KTH ROYAL INSTITUTE OF TECHNOLOGY

Power to Industrial Heat: Techno-Economic System Opportunities Driven by EU Electricity Market

Silvia Trevisan, Bjarke Buchbjerg, Rafael Guedez

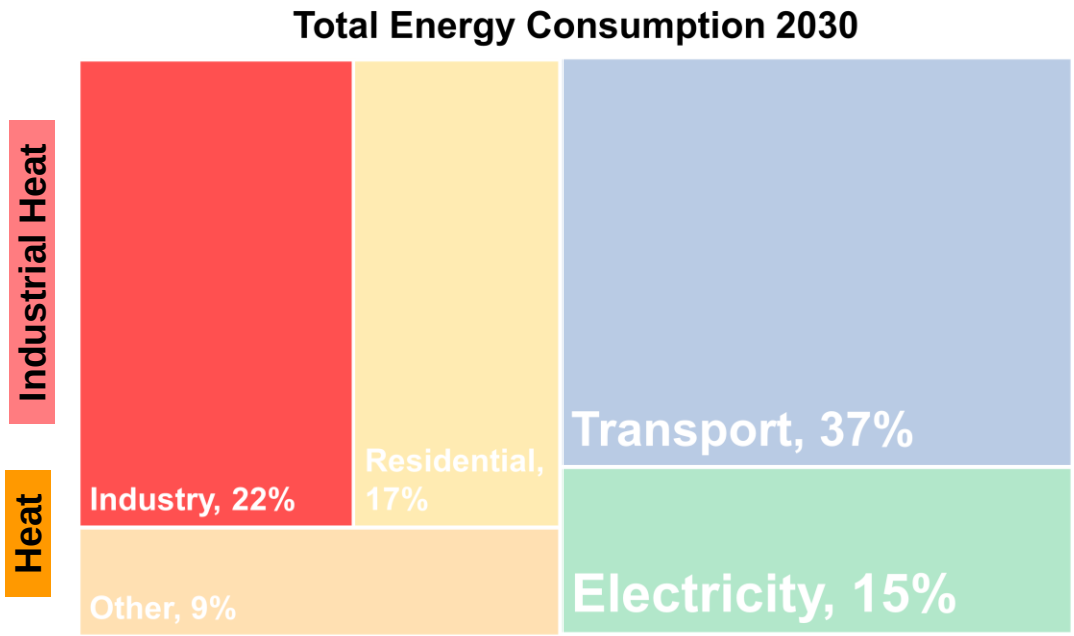
trevisan@kth.se

rafael.guedez@energy.kth.se

Layout of the presentation

- **Why power-to-heat integrating TES for industry?**
- **Proposed system layout**
- **Methodology & KPIs**
- **Results**
  - Base case
  - Key EU countries
  - 2021 vs 2022
- **Conclusions**

Industrial Heat

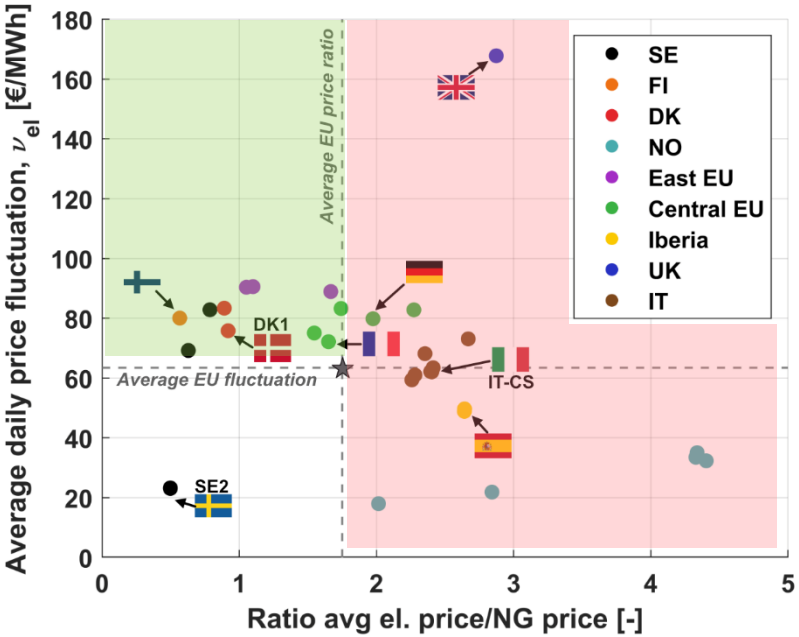


IRENA, Global Energy Transformation - A Roadmap to 2050.

