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Thermal Energy

Kamel Hooman, TUDelft



TU Delft Delft University of Technology

TU/e Eindhoven University of Technology

University of Twente.

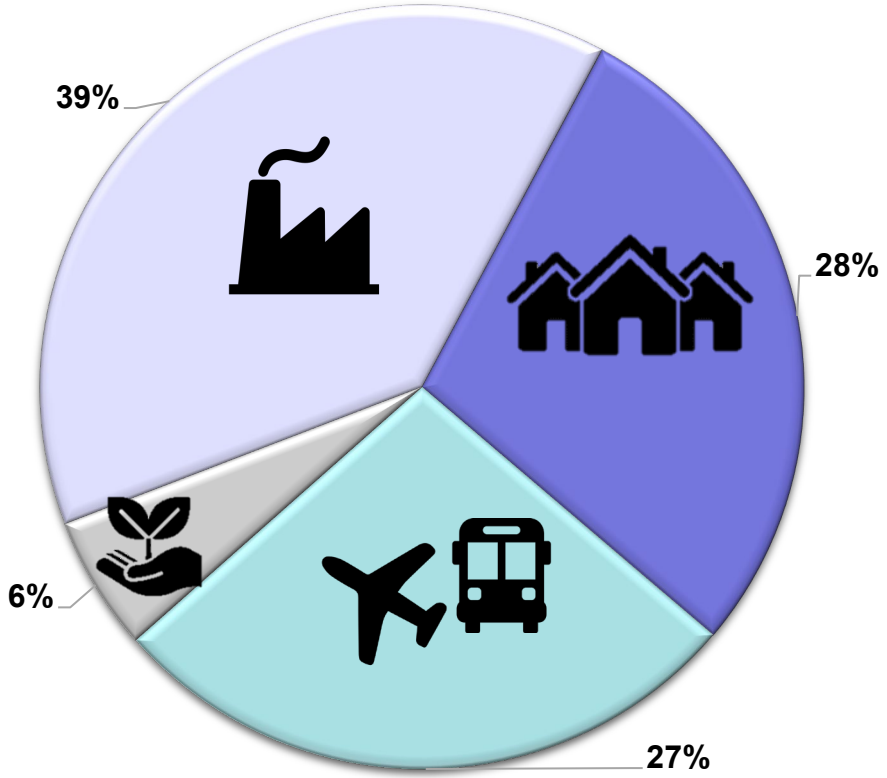
Wageningen University & Research

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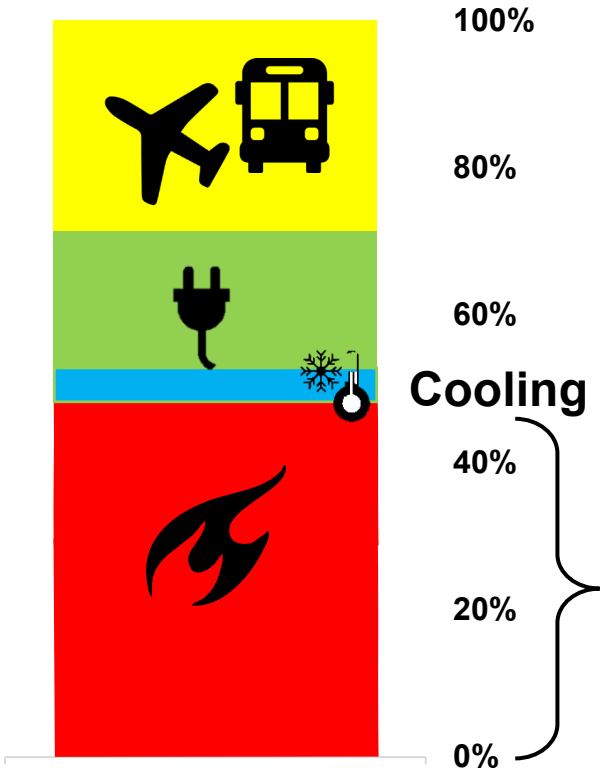
university of groningen

