AALBORG CSP
- Changing Energy

Advanced Thermal Energy Storing

with the most efficient use of the ressources

Peter Badstue Jensen
Vice President - Partner

November 30, 2017

BUSINESS AREAS

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CSP power plant technologies

- Solar tower receiver (direct steam)
- Solar tower receiver (molten salt)
- SGS3 Steam generator system (thermal oil)
- SGS4 Steam generator system (molten salt)
- Fresnel steam island

Integrated Energy Systems

Novel configuration of renewable technologies with CSP acting as focal point of the system to holistically satisfy multiple energy needs for:

- ✓ heating
- ✓ clean water
- ✓ electricity
- ✓ process steam
- ✓ cooling
- ✓ mechanical power

Solar district heating

- Solar heating
- Combined heat and power generation
- TES Thermal energy storage
- Direct water or thermal oil applications
- District Cooling

Thermal Energy Storage (TES)

- Storage for CSP plants with thermal oil

In collaboration with:

EnergyNest

SaltX Technology

HELIAC

R&D Activities

- Direct-steam-to/from-concrete storage
- Thermo-Chemical energy storage
- Thermal Vind power storage
- Thermal storage in hot stones

ACSP the highlights

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

- **2014**

High temperature storage concept for storing solar and wind energy (Energy Nest)

- **2014**

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

- **2011**

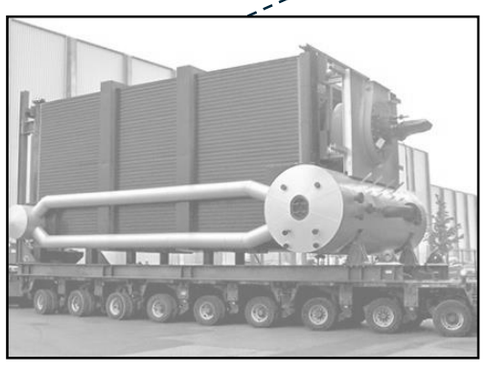
CSP for district heating optimized for local weather conditions

- **2007-09**

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

- **1988**

Traditional boiler design and development



- **2016**

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

EUDP SUPPORT

- **2017**

Firsrt Order to China SGS 4 Natural circulating Steam generator 50 Mwe Molten Salt

Energy is NOT religion

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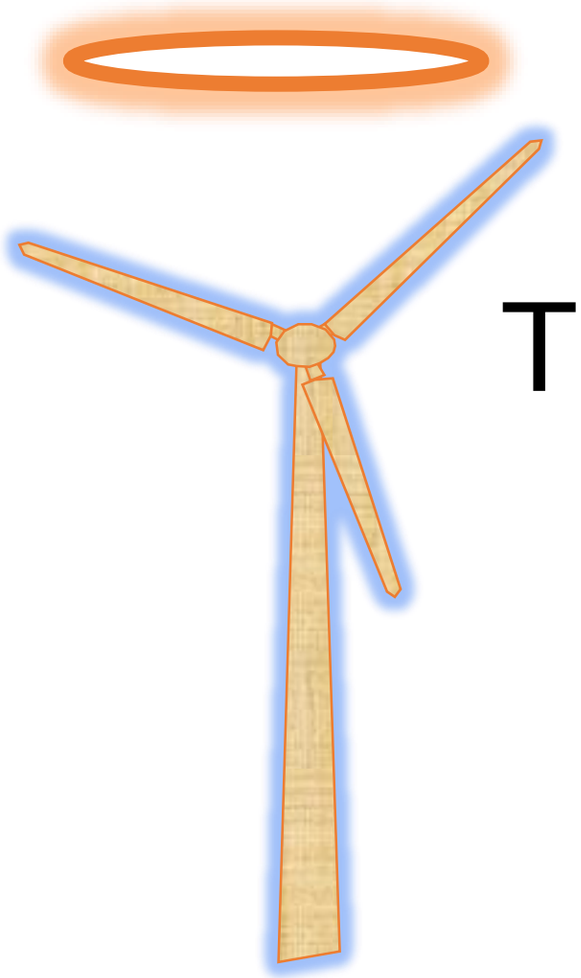

There is no all-mighty technology

Renewable Energy diversity is required like bio-diversity

The right technology for the right purpose at the right time gives the best economy and performance

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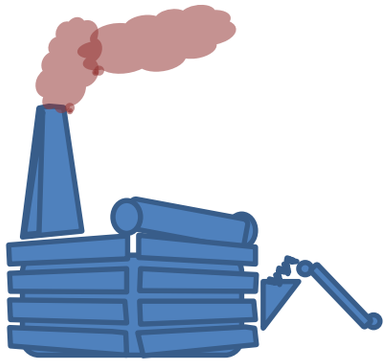
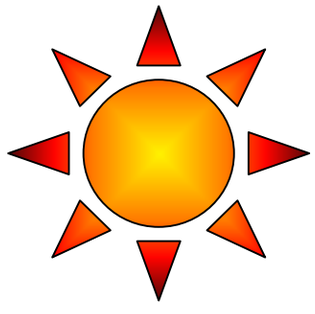
INTEGRATED RENEWABLE ENERGY

