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THE ROLE AND IMPACT OF BIOMASS HEATING SUPPORT POLICIES

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ABSTRACT: Within the EU-27 biomass heating covers about 90% of all renewable energy sources in the heating sector (RES-H). According to the NREAPs of EU member states, biomass heating should further increase from 49 Mtoe (2005) to 87 Mtoe (2020). Yet, several questions are open regarding required support policies and the expected technological, economic and system change. In this paper we develop scenarios for the heating sector in selected EU-countries based on the models Invert/EE-Lab (for the buildings) and RESolve-H/C (for the industry) up to 2030. For regions with a currently high share of biomass heating it will be essential to address the large stock of partly inefficient wood log stoves and boilers. In all regions and scenarios, wood chip and wood pellet systems as well as biomass district heating show a significant higher growth than the overall biomass heating sector. According to our scenarios biomass could cover a share between more than 80% (LT), more than 30-40% (AT, PL) and up to 10-20% (GR, DE, UK, NL) of the energy consumption for space heating and hot water. Effective combination of policy elements is crucial for the further development of the sector and integration of efficiency measures with biomass deployment.

Keywords: Bioenergy, heat, modelling, policies

1 INTRODUCTION

The 2020 EU targets for Renewable Energy Sources (RES) will require substantial growth of all RES-technologies and sectors. This includes the heating sector which – for the first time in EU legislation – is also addressed by the EU 2009 RES directive. Biomass currently clearly holds the highest share of RES-H systems (about 95%) in the EU-27. The national renewable energy action plans (NREAP) of the different European countries show that biomass is expected to show a considerable growth in the heating sector assuming that appropriate, ambitious support policies are in place.

The core objectives of this paper are:

- to analyse the role of biomass for achieving RES-H targets up to 2020 and beyond for selected EU countries in various scenarios
- to analyse the impact of different support policies for biomass heating in these countries
- to identify challenges and perspectives for biomass heating.

The work presented in this paper is based on the IEE project “RES-H Policy (Policy development for improving Renewable Energy Sources Heating & Cooling penetration in European member states)” (www.res-h-policy.eu). However, additional insights are included, in particular for the case of Germany.

2 METHODOLOGY

The analysis is carried out for selected EU countries (AT, DE, GR, LT, NL, PL, UK) and takes into account the building sector (space heating and hot water) as well as the process industry. The methodological approach includes the following steps:

- Comparative analysis of NREAPs with respect to the role of biomass heating
- Projection of possible target ranges (that could also go beyond the values indicated in the NREAPs) for different biomass heating applications, technologies and systems until 2020 and 2030
- Modelling of heating markets in these countries. For the building sector the model Invert/EE-Lab will be applied and for the industry sector, the ECN model RESolve H/C. Both models are bottom-up simulation tools.
- Simulation of the impact of different support policies by making use of these models and comparative analyses of different policies in different scenarios in different countries. In particular, this will include the investigation of the impact of multiple support mechanisms including investment subsidies, use obligations, tax incentives and renewable heat incentives.
- Simulation results and scenario settings (as well as policy design) has been discussed in a stakeholder discussion process during the project RES-H Policy on a national basis.

2.1 Modelling the space heating and hot water sector: Invert/EE-Lab

One of the core approaches of this paper is the application of the model Invert /EE-Lab. 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 society promoting certain strategies in the building related energy demand sector (space heating and hot water). A disaggregated description of the building sector and the related heating and hot water systems is the basis for this calculation. The core of the tool is a myopical, multinominal logit approach, which optimises 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. For more details regarding selected previous applications of Invert/EE-Lab and methodological descriptions see e.g. [1], [2] and www.invert.at.

2.2 Modelling the industry sector:

The RESolve-H/C model consists of multiple consecutive steps, which can all be attributed to two main loops: a.) determining the potential of RES-H in industry, resulting in a time series of energy data for the selected renewable heat technologies, and b.) 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 and expected policy expenses. The profitability of investment in a renewable heat technology is determined once the costs and avoided fuel costs are known. For each possible investment, an Internal Rate of Return (IRR) is calculated. The IRR is the interest rate that makes the net present value of the investment equal to zero. The cash flows are based on perfect foresight. Future energy prices are assumed to be known (Capros (2009). The model considers the cash flows from the perspective of the investor. Important components of the cash flows are investment costs, benefits from reduction of the energy demand and consequently the avoided fuel costs due to savings on non-renewable energy carrier expenses. Cash flows related to the loans consist of repayments and interest, with repayment assumed to take place in equal shares. Cogeneration has an effect on the cash flow through additional income through electricity sales.

2.3 Basic assumptions and input data

Energy prices: We use Eurostat price relations for 2007-2009 and take into account two different energy price scenarios according to [3] and [4].

Cost data for biomass heating (and other heating and hot water) systems: The cost data for biomass heating systems have been taken from literature, data collection from producers and regional biomass associations. We have assumed technological learning, in particular in countries with currently high costs. However it was observed that fuel prices remain the most important variable.

Investigated policies: We focus on the analysis of economic incentives (in the form of investment subsidies (AT, NL, LT, PL), income tax incentives (GR) and bonus systems (notably the UK’s renewable heat incentive) and use obligations for RES-H systems. Use obligations require stakeholders to install RES-H systems (often specifically solar thermal systems) where certain conditions apply. This may be the construction of a new building or a major renovation or just the replacement of a heating system. Extension of supplier obligations (notably the UK's Carbon Emissions Reduction Target) is also considered – this requires energy suppliers (utilities) to invest in RES-H capacities at customer premises.

Policy settings for Invert/EE-Lab simulations: We carried out simulation runs for each of the selected countries for economic incentives and for obligations (and each of them for a high-energy-price and a low-energy-price scenario). However, the detailed settings for the policy instruments vary between the regions. When comparing the results between the regions this might be biasing. On the other hand, the policy conditions and current discussions are quite different among the countries. Thus, the policy settings that we selected are reflecting to some extent recently ongoing political discussions or even decisions and should identify the impact of a somewhat ambitious policy. Partly the intention for these policy settings was also to provide insight into specific open questions for the related region. In any case we do not consider these policy settings as forecasts but as basic input for which we will investigate the impact on the solar thermal market. We have to take this into account in the conclusions and we are aware that there might be other relevant policy settings that would be interesting to cover.

