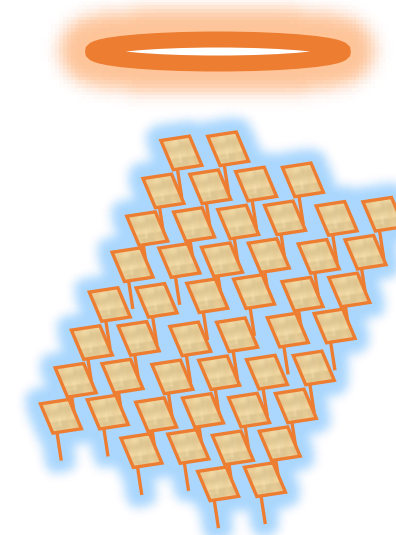
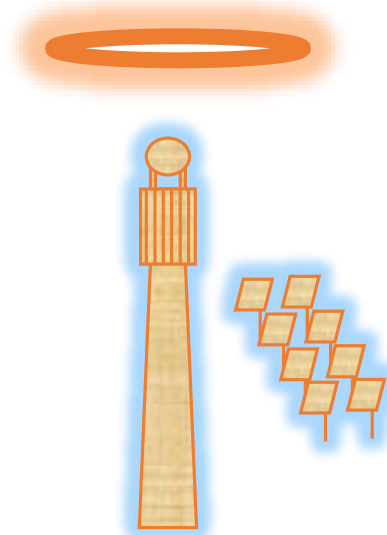
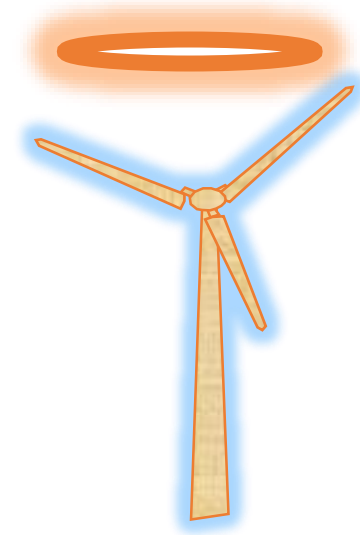


# High Temperature Thermal Energy Storage & Re-use of existing Energy assets

There is no all-mighty technology



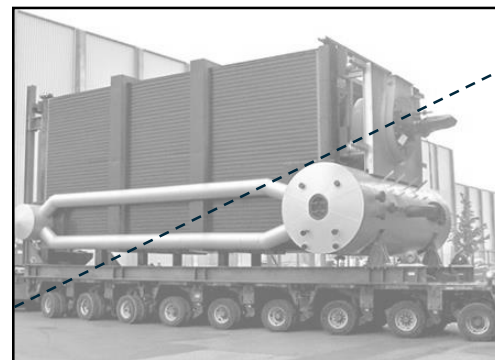
From Boilers in Aalborg to high technology Renewable systems

**AALBORG** **CSP**  
- Changing Energy

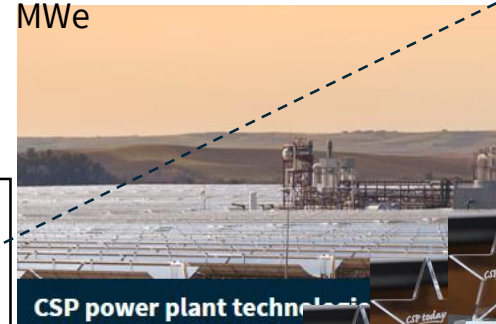


Experience from thermal systems and large-scale CSP power plants has translated into **technology integration** expertise

- **2000**  
Traditional boiler design and development



- **2007-09**  
First Steam generator systems & solar tower receivers for large-scale CSP power plants 6 x 50 MWe



- **2011**  
CSP for district heating optimized for local weather conditions



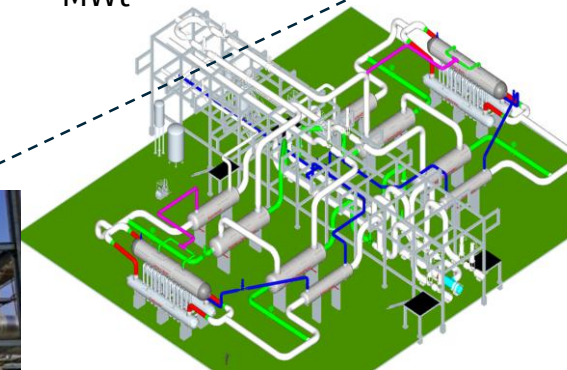
- **2014**  
Growing tomatoes in the Australian desert with the world's first Integrated CSP Energy System



- **2015**  
High temperature storage concept for storing solar and wind energy (Concrete / Molten Salt)



- **2019**  
Largest Solar plant in the World to Dubai. 3 x 2 SGS 3 Natural circulating Steam generator 600 Mwe 1.800 MWt



- **2017**  
First Order to China SGS 4 Natural circulating Steam generator 50 Mwe Molten Salt



- **2016**  
CSP developed and installed for Co-Gen with 330°C thermal oil in Denmark 2,2 Mwe



EUDP SUPPORT

In Denmark we have 5.000 MW wind power increasing to 7.500 MW

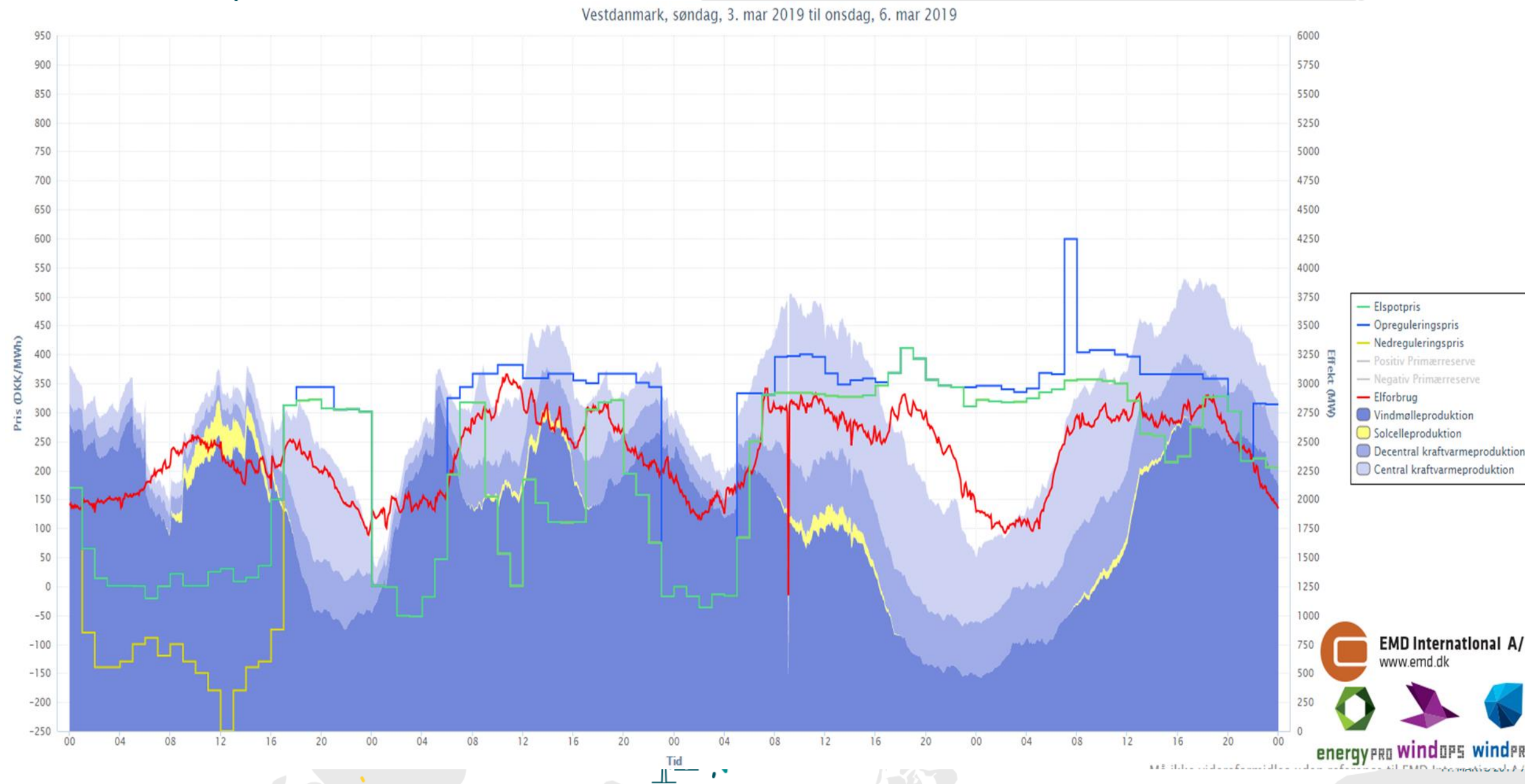
**AALBORG** **CSP**  
- *Changing Energy*



