Decarbonization Wedges Exercise

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GRIDS

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

Technology 1: Smart electricity distribution
There are two key elements to the development of grid technologies:

- Losses reductions:

Line losses range from 4 to 5% —this amounts to 15 TWh per year. If a major part of the production becomes localized and locally managed and consumed, the corresponding electricity on line losses are expected to be reduced, maybe up to 10 or 20 %

- Increased flexibility at distribution level in order to cope with large variable of renewable energy sources (RES):

– *Demand response*: adaptation of demand load curve to the availability of renewable sources — reduction of peak demand, etc.— through smart-meters that will provide differentiated tariff signals or specific contracts with the provider in order to adjust demand automatically;
– *Generation response*, or production limitation: to some extent and with the objective to minimize the loss of an electricity produced at zero marginal cost — mainly variable RES—, the generation can be adapted to the demand. Even nuclear power can be, at least partly — i.e. up to 10-20%—, adapted to the demand;
– *Local storage, Vehicle-to-grid (V2G)*: developing local storage associated with self-consumption possibly using car batteries to support the grid have two main benefits —these techniques can limit the production peak (by absorbing excess variable RES production) and use stored electricity (by re-inject it) to support the grid in case of peak demand.
– *Changes in energy vector*: with this technique at the local distribution grid scale, the change in energy vector is supposed to be essentially towards thermal uses — e.g. electric water heaters— or thermal grids, with the issues linked to seasonal variation of demand varying according to the season. For this thermal storage has to be planned simultaneously;

- Increased knowledge of the state of the grid and improved real time management of the grid:
    - Development of sensors along the lines, intelligent treatment of the data
    - Development of improved anticipation tools of production and demand for a better management of the grid at different time scales
    - Development of anticipative maintenance
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Technology 2: Coupling different energy grids —electricity, cooling/heating and gas grids
The different energy grids should be coupled in order to achieve greater flexibility. This is done by transforming energy from the grid into another form of energy —which might be easier to store according to the demand— from another grid. This process involves the following energy grids;

– Power to heat, heat/cold production (heat pump, cooling machine) and storage, —either in tanks, or in heat/cold networks (by increasing/decreasing the temperature);
– Heat to power: ORC[1], or gas turbine if hot air (> 400°C approximately) or vapor are available;
– Power to gas: H2 by electrolysis and injection of hydrogen in gas grids, or methanation ($H_2 + CO_2 \rightarrow CH_4$) and injection of methane in the gas grid;
– Gas to power: cogeneration at different levels.

[1] ORC: Organic Rankine Cycle

2. Maturity level and technological perspectives

Maturity of grids

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
Distribution	3-4	4-5	4-5	5	5
Coupling	1-2	2-3	3-4	4	5

Smart-meters are currently deploying in some countries. However R&D programs still have to be carried out in order to optimize meters use (demand response, recognizing consumption patterns, etc.).

Using changes in energy vectors for coupling is only implemented in large Northern European cities. There is still research to be carried on : on modeling and simulation systems —which are becoming more complex because of coupling— on developing performant smart-meters - e.g. high-temperature electrolysis, heat pumps, refrigeration machines, fuel cells, storage devices, Rankine cycles, Power to gas, etc.

Grids will reduce GHG emissions considerably —however it is hard to say to what extent. This is the reason why their potential contribution to emission reduction has not been quantified.

Potential development of grids

Methodological information:

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
All technologies				

3. Technological, economic and social bottlenecks

Methodological information:

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.

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
Distribution	Rank	3	4	6	1	2	5
	Key-words			New business models		Cybercrime issues	Acceptability
Couplage	Rank	5	3	6	1	2	4
	Key-words	New coupling devices		New business models, public policies. Developing facilities			

Bottlenecks are significant in terms of public policies —i.e. the role of local authorities and of states, financial and fiscal incentives, etc- development of infrastructures and also development and deployment of new business models. Bottlenecks also include the development of efficient technologies —for higher efficiencies— in order to facilitate coupling through methanation, thermal storage, cold generation, fuel cells, etc.

The acceptability of consumption data collection for smart grids is a strong bottleneck. Furthermore personal data needs to be protected in order to avoid cybercrime.

4. Potential radical and incremental innovations

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

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 innovations** (investment, risk)	**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**
Distribution	I or R	R	I	I	I	R	R
	Key-words	Applied mathematics				Cybercrime issues	Adaptation of consumption patterns
Coupling	I or R	R	I	R	I	I	I
	Key-words	Power to Gas		Companies and local authorities cooperation			

Coupling requires companies to cooperate with each other and with local authorities. Power to Gas also needs to be developed for this technology.

Research in the field of applied mathematics is also crucial to implement smart grids.