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Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

Solar Thermal Systems in District Heating Systems

UPV-EHU, Bilbao, 10-12 December 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 768567

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Index (Day 1)

1. Context
2. Performance of ST systems

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

Index (Day 2)

3. District Heating Systems
4. Solar Thermal in DH

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

Index (Day 3)

5. Solar Thermal in DH (cont.)
   - Economic metrics
   - Investment decissions
   - Operational Criteria (high-RES)
   - Operational Criteria (low-RES)
   - Sizing
   - Performance
6. Wrap-Up

5. Solar Thermal in DH (cont.)

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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5.1 Economic Metrics

- (almost) all projects in a competitive environment are funded based on economic metrics.
- Each firm has its own criteria to accept or reject projects.
- Typical criteria include:
  - Profitability of Project
    - (internal) Return Rate, IRR. Value deemed by the Project at a yearly basis in [%/year] *
    - Return on Investment, ROI. Value deemed by the Project in total [% or UNITS]
  - Value of Project
    - (discounted) Net Present Value, (d)NPV. Present value of project [€ or UNITS]
  - Value of money
    - Interest rate, (i). [%/year] *
  - Risk
    - Payback period. PB, time until investment is recovered [years]
    - Discount rates [%/year], wich incorporate risks (country, currency, custommers) *
  - Ambitions
    - Desired revenue of projects. [%/year] *
- Commonly all ítems under * are valued in a compound discount rate

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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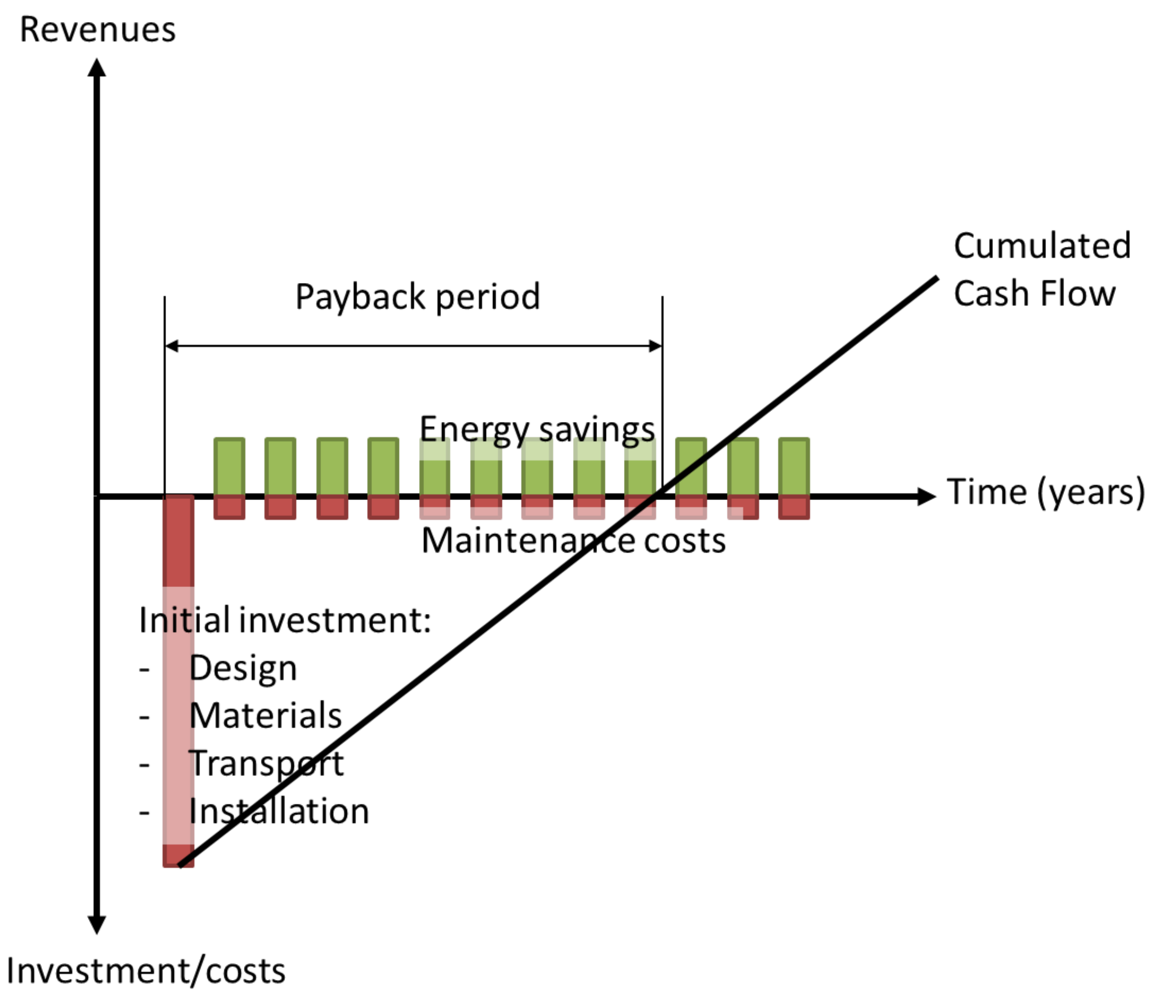
5.1 Economic Metrics