In Denmark we have 5.000 MW wind power,  
When the wind is blowing



# In Denmark we have wind power, but also Coal Power And the Spot market

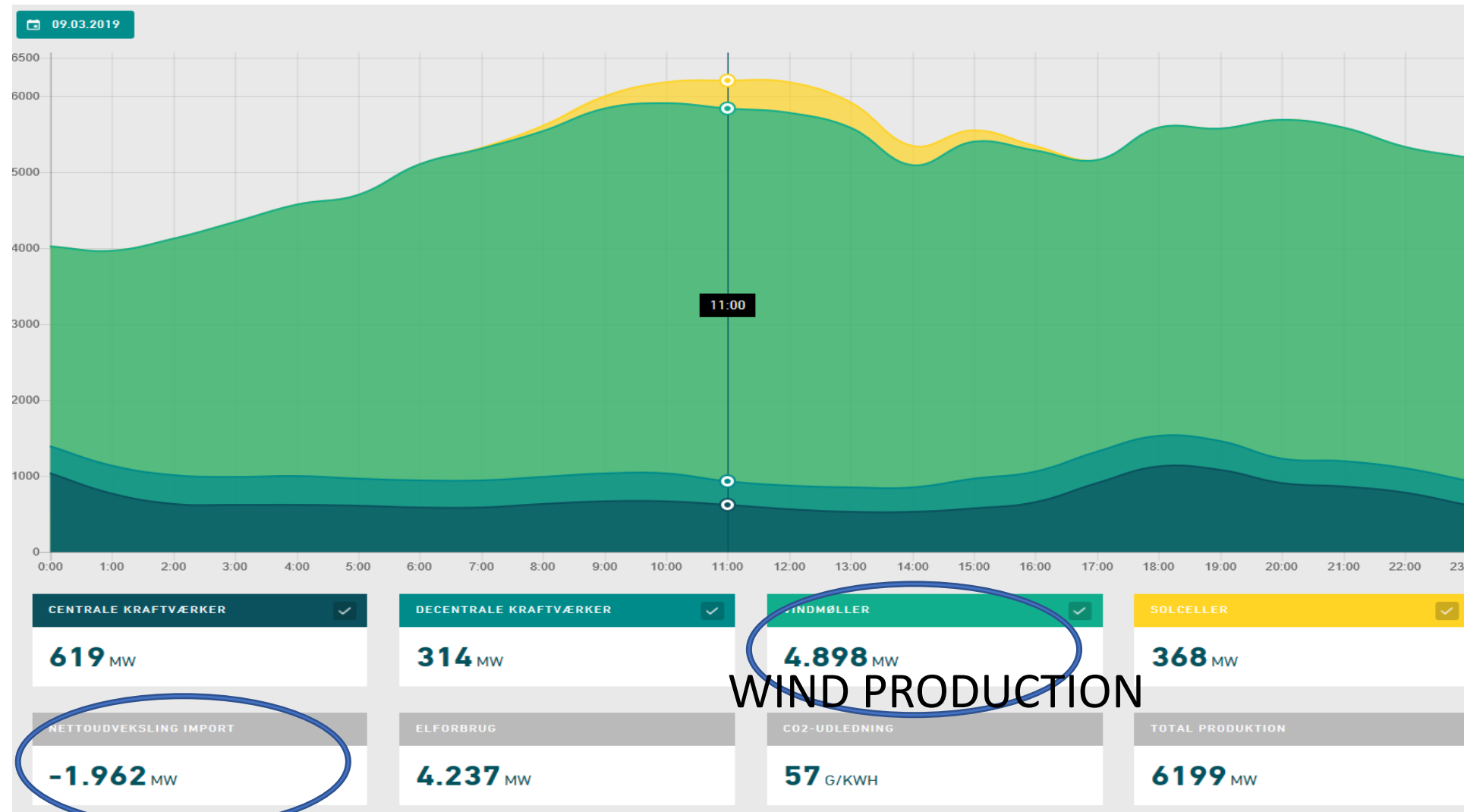


# The Danish Electricity situation – ‘Blowing in the Wind’

Eur/MWh – Nord pool DK1

09-03-2019 7.98 59 kr

**Export – 1.962 MW**  
**At 59 kr/MWh**  
**(Money in the box)**



WIND PRODUCTION

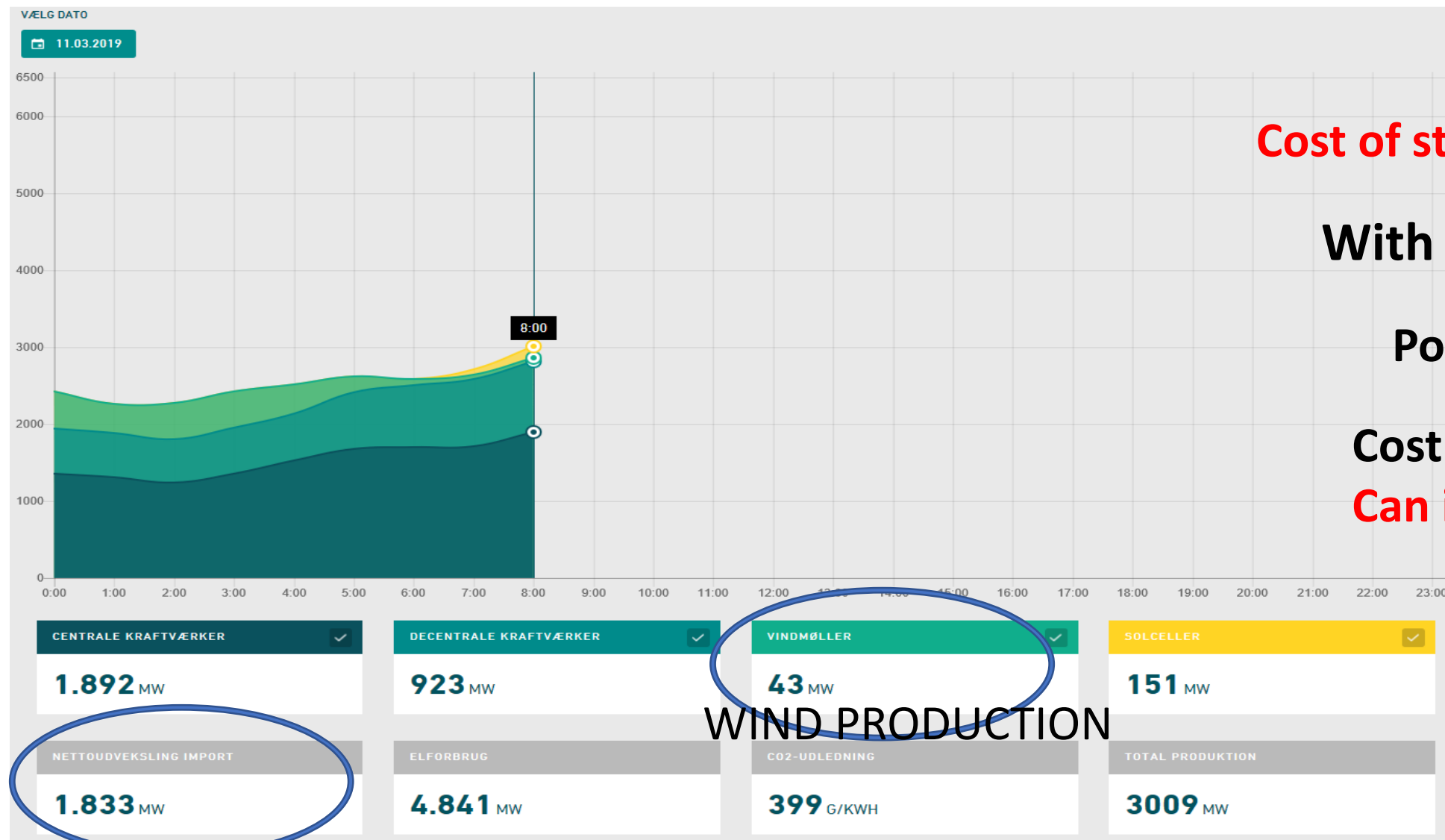
# The Danish Electricity situation – ‘Blowing in the Wind’

