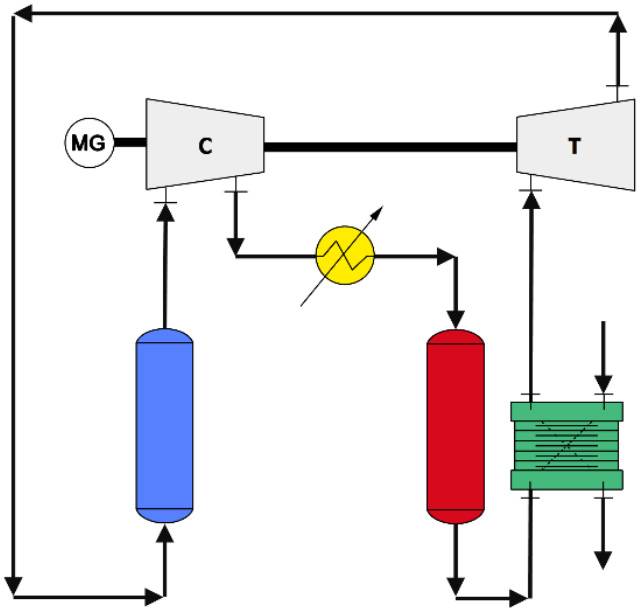
**EERA Workshop**
**Hybrid Energy and Energy Storage Systems**
***March 22, 2017, San Sebastian***

# An innovative configuration of Pumped Thermal Electricity Storage System




**Presenter: Anna Stoppato**

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# *Background*

- Energy → Essential → Development → Nations
- Total Primary Energy Consumption → Based → Non-Renewable Sources
- Fossil Fuels
  - ✓ *Stable Production*
  - × *Reserves Depletion*
  - × *Environmental Problems*
  - × Slow response time and thermo-fatigue problems
- Renewable Energy Sources
  - ✓ *Environmental Friendly*
  - × *Variable*
  - × *Unpredictable*

# *Thermal Energy Storage Units*

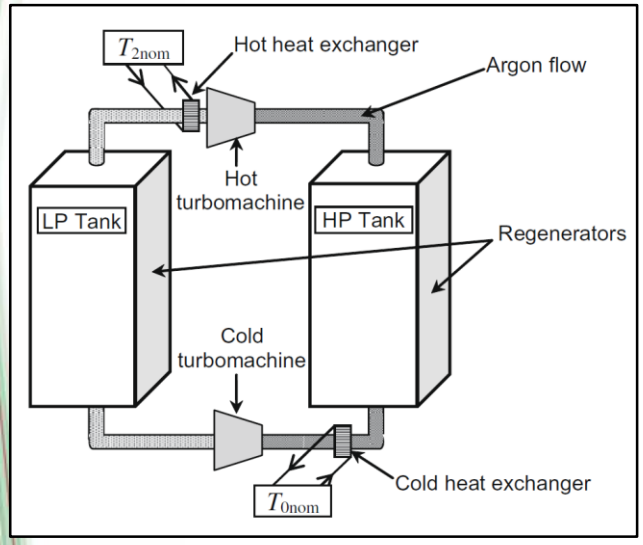
- TES systems
  - *Cryogenic Systems* → Tanks of Liquid Air
  - *Hybrid Systems* → *Hot/Cold Thermal Storage*
  - *Pumped Heat Storage Systems* → *"Sensible" or "Latent" Heat in High Temperature Storages*

- Thermal Storage
  - *Domestic Applications*
  - *Industrial Sectors*
  - *Electric Generation* → **Large Scale > 100 MWh**