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roberto.garay@tecnalia.com
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5.1 Economic Metrics

$$NPV = \sum \frac{\text{Cn}}{(1+i)^n} - I.$$

$$ROI = \frac{NPV}{I}\ x\ 100$$

PB=n, where NPVn > 0

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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5.1 Economic Metrics

- Typical values (non-profit DH company):
  - Profitability of Project
    - (internal) Return Rate, IRR. > loan interés + ~ 5 %
    - ~~Return on Investment, ROI.~~
  - Value of Project
    - discounted Net Present Value, dNPV. > 3-4
  - Value of money *
    - Interest rate, (i). Typically very low. ~0,5-1 %
  - Risk *
    - Payback period, PB. < 5-10 years (**,***)
    - ~~Discount rates [%/year]~~
  - Ambitions
    - ~~Desired revenue of projects. [%/year]~~
  - (*) DHs are stable systems with low risk, but depends also on reliability of each company
  - (**) Can be longer for very large investments
  - (***) Can be <1 year in some cases. If so, they are decided “on the go”.

5.2 Investment Decission

- Issues to be considered at DH level
  - Heating mix
  - Multi-year evolution of heating loads
  - Facility commissioning / de-comissioning cycle
  - Status of other investments
- Space & Funding availability

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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Issues to be considered at DH level

- (for the introduction of SDH)
- Heating mix
  - Number of different producers
  - Classification under Peak, Intermediate, RES & base production systems
- Base production
  - Systems with full load operational hours exceding 3000-5000 h
  - Very efficient heat production systems, CHP or large boiler systems
  - Heat production systems which require >3h of startup time

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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Issues to be considered at DH level

- Intermediate production
  - Systems with full load operational hours in the range of 1000 to 3000 h
  - Efficient, medium-size systems
  - Commonly at part load (Winter and intermediate season)
  - Commonly as base generation technology when larger producers are stopped for maintenance (summer)
  - Typically biomass/natural gas boilers & heat pups
- RES
  - Renewable energy systems
  - Industrial waste heat systems
  - In some cases, without possibility to difer heat production

Issues to be considered at DH level

- Peak & Backup production
  - Inexpensive systems
  - Activated under peak conditions (coldest days in the year)
    - Or due to failure/non-availability of other systems
  - Typically natural gas boilers
    - Heat pumps not optimal for very cold days.
  - Typically geographycally distributed
    - Redundancy for pipeline failure cases

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
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Issues to be considered at DH level

- (for the introduction of SDH)
- Multi-year evolution of heating loads
  - Is load stable?
  - Load increase due to densification of network
  - Load increase due to extension to new neighborhoods
    - Locally deployed systems?
  - Load reduction
    - Climate change?
    - Increase in building insulation levels
    - Better heat supply alternatives

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roberto.garay@tecnalia.com
Tecnalia
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Issues to be considered at DH level

- Facility commissioning / de-comissioning cycle
  - Are some old facilities expected to be de-commissioned?
  - How will this impact in the production mix?
  - Are new facilities to be constructed?
- Status of other investments
  - Viability of investments not yet paid back need to be guaranteed
  - Or discounted from newer investments

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roberto.garay@tecnalia.com
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Space & Funding availability

- Space
  - Land availability within DH plants (if VERY large)
    - Space for ST fields can be found in the viccinity of DH plants.
    - Not relevant ST capacity when compared to DH plant.
  - Towns < 5-20,000 hab.
    - Commonly reasonably-priced land is available.
  - Industrial areas
    - Roofs, parking áreas, etc.
  - Large cities
    - “imaginative” solutions
    - Building integrated, etc.

