Motivations for thermal storage in support of solar PV in Sweden

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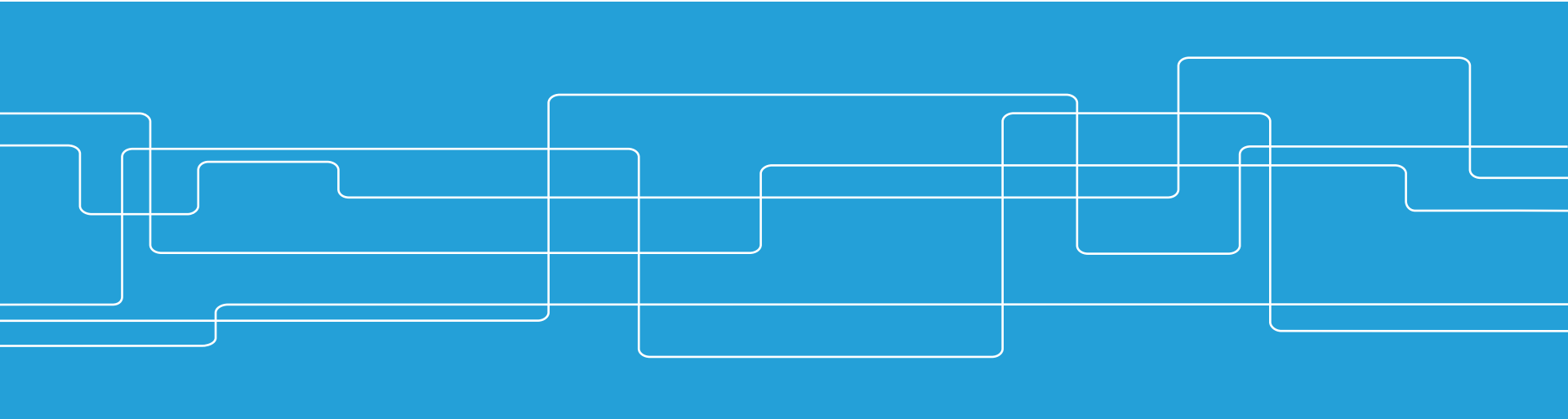


Where does PV into the energy system(s)?