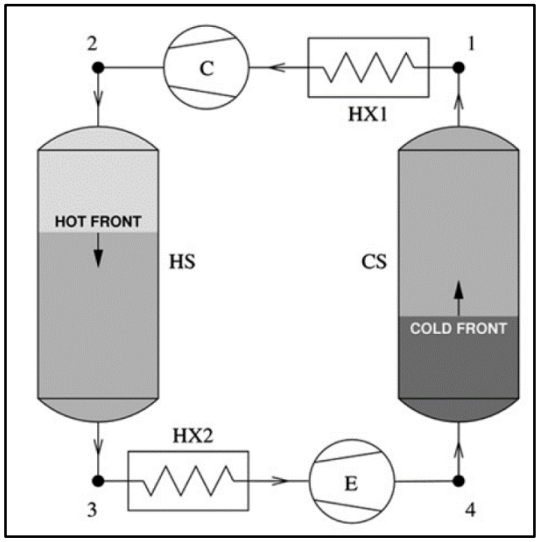
**Pumped Thermal Electricity Storage**

# *Pumped Thermal Electricity Storage Units*

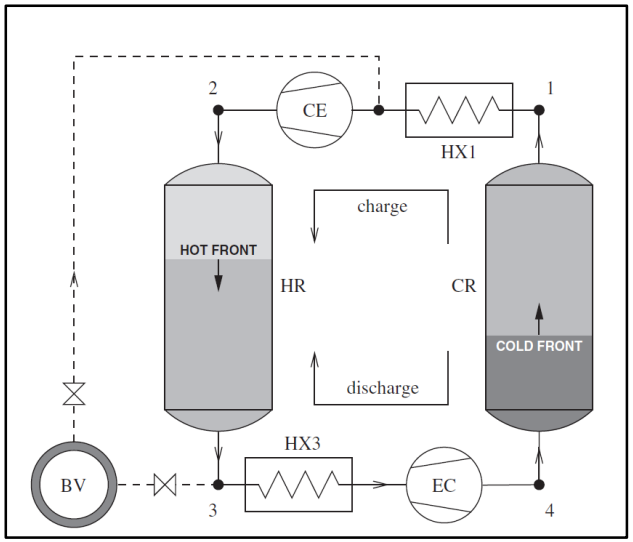
- Several Independent Patents
- Literature → Only Few Theoretical Works




- *Desruers et al. (2010)*

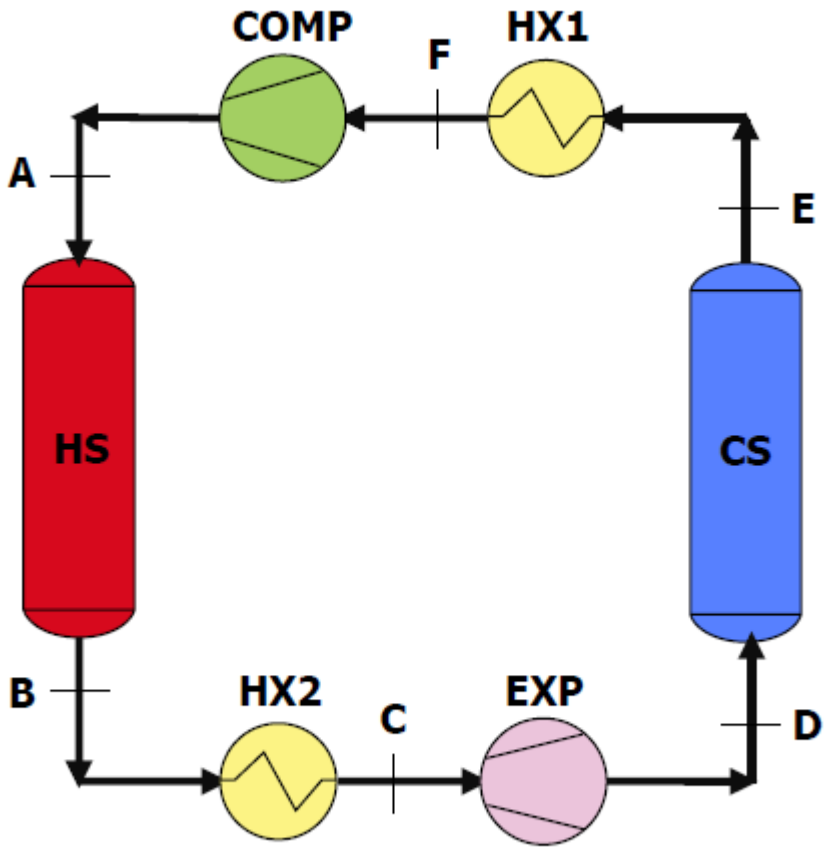



- *White et al. (2013)*




- *McTigue et al. (2015)*

# *Pumped Thermal Electricity Storage Units*



# *Why using it?*

- TES systems
- Free from the geographic constraints
- Low environmental impact
- High life devices
- Relatively high energy density

