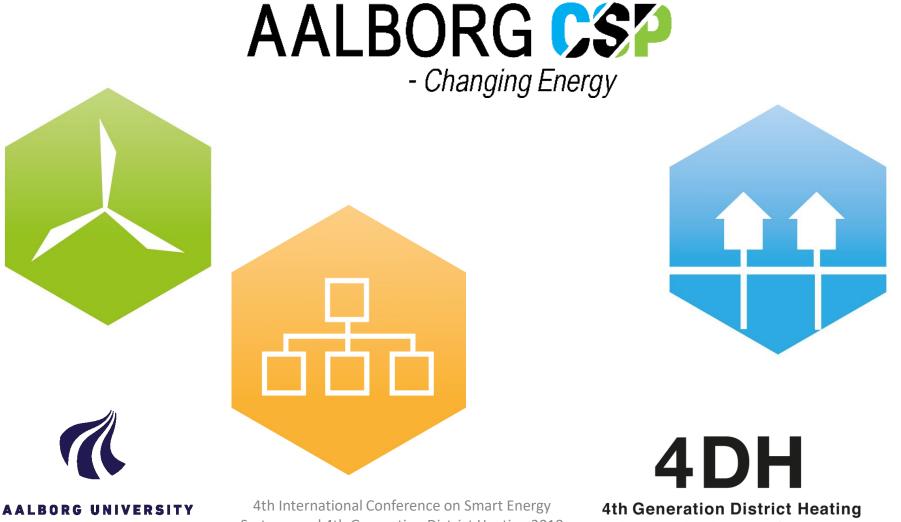
4th International Conference on Smart Energy Systems and 4th Generation District Heating Aalborg, 13-14 November 2018

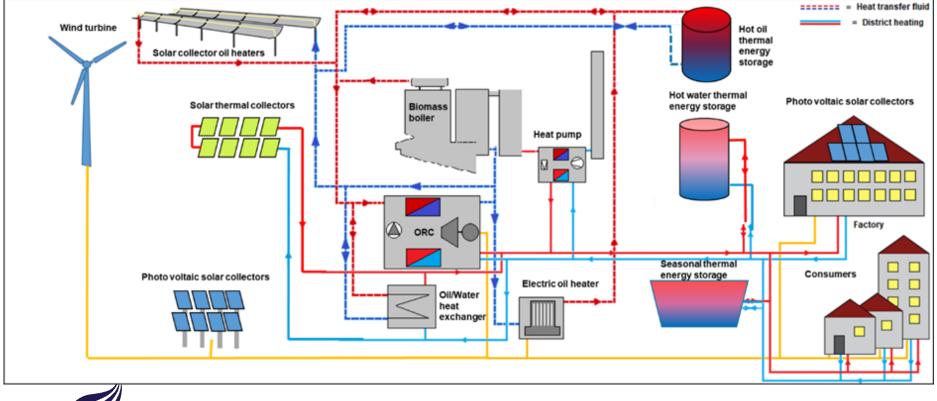


DENMARK

Systems and 4th Generation District Heating 2018 #SES4DH2018

Technologies and Systems

4G Integrated Energy Solutions BASED ON THE INTEGRATION OF CONCENTRATED SOLAR POWER -ALL WELL PROVEN TECHNOLOGIES





4th International Conference on Smart Energy Systems and 4th Generation District Heating 2018 #SES4DH2018

4th Generation District Heating

Technologies and Systems

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From Aalborg Boilers to High tech Concentrated Solar Power Boilers









4th Generation District Heating Technologies and Systems

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From Aalborg Boilers to High tech Concentrated Solar Power Boilers