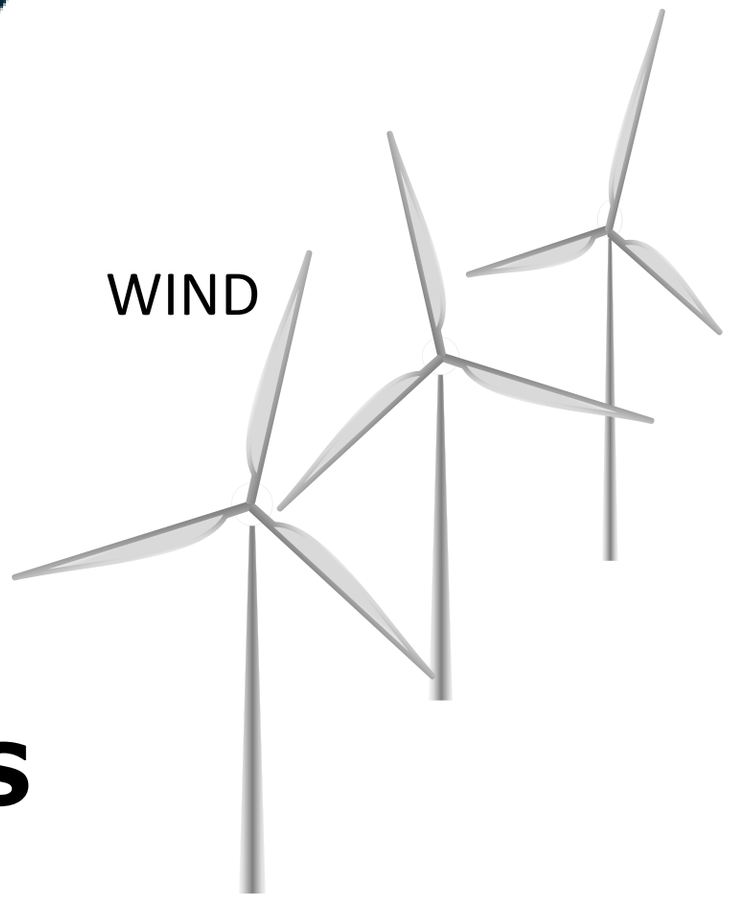
BIO FUEL



SOLAR



WIND



NEXT STEPS

INTEGRATED RENEWABLE ENERGY SYSTEMS & THERMAL ENERGY STORAGE SYSTEMS

Sun to energy

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SOLAR Energy

PV

STEAM

Electricity

Co-generation

Energy Storage

Mirrors

Water/Thermal Oil/Molten Salt

Heating

Wind to energy Traditional

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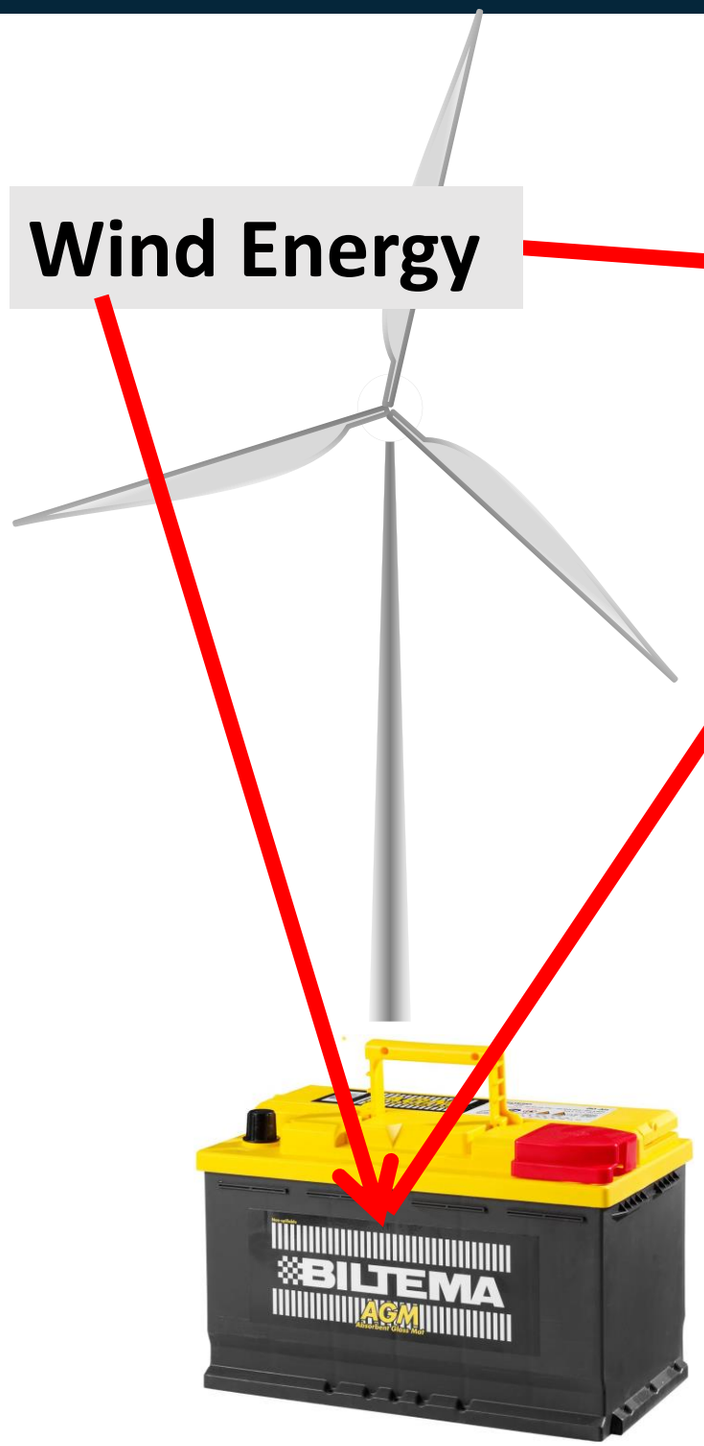
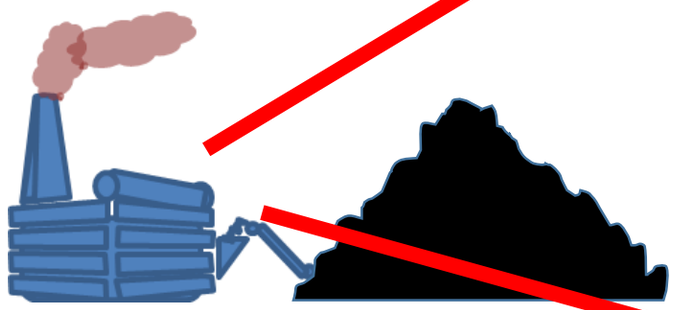
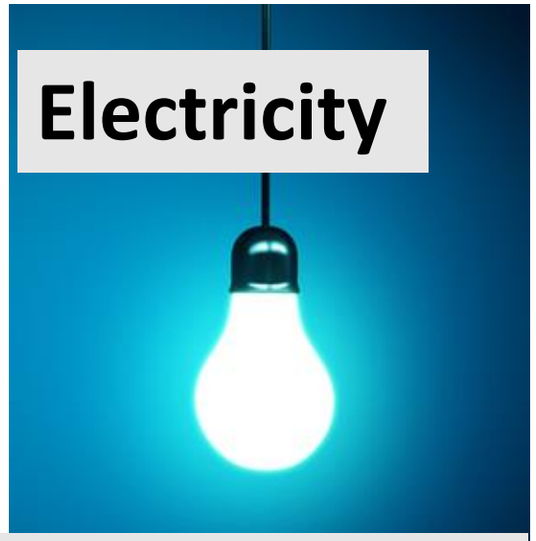
Wind Energy





Coal Back-up

Electricity



Co-generation

Heating

Wind to energy Future

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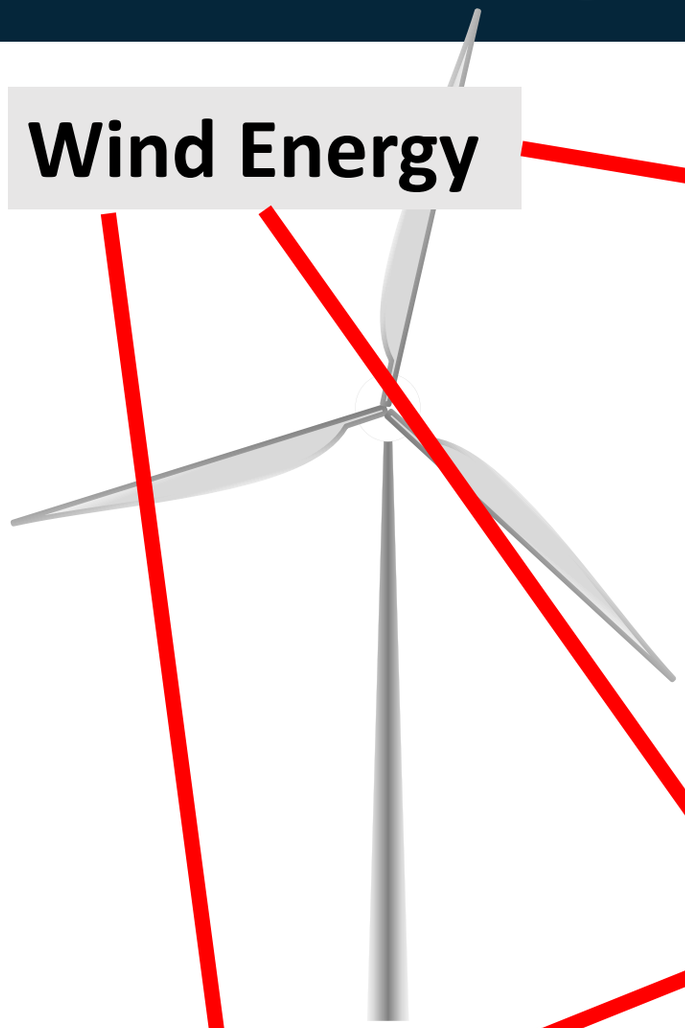
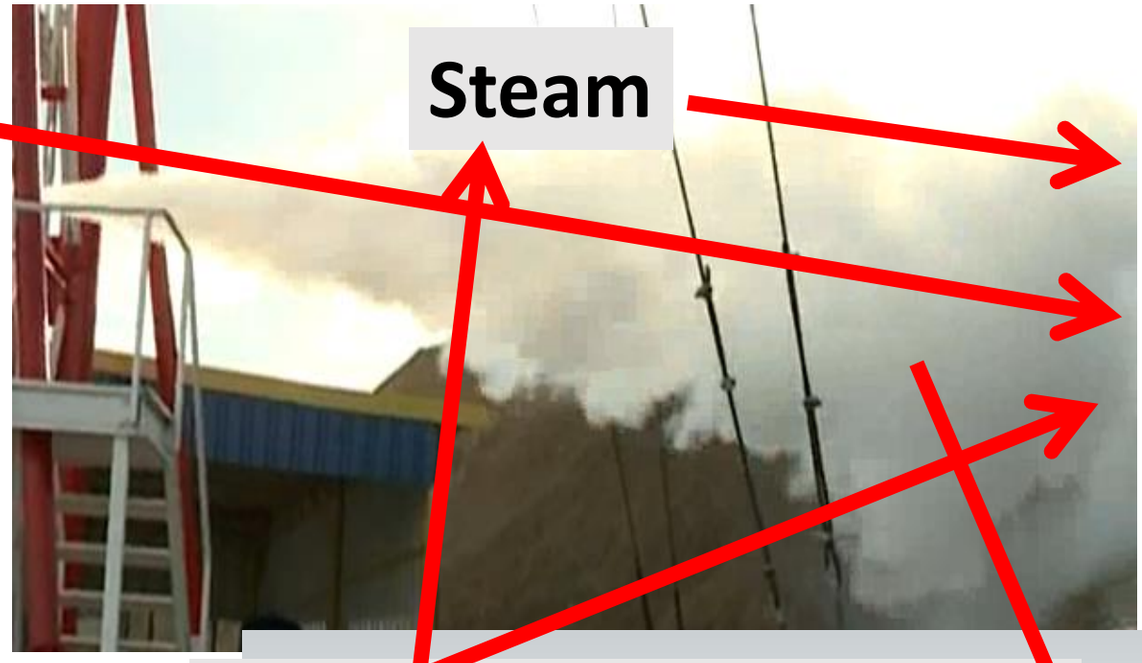
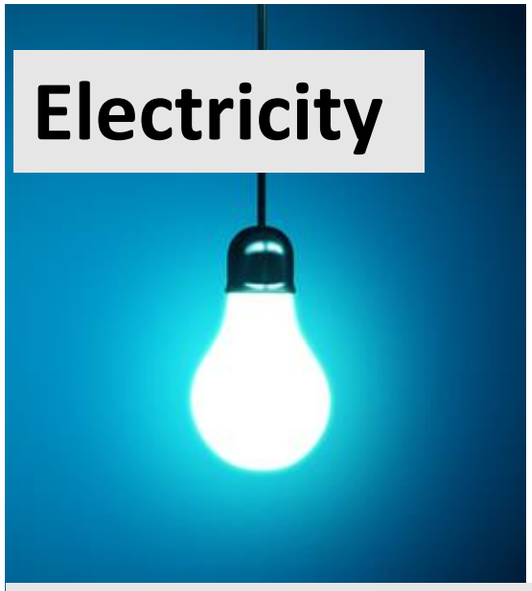
Wind Energy