- Problem: costs

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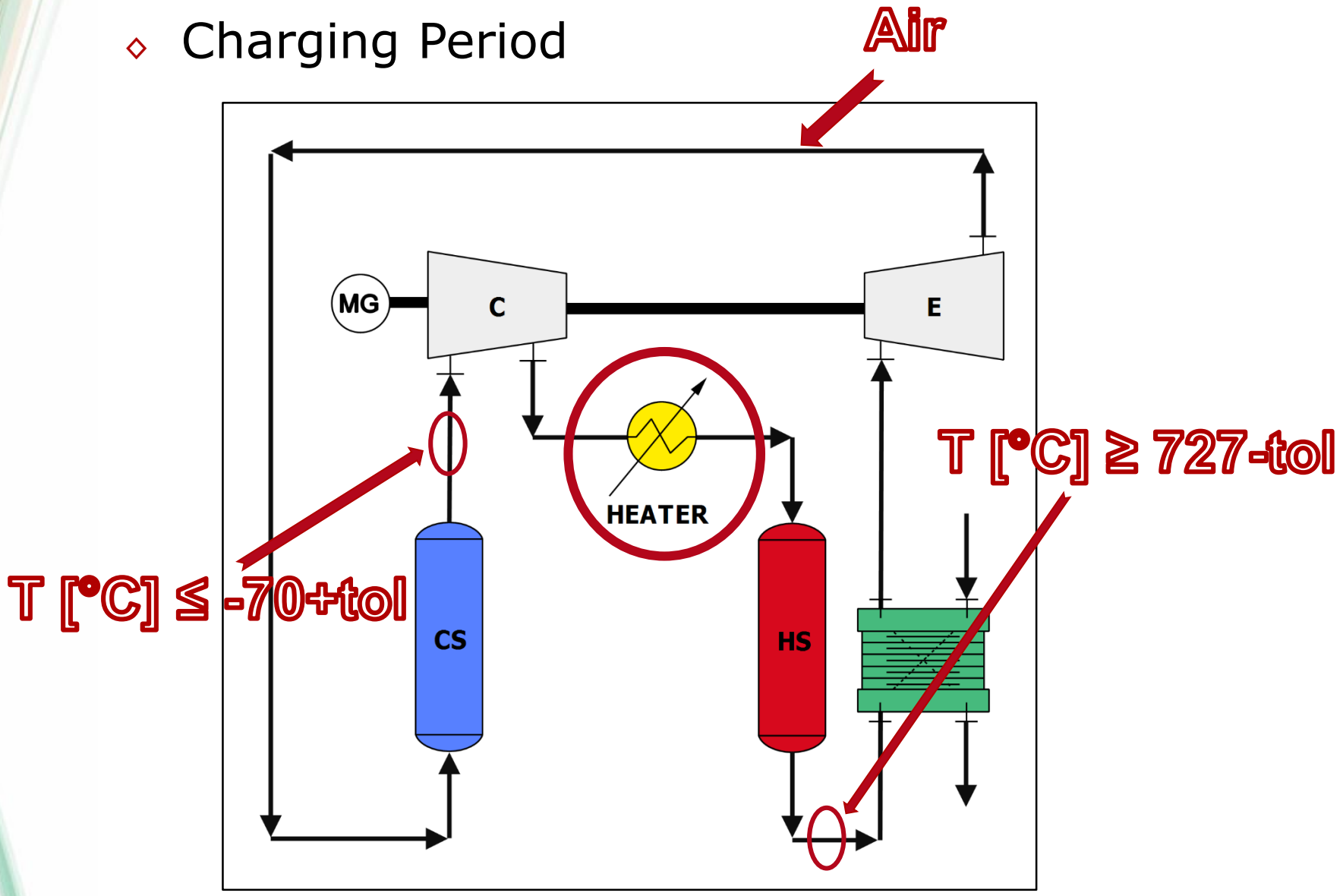
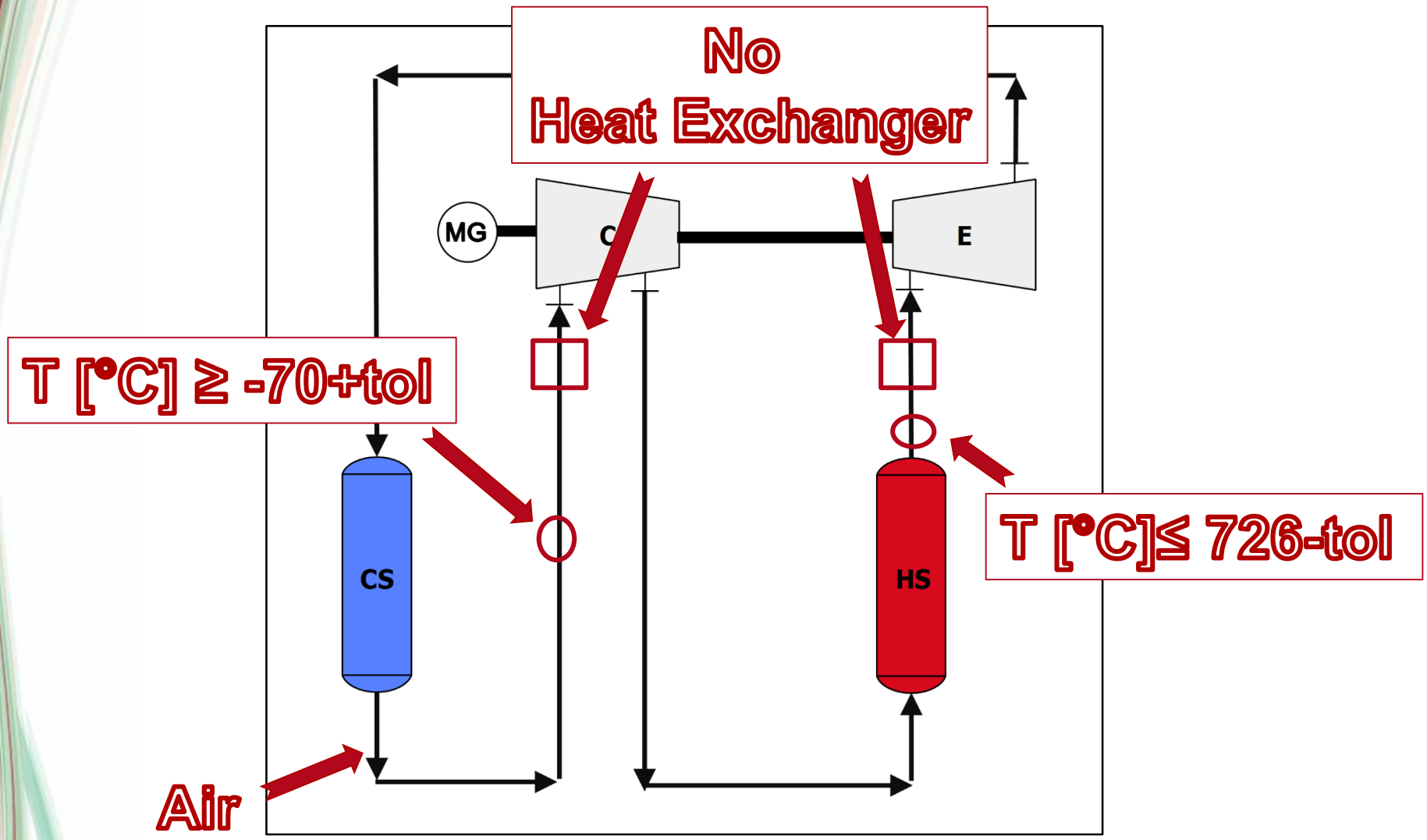
# *Modified PTES System*