20 MWe Direct steam solar 50MWe SGS1 thermal oil 50MWe SGS1 thermal oil 10 MWe Direct steam solar 4.2 MWth molten salt 25 Mwe SGS3 thermal oil 36.6 MWth Integrated Ener 1.9 MWth solar district 50 MWe molten salt SGS4 tower receiver steam generator steam generator tower receiver steam generator steam generator System based on CSP heating system steam generator Customer: undisclosed Customer: undisclosed Customer: undisclosed Customer: undisclosed Customer: undisclosed Customer: Gujarat Customer: Sundrop Farms Customer: Solrød End user: Shenzen Jinfan Location, Seville, Spain Location, Ecija, Spain Location, Ecija, Spain Location, Seville, Spain Location, Seville, Spain Location, India Location: Port Augusta, AU Fjernvarme Location: Aksai, Gansu Plant Type: Tower with Plant Type: Parabolic Plant Type: Tower with Plant Type: Parabolic Plant Type: Parabolic Trough Plant Type: Molten Salt Plant Type: Solar tower Location: Havdrup, DK Province, China Trough saturated steam Trough Capacity: 50 MWe saturated steam Steam generator Capacity: 36.6 MWth Plant Type: Flat solar panels Plant Type: Parabolic trough Capacity: 20 MWe Capacity: 50 MWe Scope: Steam Generator Capacity: 11 MWe Capacity: 4.2 MWth Capacity: 25 MWe Scope: Turnkey system Capacity: 1.8 MWth with MS Scope: Reciever panels, Scope: Steam Generator System, Turnkey installation Scope: Receiver panels, Scope: Steam generator Scope: Steam Generator Scope: Turnkey system Capacity: 50MWe Steam Drum, Installation System, Turnkey installation retrofit Installation system, turnkey installation System Scope: Turnkey system 2017 2014 2017 2009 2010 2011 201 2013 2016 50MWe SGS1 thermal oil 50MWe SGS1 thermal oil 50MWe SGS1 thermal oil 5 MWth solar tower 50MWe SGS3 thermal oil 6.8 MWth combination 0.8 MWth parabolic trough 16.6 MWth CSP combined 8 MWth solar district steam generator receiver plant for district heating test plant with biomass-ORC steam generator steam generator steam generator heating system Customer: undisclosed Customer: Greenway CSP Customer: Brønderslev Customer: undisclosed Customer: undisclosed Customer: Lauren Customer: Brønderslev Customer: Smørum Location: Seville, Spain Location, Seville, Spain Location, Seville, Spain Location, Mersin, Turkey Location: Raiasthan, India Customer: Taars Varmevær Forsyning Forsyning Kraftvarmeværk Plant Type: Parabolic Plant Type: Parabolic Trough Plant Type: Parabolic Trough Plant Type: Tower with Plant Type: Parabolic Trough Location, Brønderslev, DK Location, Brøndersley, DK Location, Taars, DK Location: Smørum, DK Plant Type: Parabolic Trough Capacity: 50 MWe Capacity: 50 MWe superheated steam Capacity: 50 MWe Plant Type: Parabolic Trough Plant Type: Parabolic Trough Plant Type: Flat solar panels Canacity: 50 MWe Scope: Steam Generator Scope: Steam Generator + Flat panels Capacity: 16.6 MWth Capacity: 5 MWtth Scope: Turnkey steam Trough Capacity: 8 MWth Scope: Steam Generator System, Turnkey installation Capacity: 6.8 MWth Capacity: 0.8 MWth Scope: Turnkey para-bolic System, Turnkey installation Scope: Receiver panels. Generator System Scope: Turnkey boiler System, Turnkey steam system, engineering Scope: Turnkey delivery Scope: Turnkey para-bolic trough system system installation trough system

SELECTED REFERENCES

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CSP FOR COMBINED HEAT AND POWER - Brønderslev, DK





Aalborg CSP designed and delivered a CSP system to be integrated with a biomass-organic rankine cycle (ORC) plant for combined heat and power generation - the first one in the world to combine these two technologies in a large-scale setting.

Location: Brønderslev. North of Denmark **Client:** Brøndersev Forsyning Status: operational Capacity: 16.6 MWth CSP aperture area: 26,929 m²



Final energy output:

Electricity

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CST APPLICATION – PORT AUGUSTA, AU

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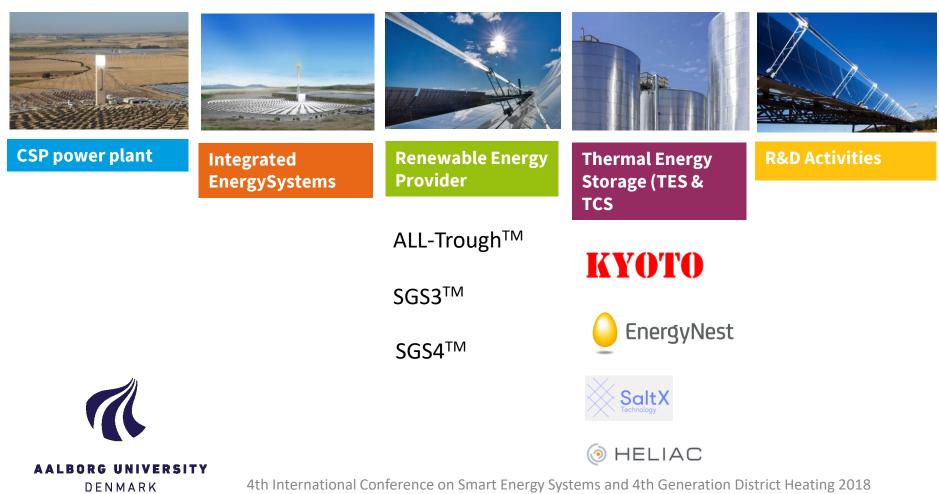
20,000 MWh/ year 250,000 m³/ year