Final Energy Consumption

By sector

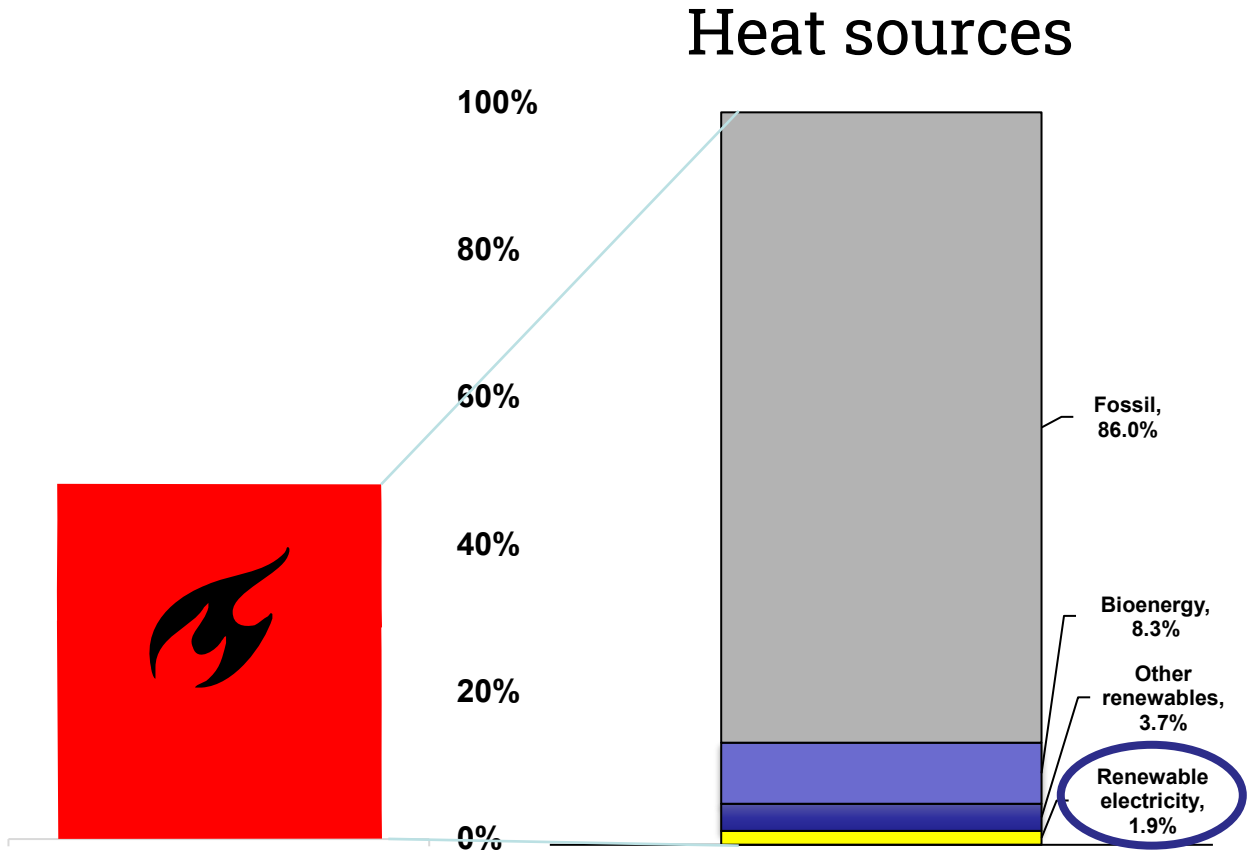


By use



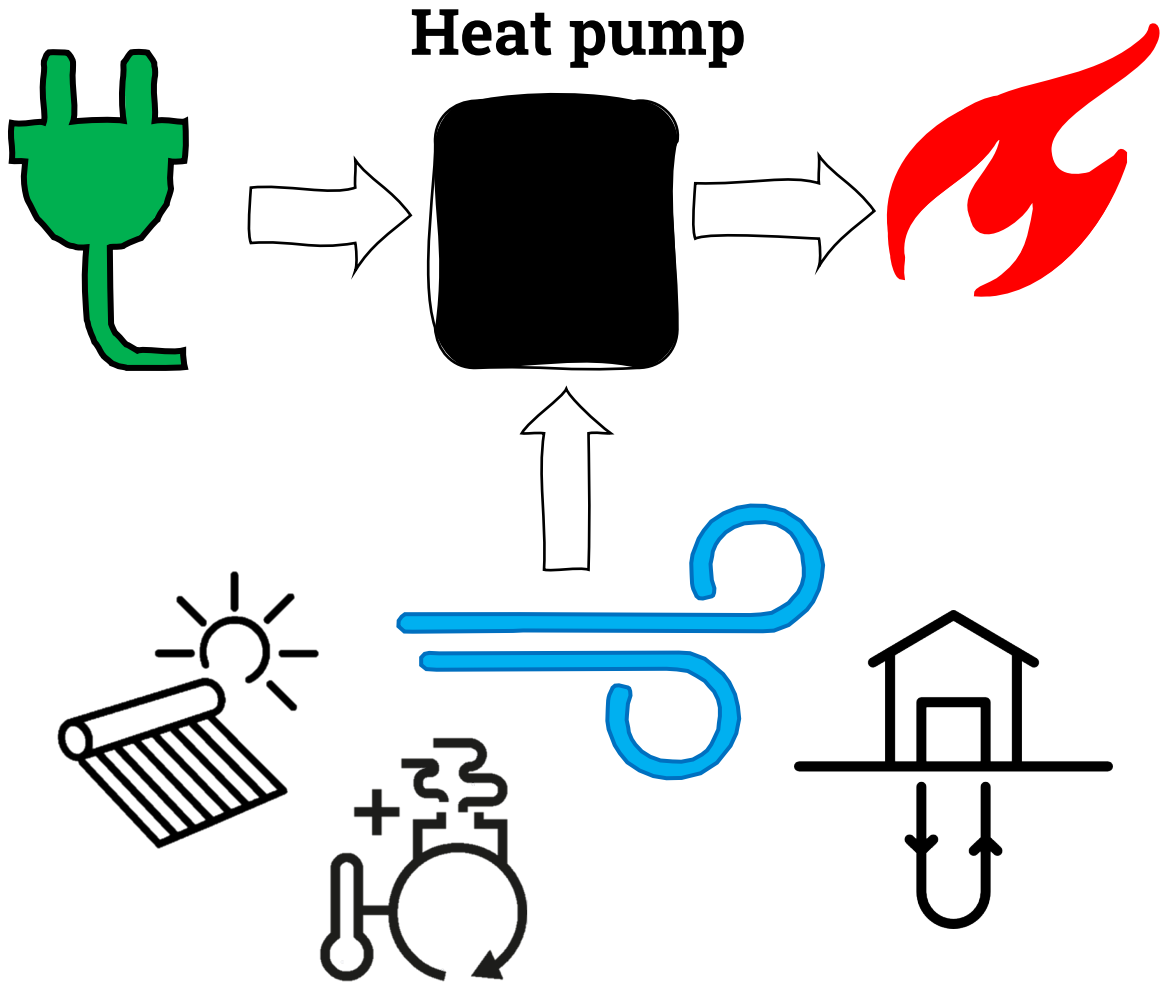
IEA (2024), World Energy Outlook 2024, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2024
IEA (2024), Renewables 2024, IEA, Paris https://www.iea.org/reports/renewables-2024

