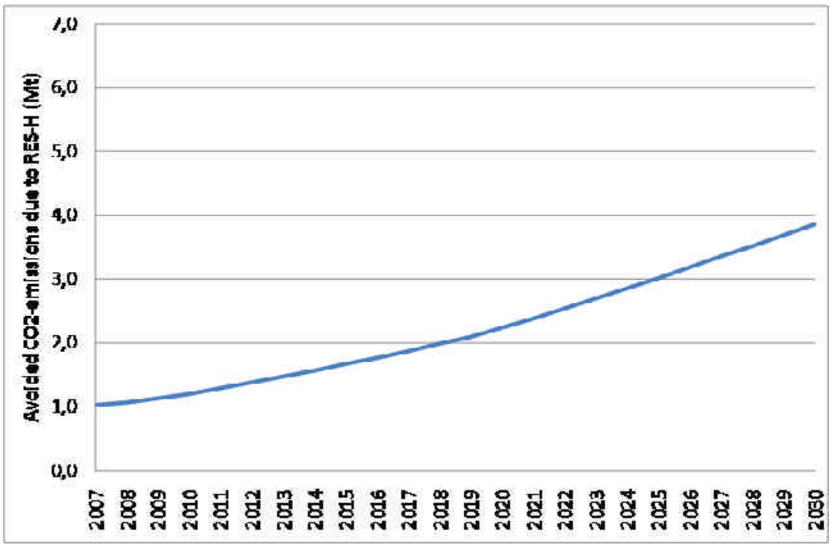

Figure 21: Reduced GHG emissions in the building sector under policy set 2 (low energy prices only)

Starting with annual avoided CO2 emission of 1.0 Mt through using renewable energy carriers in the housing sector in 2007, avoided emissions increase to 2.2 Mt (2020) and 3.8 Mt (2030) in the low price scenario.

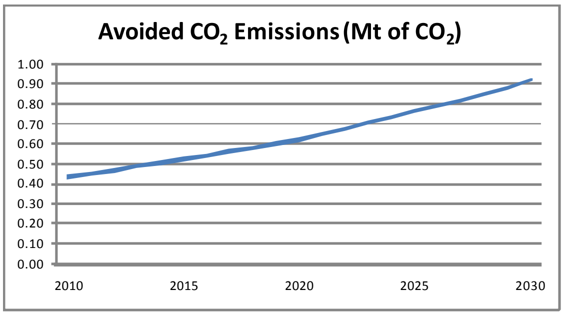

Figure 22: Reduced GHG emissions in the building sector under policy set 2 (only low energy prices, for high prices no policy variant has been modelled)

1.6 Comparison and synthesis

For both the building sector and industry renewable energy costs have been collected and used for the modelling activities in this chapter. For most technologies costs have been specified specifically for the Netherlands, based on literature research. All data have been documented in annexes to this report, from which can be concluded that most technologies, certainly for the 'low energy price scenario' are more expensive than the reference fuel prices. Regarding the future cost development it can be observed that only solar thermal energy is expected to realise significant technology learning and consequently decrease in cost level. Biomass and ambient heat through heat pumps is expected to increase in cost level, as these might be facing important increases in fuel costs or in auxiliary energy costs (depending on the fuel price scenario).

Residential sector

For the residential sector two policy measures have been evaluated through modelling activities. First observation is that *c*onventional fuel price assumptions have a very important influence on the competitiveness of the RES-H technologies and thus strongly impact the modelling outcomes. In the high price scenario a very important penetration of RES-H occurs in the 'no policy' variant, which even overshoots the amount that can has been defined as a realisable target. This outcome has impacted the research question in the current chapter: the focus has been on how policy measures effectively could stimulate renewable energy deployment *in the low conventional fuel price scenario*.

The two policy measures that have been modelled both result in comparable realisation in terms of renewable energy penetration on the longer term. The resulting avoided fuel costs are considerable for both policy measures, but slightly higher in the case of the renewables obligation, which consequently is valid for the avoided CO_2-emission. The policy costs likewise are comparable, but as a result of the penalty accompanying the obligation a significant 'benefit' is attributed to the government. This makes that the government expenses in the renewable obligation are lower than for the subsidy regime, which mat lead to the conclusion that the obligation is to be preferred above the subsidy for the residential sector. However, the government costs are not the only determinant for choosing a policy regime. For example, the penalty is a burden that directly is to be borne by the end-user, which might politically not considered feasible. Also the transaction costs (notably the monitoring costs in the case of an obligation) might vary between the policy measures, which influences the choice of the policy scheme to be preferred.

Industrial sector

Comparable to the building sector, first observation is that conventional fuel price assumptions have a very important influence on the competitiveness of the RES-H technologies and thus strongly impact the modelling outcomes. Because of the high penetration occuring in the 'no policy' variant in the high price scenario the research question in the current chapter has shifted and the focus has been on how policy measures effectively could stimulate renewable energy deployment *in the low conventional fuel price scenario*.

Two financial support measures have been evaluated in this chapter, both improving the cost-benefit ratio and the financial attractiveness of renewable heat projects. Investment subsidies help industry overcoming their barrier towards investments, and from this perspective they are a defendable policy measure. Specifically for biomass technologies an investment subsidy will not be able to cover all heat production costs, since the fuel costs represent an important share in the heat costs. A drawback of the investment subsidy is that no guarantee is provided for a continued renewable heat production: in case the owner of the installation after having received the investment subsidy decides not to use biomass fuels, usually no penalty is given. An exploitation subsidy (bonus or feed-in tariff like the United Kingdom Renewable Heat Incentive, RHI) do provide such guarantees (provided that the payments are based on metering). Likewise, lower interest rates for financing investments in renewable heat result in more advantageous values of a project's internal rate of return, which thus supports industrial players in a positive investment decision. For deep geothermal and solar thermal, investment subsidies can be very suitable, especially due to the relatively low running costs of these technologies (no fuel costs). Sensitivity runs have shown that sometimes very high support levels are needed for making these options penetrate (more than 50%, depending on the fuel price scenario, see also the sensitivity runs in the annex).

Cheapest options penetrate first: biomass heat-only (especially if based on waste streams, which are assumed to be available at very low or even negative prices in case costs for removal are avoided) good competitive strength occurs, but generally these fuel streams are very limited in potential. Biomass CHP might benefit from the sales of electricity, which makes projects more profitable. Most expensive options (solar thermal, geothermal) generally do not penetrate at low conventional energy prices without policy support.

Focusing on the 'low price scenario' the investment subsidy in industry results in a governmental support up to MEUR 250 by 2030 (MEUR 150 by 2020), being roughly the same as the exploitation subsidy, which requires a governmental support up to little above MEUR 250 by 2030 (MEUR 150 by 2020). From this perspective not a real preference can be identified, which may lead to the conclusion that from an overall view the policy implementation is not influenced strongly by the associated cost levels. Nonetheless, each policy measure has specific advantages and disadvantages, as illustrated above. Moe detail about industry-specific characteristics can be found in Chapter 5.

2 Employment effects

As one of their main political tasks, governments strive for constant economic growth and high employment. This is why assessing the expansion of RES-heating and cooling (RES-H/C)in terms of the effect on employment forms an essential part of a quantitative analysis. The results presented in this section are based on the research project *EmployRES*[2] which was directed by Fraunhofer ISI. Specific gross employment effects are derived from the EmployRES results which serve as the input data for the two approaches (top-down and bottom-up) applied to calculate the total gross employment effects.

The gross employment effects of RES-H/C result from the economic impact of the renewable heating industry and the industries indirectly depending on it. The latter are mainly suppliers of inputs needed in the production process or of capital goods. In this gross perspective, negative employment effects – e.g. in industries linked to conventional energy generation – are not included.

The following paragraphs introduce the modelling approach and the main assumptions made in the *EmployRES* project and then describe the methodology of calculating the employment effects using the top-down and the bottom-up approach. Subsequently, the results are presented followed by a comparison of the outcomes of the two approaches.

2.1 The EmployRES project

The research project *EmployRES* was carried out on behalf of the *Directorate-General for Energy and Transport* of the European Commission and completed in April 2009. The calculations of gross employment effects are based on the annual turnovers deriving from enhanced RES market penetration.

This study combines different models – including two macroeconomic models (Astra, Nemesis), a RES sector model (GREEN-X) and an input-output (IO) model (MULTIREG) – in order to determine the economic and technological impacts of RES expansion. The IO model MULTIREG is used to calculate the current value added of RES activities and the employment effects. The technology classification and the cost structures of RES technologies are based on the GREEN-X database. The Green-X model delivers scenarios for the future development of RES activities and their corresponding expenditures and investments. This output data then serves as the input for the macroeconomic models, which determine the economic effects. This modelling step is performed by two real-world macro models – NEMESIS and ASTRA.

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[2] “Employ RES The impact of renewable energy policy on economic growth and employment in the European Union” carried out by Fraunhofer ISI (Germany), Ecofys (the Netherlands), Energy Economics Group (Austria), Rütter + Partner Socioeconomic Research + Consulting (Switzerland), Lithuanian Energy Institute (Lithuania) and Société Européenne d’Économie (France).

With the input-output model, a demand-side approach is used, which subdivides expenditures for renewable energy use into the cost components investments, operation maintenance and fuel expenditures and allocates them to economic activities. The resulting production vectors for each RES technology, differentiated by country and by economic sector, form the basis for calculating the direct gross value added and thus the direct employment effects. The indirect economic effects are determined by incorporating the RES production vectors as additional final demand in the input-output model.

The MULTIREG model covers all the EU Member States and their main trade partners. It projects trade between the EU 27 and the rest of the world on a disaggregated, multi-sector level distinguishing 41 sectors. To calculate employment effects, the model is extended by sector- and country-specific employment data including working hours, employment as well as labour productivity and labour costs. These data are taken from the EU KLEMS database (EU Klems 2008). The EUROSTAT data on small and medium sized enterprises (SME) is another database used by MULTIREG in order to determine the economic impact of RES expansion on SMEs.

As a basis for the macroeconomic modelling, different scenarios of future global RES markets are defined. The scenarios depend on: (1) The deployment of RES technologies within the EU; (2) the deployment of RES in the rest of the world as well as (3) the world market shares of European economies, and the export shares. Different projections are derived for each element resulting in five scenarios. In this way, RES development within the EU is outlined in different policy scenarios according to GREEN-X. The deployment of RES in the rest of the world is derived from the IEA World Energy Outlook scenarios (International Energy Agency 2007). Based on the present world market shares, three projections are made for the future RES-related export shares of the European economies. In this study, the ADP-ME scenario is used, which assumes a “moderate export share” and an “accelerated RES deployment policy” combined with the “IEA Alternative Scenario” (Ragwitz et al. 2009, p. 126).

For a detailed description of the scenarios and the methodology, refer to Ragwitz et al. (2009).

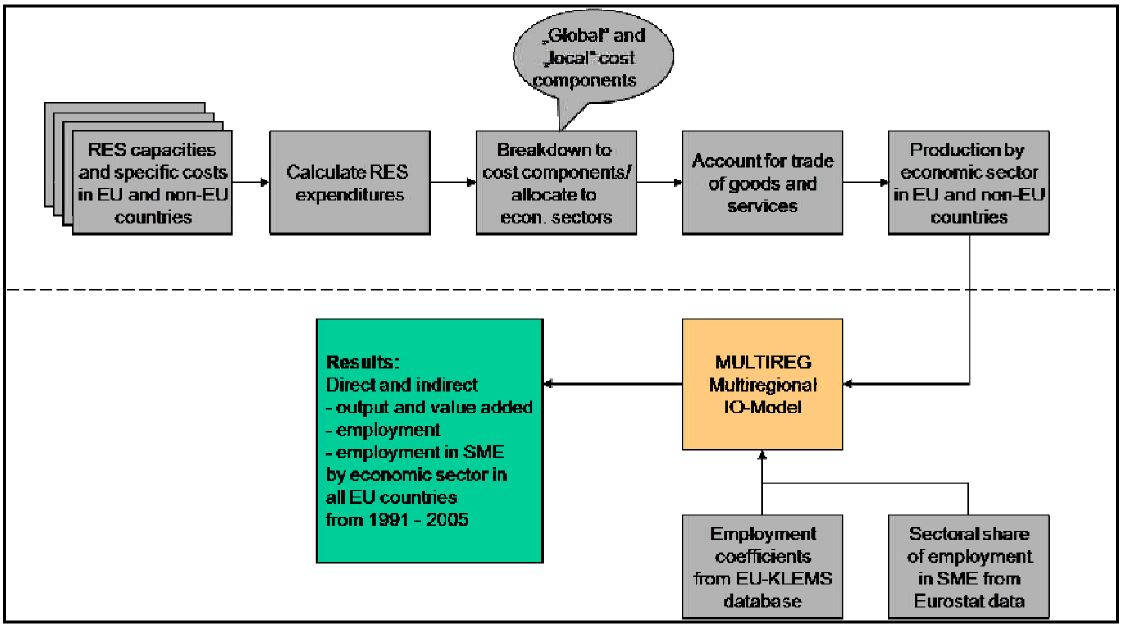

Figure 23: Overview of the modelling steps realised in the EMPLOY RES project (Ragwitz et al. 2009)

2.2 Methodology used in this paper

In this paper, the gross employment effects are calculated based on the modelling work described above as well as on the INVERT results presented in chapter 1. Thus, two approaches are adopted which are referred to as *top-down* and *bottom-up* in the following. The top-down approach conforms to the *EmployRES* method using Green-X results. The bottom-up approach applies the INVERT results in order to evaluate the different policy sets in terms of employment effects.