Steam

Electricity



Co-generation

Thermal Energy Storage

Water/Thermal Oil/Molten Salt

Heating

The consumption curves

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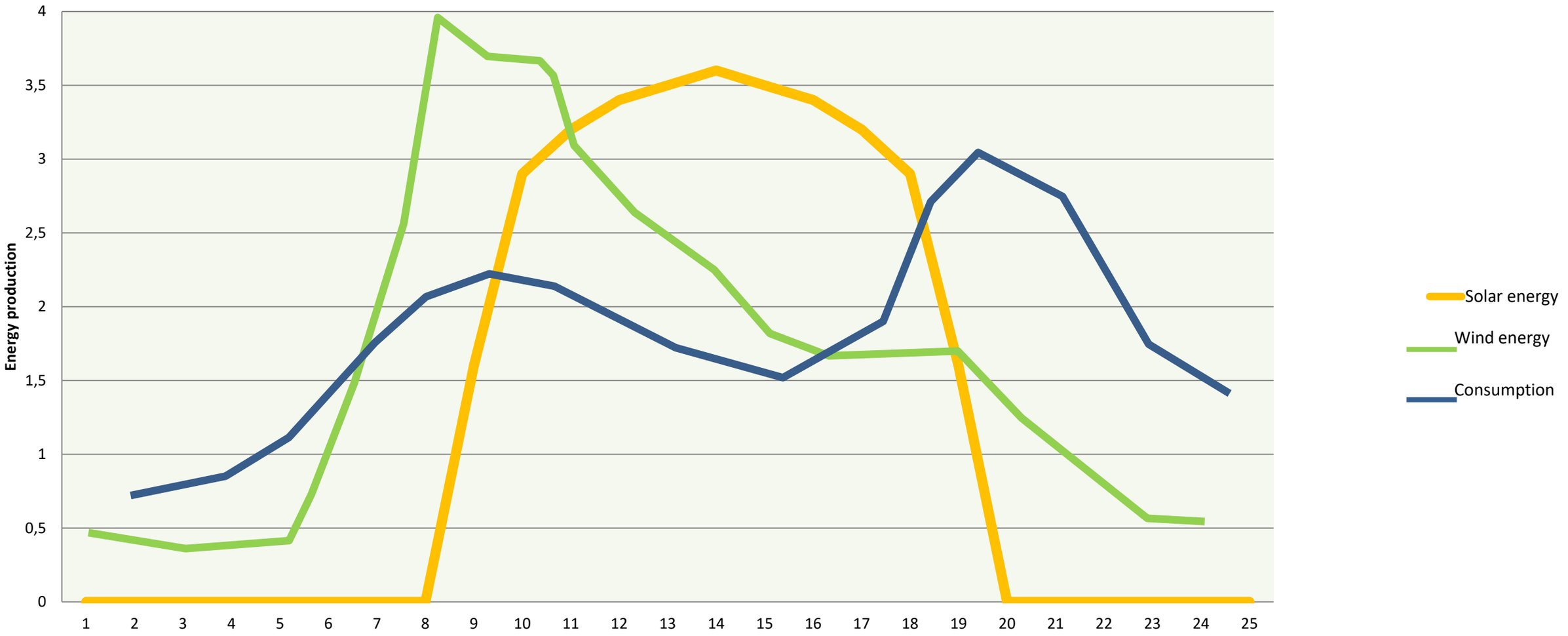
Solar and Wind Energy vs Consumption



FUTURE RE PLANTS MUST HAVE STORAGE TO BE DISPATCHABLE

The global installed storages

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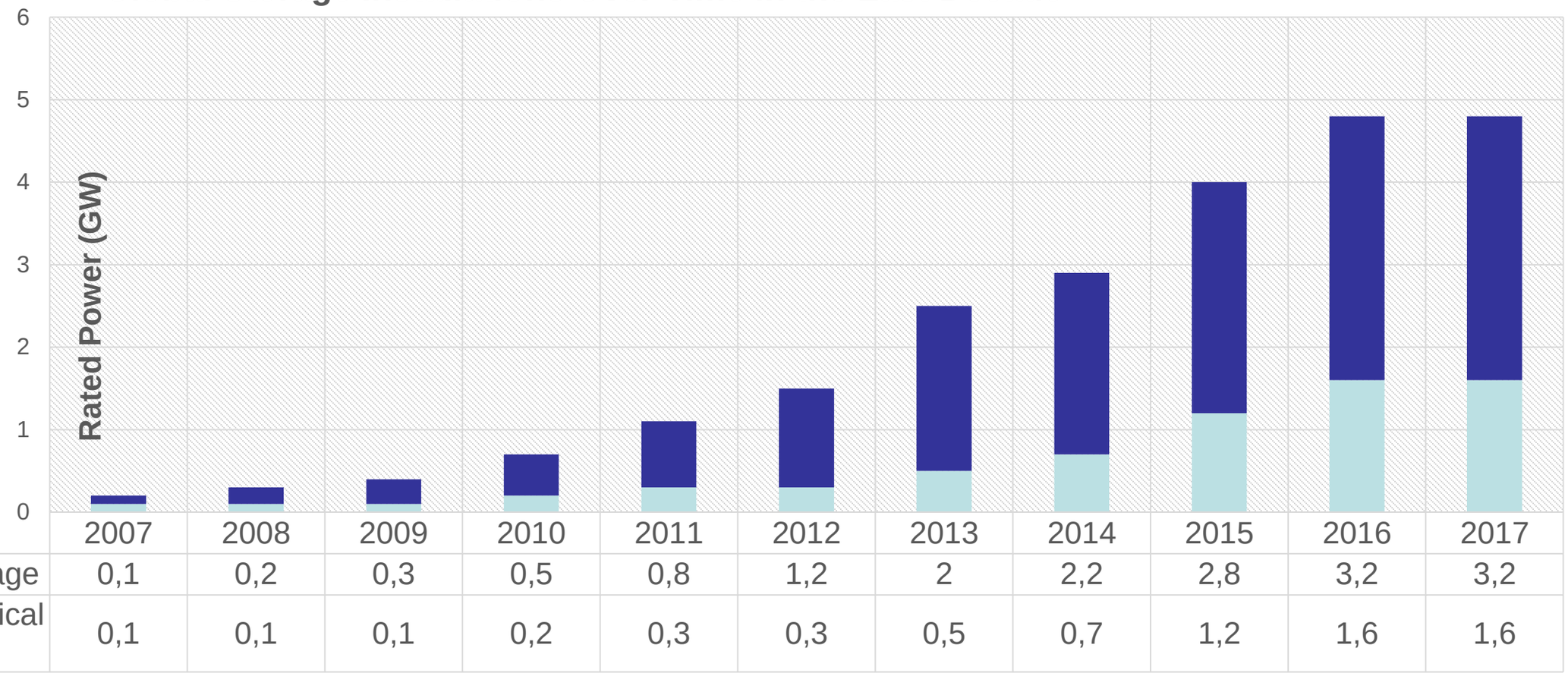

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Thermal Storage	0,1	0,2	0,3	0,5	0,8	1,2	2	2,2	2,8	3,2	3,2
Electro-Chemical Storage	0,1	0,1	0,1	0,2	0,3	0,3	0,5	0,7	1,2	1,6	1,6

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

http://www.energystorageexchange.org/projects/data_visualization

The Chinese figures

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China 1st Phase 20 Pilot CSP Projects Distribution

Qinghai SUPCON Solar Delingha 50MW MS Tower Project

Northwest Engineering Gonghe 50MW MS Tower Projectct

Huanghe Hydropower Development 135MW DSG Tower Project

Beijing Shouhang IHW Resources Saving Technology 100MW MS Tower Project

China Three Gorges New Energy Jinta 100MW MS Tower Project

YumenXinneng 50MW MS Tower Project

GuohuaYumen 100MW MS Tower Project

Northwest Electric Power Design Institute Hami 50MW MS Tower Project

Dahua Inc. Shangyi 50MW DSG Tower Project

Royal Tech Yumendongzhen 50MW PT Project

Shenzhen JinfanAkesai 50MW molten salt PT Project

Rayspower Group Yumen 50MW PT Project

CECIC Gansu Wuwei Solar Power Gulang 100MW PT Project

Inner Mongolia China Nulcear Royal TechWuzhongqi 100MW PT Project

CGN Delingha 50MW PT Project

Zhongyang Zhangjiakou Chabei 64MW PT Project

DCTC Dunhuang 50MW MS CLFR Project

Northern United Power Urad 50MW CLFR Project

CITIC Zhangbei DSG 50MW CLFR Project

ZhangbeiHuaqiang Group Zhangjiakou DSG 50MW CLFR Project

Xinjiang

Gansu

Qinghai

Inner Mongolia

Hebei

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

The China figures

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Projects commenced so far out of 20 demonstration projects to be co

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 Nulcear 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

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

Energy Pallet Renewable

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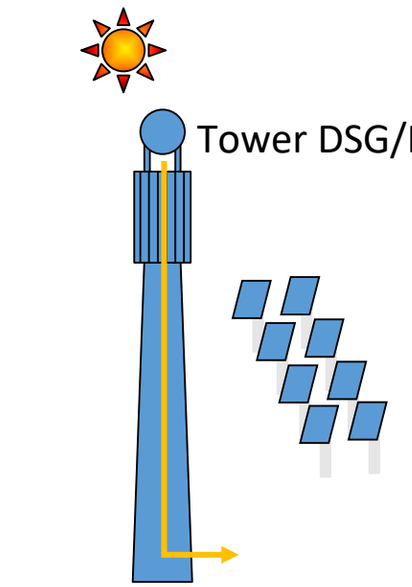
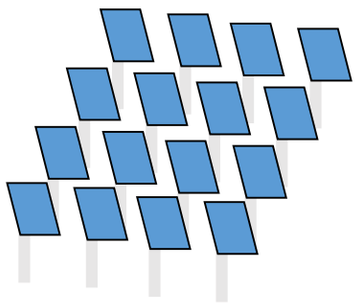
SOLAR FIELD

Tower DSG/MS

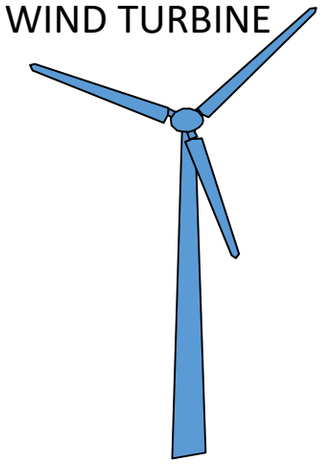


Parabolic Trough HTF/DST/MS

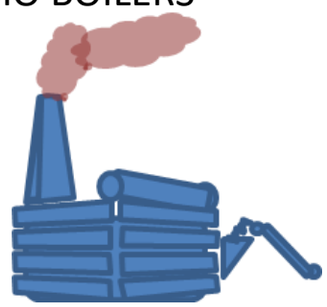
PV or Flat thermal panels



WIND TURBINE



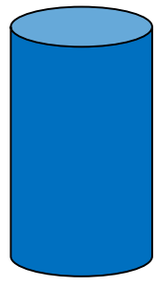
BIO BOILERS



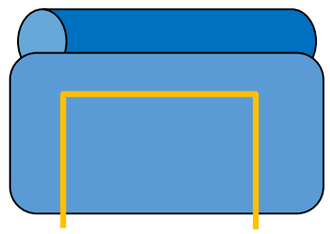
Fresnel receiver
HTF/DST/MS

THERMAL STORAGE

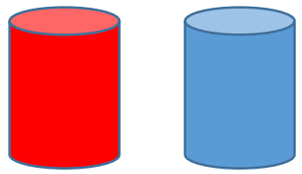
Hot water storage



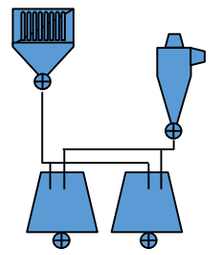
Concrete Storage



Molten Salt etc.