- Charging Period



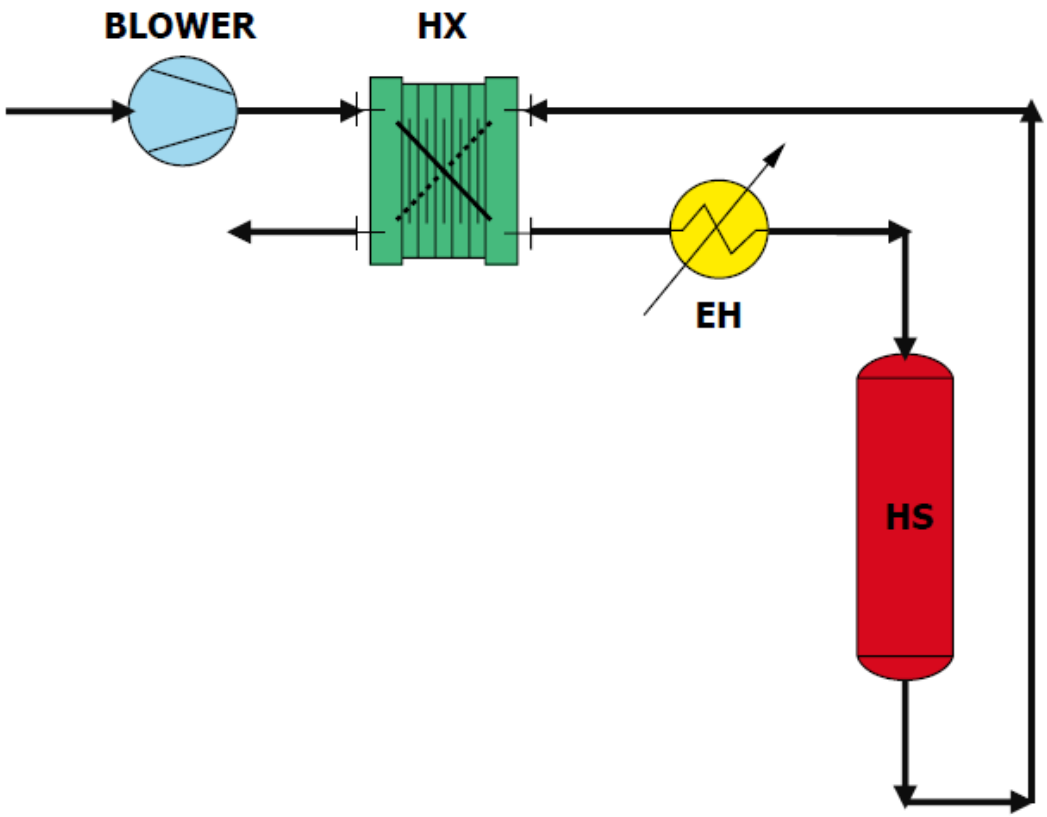
# *Modified PTES System*

- Delivering Period



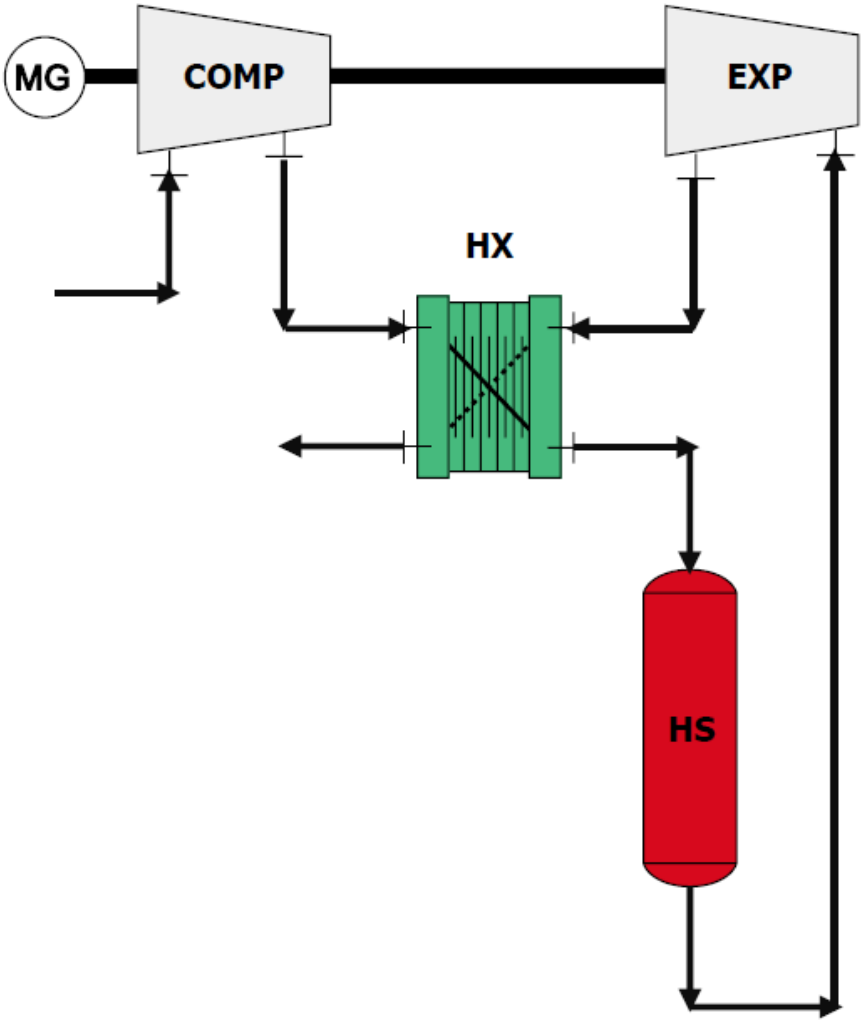
# *Integrated Energy Storage System (I-ESS)*

- Charging Period



# *Integrated Energy Storage System (I-ESS)*

- Delivering Period



# *I-ESS Advantages*

- **I**ntegrated: thermal plant units become a part of the energy storage system
- Use air as working medium
- Electric heater to maintain constant $T_{max}$
- Only a pair of compressor/expander
- Storage not pressurized