Therefore, technology-specific employment coefficients are derived from the *EmployRES* results for each cost component – investments, operations maintenance and fuel expenditures. The coefficients express the ratio of employment in full time equivalents (fte) to value added (million euro) for each RES-H reference technology. The total gross employment effects are calculated by multiplying the coefficients by the corresponding costs, or by the revenues of RES-H deployment, respectively (*Figure 24*). In the case of the *bottom-up* approach, the related costs are provided by the INVERT model. Since the specific employment coefficients account for future change in productivity, overall employment effects are likely to decrease in the future; even if there is a further expansion of RES-H.

The results of the analysis are presented in Section 2.3. Note that the policy costs have not been considered in the analysis, the relevant parameters for evaluating the employment effects have been investments, operations maintenance and fuel expenditures.

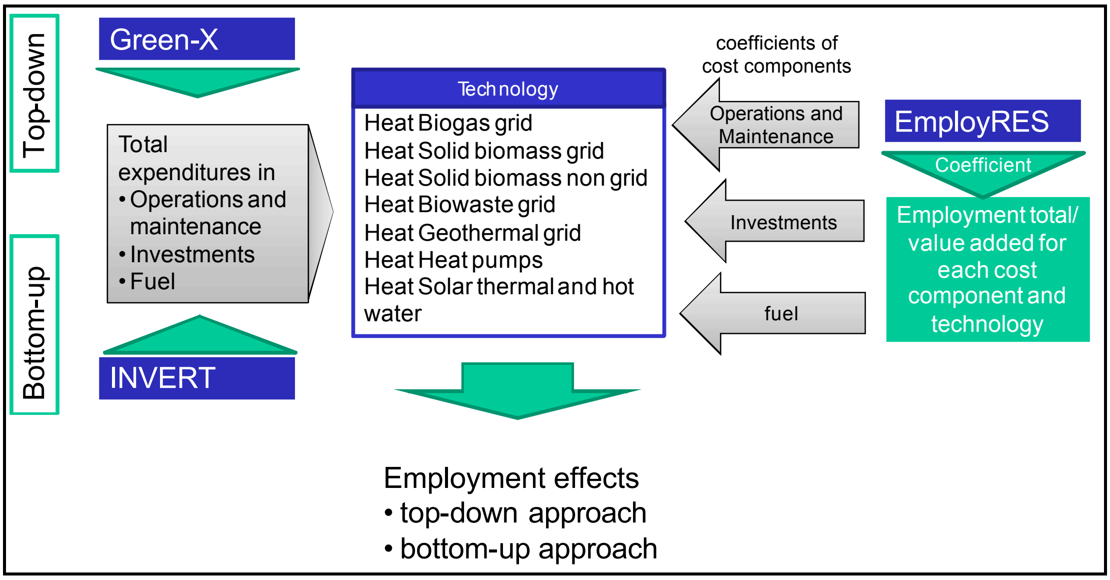

Figure 24: Calculation of employment effects with a top-down and bottom-up approach

2.3 Results

2.3.1 Bottom-up results for 'no policy scenarios' based on INVERT

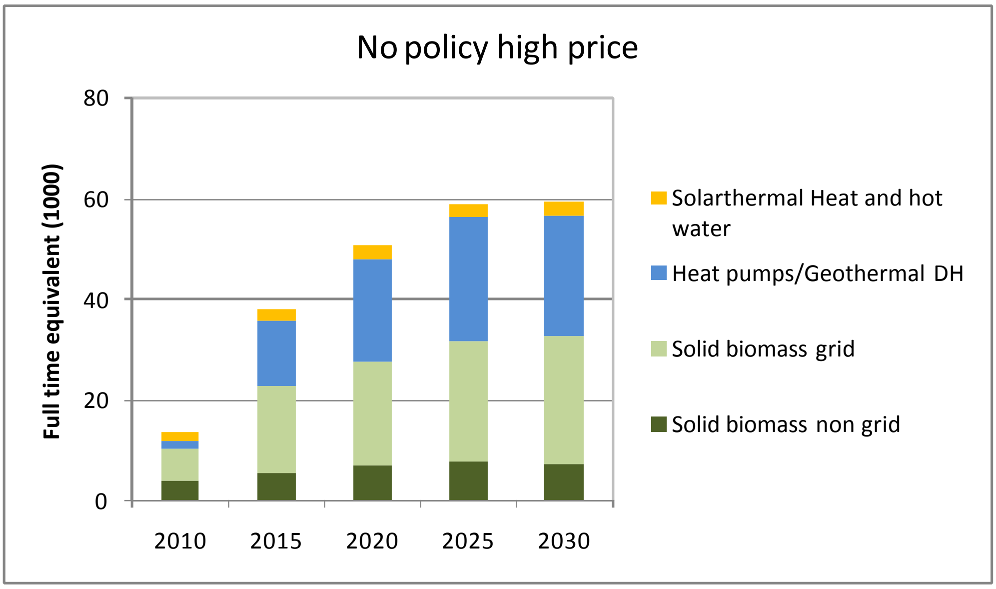

Figure 25: Annual employment effects 2010 to 2030

The high fuel prices would make employment increase considerably up to 2025, and then remaining at a constant high level due to replacement of equipment, which would secure a constant employment effect. Depending on the development after 2030, the employment might be reduced in case new installation might fall. Main fields of employment are heat pumps, deep geothermal and biomass grid, but solar thermal employment is significant as well.

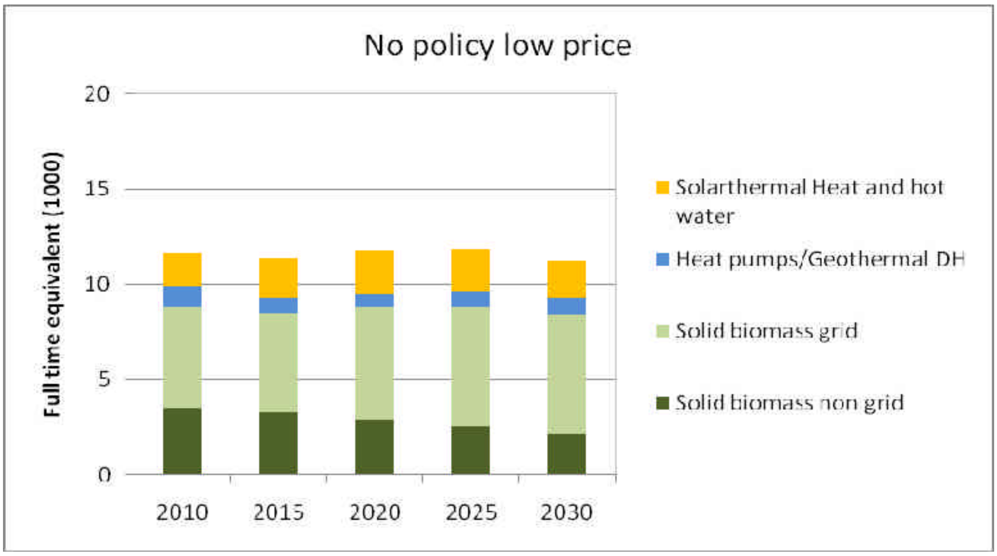

Figure 26: Annual employment effects 2010 to 2030

The ‘no policy variant’ with low fuel prices has the lowest penetration, which results in low employment effects. Note that the axis of the graph differs from the previous case.

2.3.2 Bottom-up results for ‘obligation low price’ based on INVERT

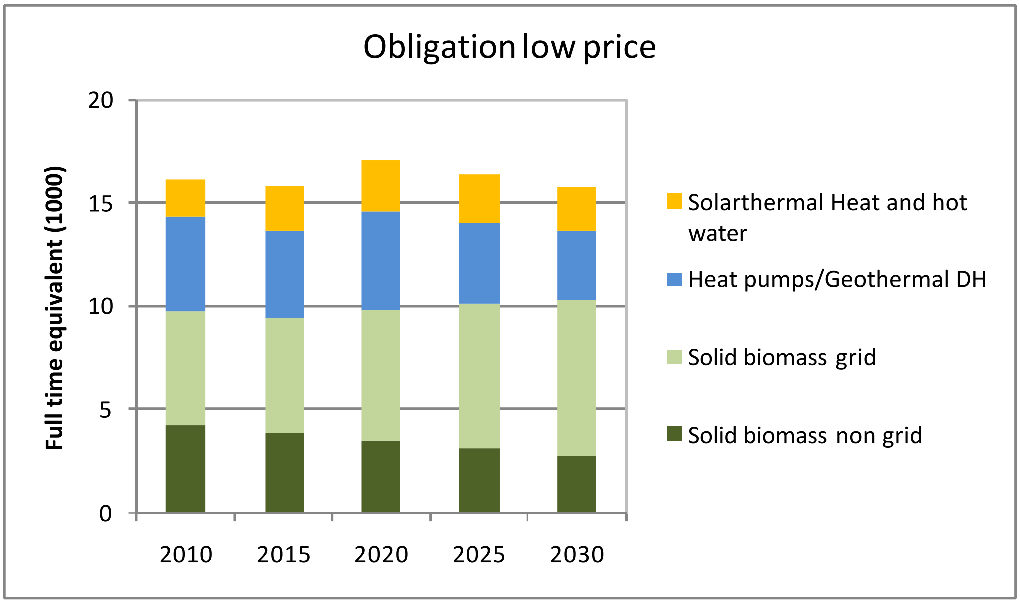

Figure 27: Annual employment effects 2010 to 2023

2.3.3 Bottom-up results for ‘subsidies low price’ based on INVERT

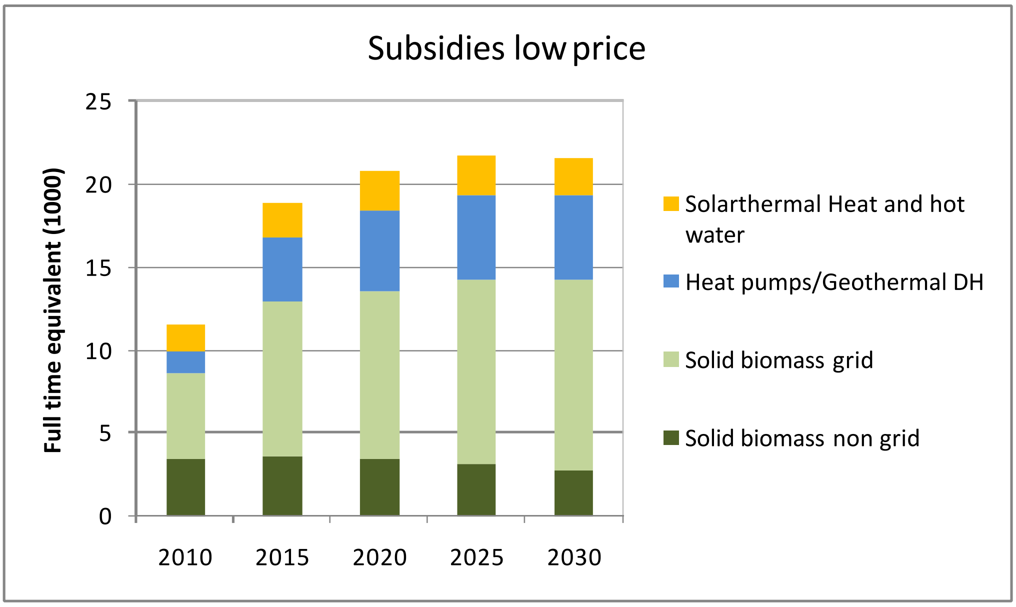

Figure 28: Annual employment effects 2010 to 2030

2.3.4 Bottom-up results for ‘subsidies and obligation low price’ based on INVERT

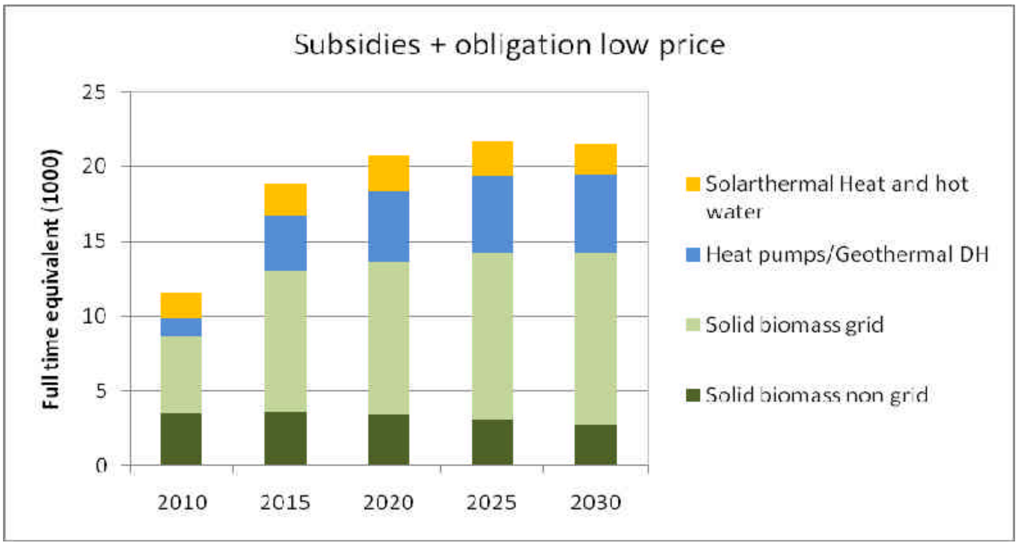

Figure 29: Annual employment effects 2010 to 2030

Combining the subsidies and the obligation does not result in higher employment effects than the subsidy scheme only.