Eur/MWh – Nord pool DK1



Import – 1.833 MW  
At 335 kr/MWh

**(Money out of the box)**



**Cost of storage - Aprox 1,600,000,000 Kr/y (2017)**

**With 3 x 800 MW Additional Wind farms**

**Potential new cost 3,200,000,000 Kr/y**

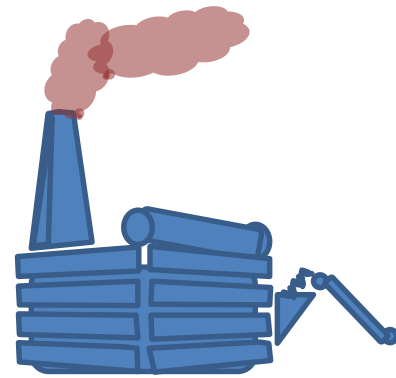
**Cost of storage – Who pays ??**

**Can it be used to pay back the investment ??**

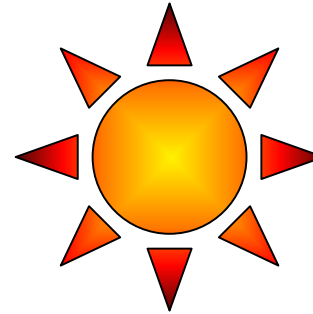




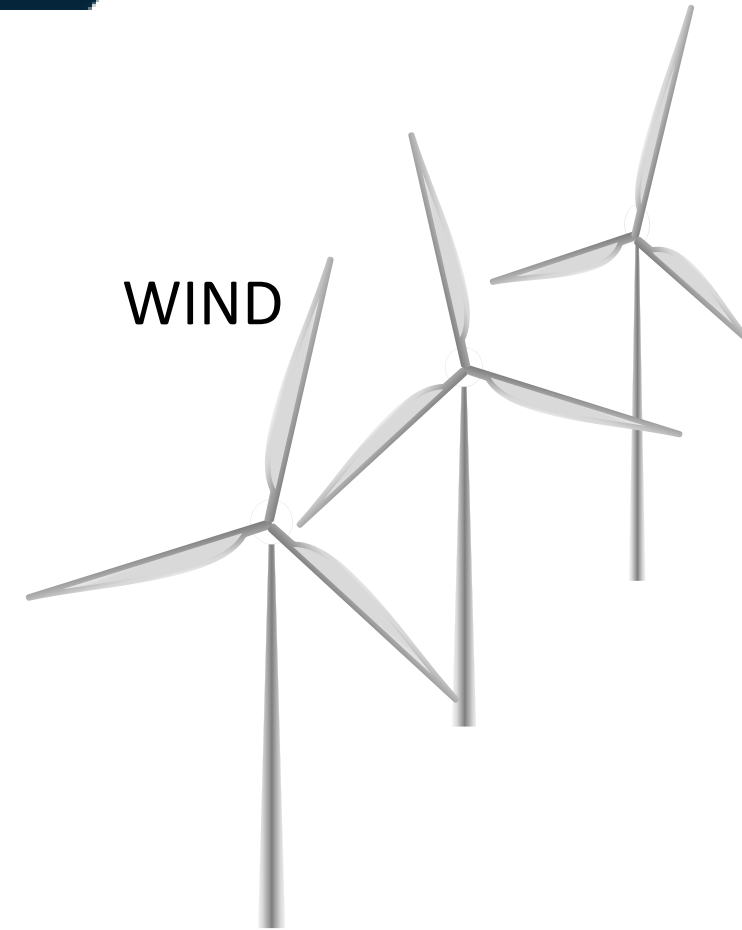
BIO FUEL



SOLAR



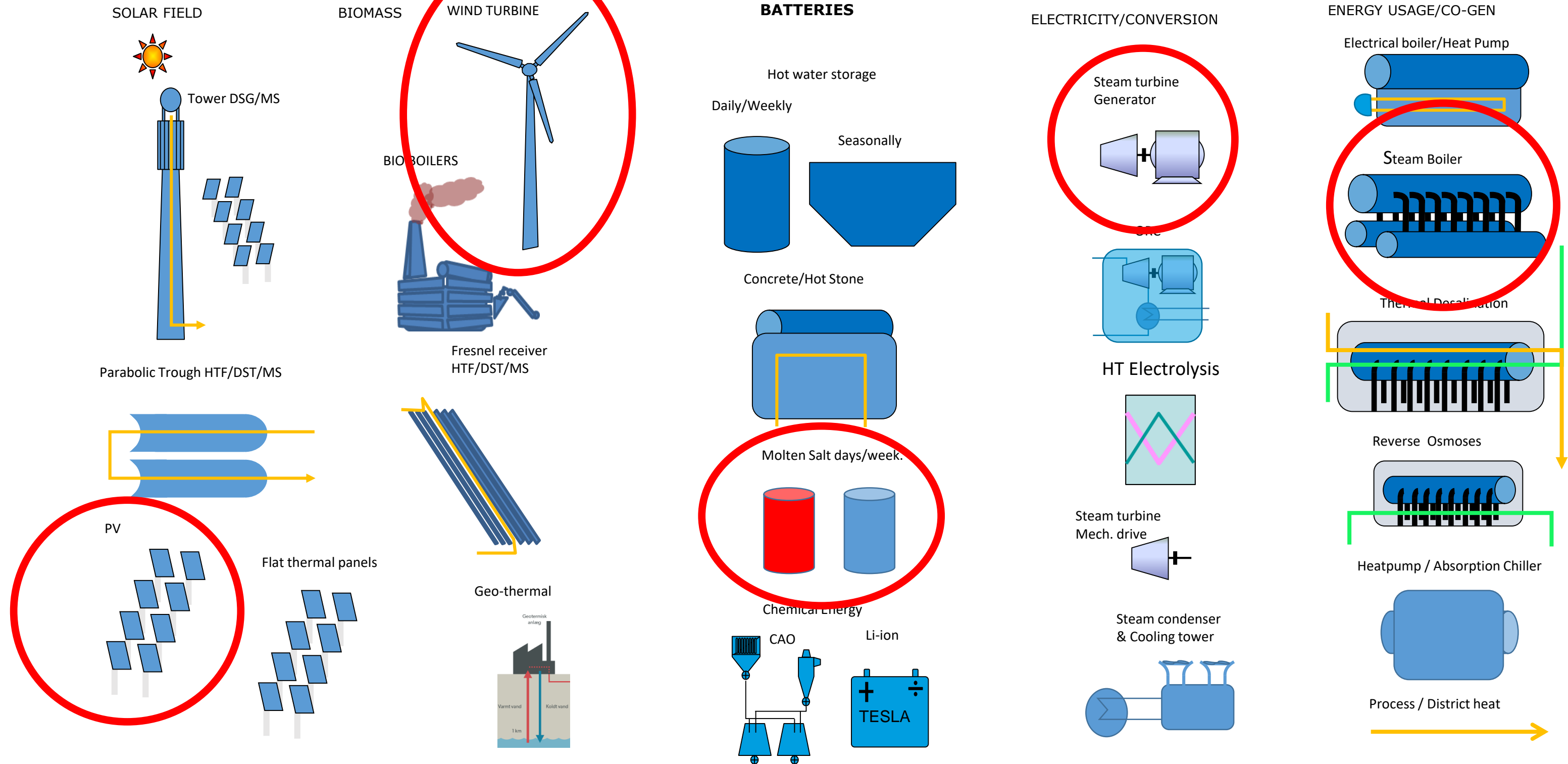
WIND



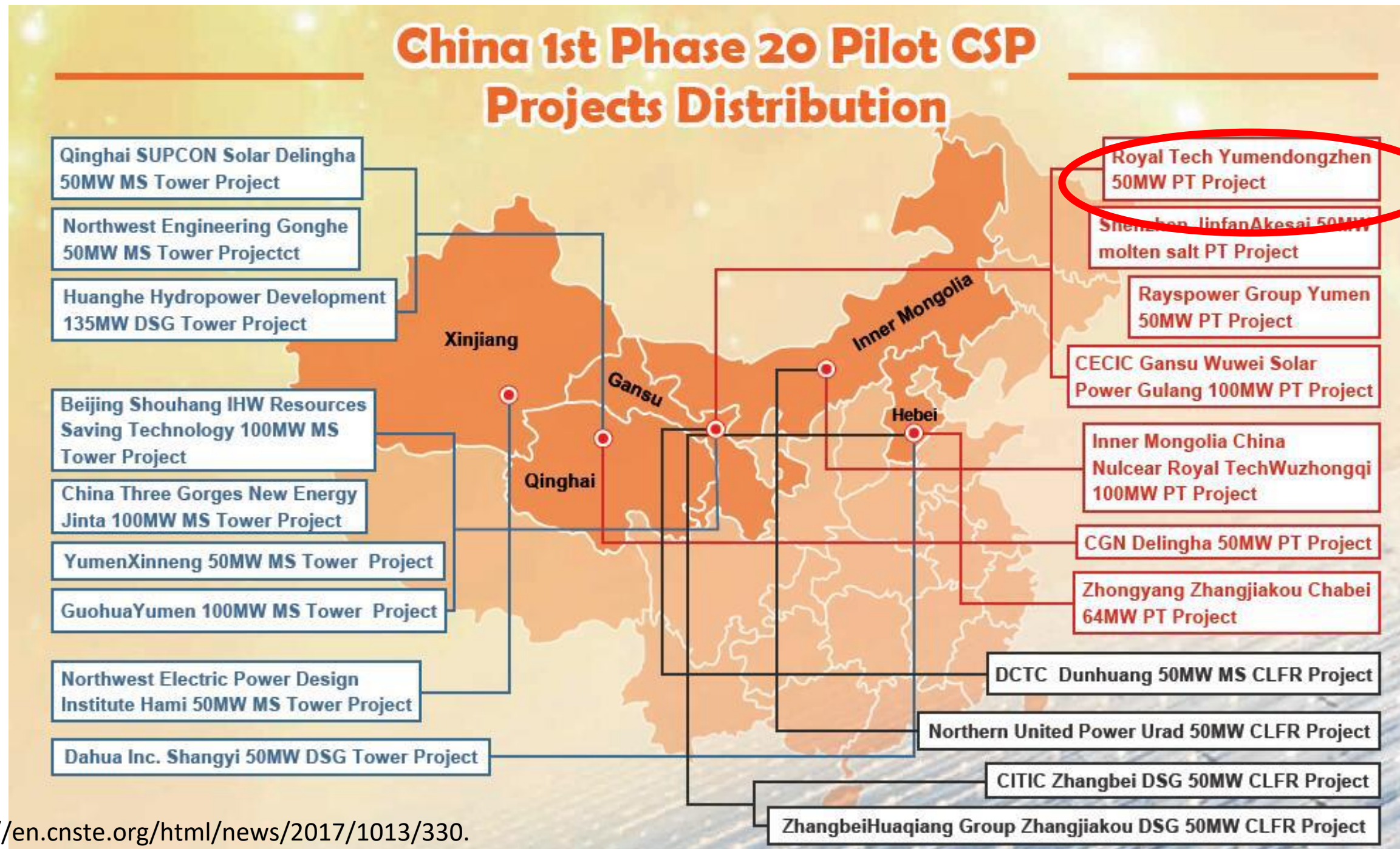
**NEXT STEPS**

## **SECTOR INTEGRATED RENEWABLE ENERGY & LARGE HIGH TEMPERATURE ENERGY STORAGE SYSTEMS**

# The 'renewable energy-palette' of possible building blocks of technologies more or less available.



Projects commenced and planned to be completed before end 2020



<http://en.cnste.org/html/news/2017/1013/330.html>

# The Chinese High Temperature Energy Storage projects commenced

Projects commenced and planned to be completed before end 2020

Project Name	Storage (Hours)
CGN Delingha 50MW HTF PT Project	9
Qinghai SUPCON Solar Delingha 50MW MS Tower Project	6
Beijing Shouhang IHW Resources Saving Technology 100MW MS Tower Project	11
Yumen Xinneng 50MW MS Tower Project	6
Shenzhen Jinfan Akesai 50MW MS PT Project	15
Inner Mongolia China Nuclear Royal Tech Wuzhongqi 100MW HTF PT Project	4
DCTC Dunhuang 50MW MS CLFR Project	13
Zhangbei Huaqiang Group Zhangjiakou 50MW DSG CLFR Project	14
Rayspower Group Yumen 50MW HTF PT Project	7
Northwest Electric Power Design Institute Hami 50MW MS Tower Project	8

Project Name Format: Investor/Developer Name + Capacity + Technology

Abbreviations:  
MS— Molten Salt; PT— Parabolic Trough; CLFR— Compact Linear Fresnel Reflector; DSG— Direct Steam Generation; HTF— Heat Transfer Fluid

3300 MWh Thermal storage

Sep. 19 Status  
4 large scale projects  
completed

High Temperature Energy Storage

Already in operation in :

CHINA, USA, Spain, Marocco

Technology is already 'BANKABLE'.

