Strategic Research Priorities for Biomass Technology

European Technology Platform on Renewable Heating and Cooling

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AUTHORS

Eija Alakangas – VTT, Finland
Gullvi Borgström – Varmeforsk, Sweden
Thomas Felber – European Platform for Small Scale Biomass Heating, Austria
Gerold Göttlicher – EnBW Holding, Germany
Panagiotis Grammelis – CERTH/ISFTA, Greece
Jan Habart – CZBIOM, Czech Republic
Walter Haslinger – BIOENERGY 2020+ GmbH, Austria
Rainer Janssen – WIP, Germany
Marcos Martin – AVEBIOM, Spain
Kari Mutka – VAPO, Finland
Alexander Weissinger – KWB, Austria
Members of the RHC – Platform Biomass Panel Steering Committee

The acknowledgements are also addressed to all additional contributors which have not been mentioned above.

EDITORS

Secretariat of the European Renewable Heating and Cooling Technology Platform
Biomass Technology Panel
Lara Mertens – AEBIOM European Biomass Association
Jean-Marc Jossart – AEBIOM European Biomass Association
Renewable Energy House
63-67 Rue d'Arlon
B-1040 Brussels
Belgium
www.rhc-platform.org

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Foreword

Through the Renewable Energy Directive (2009/28/EC), the European Union has set ambitious binding targets for renewable energy consumption in 2020 in Europe. As biomass covers more than half of the renewable energy sources for heat applications, and as heat covers about half of the final energy consumption in Europe, biomass obviously constitutes a key sector to meet the 2020 targets. Furthermore, looking beyond 2020 also reveals to be essential as the European Union puts forward an 80 to 95% greenhouse gas reduction target for 2050. Considering the significant challenges the future holds, such as the rising population or global warming, it is evident biomass will continue playing an important role in the long run.

Although biomass for heat applications is fully commercial by now, there is more than ever a need for continuous improvement to reach more efficient and environmentally sound technologies. This is where the Biomass Panel of the European Technology Platform on Renewable Heating and Cooling plays a crucial role. Together with industrial and R&D stakeholders, we aim to pave the way for biomass in our future heat supply for 2020 and beyond. This publication represents a first step in this process, defining a common vision and outlining the strategic needs for future European support to R&D. In this crucial period for biomass to heat development, the Biomass Panel of the European Technology Platform on Renewable Heating and Cooling offers an opportunity which should not be missed out on.

Join us!

Kari Mutka
Chairman of the Biomass Technology Panel
European Technology Platform on Renewable Heating and Cooling

1. Executive Summary

1. Executive Summary

Each year, almost 50% of the total energy consumed in Europe is used for heat generation, either for domestic or industrial purposes. The heating and cooling sector is expected to contribute substantially towards the achievement of the renewable energy targets set out in the Renewable Energy Directive (2009/28/EC) and to the 2050 EU greenhouse gas reduction targets. Biomass, as the largest renewable energy option at present, constitutes a key sector. In this context, the Biomass Panel of the European Technology Platform on Renewable Heating and Cooling (RHC-Platform, www.rhc-platform.org) plays a crucial role by bringing together industry and research stakeholders to define a common strategy to increase the use of biomass for heating and cooling.

The biomass market share should increase significantly from 11% in 2007 to about 25% in 2020, even considering the reduction in heat demand. By 2020, technically reliable, environmental friendly and economically attractive renewable heat solutions should be available for almost each type of consumer as alternative to fossil based systems. By 2050, renewables should cover most of the energy needs and Europe will lead in know-how and technology developments. Bioenergy will be intelligently coupled with other renewable energy technologies like solar thermal and geothermal technologies, taking full account of their individual advantages, constraints and costs.

In this view, research and development priorities which are crucial to increase the use of biomass for heating and cooling in Europe have been identified. These priorities are structured around 5 thematic priorities, which represent critical areas in which major technological advances are necessary to ensure the successful deployment of biomass based heating and cooling technologies in Europe: security of supply, fuel and load flexibility, efficiency and emissions, integrated concepts and predictive management and sustainability.

Security of supply
With the European 2020 renewable energy targets, biomass supply will become a crucial issue and should double in Europe by 2020, with a very significant increase of energy crops, by-products and residues from agriculture and through the use of forest logging residues. In this view, cost-efficient and sustainable supply of agro-biomass and forest biomass including adequate storage, drying and logistics should be developed. A focus should also be held on improving fuel quality and on the development of high grade fuels. Cost-efficient and sustainable biomass fuels from new raw material and from the biodegradable fraction of waste should also be developed.

Fuel and load flexibility
Considering the limited availability of high quality resources for wood fuel production in Europe, lower quality biomass fuels coming from wood of short rotation forestry and from agricultural and agro-industrial residues, will gain importance. Research should focus on developing multi-fuel units, using a variety of solid biomass types and waste derived fuels, as well as on managing fuel quality. In 2020, biomass based units should also be able to operate also in lower part loads, while load change will be more feasible and faster in the future, enhancing short-term flexibility.

Efficiency and emissions
Air quality and efficiency requirements are expected to increase throughout Europe in the coming years and will constitute an extremely important driving force for future energy production projects. In this view, it's upmost important to develop efficient technologies, such as lowest emission and highest efficiency fire wood stoves and residential biomass heating systems, cost-effective micro-CHP, small scale gasification systems, high efficient biomass conversion systems to tri-generation, highly efficient large-scale or industrial CHP with enhanced availability and increased high temperature heat potential.

Integrated concepts and predictive management
Biomass will play a special role in matching energy demand and production, as it can be used for peak load and participate in load regulation. Predictive management of energy flows and integration with other energy sources should be optimized. Regional concepts, concepts for co-utilization – biorefineries, hybrid systems and heat storage technologies have to be developed.

Sustainability
With the increased use of bioenergy, sustainability will constitute an important driving force of future bioenergy projects. Sustainability criteria will progressively be implemented to maximise benefits and ensure confidence of the public. In this view, better insight should be gained on sustainability issues related to biomass used for heating and cooling, such as the environmental impact of biomass production. It is crucial to develop cost-efficient, sustainable supply chains for forest and agro-biomass.

Addressing non technological issues is just as important as promoting adequate R&D activities to ensure and successful deployment of RHC technologies. In the policy arena, special focus is needed on the harmonization of administrative procedures, and on the creation of smart support schemes and a stable regulatory framework. Positive communication regarding heating and cooling with biomass and the creation of specific training is also essential.

Upcoming work of the Biomass Technology Panel will focus on implementation, which will require further fine-tuning of the defined research priorities. As a first step in this direction, a number of innovative value chains - highlighting the most urgent priorities – have been identified below. These value chains take the entire supply chains into account, as it is crucial to adequately address all dimension of a project: raw material supply, conversion technology, sustainability...

- Small scale CHP for domestic, industrial or regional solutions
- Tri-generation
- Advanced fuels (new solid biocommodities, thermally treated biomass fuels, pyrolysis oil) replacing coal and fossil oil in CHP
- High efficient large-scale or industrial steam CHP with enhanced availability and increased high temperature heat potential (up to 600°C)
- Demonstration of optimised and integrated regional concepts (including smart grids) in several European countries




2. Introduction to the Platform

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What is a European Technology Platform?

A European Technology Platform (ETP) is a European network bringing together researchers, industry and other relevant stakeholders in a particular technological field in order to foster European research and development in the concerned area. The first European Technology Platform – ACARE - was launched in 2001 in the field of aeronautics. Since then, 36 ETP have been created on various topics, including one on Renewable Heating and Cooling (http://cordis.europa.eu/technology-platforms/individual_en.html)

European Technology Platforms focus on strategic issues, for which major technological advances are necessary to ensure Europe's future growth, competitiveness and sustainability. Technology platforms play a key role in aligning EU research priorities to industry's needs. They cover the whole economic value chain, ensuring that knowledge generated through research is transformed into technologies and processes, and ultimately into marketable products and services.

The primary objective of the European Technology Platforms (ETPs) is the definition of "a coherent and unified approach to tackle major economic, technological or societal challenges of vital importance for Europe's future competitiveness and economic growth". In particular, the ETPs provide a framework to define research and development priorities and action plans for each technology domain concerned.

ETPs are designed to provide a strategic vision and research agenda for leading technologies at European level (Figure 1) and therefore contribute significantly to the realization of the objectives of the ERA. In this framework, the involvement of public authorities as well as all other relevant stakeholders is vital for the fulfilment of the mission of ETPs.

The policy objectives of the ETPs can be summarized as follows:

- Support the development and deployment of key technologies in Europe which are vital to address major economic and societal challenges
- Define a European vision and a strategic agenda for the development and deployment of these technologies
- Support the objective of increasing European private research investment by bringing research closer to industry and improving markets for innovative products

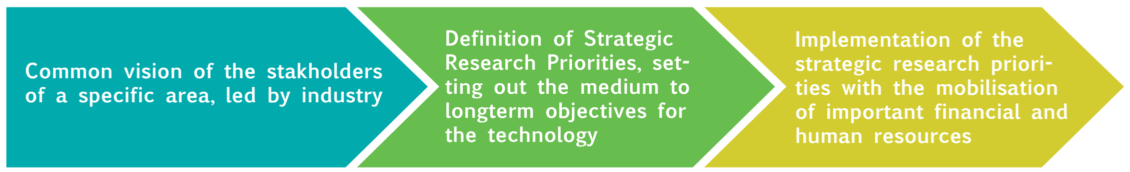

Figure 1 – Methodological framework

What is the RHC-Platform?

The European Technology Platform on Renewable Heating and Cooling (RHC-Platform,www.rhc-platform.org) has been endorsed by the European Commission in 2008. This Platform takes into account the main renewable heating sources (biomass, solar thermal and geothermal) and deals with strategic issues for growth, competitiveness and sustainability. The structure of this Platform is represented in Figure 2.

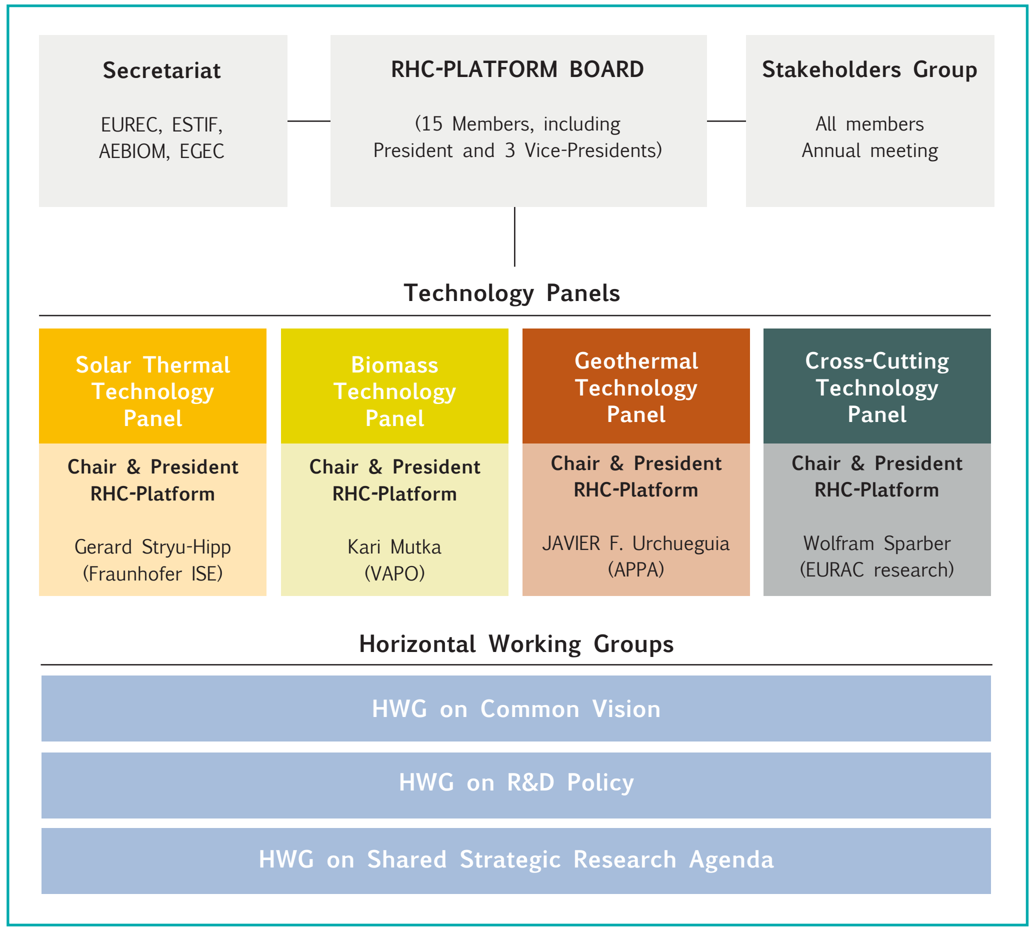

Figure 2 – RHC - Platform structure

The Biomass Technology Panel is composed of a general assembly (all persons that are registered on the web site – free of charge), managed by a Steering Committee of up to 20 persons and headed by a chairman and 2 vice chairs. The Biomass Panel comprises four Issue Groups: (1) Biomass fuels (whole supply chain), (2) Technologies for residential heating and cooling, (3) Technologies for industries and district heating and cooling (4) Market and policy deployment, communication and training.

3. Biomass for heat & cooling

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After coal, oil and natural gas, biomass is the largest energy source for fuel on Earth – it is the largest renewable energy option at present and can be used to produce different forms of energy. One of the main reasons for the large share of bioenergy within renewables is its easy storage, transportation and use with flexible load at the place and time of energy need. None of the other renewables offer such flexibility. In the future, this particular property of biomass will remain a special value and advantage, implying that biomass cannot be fully replaced by other renewable energies.

Biomass routes to heat are manifold. Heat appliances can range from small scale stoves for room heating, to boilers of a few kW for house heating, to multi MW boilers for industry or district heating (DH) and in the future even high temperature process heat. Large scale units can be combined with power cycles for combined production of heat and power (CHP). Novel technologies like Organic Rankine Cycle (ORC) and gasification also offer the possibility for efficient cogeneration in decentralised small scale and microscale units (<150 kWel). Fermentation to a combustible biogas is an alternative route for wet based raw materials. Biogas can be burned directly in a boiler for heat or in an engine for cogeneration, while upgraded biogas (methane) can be injected in the natural gas grid and used directly by the consumer in boilers or small CHP systems.