2.3.5 Comparison of top-down results and bottom-up results

The difference between top-down and bottom up results on one hand from the different RES-H expansion in the analysed policy scenarios, on the other hand from the subsequent adaption of the productivity rate in agriculture and forestry sector.

Note that the results according to Green-X in the 'top-down' approach (yellow line in figure below) basically is the result calculated within the Employ-RES project. Because the scenarios modelled here are different from the Green-X result this line can no further meaning in for the interpretation of the employment effects.

The 'no policy high price' variant has the highest penetration of renewable heat technologies and therefore the employment effects are most significant in this scenario.

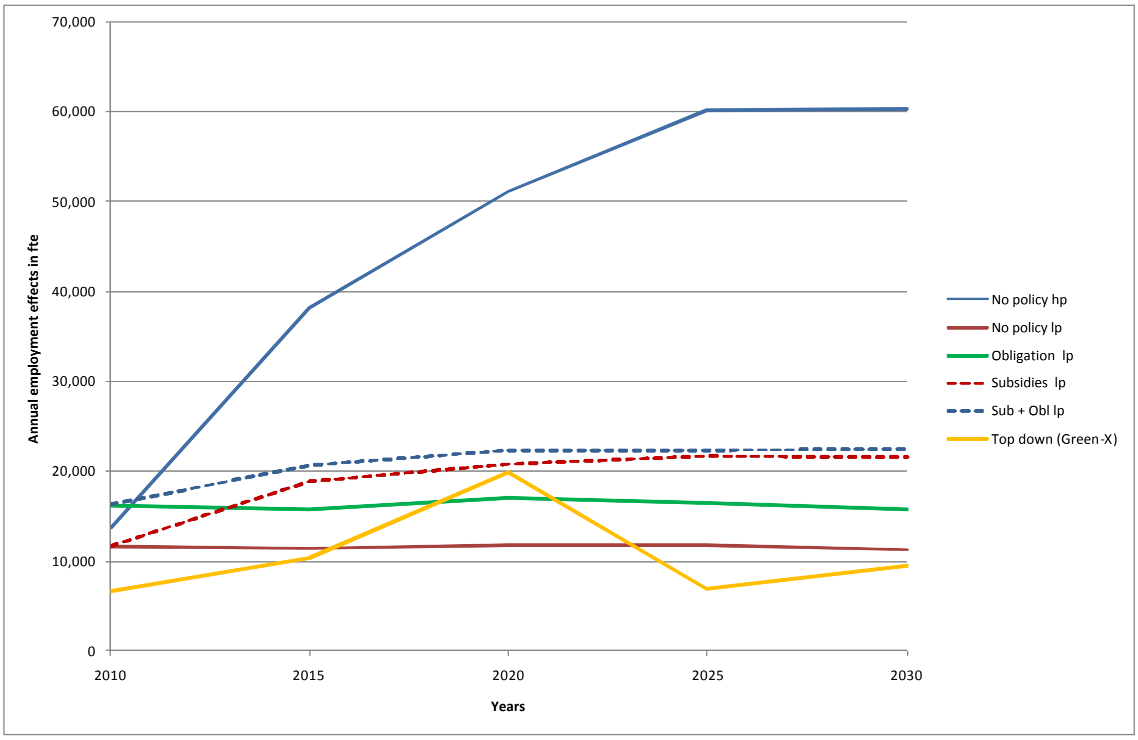

Figure 30: Overview of bottom-up results for all policy sets as well as top-down results

2.4 Comparison and synthesis

Based on the results from Chapter 1 it can be concluded that the 'high fuel price scenario' results in the highest penetration figures. The high fuel prices would also make employment increase considerably. Replacement of equipment would secure a constant employment effect. Main fields of employment are heat pumps, deep geothermal and biomass grid, but solar thermal employment is significant as well. The 'no policy variant' with low fuel prices has the lowest penetration, which results in low employment effects. The resulting higher penetrations in the two policy variants lead to higher employment effects, but combining the subsidies and the obligation does not result in higher employment effects than the subsidy scheme only.

3 Transaction costs

3.1 Introduction

The government incurs costs during the implementation of policy. These costs are not the amounts paid for support measures (e.g. subsidies and rates themselves), but those incurred for the payment thereof and everything else related to this.

The past has revealed how substantial these implementation costs can be. In a subsidy provision for the purchase of energy-efficient refrigerators by consumers during the 1980s, the implementation cost was 25% of the total cost (33 guilders in implementation costs for 100 guilders in consumer subsidy). Such a ratio is unfavourable. These costs should certainly be kept lower during the formulation of policy. The implementation costs for consumer schemes are relatively high, especially when the implementation costs per unit of renewable energy are taken into consideration.

The quantification of implementation costs is a sensitive issue. In order to make recommendations about potential support measures for renewable heat, it is necessary, however, to include this aspect in the assessment. Agentschap NL is the Dutch government body responsible for paying out energy-related subsidies. This organisation is sympathetic towards the objective within the RES-H Policy project to include the implementation costs of subsidy measures in the analysis, but has indicated that it wishes to keep the data confidential. However, the organisation is willing to give some quantitative insight. The results in the following section have therefore not been quantified but are nevertheless suitable for the analysis.

From questions posed in the Dutch House of Representatives, it can be concluded that the implementation costs for the Stimulating Sustainable Energy (SDE) regulation in 2008 accounted for approximately 1% of the total budget (3 million euro in implementation costs out of a total cost of 300 to 350 million euro[3]. It is extremely difficult to interpret this figure of 1% correctly, however. By way of example, indicating the specified amount in total costs is an arduous task. It is also not clear over how many years this must be spread. The number of FTEs could also be increased during the period in question. Finally, there are also obligations from the MEP subsidy, the precursor of the SDE, which are possibly not included in the specified amount.

3.2 Results of the quantitative analysis

The two measures introduced in D9 entail investment subsidies and the (tightening up of) the energy performance standard (see D9 for a more detailed description). In the previous chapter, moreover, the obligation of renewable heat for new constructions and large-scale

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[3] Source: http://zonnepaneel.groenlinks.nl/schriftelijkevragen_zonnepaneel.pdf

renovations was also calculated. An assessment of these measures in qualitative terms is provided below.

- Investment subsidies
- Energy performance standard in the built environment
- Obligations for new constructions and large-scale renovations

The aforementioned measures are discussed below in qualitative terms.

- *Investment subsidies*
  Subsidies reduce the investment barrier and the payback period of renewable heating options, thereby ensuring that the investor takes a more favourable investment decision. The benefit for the subsidy provider is that an investment subsidy is a one-off payment. Once it has been processed and paid out, the application is closed without any further expenditure in terms of time and resources. This is in contrast to operating fees, which need to be paid annually for the entire duration of a project, for example. A distinction also has to be made between subsidy schemes aimed at realising as many installations as possible (ensuring output) and investment schemes that foster innovation. The implementation costs of the latter are fairly high per euro of subsidy because a more stringent evaluation of applications is required. Finally: since the renewable heating scheme involves *small* installations, the implementation costs of the subsidy scheme are relatively high, especially when considering the implementation costs per unit of renewable heating.
- *Energy performance standard in the built environment*
  The energy performance standard on its own entails considerable transaction costs for different parties. For the construction industry, these costs are the administrative burden of having an EPC calculation done and determining the desired package of measures (information costs), efforts to ensure compliance with the legal obligation (negotiation costs) and the administrative burden of verifying the implementation itself and that of the government (enforcement costs). These transaction costs probably barely change after further tightening up. There is also a degree of synergy that arises with the construction permit obligation. Renewable heating technologies can practically join in on the already institutionalised instrument without any additional effort. When tightening up results in additional renewable heat, the government has no or hardly any additional implementation costs.
- *Obligations for new construction and large-scale renovations*
  An obligation for new construction and large-scale renovations could be incorporated in the instruments of the EPC. The transaction costs for the government would therefore be relatively small for an obligation: apart from bills and amendments, implementation lies with the market. Furthermore, local authorities must ensure compliance with the EPN, but these costs cannot be attributed to renewable heat alone.
- *Operating fee*
  A specific feature of the operating fee is that there is a relationship with the support recipient throughout the entire project. The transaction costs for an operating fee are

therefore slightly higher, in absolute terms, than that for an investment subsidy; that is the price paid for the certainty that renewable energy is actually produced. On balance, the transaction costs as a percentage of the total subsidy paid out are very small, however, since the periodic payments are handled completely automatically.

For the sake of clarification, the assessment above has been translated into an indicative table.

	Transaction costs per installation
Investment subsidies*	Average
Energy performance standard in the built environment	Zero
Obligations for new constructions and large-scale renovations	Low
Operating fee*	Relative: low Absolute: high

* When the transaction costs are expressed per unit of renewable energy, the costs for small installations are higher than those for large installations in relation to investment subsidies as well as an operating fee.

However, assessing transaction costs depends on many factors that make it exceptionally complex to quantify them, and difficult to describe in a single figure. An indication of what this looks like in practice is provided below. The situation relating to the granting of a subsidy is described in general terms, without specifying the type of measure in greater detail.

To start with, when determining the implementation costs of policy, a distinction must be made between *fixed costs* (costs made for the support scheme as such and not related to the number of applications) and *variable costs* (costs that increase when the number of applicants rise). Within these costs, a distinction can be made between *direct costs* and *indirect costs*. The table below provides a number of examples per cost category. For each scheme, the cost level is strongly linked to the number of applications. If there are large numbers of applications, many can be automated so that implementation costs are reduced.

Finally, it must be mentioned that the transaction costs per technology can differ significantly. An example is the Stimulating Sustainable Energy (SDE) regulation, which Agentschap NL has considerable experience with. Applications for this have to be submitted via the Internet. Some technologies, such as the solar PV application, could be processed completely automatically, resulting in a few minutes per application. The automatic rejection did not require much time. Setting up the automatic rejection, however, required a significant investment in terms of work resources. Other technologies, especially when these are the first of their kind, have to be supervised far more intensively for the subsidy provider because a wealth of detailed data needs to be transferred, or example. This is the case for the subsidy granted for offshore wind energy.

The table below indicates the components of fixed and variable costs.

	Fixed costs	Variable costs
Direct costs	Scheme setup	Application handling Dossier management Modification costs for changing an application Determination costs at end of period
Indirect costs	Policy monitoring Automation Systems maintenance Financial reporting Supervision (internal controlling Helpdesk Legal advice Maintenance of schemes, governmental degree Staff communication Management for staff support	Helpdesk communication

4 Cost optimisation for renewable heat in overall renewable mix

The RES-H Policy project is focusing on renewable heat without placing its contribution in the perspective of the two renewable alternative options: renewable heat and renewable transport fuels. Such an analysis is relevant, however, since it can indicate the extent to which policymakers could achieve the EU target for renewable energy in 2020, for example when a cost minimisation is taken as the point of departure, also a recommendation from one of the policy workshops in the Netherlands. This chapter provides an onset for such an analysis.

As the RES-H Policy project does not offer calculation tools that enable this consideration, an instrument at ECN's disposal was used for this purpose: the Analysis Tool of the Options' Document[4].

Although the Options' Document and the Analysis Tool were updated recently (October 2010), the information and data for options in several sectors have not been updated. Unfortunately this applies particularly to options in households and utilities, including solar heating, heat pumps and aquifer thermal energy storage, which are of special interest within the framework of this exercise. Upon conclusion of the RES-H Policy project, it is advisable to initiate a follow-up process during which options in these sectors would be updated thoroughly and the costs of solar heating and ambient energy would be examined in greater detail.

A key precondition, moreover, is the applied cost method[5]. The costs are calculated on the basis of (detailed) technology and option costs and fuel prices, and the perspective in that regard is 'national costs' or 'social costs'. These are being specified at the level of 'BV Nederland'. Investment depreciation occurs over periods of 10 to 25 years; the applied discount rate is 4%. Subsidies and taxes do not play any role in this approach. The overviews presented below therefore make no mention of 'end-user costs', and the savings that the consumer experiences due to reductions in fuel costs are not quantified.

In the analysis in this chapter, the National Renewable Energy Action Plan (NREAP)[6] is used as the starting point for a scenario with intended policy. The NREAP comprises the Netherlands' plans for attaining the European target for renewable energy in 2020, which totals 14.5% on the basis of final energy.

This approach posed a number of challenges, namely the translation of projections from the NREAP to data that could be used for the options and the analysis tool, compiling data for

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[4] For background information, see http://www.ecn.nl/units/ps/themes/dutch-energy-and-environmental-policy/options

[5] More information about the applied cost method can be found in the report ECN-C-05-105, chapter 3.4: http://www.ecn.nl/docs/library/report/2005/c05105.pdf

[6] National action plan for energy from renewable sources, Directive 2009/228/EC

new options, determining whether the policy potentials indicated in the NREAP are also the technical potentials, and modelling the NREAP contributions from the various options by means of instrumentation.

A first step involved analysing the data from the NREAP and comparing it with similar data in the background scenario (with implemented policies and measures, work name RR2010-SV), which serves as the basis for further calculations. The NREAP has three main themes that contribute to the 14.5% target: renewable electricity, renewable heat and biofuels in transport. In NREAP, the contribution of biofuels is up to 10.3% of the fuel requirement in transport. This percentage, however, is already being reached in RR2010-SV and is therefore fully included in the background data. The additional use of biofuel options is therefore not required and does not feature in the following optimisation.

This is not the case for renewable electricity and heating as an additional effort is most certainly needed. The tables below indicate per option/technology how much final electricity and heating is delivered.