International Banks can provide financing.

In DK electrification of existing power plants  
can be relatively inexpensive

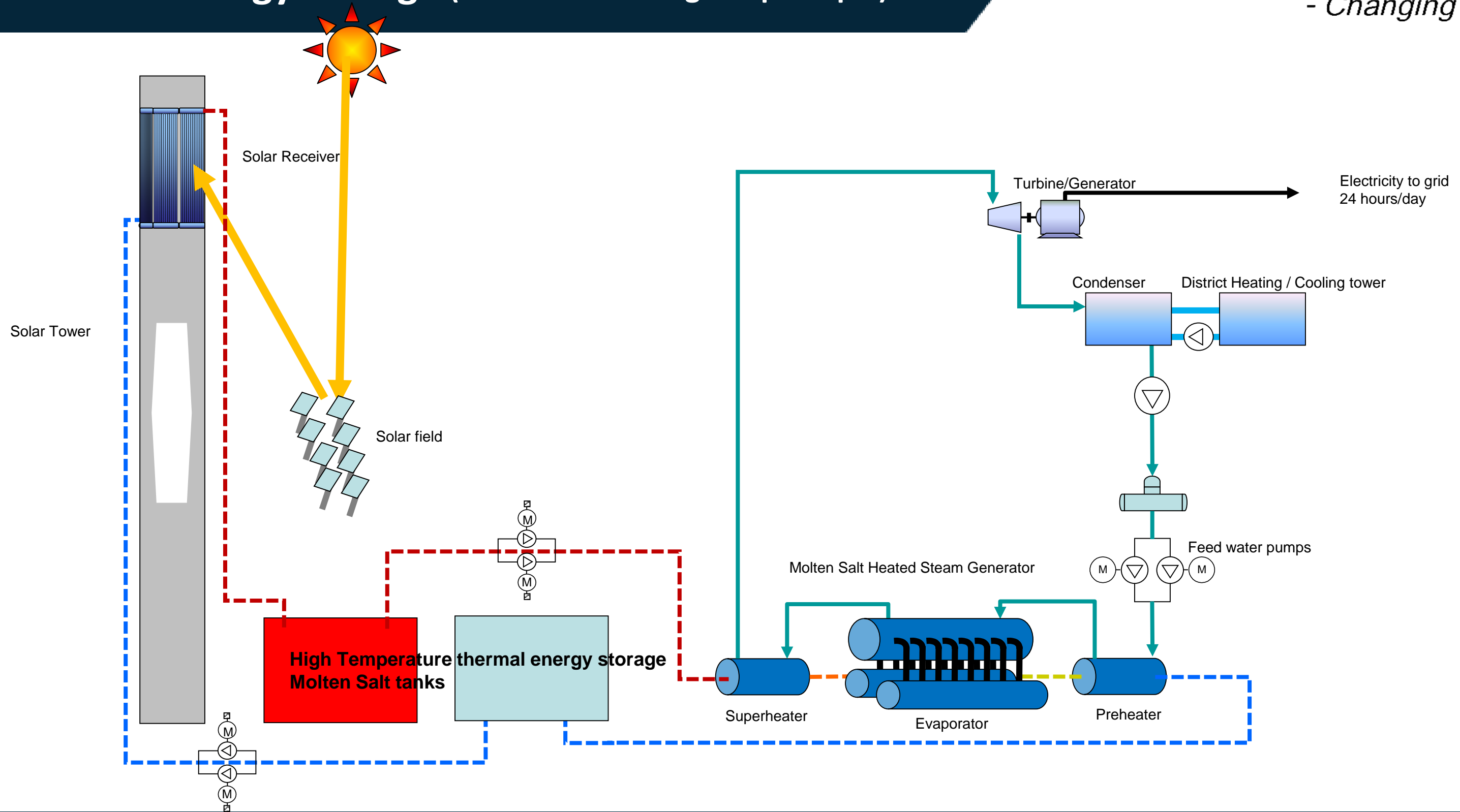
23-27 USD/MWht cover Heater, Storage &  
Steam Generator + cost of retrofit to Turbine

Cost of demolishing Coal & Ash plant and  
cleaning of plot must be done anyway.

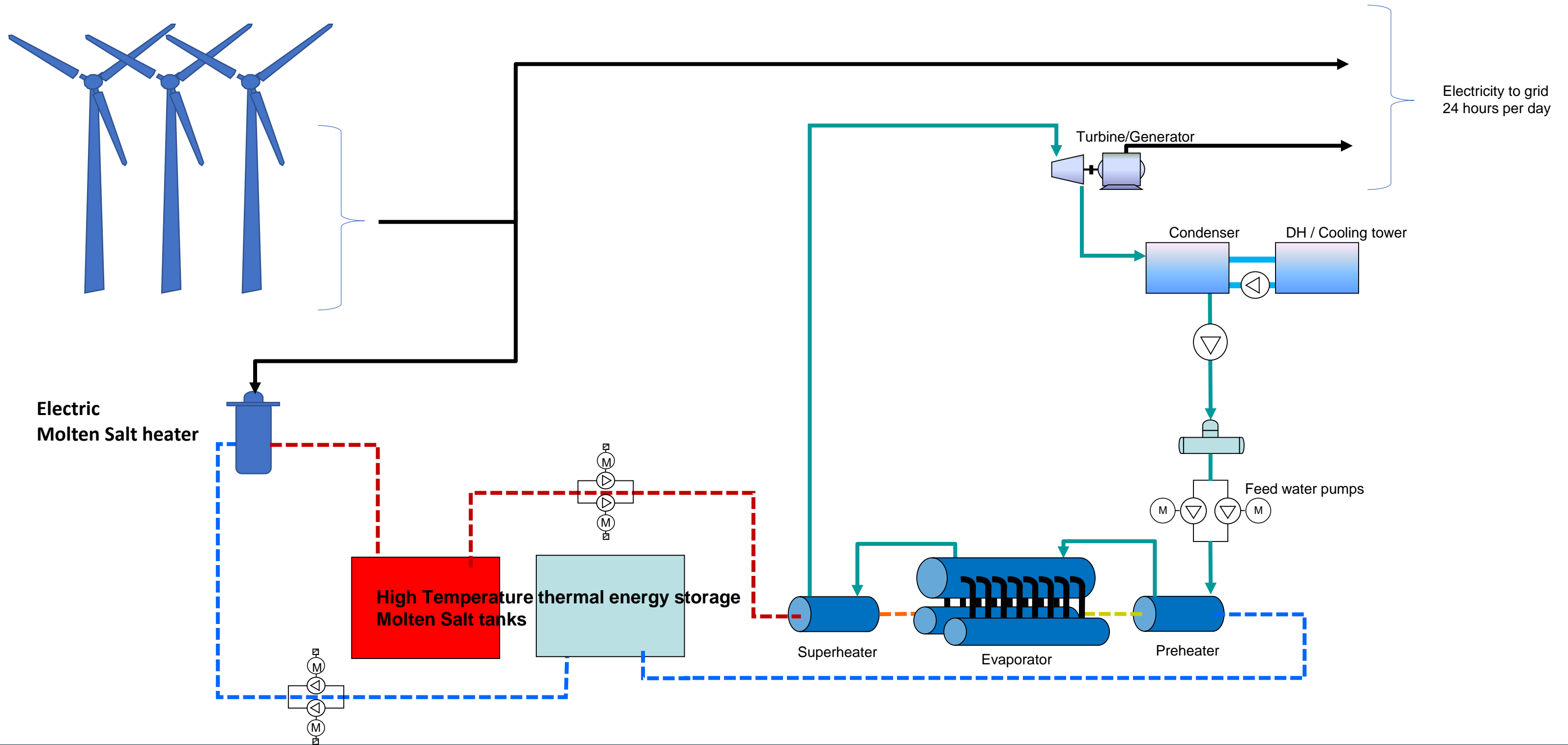
MOLTEN SALT CSP TOWER



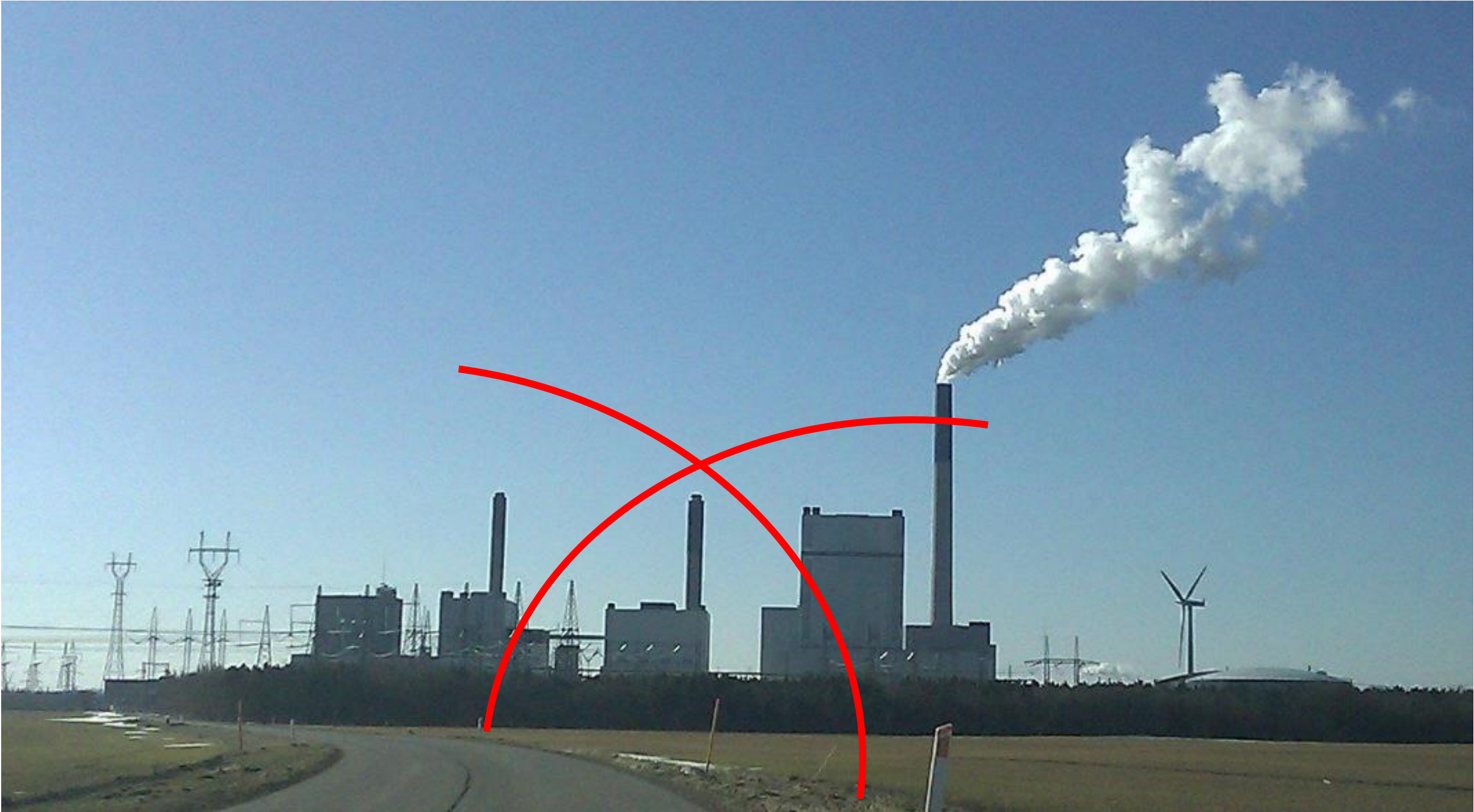
# Typical CSP power plant with Molten Salt HIGH TEMPERATURE Energy Storage (for understanding the principal)