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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Space & Funding availability

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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http://solarheateurope.eu/2018/06/18/big-solar-graz-the-largest-solar-district-heating-plant-is-moving-ahead/

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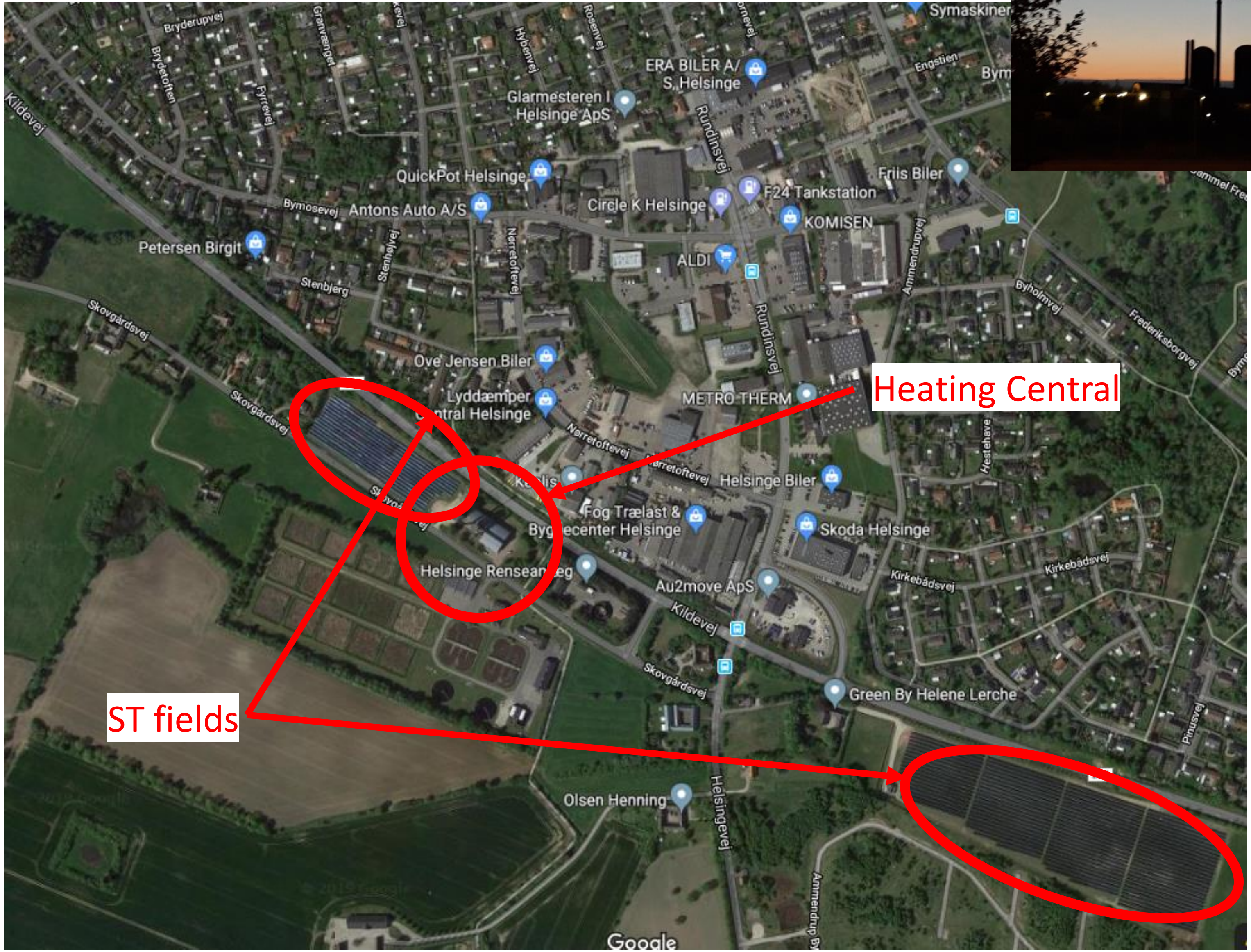
Space & Funding availability



Google Maps. Aerial photo of Helsinge DH plant (DK)

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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Space & Funding availability