Policy settings in RESolve-H/C simulations:

Exploitation subsidies like the United Kingdom Renewable Heat Incentive (RHI) and investment grants can be considered, increased CO_2-costs, taxes and transport and distributions costs for energy can be taken into account. A certain share of the investments is to be financed with loans.

Table I and Table II show the summary of policy settings for the simulation runs in the investigated EU-countries. More detailed information are available at www.res-h-policy.eu.

Table I: Summary of policy settings for the country simulations for the building sector: (1) economic incentives

	Policy settings Economic incentives
AT	Investment subsidies (25-35%, about the same level as recent support schemes)
DE	Investment subsidies (7% - 15 % for existing buildings; for new buildings 25 % less)
GR	Income tax incentives (25%-30%, in a similar range as recent support schemes)
LT	Investment subsidies (20 to 30%)
NL	Investment subsidies (ranging from 10-45%, slightly higher level than recent support; simulated for the low-price scenario in order to achieve the range of NREAP-Targets)
PL	Investment subsidies (higher level than recent support): 20%-45% of investment costs
UK	Renewable heat incentive (corresponding to [5]): 8 p/kWh (stand alone) and 2 p/kWh for biomass district heating

Table II: Summary of policy settings for the country simulations for the building sector: (2) regulatory instruments

	Policy settings Obligations
AT	Overall RES-H obligation for new buildings and buildings with major renovation (2011 7%, 2015 15%, 2020 20%, 2030 30%, a penalty of 20€/m² if no RES-H is applied)
DE	Overall RES-H obligation for new buildings: 30% from 2010 onwards, enhanced energy efficiency – overfulfillment of building code's requirement – as alternative measures (as it is implemented in the Renewable Heat Act in Germany)
GR	Overall RES-H obligation for new buildings and buildings with major renovation (2011 60% RES hot water, 2014 50% of total space heating and hot water energy demand; penalty for not fulfilling the obligation: 50€/m^2)
LT	Overall RES-H obligation for new buildings and buildings with major renovation, target of 30% RES-H up to 2020, 50% between 2020 and 2030, a penalty of €50/m², if no RES-H is applied
NL	Overall RES-H obligation for new buildings and buildings with major renovation (starting with 10% RES-H in 2011 to 30% in 2030; penalty for not fulfilling the obligation: 55 €/m²)
PL	Overall RES-H obligation for new buildings and buildings with major renovation; obligation level of 20 % from 2010 to 2030; penalty for not fulfilling the obligation: 60 €/m² dwelling area
UK	Combined renewable heat incentive and supplier obligation (implemented as an obligation on the whole building stock); obligation level of 12% RES-H in 2020, 20% in 2030; penalty for not fulfilling the obligation: 50€/m² dwelling area

Table III: Summary of policy settings for the country simulations: modeled incentives in the industry sector

	Policy settings Economic incentives
AT	Investment subsidies (25%)
GR	Investment subsidies (25%)
LT	Investment subsidies (25%)
NL	Investment subsidies (25%), exploitation subsidy (bonus - RHI)
PL	Investment subsidies (25%)
UK	Investment subsidies (25%), exploitation subsidy (bonus - RHI)

2.4 System boundaries

Our system boundaries are mainly specified by the following aspects:

Regional boundary: We investigate the solar thermal developments within the national borders of the following countries: Austria, Greece, Lithuania, Netherlands, Poland, UK.

Technological and system boundary: We investigate all relevant types of biomass heating systems, both in the existing stock of systems and for new installations. This includes single stoves, central heating boilers fired with wood log, wood chips, wood pellets. Typically available technologies are distinguished between regions.

Investigated sectors: We investigate the uptake of biomass heating systems in buildings (space heating and hot water). We consider residential and non-residential buildings as well as process industry.

Policies: We focus on economic incentives and regulatory instruments. We do not explicitly analyse the impact of so-called "soft" measures like training, awareness raising, campaigns etc. However, we are aware of the crucial relevance of these measures in reducing barriers.

Simulation time frame: The base year for the simulations is 2007, so simulation runs start from 2008. Although simulations are calibrated to the most recent statistical data, some deviations may occur between simulation results and official statistical data for the years 2008 and 2009.

Biomass potentials: As a consistency check we compared the total biomass energy demand in the scenario with the bioenergy potential available for residential heating purposes (weak coupling, no strict restriction). The biomass potential is derived from [6]. For determining the biomass potential available for heating we subtract the energy demand for electricity and transport for the different bioenergy fractions according to the Green-X scenario according to [4]. This allows to judge whether biomass imports are acceptable or whether biomass exports should be possible. Results are documented more detailed at www.res-h-policy.eu.

3 NREAP targets

All EU Member States were obliged to submit National Renewable Energy Action Plans (NREAPs) to the European Commission by June 2010, outlining how they expect to meet their 2020 renewable energy target, including the technology mix they intend to use and the trajectory they will follow. In January 2011 all 27 NREAP documents were available from the Transparency Platform on Renewable Energy[1] of the European Commission. This means that in reasonable detail projections form the Member States are now available, which can be attributed a considerable weight as all plans have been approved by the respective governments.

In a compilation document [7] released by the

[1] The European Commission Transparency Platform on Renewable Energy is available at http://ec.europa.eu/energy/renewables/transparency_platform/transparency_platform_en.htm

European Environmental Agency (EEA) and the Energy research Centre of the Netherlands (ECN) all projections have been summarised and expected contributions from biomass-based renewables can be made explicit based on these figures[2].

Figure 1 clearly indicates the expected dominance of biomass-based energy carriers in renewable heating and cooling in absolute terms, with a small role for ambient heat (11% of all RES-H/C), a minor role for solar thermal energy (3%) and a tiny contribution of deep geothermal energy (1%). In addition, it should be noted that the growth of biomass heat is still considerable, increasing from 49 Mtoe in 2005 to 87 Mtoe by the year 2020. Figure 2 confirms this in relative terms: although the biomass share in total RES-H/C is projected to decrease towards the year 2020, its share still is nearly 80%. Because of the expected savings in gross final energy consumption the biomass contribution is expected to show an upward trend. Currently Member States are releasing documents with 'further information' or even 'resubmitted NREAP reports' on the Transparency Platform, which for some countries will reveal more detail on the case of biomass in the coming decade.