# Principal future Wind/Electrified power plant with Molten Salt HIGH TEMPERATURE Energy Storage



Denmark operates 3 coal fired power plants





## 3 Coal fired plants Combined CO2 in 2017:

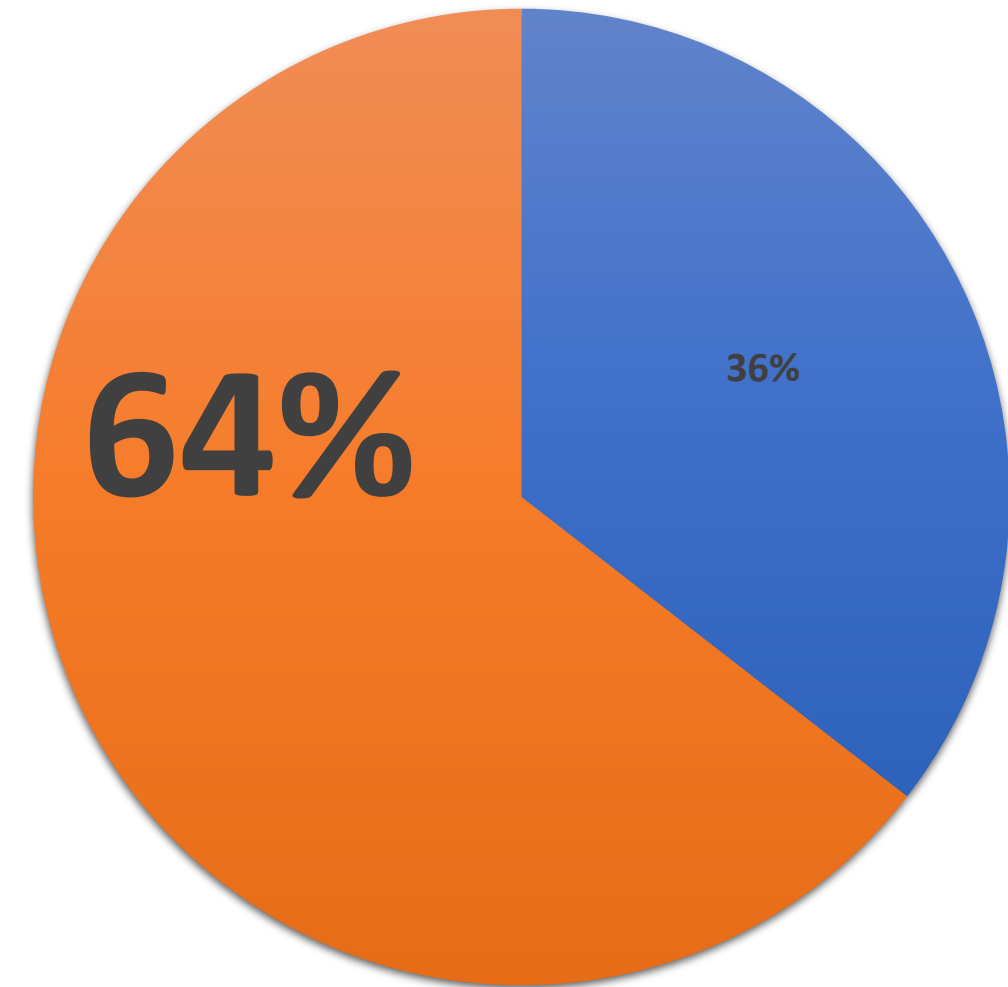
- 4.609.111 Ton.CO2/Year 2017.

### Potential equivalent CO2 if from cars:

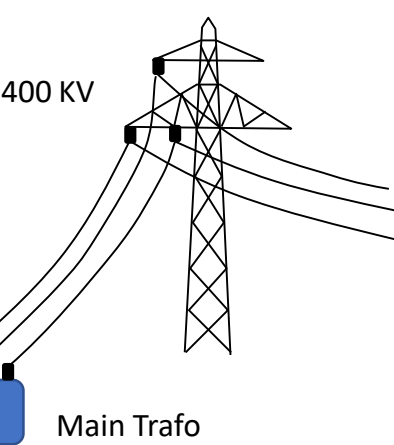
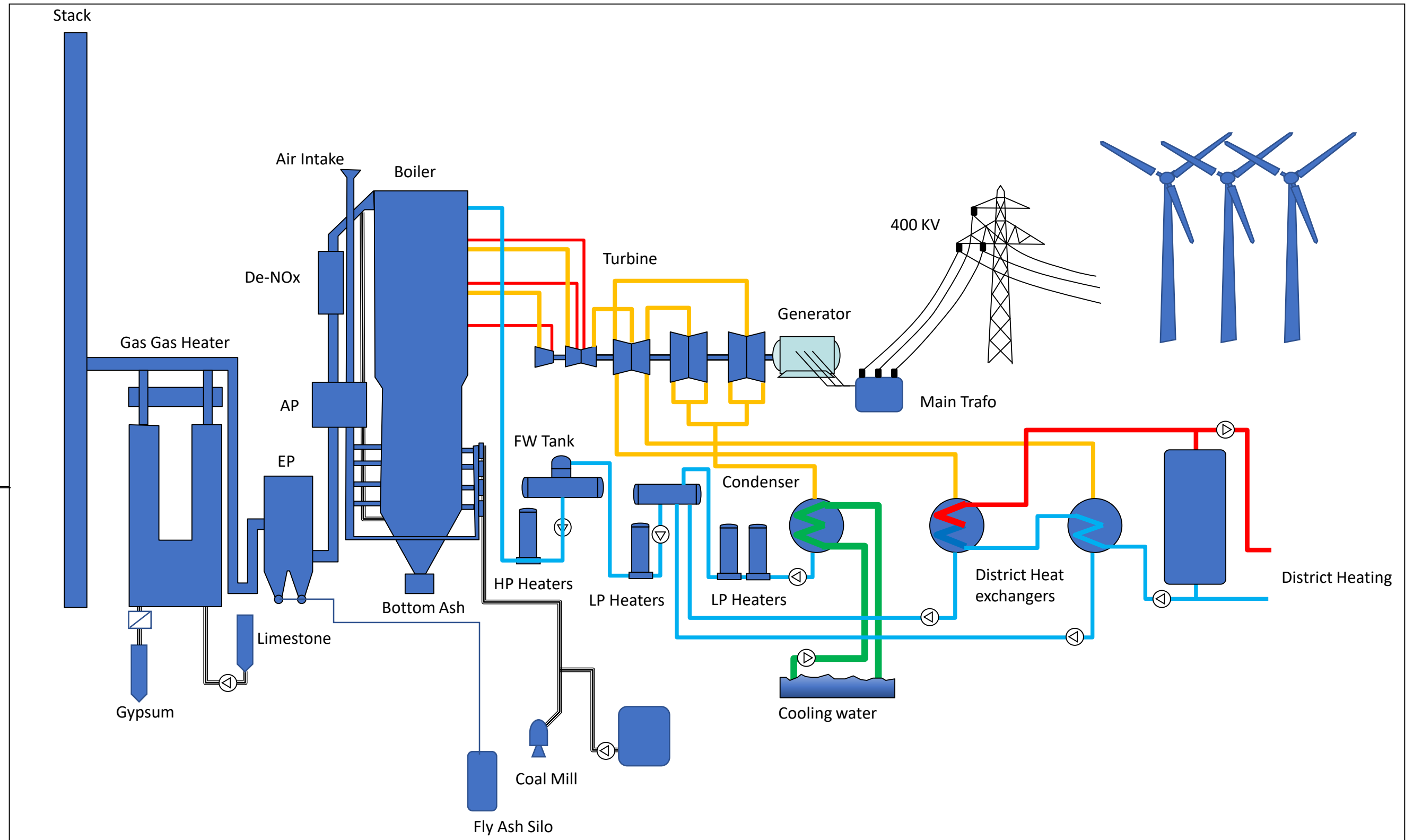
• Reduction number of cars:	1.936.601
Total Cars in DK.2019	3.002.889