AALBORG CSP - Changing Energy



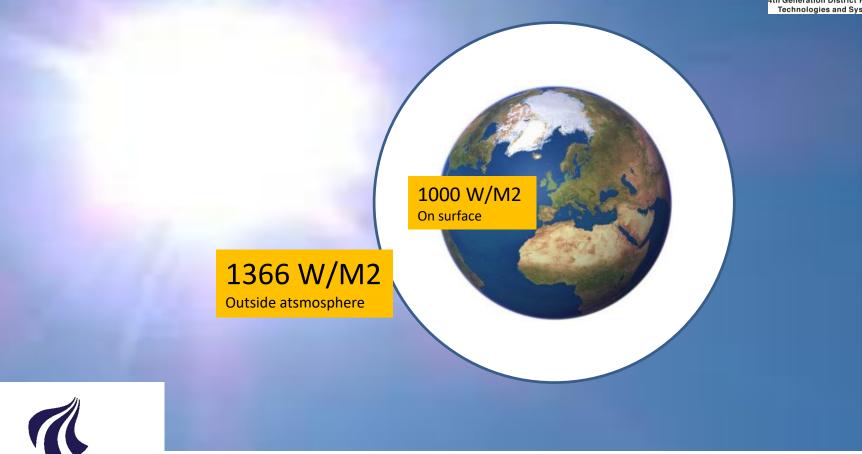


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Solar Irradiation

Insolation from the sun on a clear day





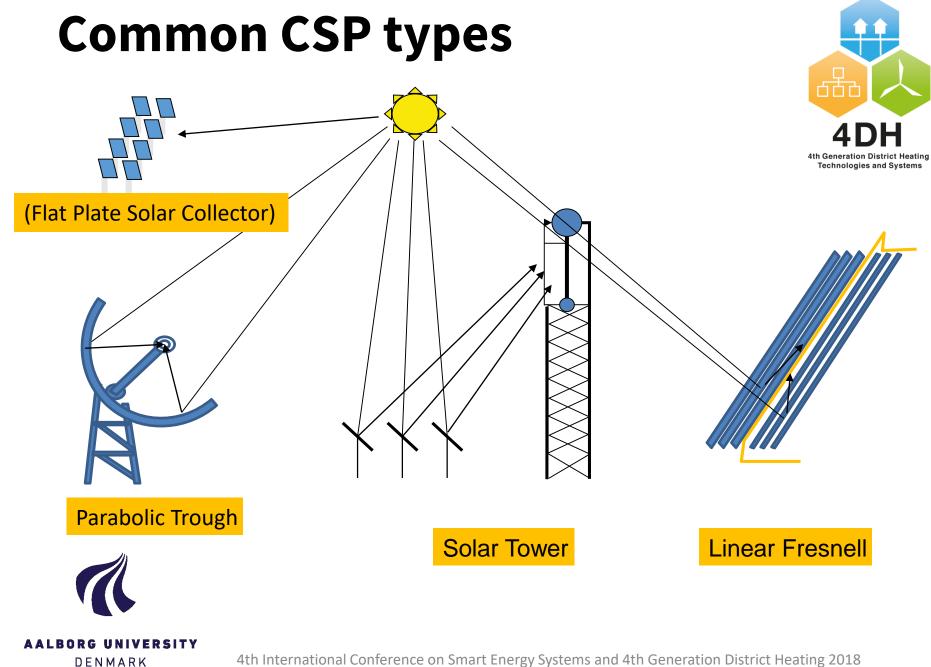


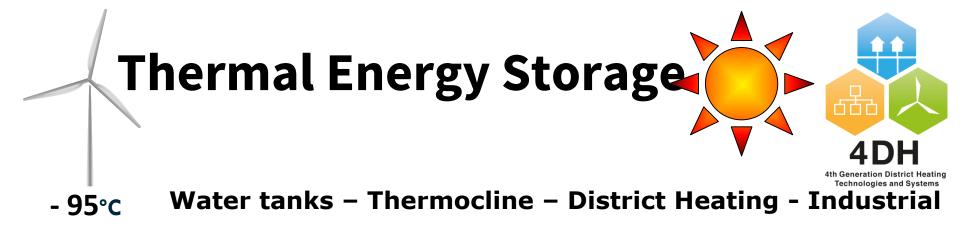
Solar amount







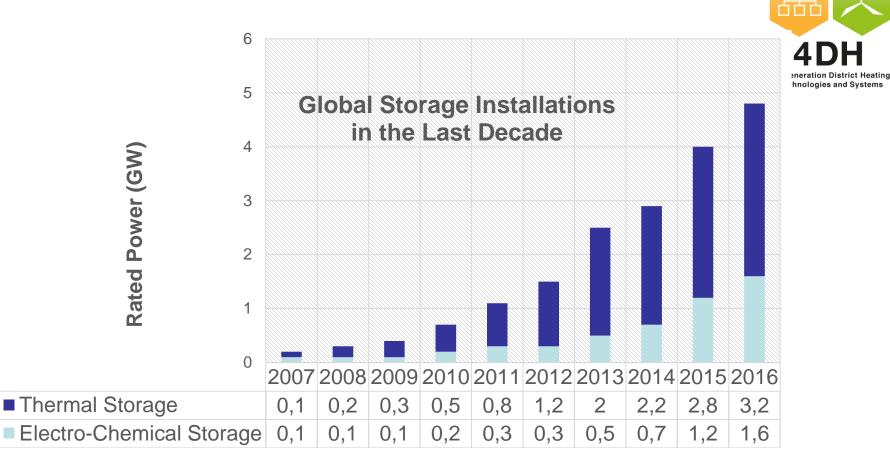




- 430°C Concrete Heat Storage Thermal oil/Steam DH Plant