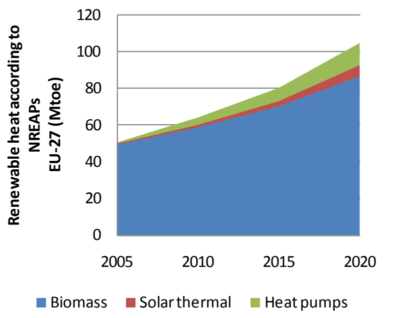

Figure 1: RES-H/C according to NREAPs in EU-27 [7]

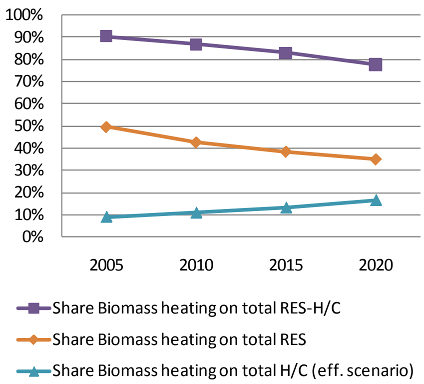

Figure 2: Share of biomass heating on total RES-H/C, on total RES and on total gross final energy consumption in the H/C sector according to NREAPs in EU-27 [7]

3 HIGHLIGHTING SELECTED RESULTS

This section presents selected results of different EU-member states. We will give a short introduction of the state of the biomass heating sector, explain the current state of support policies for biomass heating and discuss the results for the scenarios simulations.

We carried out analyses for the countries AT, DE, GR, LT, NL, PL, UK. Conclusions refer to all of these investigations. However, this section does not include results from all of these countries. Rather, some highlights are presented.

3.1 Austria

Biomass for heating has a long tradition in Austria. Despite strong recent growth of biofuels for transport and electricity generation from biomass, biomass for heating still plays a dominant role in the use of bioenergy. Until the end of the last century, total heating energy consumption showed continuous growth and biomass for heating took a more or less constant share of about 23%. In Austria since the beginning of this century, energy consumption for heating remains more or less constant or is slowly declining. At the same time, new and modern biomass heating systems as well as the thermal output of biomass increased strongly, which led to a share of biomass in the heating sector of 30% in 2009 [8].

In the building sector, pellet boilers showed a considerable increase over the last decade (with an interrupted after 2007 for several reasons). However, the vast majority of biomass heating systems are wood log boilers in rural areas.

In the industry sector, biomass plays a major role in the wood working industry, which takes a strong position in the Austrian economy. This refers to the saw industry, the fibre board industry and the paper and pulp industry.

Policies for renewable small scale space heating and hot water systems as well as all building regulations are in the responsibility of the nine regional governments. All these regions provide investment subsidies for biomass heating systems in the range of about 20%-35%, sometimes with absolute maximum support levels. In all regions strong emission and efficiency requirements of biomass boilers are in place.

Table IV shows the simulation results and NREAP targets for biomass heating in Austria.

The main results are:

- Alongside the policies supporting biomass heating, the energy price is a strong driver for biomass deployment.
- All scenario simulations presented in this paper show a growth of biomass in the heating sector. However, biomass district heating shows much lower growth than non-grid systems. Within the non-grid sector, wood log systems are currently the dominant technology though, it may be that comfort reasons could see use of this technology decrease. Within the non-grid sector wood chips and wood pellets in general grow more strongly than the overall sector.
- According to the results, obligations of RES-H utilisation in the building sector might lead to similar outcome than investment subsidies – at least in the high-price scenarios. However, in the low-energy price scenarios, investment subsidies show a higher biomass heating output. This is because under these conditions, solar thermal (or heat pumps) turn out to be a more attractive option to fulfil the RES-H obligation (at least if the level of the use obligation target for a building is not too high).

[2] The EEA/ECN report is available at http://www.ecn.nl/nreap (version used in this paper: February 1st, 2011)

The NREAP target for biomass heating clearly is less ambitious as the simulation results in the high price conditions or with ambitious policy instruments.

Table IV: Simulation results and NREAP-targets for biomass heating, Austria (PJ) [1], [9]

	2010(*)	2020	2030
Space heating and hot water			
Low-price - subsidies			
Wood log non-grid	54	45	37
Wood chips non-grid	11	20	24
Wood pellets non-grid	9	22	29
Biomass non-grid total	74	87	89
Biomass district heating	23	27	28
High-price – subsidies			
Wood log non-grid	54	56	57
Wood chips non-grid	11	22	26
Wood pellets non-grid	9	25	31
Biomass non-grid total	74	104	113
Biomass district heating	23	26	24
Low-price obligations			
Wood log non-grid	54	40	30
Wood chips non-grid	10	17	23
Wood pellets non-grid	9	21	28
Biomass non-grid total	72	78	81
Biomass district heating	23	27	27
High-price obligations			
Wood log non-grid	54	55	56
Wood chips non-grid	10	22	26
Wood pellets non-grid	8	25	33
Biomass non-grid total	73	102	115
Biomass district heating	23	26	25
Process heat			
High-price - subsidies	36	73	79
Low-price- subsidies	36	39	43
NREAP			
Non-grid	116	121	
Grid	27	29	
Total	143	150	

(*) Values for 2010 are simulation results and might deviate from historic data.

3.2 Germany

In Germany the current share of renewable energy sources on total heating demand equals 9.8 % [10]. Thereby, the vast majority of RES contribution is provided by the energetic use of biomass. In private households biomass is still used mainly in supplementary heating systems such as stoves or fireplaces, though the share of biomass fired central heating boilers has increased significantly for the last ten years. The market diffusion of these modern heating systems like pellet boilers has been driven by so called *Market Incentive Program* which provides investment subsidies (small-scale applications) and soft loans (large-scale applications) for RES-H technologies since 1999. Up to now over 250 000 biomass installations have been supported with investment subsidies accounting for 412 Mio. € [11]. On total 700 000 biomass boilers, 1200 heating plants (district heating and non-grid installations above 500 kW_{th}) and about 250 biomass fired cogeneration plants are currently installed in Germany [12], [13].