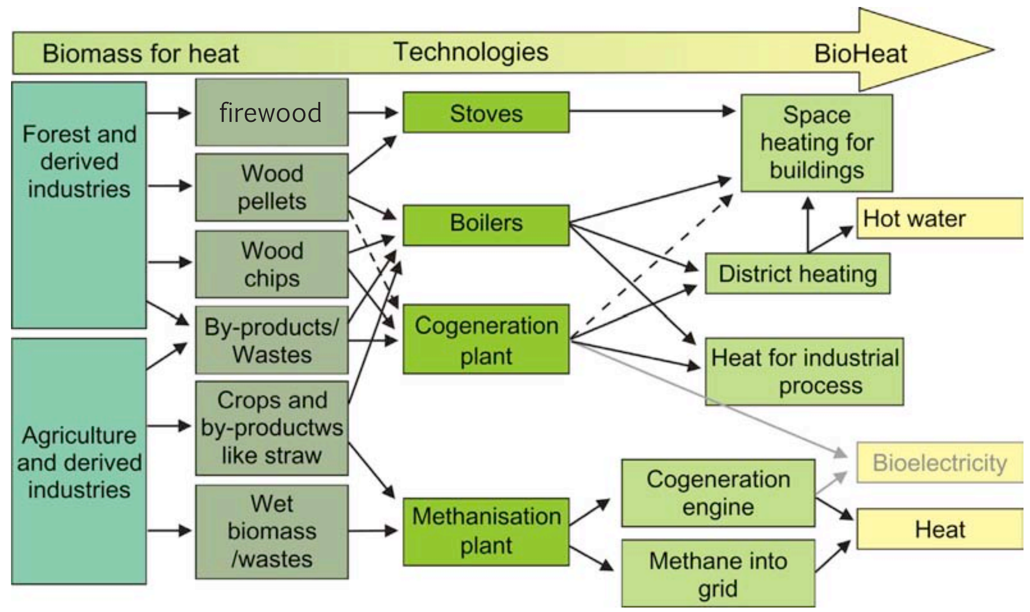

Figure 3 – Biomass sources and use of biomass in different applications

Heat represents roughly half of the final energy demand in Europe (Table 1). A large part of electricity is used for heating and cooling purposes as well, through hot boilers, direct heating and air conditioning systems. Heating with biomass represents 97% of all renewable heat production[1].

[1] Source: EREC, 2010

Biomass for heat & cooling • RHC-Platform

Table 1 - Final energy consumption in EU27 in 2008 (Source: Eurostat)

Sector	Final energy consumption	Here of heat[2]	
	Mtoe	%	Mtoe
Industry	313	69%	216
Households	297	76%	227
Commerce & Services	144	53%	76
Transport	378	0%	0
Agriculture	378	83%	21
Total	**1,157**	**47%**	**540**

The Eurostat balance sheet (Figure 4) depicts the bioenergy balance for 2008. The European Union consumes approximately 105 Mtoe of biomass[3]. Over 1/3 is fed to electricity, CHP and district heating (DH) plants, while the rest is consumed in the private, commercial and industrial sector for heating purposes. About 10% is used as biofuel in the transport sector. Allowing for heat recovered from CHP, 60% of the biomass used is providing useful heat.

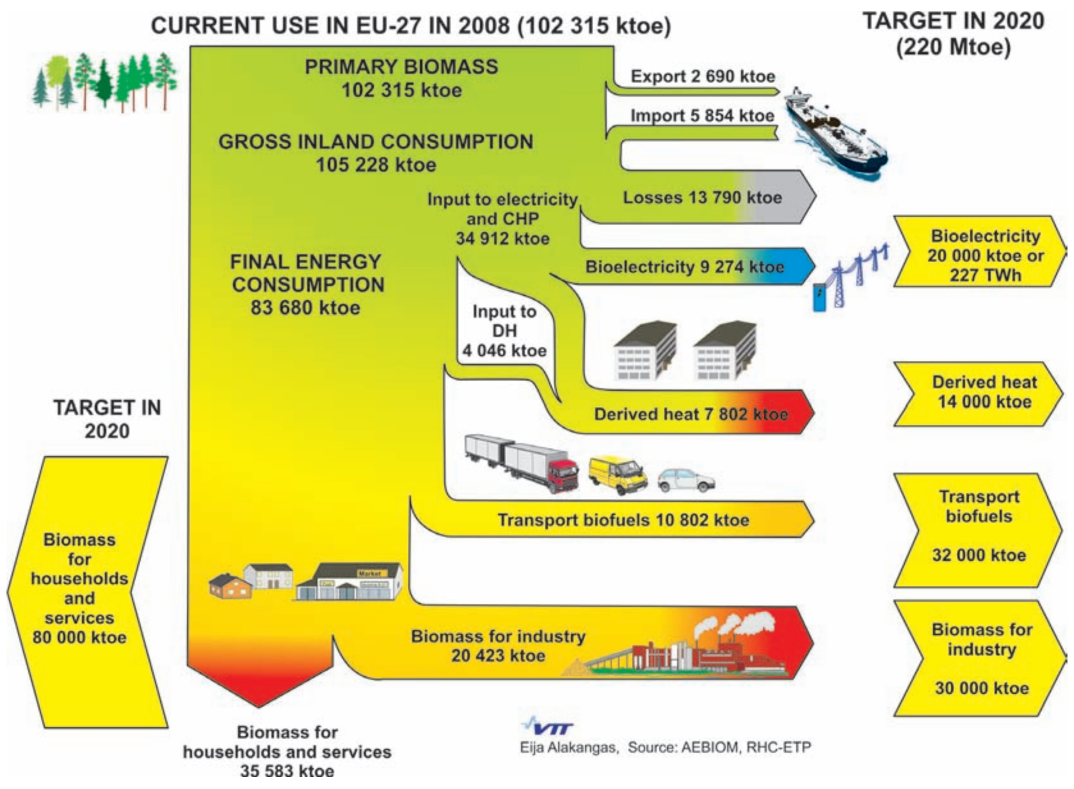

Figure 4 – Bioenergy balance sheet in 2008 (Eurostat)

[2] The final energy consumption for heating has been estimated by substracting the final electric energy consumption from the total final energy consumption in the EU 27, with the exception of the transport sector in which the heat consumption was assumed to be zero.

[3] In EUROSTAT figures, biomass includes organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation. Biomass also includes biodegradable waste.

4. Benefits for Europe

Photo credits: www.wagner-solar.com

4. Benefits for Europe

Our current use of fossil energy is insecure, expensive for our economies and damaging to our environment. Europe is seeking to change this trend and is paving the way for a new energy paradigm: 100% renewables. Europe should keep its position as world leader in renewable energies, and the heat sector, as the main contributor to global renewables, should be a corner stone of this strategy.

The benefits of heating with bioenergy are substantial. The use of endogenous biomass reduces the energetic invoice and ensures security of supply. Depending on the Member State and the reference fossil fuel, biomass use can in some cases reduce costs up to 50%. Converting our energy sourcing from imported fossil resources to European domestic biomass will save more than € 60 billion in 2020 of import expenses, assuming a 12 €/GJ (43.2 €/MWh) cost of fossil fuels. This money will be invested in our economy, creating welcome leverage effects.

Bioenergy brings economic growth. Assuming that investment costs for heat appliances range from 200 to 600 €/kW installed, and that biomass costs range from 10 to 50 €/MWh, one can calculate a rough estimation of the turnover for the biomass heat sector, reaching € 80 billion in 2020, and € 115 billion in 2050. Moreover, new companies will be created over the whole value chain, developing activities in biomass collection, treatment (crushing, drying, etc.), logistics, boiler and accessories (piping, software, ect.) production, installations, maintenance etc. Assuming that a € 100,000 turnover generates one job, a total employment need of 800,000 jobs in 2020 in Europe is evaluated. Both small enterprises and large heat services companies will hire personnel of various qualifications, ranging from drivers, craftsmen, to engineers, traders, project developers, etc.

The gross employment generated by the renewable energy sector is represented in Figure 5.

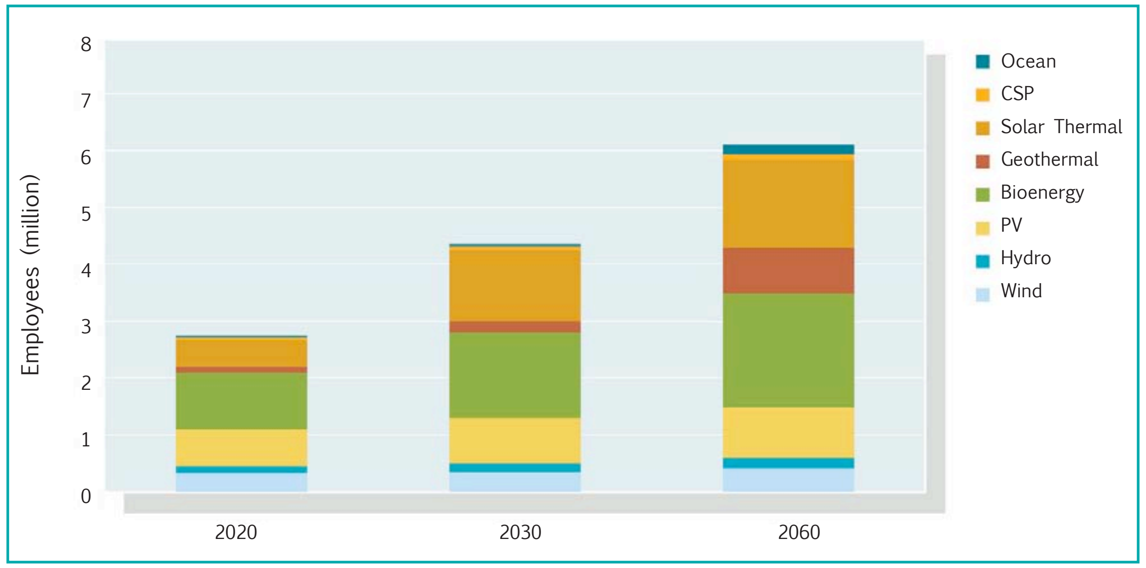

Figure 5 - Gross Employment in the Renewable Energy Sector 2020 - 2030 - 2050 (Source: EREC)

Biomass for heat is a decentralised market by nature, both in terms of biomass production in forests and agriculture as in terms of heat use. This sector therefore entails a large potential for rural development. The vast majority of jobs related to bioenergy cannot be centralised.

The promotion of internal resources will largely benefit producers of biomass in rural areas through new sources of income for farmers, land-owners, and others who harness biomass resources. Rural economies will benefit of increased demand for crops and biomass; new jobs, new investments in rural economies and improved energy security and environment. In smaller geographical areas like regions and villages, salaries earned from the biomass to heat sector will be reinvested for other goods in a virtuous cycle.

Bioenergy development in Europe implies cooperation with third countries or continents, such as Canada, Russia, Latin America, Asia and Africa, in which the huge and potentially exploitable biomass resources are stimulating sourcing. The cooperation with third countries should however be followed up closely and regulated to ensure sustainability and to maximize benefits to local economies and populations.

Biomass for heat replaces fossil fuels and therefore reduces greenhouse gas (GHG) emissions. Assuming a GHG emission intensity of 3 tons GHG/toe or 71.3 g/MJ (Eurostat), biomass to heat could avoid a total emission of 370 million tons GHG in 2020, which is equivalent to 7% of the 2005 emissions. This reduction would apply mainly to the non ETS (Emission Trading Scheme) sector where mandatory targets are not so easy to enforce. In addition, the public costs related to the reduction of GHG emissions through the replacement of fossil fuels by biomass is rather low, typically lower than 20 € par ton CO_2 equivalent.

5. Vision for 2020 – 2030 –2050

5. Vision for 2020 – 2030 – 2050

While renewable energy sources are essential for all markets - heating & cooling, electricity and transport – the development of alternatives to fossil fuels is particularly critical in the heat sector as private consumers, especially with lower incomes, will suffer from rising oil prices. Industries and district heating plants also have to be prepared to diversify their energy supply towards more environmental friendly fuels. In all fields, low emissions and ease of handling will be crucial for high acceptance.

Bioenergy markets will be influenced by many driving forces from today to 2050, for example support policies, fossil fuel prices and the CO_2 emission costs. The bioenergy targets fixed by the RHC-Platform's Biomass Panel are represented in Table 2. In the longer term, several trends will shape the energy picture such as high demands on energy efficiency, high probability of oil price increase and subsequently of natural gas, high probability of geopolitical tensions due to resource scarcity, increasing importance of energy independence and climate change, and the globalisation of the world economy, with Brazil, Russia, India and China exerting much greater influence.

In the short term, the Renewable Energy Directive (2009/28/EC) provides a clear 20% renewable energy target for 2020, in terms of percentage of the gross final energy consumption. Members States have the flexibility to favour the renewables and energy sectors which correspond best to their RES potential, their market structure and their priorities. As bioenergy represents 2/3 of renewables today, it is likely that bioenergy will make a significant contribution to the targets in 2020. According to the European Renewable Energy Council (EREC), bioenergy will account for more than 60% of RES in 2020.

The biomass heat market share in Europe should rise from 11% in 2007 to about 25% in 2020, even considering the reduction in heat demand. By 2020, technically reliable, environmentally friendly and economically attractive renewable heat solutions should be available for almost each type of consumer as alternative to fossil based systems.

By 2050, the EU Low Carbon Economy strategy targets to bring down EU greenhouse gas emissions of 80 - 95%. The SET-Plan objective in this regard is to further lower the cost of low-carbon energy and put the EU's energy industry at the forefront of the rapidly growing low-carbon energy technology sector. In 2050, renewables should cover most of the energy needs and Europe will lead in know-how and technology developments.

The energy picture in 2050 will be altered with different proportions of heat, electricity and transport fuels. High oil prices will lead to an efficient use of energy. The heat demand will decrease in the residential and tertiary sectors thanks to better insulation and low energy consumption buildings. Bioenergy will be intelligently coupled with other RES technologies like solar thermal and geothermal technologies, taking full account of their individual advantages, constraints and costs. Decarbonisation of high temperature process heat in cement and steel production will largely depend on using biomass. Liquid transport fuels will compete with electric cars in the private sector but heavy vehicles, ships and planes are expected to require similar volumes even considering an increase in train transport. Within the whole final energy consumption, electricity will become proportionally more important. The challenge for Europe in the long run is to maintain its high standard of living during the transition to a sustainable climate safe society.

By 2050 the energy needs will have radically shifted towards increased electricity and reduced heat demand. Bioenergy will still play a key role in all markets and sustainable land use and resource management will be crucial to secure the availability of biomass for heating and cooling. High conversion efficiency will be absolutely essential.

[4] EREC Renewable Energy Technology Roadmap to 2020 (2007)

[5] Communication SEC(2011) 287

EU Roadmap for the transition to a competitive low carbon economy in 2050

In order to keep climate change below 2°C, the European Council reconfirmed in February 2011 the EU objective of reducing greenhouse gas emissions by 80-95% by 2050 compared to 1990. In this framework, the Communication SEC(2011) 287 sets out key elements that should shape the EU's climate action, based on the view that innovative solutions are required to mobilise investments in energy, transport, industry and information and communication technologies, and that more focus is needed on energy efficiency policies. This Communication presents a Roadmap for possible action up to 2050 which could enable the EU to deliver greenhouse gas reductions in line with the 80 to 95% target, bearing in mind that the EU reduction objective will largely have to be met internally.

Table 2 - Summary of biomass/bioenergy targets (source: Eurostat, RHC platform Biomass Panel)

[Mtoe]	2008	2020	2030	2050
Primary biomass[6]	102	200	270	330
Imports	6	20	30	40
Exports	3			
Gross inland concumption[7]	105	220	300	370
Input to electricity and CHP	4	10	20	15
Input for second generation biofuels	0	5	10	30
Biomas for households and services	36	80	115	130
Biomass for industry	20	30	35	45
Bioelectricity (TWh)	9 (105)	20 (227)	35 (404)	56 (645)
Biomass for heat[8]	56	110	150	175
Bioheat (or derived heat)[9]	8	14	32	56
Transport biofuels	11	32	45	70
Final energy consumption from biomass	**84**	**175**	**261**	**357**

[6] Primary biomass production is the extraction of primary fuels from biomass sources. In EUROSTAT figures, biomass includes organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation. Biomass also includes biodegradable waste.