Note that in the background scenario, it has already been assumed that thermal solar energy and heat pumps are in use (see table 4.2).

Renewable electricity production in NREAP could be completely covered with existing options in the Tool.

The correspondence for heating is less since several options are lacking in the NREAP or have not been itemized in detail. The NREAP, for example, only indicates heating from heat pumps and aquifer thermal energy storage collectively, while RR2010-SV makes a distinction between electrical and gas heat pumps and aquifer thermal energy storage. Moreover, RR2010-SV also specifies PJ for cooling (6.85 PJ), while (renewable) cooling does not appear in the NREAP. Negative differences have not been worked out further because it is not certain that the existing usage would decrease. Consequently, the analysis tool does not make any additional assumptions for heat pump options. The negative difference for wood-burning heaters has also not been worked out further. It would entail some additional gas consumption and therefore emissions, but these are deemed negligible given the limited amount involved.

Table 4.1 : Final electricity production in RR2010-SV and NREAP

Electricity (PJe)		RR2010-SV		NREAP		difference
	Hydropower	0.72		2.57		1.85
	Solar PV	0.66		2.05		1.39
	Offshore wind	22.50		68.53		46.03
	Onshore wind	32.31		48.14		15.83
	Waste incineration	3.83		3.83		0
	Small-scale biomass	2.04		9.20		7.16
	Large-scale biomass	0				
	Biomass co-firing	0		30.10		30.10
	Biomass CHP	0				
	Sewerage treatment plant	0.84		2.20		1.36
	Manure fermentation	0.88		11.60		10.72
	Organic waste fermentation	0.36		1.70		1.34
	Wastewater treatment	0.21		1.20		0.99
Total		64.35		181.12		116.77

Table 4.2: Final renewable heat production in RR2010-SV and NREAP

Heat (PJ)		RR2010-SV		NREAP		difference
	Solar boilers	0.28		0.96		0.68
	Waste incineration	5.29				
	Aquifer thermal energy storage	6.70*		-		
	Geothermal energy (deep geothermal)	1.05		10.84		9.79
	Gas heat pump	0.00*		-		
	Electrical heat pump	13.47*		15.78*		-4.39*
	Small-scale biomass	0.41				
	Large-scale biomass	0.00				
	Biomass co-firing	0.00				
	Biomass CHP	0.00				
	Wood-burning heaters	6.90		6.66		-0.24
	Sewerage treatment plant	0.25				
	Manure fermentation	0.26				
	Organic waste fermentation	0.10				
	Wastewater treatment	0.21				
	From solid biomass, excl. heaters	5.70		20.56		14.86
	From gaseous biomass	0.82		12.06		11.24
	Green gas	0.00		24.37		24.37
	Total	34.92		91.23		56.32

* These figures have been used to calculate the difference

These tables do not provide an insight into the amount of heating that is generated together with renewable electricity. Small-scale biomass, fermentation and wastewater treatment in particular also generate additional heat from solid and gaseous biomass (1.44 and 4.52 PJ of heat respectively). These amounts are determined using production data from RR2010-SV and scaled according to the amounts indicated in the “difference” column in the electricity generation table.

The use of electricity options could be based clearly on the expected final electricity production from the NREAP. This was not the case for renewable heat as the analysis tool does not (yet) have a heat balance comparable to the existing electricity balance. The options with regard to heat have been modelled with “avoided PJ natural gas” and not with ”heat”. The conversion from heat to avoided natural gas was calculated using an assumed boiler efficiency for natural gas boilers, of which the heat production was displaced by renewable heat options. Technical and cost data for heat options have been derived from the report “Draft advice base rates 2011 for electricity and green gas in the framework of the SDE scheme”, ECN-E-10-053.

The options were then used to fill in the targets of the NREAP. Where more than one option appeared to be available, the target was allocatedproportionally to the concerned options (e.g. solar boilers in households and utilities), or, due to other reasons, preferentially assigned to one option while the other option(s) were assigned what was left – if present – (e.g. biomass co-firing, which are preferred at existing coal-fired power plants because these are ”co-firing ready”, and therefore require lower costs compared to new coal-fired power plants where a biomass storage and transport system still needs to be built).

The deployment of options is included - via factors – as instrumentation in the analysis tool. This instrumentation is the determining factor for the calculation of the NREAP scenario.

A variant of NREAP has also been calculated. This assumes that the same amount of fossil energy must be avoided by using renewable energy options only. This calculation is now made on the basis of cost effectiveness and provides the optimal solution to the specified problem. Although the amount of avoided fossil energy has remained the same as in the NREAP, the content thereof differs significantly. Renewable heat, biomass CHP and co-firing biomass in coal-fired plants contribute more compared to the NREAP. The contribution of costlier end sector options, but also wind energy and co-fermentation of manure is decreasing or disappearing. The approach based on the cost-effective avoidance of fossil energy benefits renewable electricity options since these replace electricity generated by the average fossil-fired plant. A significant percentage of coal and a lower yield from electricity power stations compared to (natural-gas-fired) boilers for heat production means within the current calculations that renewable electricity displaces more fossil energy than renewable heat. This does not have to be the case with an optimisation towards the cost-effective displacement of final energy.

The latter implies that carrying out an analysis in which final energy method is used as a precondition for optimisation could prove favourable for renewable heat options. Solar boilers and heat pumps could feature more prominently, for example.

The results of the exercise for the target year of 2020 are displayed in the figure below. The contributions of the three variants to renewable electricity (E), heat (H) and transport fuels (TF) are indicated, with 14.5% in renewable energy realised for each variant:

- " NREAP doc" : realisation according to the Dutch action plan for renewable energy
- "NREAP OD" , translation of NREAP to Option Document, by definition identical to "NREAP doc" .
- "NREAP Opti OD", cost-optimisation based on costs per avoided fossil amount.

The bars at the bottom (with legend RR2010-SV) indicate the contribution according to the background scenario, in which 6.3% in renewable energy is realised. It must be noted that the performed analyses indicate the additional use on top of the background scenario in order to achieve a total of 14.5% in renewable energy. Already existing renewable energy contributions in the background scenario (see table 4.2) are not replaced or displaced by this additional use.

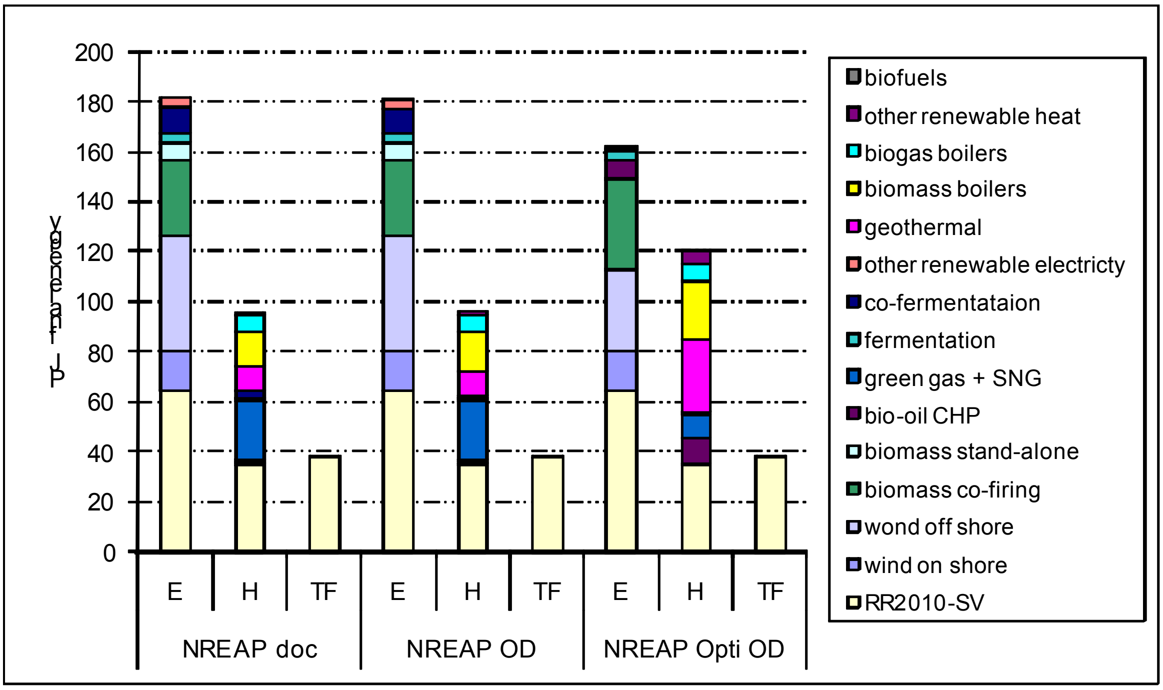

Figure 31 Three variants, all resulting in 14.5% in renewable energy in 2020

It must also be noted that cost optimisation is an extremely one-dimensional approach to fulfilling the target for renewable energy. From the perspective of energy supply certainty, emission reductions and employment, for example, it is advisable to ensure the extensive use of solar boilers in new constructions, even though this is initially not the most obvious choice from a cost perspective. The tightening up of the energy performance standard is expected to provide sufficient stimulus in order to achieve this. Another important market that can be developed is that of large systems for solar heat, either collective or in industry.

The figure below depicts the cost curve for the two variants ‘NREAP’ and ‘NREAP cost optimisation on the basis of the Option document’. It is clear that the first variant also uses options that are relatively expensive: solar PV and solar boilers appear at the right end of the cost curve. The optimised variant uses more of the cheaper options, to the detriment of costlier technologies. Fulfilling the target of 14.5% in renewable energy remains limited to options with costs below 20 EUR$_{2000}$/GJ$_{final}$ (approximately 25 EUR$_{2010}$/GJ$_{final}$). When the EU target for renewable energy is calculated using the national cost method, the total annual costs for the ‘NREAP’ variant are 2.5 billion EUR$_{2000}$ in 2020 (approximately 3.1 billion EUR$_{2010}$). The optimised variant with the same percentage of renewable energy (via avoided fossil and only with the use of domestic measures) amounts to 1.5 billion EUR$_{2000}$ in 2020 (approximately 1.9 billion EUR$_{2010}$).

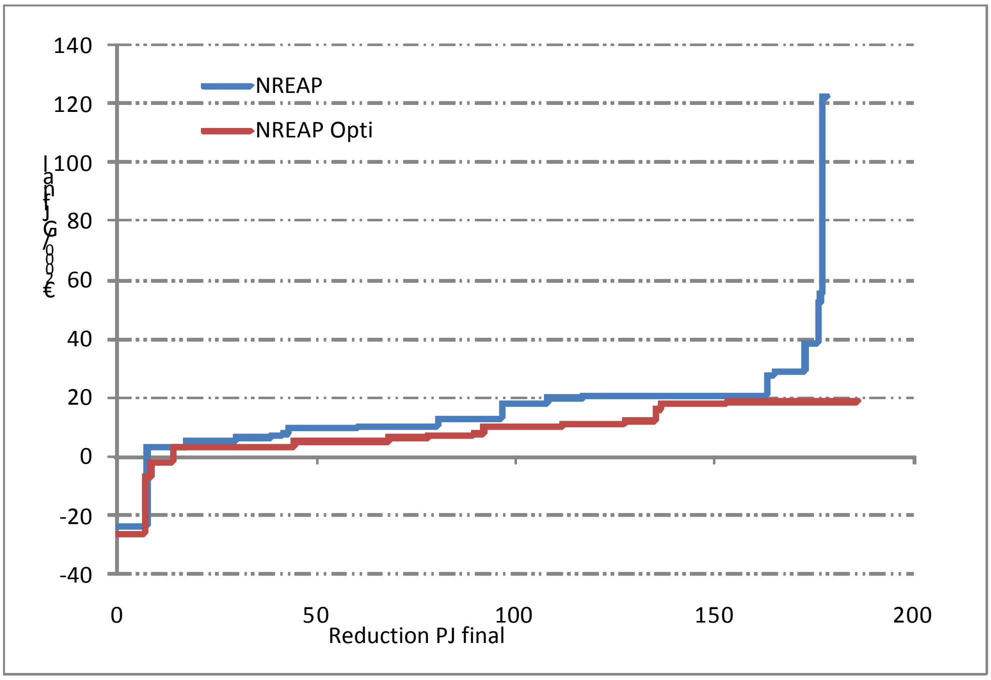

Figure 32 Comparison of two cost curves for renewable energy in the year 2020, both resulting in 14.5% in renewable energy

The two figures below clarify where technologies are located in the cost curve. The first figure does this for the NREAP variant, and the second for the optimised variant. Three additional comments are included once again:

- The cost optimisation has occurred on the basis of avoided primary energy, not on the basis of final energy. That means that options for renewable heat are in disadvantage compared to options for renewable electricity. To paint an accurate picture, the exercise should be carried out according to costs per unit of final energy, but the applied analysis tool is not yet suitable for that purpose.
- During the conference on renewable heat organised by ECN and DE Koepel[7], it emerged that the cost figures used for solar heat and heat pumps were possibly not endorsed by the sector because they could be lower. This means that the costs presented below for solar heat and ambient energy may be too high. The figures presented for solar heat only relate to existing buildings and not to new ones (where solar energy can be up to 35% cheaper).
- Cost optimisation is a very rational approach to achieve the renewable energy target and does not do justice to other benefits of renewable energy and renewable heat in particular.