Power to heat and need for storage

Low electricity prices with high electricity price fluctuation

→ Electrification can limit costs with respect to fuels
→ Need for storage and flexibility to cope with high price volatility



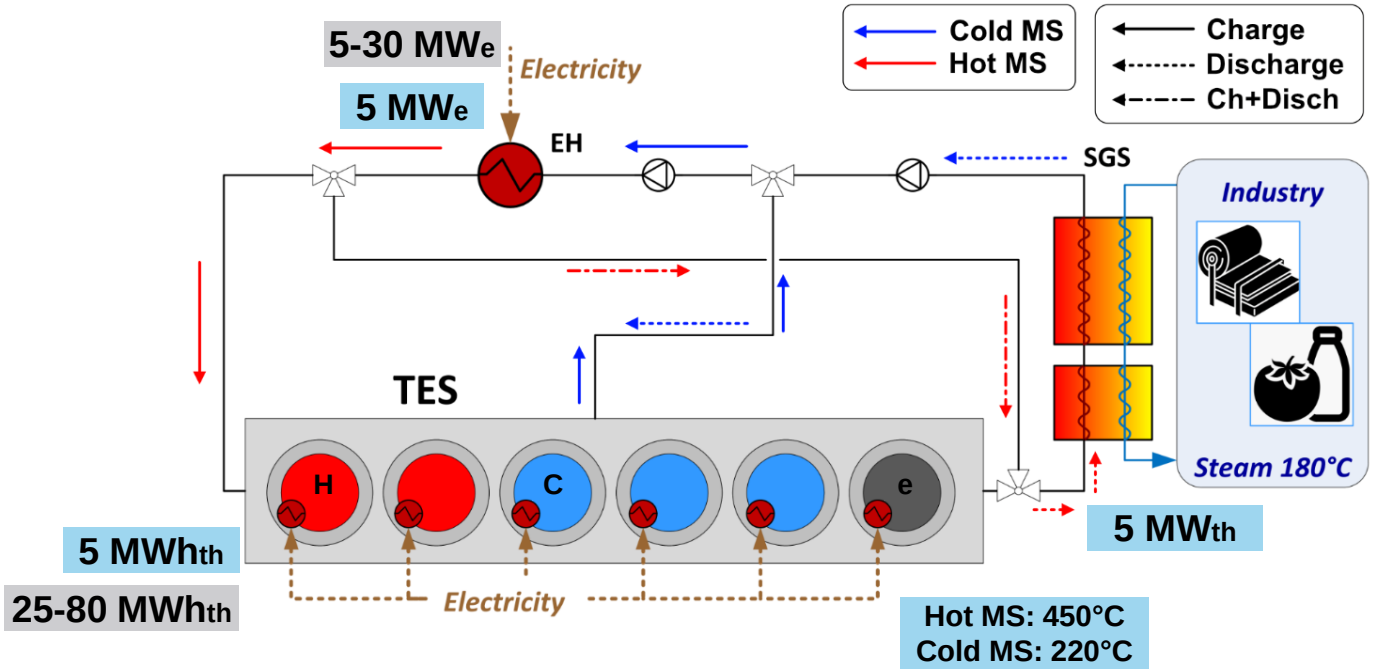
High electricity prices

→ Fuels might be still cheaper unless high CO_2 taxes are in place

OBS: electricity and NG prices of 2021

System layout

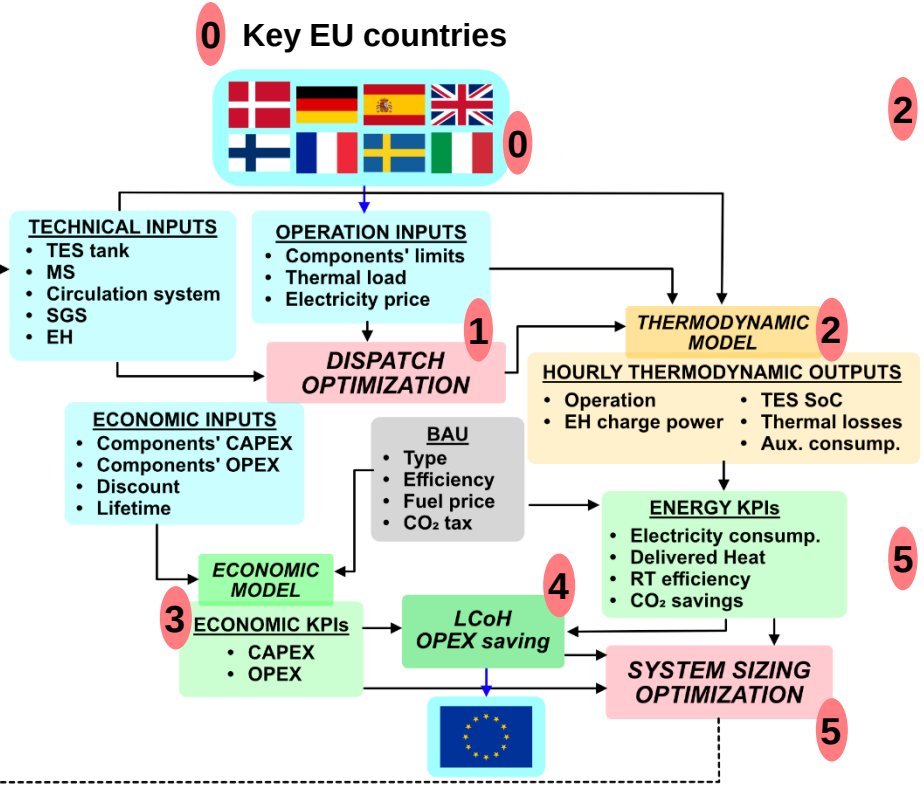
Modular power-to-heat with integrated TES



Methodology

1 Dispatch MILP optimization problem
Inputs: Electricity spot prices