Final Energy Consumption

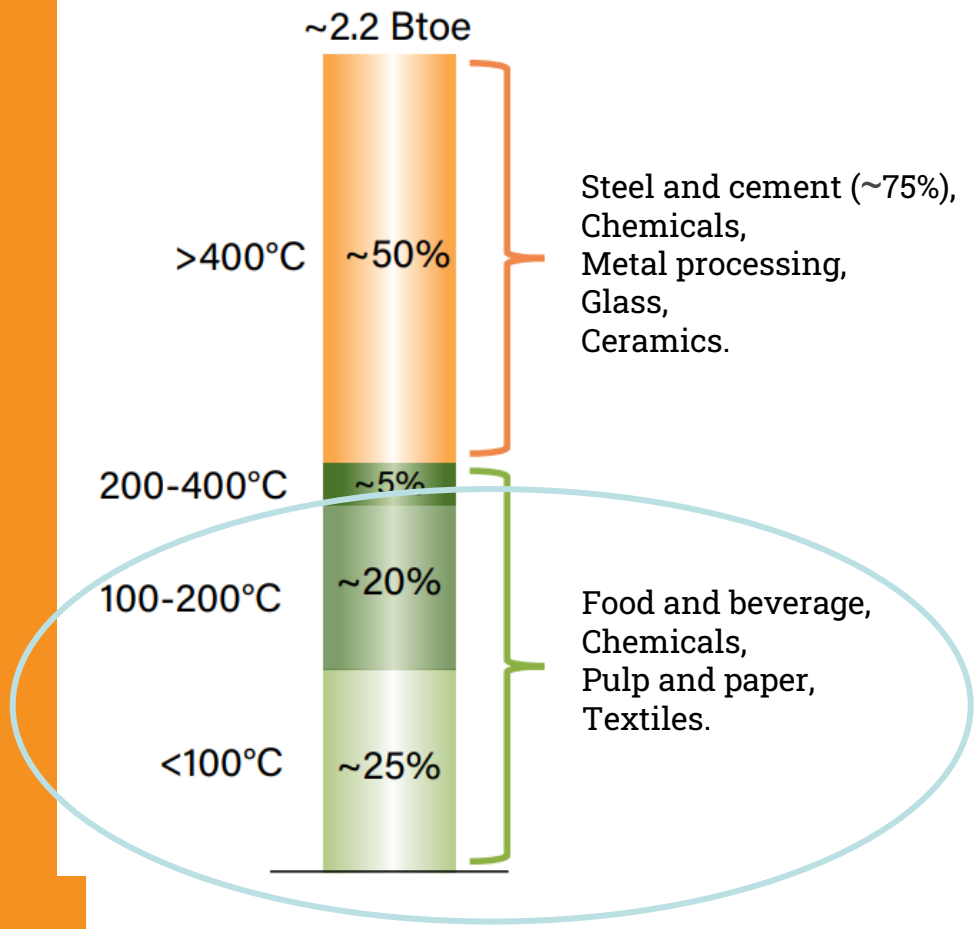


IEA (2024), World Energy Outlook 2024, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2024
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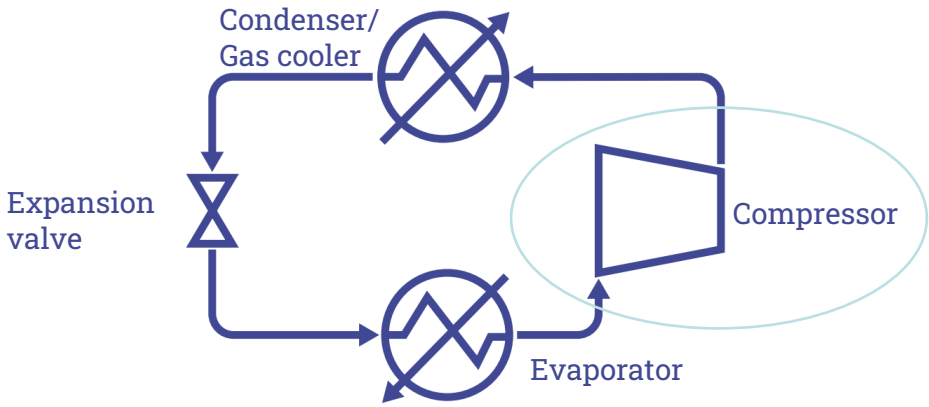
Electrification: CoP



Industrial Heat



Current High Temperature Heat Pumps (HTHP) < 165 °C



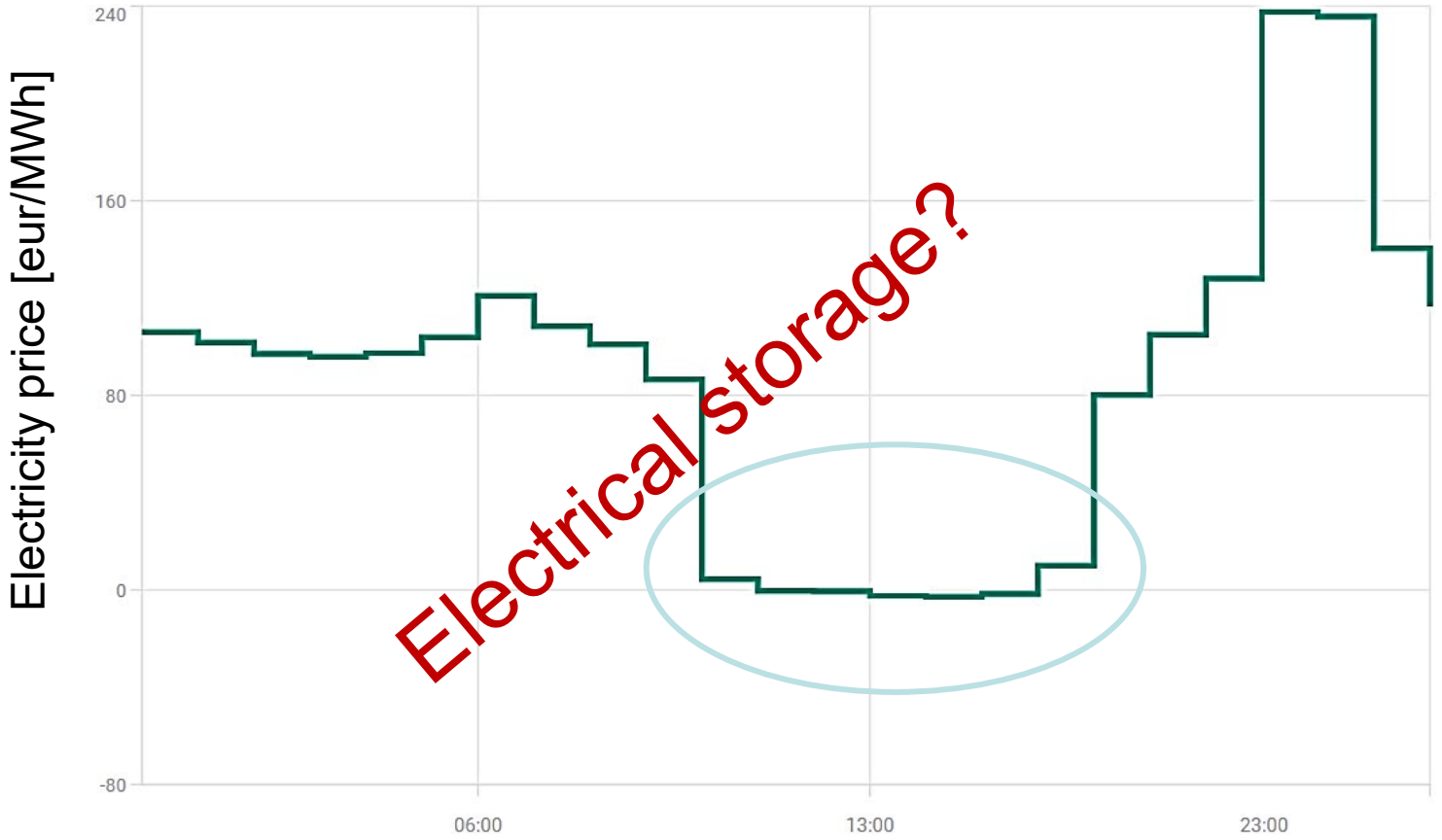
Compressor is one of the main bottlenecks:

- High pressure/temperature requirements
- High pressure ratios
- Suitable lubricants in the whole temperature range