- 550°C Chemical Heat Storage CAO/Steam CHP plant
- 565°C Molten Salt Storage MS/Steam Power & CHP Plant
- > 600°C Other Heat storage systems Aluminum Sulphur etc.

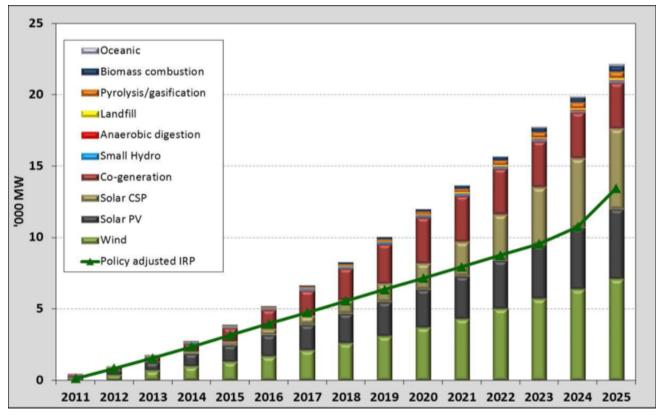
 Image: Construction of the storage systems and 4th Generation District Heating 2018

The Global installed TES



Technology Type	Projects / Plants	Rated Power (MW)
Electro-Chemical	992	3296
Thermal Storage	207	3692