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[7] See http://www.ecn.nl/conferentie_hernieuwbare_warmte

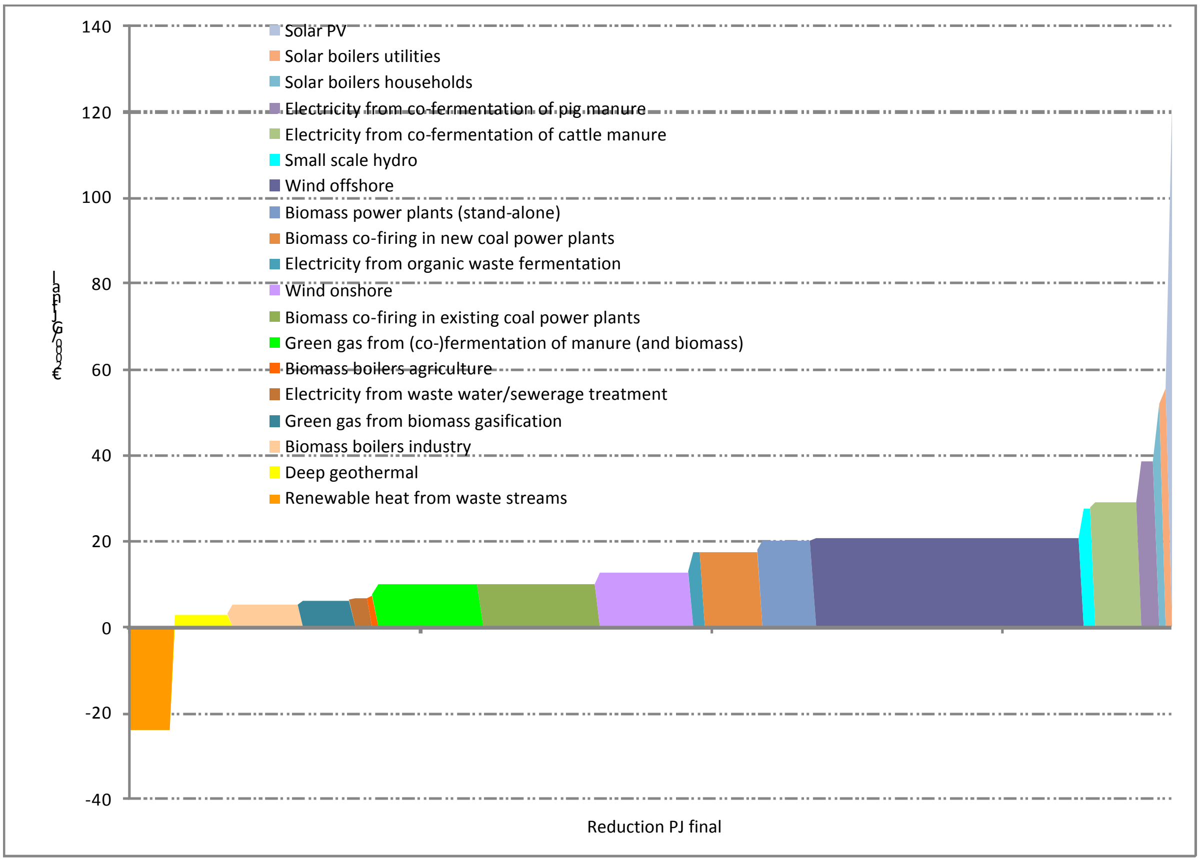

Figure 33 Cost curve for renewable energy in the year 2020 according to the Dutch action plan, achieving 14.5% in renewable energy

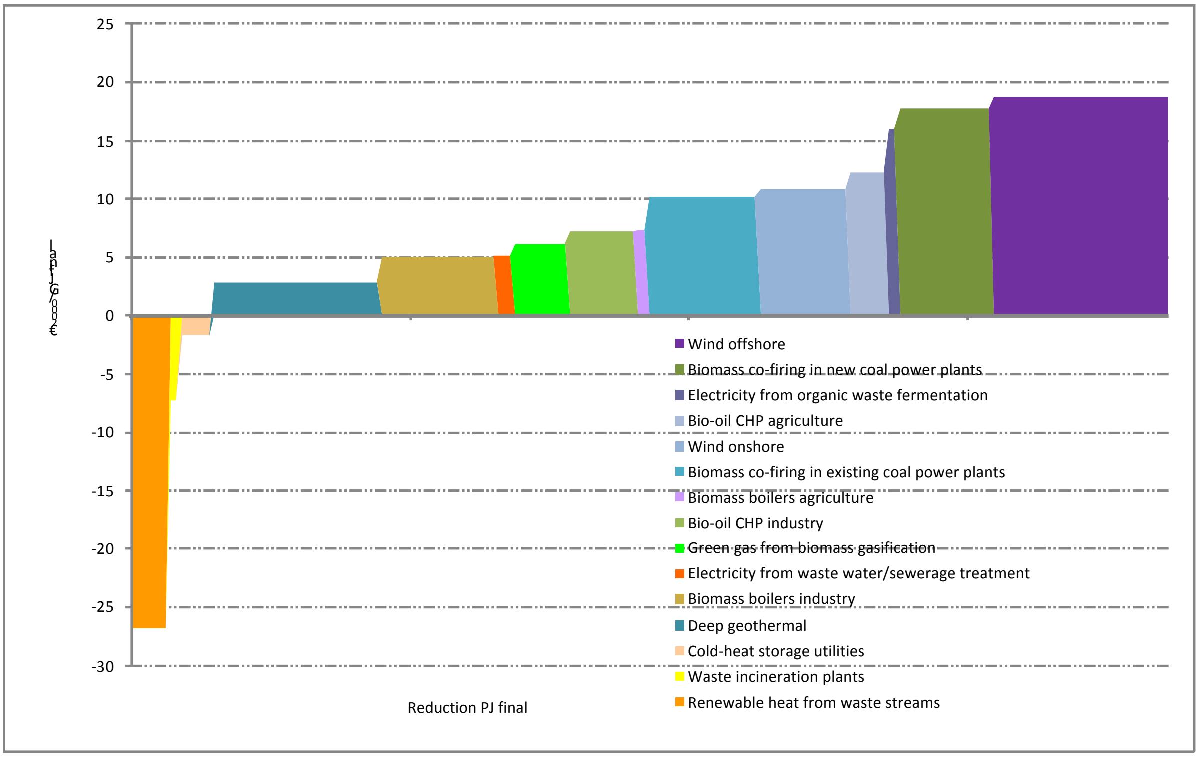

Figure 34 Cost curve for renewable energy in the year 2020 according to a cost optimisation based on the same amount of avoided fossil energy as in the Dutch action plan (NREAP), achieving 14.5% in renewable energy, but involving another deployment of options.

5 Renewable heat in industry

Renewable energy policies often focus on electricity, such as wind turbines, hydropower or photovoltaic solar power, or on systems for buildings, such as solar thermal energy, ambient heat or aquifer thermal energy storage. However, the industrial sector, a large-scale consumer of energy, also merits attention.

5.1 Energy consumption in industry

Figure 1 shows the distribution of the total energy consumption for the EU-27 for the year 2007[8]. Total consumption was 1, 810 Mtoe, or about 76, 000 PJ. Gas, oil and coal were the main sources of energy, while over 8% was from renewable energy sources. Part of this energy is used for electricity production, district heating or oil refinery. Conversion losses, including use by the energy sector, total about 25%. In addition, 3% is used as fuel for shipping and air transport and 7% as raw materials (non-energy carriers). The remaining 65% (1, 160 Mtoe; 48, 500 PJ) is supplied to end users. Of this, about 21% is supplied as electricity, 3% as heat and 76% as another energy source. The distribution of consumption by the various sectors is shown in Figure 2.

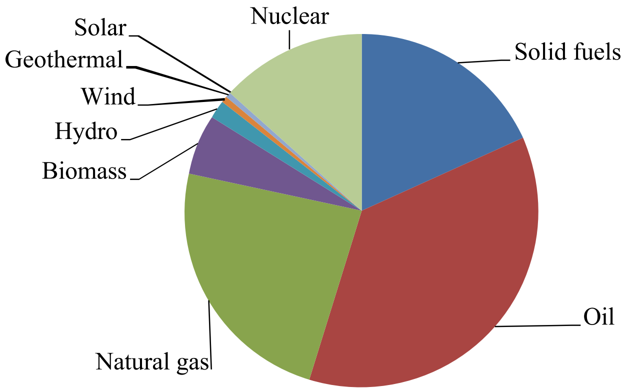

Figure 1 Energy consumption distribution in the EU-27 in 2007

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[8] Source: EU Energy in Figures 2010.

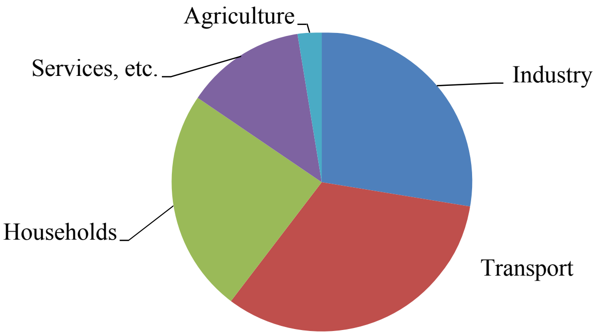

Figure 2 Energy consumption distribution by sector in 2007

Industry is, at 28%, the third largest end user after the built environment and transportation. However, if raw materials are also taken into account, consumption by industry increases to 450 Mtoe, making industry the largest energy consumer. This consumption consists of 130 Mtoe raw materials (oil for the petrochemical industry, coal for the steel industry and gas for the production of artificial fertilizers, for example), 100 Mtoe electricity, about 20 Mtoe heat, 40 Mtoe solid fuels, 40 Mtoe oil, 90 Mtoe gas and 20 Mtoe biomass (see Figure 3, calculated using Eurostat data[9]). Fuel is mainly used to produce heat, and a small amount is for power. A small proportion of the electricity consumption is also for the production of heat.

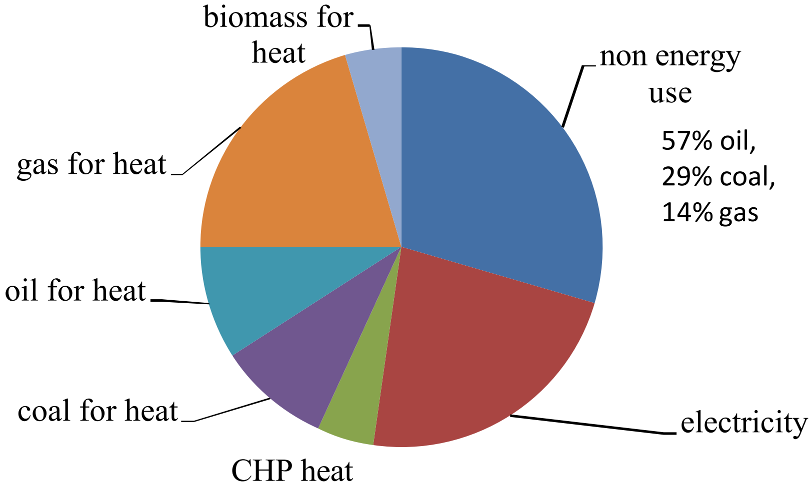

Figure 3 The use of energy and raw materials in industry in 2007 (EU-27)

5.2 Characteristics of industry

Industry is characterised by its often dense energy demand: a high energy demand over a small area and at high temperature levels. However, part of the demand for heat in industry is for heating build-

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[9] Source: Energy Yearly Statistics 2008. Eurostat, 2010 edition.

ings and cooling offices and production areas. If there is no industrial residual heating available locally, then the same renewable heat options apply here as to the services sector.

A number of factors make the implementation of renewable heat more challenging in industry:

- *Lower energy prices.* The higher demand for energy means that prices are usually lower; large-scale users can negotiate lower prices. The number of working hours also has a positive effect on the price and distribution costs are lower due to the size of the connection. In addition, it is the usual policy of governments to tax energy for large-scale consumers at a lower rate. A lower energy price means that renewable energy is financially less attractive.
- *High financial requirements.* Compared to other sectors, expectations are higher regarding the return on investment costs. Furthermore, many companies are under pressure to limit investments as much as possible. This too does not help investment in renewable heat.
- *Specific information required.* As far as information is concerned, there are many more differences in type of energy supply than, for example, in the case of an office building. More specific information is therefore required for each sector.
- *Focus on industrial production.* The emphasis in industry is on the production of goods, and energy is often just regarded as another, limited, production cost. People are not prepared to let risks in the energy supply interfere with the primary process.
- *Great demand for high temperature heat.* About 50% of the heat demand[10] is for temperatures above 250°C. It is not possible to supply such high temperatures using solar energy, deep geothermal energy or heat pumps.

Renewable heat can also benefit industry in a number of ways:

- *Geothermal energy suitable for large-scale use.* The higher energy demand offers opportunities for large-scale renewable heat projects such as aquifer thermal energy storage or geothermal energy.
- *Biomass cleaner and cheaper for large-scale users.* Industry is in a favourable position as far as the use of biomass is concerned, as biomass systems are relatively cheaper the bigger they are. Bulk purchase is an advantage in this case too. Finally, it is easier and cheaper to implement measures that reduce the environmental load in bigger systems.
- *Energy from waste possible.* The food industry and wood sector produce biogene waste streams that can be used to generate energy.
- *A single industrial contact has a large energy impact.* Because of the high energy demand in industry, a specific government action would have a great impact on energy consumption. The transaction costs per MJ are therefore much lower. For example, it would cost the government much less time to provide a few companies with renewable heat subsidies or advice than thousands of individual households.
- *Heating buildings has the same characteristics as the services sector.* What has been developed for the services sector, for example, can also be applied to industrial buildings.
- *Space available for renewable electricity.* Although it is not renewable heat, industrial areas offer good opportunities for wind turbines as there are less landscape objections and industrial background noise is already present. Large warehouses are also often used in industry. If strong enough, the roofs of these warehouses can be used for solar panels or solar cells.