In the industry sector, final energy demand of biomass accounts for 23.5 TWh (including space heating and hot water in industry buildings) which is about 5 % of the total thermal energy demand in this sector [14], [10].

Since 2009, the support framework for biomass heating is supplemented by the *Renewable Energy Heat Act* [15]. This act introduced an obligation for owners of newly constructed buildings to use renewable energies in their buildings. *The Bundesländer* (German Federal states) are given the opportunity to extend the Act to cover existing buildings as well. The use obligation is defined as a RES-specific share of the overall thermal energy demand for heating, cooling and hot water supply. In case of solid and liquid biomass applications, at least 50 % of the thermal energy demand has to be covered. The minimum share of gaseous biomass is only 30 %, however, combined heat and power technologies (CHP) needs to be installed in order to comply with the law in case of using gaseous biomass.

In addition to the direct support instruments – *Market Incentive Program* and *Renewable Energy Heat Act* – indirect support for biomass heating is provided by the *German Energy saving Regulation* (building code). It regulates the maximum allowable primary energy consumption of new buildings and existing buildings in case of renovation. Since biomass as energy source is assigned with a low primary energy factor of 0.2 [16], buildings with biomass fired heating systems benefit from lower requirements concerning thermal insulation than those with fossil fuel based systems.

The case of Germany has been not part of the scenario analysis in this study. However, INVERT/EE-Lab model has been applied in recent studies for the German *Ministry of Environment, Nature Conversation and Nuclear Safety* in order to analyse effects of different policy instruments on future development of biomass heating and other RES-H technologies in the building sector [17]. Even if the analysis includes only a scenario up to 2020 and other energy price levels are assumed as for the other countries, the results provide an interesting comparison to the other selected Member States in this paper. Table V summarises the simulation results for the current policy setting – investment subsidies and use obligation – in Germany as well as the NREAP targets.

Table V: Simulation results and NREAP-targets for biomass heating, Germany (PJ)

PJ	2010(*)	2020
Space heating and hot water		
Wood log non-grid	198	169.2
Wood chips non-grid	7.2	21.6
Wood pellets non-grid	21.6	75.6
Biomass non-grid total	226.8	266.4
Biomass district heating	54	93.6
Biomass total	280.8	360
Process heat	82.8	90
NREAP		
Solid biomass	313.2	374.4
Biogas and bioliquids	64.8	100.8
Biomass total	378	475.2

(*) Values for 2010 are simulation results and might deviate from historic data.

3.3 Greece

In Greece the share of renewable energy in heating and cooling needs in 2010 accounted to 14.7% [18].In the last decades the share of biomass in the total RES heat production ranged between 83% - 90% [19], making biomass the main contributor to renewable heating, in the residential and industry sectors.

A closer look at the residential sector will reveal that biomass burning is linked more with outdated technologies such as open fire-places, wood log burning stoves etc, and less with high efficient biomass heating systems using for example pellets or woodchips, while in the industry sector the wood-fired technologies constitute the most important part of the RES-H production.

The current support framework for RES-H comprises to a tax deduction scheme, that considers all small domestic RES systems to be eligible for a 20% tax deduction, capped at 700€ per system [20]. Also according to a recent Law, from 2011 and on in new buildings as well as in renovated buildings a 60% minimum RES-H share in final energy demand for Domestic Hot Water is required [21].

Especially for the development of biomass systems, the above mentioned policies are considered to be insufficient and besides that there are also legislative barriers that impede the development of biomass heating systems in the residential sector. Specifically, there is a Ministerial Degree in force [22], that forbids the use of central biomass heating systems in the two bigger cities of Greece (Athens and Thessaloniki), leaving this way the great majority of the Greek population without the choice of installing central heating systems with biomass boilers in their houses. This restriction was implemented due to air pollution reasons, since biomass boilers back then did not fulfil any emissions standards and deteriorated this way the already bad air quality of the two cities. Nowadays this restriction should be changed, by narrowing it down to boilers that don't meet certain minimum emission standards.

Table VI: Simulation results and NREAP-targets for biomass heating, Greece (PJ)

	2010(*)	2020	2030
Space heating and hot water			
Low-price – tax incentives			
Wood log non-grid	30	22	12
Wood chips non-grid	0.2	0.2	0.2
Wood pellets non-grid	0.2	0.4	0.5
Biomass non-grid total	30.4	22.6	12.7
Biomass district heating	0	0.02	0.1
High-price – tax incentives			
Wood log non-grid	30	22.2	12.8
Wood chips non-grid	0.2	2.2	4.7
Wood pellets non-grid	0.2	3	6.6
Biomass non-grid total	30.4	27.4	24.1
Biomass district heating	0	0.9	2.3
Low-price obligations			
Wood log non-grid	30.2	23.2	15.4
Wood chips non-grid	0.2	0.5	1.1
Wood pellets non-grid	0.2	0.6	1.3
Biomass non-grid total	30.6	24.3	17.8
Biomass district heating	0	0.01	0.04
High-price obligations			
Wood log non-grid	30	22.2	12.8
Wood chips non-grid	0.2	2.2	4.7
Wood pellets non-grid	0.2	3	6.6
Biomass non-grid total	30.4	27.4	24.1
Biomass district heating	0	0.9	2.3
Process heat			
High-price - subsidies	16.1	23.7	31.8
Low-price- subsidies	13.6	21.7	30.1
NREAP			
Residential	25.7	24.9	29.9
Industry	16.3	24.2	31.6
Total	42	49.2	61.4

(*) Values for 2010 are simulation results and might deviate from historic data.

Table VI shows the simulation results and NREAP targets for biomass heating in Greece.

- All scenarios in the building sector show a decrease of biomass. In low-price scenarios this decrease is steeper, while in high-price scenarios it is more moderate. This result is due to the large stock of old and inefficient wood log stoves. It should be taken into account that there is uncertainty with respect to the future development of this stock of heating systems. In any case this indicates that the single implementation of either the tax incentives or the use obligations does not seem enough to reach the required share of RES-H in the final heat demand of the building sector in order to comply with the RES targets. That means that in order to reach the RES targets, scenarios of combined policy sets or the readjustment of the levels of the proposed policy sets should be examined (e.g. higher level of tax incentives, or stricter use obligations).
- It should also be kept in mind, that both the proposed policy instruments (tax incentives and use obligations) assume minimum efficiency

criteria for the biomass systems that will be installed in the future. This element together with the assumption that new buildings and existing ones that undergoes renovation become more and more efficient, has as a result the energy demand from biomass to be decreased until 2030. This is also depicted in the NREAP targets. Without having these two factors in mind and looking at the results, it is easy to assume that not many changes happen in the biomass sector, which is misleading and does not depict the transition towards more efficient biomass systems and buildings with less heating needs.