SDH project

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
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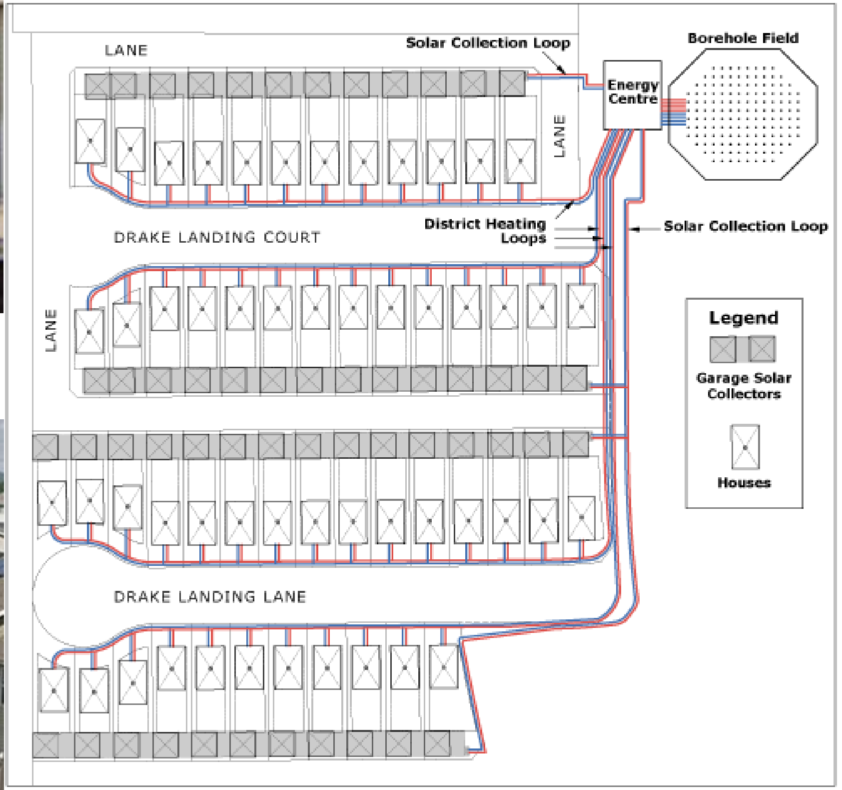

Drake Landing Solar Community (CA)

Space & Funding availability

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roberto.garay@tecnalia.com
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- Funding
  - Own funds.
    - Commonly limited to investments < 5 % of yearly turnover.
    - Low impact at large scale
  - Multi-party agreements
    - For all large-scale investments
    - Funding from Banks & Investment funds
    - Subsidies from National & Regional government
    - Guarantees
      - Multi-year heat purchase agreements at ~fixed Price
      - Feed-in tariffs & subsidies (e.g. CHP electricity)
      - (stability of normative framework)

5.3 Operational Criteria (high-RES)

- SDH plant is “systemic”
  - Produces a relevant share of heat in a given period (e.g. >20%)
  - Stable heat production capacity
    - Substitutes other heating technologies (e.g. other plants are stopped for maintenance)
- Criteria
  - Meet DH Flow temperature levels
  - Stabillize production, with at least daily/weekly thermal storage
  - Incorporate backup heat production system

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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5.4 Operational Criteria (low-RES)

- ST produces some free heat
  - Small share heat production (e.g. <5%)
  - Variable heat production
    - Excedentary heat from a building/factory
- Criteria
  - Preferrably, production at DH Flow temperature level
    - Lower Flow temperature accepted (e.g. -5-10ºC).
  - Injection to return level is posible (in some systems)
    - Much higher performance, but higher heat los & lower price of heat
  - No storage or backup heating

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roberto.garay@tecnalia.com
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5.5 Sizing

- Collector field
  - Optimal orientation: ~South
  - Optimal slope: 30-40º
- Storage
  - Inertia/short-term <0,05 m^3/m^2
  - Daily ~0,3 m^3/m^2 (vertical tank)
  - Seasonal ~ $2m^3/m^2$ (borehole/pit storage)

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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5.6 Performance

[Exercises]

- For educational purposes only
- Proper design requires
  - Basic engineering of ST plants
  - Transient load & production análisis (e.g. hourly)
  - CFD análisis of storage tanks
  - Detailed control loops
  - Cost analysis

[Exercise]

- Turning point for a collector (perf >0)
- DH temperature levels: 60/30ºC
  - Collector mean Surface temperature: 45 ºC
- Ambient temperature: 5 ºC
  - AT: 40 ºC
- perf = 0,853 - 2,71*(AT/I) - ~~0,0046*(AT²/I)~~
  - I where perf > 0 : 127 W/m²
  - Performance at 300 W/m² 49 %