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[10] Source: Solar Industrial Process Heat -State of the Art- . K4RES-H, WP3, Task 3. 5, 25 August 2006.

5.3 Does CO_2 emissions trading (ETS) favour sustainable heat?

The European Union aims to reduce greenhouse gas emissions in the European Union by 20% in 2020 compared with 1990. In addition to objectives regarding energy savings, greener vehicles and renewable energy, the emissions trading system (ETS) is also a very important instrument. All large energy consumers in industry and the energy sector fall under the emissions trading system and are required since 2005 to determine their CO_2 emissions each year and to trade emissions rights with the government.

The third trading period will run from 2013 to 2020. The number of available emissions rights decreases each year by 1.74%, reaching the target set for large energy consumers in 2020. For the ETS companies, this represents a reduction in emissions of 21% in 2020 compared with 2005[11]. The ETS companies need to achieve 70% of this themselves, and about 4.6% (maximum) may be bought via JI and CDM in countries outside the EU[12]. The decision-making process regarding this third trading period is not yet complete.

An increasingly smaller proportion of emissions rights will be given free of charge to companies during the third trading period. The remaining rights will be auctioned. There are three categories:

- Rights will no longer be provided free of charge for electricity production.
- For companies with little international competition, the amount of rights provided free of charge will decrease from 80% to 30% in 2020, and to 0% in 2027.
- Companies with a high level of global competition will retain 100% free rights. What 100% exactly means will be determined by assessing the 10% top companies in the sector concerned (benchmark).

5.4 ETS has two aspects relevant to renewable heat

In the third period, the ETS will set the exact number of emissions rights available to the trading companies between 2013 and 2020. A company that emits more must purchase additional rights. Elsewhere, then, a company will have taken measures to limit its emissions[13]. The total emissions of all ETS companies may no longer change. If companies within the ETS start to use renewable heat,

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[11] The EU's emission reduction target, intended use of CDM and its +2°C. Note IP/A/ENVI/NT/2008-14 PE 408. 552, Policy Department Economic and Scientific Policy.

[12] JI and CDM are part of the Kyoto mechanism. JI and CDM mean that it is possible to pay for certain projects outside the EU that reduce greenhouse gas emissions through energy savings or renewable energy. This reduction may then be traded within the European ETS to compensate for emissions.

[13] This can be explained using electrical cars, for example. If the majority of people in Europe start to refuel their cars using the electricity grid, the CO_2 emissions of the transport sector will fall, due to the decrease in the use of petrol and diesel. The electricity companies will then need to produce more electricity, but there are NO extra rights available for this. The ETS emissions may not increase or decrease. In other words, in the case of an increase in the number of electrical cars, ETS companies somewhere in Europe need to take extra CO_2 mitigating measures.

this also no longer influences the total number of emissions rights. In other words, it does not produce CO_2 emissions reductions for the government.

It may even be the case that ETS companies start to use wood that would otherwise have been used as fuel by smaller companies outside the ETS. In this case, CO_2 emissions would actually increase.

These kinds of problems can be solved by implementing a fourth trading period, for example by applying an extra reduction on the total amount of rights for wood burning in industry and electricity plants.

As far as CO_2 emissions in the period 2013-2020 are concerned, the government therefore does not benefit from stimulating renewable heat in ETS companies. However, the use of renewable heat can contribute to renewable energy objectives. Renewable heat, just like energy savings, reduce a company's CO_2 emissions and therefore also reduce the financial risk due to price variations (or increases) in the ETS. Renewable heat from purchased biomass (for example wood) is less advantageous in this respect. Should the CO_2 price increase, demand for biomass will also increase, resulting in price increases. Very high CO_2 prices can even lead to a run on biomass in the industry and electricity sectors.

The ETS also means that CO_2 has a price. Various factors affect this price. A reduction in the number of rights, or increasing demand due to economic growth, will result in a higher price. If companies make energy savings or reduce their greenhouse gas emissions in other ways, the demand for rights will also decrease, as will the price. There are also CDM and JI rights for projects outside the EU. However, companies may only use a limited number of CDM and JI rights. In the second trading period the price of CO_2 emissions rights varied between 15 and 20 euros/ton, with a peak of 30 euros/ton CO_2. Converting to fuel prices, this represents an increase of between one and two euros/GJ. Comparing this with the industrial gas price of nine to ten euros/GJ[14] shows the limited effect of this price. The current and expected CO_2 price is therefore too low to provide a significant incentive for renewable heat. Although it affects the profitability of a project, a CO_2 price ten times as high is needed if it is to be a significant incentive.

5.5 The use of fossil non-energy carriers in industry

There is a third option for reducing the amount of fossil energy use, in addition to renewable heat and electricity. The use of fossil energy as a non-energy carrier in industry can be replaced with the use of renewable energy.

Coal and coke are used to produce iron in the heavy metal industry, but could also be replaced with sustainably produced hydrogen[15] and/or charcoal.

Naphtha is used in the petrochemical industry to produce polyethylene, but instead of naphtha, bioethanol could also be used as a raw material.

Another example is natural gas, which is used to supply hydrogen for the production of artificial fertilizer. This could be replaced by sustainably produced hydrogen.

The use of renewable energy (such as biomass or sustainably produced hydrogen) as a raw material for chemical processes usually falls outside the ETS system. Only in the case of hydrogen production as a raw material for ammonia or in oil refinery is CO_2 released that falls within the trading system.

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[14] Source: Half-yearly electricity and gas prices (EUR). Eurostat, January 2011

[15] Sustainable hydrogen can be produced from electrolysis using sustainable electricity, from biomass, or from concentrated solar energy (for example through the Solzinc process using ZnO).

In these cases, companies that use a renewable feedstock can save on their CO_2 costs. As non-energy carriers are also not included in the definition of end users, renewable raw materials also make no contribution to renewable energy objectives. Only if a distinction is made in the waste stage (for example between polyethylene from oil or bio-ethanol) could there be a contribution through energy generation from waste incineration.

There is a discrepancy in the way renewable resources that replace fossil fuels are treated in European policy. It may be an idea to consider providing emissions rights for CO_2 in products, as with JI or CDM.

5.6 Examples of renewable heat in industry

Biomass waste
It is possible to produce sustainable heat in industry using the waste produced on-site. In the wood processing industry and the food industry, waste products are sometimes released that can be burnt to generate energy. Wet products from the food industry or industrial water treatment plants can also undergo fermentation to produce biogas. This biogas can then be used to produce electricity and heat. This is profitable and is therefore already implemented in many places, though there is still potential for growth. The extent of implementation will however remain limited.

Wood burning in industry
The purchase of wood for heat and electricity generation also provides possibilities for the production of renewable heat. Despite high investment costs, these kinds of systems are already implemented in many places, in particular in areas in which large amounts of wood are available at a low price. The advantage of large-scale wood burning is that the large systems are relatively cheap per unit of energy produced. The air pollution per kilogram of wood burnt is also lower for large systems. When purchasing wood it is necessary to take into account that the demand for wood may increase, which may result in a price increase.

Aquifer thermal energy storage
Aquifer thermal energy storage has increased in popularity in the Netherlands and Sweden in particular. The heat of summer is used as heating in the winter, and the winter cold as cooling in the summer. Costs are recovered in about five years. Although most projects concern offices in the services sector, about 5 to 10% of the projects are for industry[16]. Large projects are also being carried out in other countries, inside and outside Europe. Storage is possible both in aquifers and in hard rock cavities. Combinations are also possible with heat pumps, solar thermal energy or cold storage. These types of projects are suitable for a limited temperature range.

Geothermal energy
A large local energy demand is ideal if drilling for geothermal energy is to be profitable as it saves on a heat distribution network. Studies show that such a scheme can be profitable[17]. Improvements in drilling techniques and seismic exploration mean that geothermal energy is gradually becoming

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[16] Source: IFTech: http: //www. i3con. org/files/conference-1/6-Fri-Energy_Efficiency/3_I3Conference%20-%20IFTech. pdf
[17] Bron: Ecofys: Duurzame warmte en koude 2008-2020: potentiëlen, barrières en beleid.

cheaper. The temperature levels at greater depths can be used to generate electricity; the electrical power from geothermal energy in Europe is increasing by over 5% a year. Although the temperature levels are also suitable for process heat, this still has few industrial applications[18].

Solar thermal energy
Solar panels similar to those used on houses can be used to produce warm water in industry. Although industrial systems are used, they are not sufficiently cost-effective without a subsidy. Further cost reductions therefore need to be made. As well as the solar panel, a storage system is also required for industrial applications. The number of new systems seems to have now stabilised[17].

Concentrated solar thermal energy
A fast-moving market at the moment is concentrated solar thermal energy. The solar energy is first concentrated, for example using mirrors, so that much higher temperatures can be reached. Electricity generation is currently the major application. What is interesting is that the development of high temperature storage systems is also being considered, so that electricity can also be generated at night. If high temperatures can be made available over a longer period, then the opportunities for application of this technology in industry will also increase. In theory, very high temperatures for chemical reactions can also be achieved. Such a system can already produce a temperature of 1200 °C for the direct production of hydrogen from zinc oxide (the Solzinc process).

5.7 Lessons from modelling renewable heat in process industry

In the RES-H Policy project modelling activities have been performed for evaluating penetration of renewable heat options and the possible impact of policy measures in process industry. From the wider range of technologies listed above, a selection of technologies has been considered in these activities: biomass (both heat only and combined heat and power) for all temperature levels and deep geothermal and solar thermal, the latter technologies up to temperature levels of 200°C. The modelling activities have taken place for the six target countries in the project: Austria, Greece, Lithuania, the Netherlands, Poland and the United Kingdom. The most important lessons from the modelling have been listed below:

- For all countries: fuel price is a decisive modelling input. At low conventional energy prices (almost) no (additional) penetration of renewable heat options occurs in process industry.
- Financial support measures improve the cost-benefit ratio and the financial attractiveness of renewable heat projects. Investment subsidies help industry overcoming their barrier towards investments, and from this perspective they are a defendable policy measure. Specifically for biomass technologies an investment subsidy will not be able to cover all heat production costs, since the fuel costs represent an important share in the heat costs. A drawback of the investment subsidy is that no guarantee is provided for a continued renewable heat production: in case the owner of the installation after having received the investment subsidy decides not to use biomass fuels, usually no penalty is given. An exploitation subsidy (bonus or feed-in tariff like the United Kingdom Renewable Heat Incentive, RHI) do provide such guarantees (provided that the payments are based on metering). Likewise, lower interest rates for financing investments in renewable heat result in more advantageous values of a project's

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[18] The State of Renewable Energies in Europe; 10th EurObserv'ER Report 2010

internal rate of return, which thus supports industrial players in a positive investment decision. An advantage of supporting large industrial installations is that the transaction costs for governments are lower compared to supporting small-scale installations (this effect has not been modelled explicitly). For deep geothermal and solar thermal, investment subsidies can be very suitable, especially due to the relatively low running costs of these technologies (no fuel costs). Sensitivity runs have shown that sometimes very high support levels are needed for making these options penetrate (more than 50%, depending on the fuel price scenario).

- Cheapest options penetrate first: biomass heat-only (especially if based on waste streams, which are assumed to be available at very low or even negative prices in case costs for removal are avoided) good competitive strength occurs, but generally these fuel streams are very limited in potential.
- Most expensive options (solar thermal, geothermal) generally do not penetrate at low conventional energy prices.
- In some countries the potential for solar thermal energy in industry has been found to be very limited. Deep geothermal is slightly better positioned, but due to a mismatch in the availability of geothermal hot-spots and industrial activity the realisable potential still might be zero. Biomass potential in all countries is regarded as the most important option for process industry.
- Sensitivity analyses show that besides the impact of the level of conventional fuel prices high uncertainty in modelling output occurs through biomass price scenario choices.

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Annex A Model descriptions

A.1 Modelling of space heating and hot water demand in the residential and service sector with the Invert/EE-Lab modelling environment

Invert/EE-Lab is a dynamic bottom-up simulation tool that evaluates the effects of different promotion schemes (in particular different settings of economic and regulatory incentives) on the energy carrier mix, CO_2 reductions and costs for RES-H support policies. Furthermore, Invert/EE-Lab is designed to simulate different scenarios (price scenarios, insulation scenarios, different consumer behaviors, etc.) and their respective impact on future trends of renewable as well as conventional energy sources on a national and regional level.

The basic structure and concept is described in Figure 35.

