ANCRE
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Decarbonization Wedges Exercise

COMBINED HEAT AND POWER (CHP) PRODUCTION FROM BIOMASS[1]

1. State of the art and current development in different world regions

Technology 1: Combustion followed by water-steam cycle
Power production based on biomass combustion systems is an old and mature technology. Biomass is burnt in a boiler —e.g. stoker or fluidized bed— to produce high-pressure steam that is expanded totally or partially in a steam turbine. At different points of the process, residual thermal energy can be recovered for heat applications —e.g. by extracting steam from the turbine.

Technology 2: Co-firing
Biomass can be also co-fired with coal in an existing coal-fired power plant, especially in large plants that are sometimes not adapted to dedicated biomass combustion because of limited local biomass availability. In direct co-firing, a percentage of biomass is added to the fossil fuel. Thus it is possible to burn up to 5 to 10% of biomass in terms of energy without extensive feedstock pre-treatment nor plant retrofitting. In 'parallel co-firing' configuration, biomass and coal are burnt separately in different boilers.

Technology 3: Gasification followed by syngas combustion
Gasification systems convert biomass by partial oxidation at elevated temperatures to obtain a syngas mainly composed of CO, H_2 and CH_4. The producer gas is then cooled and cleaned before being usually burnt in an internal combustion engine in the case of CHP decentralized production. Conditioning the producer gas —tar removal, etc. — to match the requirements of the gas engine is the main bottleneck for this technology.

2. Maturity level and technological perspectives

Maturity of combined heat and power (CHP) production from biomass

Methodological information:

The maturity level is the TRL, reduced to 5 levels with market deployment enclosed in the higher TRL classes; maturity level scaling: 0 = none; 1 = fundamental research; 2 = R&D; 3 = demonstrator; 4 = low deployment; 5 = large deployment.

	2015	2020	2030	2040	2050
Combustion	5	5	5	5	5
Co-firing	5	5	5	5	5
Gasification	3	4	5	5	5

[1] Sources: EDF internal documentation (on electricity, heat and biofuels); IEA *Technology Roadmap: Bioenergy for Heat and Power*. This IEA document assesses the importance of bioenergy according to geographic location »

Potential development of combined heat and power (CHP) production from biomass

<u>*Methodological information:*</u>

Potential development is measured as the percentage of the technology's contribution to environmental protection. This means evaluating, in terms of carbon emissions and of carbon emissions reduction, to what extent this new technology can contribute to limiting temperature increase to 2°C above pre-industrial level according to the time horizon considered in this study. Potential development scaling: 0 = not significant; 1 = significant (i.e. more than 1% of global emissions reduction) in some countries; 2 = significant on the global scale; 3 = very significant on the global scale (i.e. up to 3% of global emissions reduction); 4 = major technology vs. climate change (i.e. more than 3% of global emissions reduction).

	2020	**2030**	**2040**	**2050**
Combustion	2	3	3	3
Co-firing	1	1	1	1
Gasification	0	1	1	1

Gasification is still at a pre-industrialization level and is not largely deployed yet. The development of processes aimed at reducing costs —e.g. multi-fuel operations, syngas cleaning— will condition the large deployment of this technology for CHP decentralized production.

Co-firing is very dependent on policies. For example Poland, the U.K. and Belgium have stopped financing co-firing plants as they were facing electricity overproduction.

Slight improvements in biomass plant efficiency and performance must be achieved in order to power very large units (> 50 MW). The main issues are sustainability of long-term supply plan and biomass price.

3. Technological, economic and social bottlenecks

<u>*Methodological information:*</u>

The following table ranks the bottlenecks according to their impact on the development of the technology. A bottleneck ranking at 6 on the scale will hinder or stall the deployment of the technology compared with bottlenecks ranking at 1; conversely, a bottleneck ranking at 1 will hinder the deployment of the technology much less than bottlenecks ranking at 6. Note that the ranking is relative, meaning that a bottleneck ranking at 6 is not necessarily hard to remove; conversely, a bottleneck ranking at 1 is not necessarily easy to remove. Technologies rank according to: research, finance, regulations, resources & environment, security and acceptability. The table also contains keywords associated with each bottleneck.

It must be stressed that the ranking of such different factors must be considered with caution; as an expert's judgement, not a quantitative assessment.

Technology		**Research & technological bottlenecks**	**Economy and financial bottlenecks** (investment, risks)	**Regulation & institutional environment**	**Resources & environmental impacts** (including scarcity of raw materials, water, land, climate)	**Safety & security** (impacts on health, people and security assets)	**Socio-technical feasibility**
Combustion	Rank	1	4	6	5	3	2
	Key-words	Corrosion, agglomeration		Uncertain incentives	Biomass supply, sustainable development	Dust and fine particle emissions	
Co-firing	Rank	1	3	5	6	4	2
	Key-words			Uncertain incentives	Biomass supply, sustainable development	Accidental fires, dust emissions	
Gasification	Rank	2	6	3	1	4	5
	Key-words	Tar removal	Hazards and contingencies	Lack of regulatory consistency	Matching of size to local resources	ATEX zone, liquid waste treatment	Acceptability

For all technologies, scarcity of resources and soil depletion are bottlenecks that can be easily tackled if the plant size is adapted to the production of a sustainable and local biomass, without competition with other industries that use biomass.

Investment is high, especially for gasification. Furthermore biomass costs often account for a large part in the levelized cost of electricity. This main feature hinders the financing of projects that come with high risks, especially when compared to other renewable energies. Long-term sustainable supply —regardless of the associated costs— also represents a financial bottleneck.

The size of projects is mainly linked to national policies. For example in France, facility sizes range from rather small to medium and these facilities aim at heat production. In the U.K. several electricity generation projects have been launched. For the time being, Poland favors co-combustion. The regulation bottleneck is crucial as it depends on the sustainability of political guidelines.

Other bottlenecks concerning research for cogeneration are worth mentioning —e.g. improving energetic efficiency.

4. Potential radical and incremental innovations

Methodological information:

The following table lists the nature of innovations needed to overcome the bottlenecks mentioned earlier. There are two types of innovations: I stands for 'incremental innovation' (i.e. improving existing products and processes) and R stands for 'radical innovation' (i.e. developing new products and processes).

Technology		**Research & technological innovations**	**Economy and financial bottlenecks** (investment, risks)	**Regulation & institutional environment**	**Resources & environmental impacts** (including scarcity of raw materials, water, land, climate)	**Safety & security** (impacts on health, people and security assets)	**Socio-technical feasibility**
Combustion	I or R	R	I	R	I	I	I
	Key-words	Technological breakthrough		Incentives			
Co-firing	I or R	R	I	R	I	I	I
	Key-words	Technological breakthrough		Incentives			
Gasification	I or R	R	I	R	I	I	I
	Key-words	Technological breakthrough		Incentives			

Most innovations are being introduced to:

- Simplify and standardize the regulatory framework;
- Clarify sustainability criteria for the use of biomass;
- Optimize the organization of supply chains;
- Finance the development of new conversion technologies to bring down production costs —pre-treatment and conditioning of biomass, plant flexibility, treatment of effluents, gasification.

Securing technological research through research programs over a sufficient period of time —i.e. over five years— is crucial, especially for gasification. These research programs should involve industrial and academic partners —e.g. by joint research chairs. The goal is to speed up the transition from the fundamental and applied research stage to the technological development stage. This will lead to innovative, efficient and competitive solutions.