*Or 6.000 Jumbojets CPH – New York t/r*

CO2 Savings Denmark Equivalent to 64% of total Privat Cars

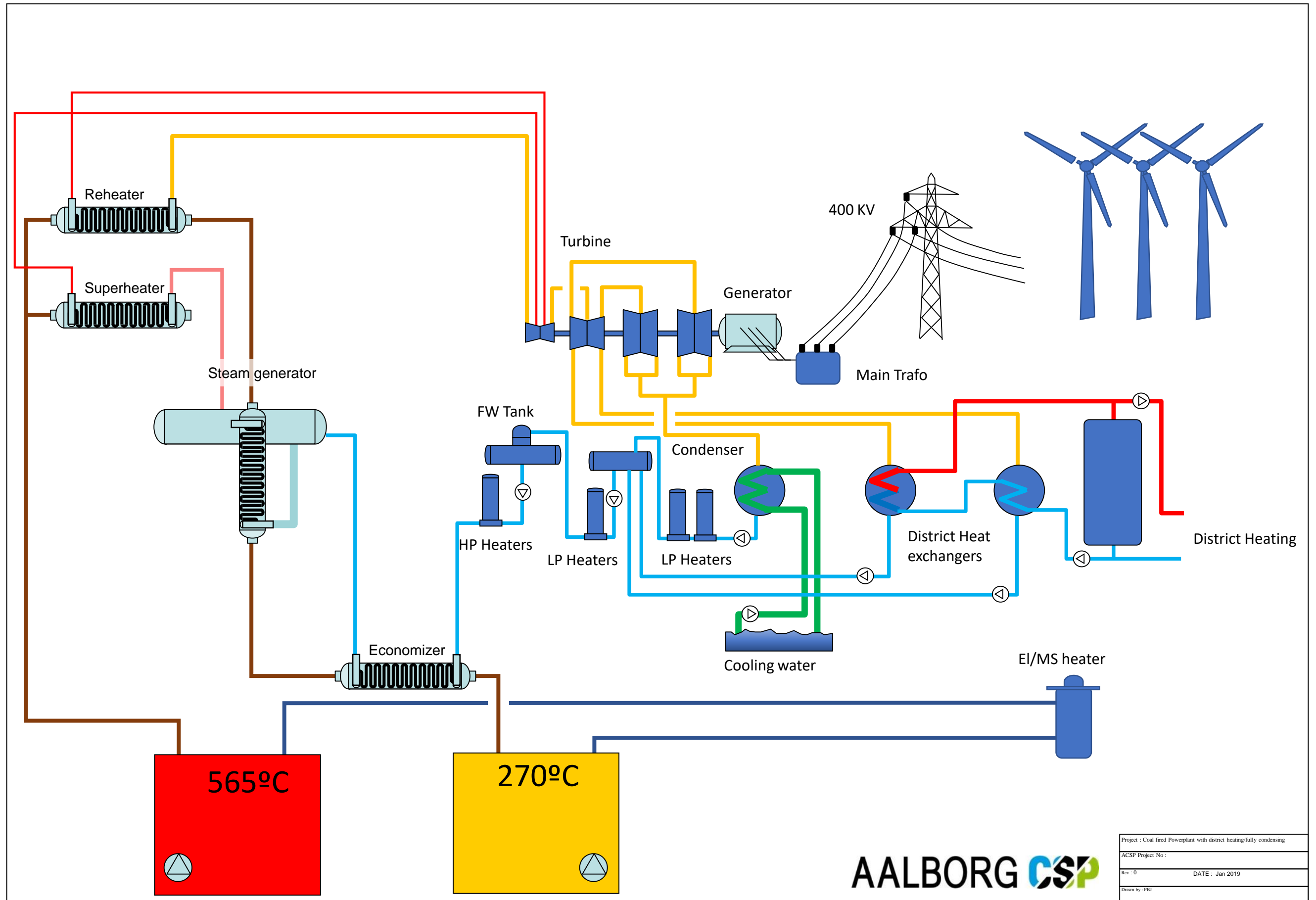


# Typical Coal fired power plant unit generating electricity and heat



Project : Coal fired Powerplant with district heating/fully condensing	
ACSPP Project No :	70004
Rev : 0	DATE : Jan 2019
Drawn by : FBI	

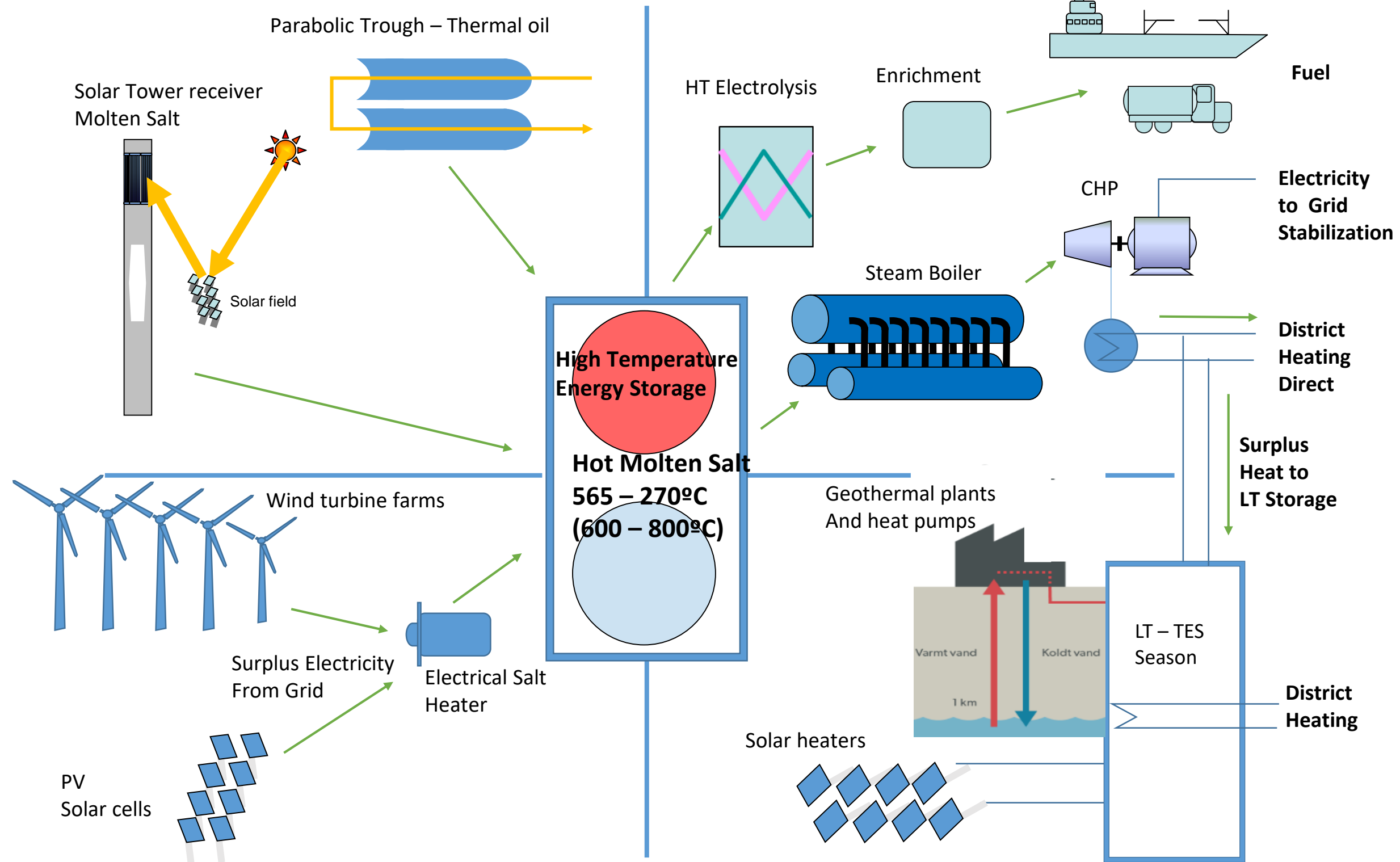
# Coal fired power plant Retrofitted and downscaled to operate 100% Renewable



Project : Coal fired Powerplant with district heating/fully condensing	
ACSP Project No :	
Rev : 0	DATE : Jan 2019
Drawn by : FBI	

**AALBORG CSP**

A solution can combine CSP and surplus Wind Electricity with high temperature and low temperature storage



# Investment

Installation of one plant 4.000 MWh High temperature Energy Storage

Investment cost 100 mio or 650 mio DKK

Investment in 40.000 MWh (10 x 4.000 MWh)

= 10 x 650 = 6,5 bill. DKK

Annually potential saving from IM/EX = 1,6 - 3,2 bill. DKK

-Capex financing through grants from Danish "Klimakompenseringsfonde"