- According to the simulation results, in the building sector use obligations for RES-H and tax incentives lead to similar outcomes in the high-price scenarios, while in the low-price scenarios, use obligations show a higher biomass heating output, than the proposed tax incentives. This is mainly because in the low - price scenarios the level of the proposed tax incentives is low and does not offer a strong incentive for investing in biomass technologies.
- In industry the wood-fired technologies (mainly biomass heat-only and biomass combined heat & power from wood) constitute the most important part of the RES-H penetration. The modelling outcome is importantly influenced by the assumed inputs, notably the assumed fuel prices. As the biomass prices are relatively low, even in a 'no policy' case there is an important penetration of renewable biomass heat into the Greek industry energy picture.
- The net avoided costs of substituting biomass technologies for fossil fuels have been also calculated and found positive. This means that, based on the financial considerations, it is beneficial to start using biomass as a fuel. However, reality faces a lot of uncertainty that is not represented in the model, notably the chance of being able to purchase, on a long term, low-priced biomass fuels.

3.4 Netherlands

Biomass for heating purposes is an important contributor to the renewable energy production in the Netherlands. In the households sector this is mainly through stoves, a technology that is not projected to grow significantly in future due to local emissions and absence of fuel storage opportunities in Dutch households. In industry biomass-fuelled boilers are in place, mainly using residual streams of biomass. Energy from waste is an important heat supplier, either to district heating or as a supplier of steam to industry. In agriculture biomass combustion and digestion are commonly used [23].

Applied policy instruments are: a.) investment subsidies (both in the residential sector (new and existing dwellings) and in industry (25%) and b.) Energy Performance Standard (EPN) in new dwellings and an exploitation subsidy in process industry. Modelling the Energy Performance Standard (EPN) in INVERT has been performed in an indirect way, by assuming 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. 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).

The effect of fuel prices is illustrated in the table below of the 'no policy' variant: the 'high price' penetrations almost fully exploit the potential in the residential sector, whereas in the 'low price' variant this is hardly the case, not even with investment subsidy. The cumulative results have been displayed in Figure 1. It is important to realize that the NREAP figure includes more sectors (notably the horticultural sector which is very important in the Netherlands).

Table VII: Simulation results and NREAP-targets for biomass heating in both the building and industrial sectors, including a comparison to NREAP projections, Netherlands, [24], [7]

Sector	Technology type	2010(*)	2020	2030
Low price No policy variant				
Buildings	Non-grid	11.2	8.3	5.1
	Grid connected	4.0	4.8	5.7
Industry	Heat only	1.2	1.7	1.9
	Combined heat and power	1.1	3.0	4.6
Total	**All types**	**17.5**	**17.8**	**17.3**
Subsidies				
Buildings	Non-grid	11.2	8.9	5.9
	Grid connected	4.0	6.9	8.6
Industry	Heat only	1.2	1.7	1.9
	Combined heat and power	2.6	5.4	8.5
Total	**All types**	**19.0**	**22.9**	**24.9**
Obligation				
Buildings	Non-grid	11.6	9.7	6.8
	Grid connected	4.1	6.5	8.3
Exploitation subsidy				
Industry	Heat only	1.3	1.8	2.0
	Combined heat and power	5.7	7.9	11.4
Combination obl. and expl.				
Total	**All types**	**22.7**	**25.9**	**28.5**
High price No policy variant				
Buildings	Non-grid	11.2	11.0	10.4
	Grid connected	4.1	9.5	12.3
Industry	Heat only	1.2	1.7	1.9
	Combined heat and power	5.0	7.6	11.1
Total	**All types**	**21.5**	**29.8**	**35.7**
All*	Biomass	28.6	39.3	

(*) Values for 2010 are simulation results and might deviate from historic data.

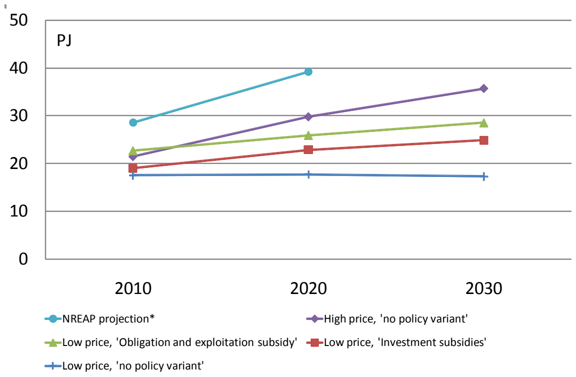

Figure 3: All policy variants compared, see Table VII for the sectoral breakdown

For the residential sector two policy measures have been evaluated through modelling activities. 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. In the high price scenario a very important penetration of RES-H occurs in the 'no policy' variant. The resulting avoided fuel costs are considerable for both policy measures evaluated, but slightly higher in the case of the renewables obligation, which consequently is valid for the avoided CO_2-emission. The policy costs like-wise 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 may 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.

Also for the industrial sector conventional fuel price assumptions have a very important influence on the competitiveness of the RES-H technologies and thus strongly impact the modelling outcomes. Two financial support measures have been evaluated, 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. Another 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 (or bonus or feed-in tariff) does 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. As expected, 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.

3.5 UK

Deployment of RES-H in the UK is very low, only exceeding 1% of total heat use in 2007 and accounting for 1.6% of total heat (10.5 TWh) by 2009. Biomass accounts for around 93% of this total. This fraction has remained fairly stable even though biomass combustion for heat expended by 62% in the period from 2005 to 2009. [25] The UK has set itself a target of 12% of all heat to come from renewable sources by 2020, as part of its obligations under the 2009 Renewables Directive. Given the low base and correspondingly low level of support capacity, this represents a highly ambitious target.