- Use of already existing devices
- Higher energy density

# I-ESS Advantages

| Energy storage technology | Energy density [kWh/m$^3$] | Price per energy unit stored [Euro/kWh] |
|---|---|---|
| Pumped hydro storage [102] | 0.5-1.5 | 10-70 |
| Compressed air energy storage [102] | 3-6 | 2-140 |
| Lead-acid battery [102] | 50-80 | 100-830 |
| Lithium-ion battery [102] | 200-500 | 500-2000 |
| Sodium-sulphur battery [102] | 156-225 | 280-700 |
| Sodium-nickel chloride battery [102] | 150-290 | 75-150 |
| Zinc-bromine flow battery [102] | 30-60 | 110-750 |
| Polysulphide-bromine flow battery [102] | 16-60 | 120-1000 |
| Vanadium redox battery [102] | 16-33 | 110-750 |
| Hydrogen-based energy storage system [102] | 2.7-160 | 2-15 |
| Pumped Thermal Energy Storage [43] | 50 | - |
| **Proposed I-ESS Scheme** | **65** | **94** |

# *I-ESS: Where We Are?*

- Patent of an Innovative Thermal Energy Storage Unit (Plant and method for Energy storage and the following electricity production, Alberto Benato, Alex Pezzuolo, Anna Stoppato)
- Simulation and optimization of the main thermodynamic cycle parameters
- Choice of the machines
- Preliminary dynamic analysis on the thermal storage

# *I-ESS: Future Works*

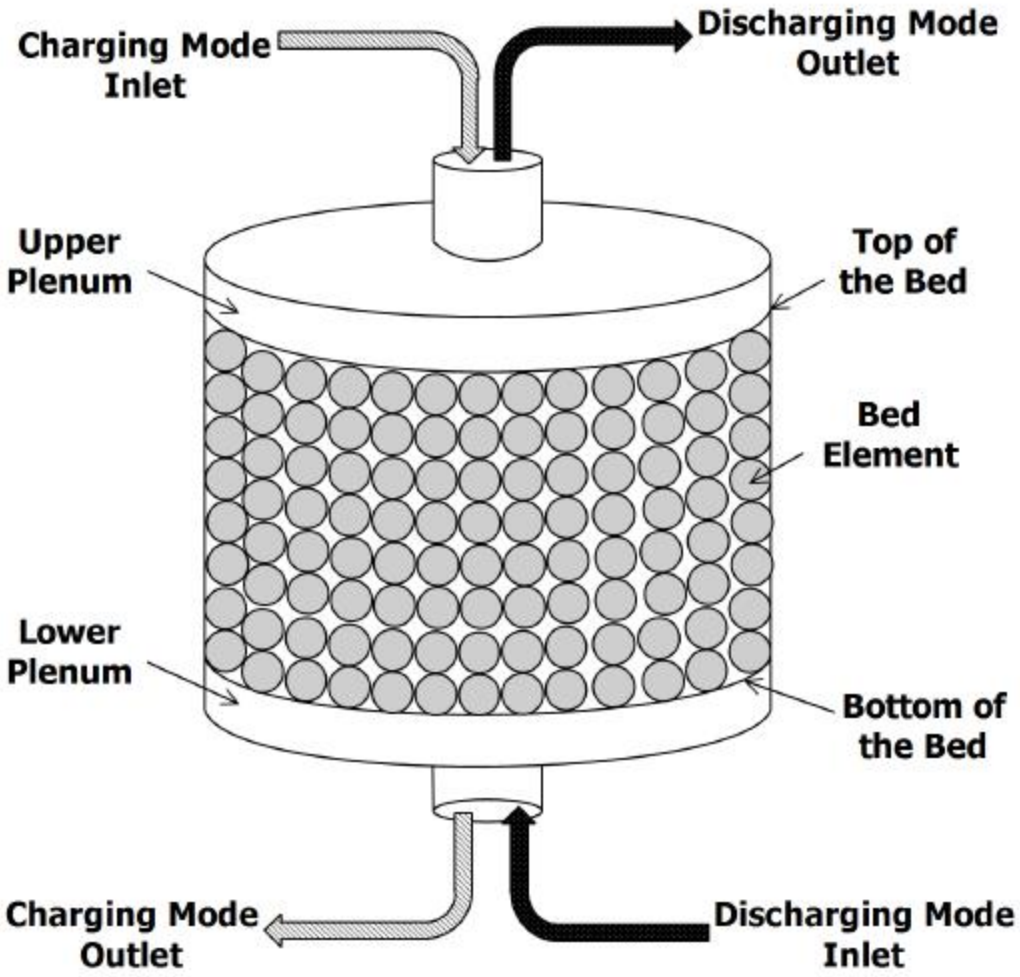
- Experimental analysis on thermal storage behavior
- Dynamic analysis of the system
- Optimization of control strategy