[7] Gross inland consumption is defined as primary production plus imports, recovered products and stock change, less exports and fuel supply to maritime bunkers (for seagoing ships of all flags). It therefore reflects the energy necessary to satisfy inland consumption within the limits of national territory.

[8] Biomass available for industry, households and services.

[9] Biomass derived heat from CHP and heating plants

[10] Final energy consumption includes all energy delivered to the final consumer's door (in the industry, transport, households and other sectors) for all energy uses. It excludes deliveries for transformation and/or own use of the energy producing industries, as well as network losses (Source Eurostat).

5.1 Vision for biomass fuels

Several studies show that the annual amount of sustainable biomass available for the energy sector is significant, typically around 200 Mtoe (2,326 TWh) by 2020, which is more than double compared to the present use. The German Biomass Research Centre (DBFZ)[11] has estimated an annual total potential of bioenergy sources for the EU27 of 201–352 Mtoe (2338 – 4,094 TWh) in 2020 assuming a potential for energy crops of 62–186 Mtoe (721 – 2,163 TWh) per year, depending on the land released. According to the EUBIONET III project, the economic potential of biomass resources, excluding the renewable waste potential, amounts to 157 Mtoe (1,826 TWh)[12]. EUBIONET III (www.eubionet.net) estimates a sustainable biomass potential from agriculture of 1,582 PJ (38 Mtoe) and presents much smaller figures for herbaceous and fruit biomass as other resource assessment studies. The Biomass Futures project (www.biomassfutures.eu) has estimated an annual sustainable theoretic biomass potential of 375 Mtoe (4,361 TWh), which is much higher than the estimations published in other studies. The estimated potential for agricultural residues of 106 Mtoe (1,233 TWh) is particularly high. According to European Environmental Agency (2006), the sustainable primary biomass potential comprises 100 Mtoe (1,163 TWh) waste and residues, 80 Mtoe (930 TWh) agricultural biomass and 40 Mtoe (465 TWh) forest biomass (Figure 6). Note that the forestry potential only includes forest residues. Wood processing industry residues are considered as wastes. The most unutilised woody biomasses are logging residues. According to the study of Finnish Forest Research Institute[13], the volume of technically available forest wood in the EU27 is of 187 million m3 solid (36 Mtoe, 733 TWh).

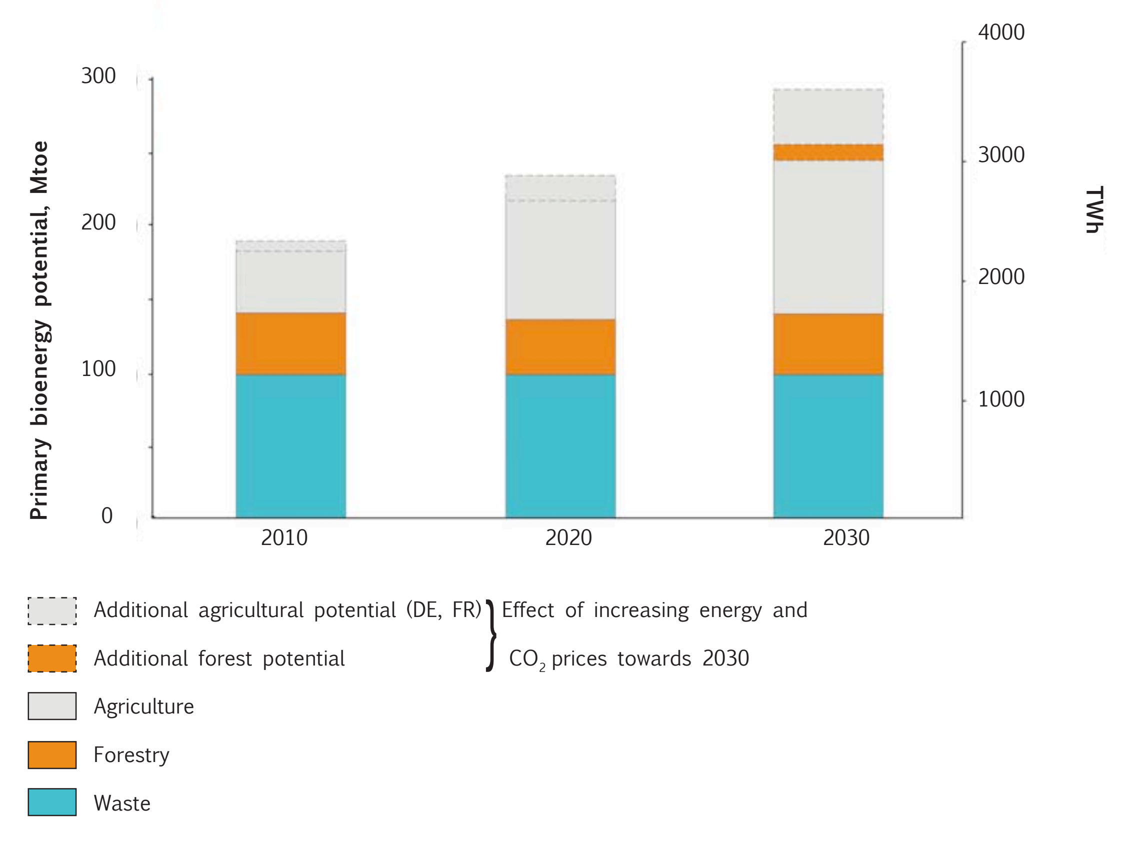

Figure 6 - Environmentally-compatible primary bioenergy potential in Europe (EEA 2006)[14].

[11] Thrän, D., Weber, M., Scheuermann, A., Fröhlich, N., Thoroe, C., Schweinle, J., Zeddies, J., Henze, A., Fritsche, U., Jenseit, W., Rausch, L. & Schmidt, K., 2006. Sustainable Strategies for biomass use in the European Context, IE – Report 1/2006.360p

[12] Junginger, M. van Dam, J. Alakangas, E., Virkkunen, M., Vesterinen, P., & Veijonen, K. Solutions to overcome barriers in bioenergy markets in Europe – Resources, use and market analysis, 56 p. February 2010

[13] Asikainen, A., Karjalainen, T., Peltola, S, Laitila, J., Liiri, H., 2007. Forest Energy Potential (EU27), Finnish Forest Research Institute – Working papers of the Finnish Forest Research Institute 69. Joensuu 2008. 33 p. (http://www.metla.fiwww.metla.fi)

[14] Forestry is only forest residues. Waste includes also industrial wood residues

Waste presents an interesting potential for biomass expansion in the short term. In 2006, about 260 million tons of municipal waste (MSW) were produced in the EU27, of which 20% were incinerated, producing 5.8 Mtoe (61.6 TWh) of energy. If about 50% of our waste was to be used for energy, it could yield 37 Mtoe (442 TWh) of energy. Typically, if a biodegradable fraction of about 50% and an average net calorific value of about 10 MJ/kg[15] (in highly industrialized old EU member states) are assumed, the biobased waste potential can be estimated at 18 Mtoe (215 TWh). Landfill gas must be collected more intensively and organic wastes will gradually be used for energy production, in an increasingly efficient manner, through progressive banning from landfill. The large untapped potential for biogas production from manure and various kinds of organic wastes should be exploited as well. The primary biogas energy production in the EU 27 amounted to 8.3 Mtoe in 2009[16]. AEBIOM estimates a 39.5 Mtoe biogas primary energy potential from agriculture and waste in 2020[17].

The use of conventional firewood currently dominates the biomass fuel market. In heating systems (< 1 MWth), the quality of the wood fuel plays an important role. The general rule of thumb says that the smaller the system, the higher the quality demands in terms of fuel. In installations below 100 kWth, the dominating fuel is firewood with an increasing market share of wood pellets. A major market for wood pellets is situated in the range below 0.5 MWth. High quality wood chips, from delimbed small wood stems from precommercial or commercial thinnings, are also used in small installations. In case lower quality chips can be fired, whole tree chips from undelimbed small tree stems can be used as well. In medium scale installations (>5 MWth) the variety of usable forest fuel sources increases. Logging residues, stump wood but also straw and other herbaceous biomass fuels are applicable in such installations. If available, forest industry by-products such as bark, sawdust and cutter chips can also be used as fuel. In district heating and large-scale combined heat and power (CHP) production plants, fuel deliveries must be reliable and on time. A clear fact is that the fuel supply can seldom be based on wood alone. To secure fuel availability, to reduce costs and to level out quality variations, large plants usually have multifuel boilers using bark, sawdust, peat with forest chips or wood pellets and co-firing with coal. Common wood fuels represent about a third of the plants' fuel flow. The combined use of wood and other fuels creates special requirements in terms of supply logistics but also for the handling and blending of the fuels at the plant.

In 2020, the use of conventional biomass fuels like wood chips and pellets will still play an important role in the heating market. The use of refined solid biomass fuels such as pellets & briquettes increases, and more agrobiomass materials are used as raw material for the production of pellets,briquettes and other biomass fuels. The use of biomass fuels in the residential sector is adapted to the decrease in heat demand in new buildings (lower energy demand). In 2020, existing buildings still represent the main market, but biomass is also increasingly used in mini-district heating (heating of several houses by same boiler) and other district heating sectors including CHP.

By 2020, the biomass fuel supply should be doubled by developing standardised and sector oriented sustainable biomass fuels at competitive production costs and the biomass fuel supply should be secured to the end use.

[15] Vehlow, J. Bergfeldt, B, Visser, R. & Wilen, C. European union waste management strategy and ist importance of biogenic waste. J Mater Cycles Waste Management (2007) 9 p. 130-139.

[16] EurObservER 2010

[17] A biogas roadmap for Europe, AEBIOM 2009

Due to the future reduction in heat demand, the total use of fuels in the heating sector is expected to decrease from 570 Mtoe to about 350 Mtoe by 2030. As a consequence, the share of biomass fuels in the heating market can increase by 30 – 40% and the use of light fuel oil could drop to almost zero. Aquatic biomass will be increasingly used as a raw material. By 2030, biomass will constitute an outstanding solution for individual heating, dominated by (standardised and certified) pellets in urban areas and by wood chips, firewood and pellets in rural areas. The boiler and stove markets will progressively shift from oil to biomass based systems, as heating oil progressively becomes unaffordable. The use of refined biomass fuels, including liquid bio-oils, increases in the residential sector. Agro-biomass raw material used in district heating and CHP increases and new sustainable supply chains for forest and agro-biomass (herbaceous and fruit) are successfully demonstrated and widely implemented. Technology export increases to countries outside Europe and so do imports of biomass fuels from Africa, Asia and America to the EU.

The vision for 2030 is to replace 50% of fossil fuels in the heating sector and increase the use of biomass fuels by 10% in the cooling sector by developing advanced, cost-efficient, sustainable solid and liquid biomass fuels from agro-biomass, biodegradable waste, forestry and aquatic biomass.

In 2050, the final heat demand will further decrease in the space heating sector and most of the houses will be renovated into low-energy houses. The use of conventional solid biomass fuel decreases and second generation solid and liquid biomass fuels for heating and cooling become increasingly available on the market. Diversified and more challenging raw materials will be increasingly used in fuel production. In southern Europe, cooling with biomass will have increased remarkably. Due to scarcity, the prices of fossil fuels will be very high and environmental sanctions costly. Fossil fuels will be fully replaced by renewable energies in heating sector. Recycling and production technologies to upgrade biodegradable waste fractions to fuels or energy will be largely developed.

The 2050 vision is to fully replace fossil fuels in the heating sector and increase the use of biomass fuels remarkably in the cooling sector by developing advanced, cost-efficient and sustainable solid and liquid biomass fuels from agro-biomass, biodegradable waste, forestry and aquatic biomass.

5.2 Vision for residential heating & cooling

In 2007, about 35 Mtoe of biomass have been used for grid independent supply of energy to households and services within the EU-27, which make it the dominating application for bioenergy, and more largely for renewable energy in general in Europe. This is mainly due to fuel availability, tradition and on fairly well established economic competitiveness with fossil fuel based energy supply. The utilization of bioenergy for residential heating and the dissemination of the respective technologies strongly differ throughout Europe. In some European countries, incentives exist for the installation of bioenergy boilers and stoves in new buildings as well as support schemes for the substitution of both, old oil and gas fired boilers and technologically out-dated log wood boilers. The key drivers for the marketing of high-efficient and low-emission technologies in Central Europe are strict legal requirements regarding emissions and efficiency as well as the establishment of corresponding technical standards for fuels, fuel logistics and for combustion technology type testing.

In 2020, substitution of existing fossil fuel boilers will still be a key market for bioenergy in residential heating and cooling. Increasingly stringent air quality demands will constitute a major driver for the renewal of existing high emission biomass boilers into high efficient, low emission technologies.

Ecodesign labels will be available to characterize the performance of products and/or installed systems. The thermal refurbishment of buildings in addition to improved system solutions and integration will induce a decrease of the required thermal power of wood boilers. In newly built low-energy or passive houses, solar thermal will be a key technology but integrated hybrid systems solar/biomass are attractive to combine solar thermal technologies in summer for sanitary hot water while biomass remains the main heat source for hot water and space heating during the rest of the year. In such hybrid products, only low power bioenergy technologies will be required, as back up for heat and hot water supply but and also for ventilation and cooling. Operators influence on the performance of the systems will be restricted to convenience issues. Stoves are a cost-saving heating solution based on renewable energy and are applicable as primary heating solution in low and passive energy buildings. In other buildings stoves can constitute an additional heating solution to the primary heating installation.

The 2020 vision for residential bioenergy technologies is to replace heating oil totally in the boiler exchange and refurbishment market, to strongly compete with natural gas and to add value to other renewable energy technologies in the new building sector.

In 2030, lowest nominal load boilers, mostly fully integrated into HVAC solutions and stoves with water heat exchanger will be mature technologies for the new building market. Control concepts will be available which include and optimally integrate (plug & play) all heating, ventilation and air-conditioning (HVAC) components.

The 2030 vision for residential bioenergy technologies is to have fully replaced heating oil in the existing building stock.

Biomass based micro scale co- and trigeneration technologies (CHP-C) should be introduced on the market, including for grid independent operations. Direct combustion based micro-scale cogeneration systems are already marketed in Europe. These systems are available for liquid biofuels (diesel engines) and for biogas (gas otto engines and micro gas turbines). Indirectly fired micro scale technologies for solid biomass however are not marketed yet; steam engines, ORC, Stirling engines, thermoelectric generators mainly coupled with automatically stoked wood boilers and small scale gasification concepts (up to 500 kW fuel input) coupled with gas engines are currently under development. Residential cooling technologies based on bioenergy are not marketed either, but biomass fired absorption as well as adsorption cooling technologies are under development. Combined heat-power and cooling (CHP-C) based on biomass will be progressively available in all sizes even at household level and for nearly all part load cases.

The 2050 vision for residential bioenergy technologies is to have successfully contributed to the full replacement of fossil energy for space heating. All existing dwellings are equipped with bioenergy technology as primary or secondary heating source. There is no biomass combustion installation without cogeneration, out of which a share of 25% produces electricity, and a share of 10% is coupled with a cooling technology.