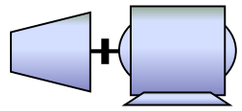


Chemical Energy

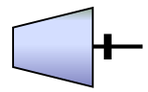


ELECTRICITY/CONVERSION

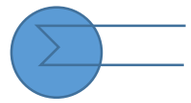
Steam turbine
Generator



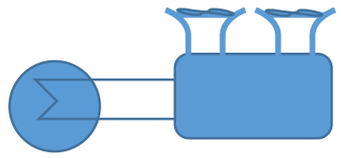
Steam turbine
Mech. drive



Steam condenser

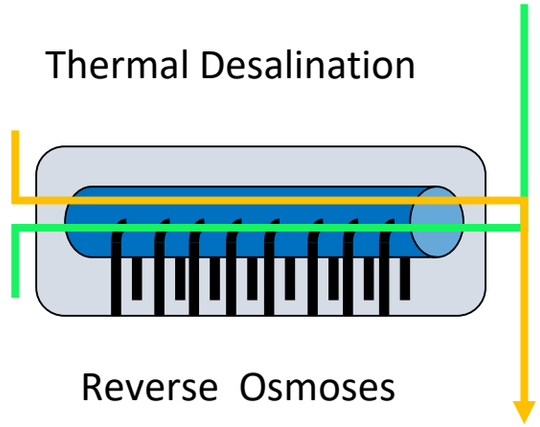


Steam condenser
& Cooling tower

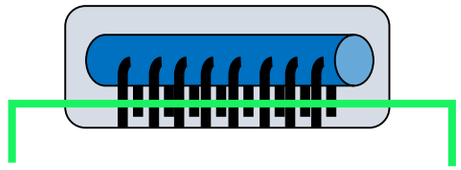


THERMAL USAGE / COGEN

Thermal Desalination



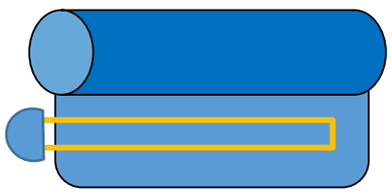
Reverse Osmoses



Absorption Chiller

Process / District heat

Electrical boiler/Heat Pump



Temperature is the key

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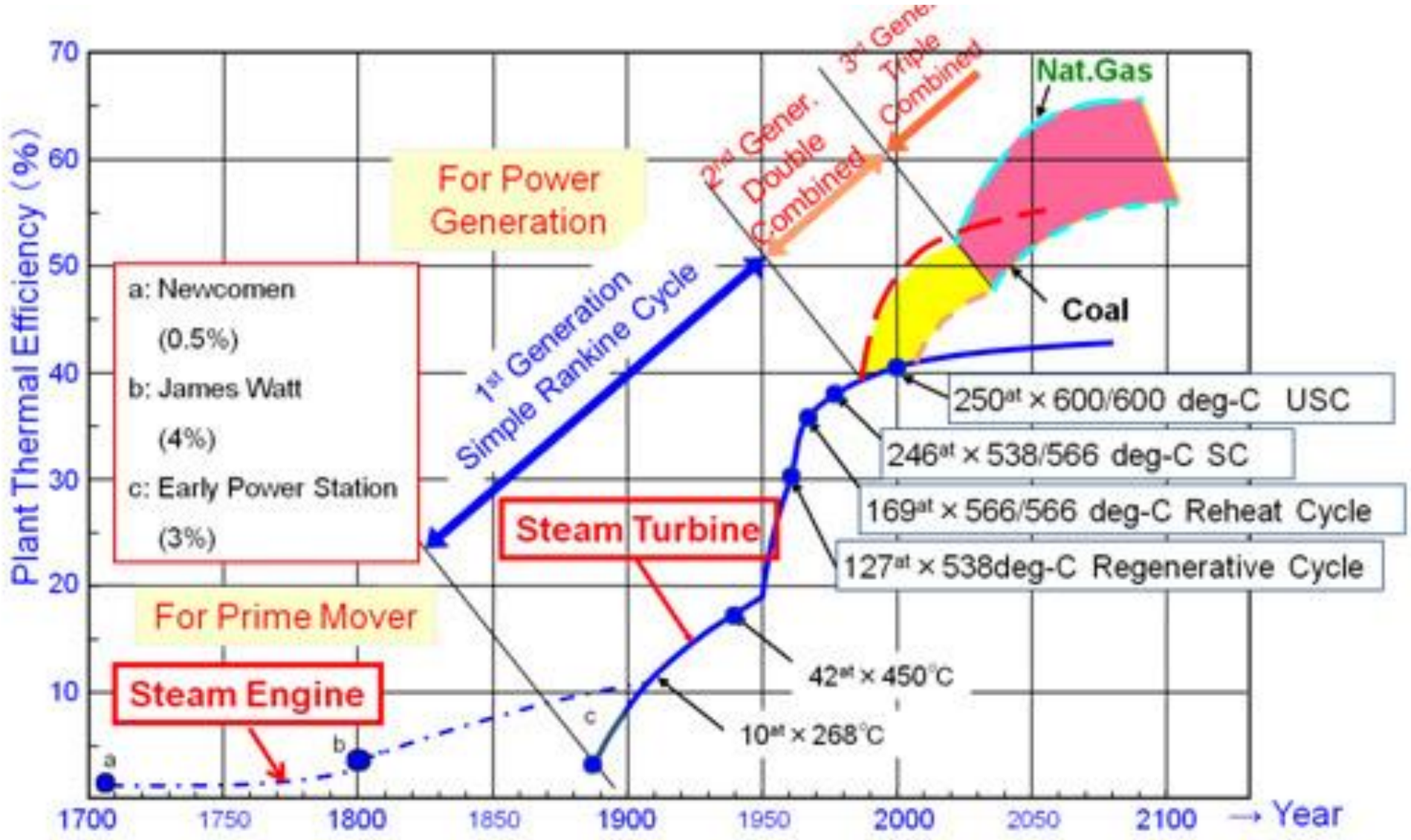
Higher temerature equals potentially higher steam turbine efficiency



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THERMAL ENERGY STORAGE TES

- 95 Water tanks – Thermocline – District Heating - Industrial

- 430 Concrete Heat Storage - Thermal oil/Steam – Power Plant

- 550 Chemical Heat Storage – CAO/Steam – Power plant

- 565 Molten Salt Storage – MS/Steam – Power Plant

> 600 Other Heat storage systems – Aluminium – Sulphur etc.

TES Hot water Integrated system

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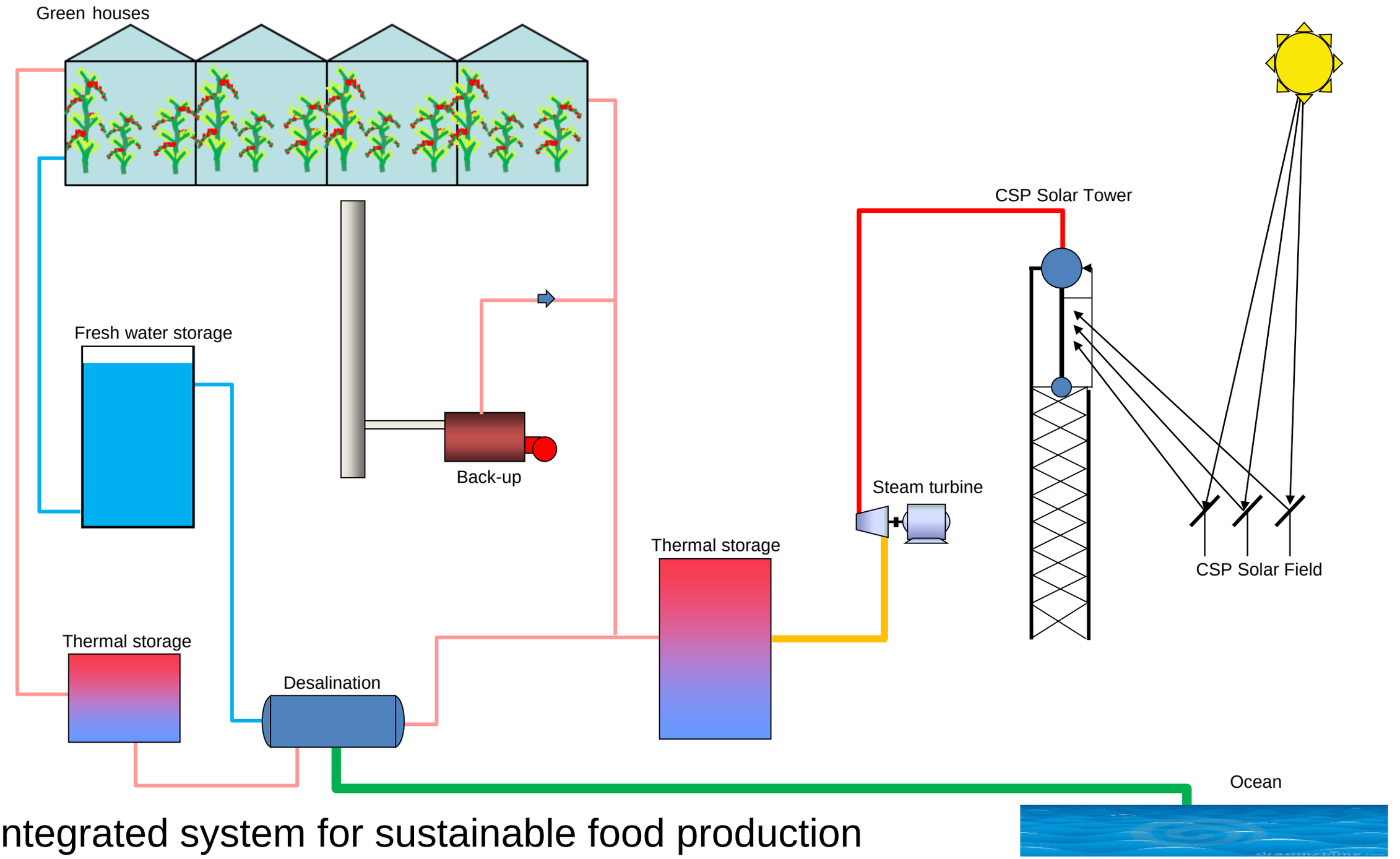