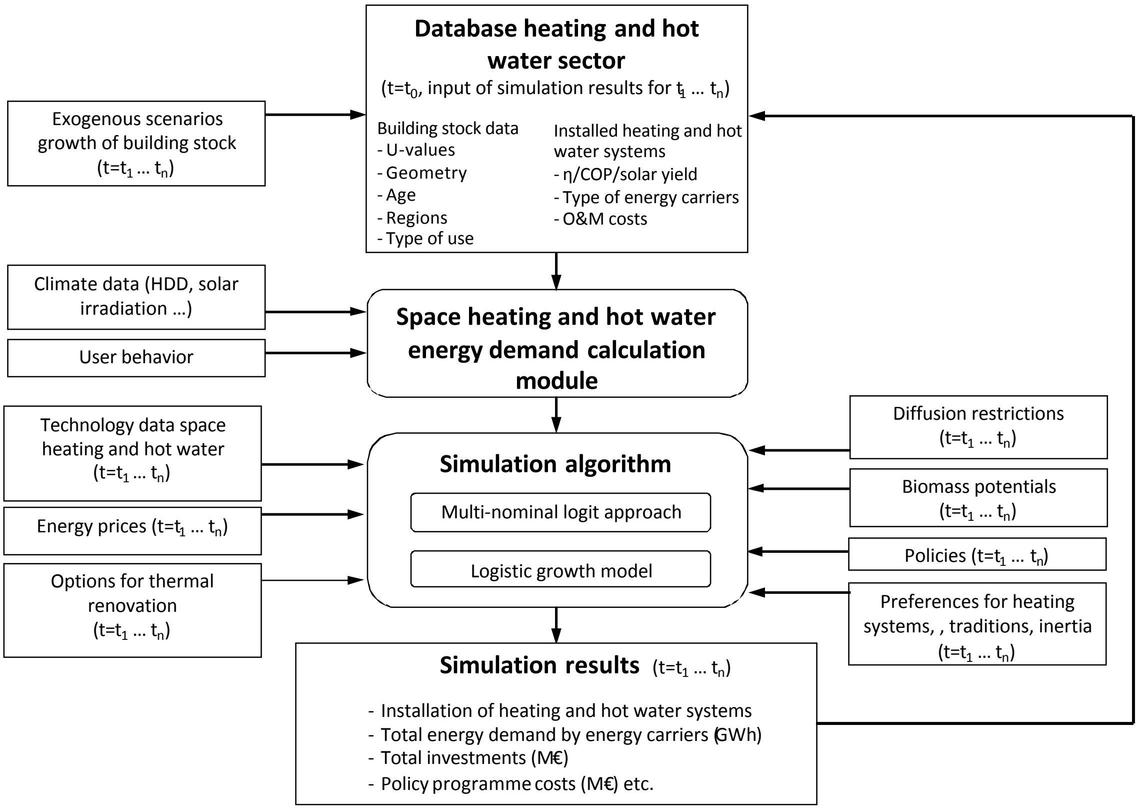

Figure 35: Overview structure of Simulation-Tool Invert/EE-Lab

Invert simulation tool originally has been developed by Vienna University of Technology/EEG in the frame of the Altener project Invert (Investing in RES&RUE technologies: models for saving public money). During several projects and studies the model has been extended and applied to different regions within Europe, see e.g. (Biermayr et al., 2007), (Haas et al., 2009), (Kranzl et al., 2006), (Kranzl et al., 2007), (Nast et al., 2006), (Schriefl, 2007), (Stadler et al., 2007). The last modification of the model in the year 2010 included a re-programming process and accommodation of the tool, in particular taking into account the inhomogenous structure of decision makers in the building sector and corresponding distributions (Müller, 2010). The current state of the model relies on this new calculation-core (called EE-Lab) leading to the current version of the model Invert/EE-Lab506 which has been used in this project.

The core of the tool is a myopical, multinominal logit approach, which optimizes objectives of “agents” under imperfect information conditions and by that represents the decisions maker concerning building related decisions. Invert/EE-Lab models the stock of buildings in a highly disaggregated manner. Therefore the simulation tool reflects some characteristics of an agent based simulation.

A.2 Modelling of industrial process heat using the RESolve-H/C model

The RESolve-H/C model[19] consists of numerous consecutive steps, which can all be attributed to two main loops:

1. Determining the *realisable potential* of RES-H in industry, resulting in a time series of energy data for the selected renewable heat technologies
2. Determining the *penetrations* of RES-H in industry under various policy assumptions, resulting in a time series of energy data for the selected renewable heat technologies, expected policy and fuel expenses and impacts on CO_2-emission

These two loops will be briefly explained in the following sections.

A.1.1 Determining the potential of RES-H in industry

This section describes the consecutive steps applied to evaluate the potential of renewable heating and cooling sources (RES-H/C) and technologies. Starting point for the modelling work is based on EU-wide data sources. The advantage is that the modelling can take place based on generic datasets combined with relatively few country-specific data (or assumptions when specific data are lacking). The result of the modelling train described in this annex is realisable potentials (or targets) for RES-H/C penetrations in industry.

In a few words, the modelling approach can be summarised as follows:

A. Based on several data sources, non-electric and non-feedstock energy use in industry is decomposed into energy use per energy carrier, per temperature level and per industry subsector and extrapolated to the year 2030. A breakdown into the three required steps is provided in the table below (step 1 to 3).

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[19] The RESolve-H/C model has been designed by the Energy research Centre of the Netherlands (ECN).

B. For the base year 2005, each of the abovementioned decomposed energy uses are assigned energy conversion technologies, based on statistical information. A breakdown into the two required steps is provided in the table below (step 4 and 5).

C. By applying a series of substitution and exclusion rules, a set of constraints is complied which indicates which share of the industrial energy use is available for RES-H/C: the potential of target. A breakdown into the three required steps is provided in the table below (step 6 to 9).

An more detailed outline of the A to C described above is provided in the overview below:

A.	Calculate energy use per energy carrier, temperature level and industry subsector and extrapolation to 2030	Step 1: Energy use per energy carrier and per subsector Step 2: Future development of the industry subsectors Step 3: Decomposing heat demand into temperature levels
B.	Assign energy conversion technologies to historic final energy data (fuel use)	Step 4: Conversion technologies and efficiencies Step 5: Match existing biomass technologies to projections
C.	Apply a series of substitution and exclusion rules to find constraints to RES-H/C penetration	Step 6: Match RES-H/C technologies to temperature levels Step 7: Limiting the number of technologies Step 8: Define constraints to RES-H/C potential in industry Step 9: Amending the potential by applying expert's view

Firstly, the heat demand in process industry has been decomposed into temperature levels for heating and cooling requirements: five heating categories H1 to H5 have been defined, and three cooling levels C1 to C3. These temperature ranges then are to be matched to the RES-H/C technologies, as each renewable energy source for heating and cooling performs best in a window of temperature ranges. The table below shows in general terms which RES-H/C technology can serve which temperature level.

Table 1 *Matching of RES-H/C technologies to temperature levels*

Level	Temperature range	Biomass	Deep geothermal	Heat pumps	Solar thermal	Underground heat/cold storage
H5	Above 600°C	x				
H4	Between 200 and 600°C	x				
H3	Between 100 and 200°C	x	x		x	
H2	Between 65 and 100°C	x	x		x	
H1	Below 65°C	x	x	x	x	x
C3	Between +10 and +15°C			x	x	x
C2	Between -30 and +10°C			x		
C1	Below -30°C					
Losses	Several temperature levels					

For heat pumps only heating is considered as defined by Article 5.5 in the Directive 2009/28/EC). The leading principle for filling out the table has been to use standard technology configurations, ready for uptake. Exotic configurations thus haven't been listed; for example concentrating solar thermal for the highest temperature level is not considered.

Applying a set of constraints (step 8) results in a 'realisable potential', corresponding to the terminology in the Green-X and INVERT modelling approach: it represents the maximum achievable potential assuming that all barriers can be overcome and all driving forces are active. The realisable potential quantifies in a time dependent manner to what extent renewables can penetrate in a sector.

The realisable potential takes into account the following limiting factors:

1. Constraints on fuel supply (mainly relevant for biomass technologies)
2. Constraints on equipment supply (relevant for all manufactured technologies)
3. Constraints on the demand side (relevant for most options; this regards for example maximum market growth rates and planning constraints)
4. Constraints because of competition (some technologies compete for delivering the same energy service)

The four above factors all limit the realisable potential. If required, experts may modify the resulting potentials (step 9).

This potential is then further reduced to calculate the penetrations under fuel price and policy assumptions (see next section).

A.1.2 Determining the penetration of RES-H in industry

Once the realisable potential has been defined, an additional constraint determines the extent to which renewable options effectively penetrate into the market. This means that on top of A to C as introduced in the previous section an item D can be defined:

D. Applying a series of constrains in order to evaluate the price effect of substitution of non-renewable energy sources, policy measures, and stakeholder behaviour. A breakdown into the three required steps is provided in the table below (step 10 to 12).

D.	Add information that allows to simulate market behaviour from industrial stakeholders in RES-H/C investment decisions	Step 10: Determine costs and benefits of renewables Step 11: Determine effects of policy measures Step 12: Project stakeholder behaviour

The result of the series of A to D results in projected RES-H penetrations in process industry, and derived indicators such as required budget for investments and impact on CO_2-emission.

The profitability of investment in a renewable heat technology can be determined once the costs and avoided costs are known. For each possible investment, and Internal Rate of Return (IRR) is calculated. The IRR is a measure to compare the profitability of investments: the higher the internal rate of return for a project is, the more desirable it is to invest. The IRR represents the interest rate at which the net present value of all project costs (investment, fuels costs, operation and maintenance) of the investment equals the net present value of the benefits (avoided fuel costs, electricity sales (for CHP technologies)) of the investment. The cash flows are based on perfect foresight. Future energy prices are assumed to be known. Also subsidies, CO_2-costs, taxes , and exploitation subsidies can be taken into account.

Modelling policy measures can be performed for various (country-specific) options:

1. An investment subsidy of a certain percentage
2. An exploitation subsidy

3. Cheap loans

Implementing these measures will modify the cashflows and likewise the value of the IRR in every renewable energy project, making the generation of renewable energy ‘as perceived by the investor’ more profitable. Once a project becomes more beneficial, this impacts the internal rate of return, which is decisive in estimating the penetration for each technology.

The stakeholder behaviour, i.e. whether to invest or not in a renewable heat project, finally is modelled assuming penetration levels that match the anticipated level of the IRR based on an s-curve approach: the higher the IRR is, the more investments are being simulated and the higher the resulting penetration of renewable heating in industry will be. In this step all previous inputs have been considered.

Annex B Heat generation costs

B.1 Technology costs: input data

Two levels exist in the input data. Firstly, the data as researched by ECN for the technologies based on market and literature research. Secondly, the data as prepared by EEG for the purpose of modelling. The set from the literature research does not match exactly the modelling dataset, for example because of the different power ranges needed for the modelling. In order to have all data work available for future reference, both datasets have been documented in this Annex (see next two subsections).

B.1.1 Raw data from market research

The table blow specifies data as found after researching literature and market analysis. The data have been collected from equipment catalogue databases and in some cases from suppliers directly. A listing of general data comments is provided below:

- Prices are excluding VAT
- Cost items are total investment costs: material and installation (see also comments)
- Full costs (not additional costs)
- For existing dwellings/renovation (not new dwellings): small share of replacement costs are included
- For single family dwellings
- Individual costs (no project-based lower costs)
- Assumption hourly rate service personnel: 39 euro

The table specifies in the last column more specific comments.

	Capacity	Capacity	Total investment	Comment
		Unit	€	
Gas boiler	30	kW	1942	Type: 12,5 - 24 kW gas boiler Material costs: 1,431 euro Installation: 511 euro Date applicable: January 1st, 2008
Gas condensing boiler	30	kW	2431	Type: 21 - 28 kW gas condensing boiler Material costs: 1,213 euro Installation: 1,218 euro Date applicable: January 1st, 2008
Oil boiler	30	kW	2678	Type: oil boiler combi (heat+hot water) Share material/installation costs unknown Date applicable: January 1st, 2007
Oil single	30	kW	1618	Type: radiation heating, no boiler system Share material/installation costs unknown Date applicable: January 1st, 2007

Gas single	30	kW	1544	Type: radiation heating, no boiler system Share material/installation costs unknown Date applicable: January 1st, 2007
Wood log	30	kW	500 - 5,000	price of wood log burners (heat radiation only, no boiler system) can vary greatly, on average between 500 and 5.000 euros according to some Dutch sources. Date applicable: January, 2010
heatpump air/water	15	kW	19565	Type: 15 kW, no combi (heating only) Material costs: 16,629 installation costs: 2.936 material and installation includes low-temperature radiators, for 2,574 euros Date applicable: January 1st, 2008. For new dwellings: Cost deduction based on proportion of costs for renovation compared to new buildings, as mentioned by Holland Solar, personal communication, 13 January 2010 (assumption 50% of 36% mentioned for solar thermal combi, applies to heat pumps)
	25	kW	34080	Type: 26 kW, collective heat pump (heating only) Material costs: 30,910 installation costs: 3170 material and installation include low-temperature radiators, for 4,830 euros Date applicable: January 1st, 2008
heatpump brine/water shallow	15	kW	50255	Type: source surface water, 13,9 kW, no combi (heating only) Material costs: 45,769 installation costs: 4,486 material and installation include low- temperature radiators, for 2,574 euros Date applicable: January 1st, 2008. New dwellings: Cost deduction based on proportion of costs for renovation compared to new buildings, as mentioned by Holland Solar, personal communication, 13 January 2010 (assumption 50% of 36% mentioned for solar thermal combi, applies to heat pumps)
	25	kW	32281	
heatpump brine/water deep	15	kW	29589	Type: source ground water, 13,9 kW, no combi (heating only) Material costs: 26,718 Installation costs: 2,871 material and installation include low- temperature radiators, for 2,574 euros Date applicable: January 1st, 2008. New dwellings: Cost deduction based on proportion of costs for renovation compared to new buildings, as mentioned by Holland Solar, personal communication, 13 January 2010 (assumption 50% of 36% mentioned for solar thermal combi, applies to heat pumps)
	68	kW	23749	
Solar	4	kW	7089	Price for existing dwelling/renovation