Vision for 2020 - 2030 - 2050 • RHC-Platform

	Today	2020	2030	Beyond 2030
Air quality/emissions	• Imission--values set by EU • Emission-limits & -policies not existent/not harmonised => different requirements further to CE-mark	• Limits (type-testing) are harmonized on ambitious level (LOT15 of EuP[18]) • Regulations regarding use of individual biomass heating harmonized (no restrictions on local level)		
Safety of energy supply	• Major effects of force majeure (gas crisis, floodings, snow, ..) on availability of heating in homes • No EU-wide concept to increase safety of citizens	• Small scale biomass heating regarded as means to increase the individual security (e.g. stoves) • EU-wide policies to encourage the usage of modern, emission-less wood appliances	• For EU-citizens, the distribution of wood appliances diminishes the effects of force majeure	• Combined with the complete shift to renewable heating, EU is self-sufficient in energy in the heating sector
Building requirements	• A number of countries have acknowledged the need for legal requirements regarding building structure when it comes to biomass heating (e.g. safety, chimneys, ...) – but not all	• Harmonised building regulation, that requires every new residential dwelling to be suitable for individual biomass heating • Target: 80% of new buildings meet this requirement (safety, chimney...)	• Target: 100% of new buildings meet the requirements (safety, chimney...)	• Vast majority of existing building stock meet the requirements (safety, chimney...)
Harmonisation of standards, legislation, testing	• No harmonization	• Respective standards harmonised, as well as national legislation		
Existing heating stock	• Policies regarding emissions, efficiencies, etc. tackle only new appliances => biggest problem is heating stock	• EU-wide policies in place to replace existing heating stock to modern, emission-less appliances • No new fossil fuel appliances allowed to be installed	• Majority of old fossil fuel appliances exchanged by modern, low emission wood appliances	• 100% switch from fossil fuel to biomass (in combination with solar thermal) also on individual level
Market penetration	• Grant schemes or subsidies	• Green European Investment bank, access to private equity	• Low carbon economy taxation rate	• HVAC system efficiency determination harmonized
Efficiency	• Steady state type testing, technologies well developed for steady state operation	• System type efficiency testing protocols available. Improved transient load operation behaviour	• System efficiency testing harmonized, significantly improved annual efficiencies (+20% compared to today)	

[18] Lot 15 is a preparatory study on Solid Fuel Small Combustion Installations carried out for the European Commission (DG TREN) in the context of the Framework Directive on ecodesign of Energy using Products (EuP) http://www.ecosolidfuel.org/

5.3 Vision for industrial and district heating & cooling

Bioenergy in industrial processes and District Heating and Cooling (DHC) systems is produced through thermo-chemical or biological conversion units, with one or two transformation steps. In 2008, about 60 Mtoe or 56% of the gross inland consumption of biomass was used in electricity plants, DH or industrial processes (Figure 4). Due to the need for rationalized energy consumptions, biomass use in industrial power plants and DHC is expected to roughly double reaching 105 Mtoe in 2020 (Table 2), which represents about half of the gross inland consumption. Projections for 2050 are even higher, as high temperature industrial process heat will highly rely on biomass and industries will need to produce energy in a more environmental friendly way. Most district heating and cooling systems will be retrofitted with solar thermal, biomass and geothermal and many new small heating, cooling and biogas networks will appear.

Industrial and district heating and cooling covers a demand range starting from several hundred kW in small heat grids or industries and up to several hundred MW in large towns or industries. District heat is supplied to a grid in the form of hot water at temperatures between 75°C and 120°C and with return temperatures exceeding 55°C. The load in district heating varies seasonally, with a peak during the heating period. On the contrary, industrial heat is often characterized by a continuous demand throughout the whole year. Typically, industrial heat is supplied as steam (temperatures ranging from 100°C to 400°C), but also as hot water (below 100°C and up to 220°C). High temperature heat also represents a significant fraction, especially for temperatures above 1400°C (Figure 8). The load flexibility in district or industrial cooling is comparable. Load changes in the district heat network can be forecasted in correlation with the outdoor temperatures, while the situation is completely different in industrial applications, since extreme load changes may occur sometimes rapidly. Based on the above, it is concluded that a wide range of technologies have to be considered in this chapter.

In the future, efficiency and investigation on operational bottlenecks (corrosion...) will be major driving forces for bioenergy projects; the increase of the thermal share in large-scale CHP plants will thus be enhanced and power production without cogeneration of heat or heat production without cogeneration of power will be restricted. Approximately a quarter of boilers operate in the CHP mode today. In the future, more biomass based units should produce electricity and heat in parallel, reaching 50% of the total installed capacity in 2020. Concerning biogas production, heat utilisation rates will be enhanced to 80% in 2020, as compared to the current 20%. More biogas units will be connected to grids, while the organic residue will be reduced by 10% on weight basis. In 2030, over 80% of the biomass units will operate in the CHP mode. In biogas units, all heat will be utilised and more than 90% of the units will be connected to the grid. Less than 20% of the organic residue will remain. Beyond 2030, biogas units will use all available heat. More than 95% of these units will be connected to the grid and all residues will be re-used.

	Today	2020	2030	Beyond 2030
CHP share on heat	**25%**	**50%**	**80%**	**100%**
Biogas production	20% heat utilization, few grid connections, 40% organic residue	80% heat utilization, 60% of energy connected to grids, 30% organic residue	100% heat utilization 90% of energy connected to grid 20% organic residue	100% heat utilization 95% grid connection All residue utilized

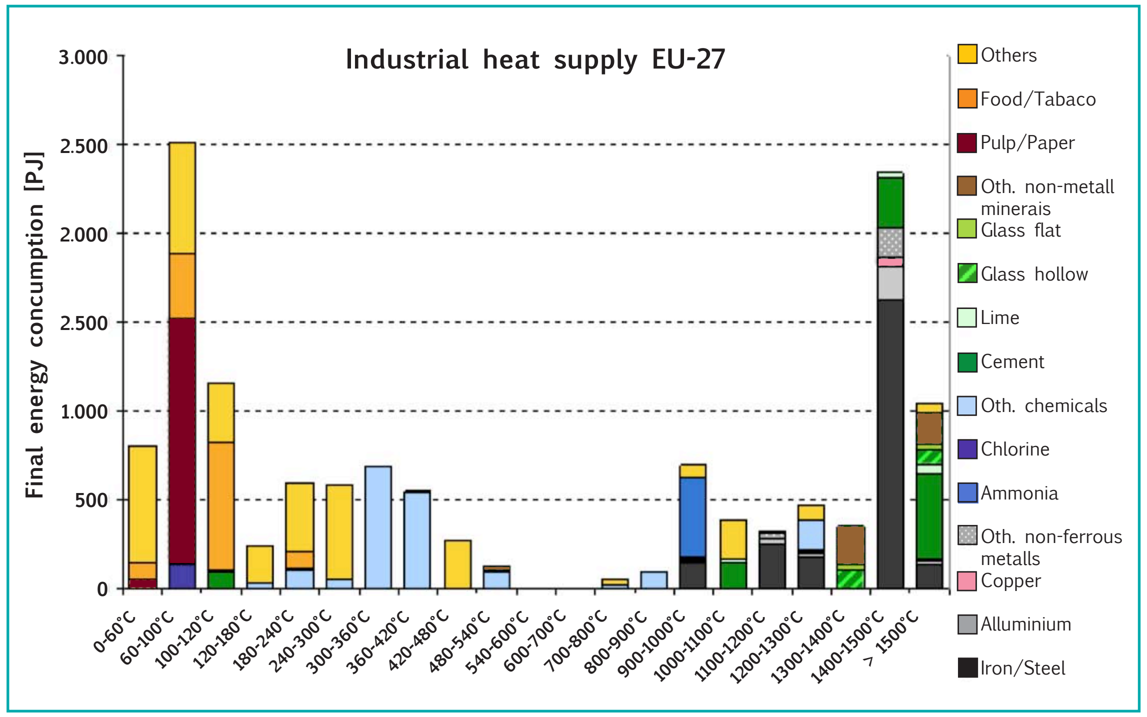

Figure 7 -Temperature distribution of industrial heat in EU-27 in 2009[19]

By 2020, bioenergy produced from large scale and industrial systems should increase significantly by developing multifuel units with high efficiency rates and increased operational availability.

Bioenergy production from large scale systems for the electricity, industrial and heating sector will be increased by 160% in 2020. Based on the findings of DHC+ Technology Platform, the share of DH networks will be doubled from 7% to 14% by 2020.

By 2030, biomass residues and waste derived fuels will be handled as a standard fuels, with no serious technical problems, in industrial units of enhanced efficiency and availability. Biomass will significantly contribute to high temperature heat processes. The first regional carbon negative heating systems are applied.

In 2050, significant shares of fossil fuels will be replaced by biomass in industrial process heat at highest temperatures, e.g. in cement and metal production. Almost all industrial process heat at highest temperatures, which cannot be supplied by solar energy or renewable electricity, will be provided by biomass.

The vision for 2050 is to be able to utilize 80% of the sustainable and economically competitive biomass potential, implying any type of biomass, either directly thermally or via fermentation in high efficiency industrial or district heating and cooling. Fully carbon neutral energy and even carbon negative regional biomass concepts with heat or gas grids and integrated networks will be a standard solution and will efficiently decouple heat and electricity peak loads. Biomass will play a key role in decarbonising high temperature process heat.

[19] Kuder, Blesl (2010): Technology orientated analysis of emission reduction potentials in the industrial sector in the EU-27, Full paper international energy workshop (IEW) 2010, Stockholm

5.4 Vision for market & policies deployment, communication & training development

In addition to cost and energy efficient technologies, successful market deployment needs a variety of favourable framework conditions, including developed qualification schemes, standardised products and processes, supportive policy instruments, public acceptance, and finally administrative procedures that do not hinder bioenergy project implementation.

In order to ensure successful market deployment of biomass for heating and cooling, efforts are required on the **development and harmonisation of training activities** for practitioners, technicians, engineers and scientists on European level.

Certified training courses need to be developed for installers of residential heating and cooling systems to guarantee high quality and good performance of installed systems. Such courses shall be in line with Article 14 of the European Renewable Energy Directive (RED) which calls for the establishment of certification schemes or qualification schemes for installers of small-scale biomass boilers and stoves based on existing schemes and training programmes.

Furthermore, future needs in the fields of graduate, post-graduate, life-long, and professional training in the bioenergy sector will be assessed in the framework of the SET-Plan European Energy Education and Training Initiative recently announced by the European Commission. This initiative covers 10 energy related sectors with the objective to deliver the quantity and quality of human resources required for the achievement of the ambitious European climate and energy targets for 2020. Thereby, suitable integration of biomass for heating and cooling in graduate, post-graduate, life-long, and professional training shall be ensured on European level.

In order to facilitate further stable market development, **standards for products and processes** along bioenergy supply chains are needed. Recent progress in the development of quality (and sustainability) standards for solid biofuels will have positive influence on market development, but further standardisation effort at European level is needed, including the continuous development of existing standards and the development of new standards (e.g. for combustion equipment, safety and health aspects in transport and storage, installation services). By 2020, recognised and practical standards should cover most aspects in current bioenergy supply chains.

The full transformation of the heating market towards bioenergy and other renewable technologies needs **political support**, both to increase the replacement of old heating systems and to increase the uptake of renewable technologies in new and existing buildings. Already today, bioenergy chains are in many cases cost competitive with fossil alternatives and the situation will further improve with technological progress and the development of supply chains. In addition, the removal of fossil fuel subsidies and in a second step, putting a price on CO_2 e.g. through taxation of fossil energy carriers, can help to create a level playing field. Such measures, together with increasing prices of fossil fuel should make bioenergy fully cost competitive by 2020. In the meantime, this process can be facilitated by implementing financial support schemes (direct subsidies, tax reductions, etc.) and building regulations requiring the installation of bioenergy (and other renewable) technologies. In any case, policies must aim at providing a stable and reliable framework regarding political targets and political support in order to increase confidence at the investors' and the end-users' side.

To safeguard the positive environmental, social and economic impacts of biomass based heating and cooling, suitable schemes ensuring sustainability need to be established to maximise positive impacts such as GHG emission reductions, energy security, employment generation, and rural development. Ensuring sustainability can thereby contribute to a **positive perception of the European public** and highlight the societal benefits of biomass based heating and cooling which is essential for successful future market development. The implementation of complex sustainable certification schemes could create a burden on small forest land owners, which produce the vast majority of European biomass resources. A cost efficient scheme should be developed with the aim of mobilizing in a sustainable manner the endogenous biomass resources.

The time and the costs dedicated to the **administrative procedures** related to the set-up of a biomass thermal project can constitute an important bottleneck, in particular for small owners and SMEs. The burden related to the acquisition of administrative permits varies widely among member states: more than 7 permits are required in Spain as opposed to just 1 in Italy and Germany. Also the duration required to obtain the permits goes from 5 to more than 25 months (Figure 8).

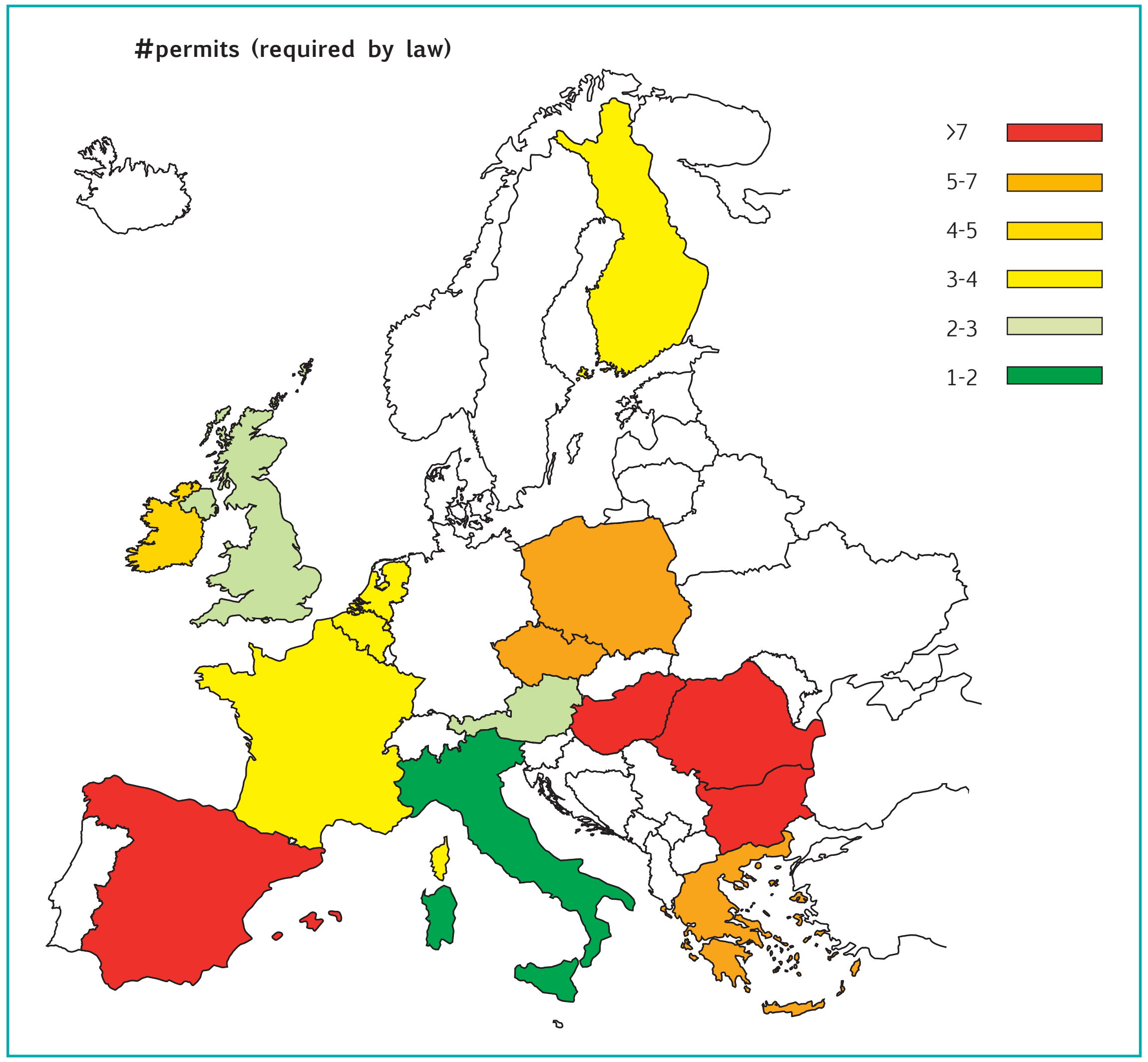

Figure 8 – Number of permits required by law related to the set-up of a biomass thermal project (Source: ECOFYS)

Simplification and homogenization of the administrative procedures and costs related to bioenergy projects on European level is crucial in order to promote bioheat installations in buildings. Realistic National Renewable Action Plans with guidelines and accurate indicators to measure the success of implementation will also contribute to creating the regulatory framework needed to ensure stability and to stimulate confidence of investors, promoters and financial entities. Positive communication on bio-heating and cooling, for instance on the benefits at social and political level, is equally important in the promotion of the sector.