The RE Market Expectations



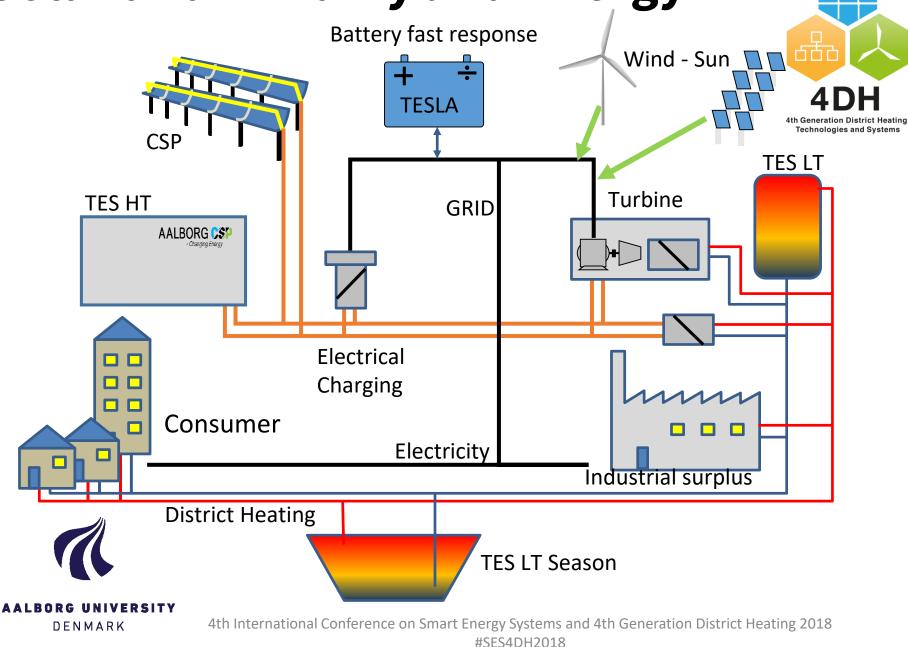


Source: , Thierry Giordano, ResearchGate, Electricity generation Capacity2011-2025

- A factor 3 increase in installed capacity from now until 2025
- The most potential RE source
- CSP is predicted to in 2022 to surpass the installed PV capacity
- Solar combined is expected to be at the same level as wind power in 2025



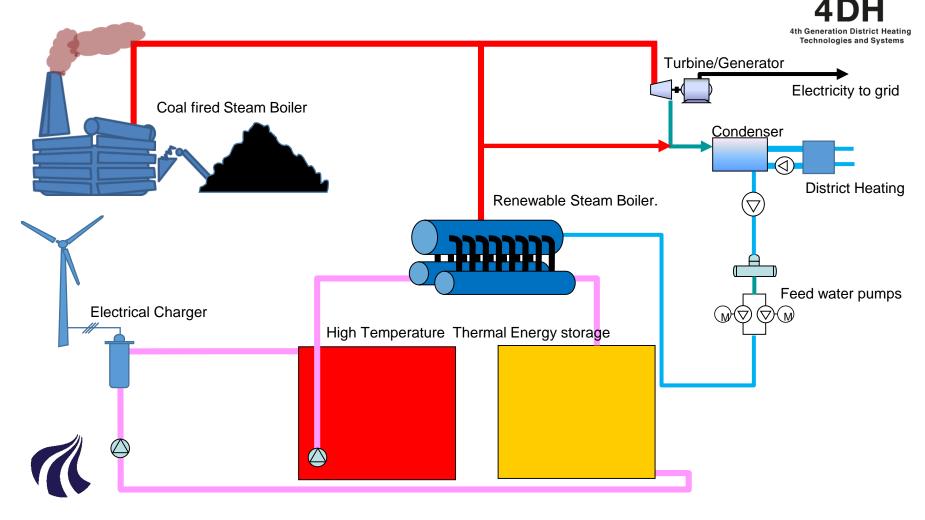
Solar and Wind Hybrid Energy



Today's direction in Denmark = Wind to energy Via cables to Norway / UK / France/Polen/Germany **Electricity** Wind Energy **Co-generation** Hydro Back-up Heating **Coal/Nuclear Back-up**

DENMARK

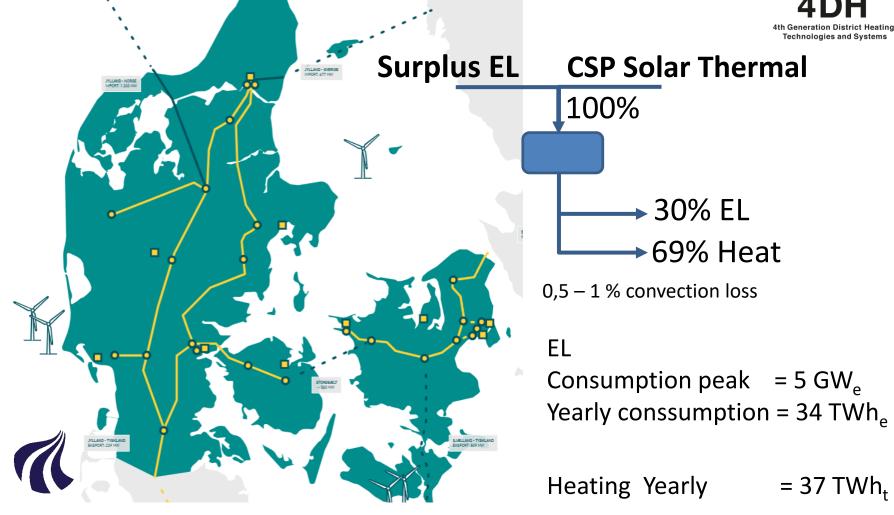
Wind to Molten Salt power plant = El to El + District heating