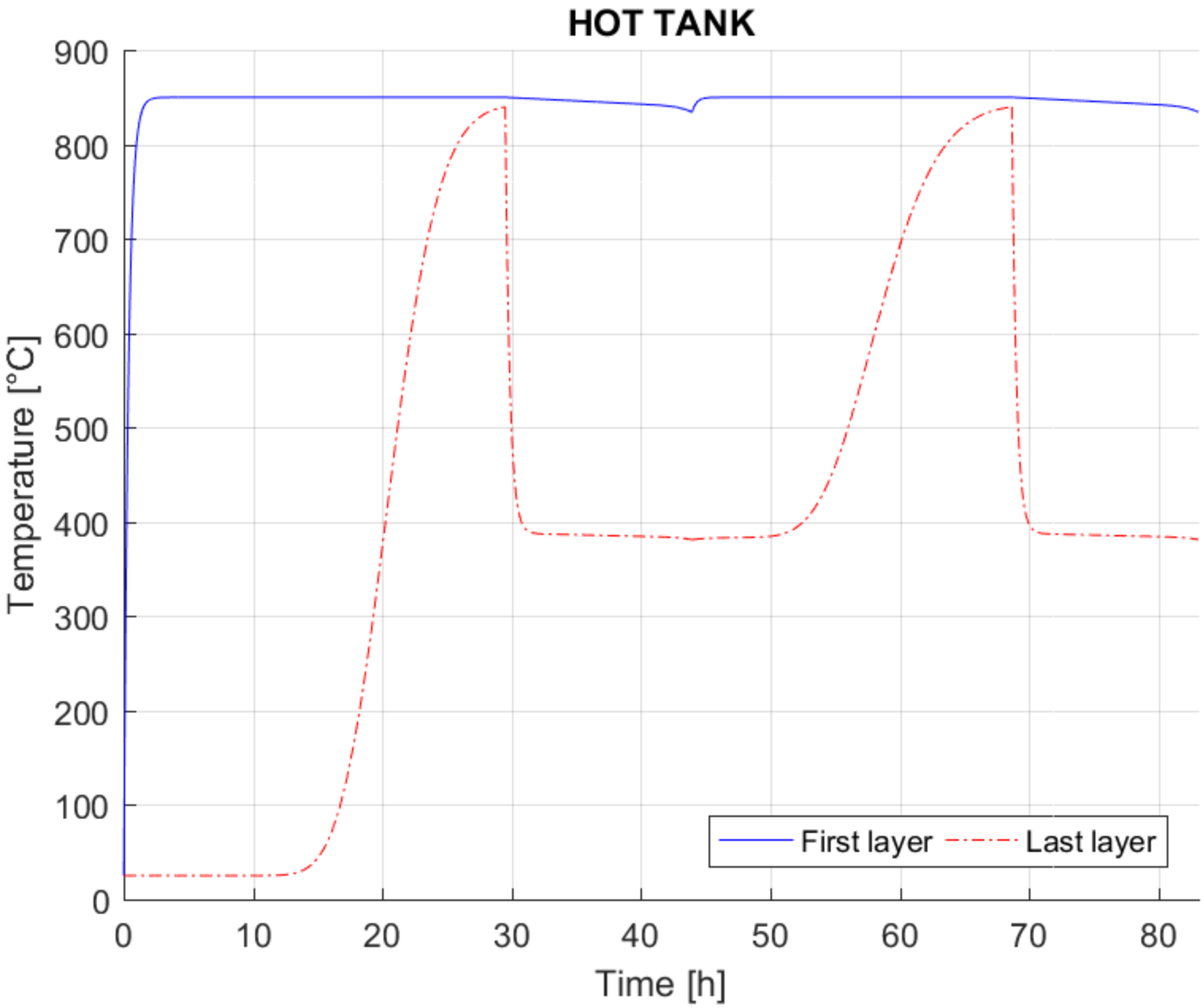
# *I-ESS: Other Opportunities*

- Use also of waste heat from the thermal power plant
- Integration with system using heat (e.g. CHP plants)
- Bottoming cycles other than ABC (e.g.ORC)