By 2020, certified training courses for installers of residential heating and cooling systems are available in all European Member States. Suitable integration of biomass for heating and cooling in graduate, post-graduate, life-long, and professional training on European level is achieved.

Recognised and practical standards cover most aspects in current bioenergy supply chains.

Heating from biomass will be cost competitive with heating from any fossil fuel in all member states without additional subsidies. Bioenergy is a standard technology for heat production in new buildings and after refurbishments.

Suitable schemes are established for biomass based heating and cooling, ensuring sustainability and public acceptance.

By 2030, the establishment of a biomass heating and cooling system should require only a "one stop shop" administrative procedure.

By 2050, the administrative cost related to the establishment of heating and cooling systems should be reduced by half.

6. Strategic research priorities

6. Strategic research priorities

Major technological advances are necessary to ensure the successful deployment of heating and cooling technologies with biomass. Environmentally sound technologies need to be developed, requiring major improvements in terms of efficiency, emissions and fuel or load flexibility. Considering the use of biomass by different sectors, supply challenges have to be addressed and sustainability will become central to the successful deployment of any biomass project. Integration and predictive management will be essential to maximise the benefits of heating and cooling with biomass.

Research, development and demonstration priorities which are crucial to increase the use of biomass for heating and cooling in Europe are detailed in this chapter and structured around 5 thematic priorities: **security of supply, fuel and load flexibility, efficiency and emissions, integrated concepts and predictive management and sustainability**. Significant technological progress in these five critical areas is essential to ensure the successful deployment of heating and cooling with biomass in Europe.

6.1 Security of supply

With the European renewable energy targets for 2020, biomass supply will become a crucial issue and should increase significantly to meet the demand of all sectors - heat, electricity, and transport biofuels. By 2020, the biomass supply in Europe should double with a very significant increase of energy crops, by-products and residues from agriculture in addition to the use of forest logging residues. In the long run, biomass resources from agriculture, forest and waste streams should be mobilized intensively and efficiently.

Approximately 98 Mtoe of biomass were used in 2007 in Europe and this amount could fourfold in the longer term through a higher contribution from agriculture, forest and waste streams. Table 3 shows the projected availability of biomass, as derived by the biomass experts of the RHC-Platform.

Table 3 - Expectation of biomass supply in 2020–2030–2050

		2007		2020		2030		2050	
		Surface (Mha)	Biomass (Mtoe)	Surface (Mha)	Biomass (Mtoe)	Surface (Mha)	Biomass (Mtoe)	Surface (Mha)	Biomass (Mtoe)
Agriculture	Energy crops	5.2	10	20	43	25	75	30	129
	By-products		4		20		30		30
	Other						5		15
Forestry	Residues		18		40		55		55
	Industrial by-products and residues		54		65		65		66
Waste[20]			10		32		40		35
Imports			2		20		30		40
Total		5.2	98	20	220	25	300	30	370

[20] Waste includes only the biodegradable waste fraction.

Forest based industries (pulp & paper, board industry, sawmills...) currently provide most of the biomass used for energy. European forests are continuously growing and offer a great opportunity to sustainably increase the biomass supply through improved forest exploitation with thinnings and through the use of logging residues. The increase of the forest area should be accompanied by logistical improvements (machinery and field pretreatment, methods for harvesting and collection, transport and storage). As most of private forest owners hold small stands and live in urban areas, it is most important to develop production chains, machinery and business models for small-scale procurement of woody biomass and also to promote the trading of wood resources by forest owners. Most of the unutilised woody biomass potential lies on forest residues. In order to exploit this potential in different forest conditions and increase the overall biomass supply, there is a need to develop efficient supply chains and machinery but also to enhance the networking amongst different operators in the supply chain to decrease production costs.

Agriculture should play a key role by mobilizing 20 million hectares in 2020 for different kinds of energy crops to produce transport fuels, biogas and solid biomass. Arable land will increase progressively after 2020 in parallel with the yield from energy crops. Yields should increase by 1 – 2% per year for different biomass species. Cultivation of degraded lands around the world with adapted energy crops represents a significant challenge. The promotion of energy crops through demonstrations, pilot projects and information campaigns should lead to a significant increase in the biomass supply from agriculture. Machines and combiners for non-arable land should be developed.

While expansion is limited by competition with other sectors, mind that the increased demand for biomass will generate all sorts of waste to energy streams. Waste derived fuels should be developed leading to less waste in landfills. Driven by the ban on the landfilling of organic matters, by-products from agriculture and agrofood industries will be increasingly used for bioenergy in the future. The use of the biodegradable fraction of waste should be increased through the development of sorting technology, the healthy handling of the dry fraction for direct combustion, the processing of wet biowaste (kitchen waste, sludge, manure...) to biogas, the purifying of the gas and the improvement of the heat use. Recycling and production technologies to upgrade biodegradable waste fractions to fuels or energy should be largely available by 2050. Novel solid biofuels, such as Solid Recovered Fuel (SRF) derived from the municipal waste treatment and considered partially as biogenic (i.e. up to 60% on weight basis), will be introduced mainly in large-scale installations. Sewage sludge, originating from the steady growth in the number of waste water treatment plants, will be utilized with higher energy recovery rates.

New types of biomass fuels will have to be developed to diversify the biomass sources. The development of cost-efficient, high quality fuels such as thermally treated biomass fuels (e.g. torrefied biomass, steam-explosed biomass or "biocoal") will contribute to enhancing biomass supply and will replace coal in pulverized condensing power plants in the short term. After 2020, intensive cultivation of biomass in the form of algae should be made commercially viable.

2020	2030	Beyond 2030
• Development of standardised and sector oriented biomass fuels at competitive production costs, leading to the doubling of the biomass fuel supply • Mobilization of 20 million hectares in 2020 for different kinds of energy crops to produce transport fuels, biogas and solid biomass • Increase of yields by 1 – 2% per year for different biomass species	• Development of advanced, cost-efficient, sustainable solid and liquid biomass fuels from agro-biomass, biodegradable waste, forestry and aquatic biomass • Replacement of light fuel oil by bio-oil in heat production • Replacement of almost 70% of coal by biocoal in CHP installations • Viable commercialisation of biomass in the form of algae	• Development of advanced, cost-efficient and sustainable solid and liquid biomass fuels from agro-biomass, biodegradable waste, forestry and aquatic biomass • Total replacement of fuel oil and coal by biomass-derived fuels • Commercialisation of recycling and production technologies to upgrade biodegradable waste fractions to fuels or energy

Research priorities

Development of cost-efficient, sustainable supply of agrobiomass

- Development of sustainable, economical and effective cultivation and harvesting technologies as well as new supply chain concepts for short rotation coppice and agrobiomass;
- Demonstrations of viable chains in southern, northern and eastern Europe;
- Enhanced by-product and residue mobilization through the development of efficient supply chains and machinery and through networking of different operators in the supply chain in order to decrease production costs;
- Development of intelligent supply chains with respect to fuel quality available for users.

Development of cost-efficient, sustainable supply of forest biomass

- Development of technologies and business concepts for forest wood from thinning and small-scale stands or other stands difficult to reach;
- Demonstrations of viable chains in southern, northern and eastern Europe;
- Enhanced by-product and residue mobilization through the development of efficient supply chains and machinery and through networking of different operators in the supply chain in order to decrease production costs;
- Development of intelligent supply chains with respect to fuel quality available for users.

Development of storage, drying and logistics of biomass fuels and improvement of fuel quality

- Improvement of biomass fuel storability and reduction of impurities (fuel minerals, soil, sand, metals, snow);
- Ash content minimization of the fuel fed into the boiler and development of ash recycling;
- Characterization (mechanics, explosive and flammable nature) of biomass fuels for safe and efficient design of storage & handling systems;
- Development of storage management systems & technologies;
- Development new drying technologies (ex: solar drying in southern countries and use of waste heat in northern Europe);
- Development of terminals for large-scale biomass storing;
- Improvement of logistics and transportation equipment.

(Thermal) upgrading of biomass to high grade fuels

- Improvement of chemical (solve problems related to NOx, corrosion, ash melting behaviour, particle emissions) and physical quality of pellets produced from agrobiomass;
- Improvement of thermally treated biomass fuels (e.g. torrefaction, pyrolysis and biocarbonisation) in terms of economy and technology;
- Large-scale demonstration plants for thermally treated biomass processes (e.g. torrefaction);
- Selection of suitable raw materials for bio–oil production, torrefaction and biocarbonisation;
- Development of thermochemical, physico-chemical and bio-chemical conversion of bio-oils, optimization of manufacturing processes to obtain desired properties for use in current and future poly-generation devices;
- Economic and sustainability analysis of bio-oils;
- Demonstration of bio-oil;
- Biogas upgrading and bio-SNG production;
- Upgrading of pyrolysis oil from waste recovered fuels, such as RdF/SRF, End of Life Tyres (ELTs) etc.

Development of cost-efficient, sustainable supply biomass fuels from new raw material

- Development of algae as a raw material

Preparation of solid and recovered fuels and biogas from the biodegradable fraction of waste

- Development of solid and gaseous fuels for the industrial and district heating sector;
- Improvement of the efficiency of waste collection and applications by sorting (high value material, non-recyclable material through mechanical and biological treatment)

6.2 Fuel and load flexibility

Non-woody biomass fuels usually have less favourable fuel characteristics than woody biomass fuels, such as higher ash contents with lower ash melting temperatures and higher amounts of chemical elements which are responsible for harmful emissions. Taking into consideration that the availability of high quality resources for wood fuel production in Europe is limited, one has to acknowledge that lower quality biomass fuels, coming from wood of short rotation forestry and from agricultural and agro-industrial residues, will gain importance. At the same time it is expected that strictness of air quality requirements will increase throughout Europe in the coming years.

For small scale biomass combustion appliances (boilers and stoves) lots of efforts have been undertaken to develop value chains based on highest quality fuels (i.e. class A2 wood pellets according to EN 14961-2, dry log wood, high quality wood chips). However, some markets (geographic and sectors), which require the development of small scale fuel flexible boilers. Such boilers – for instance burners and grates – should be able to handle ash rich fuel with challenging ash melting characteristics. By 2030 these systems should operate with sensor concepts, which identify type and quality and adapt the operating parameters of the boilers automatically to the used fuel.

The objectives in terms of fuel flexibility for residential scale boilers are detailed in the table below. Load flexibility issues of residential scale biomass combustion appliances are discussed in section 6.3.

	TODAY	2020	2030	Beyond 2030
Fuel Flexibility	• Boilers for one type of fuel (wood chips, wood pellets) or fixed control options to switch manually between two fuel options	• Boilers for a wider range of fuel qualities with the need to manually adjust control options • Automatic adaptation to changing moisture contents of the fuel	• Multi-sensor fuel recognition and automatic adaptation of operation	• Fuel flexible boilers for a wide, but defined range of fuel qualities

Facilities exceeding about 0.5MWth are expected to exploit more challenging solid biomass fuels instead of the wood chips widely used today. In this way, wood chips utilised in such units will be reduced by half by 2020, while less waste will be landfilled. Multi-fuel units, using a variety of solid biomass types and waste derived fuels, need to be developed. By 2050, all units exceeding 0,5 MWth will have the flexibility to exploit a great variety of biomass types, from industrial bio-products to waste derived fuels, with remarkably high conversion rates and operational availability.

Load flexibility of boilers should be increased, e.g. for simplified weekend-shut down or start-up and for short-term flexibility. Load changes in the district heating network can be forecasted in correlation with the outdoor temperatures, while the situation is completely different in industrial applications, since extreme load changes may occur sometimes rapidly. In 2020, biomass based units will be able to operate also at lower part loads, while load changes will be more feasible and faster.

Objectives in terms of load and fuel flexibility for industrial scale boilers are detailed in the table below.

	TODAY	2020	2030	Beyond 2030
Fuel Flexibility	• Wood chips or residues from wood processing industry (>80%). Wastes not to be landfilled (<10%)	• Standard multi-fuel plants (virgin wood, waste wood, max. 30% agricultural residues, thermally treated fuels) Wood chips or residues from wood processing industry (<50%)	• Fuel blends and mixtures with enhanced efficiency, max. 50% agro-residues	• Full fuel flexibility plants
Load Flexibility	• About 10 - 70 % of wood fuels cofired in multifuel CHP plants	• Part load > 30%. Slow load change	• Part load with CHP >20% Load change speed increased, with steam storage	• Once through boilers, part load 20% Quick load change with enhanced plant control

Research priorities

Development of load flexible industrial scale boilers

- Improvement of easy load flexibility in boilers;
- Improvement of load flexibility for biogas: load change in biological gas production combined with short-term biogas storage;
- Enhanced integration of heat/cold storage systems.

Development of fuel flexible residential scale boilers

- Development of burner and grate concepts to manage ash rich fuels with challenging ash melting characteristics (robust grate cleaning concepts, fuel bed temperature control…);
- Development of sensor concepts which allow for an identification of fuel qualities (heating value, moisture content) and corresponding control concepts, which allow for an adaptation of the operating parameters accordingly;
- Development of multi-sensor and corresponding control concepts to allow for an adaptation to multiple fuel characteristics;
- Material research, development of corrosion and abrasion resistant materials.

Development of fuel flexible industrial scale boilers

- Optimization of multi-fuel systems for different blends of solid fuels and biomass (corrosion, deposition, burnout, emissions, and particulates);
- Management of ash rich fuels (e.g. fuel bed temperature control, moving grate systems…);
- Optimization of DHC systems taking into account fuel flexibility;
- Improved understanding of flow properties for solid biofuels, e.g. to avoid obstruction in conveyors or blockage in silos;
- Development of quick, improved fuel analysis methods;
- Active control of fuel quality before feeding into the boiler;
- On-line detection and removal of harmful impurities causing reduced availability of fuel feed into the boiler;
- Combustion optimization and monitoring for biomass boilers; reduced deposit formation and corrosion issues and emission minimisation;
- Process adaptations to produce harmless, valuable residues from combustion and biogas, including nutrient cycles (ash to fertilizer);
- Development of protective coatings and improved materials for boiler construction;
- Development of additives for deposit and corrosion control.