Integrated system for sustainable food production

TES Hot water Integrated system

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INTEGRATED SYSTEMS BASED ON CSP - FOR SUNDROP FARMS

Integrated Energy System - New way for CSP

- Multiple revenue streams from one CSP system
- up to 80% powered by a novel configuration of CSP technologies
- lowering energy costs

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Thermal energy storage

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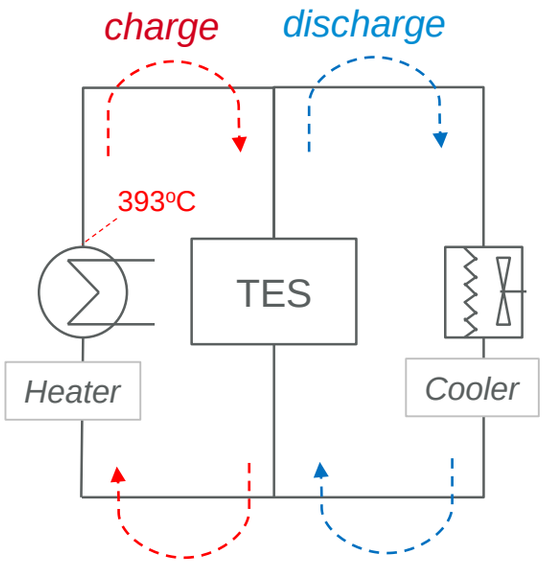
Test facility - Masdar Institute Solar Platform

Masdar INSTITUTE معهد مصدر

Heater & Cooler

TES Pilot



The hot oil-loop at MISP has been upgraded and instrumented to perform research and testing TES systems under controlled conditions

Dowtherm-A heat transfer fluid (HTF) heated by electrical heater (100 kW_{th}) to emulated solar conditions with maximum temperature of 393°C

Cooler is used to emulate HTF return temperatures from a steam generator or heat sink

Thermal energy storage

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EnergyNest **Test facility - Masdar Institute Solar Platform**

Masdar INSTITUTE معهد مصدر

Validation of constant system performance

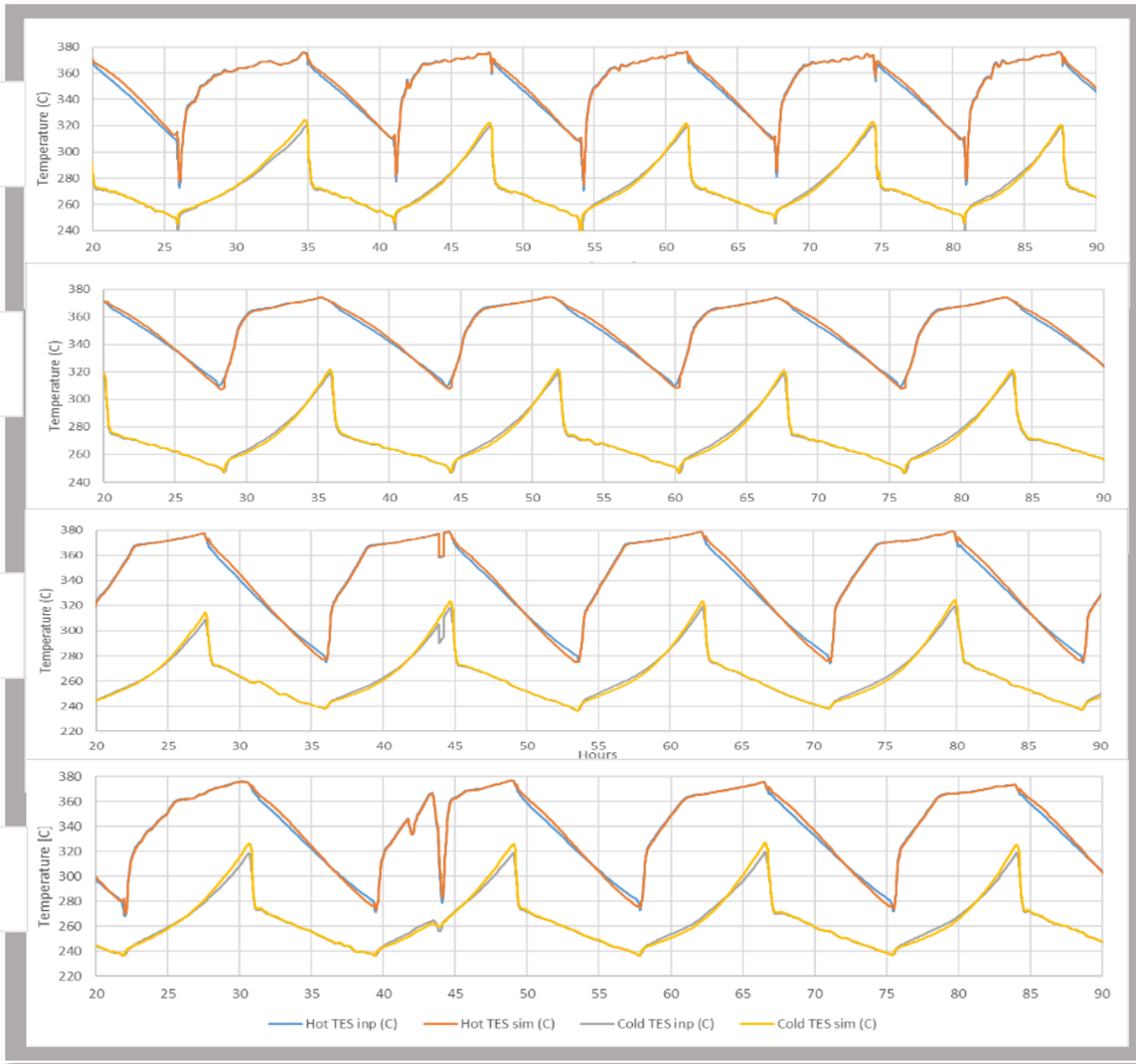
>1000 hrs
(13 hr cycles)

>1500 hrs
(16 hr cycles)

Assessment

>2000 hrs
(16 hr cycles)

>2500 hrs
(16 hr cycles)



- **Validation** of system performance is done through **direct comparison** between measured sensor values in TES and numerically simulated performance
- Virtually **no difference** in simulated versus measured performance **after operation for 1000 1500, 2000 and 2500 hours!**
- TES, as whole, shows absolutely **no sign of degradation**

Thermal energy storage

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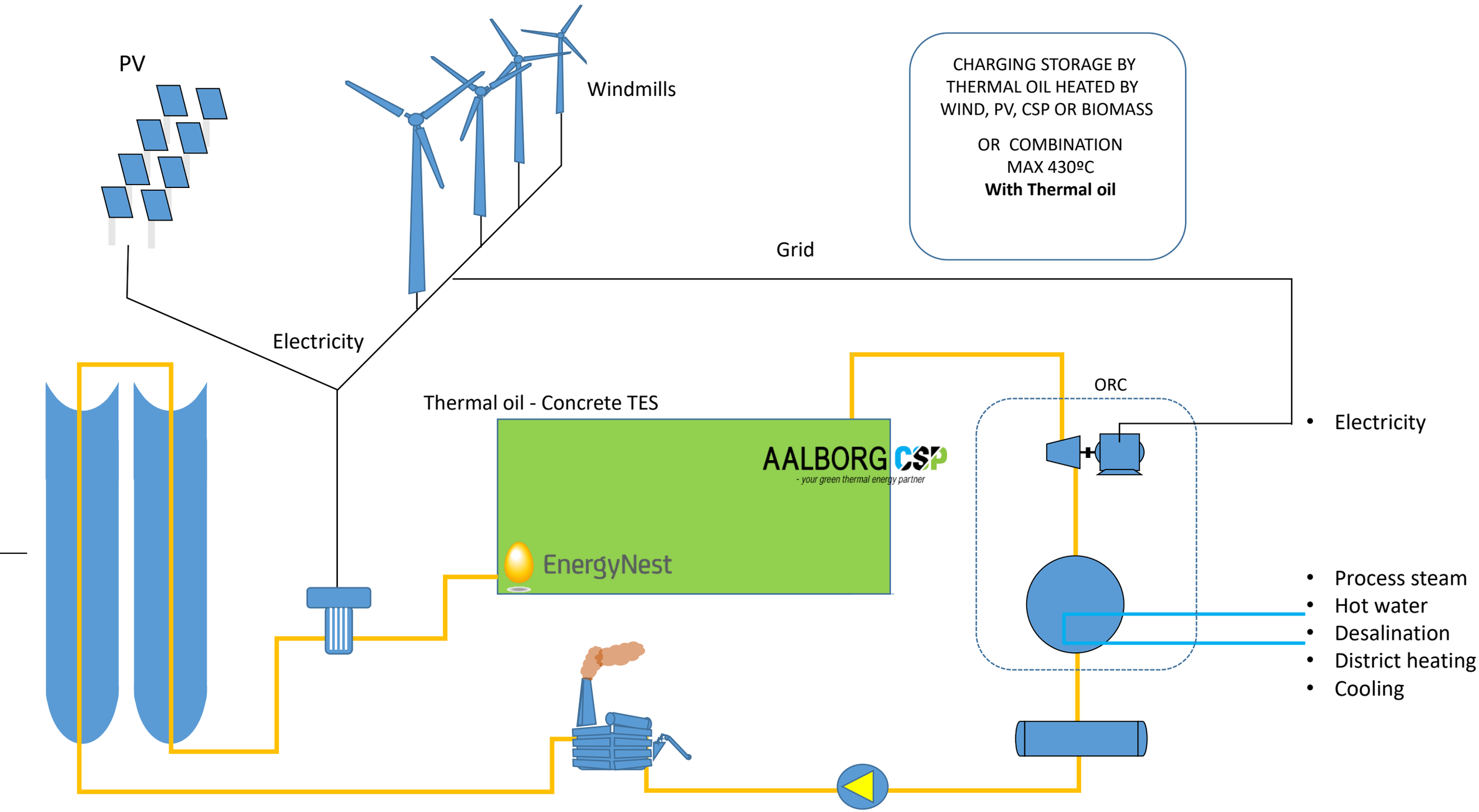