Cumulative global installations by region

Global PV

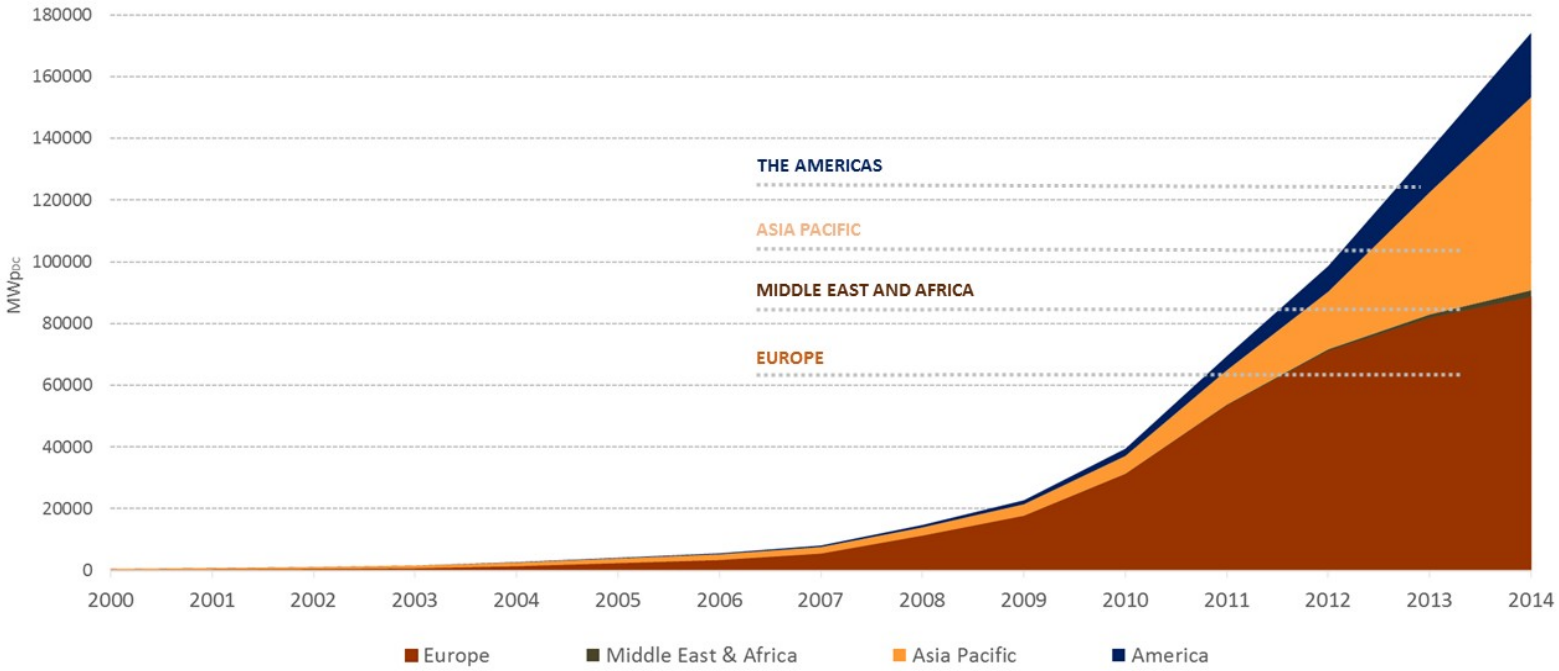
Swedish PV

Limits & Opportunities

PV/T+GSHP

Previous work

Proposed work



Source: IEA-PVPS (2015) Snapshot of Global PV Markets (T1-26:2015)

PV as a percent of electricity production

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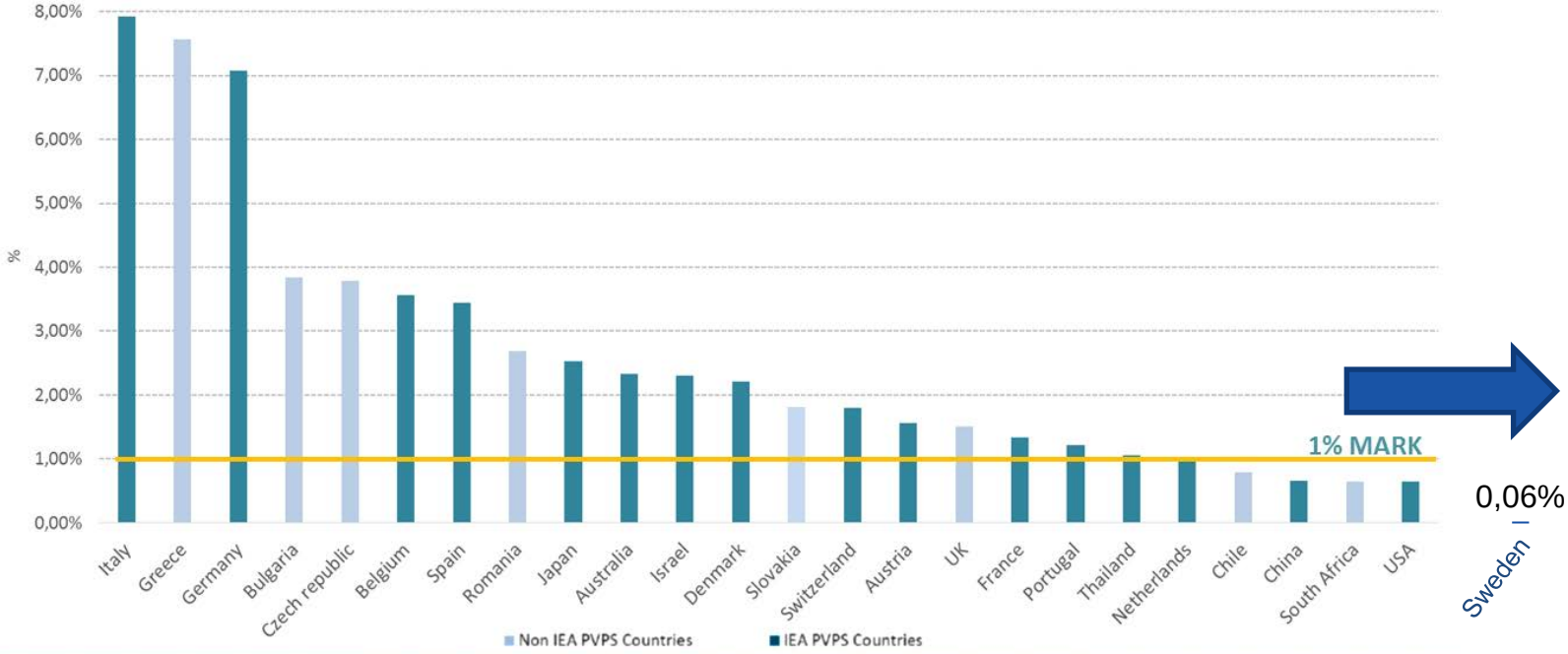
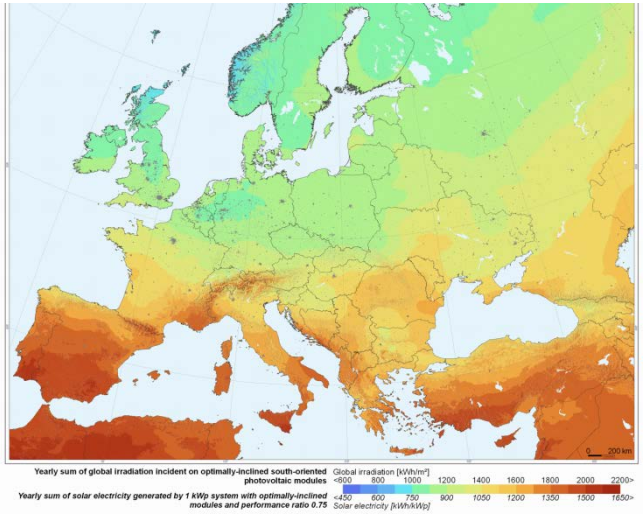