6.3 Efficiency and emissions

Stoves, cookers and fireplaces

There is a tremendous stock of stoves, cookers and fireplaces throughout Europe with excellent and continuous sales figures and this is not expected to change in the future. Commonly used fuels are high quality log wood, wood and bark briquettes and wood pellets. The major drawback for these appliances is their comparatively high emissions and significant contribution to PM concentration in ambient air as well as the low efficiency of some the technologies summarized under the term stoves, cookers and fireplaces. This imposes the need of substantial improvements in the design of the systems in order to achieve high efficient and clean combustion and to widely eliminate user influence.

By 2020, open fireplaces should no longer be sold in densely populated areas in Europe and should be fully substituted by closed fireplaces and chimney inserts to fulfil air quality and efficiency requirements. Substantially new combustion concepts for log wood stoves, chimney inserts and cookers therefore need to be developed and a growing number of log wood fired stoves, cookers and fireplaces will be equipped with secondary measures for emission reduction. Pellet fired stoves will almost perform like pellet boilers in terms of emissions and efficiency. Insulation materials with catalytic surfaces need to be developed to support combustion quality. Slow heat release stoves and inserts should be further developed and new heat storing materials and concepts should be an option to resolve the decreasing energy demand of buildings. Stoves with water heat exchangers will be an established technology.

By 2030 and beyond, user influence will be widely eliminated and stoves, cookers and inserts will perform almost like boilers in terms of efficiency and emissions, whilst maintaining lifestyle and well-being aspects for the users.

Boilers

Log wood, wood chips and wood pellet boilers are widely mature technologies, marketed throughout Europe. Key objectives for technological advancements should be improved real life behaviour in order to close the gap between testing efficiencies (up to >90%) and real life (annual) efficiency (70% and less). This mostly requires improved technology design, including control concepts, as well as improved system design. Wood chips and non-wood pellet boilers will require secondary measures for emission reduction (PM and NO_x) to handle higher emitting fuels, whilst fulfilling the strictest air quality requirements.

By 2020 automatically stoked biomass boiler systems should be characterized by intelligent load control designs. This imposes smart load control concepts on the technology side as well as smart system design and system integration, including – where appropriate – new heat storing concepts and a widely diffused combination with solar thermal technology. Moreover, advancements in material sciences will lead to the reduction of costs for condensing biomass boiler technologies whilst maintaining the reliability of operation and life time of the condensation heat exchangers.

By 2020 advanced primary measures for PM reduction, such as extreme air staging combined with fuel bed temperature control should be developed. Moreover, cost effective and reliable secondary measures (electrostatic precipitators, bag house filters from various filter materials) should be available for combustion of class B wood pellets, of non-wood pellets and of wood chips, mostly for technologies of a nominal load of 50 to 500 kW thermal. For economic reasons, the marketing of such secondary technology should only be necessary in areas of high PM concentrations in ambient air. In general, high PM concentrations in ambient air should be resolved by a mix of high and challenging fuel quality requirements with combustion technology quality requirements. Only in case both of these measures do not provide the required impact, secondary measures will be addressed.

From 2030 onwards the gap between product testing efficiency and real life (annual) efficiency will decrease. Annual efficiencies of >85% should be the state of the art for biomass based central heating systems.

Overall a strong focus on system requirements and building integration is required in order to address the changing heat demand in the building sector. On the integration side, system combinations with solar thermal technology and with building infrastructure will be substantial for the further success of biomass based heating solutions.

Small and micro scale combined heat and power (CHP) production

Small and micro scale CHP constitutes a high energy efficient solution (global thermal, including electric, efficiency > 85% scale) for flexible bio-electricity supply. Electricity is produced when most needed (peak consumption) and electricity losses in transportation are avoided. Direct combustion based micro scale cogeneration systems are available on the market in Europe. These systems exist for liquid biofuels (diesel engines) and for biogas (gas Otto engines and micro gas turbines). Solid state technologies, such as thermoelectrics, are the most promising technologies for nominal electric loads <1 kW. Steam cycle and Stirling engine technologies are currently under development for the electric power range of 1-5 kW. Several technologies, including steam engines, Stirling engines, ORC, externally fired gas turbines, and gas engines – the latter coupled with a staged gasifier – are under development for electric power up to 100 kW.

By 2020 several concepts of micro CHPs (steam cycle and Stirling engine) and small scale CHPs (staged gasification with gas engine) should have proven concept and first generation technologies should have undergone commercial demonstration.

By 2030 thermoelectric material combinations with doubled electric efficiency should be developed. The second generation of small and micro CHPs should become available. These are characterized by improved availability, reliability and cost effectiveness.

Biomass based thermal cooling technologies

Biomass based thermal cooling technologies, for use at residential scale, are not available yet. This topic is widely dealt with in the cross-cutting panel of the RHC-Platform.

Horizontal measures

Steady state standard testing procedures have strongly and efficiently supported technology development and comparability of the performance of products and technologies. Meanwhile, these procedures allow only little differentiation between tested products. The real differentiation, which is real life performance, is only poorly addressed by the existing standards.

By 2020 new testing procedures should be available to assess real life behaviour of boilers and stoves (including inserts and cookers). Testing procedures for small and micro scale CHPs should also be developed.

Residential heating and cooling – key performance data of pellets and log wood stoves (and cookers)[21]

	TODAY	2020	2030	BEYOND 2030
Testing efficiency (%) **Log wood stove (EN 13240)** **Pellet stove (EN 14785**	81 93	86 93	90 93	90 93
Real life efficiency (%)[22] **Log wood stove** **Pellet stove**	72 88	75 90	80 92	85 93
CO [mg/MJ][23] **Log wood stove during testing,** **and in real life**	703 4463	275 3000	110 1100	100 700
Pellet stove during testing, **and in real life**	50 500	25 265	25 120	25 25
OGC [mg/MJ] **Log wood stove during testing,** **and in real life**	46 664	15 350	10 80	5 30
Pellet stove during testing, **and in real life**	5 40	2 20	2 6	2 2
DUST [mg/MJ] **Log wood stove during testing,** **and in real life**	28 148	10 100	10 60	10 30
Pellet stove during testing, **and in real life**	15 60	12 30	10 10	10/5[24] 10/5

[21] Emission and efficiency data taken from the projects „Neue Öfen 2020" (FFG No: 818948) and „BioHeatLabel" (FFG No: 818950)

[22] Real life efficiency refers to annual or seasonal efficiencies. If approximated with testing procedures this should be comparable to load cycle tests common in automotive industry.

[23] Emission values are given in mg/MJ in order not to have to relate these values to different reference oxygen values as given in different standards and different national legal requirements.

[24] Only achievable with secondary measures

Residential heating and cooling – key performance data of central heating boilers[25,26]

	TODAY	2020	2030	BEYOND 2030
Boiler Efficiency / Conversion Efficiency (%)	>90% (full load) >85% (part load)	>92% (full load)[27] >88% (part load)[28]	>95% (full load) >91% (part load)	>100% (condens. boiler, full load) >95% (c.b. part load)
Annual auxiliary energy demand (%) (fuel transport and feeding, automatic ignition, boiler control, heat distribution)	3%	2%	1.5%	<1%
Annual Efficiency (%)	75%	82%	86%	90%
Electric Efficiency (%) of cogeneration systems	Based on solid state technologies (eg Thermoelectrics): Based on thermodynamic cycles (steam, Stirling, organic, ...):	2% 7%	4% 8%	5% 9%
CO [mg/MJ] **Wood fuels only**	For manually stoked boilers: 100 For automatically stoked boilers: 50	70 20	30 10	20 Close to 0
OGC [mg/MJ] **Wood fuels only**	For manually stoked boilers: 5 For automatically stoked boilers: 3	3 2	1 1	Close to 0 Close to 0
DUST [mg/MJ] **Wood fuels only**	For manually stoked boilers: 15 For automatically stoked boilers: 10	12 8	9 6	6 4

[25] As covered by the technologies tested under EN 303-5.

[26] NOx emissions are not considered as these mostly depend on the N-content of the fuels with only limited technology related reduction potential.

[27] Increase of efficiency due to growing diffusion of condensing boilers.

[28] For boilers with less than 10 kW nominal power, 88% boiler efficiency at part load is likely to be the maximum, which can be achieved, except for condensing boiler technology.

[29] Annual or seasonal efficiency refers to field efficiency. If approximated with testing procedures this should be comparable to load cycle tests common in automotive industry.

Industrial heating and cooling

District Heating and Cooling (DHC) networks will be largely developed, even in rural villages. Existing DHC networks will be adapted to energy efficiency improvements in buildings and climate change requirements. Heat distribution networks will be designed with an effective life span of 40-50 years and very low efficiency losses in terms of tubes insulation to guarantee the profitability of investments.

Co-generation as well as tri-generation (heat-power-cold) are very interesting concepts, both for industry and DHC networks. Due to the rule of decreasing specific investment with increasing unit size, such operational and technical efforts can be better handled in larger units which typically supply their energy to domestic heat consumers combined in a heating grid or to larger singular heat consumers in the industry.

Efficiency measures will lead to a maximum industrial waste heat recovery. In 2020, units will be able to use a bigger portion of industrial by-products and residues, out of which 30% will be used for energy recovery. Currently, almost all of the produced residues are landfilled or used in an uncontrolled manner. It is expected that only 10% of these solid residues will be landfilled by 2020, while 50% will be reused. In 2030, over 60% of industrial by-products and residues will be recovered for energy. In 2030, more than 80% of solid residues will be re-used and less than 5% will be landfilled. No residues will be landfilled in 2050.

Substantial technological achievements will lead to increased boiler/conversion efficiencies, reaching up to 100% in 2020. In 2030, boilers with enhanced plant control and conversion efficiency will be developed and demonstrated.

Emission thresholds will become increasingly stringent and significant progress will have to be achieved in this field. In 2020, limit values for boiler emissions will be reduced from 200 mg/ m^3_N to 100 mg/m^3_N for CO, from 100 mg/ m^3_N to 75 mg/ m^3_N for NOx and from 100 mg/ m^3_N to 50 mg/ m^3_N for dust. Emission limit values for CO, NOx and dust will be further lowered by 2030. In 2050, emission limit values for CO, NOx and dust will be below 10 mg/ m^3_N.

Biomass units normally operate today for 7,000 hours/year or at 80% operational availability. A 10% increase is projected for 2020, which corresponds to about 7,900 hours/year. In 2030, operational availability will be higher than 8,000 hours/year, while facilities of up to 20 MWth will be standardised.

By 2030, bio-CCS (Bioenergy Carbon Capture and Storage) and soil additives from char fractions or carbonized biomass residues will add to carbon negative heating systems. Reduced residential heat demand enhances the potential for carbon negative heating systems with carbon soil deposition. Currently, a lack of incentives in the ETS is holding back the development of Bio-CCS projects. Co-firing and bioethanol the production are currently identified as the most promising options for Bio-CCS. Bio-CCS in small scale units faces several challenges, in terms of economy to deployment. Research on this topic should include the analysis of bioenergy incentive systems in the EU in view of realizing economic assessments for Bio-CCS in co-firing and dedicated biomass combustion. BECCS with chemical looping is identified as very promising technology for dedicated biomass units.

These objectives are summarized in the table below.

Industrial heating and cooling

	TODAY	2020	2030	BEYOND 2030
Energy recovery on biomass based industrial by-products	5% identification of by-products and (alternative) energy ways of valorisation	30% identification of by-products and (alternative) energy ways of valorisation	60% identification of by-products and (alternative) energy ways of implementation	100% identification of by-products and (alternative) energy ways of implementation
Boiler Efficiency / Conversion Efficiency (%)	85%	Condensing boiler 100%	104%	106%
Emissions (CO-NO$_N$)[31]	200-150 mg/m^3_N	100-75 mg/m^3_N	50-75 mg/m^3_N	<10mg/m^3_N
Emissions (Dust)	100 mg/m^3_N	50 mg/m^3_N	30 mg/m^3_N	<10 mg/m^3_N
Solid Residues re-use	100% landfilled or uncontrolled reuse	10% landfilled 50% controlled reuse	5% landfilled 80% controlled reuse	0% landfilled All utilized

[25] Emission limit values are meant to be give an indicative figure. In reality, limit values often vary depending on the plants, the location, the boiler size and year of construction

Research priorities

Development and demonstration of lowest emission and highest efficiency fire wood stoves (and chimney inserts and cookers)

- New combustion concepts for fire wood stoves
- New heat storing and slow heat release concepts
  - Material development
  - System development
- Reliable and cost effective secondary measures for emission control

Development and demonstration of lowest emission and highest efficiency residential biomass heating systems

- Advanced combustion concepts for lowest emission performance, such as extremely staged combustion and fuel bed temperature control
- Intelligent control concepts including advanced sensor technologies and sensor systems
- New heat storing and slow heat release concepts
  - Material development
  - System development
- Reliable and cost-effective secondary measures for
  - Flue gas condensation
  - Emission control
- Advanced system design including a variety of advanced single components and integrated technologies tailored for existing building stock, refurbishment markets, and the new building sector
  - Optimum integration with building infrastructure (chimney, ventilation)
  - Hybrid systems
    - With solarthermal as state of the art in 2020
    - Integrated HVAC solutions

Development and demonstration of cost-effective micro-CHP

- Component and system development
- New technologies based on
  - thermodynamic cycles such as ORC, steam cycles, Stirling engine
  - solid state cogeneration technologies, such as thermoelectrics (including material R&D)
- Biogas burners and internal combustion engines, fuel cells
- Advanced implementation concepts and business models for market penetration

Development and demonstration of small scale gasification systems

- Component and system optimisation for wood based fuels
- Advanced technology development and demonstration for ash rich biogenic non wood fuels
- Advanced concepts for gas motors optimisation for tar free wood gas; and gas from biogenic non wood fuels
- Implementation concepts and business models for market penetration

Development of high efficient biomass conversion systems to tri-generation (heating, cooling and power)

- Optimization and “standardization” of the cycle process to meet optimal heating and cooling temperatures with maximal electricity production
- Development of combinations with industrial heat demand and simultaneous cooling

Development of highly efficient large-scale or industrial CHP with enhanced availability and increased high temperature heat potential

- High efficient steam CHP-plant with enhanced steam parameters (e.g. up to 600°C steam), cycle optimization, wide load ranges
- Identification of optimal gasification conditions for different biomass fuels, elimination of hot spots for downtimes, demonstration of reliable operation of gasification CHP
- Development of energy-efficient and cost effective technologies for biogas upgrade and efficient/intelligent gas distribution
- Inclusion of additives in waste incineration boilers

Development of CO_2-negative bioenergy systems

- CO_2 capture and storage/reuse from bio-energy systems
- Soil improving bio-char carbon sequestration from fractions or residues of biomass (Terra Preta)
- Biomass CCS (CO_2 capture ready, CO_2 utilization, carbon deposition in soil and soil improvement)

6.4 Integrated concepts and predictive management

Adequacy between energy demand and production should be reached, which will give biomass a special value as it can be used for peak load and participate in load regulation. Peak load electricity could be covered by flexible biogas production/storage and gasification units. Co and trigeneration systems are also available for grid independent operation and for electricity production during peak consumption. Regional concepts have to be developed, creating solutions which fit the potentials of regions in terms of demand and supply and intelligent, efficient and economic solutions have to be identified to match supply and needs.