Incentives



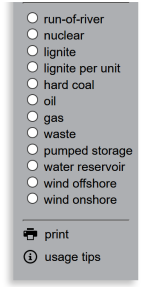
Netherlands: 17/06/2025

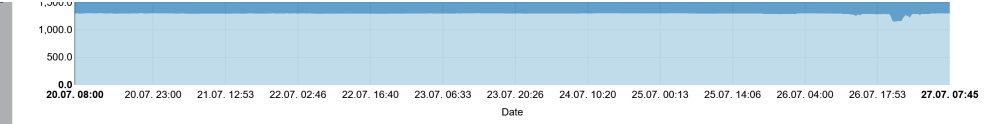


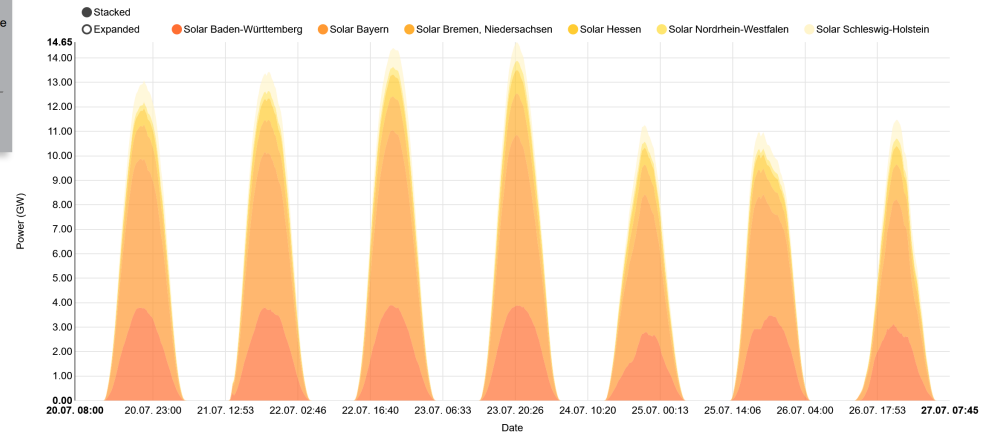
ENTSO-E Transparency Platform. [1]

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Germany

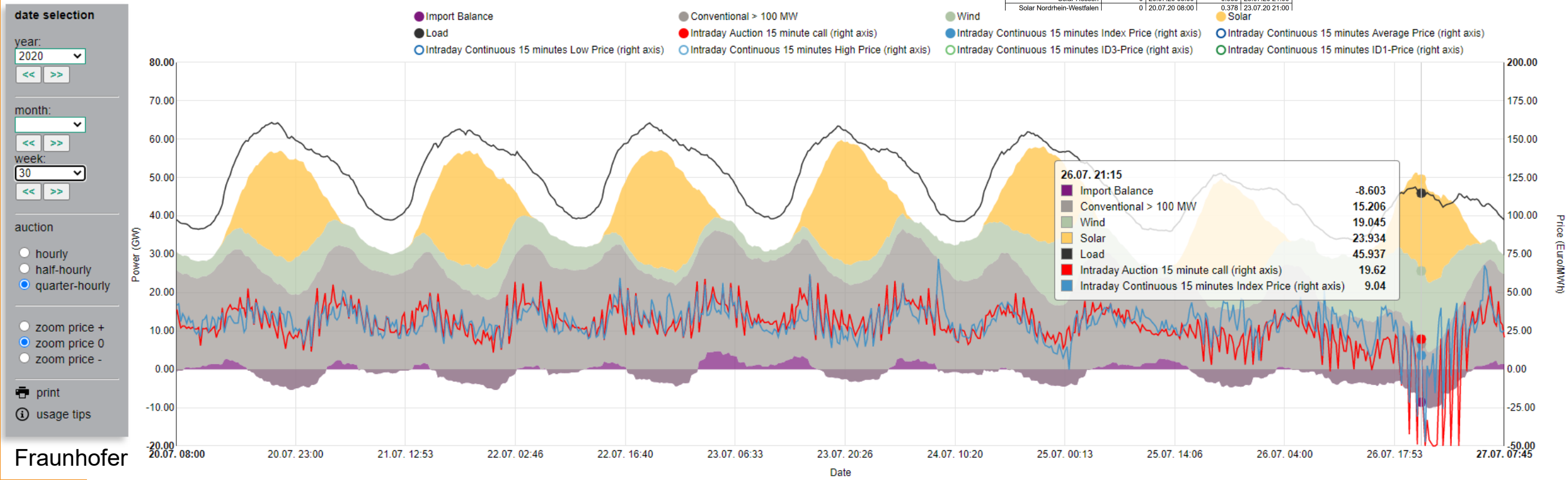






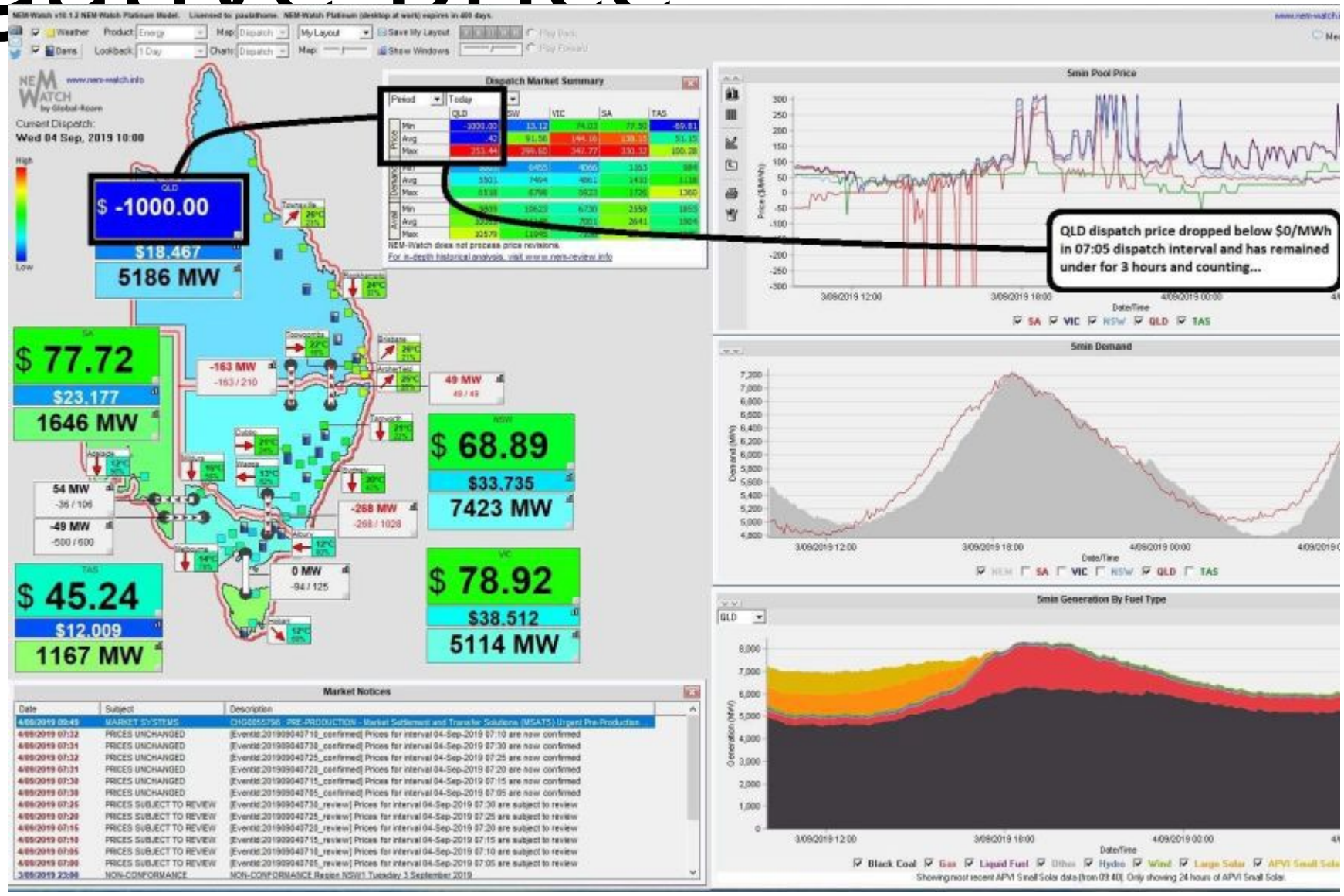
Electricity production and spot prices in Germany in week 30 2020