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
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roberto.garay@tecnalia.com
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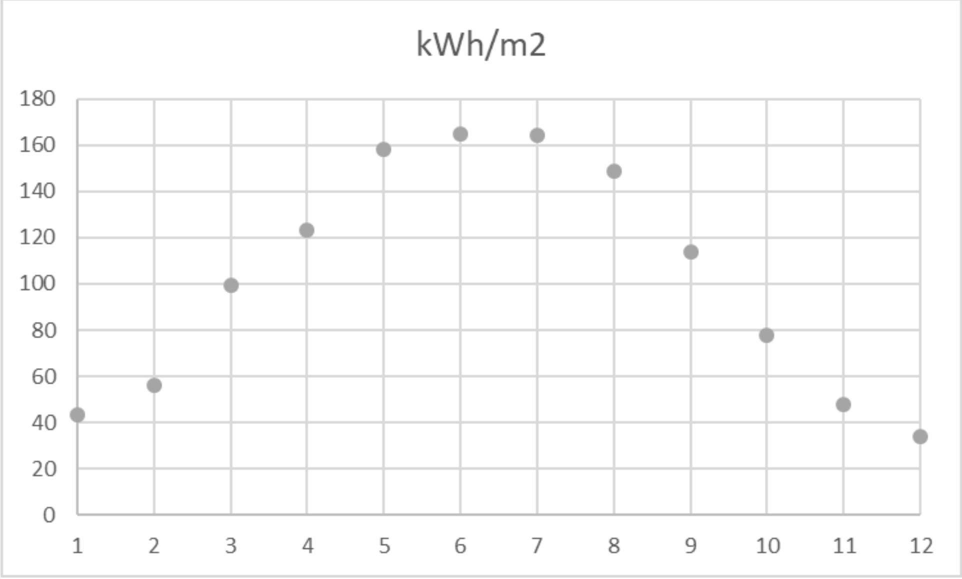
[Exercise]

- Solar energy yield
- Average collector performance: 35%
- Monthly solar energy
  - July: 5.3 kWh/m².d
  - Days in month

    31
  - Available solar energy

    164 kWh/m²
  - Input to DH

    57,5 kWh/m²



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roberto.garay@tecnalia.com
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[Exercise]

- Total DH load: 1625 MWh
- Desired solar fraction: 40 %
  - Required solar input to DH — 650 MWh
- Yearly solar energy yield: 1,2 MWh
  - Average collector performance: 35%
  - Required collector Surface — 1547 m^2
- Land-to-collector surface ratio: 3
  - Required Surface for collector field — 4642 m^2 ~0,5 ha