Source: IEA-PVPS (2015) Snapshot of Global PV Markets (T1-26:2015)

So…why isn't there any PV in Sweden?

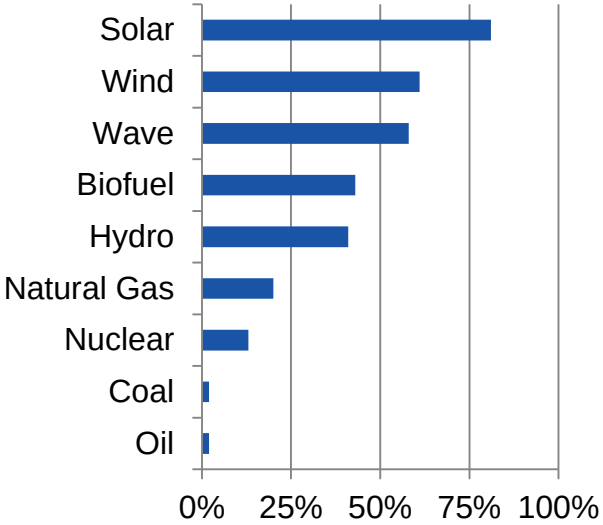
Not enough sunshine?

Similar to UK, DK, DE [1]



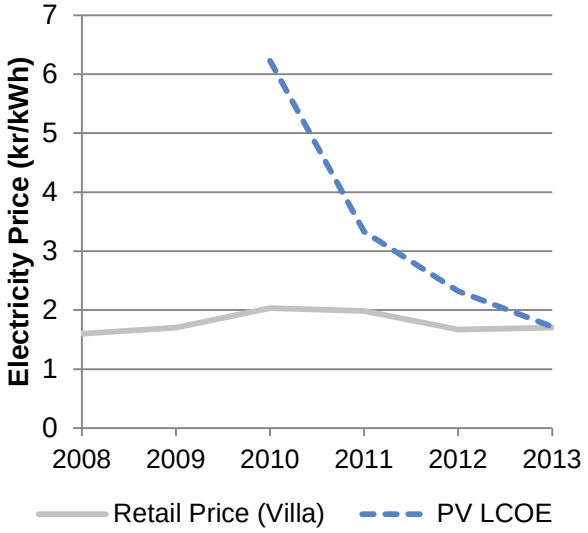
Not enough interest/support?

Most supported energy source [2]



It costs too much?

…not anymore [3]



1) PVGIS © European Union, 2001-2012

2) Hedberg P. and Holmberg S. (2014) Svenska folkets åsikter om olika energikällor 1999-2013. SOM-Institutet, Gothenburg.