Historically policy support for biomass heating has been via grant support and with relatively low levels of total funding. However, the commitment to the targets which would be enshrined in the Renewables Directive led to the introduction of the Renewable Heat Incentive (RHI). This is a tariff (or bonus) type mechanism which aims to support biomass as well as other RES-H sources. It can be regarded as being somewhat innovative – it represents the first major RES-H financial support instrument other than grants and its adoption saw assessment of various novel approaches to the problems inherent to providing RES-H support. The adoption of the RHI is in two phases, the first for non-domestic premises begins in July 2011, with biomass heating in domestic premises eligible for payments from October 2012. Initial payments under the first phase will see payments on a metered basis for generators over $1MW_{th}$ while payments for smaller boilers will be on a tiered basis, paying a high tariff initially and a much lower tariff over a certain threshold in order to discourage excess heat production purely to access payments. [26] Levels of support are set to typically allow a rate of return of 12% for biomass systems. The UK Department of Energy and Climate Change models for the RHI suggest that biomass will account for roughly half of UK renewable heat by 2020 [27]. The issue of sustainability of biomass supply is an issue in the UK and the UK Government is keen to ensure that domestic and particularly imported biomass comes from sources which are not environmentally or socially damaging. There is significant competition for biomass resource since the UK has policy to stimulate biomass co-firing for electrical generation and biofuels production for the transport sector. The UK NREAP expects biomass to become a globally traded commodity and to import to meet demand created by its RES policies.

Two mechanisms are modelled using low and high energy price scenarios. The first mechanism we model for the UK is the RHI, the second (selected following stakeholder consultation was an RHI combined with a compulsory supplier obligation, based on the UK's Carbon Emission Reduction Target (CERT) [28] and requiring utilities meet the cost of RES-H installation while being able to access RHI tariffs. This is doubly useful since it effectively allows modelling of the total costs of meeting the UK RES-H target as well as providing other outputs.

Table VIII: Simulation results and NREAP-targets for biomass heating, UK (PJ)

	2010(*)	2020	2030
Space heating and hot water			
Low-price - RHI			
Biomass non-grid total	10.2	28.0	47.6
Biomass district heating	0.03	6.0	11.1
Biogas	0.03	3.4	6.7
High-price – RHI			
Biomass non-grid total	10.2	43.5	70.1
Biomass district heating	0.05	22.6	22.9
Biogas	0.01	2.7	7.8
Low-price RHI + SO			
Biomass non-grid total	10.2	81.5	69.7
Biomass district heating	0.18	76.0	90.6
Biogas	0.1	14.4	13.6
High-price RHI + SO (**)			
Biomass non-grid total	10.3	53.2	61.9
Biomass district heating	0.21	47.6	42.0
Biogas	0.17	4.6	9.8
Process heat			
Low-price- no policy	7.6	18.7	23.7
High-price – no policy	13.0	34.5	40.2
Low-price- subsidies	10.7	27.8	35.0
High-price – subsidies	15.1	35.8	40.8
Low-price- RHI	11.1	22.9	27.3
High-price – RHI	14.5	36.3	41.8
NREAP			
Solids	12.8	151.2	
Biogas	0.8	12.6	
Total	13.6	163.8	

(*) Values for 2010 are simulation results and might deviate from historic data.

(**)The combination of RHI and SO leads to the result that high energy prices lead to lower biomass output than low energy prices. This is due higher biomass prices in the high-price scenario and that the SO/RHI-combination making it more attractive to go for other RES-H technologies to fulfil the supplier obligation. The overall RES-H output is about the same in the high- and the low-price scenarios. However, it should be noted that INVERT/EE-Lab is not able to model the energy supplier's rationality in the same level of detail as the consumer's decision making process. Thus, further research is required for a full understanding of the supplier obligation in combination of the RHI.

Modelling scenarios with alternatively low and high general energy prices produces outputs with significant different uptakes of biomass for heating purposes. The low energy price sees biomass remain the dominant RES-H provider through to 2030. The high energy price scenario however, while seeing greater overall RES-H deployment sees biomass give ground to solar thermal and heat pumps, ceding dominance around 2020. This fits with the DECC projections [27].

There are notable differences in the impact of low and high energy prices on deployment of RES-H in the buildings sector than in industry. High general energy prices leads to much higher uptake in buildings (and correspondingly higher CO2 displacement, employment and public costs). However, the models suggest industry will respond to higher energy prices independently and subsidy has little effect on uptake in that scenario, while it pushes up generation around 50% in the low energy scenario.

Only 1-2% of heating in the UK is supplied through district heating networks and none is currently used to deliver RES-H. There is no clear mechanism for increasing this in current UK policy, despite projections which suggest it will be a key element of the UK transition to decarbonised energy supply in the long term. The RHI does not provide for subsidy of network capacity and thus while our models suggests DH as a possible partial route towards meeting RES-H targets there are likely to be barriers to their expansion which may require additional policy support.

3.6 Synthesis

Figure 4 and 5 show the share of biomass on energy consumption for space heating in the low and the high price scenario under the policy settings with economic incentives (according to table I).

The starting point for biomass heating varies strongly between the different countries. Among the selected member states, Lithuania has the highest share of biomass heating in 2007 (>40%). This is due to a high share of biomass in rural areas whereas in urban areas district heating (and partly biomass district heating) plays a dominant role. Also Austria has a strong tradition in biomass heating in particular in rural areas. Moreover, the increase in biomass CHP in the past few years led to a considerable increase of bioenergy in district heating grids resulting in a share of about 30% of biomass in the total energy consumption in this sector. Poland and Greece had a similar starting point of biomass in the heating sector with about 15%. In the NL and UK biomass for heating is negligible.

The model simulations show the high impact of energy prices: The high energy price scenarios lead to considerable growth in market shares of biomass heating systems. In particular the case of UK shows that with an ambitious policy (RHI) a strong market growth is possible even with a very low starting point. In Greece, the low-energy price simulation even leads to a decrease in biomass market shares. An important aspect in this regard is the high stock of old wood log stoves.

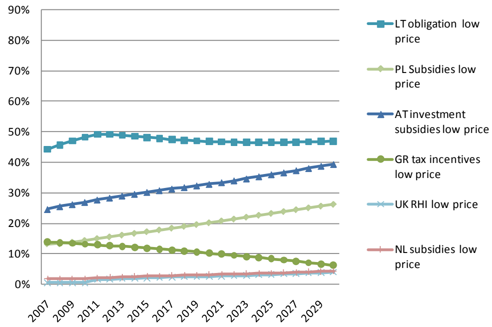

Figure 4. Share of biomass on energy consumption for space heating and hot water, low-price scenarios with economic incentives according to table I.