Thermal load, Technical constraints
Objective: *Min(OPEX)*

3 Bottom up economic model
Inputs: Components' cost functions
- *CAPEX*
- *OPEX*

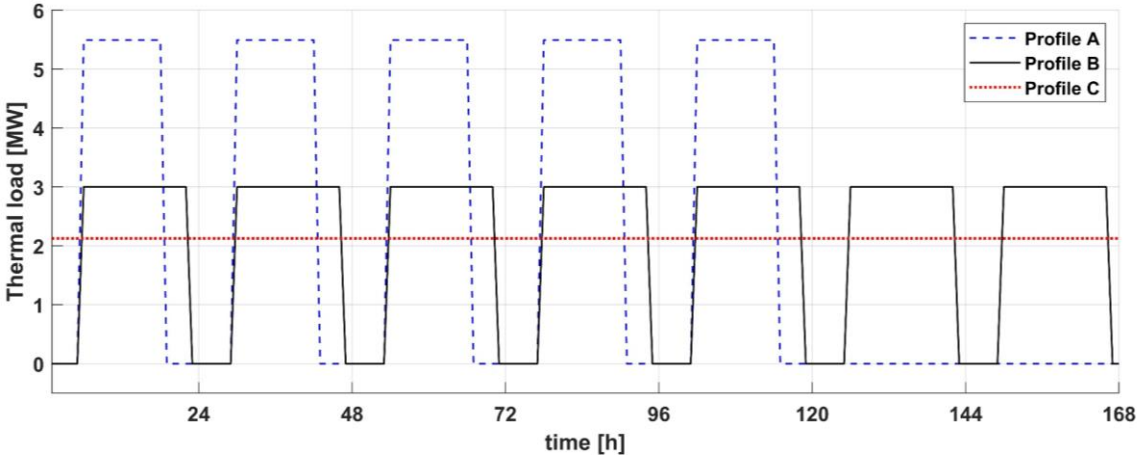


2 Quasi steady state thermodynamic model
- *TES SoC*
- *Overall electricity needs*
- *CO_2 emissions..*

4 Evaluation of KPIs

5 System sizing optimization
Decision variables: EH nominal power, TES energy capacity
Objective 1: *Min(LCoH)*
Objective 2: *Min(OPEX)*

Assumptions, boundary conditions and KPIs



Profile A: 2 shifts
Profile B: 3 shifts
Profile C: Continuous

Equal average daily energy consumption (51 MWh)

