Alliance Nationale de Coordination de la Recherche pour l'Énergie

Decarbonization Wedges Exercise

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CONCENTRATING SOLAR POWER (CSP) OR SOLAR THERMAL ELECTRICITY (STE)

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

There are three major technologies involving the use of solar thermal electricity.

Technology 1: Parabolic troughs

This technology has been used for 30 years. Parabolic troughs involve tracking receivers that focus solar irradiance to heat a circulating fluid —e.g. synthetic oil—, which generates electricity. Heat can also be stored to be later transformed in electricity when there is a demand —this represents a significant asset over the photovoltaics technology (see 'Solar Photovoltaics' template).

Technology 2: Central receiver

Heliostats focus sunlight on a receiver on top of the tower. Unlike parabolic troughs, the HTF[1] is generally molten salt that permits higher working temperature than for oil (550°C instead of 400°C) and can either generate electricity or be stored for a later use. The 1980s saw the first power tower power plants.

Technology 3: Linear Fresnel

Linear Fresnel operates the same way as technology 1 (i.e. parabolic troughs) but use generally water-steam as HTF (direct steam generation, DSG)—however the receivers are planar and are not required to track the sun. There is no current storage for this technology.

2. Maturity level and technological perspectives

Maturity of elementary technologies associated with CSP or STE

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
Parabolic troughs	5	5	5	5	5
Central receiver	4	5	5	5	5
Linear Fresnel	4	5	5	5	5

Parabolic trough plants with synthetic oil as HTF operates since mid of the 80's in California.

In 2011 the first commercial power tower power plant (technology 3) using molten salt as a working fluid and as thermal storage. Molten salt has since become the reference working fluid for solar towers, and it is currently spreading at the global level. Compared to molten salt solar towers, DSG[2] plants that use steam do not ensure storage.

For linear Fresnel technology, direct saturated steam generation is well managed and superheated steam generation is reaching maturity. However DSG involves the issue of storage. In the long term adapting molten salt to storage might be considered, even if nothing has been proven until now.

[1] Heat transfer fluid

[2] DSG: Direct Steam Generation

Potential development of CSP or STE

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
Potential development**	1	3	4	4

Currently storage CSP is favored, which is consistent as it comes as a complement to developing photovoltaic technology. Global deployment should begin in 2020 and CSP will likely play a significant role in energy transition. In 2050, IEA projects 11% of the electricity production by CSP.

According to the IEA 2014 report, 2.1 Gt of CO_2 emissions should be avoided by 2050 thanks to STE —this amount to 9% of annual worldwide emissions.

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 & environment impacts** (including scarcity of raw materials, water, land, climate)	**Safety & security** (impacts on health, people and assets security)	**Socio-technical feasibility**
Parabolic troughs	Rank	3	6	5	4	2	1
	Key-words	Molten salt	High investment cost	Land requirement	Storage materials Solar resource	Toxic biological oil	
Tower / Central receiver	Rank	4	6	5	3	2	1
	Key-words	High efficiency of thermal cycles at high tempertaure	High investment cost	Land requirement	Solar resource Other uses of nitrate salts		
Linear Fresnel	Rank	4	6	5	3	2	1
	Key-words	Molten salt	High investment cost	Land requirement	Short time storage Solar resource		

The first bottleneck pertains to finances because this technology requires high investment costs.

Switching to molten salt for parabolic troughs (technology 1) and for linear Fresnel (technology 3) would improve thermodynamic yield and make storage easier. However doing so requires managing molten salt during shutdown periods in order to prevent its solidification.

Supercritical cycles and combined cycles can be considered for solar towers as both types of cycles would improve yield. However materials and solar receiver design represent the main bottlenecks.

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 bottlenecks**	**Economy and financial bottlenecks** (investment, risks)	**Regulation & institutional environment**	**Resources & environment impacts** (including scarcity of raw materials, water, land, climate)	**Safety & security** (impacts on health, people and assets security)	**Socio-technical feasibility**
Parabolic troughs	I or R	I	I	R	I		I
	Key-words	Molten salt	Costs decrease	High carbon tax Emissions cap	Reduction of material quantity New materials		Micro-plants, polygeneration
Tower / Central receiver	I or R	R	I	R	I		I
	Key-words	High temperatures	Costs decrease	High carbon tax Emissions cap	Reduction of material quantity New materials		Micro-plants, polygeneration
Linear Fresnel	I or R	I	I	R	I		I
	Key-words	Molten salt	Costs decrease	High carbon tax Emissions cap	Reduction of material quantity New materials		Micro-plants, polygeneration

Implementing a high carbon tax would constitute a significant innovation which would accelerate the development of CSP technology. Valorizing storage capacity of CSP technologies through special feed-in-tariffs would also encourage the use of this technology.

Reducing quantity in terms of generated kWh and finding new materials for storage pertain to incremental innovations.