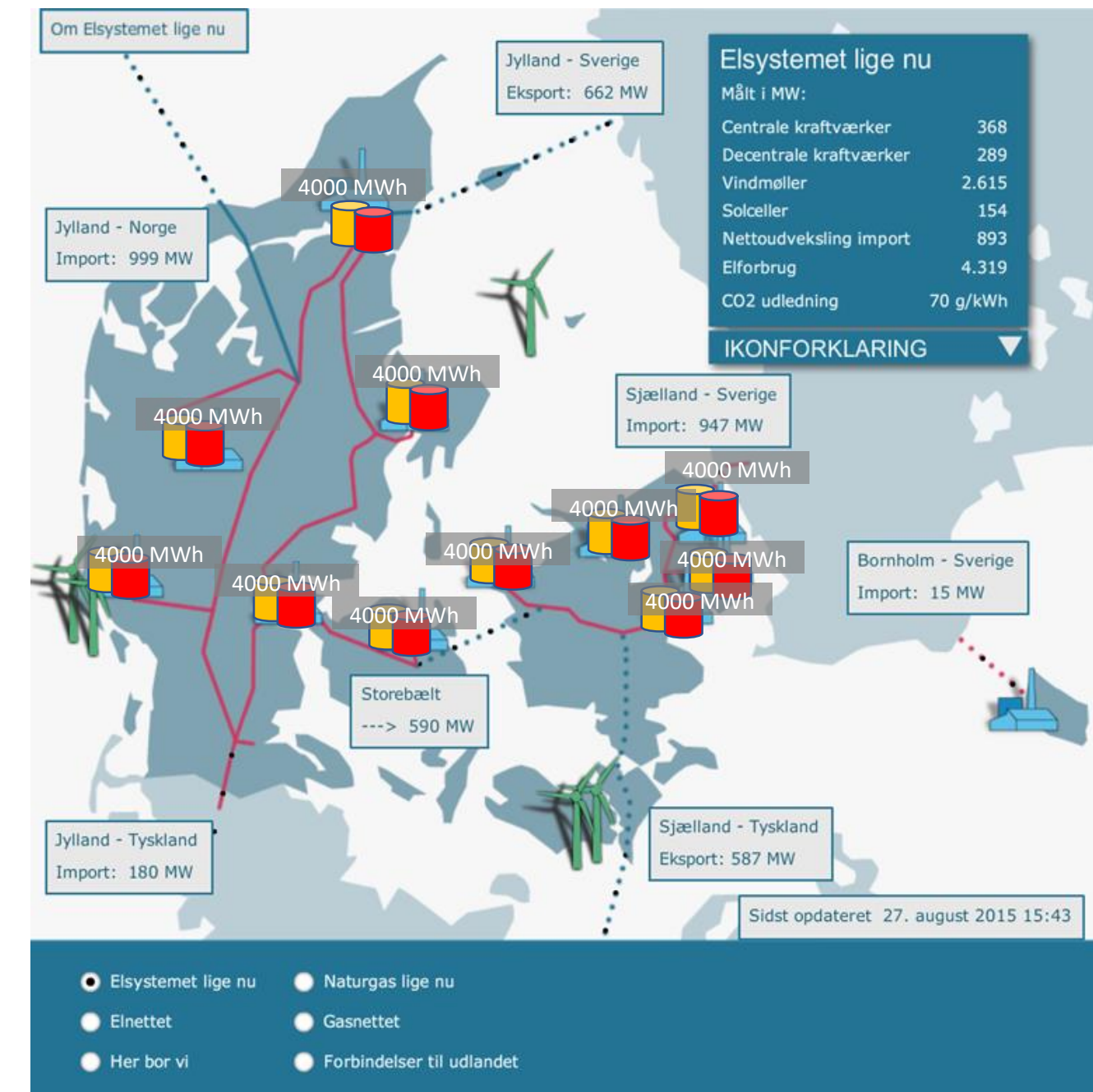
-Opex Business case through :

- Buying and selling Electricity
- Selling heat
- Provision of Grid Balancing and stability services.

El/Heat Ratio 35/40% = EL 1.400/1.600 MWh & Heat 3.600/3.400 MWh

It may not be profitable only driven by the spotmarket,

**Storing energy capacity must have a value**



Preliminary prediction of P/L (100 MWe Heater / 1500 MWh Storage)  
 NOT CONSIDERING GRID REGULATION SERVICES  
 Investment 250 mio Kr (excl retrofit)



	Reference	inkl el-afgifter	inkl el-afgifter elpatronlov	inkl kun Energinet nettarif
<b>Revenues</b>				
salg af el	44.086.068	149.373	1.106.811	10.128.814
salg af varme	56.652.000	72.000	540.000	9.630.000
<b>Revenues Total</b>	<b>100.738.068</b>	<b>221.373</b>	<b>1.646.811</b>	<b>19.758.814</b>
<b>Operation expenditures</b>				
køb af el	75.567.020	-192.593	-415.329	8.066.781
Afgifter og nettariffer	0	333.600	591.300	0
Nettariffer	0	0	922.500	6.420.000
<b>Operation expenditures Total</b>	<b>75.567.020</b>	<b>141.007</b>	<b>1.098.471</b>	<b>14.486.781</b>
<b>Net Cash from Operation</b>	<b>25.171.048</b>	<b>80.366</b>	<b>548.340</b>	<b>5.272.033</b>

**Investment in High Temperature Energy Storage incl Storage and Tanks Steam-Generator/Boiler and electric Salt-heater Using existing Turbine and DH infrastructure 23-27 USD/KWht.**

**Unique opportunity to reuse existing ASSETS such as steamturbine-generators, Transformers, high voltage switch-gear, Water treatment plant and district heating systems**