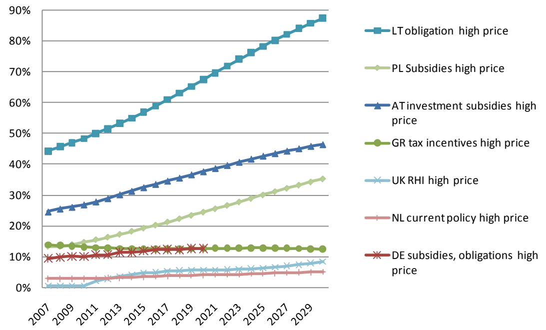

Figure 5. Share of biomass on energy consumption for space heating and hot water, high-price scenarios with economic incentives according to table I.

All countries with a high current share of biomass in the heating sector build on a strong role of wood log based heating systems. Some of these boilers are modern, efficient central heating boilers. However, a large share are old, inefficient stoves and outdated boilers. The development of this old, outdated stock of wood log fired heating systems will be one of the crucial aspects. The re-investment in these systems, emission and efficiency standards will play a crucial role. Moreover, more efficient and automatic heating systems will probably gain market share. According to the simulation results, the market growth of these systems (wood chips boilers, wood pellet boilers, biomass district heating) will be much stronger than for the rest of the biomass heating sector, in particular in those countries with a high starting point of biomass heating. Figure 6 and 7 show the share of non-wood log biomass heating on energy consumption for space heating and hot water.

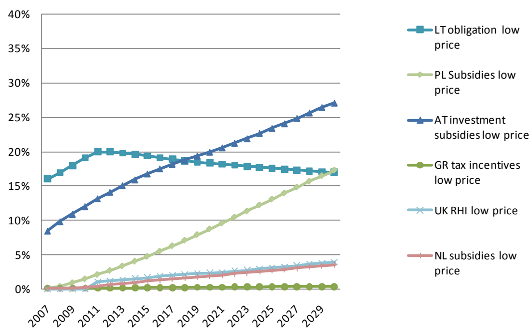

Figure 6. Share of non-wood log biomass heating on energy consumption for space heating and hot water, low-price scenarios with economic incentives according to table I.

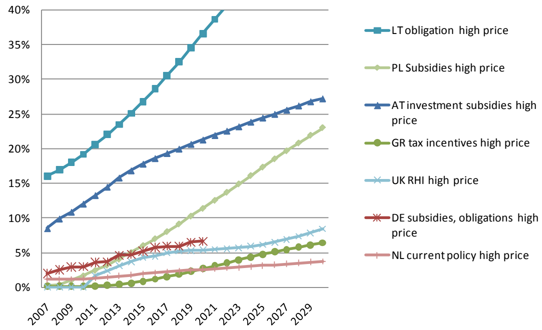

Figure 7. Share of non-wood log biomass heating on energy consumption for space heating and hot water, high-price scenarios with economic incentives according to table I.

Figure 8 shows that those countries with a currently high share of renewables in the heating sector have it due to their high biomass share. For the future development, these countries are maintaining their focus on bioenergy whereas the countries with a currently low share of biomass heating (and overall RES-H) like UK and NL put a much stronger focus on other RES-H options like ambient energy and solar thermal energy, too. In Figure 8 this means a shift towards the bottom right whereas the our scenarios in the countries with a high biomass heat share (like LT, AT) move to the top right corner of the graph (in the high price scenario LT is even much higher than 50%, as depicted in the figures above).

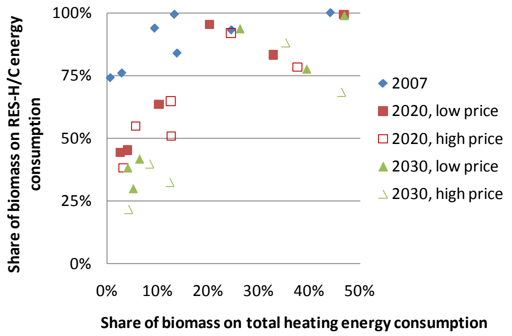

Figure 8. Share of biomass on RES-H energy consumption subject to the share of biomass on total heating energy consumption in the years 2007, 2020 and 2030 in the investigated countries.

4 DISCUSSION AND CONCLUSIONS

Conclusions refer to the huge variety of impact factors that explain the different penetration of biomass heating systems. These include energy prices and other economic conditions, the structure of the heating market, the historical role and tradition of biomass heating, the role of district heating and the role of biomass in the district heating sector, the know-how and awareness of stakeholders and the availability of competition for biomass resources. In the following we will discuss some of these aspects.

4.1 Regional differences

The data and results presented in this paper show the huge differences among several selected regions in Europe: Some countries have only a negligible or very small current share of biomass heat (e.g. UK, NL) in other countries the share of biomass heat amounts to about 9-15% (e.g. DE, GR, PL) and in others more than 25% (AT) or even more then 40% (LT). This corresponds to a stock of technologies, experience and tradition that strongly impacts the future development of the sector. Policies have to take into account of these different starting points.

Regions with a low starting point of biomass heating have to overcome essential barriers. The analysis of the UK leads to the conclusion that ambitious policies may result in very ambitious market growth. However, a lot of barriers have to be addressed like development of know-how, trained staff etc.

In all regions with a significant share of biomass heating, wood log heating systems play a crucial role. The future of this stock of partly inefficient systems has a high relevance for the whole sector. Important impact parameters are comfort requirements, rural development, economic development, emission standards and comfort aspects of new equipment, etc. In case that such a stock of old systems is combined with unfavourable conditions this may lead to a decline in biomass heating (e.g. as it has been shown for the case of Greece).