Direct steam storage system

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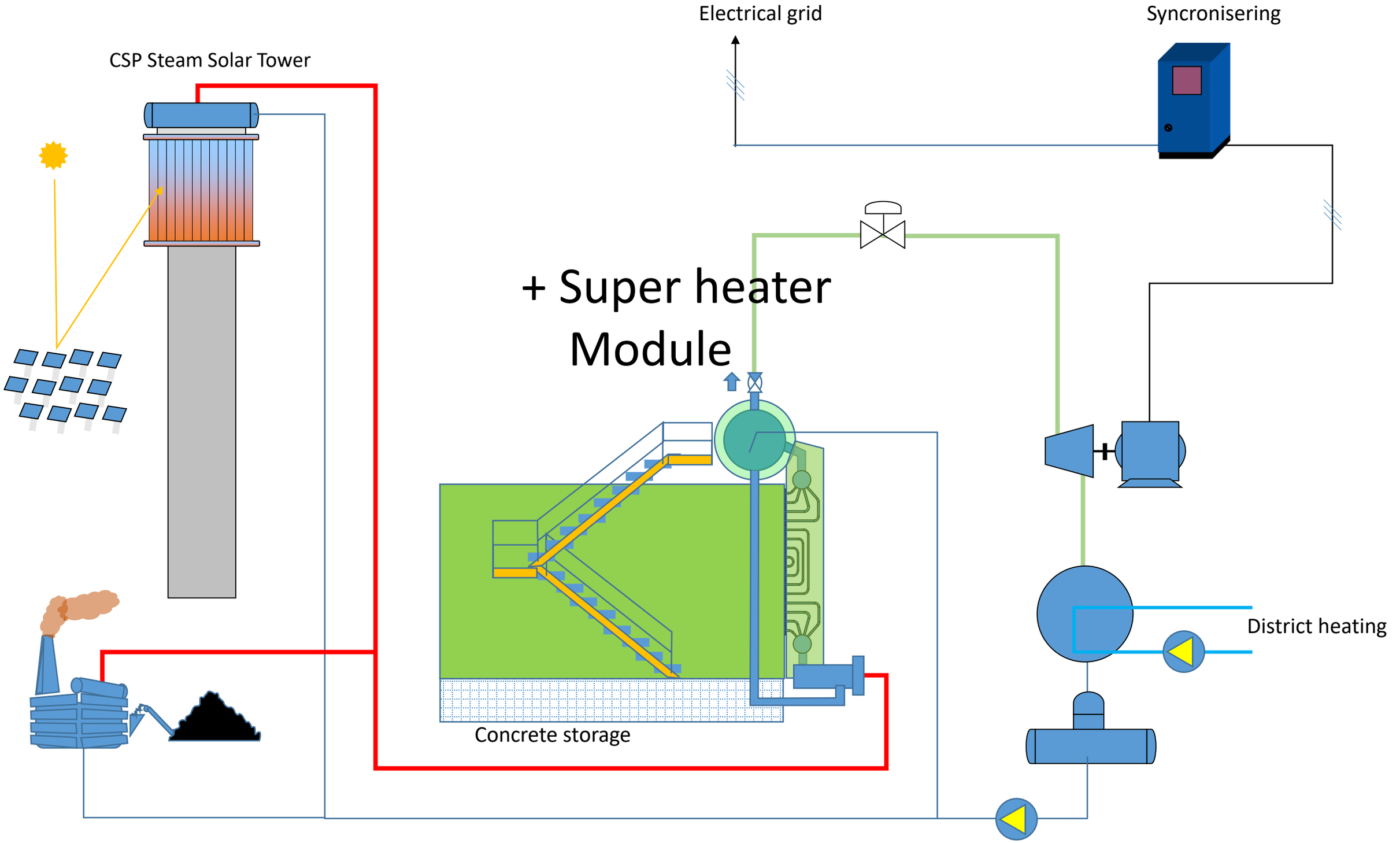

Wind power plant Electric system

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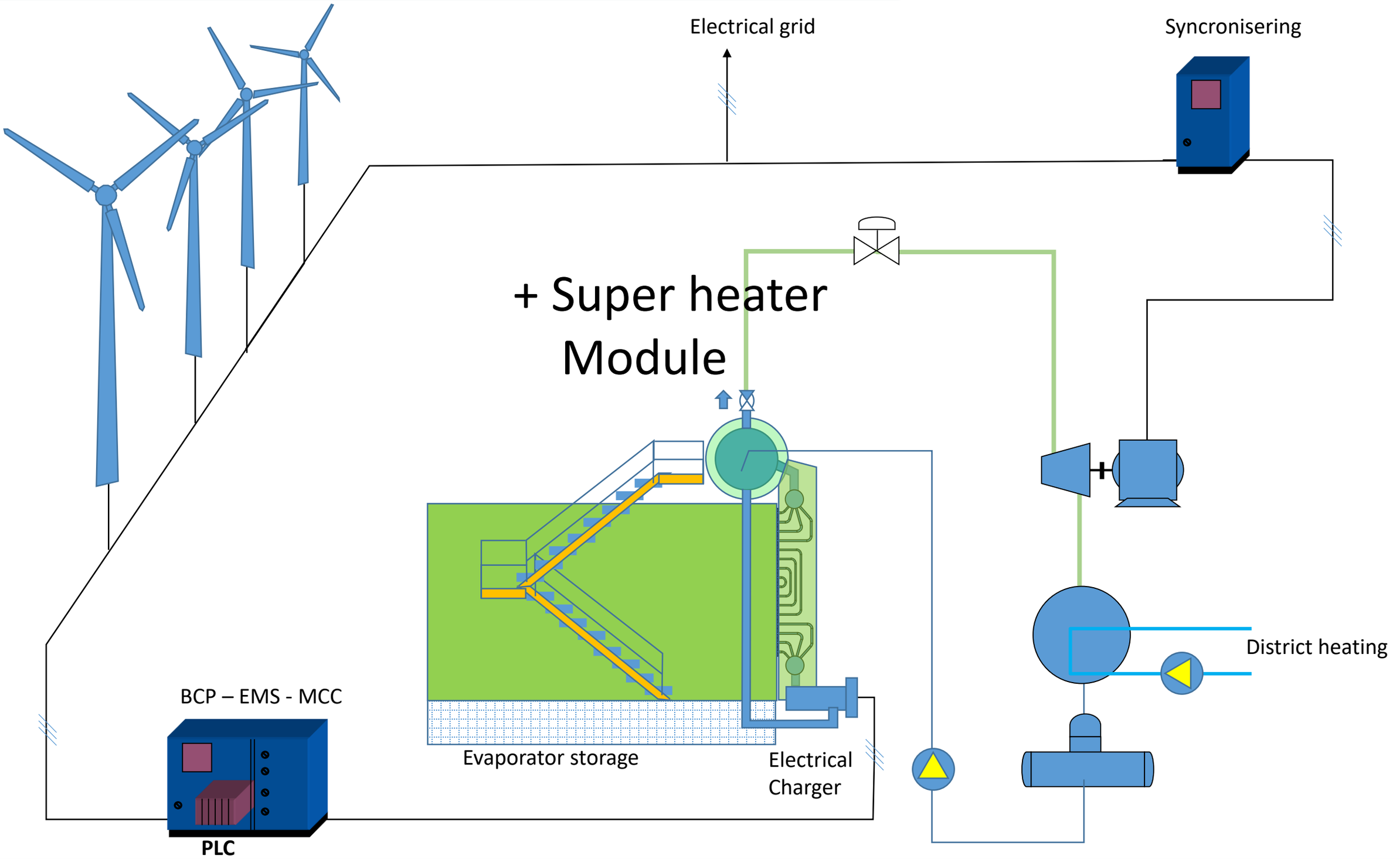

Wind power plant electric system

AALBORG CSP
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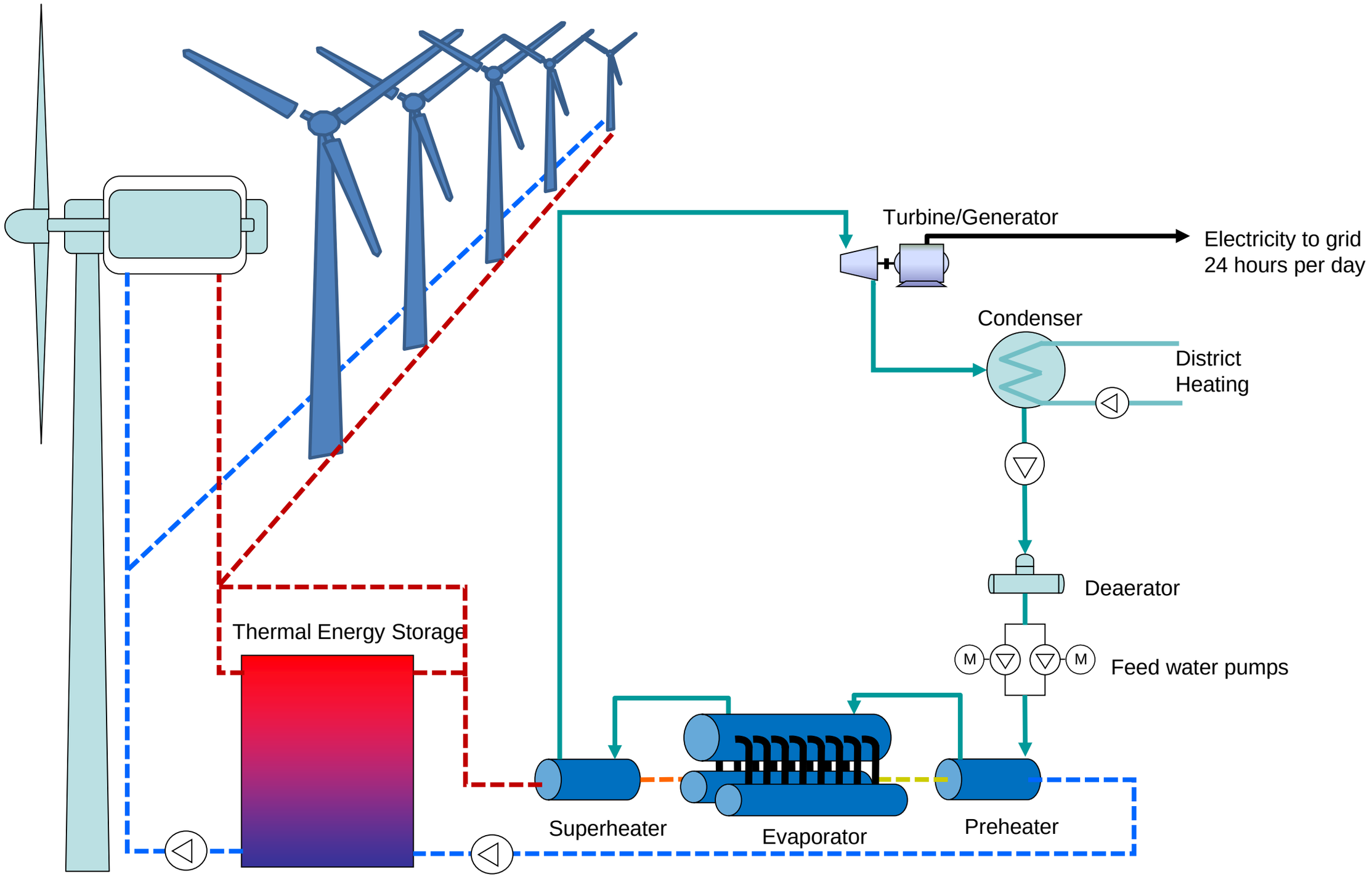