thermal Combi (heat+dhw)				Type:4m2, combi (heating+hot water) Material costs: 5,296 (includes material+installation of gas condensing boiler, for 1,989 euros) Installation costs: 1,793 Date applicable: January 1st, 2008. New dwellings: Price of new dwelling, project-based Type: 2,5-3m2 surface Material costs, including installation: 1,800 Costs condensing boiler equal to renovation: 1,989 Source: Holland Solar, personal communication, 13 January 2010
Micro CHP boiler (HRe ketel)	24	kW	7,000-10,000	Type: Baxi Ecogen 24 combi (heat+hot water), Stirling motor + low-temperature system. Price estimate includes price of standard gas condensing boiler (+/- 2,000) + additional cost of micro CHP boiler Date applicable: January, 2010 Not yet available on the market, price range is rough estimate based on scarce literature
Hybrid system (gas and ambient heat)	24	kW	3360	Type: 24 kW Daalderop Combinair (UHR) ketel (gas condesing boiler with air/water heat pump technology) Date applicable: January 14th, 2010
Solar thermal DHW	4	m²	3738	For existing buildings/renovation Type: 4m2 surface, single (hot water only) Material costs: 2,901 Installation costs: 837 Date applicable: January 1st, 2008. For new dwellings: price solar heating sytem combi costs of condensing boiler .
Electricity stand alone DHW	1	kW	1446	Type: 1000W electric domestic water heater (water storage) Material costs: 992 Installation costs: 454 Date applicable: January 1st, 2008
Geyser gas kitchen DHW	9.5	kW	819	Type: 9,5W gas water heater (no water storage), for kitchen Material costs: 493 Installation costs: 326 Date applicable: January 1st, 2008. overall system efficiency: 53% installation efficiency: 77% (ISSO publicatie 82,3 blz. 84, EPA maatwerkadvies)
Geyser gas bathroom DHW	17.4	kW	1075	Type: 17,4W gas water heater (no water stock), for bathroom Material costs: 710 Installation costs: 365 Date applicable: January 1st, 2008. overall system efficiency: 56% installation efficiency: 77%

				(ISSO publicatie 82,3 blz. 84, EPA maatwerkadvies)
Heat pump boiler DHW	200	liters	4680	Type: heat pump water heater (water stock), source air, volume 200 liters Material costs: 4,011 Installation costs: 669 Date applicable: January 1st, 2008

B.1.2 Prepared data for INVERT modelling

For calculating the heat generation costs the inputs as displayed on the next page have been used. These data all apply to the Dutch market specifically. In order to define the parameters in the way INVERT allows to import them the data from the previous section needed to be adjusted. For this reason differences exist between the datasets.

Table 4 *Data used in the INVERT modelling*

		Investment cost for various thermal capacity ranges														
	Fuel type	Minimum power		Power level 2		Power level 3		Power level 4		Maximum power		Operation &	Lifetime	Annual use	Annual use	Service
		Capacity	Cost	Capacity	Cost	Capacity	Cost	Capacity	Cost	Capacity	Cost	Maintenance		factor	factor DHW	factor
		kW	€/kW	kW	€/kW	€/kW	kW	€/kW	kW	kW	€/kW	€/kW.a	years	-	-	-
Individual heating oil	Fossil	10	2186	30	3186	50	3796	70	4261	100	4815	11	15	0.85	0.77	0.90
Individual heating gas	Fossil	10	1522	30	2311	50	2806	70	3189	100	3652	13	15	0.88	0.79	0.90
Individual heating gas condensing	Fossil	10	2035	30	2893	50	3406	70	3794	100	4252	13	15	0.91	0.82	0.90
Individual heating wood log	Biomass	15	14952	25	16027	40	20241	60	23756	60	23756	8	15	0.63	0.57	0.80
Individual heating wood chips	Biomass	30	26234	30	26234	50	31167	150	88400	350	198333	18	15	0.69	0.62	0.90
Individual heating wood pellets	Biomass	7	12098	10	12098	20	15867	40	23800	60	22610	18	15	0.77	0.69	0.90
Heat pump air/water	Ambient	8	16094	10	17452	15	20220	20	22445	25	24339	17	15	3.10	2.64	0.90
Heat pump brine/water shallow	Ambient	8	18163	10	20010	20	27033	30	32234	40	36521	7	15	4.20	3.57	0.90
Heat pump brine/water deep	Ambient	8	23908	10	26946	20	39070	30	48554	40	56649	7	15	4.20	3.57	0.90
District heating conventional	Fossil	30	14100	30	14100	30	14100	60	24675	100	35250	17	15	0.98	0.88	0.90
District heating geothermal	Geothermal	20	34510	20	34510	30	51765	60	100674	100	167790	17	15	0.98	0.88	0.90
District heating biomass	Biomass	20	17850	20	17850	30	26775	60	49980	100	83300	17	15	0.98	0.88	0.90
Individual heating hybrid	Fossil/ambient	30	6500	30	6500	50	7654	70	8524	70	8524	17	15	1.40	1.26	0.90
Individual hot water gas	Fossil	5	730	8	902	10	997	15	1197	20	1362	13	15	0.88	0.88	1.00
Individual hot water electric	Fossil	5	1976	8	2058	10	2098	15	2172	20	2227	2	15	1.00	1.00	1.00
Individual hot water heat pump air/water	Ambient	5	13570	8	16094	10	17452	15	20220	20	22445	17	15	2.00	2.00	1.00
Solar hot water system	Solar	3	3430	5	5437	8	8308	12	11976	15	14646	7	15	350.00	0.00	0.00
Solar heating and hot water system	Solar	5	5531	10	10264	25	23242	35	31377	50	43131	9	15	320.00	0.00	0.00

B.2 Fuel price assumptions

Here an overview of the fuel price assumptions for residential and industry.

B.3 Resulting heat generation costs

The heat generation costs of the different technologies included in the INVERT modelling runs are shown in the two following figures. For each technology the bandwidth of the heat generation costs, which is due to decreasing specific investment costs with rising system sizes, is indicated for the years 2010, 2020 and 2030. It can be concluded that most technologies, certainly for the ‘low energy price scenario’ are more expensive than the reference fuel prices. Regarding the future cost development it can be observed that only solar thermal energy is expected to realise significant technology learning and consequently decrease in cost level. Biomass and ambient heat through heat pumps is expected to increase in cost level, as these might be facing important increases in fuel costs or in auxiliary energy costs (depending on the fuel price scenario).

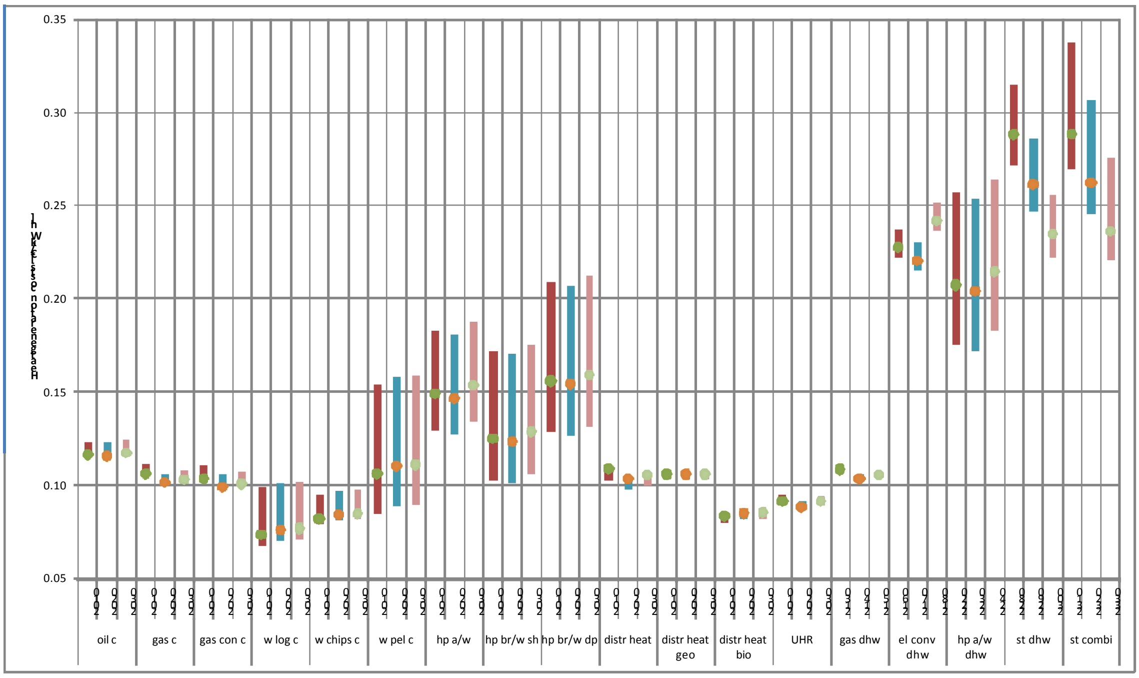

Figure 36: Range of heat generation costs in the building sector (low-price scenario, see table for legend)

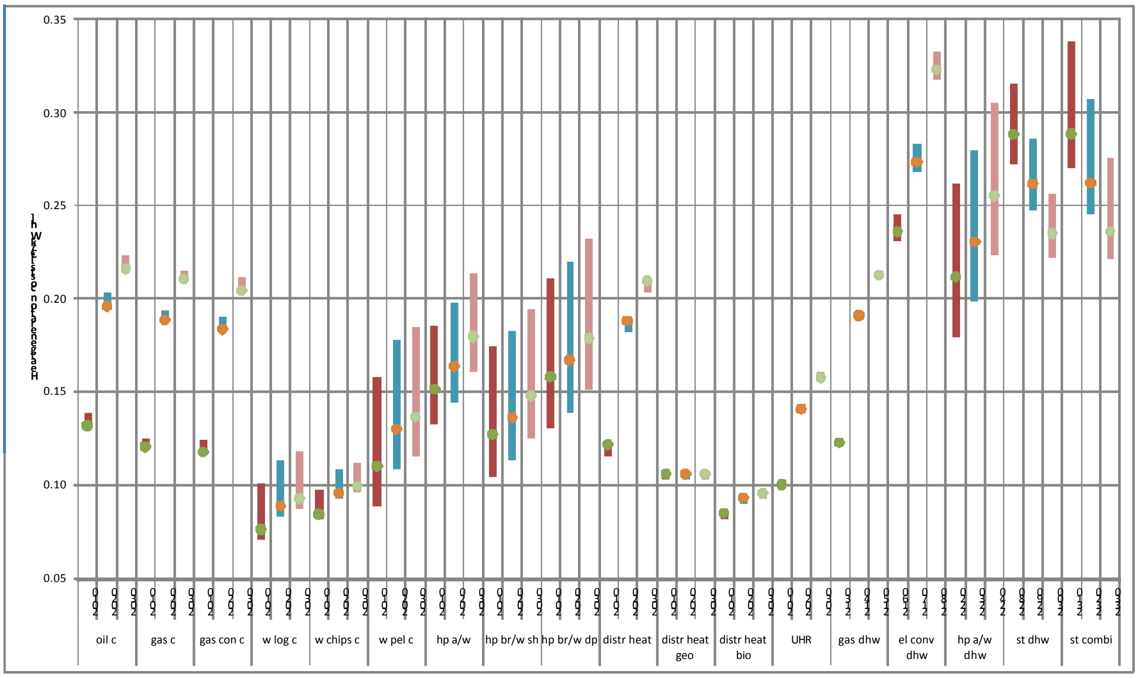

Figure 37: Range of heat generation costs in the building sector (high-price scenario, see table for legend)

Label	**Technology**
oil c	Oil central
gas c	Gas central
gas con c	Gas condensing central
w log c	Wood log central
w chips c	Wood chips central
w pel c	Pellets central
hp a/w	Heat pump air/water
hp br/w sh	Heat pump brine/water shallow
hp br/w dp	Heat pump brine/water deep
distr heat	District heating central
distr heat geo	District heat deep geothermal central
distr heat bio	District heat biomass central
UHR	Hybrid gas / ambient heat boiler (‘*ultrahoog rendement*’)
gas dhw	Geyser
el conv dhw	Electrical converter single (Domestic hot water)
hp a/w dhw	Heat pump air/water (Domestic hot water)
st dhw	Solarthermal for DHW only
st combi	Solarthermal Combi System

Annex C Industry modelling: sensitivity runs

C.1 Varying subsidy levels for solar thermal energy

The table below lists the modelled penetrations for different levels of investment subsidy for solar thermal energy in industry in the ‘low price scenario’. It can be observed that only very high subsidy levels (more than 90%) result in a significant share of the potential. Note that the input data are very important for the interpretation of this result (see other sections in this report).

	2010	2020	2030
0% investment subsidy	0.0	0.0	0.0
25% investment subsidy	0.0	0.0	0.0
80% Investment subsidy	0.0	0.0	0.0
90% Investment subsidy	0.0	0.0	0.1
95% Investment subsidy	0.0	0.2	0.7
Potential		0.2	0.8

C.2 Varying subsidy levels for deep geothermal energy

The table below lists the modelled penetrations for different levels of investment subsidy for deep geothermal energy in industry in the ‘low price scenario’. It can be observed that high subsidy levels are needed (more than 40%) to capture a significant share of the potential. Note that the input data are very important for the interpretation of this result (see other sections in this report).

	2010	2020	2030
0% investment subsidy	0.0	0.0	0.0
40% investment subsidy	0.0	0.1	0.2

60% Investment subsidy	0.1	0.2	0.5
Potential		0.2	0.8