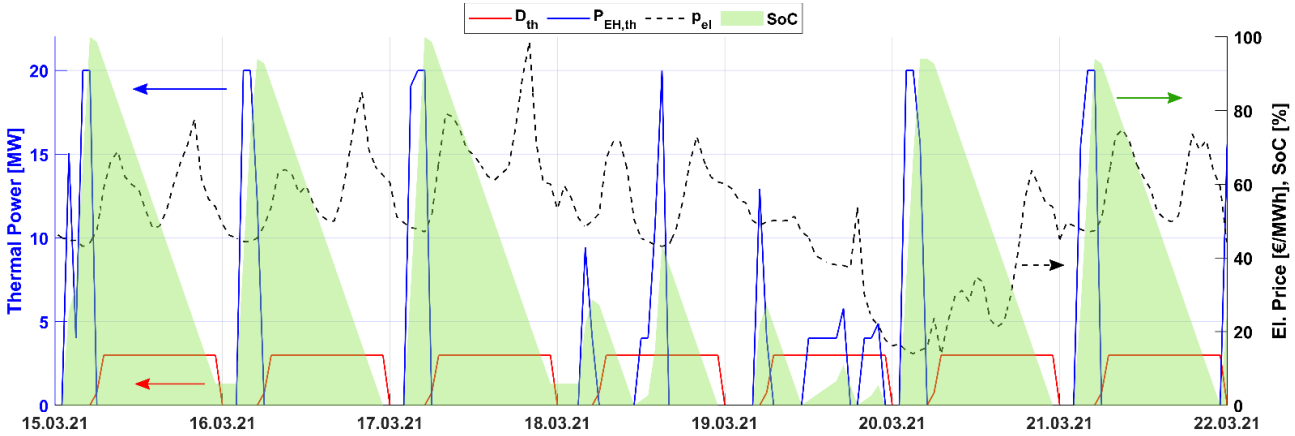
$$LCoH = \frac{(1-\gamma_{CAPEX}) \cdot CAPEX + \sum OPEX^{*} + \sum DECOMM^{*}}{\sum ENERGY^{\blacksquare}}$$

$$\Delta OPEX = OPEX_{BAU,x} - OPEX_{P2H}$$

* : *economic discount rate (5%)*
$^{\blacksquare}$: *tech degradation rate (1.5%)*

Results – Base case

Denmark (DK1)
TES = 45 MWhth
EH = 15 MWe

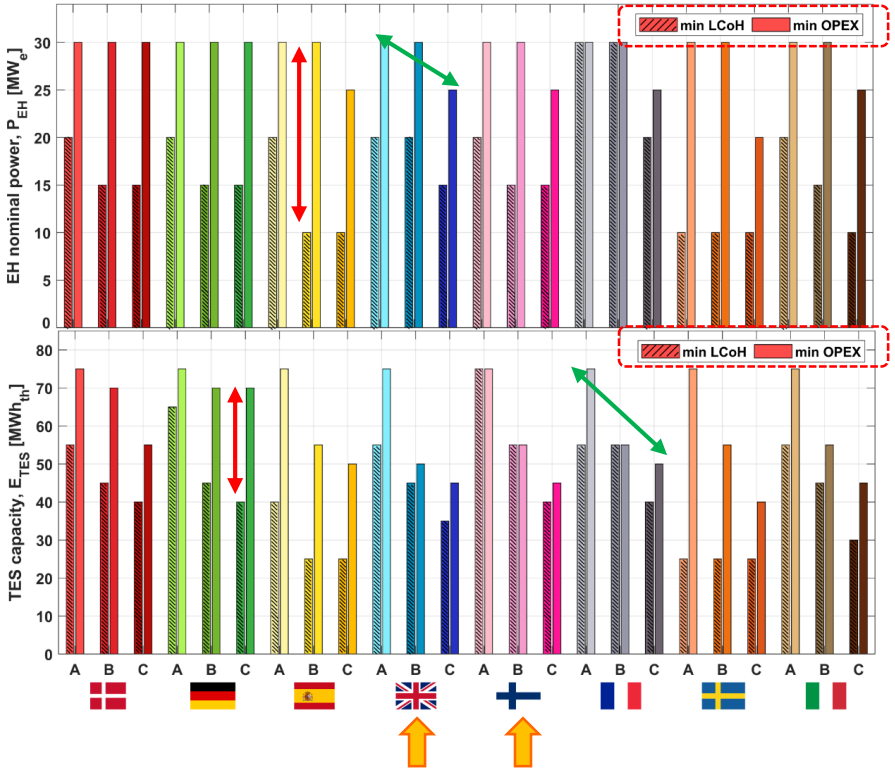


Main charge during night hours, charge during central hours might occur.
If consistent price reduction around noon, the TES could be downsized relying on multiple full cycles during a day