Source	Minimum Power (GW)	Date	Maximum Power (GW)	Date
Solar Baden-Württemberg	0	20.07.20 08:00	3.896	22.07.20 20:30
Solar Bayern	0	20.07.20 08:00	7.172	22.07.20 21:00
Solar Bremen, Niedersachsen	0	20.07.20 08:00	1.716	23.07.20 21:15
Solar Hessen	0	20.07.20 08:00	0.955	23.07.20 21:00
Solar Nordrhein-Westfalen	0	20.07.20 08:00	0.378	23.07.20 21:00



Our negative price

4/9/19



Paradigm shift

- Extra miles

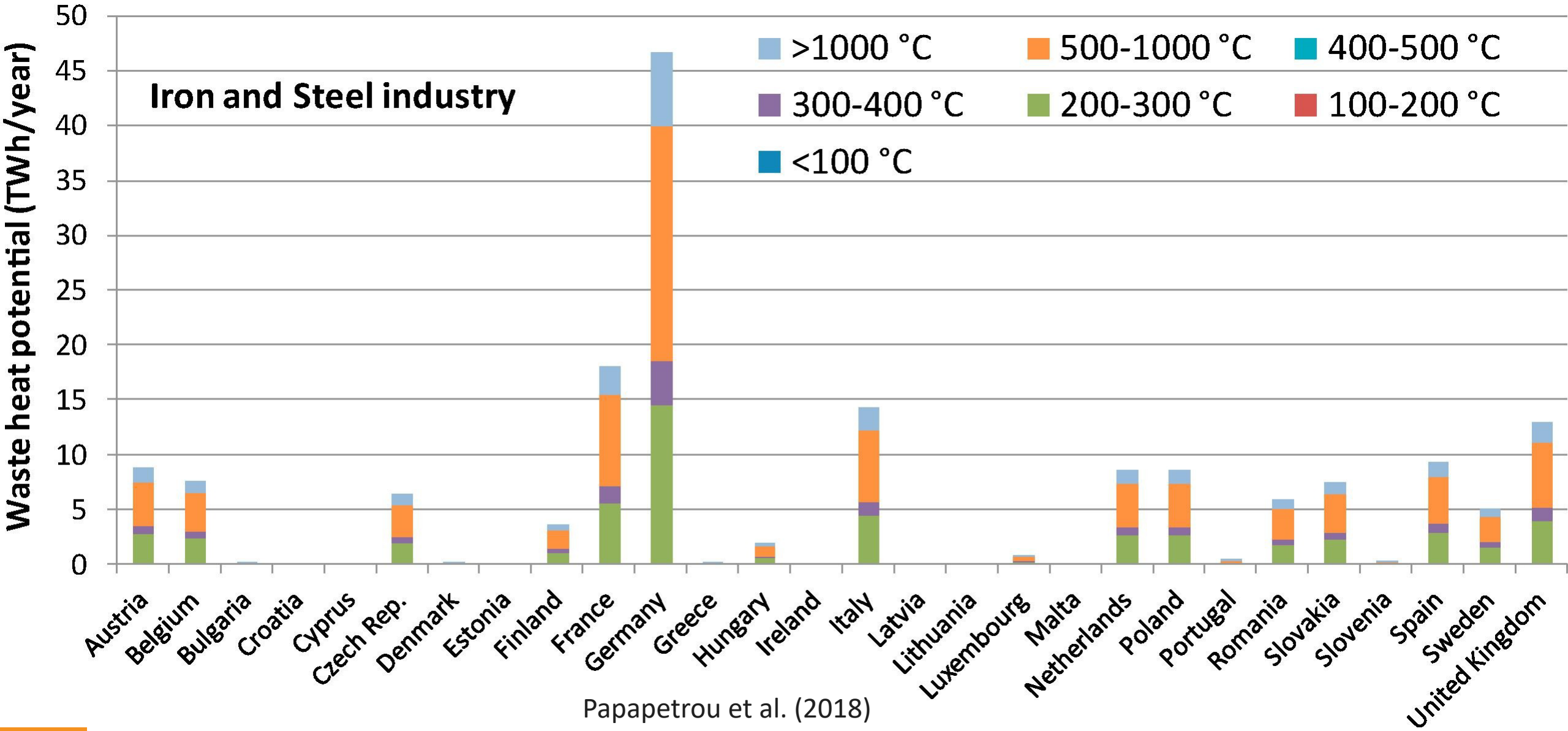
Current practice

PV generating electricity at 15% → Heat at CoP ~3-4 → 60% (of the input energy)

Solar collectors can be as high as 80% efficient at a reasonable cost…

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Wasteful



Papapetrou et al. (2018)

Heat market



- Enthalpy (magnitude of heat)
- Temperature
- Time

€/kWh

Heat as a “commodity”

Currency: Inclusive Market

Selection criteria:

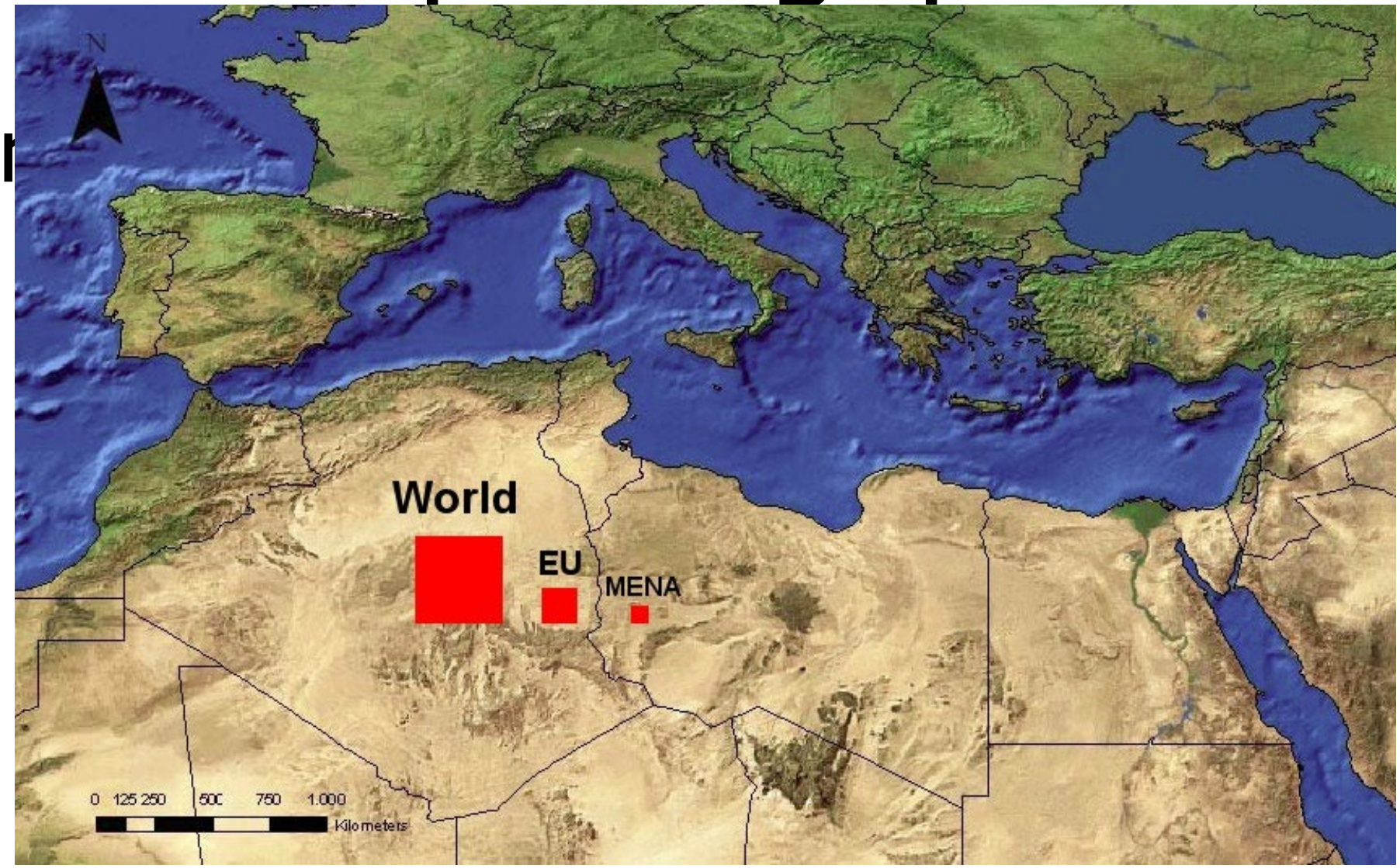
- Nature-based (susta
- Renewable
- Inexpensive
- Efficient (minimal los
- Solid state (no grid)
- Modular
- Presentable





Spatial & temporal gap

- $1m per



Ice King

- Exported ice (Boston) on ships to India (Calcutta)