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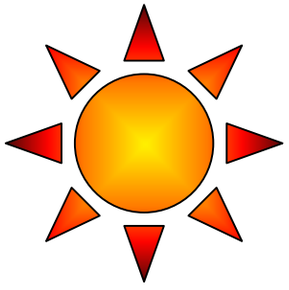
THERMAL ENERGY STORAGE TES



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SaltX storage system

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Charging Day - Releasing Night

Continious Power
Day and Night!

thermal energy

$$CaO^{NCS} + H_20 \longleftrightarrow Ca(OH)_2$$

550ºC

Tested at SaltX lab,
at Stockholm University (Sweden)
and at DLR (Germany).

NCS: Nano Coated Salt

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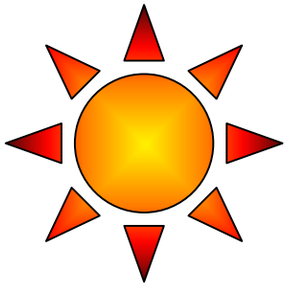
THERMAL ENERGY STORAGE TES



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CSP Molten Salt power plant

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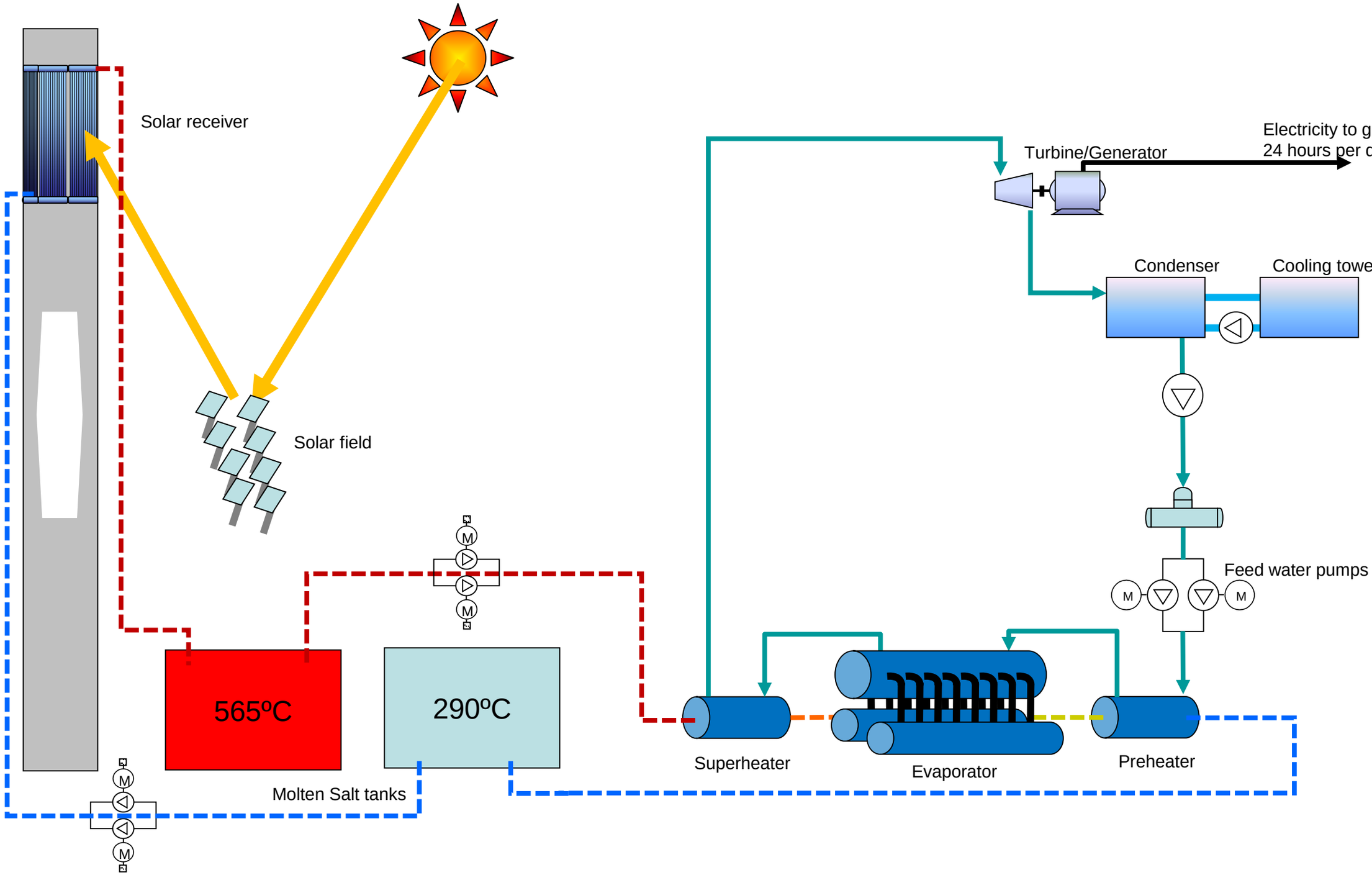

Vind Molten Salt power plant

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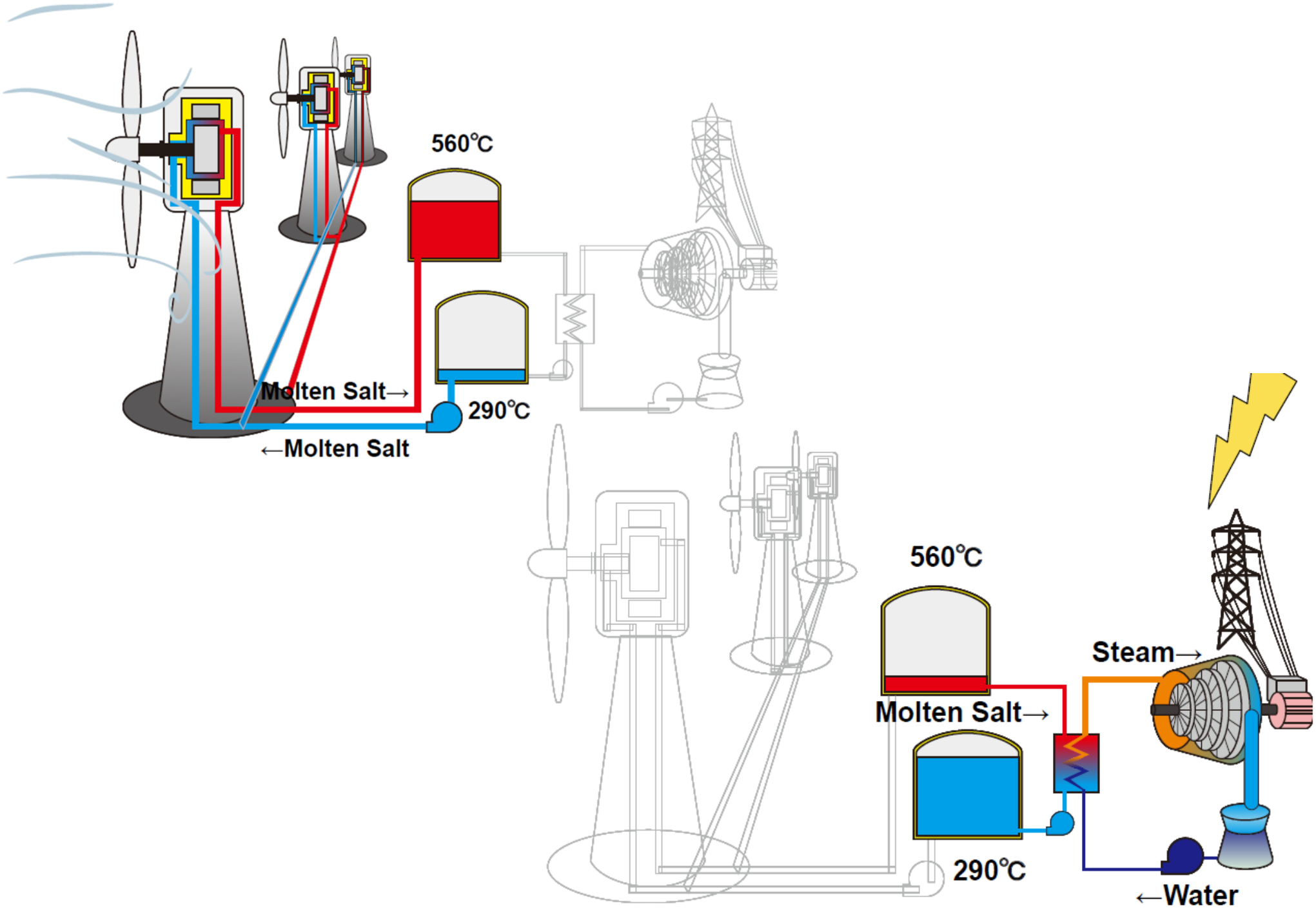
- Changing Energy