# *I-ESS: Other Opportunities*

- Already existing collaboration with a thermal power plant
- Interest of an electric heater manufacturer
- Interest of two manufacturers of small plants using waste heating recovery
- Interest of a manufacturer proposing heat storage systems for buildings


Charging Mode Inlet
Discharging Mode Outlet
Upper Plenum
Top of the Bed
Bed Element
Lower Plenum
Bottom of the Bed
Charging Mode Outlet
Discharging Mode Inlet


HOT TANK
Temperature [°C]
Time [h]
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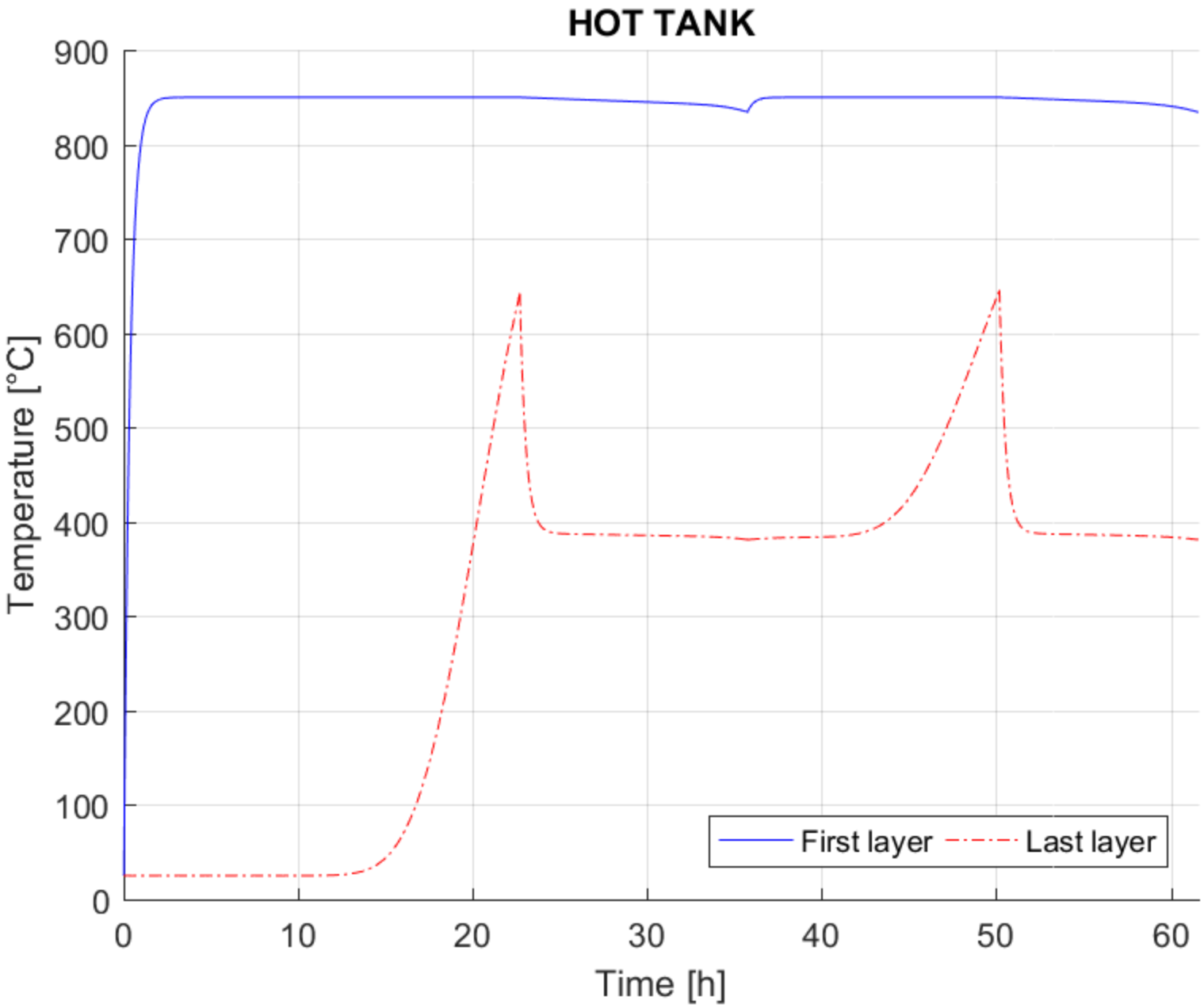
First layer
Last layer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