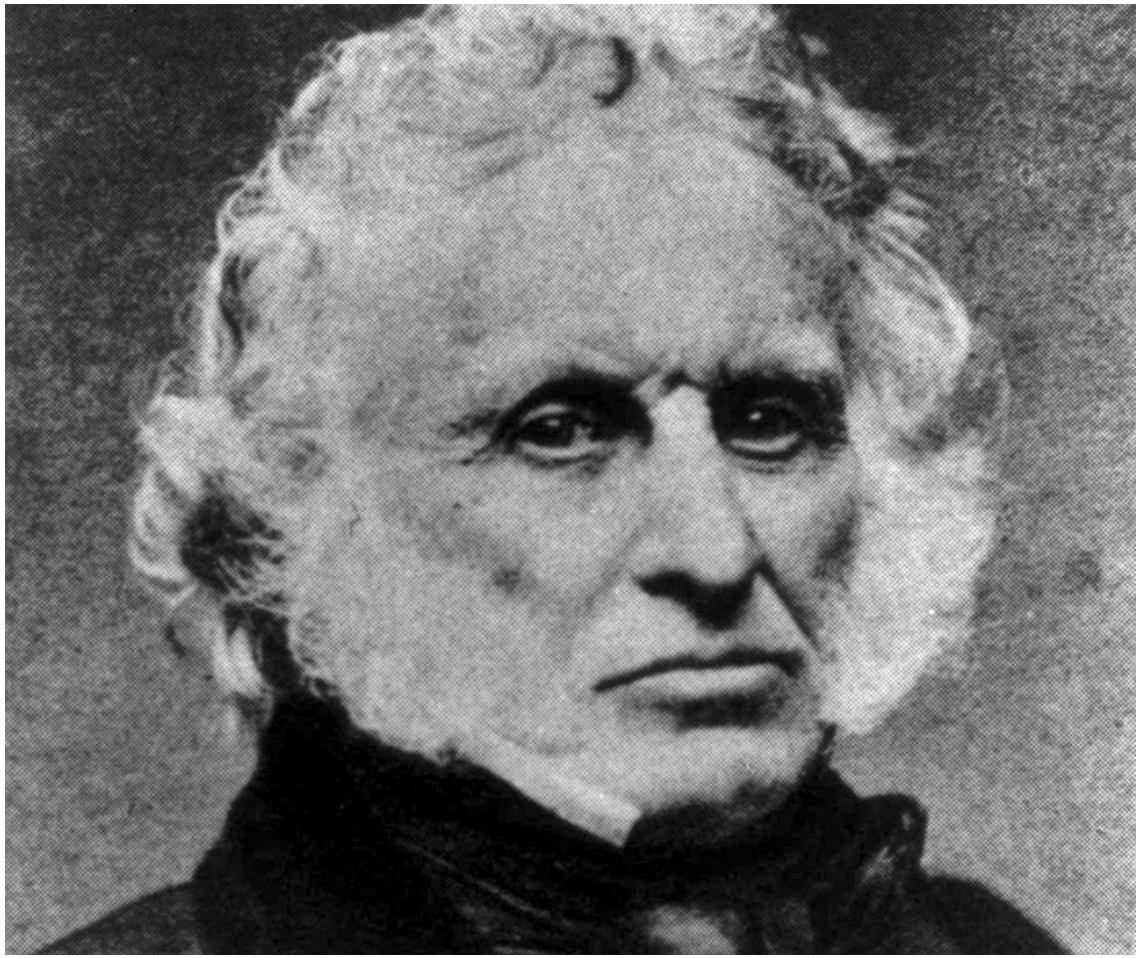
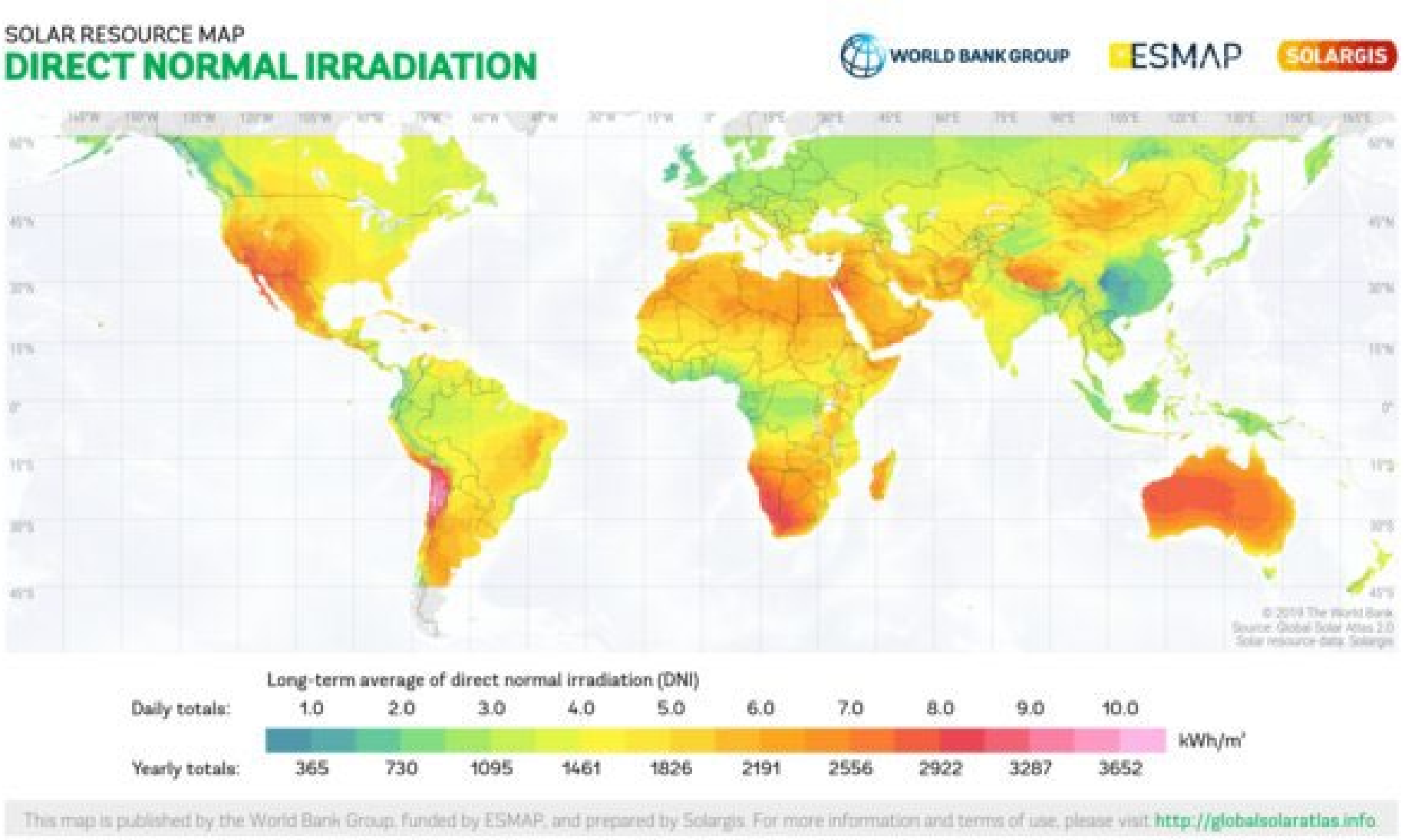


Photo from Wikipedia

Solar heat


SOLAR RESOURCE MAP
DIRECT NORMAL IRRADIATION
WORLD BANK GROUP
ESMAP
SOLARGIS
Long-term average of direct normal irradiation (DNI)
Daily totals: 1.0 2.0 3.0 4.0 5.0 6.0 7.0 8.0 9.0 10.0
kWh/m²
Yearly totals: 365 730 1095 1461 1826 2191 2556 2922 3287 3652
This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit http://globalsolaratlas.info

The Netherlands

- Annual average DNI



Benefits: LCA, security, $, …

- Over 90% of our solar thermal systems are made in Europe.
- Low CO_2 emissions from the production: ranging from 6 to 20 grams per kWh, lower than any other renewable energy source.
- Over 90% of the collectors can be recycled using normal channels; no critical minerals, such as rare-earth metals.
- Large heat storage integrated into district heating systems is up to 200 times cheaper than batteries and can provide seasonal storage.

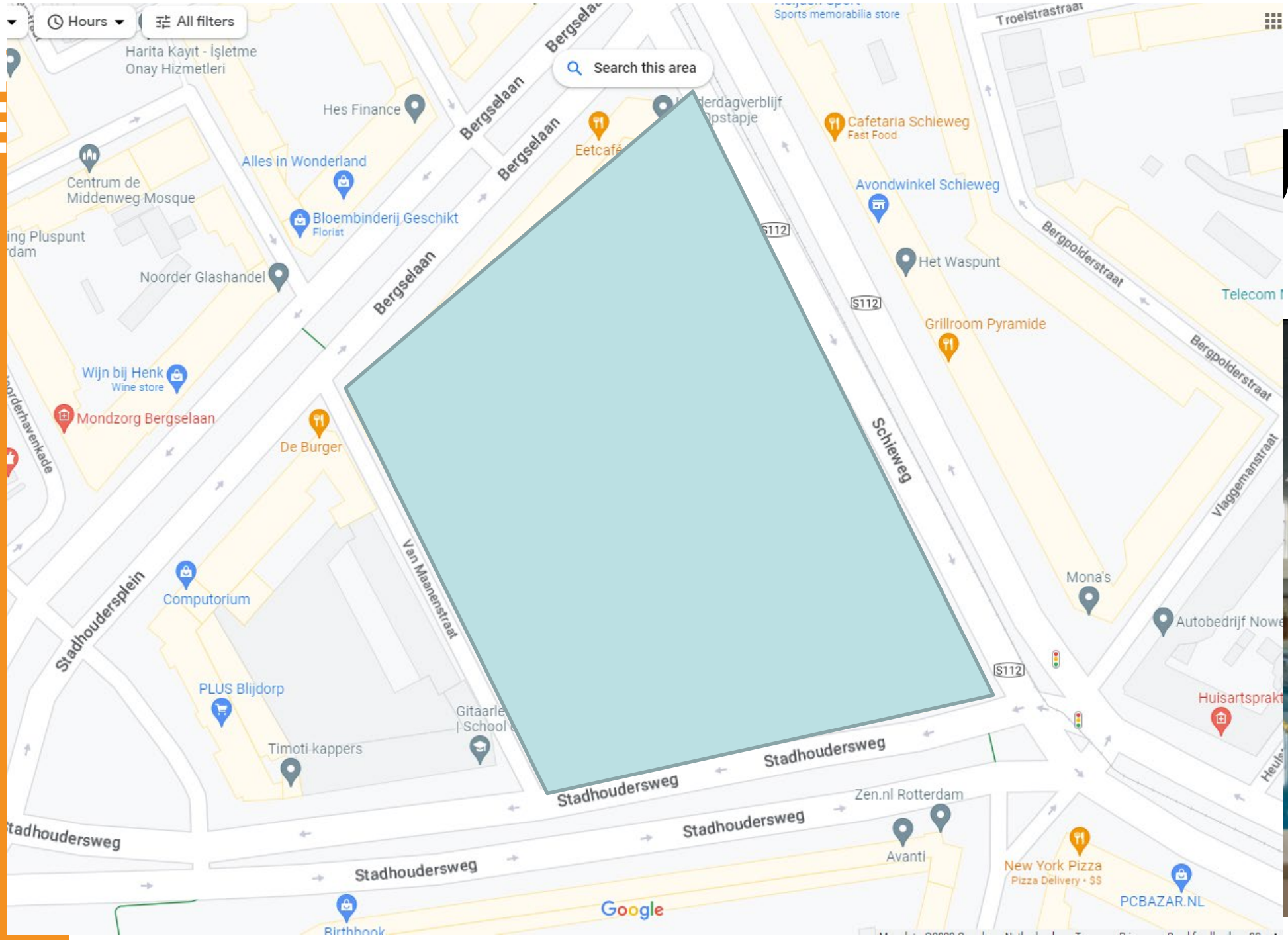
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North to South!