Largest CAPEX due to TES tanks and MS (together about **43 %**)
Electrical components accounts for about **23 % of total CAPEX**

OPEX dominated by electricity for charging the TES (88 %) and for compensating for the thermal losses (4.5 %)

Results – Sizing Optimization

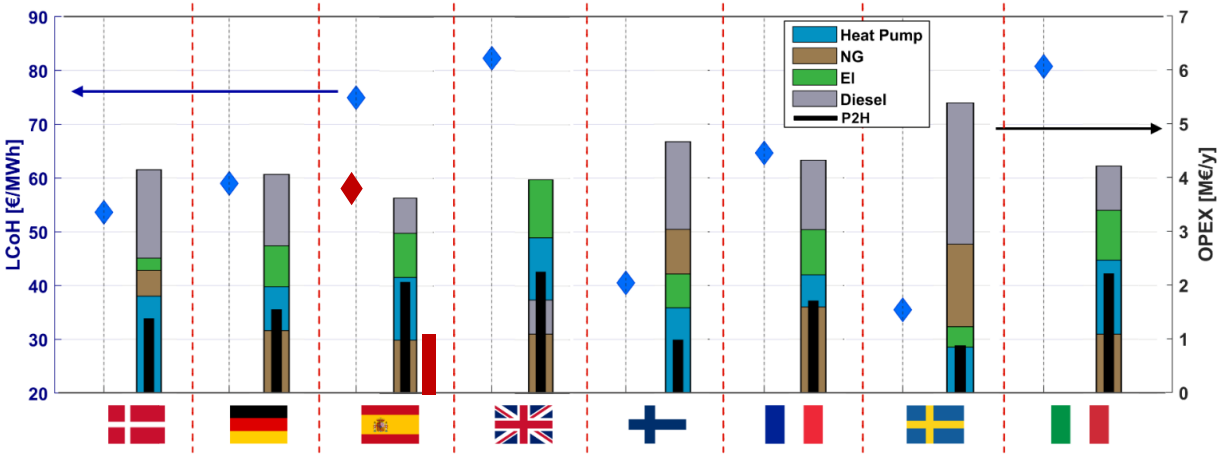


1 To **minimize LCoH downsized** systems are preferred, **limiting CAPEX**
To **minimize OPEX oversized** system are suggested to **maximize the exploitation of cheap electricity hours**. Most critical component is the electrical heater.
→ sizing choices are related to the considered business model

2 For the same daily energy demand, **thermal load profiles with low power requirement but constant for all 24 hours requires smaller systems** (lower TES energy capacity)

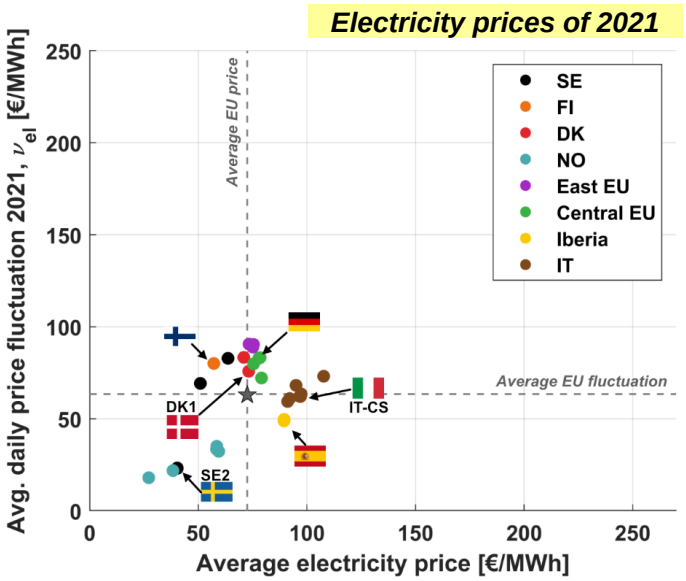
3 At **high volatility** of the electricity prices the **sizing difference**, particularly for the TES energy capacity, **are limited**.