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
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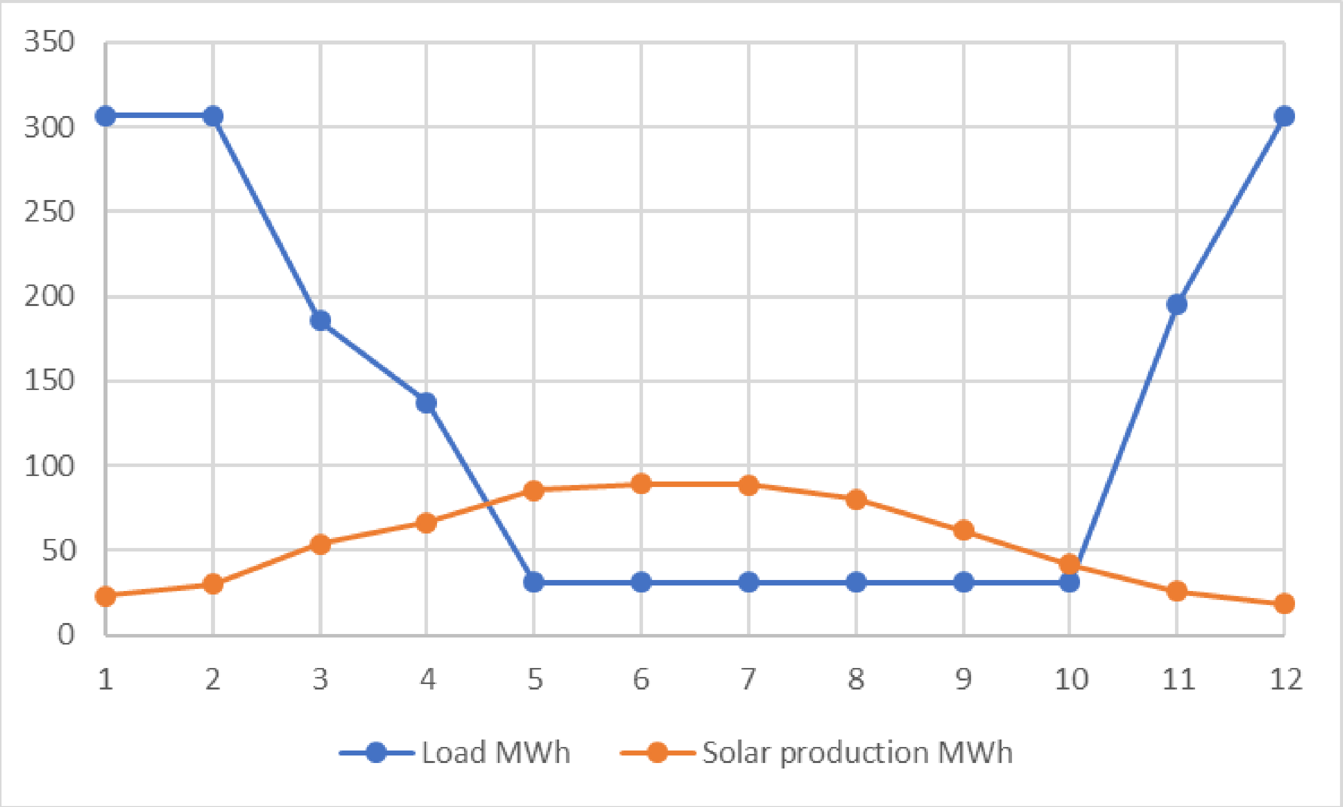
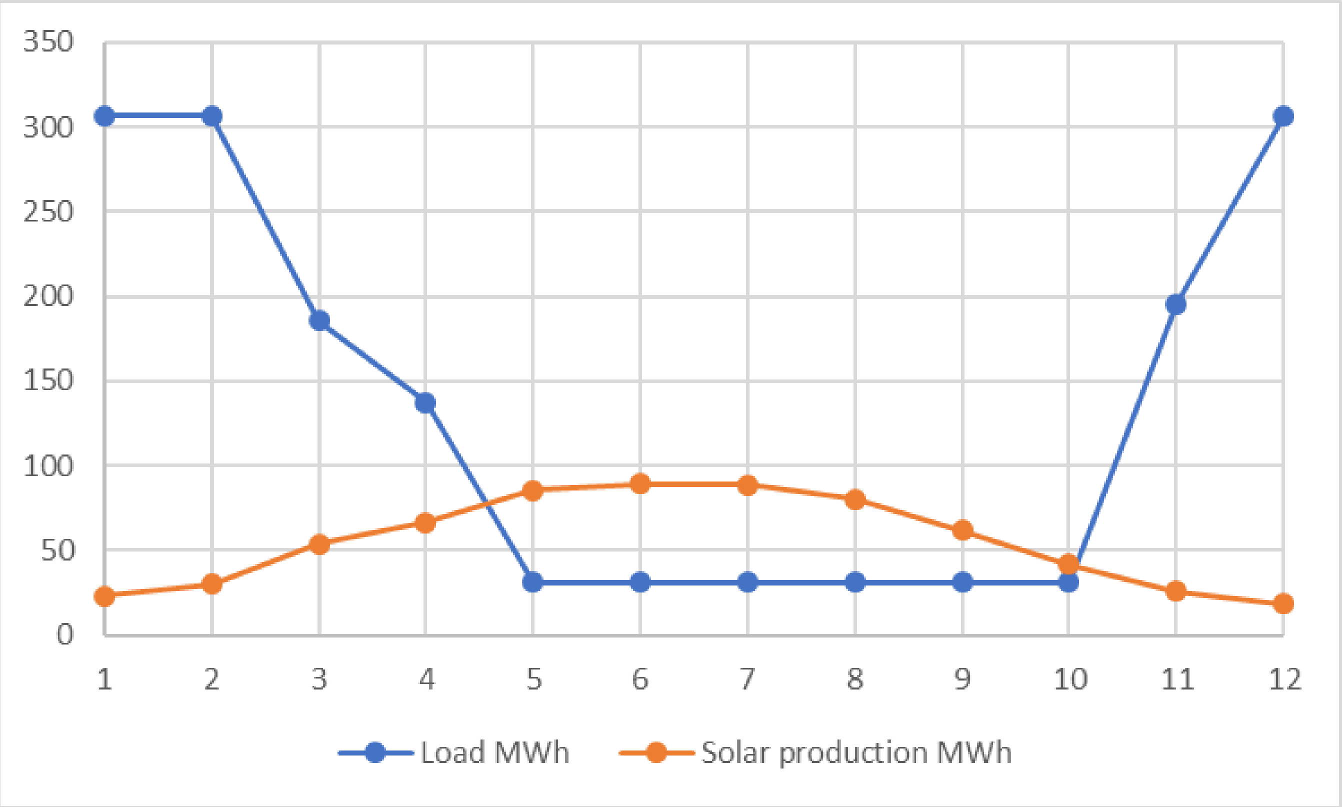
[Exercise]