4.2 Biomass policies as key drivers

In our work, we investigated the possible impact of different policies. Policies were identified and defined together with regional and national stakeholders and policy makers. Key conclusions are:

- It is not possible to give a clear recommendation for a specific instrument. Rather it is a question of the right policy design.
- Subsidies and tax incentives for a long time were the most common support instruments in the EU for the RES-H sector. Crucial questions are how a continuous availability of public budget can be guaranteed in order to avoid stop and go policies.
- RES-H use obligations are increasingly established in EU-member states, which is in line with Article 13(4) of the renewable energy directive (2009/28/EC). The technology mix that is supported by this instrument depends on the level of implemented RES-H obligation for each building: for low obligation levels (e.g. 15%) it may be economic rational to fulfil the obligation by solar thermal collectors, for higher obligation levels by biomass or heat pumps. Therefore, a combination of use obligation and economic incentives seems to be reasonable.

  Moreover, it should be taken into account that use obligations are most appropriate in regions with a mature market, because technologies have to be available at the market at acceptable cost and high quality.
- RHI: The development of the renewable heat incentive (RHI) in the UK represents a significant step forward in terms of the design and implementation of a nationally applicable instrument to provide the financial support to drive large scale uptake of multiple RES-H technologies, with biomass set to provide a major element of that expansion.

  The UK's Department of Energy and Climate Change suggests biomass will account for half of RES-H generated in 2020, though this is subject to volatility in both general and international biomass energy pricing. [26]

  The RHI is notable for its attempt to introduce a financial incentive rather than the regulatory obligations that characterise efforts elsewhere in Europe (including Germany and Spain). Its early adoption has compelled the UK to address key issues specifically relating to incentivising RES-H, including metering issues and protection of public funds and the need to match RES-H policy with energy efficiency measures. The conceptualisation of 'deeming' as a way to allot funds to small scale RES-H generators such that the need for metering is circumvented while also providing only enough incentive to stimulate RES-H deployment only when associated with adequate energy efficiency provided a novel approach to a difficult problem and it will be interesting to see whether it is maintained in the domestic version to be adopted in October 2012. The shift to tiered tariffs for small and medium-scale biomass in commercial premises provides an interesting and simple approach to removing perverse incentives and protecting the public purse.

  The RHI has also made initial payments dependent on the submission of data concerning performance, which should allow for enhancement of models and broaden knowledge of real world performance of rES-H technologies. The dependence of RHI payments on the installation of approved technologies by approved installers puts in place an essential protection for public funds and for less knowledgeable investors. While the UK scheme has had criticism the underlying aim is a vital one.
- All policy instruments need strong combination with awareness raising, technological development, training etc.

4.3 Energy prices as key drivers

Energy prices have turned out to be key drivers of biomass heat (and general RES-H) technologies. Thus, efficient and effective policies should take into account this interaction with energy prices in mid- and long-term.

We took into account coupling of biomass prices with fossil energy prices. However, it turns out that the share of fuel costs for biomass heating systems is considerably smaller than for fossil fuelled heating systems. Thus, the sensitivity of biomass on fuel price fluctuations is smaller than for fossil heating systems which lead to a higher economic attractiveness of biomass in case of increasing energy price levels.

Regarding biomass prices in industry we want to emphasize that additional research is necessary in order to properly depict the multiple impact factors on industry prices for different biomass fractions, the barriers to make use of them and the effect on the uptake of bioenergy technologies in different industry sectors.

4.4 Lessons from modelling biomass options 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. To do so, two types of biomass technologies have been considered: heat only and combined heat and power. 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 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).
- 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 potential in all countries is regarded as the most important option for process industry, i.e. more important than solar thermal and geothermal energy.
- 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.

4.5 Biomass district heating

District heating systems can provide an enabling infrastructure for the utilisation of biomass since they facilitate the use of low grade biomass such as biodegradable waste and agricultural and forestry residues that are not suitable for individual boilers. Many of the European countries with a high proportion of biomass in their energy supply are also characterised by high penetration of district heating. This is the case in Austria, Denmark, Finland and Sweden [29]. In for example Sweden where biomass accounted for 18% of the energy supply in 2007, district heating accounted for 50% of the heating of buildings and almost 53 % (30 TWh) of the district heat was produced from biomass (including biodegradable waste) [30]. However, until about 1980 the Swedish DH production was based to 100% on oil. After that there been profound changes in the DH production as a response to changes in relative fuel prices and various policy instruments. The massive biomass expansion in DH production started in the early 1990s as a response to the carbon tax that was introduced in 1991.

There are however also countries with high penetration of district heating, but where fossil fuels dominate as energy source. This is the case in for example Poland and Lithuania. With the right incentives in place, biomass district heating could play a more important role in these countries. An initial approach could be to co-fire biomass in existing fossil fuel fired DH and CHP plants.

DH systems are typically found in densely populated urban areas where the concentration of heating demand is high. The DH systems provide an opportunity of using biomass for heat in urban areas where individual biomass boilers are generally inappropriate for air quality reasons. Centralised combustion plants such as DH or CHP plants are preferable in this regard since they may apply sophisticated cleaning equipment.

The conditions for using biomass in DH production vary depending on the local availability of biomass or access to appropriate infrastructure for long-range transport of biomass. While small-scale systems using biomass generally rely on local resources, this may not be possible for large biomass fired CHP plants in urban areas. For example, many CHP plants in coastal Swedish towns receive their biomass by seaway from other parts of Sweden as well as abroad [31].

4.5 Future perspectives of biomass heating

Comparing the scenario results with NREAP targets leads to quite different conclusions among the countries. For some countries, the NREAP target values seem to be quite ambitious (in particular the UK). In these countries, a comprehensive combination of different policy elements are required if these targets should be fulfilled. For other countries (e.g. AT) the targets seem to be achievable with very moderate effort.

Considering the huge potential for improving thermal building quality and increasing efficiency in combustion units (in particular in the stock of old building stoves in some of the countries), the core challenge of future biomass heating will be to supply an increasing share of buildings with constant or even decreasing primary energy input. In the long-run, the building stock provides the potential to significantly reduce the required energy input and supply a high share of remaining energy demand with low-valued sources like ambient energy or solar thermal energy. Thus, towards the second half of this century the focus of biomass heat utilization could and should shift more and more to high-temperature applications in industry. Corresponding measures have to start now. Though, due to the high inertia and lead times of the building stock, it will need at least several decades to carry out this transition process. During this transition period, biomass will continue to play an important role for supplying renewable heat for different type of applications, both in industry and buildings.

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