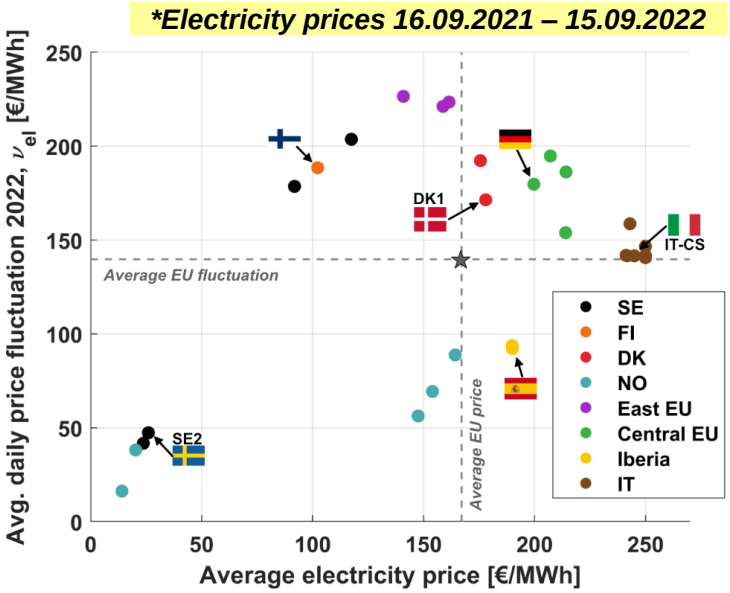
Results – Key EU countries



- **P2H-TES is the best RES based alternative in all scenarios.**
- **P2H-TES can offer the lowest OPEX and LCoH in Finland** and north **Sweden**. OPEX savings of more than 66 % with respect to fossil fuels and heat demand is large in 100-500°C, good market.
- **P2H-TES** provide **competitive OPEX** (parity with NG) in **Germany** and **France** where there is also large heat demand.
- Based on only grid charging **Italy** and **Spain are not interesting markets for P2H-TES** → **on-site RES integration** is needed (OPEX and LCoH reduction by more than 50% and 25%, respectively)

Need for storage… 2021 vs 2022*



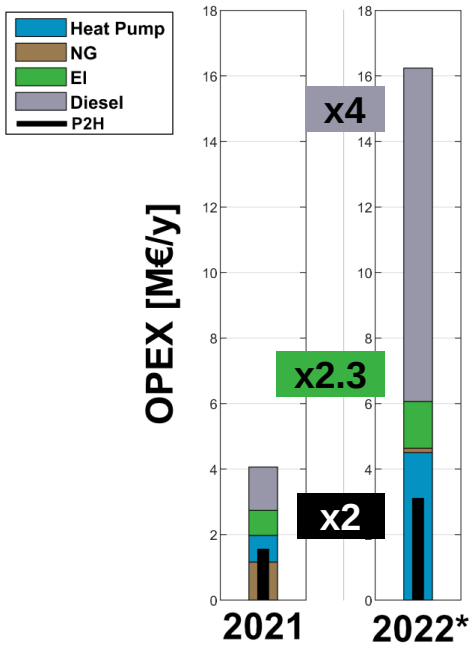


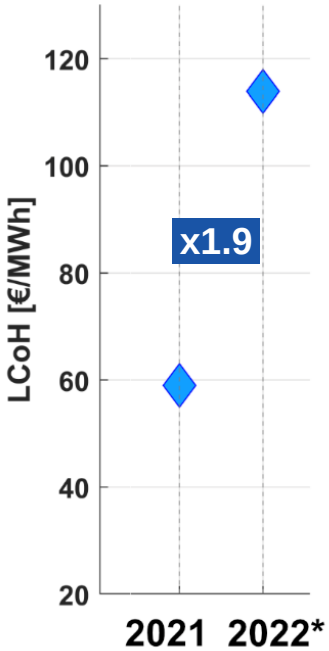
Average electricity price in 2022* = **x 2.4** average electricity price in 2021

Average daily price fluctuation in 2022* = **x 2.3** average daily price fluctuation in 2021

Germany 2021-2022*

**Electricity prices 16.09.2021 – 15.09.2022*





En. Market [€/MWh]	2021	2022	Δ
Average price	75.4	199.7	x2.6
Average daily fluctuation	79.8	179.7	x2.3
Average NG price	56	224	X4