Integration with other renewable energy sources should cover fluctuation in loads of heat, cooling and electricity. Biomass boilers and stoves are very well suited to back up solar thermal hot water and heat production. Hybrid systems solar/biomass combine solar thermal technologies in summer for sanitary hot water while biomass constitutes the main heat source during the rest of the year for hot water and space heating.

To cope with the future energy fluctuations, smart grids have to be introduced - also for heating and cooling - which are able to manage multiple heat sources besides biomass and level load peaks with heat storage and peak load CHP. Smart heating and cooling grids are essential to manage different renewable energies in a combined intelligent system, delivering energy at the appropriate time and for the appropriate use. In 2030, smart energy exchange networks with optimal resource allocation of low carbon energy sources will prevail. In 2050, smart heating and cooling grids based exclusively on the CHP mode will operate. Fully carbon neutral energy solutions through regional and integrated networks will cover the demand.

TODAY	2020	2030	Beyond 2030
90% of networks are only used to transmit energy - pure vector	20% of the production will be dissociated from the energy demand and networks will have to manage multiple sources	50% of the production will be dissociated from the energy demand and networks will have to manage multiple sources	100% (smart heat and cooling grid)

Research priorities

Development of hybrid systems

- Combination with other heat production technologies (e.g. solar and geothermal)
- Adsorption and absorption based cycles
- System design of central heating systems

Development of regional concepts

- Integration with other heat sources (renewables, waste heat)
- Development of intelligent, efficient and economic solutions to match regional supply and needs (ex: smart grid…)

Development of enhanced concepts for co-utilization – biorefineries

- Combination of CHP with biofuels production (DME, Ethanol…)
- Integration of by-product utilization with biomass production and energy systems (separate utilization of valuable ingredients …)

Predictive management of energy flows

- Efficient planning and decision making of optimal biomass utilization
- Quick load flexibility to balance fluctuations from wind, solar integration

Development of heat storage technology

- Scalable heat storage concepts (e.g. heat batteries – similar to the concept of DLR)

6.5 Sustainability

With the increased use of bioenergy, sustainability criteria will progressively be implemented to maximise benefits and ensure confidence of the public.

An increasing production of biomass in agriculture and forestry and the mobilization, conversion and use of by-products and wastes should be done in a sustainable way, considering the environmental, social and economic aspects (Figure 10). Sustainability of biomass for heating and cooling should consider the whole chain, from biomass production and supply to conversion, use and ash utility. Economic sustainability is necessary for market success and social factors include the creation of jobs in production areas and access to biomass and bioenergy. Considering the increasing world population and the competition for biomass between different sectors, such as food production, pulp and paper or biofuels, pressure on land will inevitably increase. In order not to damage biodiversity, areas for nature and wildlife protection will have to be preserved and biomass should be cultivated in new, sustainable and diverse ways. Sustainable land use management will become a crucial issue. Best practice has to be studied in view of identifying the proper use of biomass as a limited natural resource.

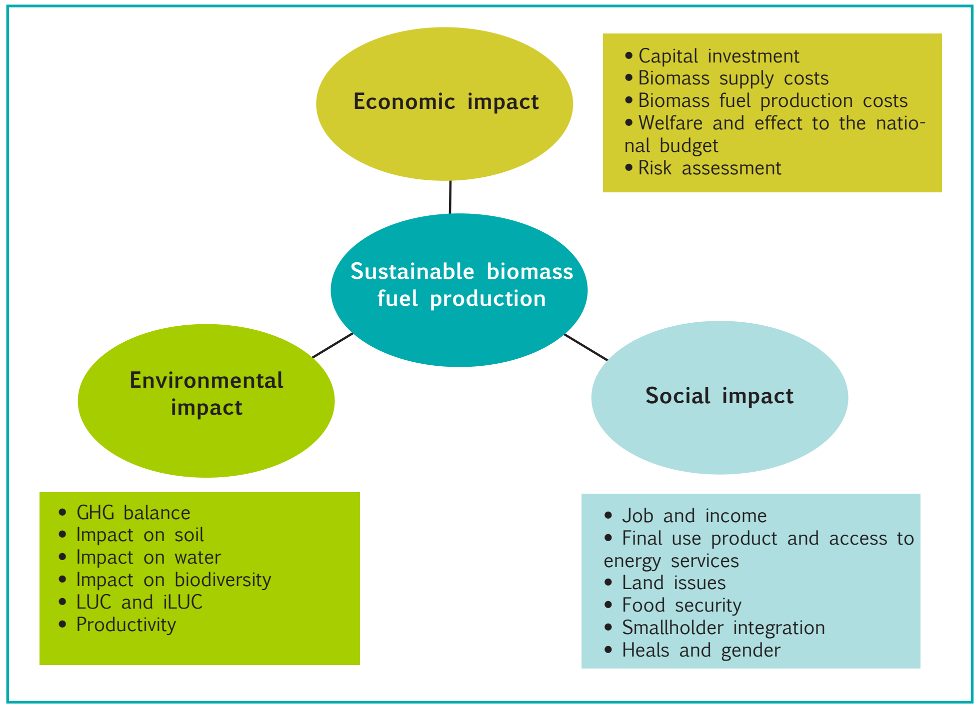

Figure 10 - Diagrammatic visualization of sustainability of biomass feedstock production with a wide range of potential environmental, economic and social impacts (IEA, 2010)[32]

Soil fertility constitutes a very important indicator; management changes in agriculture as well forestry may positively or negatively influence soil quality and the amount of carbon stored in the soil. The conservation of soil and its organic fraction is a very important factor, which may limit intense land use for bioenergy purposes in the future or even residue utilization from fields and forests. The closing of the nutrient loop via either ash nutrient recovery or direct return of the ash should be considered.

Assuming sustainable raw material production and use, bioenergy will always have sufficiently low CO_2 emissions and fossil energy used for its production, to ensure high CO_2 savings per toe biomass or per hectare land used. With new primary and secondary measures, emissions of dust, hydrocarbons, CO, NOx and heavy metals can in the future be reduced to extremely low values which will not have a significant impact on sustainability.

[32] Martikainen, A, & van Dam, J. Evaluation report on different criteria for sustainability and certification of biomass, and solid, liquid and gaseous biofuels – D4.4.1, November 2010, 44 p.

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The European Commission Report SEC(2010) 65-66 on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling invites Member States to take into account a number of recommendations for sustainability criteria and for reporting and monitoring. In the future, the sector will have to be prepared to address sustainability concerns. Rules for sustainability of heating and cooling from biomass will be developed and integrated into normal practise. Methods to fulfil sustainability requirements in the production, conversion and use of biomass will be improved. Mind that sustainability, in environmental, social and economic terms, will limit the biomass potential. Detailed analysis on local scale will give enhanced clarity on the effective potential and the optimal biomass types, cultivation practices and uses for a given region. A special focus on imports will be needed as the controls on third country agriculture and forestry is more challenging than in the EU.

European Commission Report on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling

In its report SEC(2010) 65-66 on sustainability requirements for the use of solid and gaseous biomass sources in electricity, heating and cooling, the European Commission decided not to propose binding criteria at EU level as the wide variety of biomass feedstock made it difficult to put forward a harmonised scheme and as the sustainability risks relating to domestic biomass production originating from wastes, agricultural and forestry residues are considered low. However, to minimise the risk of the development of varied and possibly incompatible criteria at national level, leading to varying degrees of mitigation, barriers to trade and stifling the growth of the bio energy, the Commission recommends that Member States that either have, or who are in the process of sector introducing national sustainability schemes for solid and gaseous biomass used in electricity, heating and cooling, ensure that the criteria are in almost all respects identical to those laid down in the Renewable Energy Directive. The Commission will report in spring 2012 on whether national schemes have led to barriers to trade and barriers to the development of the bioenergy sector and will consider if additional measures such as common sustainability criteria at EU level would be appropriate.

Research priorities

Development of cost-efficient, sustainable supply chains of forest and agrobiomass

- Sustainability impact assessments and system analysis of different chains;
- Bi-annual sustainable biomass resources assessment studies.

Assessment of the environmental and social impact of biomass production and utilization

- Economic and social impacts assessments on EU and non-EU countries;
- Impact assessments of large-scale bio-resource production on food security, indirect land use change and on small-scale farming;
- Impact assessment of increased biomass utilization on soil quality and soil organic matter content with focus on carbon sequestration/leakage of carbon; drafting of recommendations for improved of soil fertility as well as increased soil carbon.

Development of criteria for biomass transport, storage and handling

- Optimization and harmonization between member states of the requirements and conditions for effective transport, safe handling and storage of biomass, including biological health impacts, in view of increasing sustainability and protecting the environment from negative impacts.

7. Policy support for market deployment

7. Policy support for market deployment

All Member States of the European Union have ambitious renewable energy targets. To reach these targets biomass will have to play a key role. This is why the European Biomass Action Plan recommends establishing biomass strategies on a national level. Support mechanisms for the development of biomass supply chains, including fuel supply and transport, need to be considered by policy-makers targeting biomass-based heating.

The broad and diverse situations regarding non-technological aspects of heating and cooling development with biomass in EU member states require an effort on market and policy deployment as well as on communication and training development. Recommendations to ensure the successful market deployment of RHC technologies are detailed below.

Harmonize administrative procedures

In view of promoting biomass heating and cooling installations in buildings in an efficient way, procedures have to be harmonized in all member states at administrative level, in order to make the establishment of a biomass boiler as simple as possible. Policy and permission requirements for the construction of biomass plants vary greatly and proper understanding of these differences is necessary. Permission processes in individual member states need to respect transparency and ensure cost effective and dynamic developments.

Create "smart" support schemes to promote the implementation of a CO_2 tax and to balance incentives for heating and electricity production with biomass

Historically, in most countries, renewable heating has not received as much policy support as renewable electricity or biofuels for transport. This disparity is, at least in part, due to a lack of legislative tools and policies to support the market development of specific heating and cooling technologies. Policy support and communication with the public for the promotion of bioenergy for heating and cooling has to be adaptd to local circumstances in each starting country. Local conditions in some of the starting countries are not adequate for traditional supporting schemes and the adoption of possible alternative solutions needs to be studied.

Assess the economic and social impact of different supporting bioenergy schemes, interactions between biomass and energy subsectors in a regulated market

Supporting schemes are frequently focused on particular subsectors and research is needed to determine the influence of the support to the biomass heating and cooling subsector on other energy subsectors competing for the same fuel source (with different level of support). Research focused on RHC supporting schemes and their influence on macro economical parameters such as the price of electricity or heat, taxes and state budget expenditure needs to be carried out. The understanding of conflicts between different goals for bioenergy use, i.e. climate change mitigation, energy security, rural development… should be increased. Solutions providing low financial impacts and high motivation for investors and users of RHC should be identified and balanced support avoiding social and economic negative impacts on the market should be achieved.

Create realistic National Renewable Energy Action Plans with clear guidelines and accurate indicators to measure the success of implementation

Solid National Renewable Energy Action Plans, comprising a clear strategy for the promotion of RHC with biomass, are absolutely essential. Simple indicators should be developed to measure the achievement of the projected targets.

Create a stable regulatory framework to give confidence to investors, promoters and financial entities

Financial entities need a convincing climax on political level to commit to bioenergy and to understand the links between biomass producers and energy producers.

Enhance positive communication of the benefits related to RHC with biomass, at social and political level

The benefits of heating and cooling with biomass need to be communicated in a proper and harmonized way, in order to bring the topic to the top of political discussions. The horizontality of biomass provides local benefits and the impact of heating and cooling with biomass needs to be measured and benchmarked among member states.

Potential customers should be identified and "tailor made" communication provided for each, at domestic and industrial level. Each member state has a different educational system as regards energy and particularly biomass for heating and cooling. Optimal transfer of knowledge, with focus on renewable energy (especially biomass for heating and cooling), has to be achieved in view of harmonizing the general public's understanding and for awareness. The social acceptance of large-scale bioenergy systems should be better understood.

Enhanced communication with actors in the supply chain, such as biomass producers, is also essential. Close cooperation should for example be established with farmers' representatives, at local, national and EU level. Past experiences have revealed that support from farmers' representatives is absolutely necessary to promote energy crops production.

Create specific training in RHC with biomass for engineering, installation, operation and maintenance, taking into account the integration with other renewable energy sources

Training programmes in Europe need to be increased significantly, not only at university level, but also professional level. Professional training should fulfil the needs of the biomass based heating and cooling industry. For residential heating and cooling, the influence of poorly trained operators can be reduced through improved operating manuals, operator trainings and public campaigns. Knowledge and skills are frequent barriers for biomass growth particularly in small applications. Potential of labour force has to be deeply studied to optimize education and requalification of employees and vocational training.

2020	2030	Beyond 2030
• Certified training courses for installers of residential heating and cooling systems in all European Member States • Suitable integration of biomass for heating and cooling in graduate, post-graduate, life-long, and professional training on European level • Recognized and practical standards for most aspects of current bioenergy supply chains • Competitiveness of heating from biomass with heating from any fossil fuel in all member states without additional subsidies; recognition of bioenergy as standard technology for heat production in new buildings and after refurbishments • Establishment of suitable schemes for biomass based heating and cooling, ensuring sustainability and public acceptance	• "One stop shop" administrative procedure required for the establishment of a biomass heating and cooling system	• Administrative cost related to the establishment of heating and cooling systems reduced by half

8. Outlook on implementation

8. Outlook on implementation

After the identification of the major R&D needs for biomass based heating and cooling development in Europe, the RHC-Platform Biomass Panel will enter an implementation phase in which research priorities will have to be further fine-tuned and appropriate funding instrument identified. This Chapter provides an outlook on upcoming activities by outlining the main EU funding tools as well as a limited number of research priorities to be focused on for implementation.

The European Strategic Energy Technology Plan (SET- Plan) – intended by the European Commission to accelerate the deployment of low-carbon energy technologies – recognises the essential role of renewable energy sources for heating and cooling as part of the EU's strategy to improve the security of energy supply and to create markets for highly innovative technologies which are useful to society and led by European industry.

Implementation of the SET-Plan started with the establishment of the European Industrial Initiatives (EIIs) which bring together industry, the research community, the Member States and the Commission in risk-sharing, public-private partnerships aimed at the rapid development of key energy technologies at European level. The European Industrial Initiative "Smart Cities and Regions", already included in the SET-Plan, aims at positioning committed cities and regions at the forefront of the development of the low carbon economy. For the renewable heating and cooling (RHC) industries, this initiative represents a unique opportunity for deploying large scale innovative renewable heat solutions.

In the short term, the FP7 Energy Work Programme (running from 2007 to 2013) is the main instrument at disposal of the European Commission to support the implementation of the SET-Plan. The research priorities developed by the RHC-Platform can give a direct input to priorities for new calls, both for FP7 and the following Framework programme Horizon 2020.

NER300, launched by the European Commission, is the world's largest demonstration programme for low-carbon technologies, which will act as a catalyst for the demonstration of new low carbon technologies on a commercial scale. NER300 offers co-financing opportunities for CCS and innovative renewables demonstration projects. This will contribute to ensuring RHC technologies will achieve market penetration.