70% National CO2 reduction goal

United Nations Sustainable Development Goals

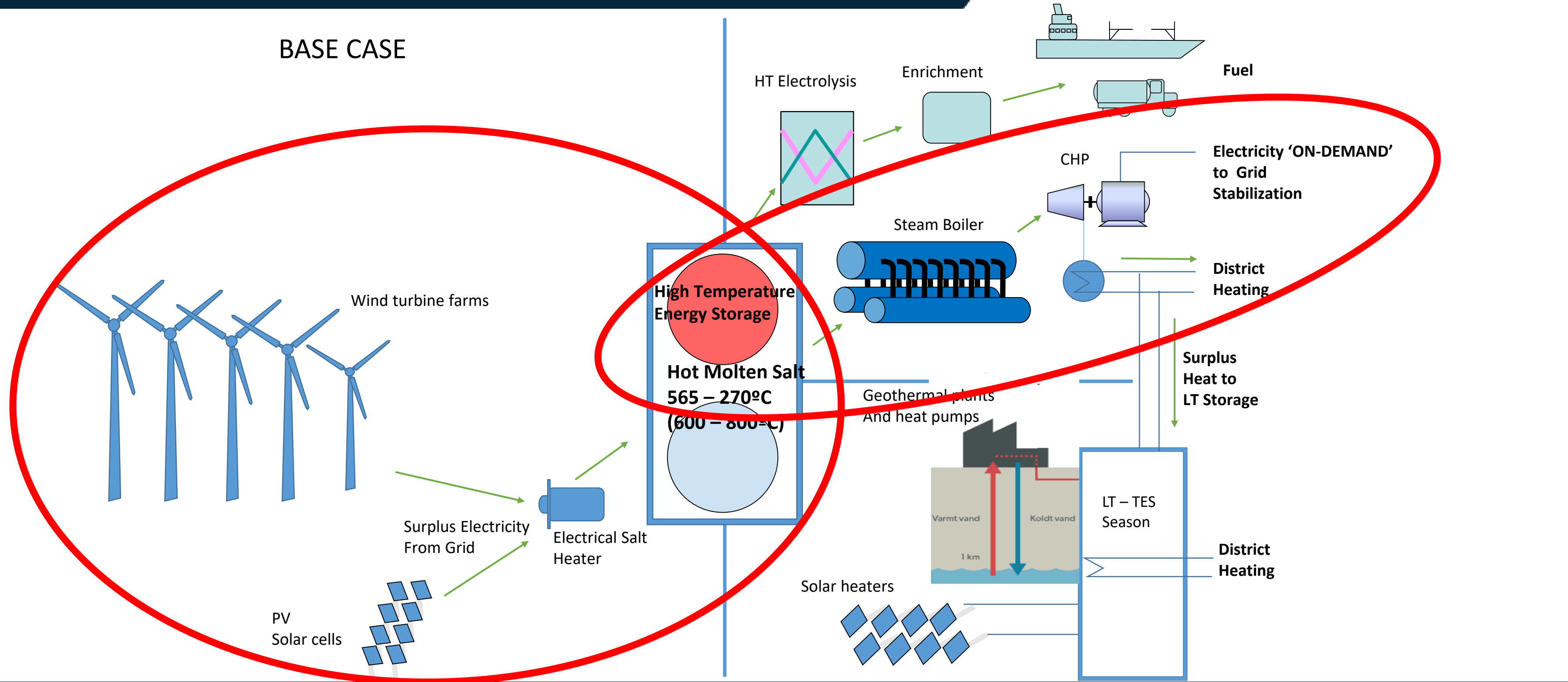




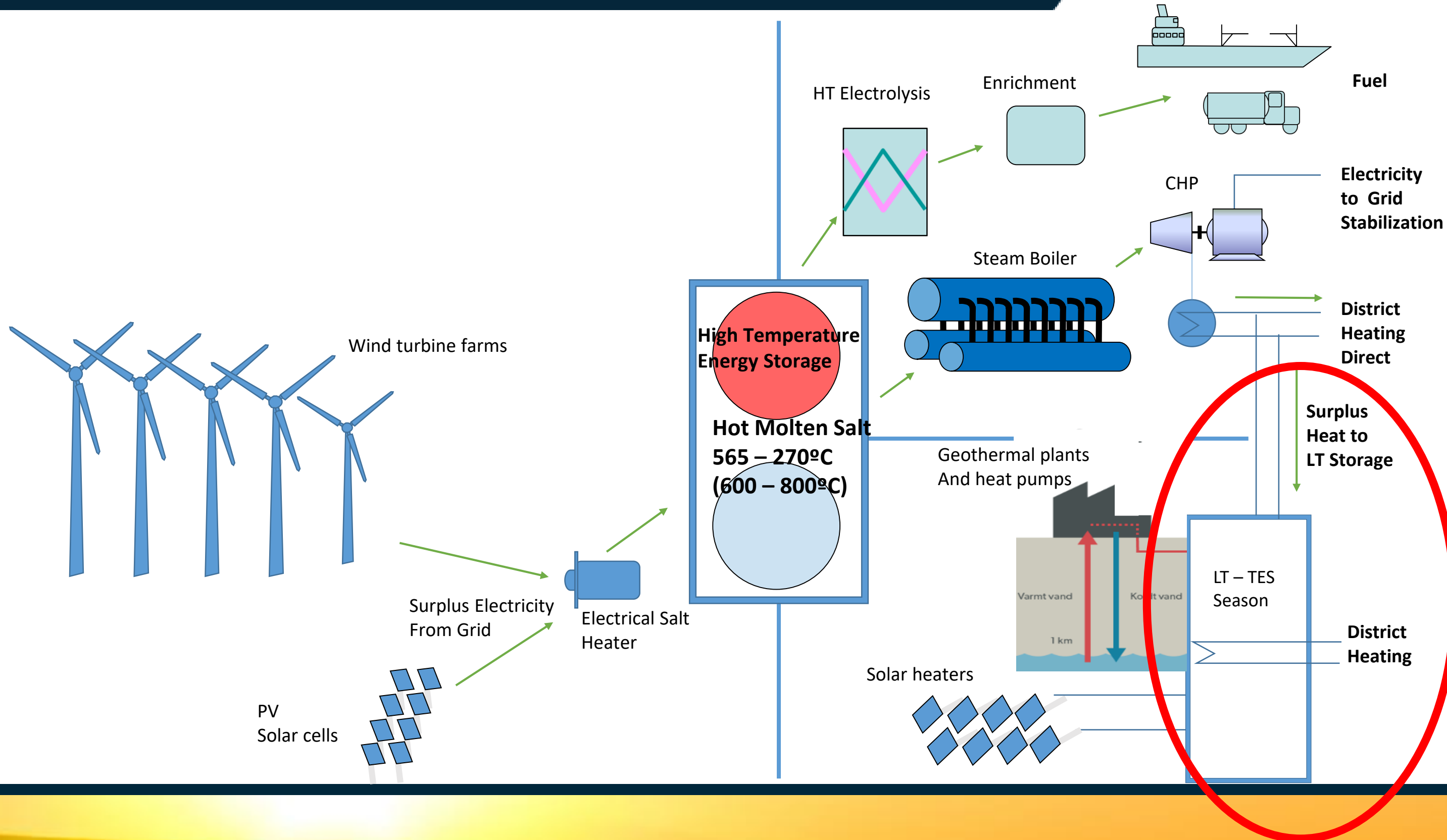


# Surplus Wind and Solar Electricity charging to High Temperature Energy Storage – Discharge on demand

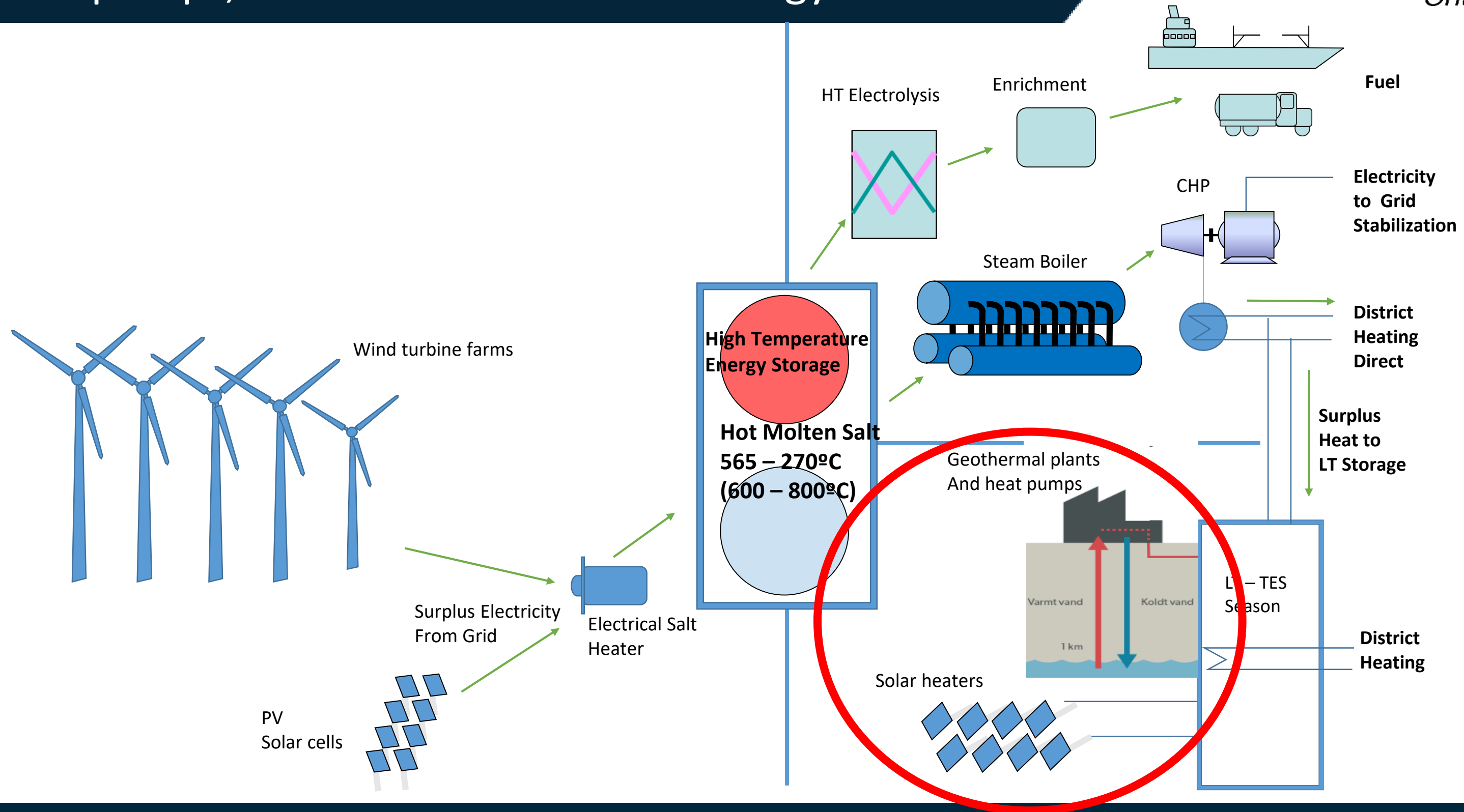
BASE CASE



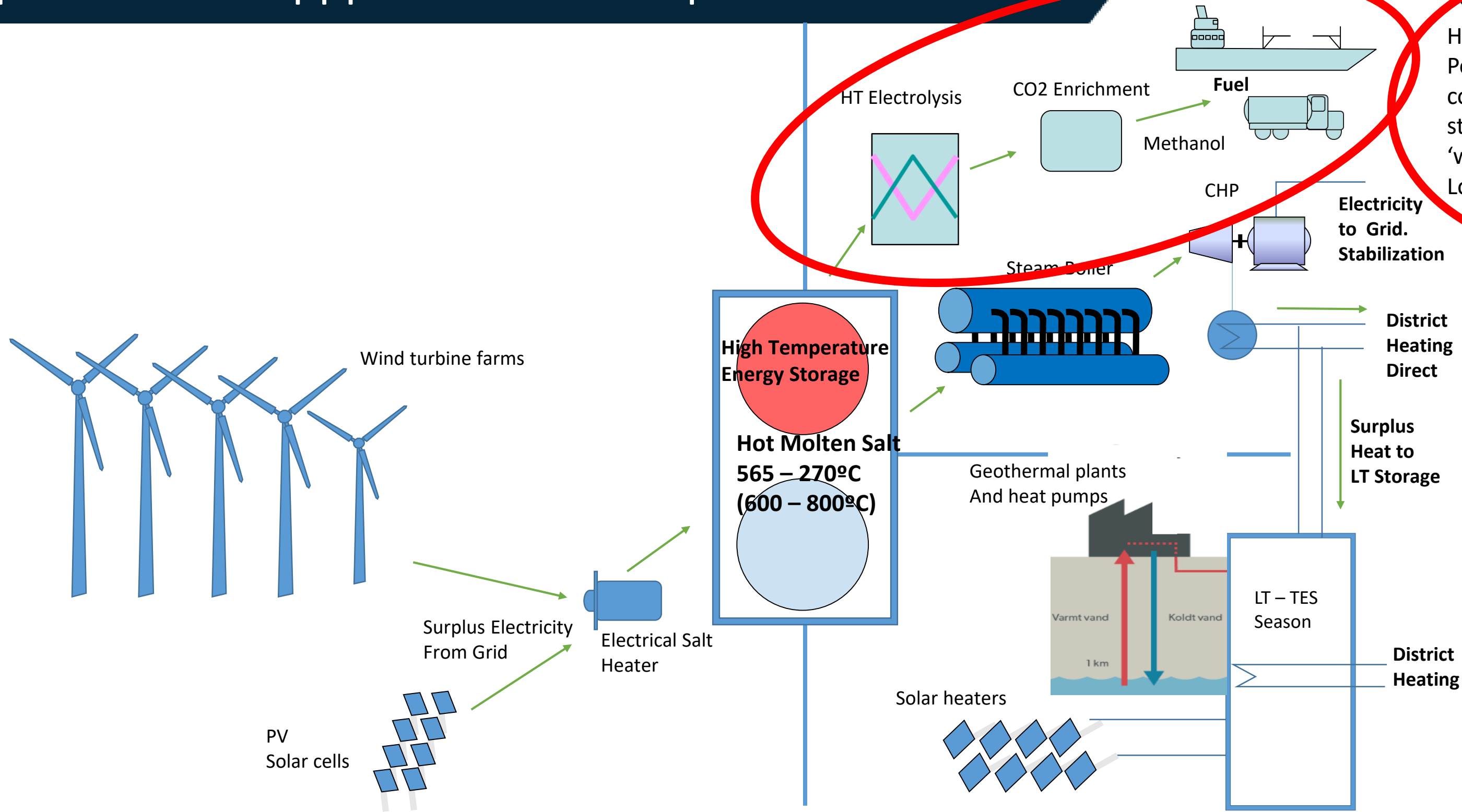
# Integration with low temperature energy Storage (Dam-lager)



# Integrated optimized operation through use of Heatpumps, Solar and Geothermal energy



# Possible Sector-integration to Hydrogen and fuel production. Support Green Transport Sector



Hydrogen production need stable Power supply. Not realistic to consider a large scale factory starting and stopping as the 'wind blows'. Storage secures Low price power purchase

# Possible integration with CSP Solar plants for Export opportunities

# AALBORG CSP

- Changing Energy

Hydrogen production need stabil Power supply. Not realistic to consider a large scale factory Starting and stopping as the 'wind blow'