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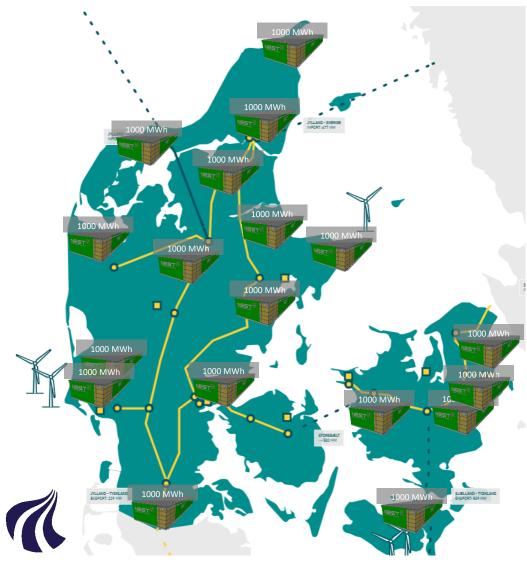
Annual Power Consumption Denmark





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Denmark towards renewable



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Storage to Cover Consumption peak 5 GWh_e = around 17 GWh_{th}

Using Molten Salt as TES a unit of 1 GWh_{th} can be built at the cost of DKK 180 Mio.

17 Units of 1 GWh_{th} gives a total investment DKK 3 Mia

Can be charge and discharge at all time acting as grid equalizer

Why does this transition not happen in Denmark??



BECAUSE

THERMAL STORAGE OBVIOUSLY DOES NOT REPRESENT ANY VALUE TO OR FOR THE SOCIETY

HOWEVER

- Hence no un-subsidized RE will have a
 chance to grow before it reaches grid parity on it's own.
- The CO2 Kvota system has failed the CO2 kvota prices are neglectable (is 40-45 DKK/T should have been 200 DKK/T).
 Hope that the reboot will succed
- The politicians are right now adopting a law that makes it legal to install electrical driven heat pumps (Split Aircondition units) with governmental subsidies, in private houses eventhough there already is a district heating network available.
- No more obligations to connect to District Heating.

Had the Wind Mills faced same conditions

NO WIND MILLS WOULD EVER HAVE BEEN INSTALLED IN DENMARK

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What is the benefit of High Temperature Thermal Energy Storage ???

- ✓ The TES systems can be integrated using the existing infrastructure
 - At Power Plant utilizing existing Steam turbines, feed water systems etc.
 - At decentralized CHP plants utilizing existing District Heating systems
- Give the possibility of import/export of large amounts of Electricity



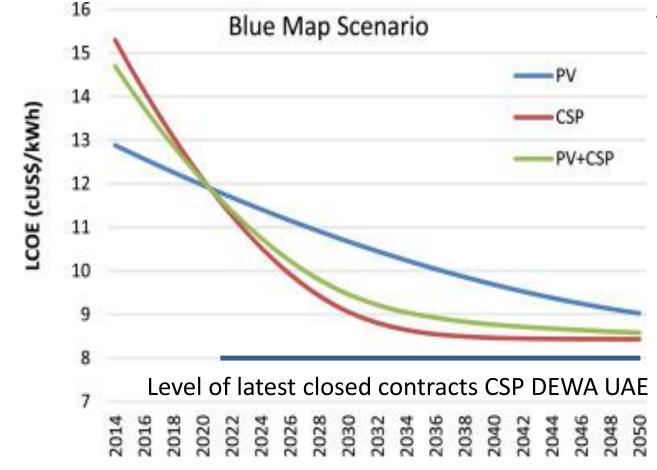
 Most of the Thermal plant components can be made and maintained by local workforce. (Most Split Air-con units (Heat Pumps) are made in China or Asia.)





Expected Development of solar electricity prices 2014





Source: ScienceDirect, Energy, Volume 94 Jan, 1, 2016

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YES WE CAN All technologies are available

Thank you for your attention



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