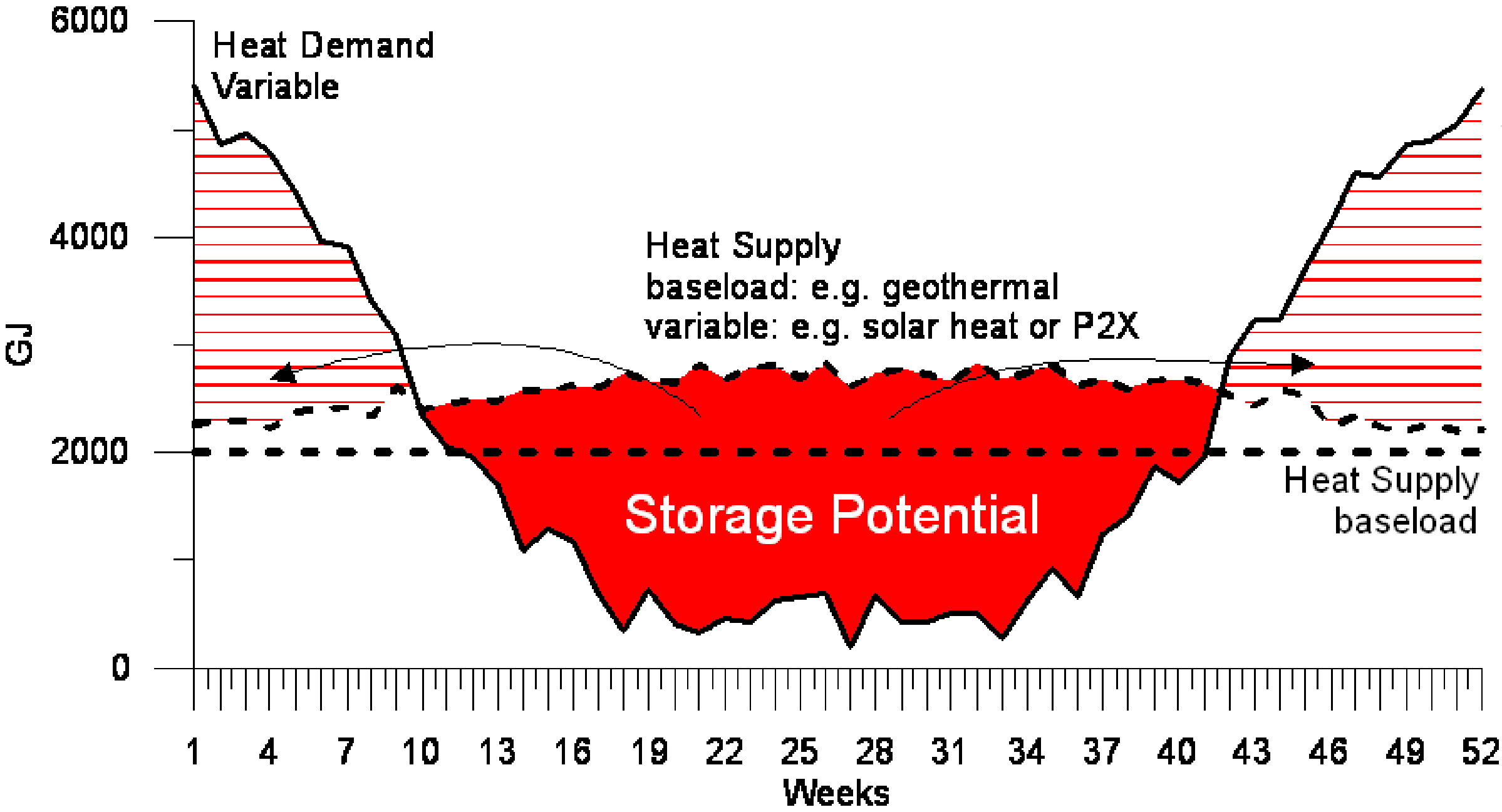
- A thermosiphon system (2.8 kW_{th}) with diurnal thermal storage (12.7 kWh_{th}), can supply domestic hot water in a Mediterranean country to a family of four for less than 0.02 € per kWh.
- A large solar district heating system (35 MW_{th}) with seasonal thermal storage (142 MWh_{th}) in Denmark achieves remarkable generation costs of only 0.035 € per kWh.*
- Dutch projects?

- www.solariseheat.eu
  - Novar

je


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Fast Food
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VAN MAANENBAD


6000
4000
2000
0
GJ
Heat Demand
Variable
Heat Supply
baseload: e.g. geothermal
variable: e.g. solar heat or P2X
Storage Potential
Heat Supply
baseload
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
Weeks

Decision makers: political

- … [Brussels does not get it] … “because there is not a common European market for heating and cooling, meaning that the European Commission (and national authorities) do not have the regulatory role, the means, the expertise, and the tools to address heat as they do for electricity or gas.”*

*ESTIF (2022)

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Thank you!