CSP power plant system

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Nom. capacity: 1000 MWh_{th}

3500 m^2 footprint
12 meters high

HEATCRETE®

Heatcrete® specially developed concrete with superior thermal performance

Fossil free Denmark in 5-10 years

AALBORG CSP
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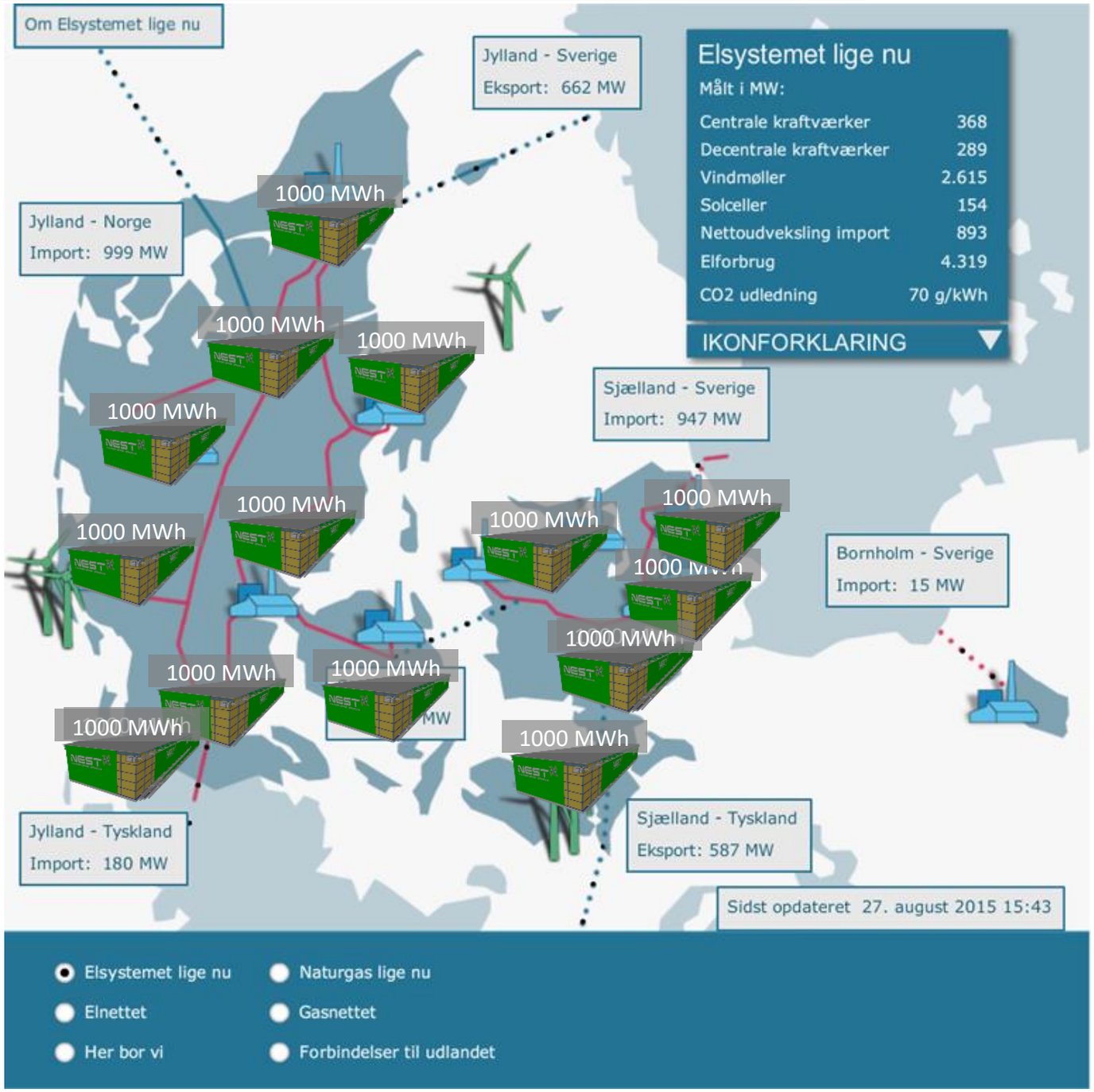

Fossil free Denmark in 5-10 years

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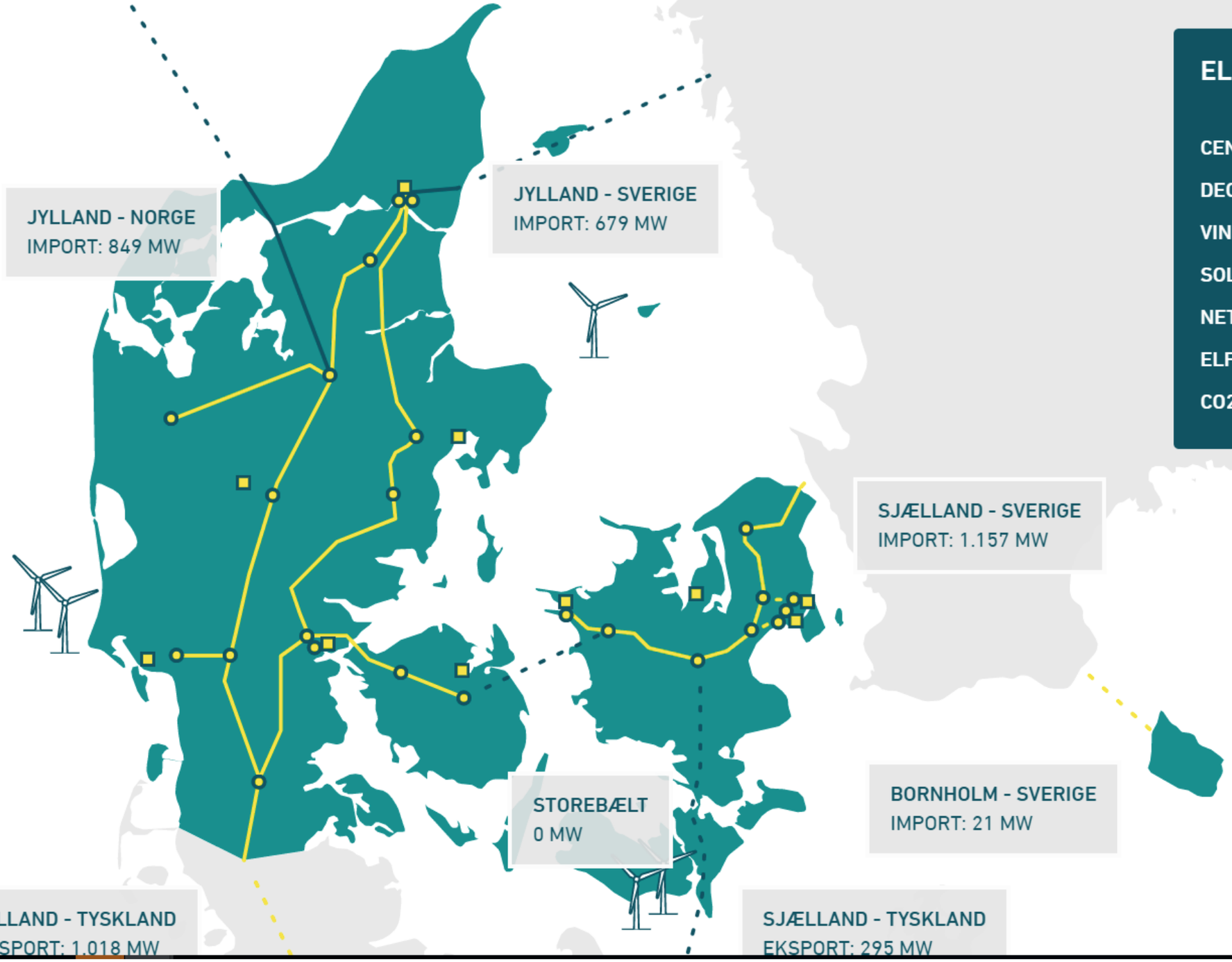

ELSYSTEMET LIGE NU

CENTRALE KRAFTVÆRKER	1.920 MW
DECENTRALE KRAFTVÆRKER	1.054 MW
VINDMØLLER	95 MW
SOLCELLER	55 MW
NETTOUDVEKSLING IMPORT	1.394 MW
ELFORBRUG	4.518 MW
CO2-UDLEDNING	383 G/KWH

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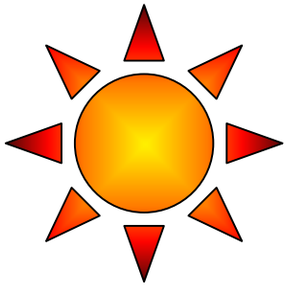
THERMAL ENERGY STORAGE TES



- 95 Water tanks – Thermocline – District Heating - Industrial

- 430 Concrete Heat Storage - Thermal oil/Steam – Power Plant

- 550 Chemical Heat Storage – CAO/Steam – Power plant

- 565 Molten Salt Storage – MS/Steam – Power Plant

> 600 Other Heat storage systems – Aluminium – Sulphur etc.

Storage solutions under development

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Aalborg CSP storage R&D activities:

- Development of Chemical bound energy storage ENERSTORE® Together with SaltX, Sweden. Pilot planned in Berlin 2018
- Storage of energy in Molten Aluminium, with TI Århus
- Development of Hot stone storage with Heliac
- Development of Sulphur based Energy storage with Solar Research and development Ltd, UK
- CSP Liquid Sodium tower receiver for supercritical CO2.

Thank you

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Questions or Comments