- **Today's prices demand more deployment of storage**
- **Electrification including TES is the most competitive alternative**
- P2H-TES permits to **limit the OPEX and LCoH increase**
  - OPEX P2H-TES increase by x2
  - OPEX electrification increase by x2.3
  - OPEX fossil fuels increase by x4
  - LCoH P2H-TES increase by x1.9

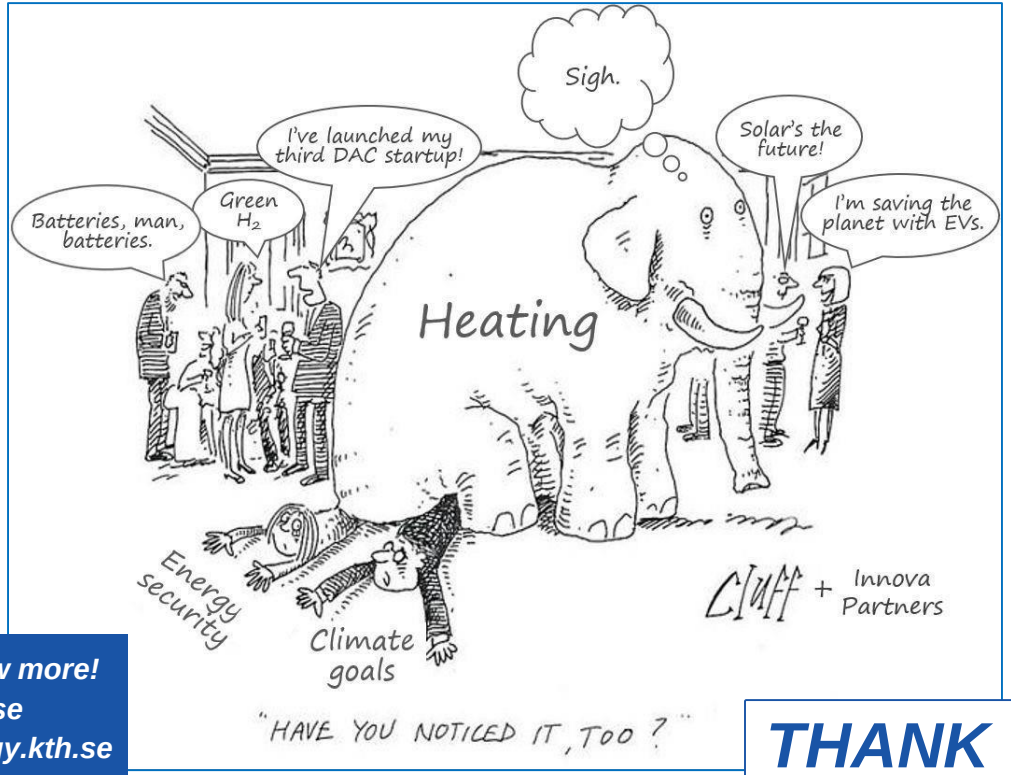
Conclusion

Key drivers to be considered for techno-economic potential of power to heat systems integrating TES are:

- **Cost of alternatives**: NG, diesel, CO_2 taxes
- **Electricity market**:
  - **volatility** and **intraday** min/max **fluctuation** → higher values maximize profitability of TES
  - **average prices** → low values limits OPEX of electrified solutions

P2H-TES is the best RES based alternative in all scenarios → specific industrial integration feasibility studies should be done

- In **Finland** and **south of Sweden P2H-TES** can offer the **lowest OPEX and LCoH**. Potential saving of more than 66%. Heat demand is generally low but large in 100-500°C (pulp and paper sector).
- **Germany** and **France** have **large heat demand** and **P2H-TES** can provide **competitive OPEX** (vs NG). Current **fuel price increase** and **higher volatility** leads to **improved performance**.
- Based on only grid charging **Italy** and **Spain are not interesting markets for P2H-TES → on-site RES integration is needed.**



Open PhD position!

We are looking for you!

Get in touch to know more!
trevisan@kth.se
rafael.guedez@energy.kth.se

THANK YOU!!

TES integration in power-to-heat systems can enables higher renewable penetration and de-carbonization of the energy intensive industrial sector whilst reducing operating costs