- Load & production patterns
- Storage size
  - ~60 MWh ? No
  - ~90 MWh ? No
  - ~250MWh ? Yes

[Exercise]



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roberto.garay@tecnalia.com
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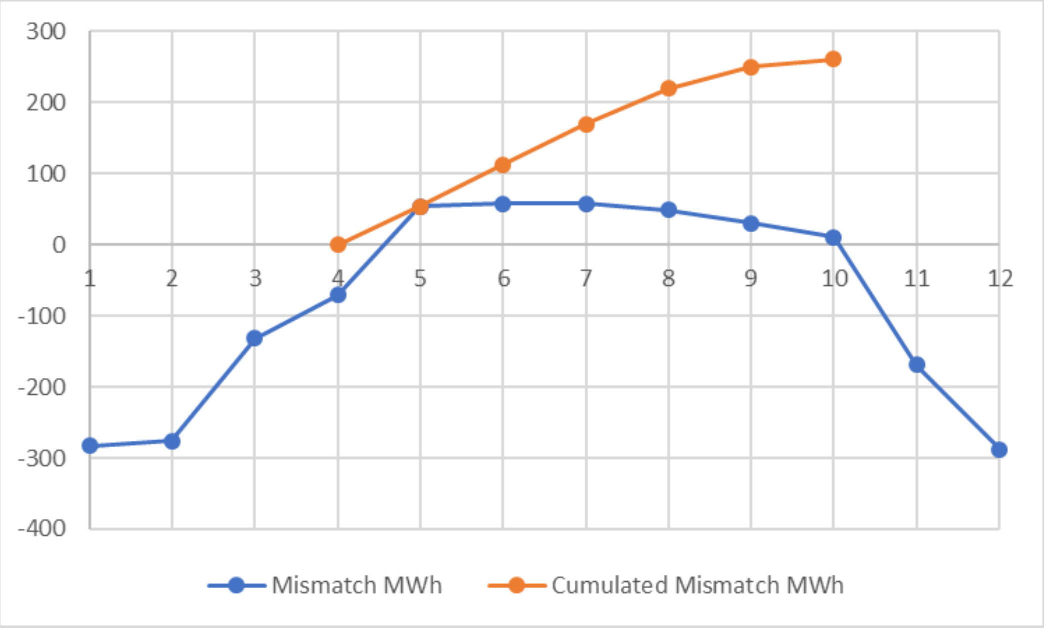

[Exercise]

- Storage capacity: 250 MWh
  - Cp: 4,1 kJ/kg.K
  - density: 1000kg/m3
  - AT: 30 ºC
  - 1kWh =3600 kJ
  - (effective) storage volume: 7300 m^3
- Vertical tank
  - Diam 20 m / floorplan 314 m^2
  - Height: 23 m

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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[Exercise]

- Collector Surface: 1547 m2
  - Unit cost: 300 €/m2
- Storage volumen: 7300 m3
  - Unit cost: 300 €/m3
- Total investment 2.654.100 €
- Service life: 15 years
- Yearly heat production: 667 MWh
- Cost of heat: ~265 €/MWh
- Is this profitable? No (should be ~20-30 €/MWh
- Reasons? Small field & large tank

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

[Exercise]