The SET-Plan is the technology pillar of the EU's energy and climate policy

The European Strategic Energy Technology Plan (SET-Plan), adopted by the European Union in 2008, is the principal decision-making support tool for European energy policy to accelerate the development and deployment of cost-effective low carbon technologies. The main goals of the SET-Plan are accelerating knowledge development, technology transfer and up-take; maintaining EU industrial leadership on low-carbon energy technologies; fostering science for transforming energy technologies and contributing to the worldwide transition to a low carbon economy by 2050.
For 2020, the SET-Plan provides a framework to accelerate the development and deployment of cost-effective low carbon technologies, in view of reaching the EU's 20-20-20 goals (20% reduction of CO_2 emissions, a 20% share of energy from low-carbon energy sources and 20% reduction in the use of primary energy by improving energy efficiency by 2020). For 2050, the SET-Plan is targeted at limiting climate change to a global temperature rise of no more than 2°C, in particular by matching the vision to reduce EU greenhouse gas emissions by 80 - 95%.

European Industrial Initiative on Smart Cities[33]

The European Industrial Initiative on Smart Cities will foster the dissemination throughout Europe of the most efficient models and strategies to progress towards a low carbon future by triggering a sufficient take-up (reaching 5% of the EU population) of energy efficient and low carbon technologies, by reducing greenhouse gas emissions[34] of 40% by 2020; and by effectively spreading across Europe best practices of sustainable energy concepts at local level, for instance through the Covenant of Majors. This Initiative will support cities and regions in taking ambitious and pioneering measures to progress by 2020 towards a 40% reduction of greenhouse gas emissions through sustainable use and production of energy. This will require systemic approaches and organisational innovation, encompassing energy efficiency, low carbon technologies and the smart management of supply and demand. Heating and cooling holds a special place and is expected to deliver innovative and cost effective biomass, solar thermal and geothermal applications; innovative hybrid heating and cooling systems from biomass, solar thermal, ambient thermal and geothermal with advanced distributed heat storage technologies, highly efficient co- or tri-generation, district heating and cooling systems.

[33] http://setis.ec.europa.eu/about-setis/technology-roadmap/european-initiative-on-smart-cities

[34] Reference year 1990

Seventh Framework Programme[35] (FP7)

The Seventh Framework Programme (FP7) bundles all research-related EU initiatives together under a common roof playing a crucial role in reaching the goals of growth, competitiveness and employment; along with a new Competitiveness and Innovation Framework Programme (CIP), Education and Training programmes, and Structural and Cohesion Funds for regional convergence and competitiveness. It is also a key pillar for the European Research Area (ERA). The broad objectives of FP7 have been grouped into four categories: Cooperation, Ideas, People and Capacities. For each type of objective, there is a specific programme corresponding to the main areas of EU research policy. All specific programmes work together to promote and encourage the creation of European poles of (scientific) excellence.

Horizon 2020 – the post 2013 Framework Programme for Research and Innovation[36]

The proposed Framework Programme for Research and Innovation Horizon 2020, which will be introduced post-2013, will build upon the successes of the current Framework Programme for Research (FP7), the Competitiveness and Innovation Framework Programme (CIP) and the European Institute of Innovation and Technology (EIT). The ultimate aim is to maximise the contribution of EU funded research and innovation to sustainable growth and jobs and to tackle the grand challenges facing Europe – for example climate change, energy and food security, health and the ageing population. Investment in research and innovation in the next seven years will be significantly increased. The European Commission has increased energy research funding going to non-nuclear energy in Horizon 2020 to about 6 billion €.

The next step of the RHC-Platform Biomass Panel consists in the elaboration of an implementation plan in collaboration with industries willing to take part in the process. As feedstock availability as well as economic and political frameworks are just as important as the proper development of processing technologies at industrial level, implementation will be carried out on complete integrated "value chains", from feedstock to end product. Performance demonstration of processing technologies should be carried out over entire chains to ensure successful implementation and commercial large scale deployment. The high investment costs and requirements in terms of biomass feedstock related to the implementation of the identified bio-heating and cooling value chains justifies the need for cooperation on EU level. In this view, the following innovative biomass based heating and cooling value chains have been identified combining the most urgent research priorities. These innovative bioenergy value chains will form a base for upcoming implementation activities of the RHC-Platform Biomass Panel.

- **Small scale CHP for domestic, industrial or regional solutions**
Feedstock: High quality biomass feedstock; biogas, solid or liquid biomass for combustion and gasification
Technologies: Combustion, gasification, fuel cells

- **Tri-generation**
Feedstock: High quality biomass feedstock; biogas, solid or liquid biomass for combustion and gasification
Technologies: Combustion, gasification, fuel cells

- **Advanced fuels (new solid biocommodities, thermally treated biomass fuels, pyrolysis oil) replacing coal and fossil oil in CHP**
Feedstock: All biomass, but especially agrobiomass and forest residues
Technologies: Torrefaction process, biocarbonisation, biogas upgrading or other thermal treatments, combustion or gasification tests of advanced biomass in large CHP boilers or industrial CHP, pyrolysis oil and other oil production, burner combustion technology

- **High efficient large-scale or industrial steam CHP with enhanced availability and increased high temperature heat potential (up to 600°C)**
Feedstock: Biogas and solid biomass
Technologies: Combustion and gasification

- **Demonstration of optimised and integrated regional concepts (including smart grids) in several European countries**
Cooperation with other renewable energy technologies in the heating and cooling sector and other energy sectors (electricity, transport...)

[35] http://ec.europa.eu/energy/technology/set_plan/set_plan_en.htm

[36] http://ec.europa.eu/research/horizon2020/index_en.cfm?pg=home

9. Supporting organisations

9. Supporting organisations

Close collaboration with industry is key in defining strategic research topics for renewable heating and cooling with biomass in order to ensure concrete industrial priorities and realities are appropriately reflected. Supporting organizations represented in this section have demonstrated support to this publication, by reviewing the document thoroughly and giving valuable input. Please mind that this publication is a production of the RHC-Platform and therefore all RHC-Platform members support the content of this document.

AEMA S.L
www.aemaenergia.es

Andritz
www.andritz.com

Ariterm
www.ariterm.se

Bioenergy 2020+
www.bioenergy2020.eu

Bioplat
www.bioplat.org

Centre for Research & Technology Hellas
www.certh.gr

Elforsk AB
www.elforsk.se

EnBW Energie Baden-Württemberg AG
www.enbw.com

FUNDACIÓN CIDAUT
www.cidaut.es

Helector S.A.
www.helector.gr

HKI Industrieverband
www.hki-online.de

Institute for Solid Fuels Technology & Applications
www.isfta.gr

JAMK University of Applied Sciences
www.jamk.fi

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KWB
www.kwb.at

MW Biopower Oy
www.mwpower.fi

Orientación Sur Consultoría SL
www.orientacionsur.es

Polish Technology Platform for Biofuels
www.pimot.org.pl

SATIS RENOVABLES S.L.
www.satisrenovables.com

Schiedel GmbH & Co. KG
www.schiedel.de

SINTEF Energy Research A.S.

SP Technical Research Institute of Sweden
www.sp.se

STEAG New Energies GmbH
www.steag-newenergies.com

Vapo Oy
www.vapo.fi

Värmeforsk
www.varmeforsk.se

VTT Technical Research Centre of Finland
www.vtt.fi

WIP Renewable Energies
www.wip-munich.de

Appendix 1:
Terms and abreviations

CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
CHP-C	Combined Heat, Power and Cooling (tri-generation)
DHC	District Heating and Cooling
ETP	European Technology Platform
ETS	Emission Trading Scheme
ERA	European Research Area
EU	European Union
GHG	Greenhouse gas
HVAC	Heating, Ventilation and Air-conditioning
MSW	Municipal Solid Waste
OGC	Organic Gaseous Carbon
ORC	Organic Rankine Cycle
PM	Particulate matter
RED	Renewable energy Directive (2009/28/EC)
RES	Renewable energy source
RHC	Renewable Heating and Cooling
SET-PLAN	Strategic Energy Technology Plan
SRF	Solid Recovered Fuel
TOE	Ton Oil Equivalent

Appendix 2:
Glossary of definitions

• **Agricultural residues** (EN 14588:2011)
biomass residues originating from production, harvesting, and processing in farm areas[37]

• **Agrofuels** (EN 14588:2011)
biofuels obtained as a product of energy crops and/or agricultural residues[38]

• **Bioenergy**
quantity and energy content of biomass feedstocks prior to conversion to other energy forms (e.g. electricity, heat) or upgrading bioenergy carriers (e.g. biogas)

• **Biogas** (Eurostat)
gas composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass

- landfill gas: formed by the digestion of landfilled waste;. the quantity of fuel used should be reported on a net calorific value basis
- sewage sludge gas: produced from the anaerobic fermentation of sewage sludge; the quantity of fuel used should be reported on a net calorific value basis
- other biogas: such as biogas produced from the anaerobic fermentation of animal slurries and of waste in abattoirs, breweries and other agro-food industries; the quantity of fuel used should be reported on a net calorific value basis

• **Biomass residues** (Source: EN 14588:2011)
biomass originating from well defined side-streams from agricultural, forestry and related industrial operations[39]

• **Distribution losses** (Eurostat)
all losses which occur due to transport and distribution

• **Energy crops, fuel crops** (EN 14588:2011)
woody or herbaceous crops grown specifically for their fuel value[40]

• **Gross Inland consumption** (Eurostat)
primary production plus imports, recovered products and stock change, less exports and fuel supply to maritime bunkers (for seagoing ships of all flags); reflects the energy necessary to satisfy inland consumption within the limits of national territory.

• **Final Energy Consumption** (Eurostat)
includes all energy delivered to the final consumer's door (in the industry, transport, households and other sectors) for all energy uses. It excludes deliveries for transformation and/or own use of the energy producing industries, as well as network losses

• **Firewood** (EN 14588:2011)
cut and split oven-ready fuelwood used in household wood burning appliances like stoves, fireplaces and central heating systems. Firewood usually has a uniform length, typically in the range of 15 cm to 100 cm

[37] See also crop production residues in EN 14588:2011

[38] Adapted from FAO unified bioenergy terminology (UBET) [10]

[39] Adapted from the proposal within the Draft CEN Report Solid Recovered Fuels [11]

[40] See also energy forest trees, energy grass, energy plantation trees in EN 14588:2011

• **Forest fuels** (EN 14588:2011)
wood fuel produced where the raw material has not previously had another use. Forest fuel is produced directly from forest wood by a mechanical process

• **Industrial Heating and Cooling**
systems for covering the heating and cooling demands of the industrial sector.Typical capacities 1 MWth – 300 MWth or higher

• **Liquid Biofuels** (Eurostat)

- Biogasoline: includes bioethanol (ethanol produced from biomass and/or the biodegradable fraction of waste), biomethanol (methanol produced from biomass and/or the biodegradable fraction of waste), bioETBE (ethyl-tertio-butyl-ether produced on the basis of bioethanol; the percentage by volume of bioETBE that is calculated as biofuel is 47%) and bioMTBE (methyl-tertio-butyl-ether produced on the basis of biomethanol; the percentage by volume of bioMTBE that is calculated as biofuel is 36%)
- Biodiesels: includes biodiesel (a methyl-ester produced from vegetable or animal oil, of diesel quality), biodimethylether (dimethylether produced from biomass), Fischer Tropsh (Fischer Tropsh produced from biomass), cold pressed biooil (oil produced from oil seed through mechanical processing only) and all other liquid biofuels which are added to, blended with or used straight as transport diesel
- Other Liquid Biofuels: liquid biofuels, used directly as fuel, not included in biogasoline or bio diesels

• **Municipal Waste** (Eurostat)
portion of waste produced by households, industry, hospitals and the tertiary sector which is biodegradable material collected by local authorities and incinerated at specific installations; the quantity of fuel used should be reported on a net calorific value basis

• **Primary biomass production** (Eurostat)
extraction of primary fuels from biomass sources[41]

• **Residential Heating and Cooling**
systems for covering the heating and cooling demands of the residential and/or service sector.Typical capacities 0 – 300 kWth

• **SNG – Synthetic Natural Gas**
a fuel gas of natural gas quality produced via the gasification and subsequent methanation of biomass and/or other solid fuels

• **Solid Biomass** (Eurostat)
covers organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation, comprises:

- charcoal: covers the solid residue of the destructive distillation and pyrolysis of wood and other vegetal material
- wood, wood waste, other solid waste: covers purpose-grown energy crops (poplar, willow etc.), a multitude of woody materials generated by an industrial process (wood/paper industry in particular) or provided directly by forestry and agriculture (firewood, wood chips, bark, sawdust, shavings, chips, black liquor etc.) as well as waste such as straw, rice husks, nut shells, poultry litter, crushed grape dregs etc.; the quantity of fuel used should be reported on a net calorific value basis

[41] Note: Biomass includes organic, non-fossil material of biological origin which may be used as fuel for heat production or electricity generation. Biomass also includes biodegradable waste.

[42] Drying is not considered thermal treatment in this definition (Ex: torrefied biomass, charcoal)

- **Thermally treated biomass** (Source: ISO/CD 16559)

biomass its chemical composition has been changed by heat (usually by temperatures of 200 to 300°C and above)[42]

- **Thinning residues** (Souce: ISO/CD 16559)

woody biomass residues originating from thinning operations

- **Torrefied biomass** (Souce: ISO/CD 16559)

solid biofuel produced by torrefaction of lignocellulosic biomass[43]

- **Transformation Sector** (Eurostat)

report the quantities of renewables and waste used for the conversion of primary forms of energy to secondary (e.g. wind and landfill gases to electricity) or used for the transformation to derived energy products (e.g.: biogas used for blended natural gas)

- **Woody biomass** (EN 14588:2011)

biomass from trees, bushes and shrubs. This definition includes forest and plantation wood and other virgin wood, wood processing industry by-products and residues, and used wood

- **Wood processing industry by-products and residues** (EN 14588:2011)

woody biomass residues originating from the wood processing as well as the pulp and paper industry.

Appendix 3:
Secretariat of the RHC-Platform

This document was prepared by **the Biomass Panel of European Technology Platform on Renewable Heating and Cooling** (RHC-Platform), managed by the European Biomass Association (AEBIOM).

The Secretariat of the European Technology Platform on Renewable Heating and Cooling is coordinated by the European Renewable Energy Research Centres Agency and jointly managed with:

European Biomass Association
European Geothermal Energy Council
European Solar Thermal Industry

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43 Torrefacton is a mild pyrolysis process performed at temperatures between 200 - 300°C in inert atmosphere. Under these conditions, lignocellulosic biomass is altered to an intermediate between wood and charcoal. Torrefied biomass contains typically 60 – 70 % of the initial mass and 90 % of the initial net calorific value. Benefits of torrefied biomass with green biomass are energy densification, homogenization, improved grindability, hydrophobic character and enhanced reactivity

44 See also bark, cork residues, cross-cut ends, edgings, fibreboard residues, fibressludge, grinding dust, particleboard residues, plywood residues, saw dust, slabs, and wood shavings in EN 14588:2011-

Renewable Heating & Cooling
European Technology Platform

Secretariat of the European Technology Platform on Renewable Heating and Cooling

c/o EUREC Agency EEIG
Renewable Energy House
63-67 Rue d'Arlon
B-1040 Brussels - Belgium
Tel: +32 2 546 19 30
Fax: +32 2 546 19 34
info@rhc-platform.org

www.rhc-platform.org