- Collector Surface: 1547 m2
  - Unit cost: 200 €/m2
- ~~Storage volumen: 7300 m3~~ (instantaneous supply to network)
  - ~~Unit cost: 300 €/m3~~
- Total investment 309.400 €
- Service life: 15 years
- Yearly heat production: 667 MWh
- Cost of heat: ~30 €/MWh
- Is this profitable? Yes

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

6. Wrap-Up

Topics discussed

1. Context
2. Performance of ST systems
3. District Heating Systems
4. Solar Thermal in DH

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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Key Issues

- Energy sector is a fast evolving system
- De-carbonisation, sustainability & security of supply are key issues
- DHs are a relevant heat supply technology
- There is an increasing need for renewables in DHs
- Solar systems are increasingly common in DH networks
- Solar systems can de-carbonize DH networks
- Solar heat is substantially cheaper than other technologies
- Sustainability & economic performance need to complement each other

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roberto.garay@tecnalia.com
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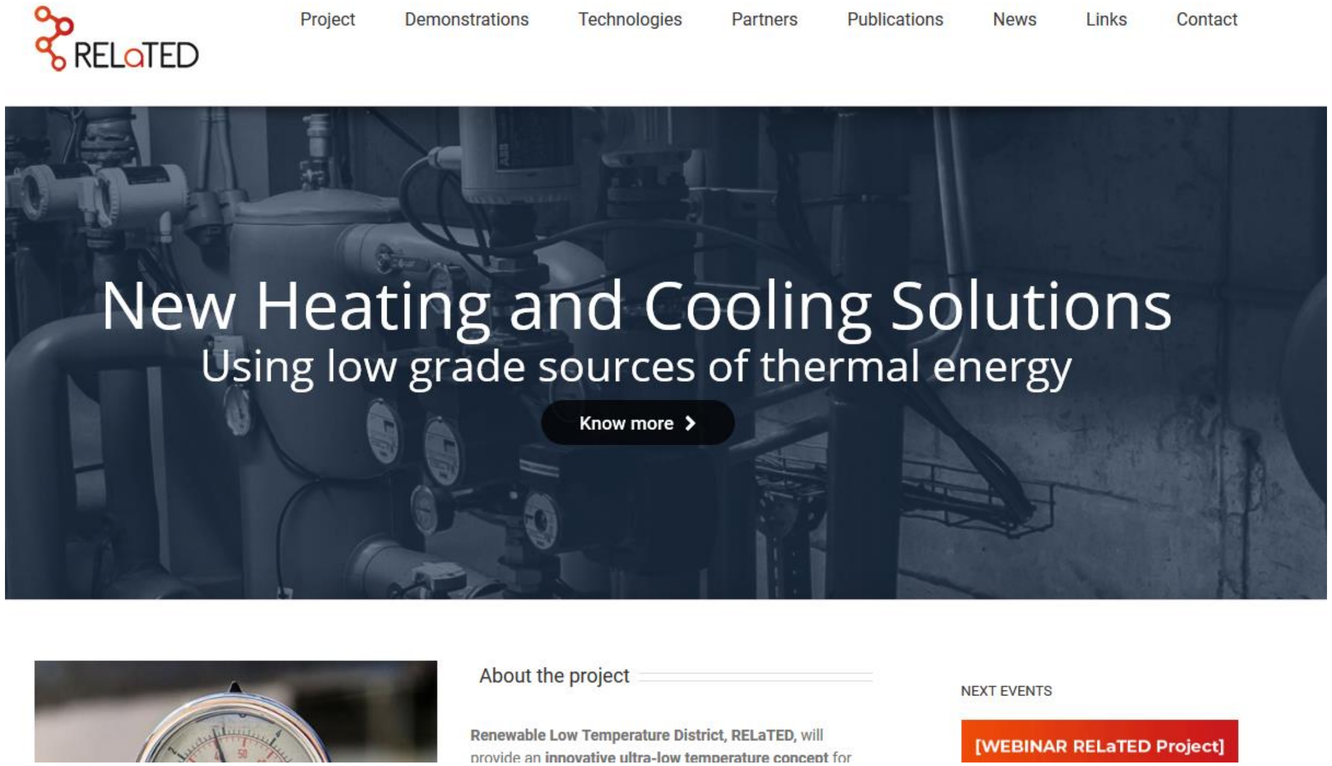
Renewable Low Temperature District (h2020 Project)

http://www.relatedproject.eu/



Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
Building Technologies Division

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End of Day 3

Roberto GARAY MARTINEZ
roberto.garay@tecnalia.com
Tecnalia
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