3) Svensk Energi, Lindahl J. (IEA-PVPS), author's calculations

Installed capacity in Sweden

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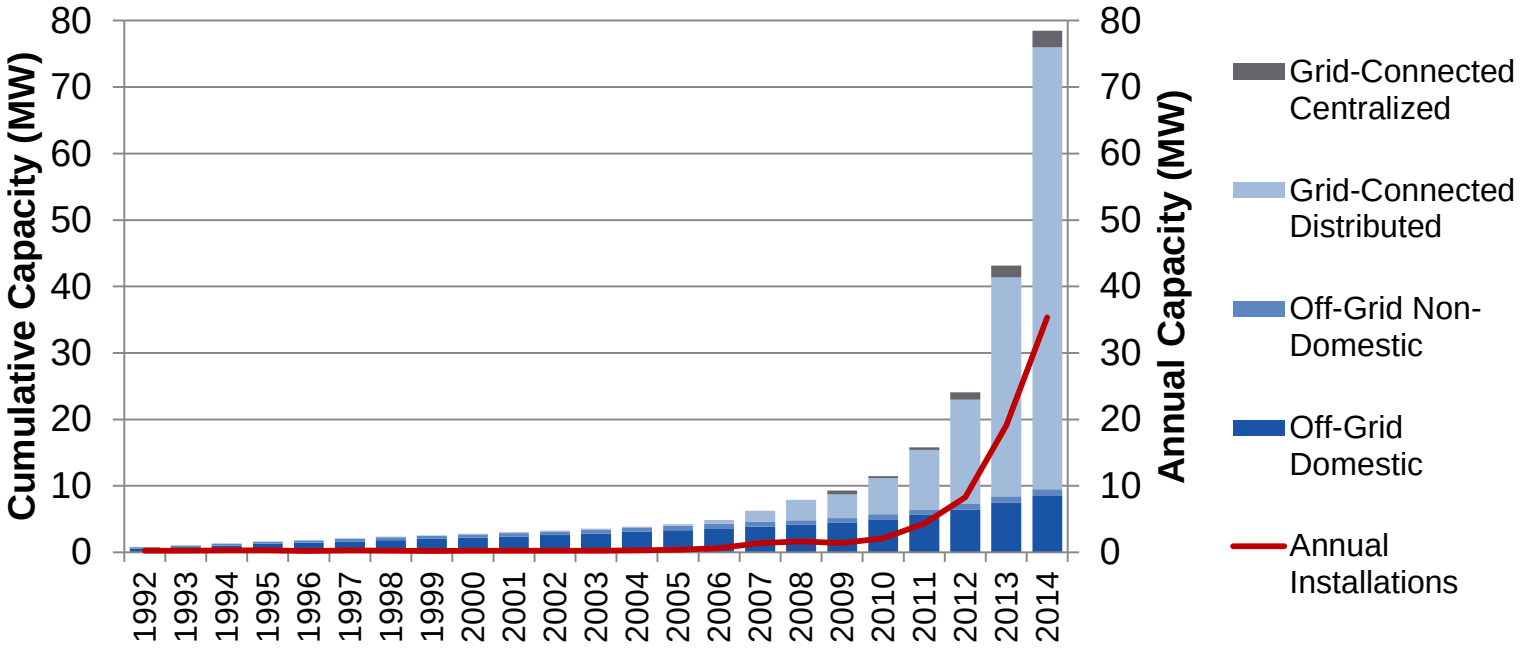

Source: Lindahl J. (2015) Swedish Summary of IEA-PVPS National Survey Report of PV Power Applications in Sweden 2014. IEA, Paris.

Government policy towards PV

- Direct support
  - Capital subsidy – 20%*
  - Green certificate market (elcertifikat) – open market pricing
  - Microproducers – 0.6 kr/kWh feed-in bonus
- Indirect support
  - Installation labor cost qualifies for 50% tax rebate (ROT-avdrag)
  - 30% deduction on loan interest
- Lack of support
  - Microproducers must pay VAT on sold electricity
  - New proposal that plants >144 kW_p must pay energy tax (~0.3 kr/kWh)

**was 35%, but the entire 2014-2016 budget was spent by October 2014. The program was refunded and subsidy reduced to 20%, but the queue is so long the rate is effectively 0%*

A fundamental problem remains…

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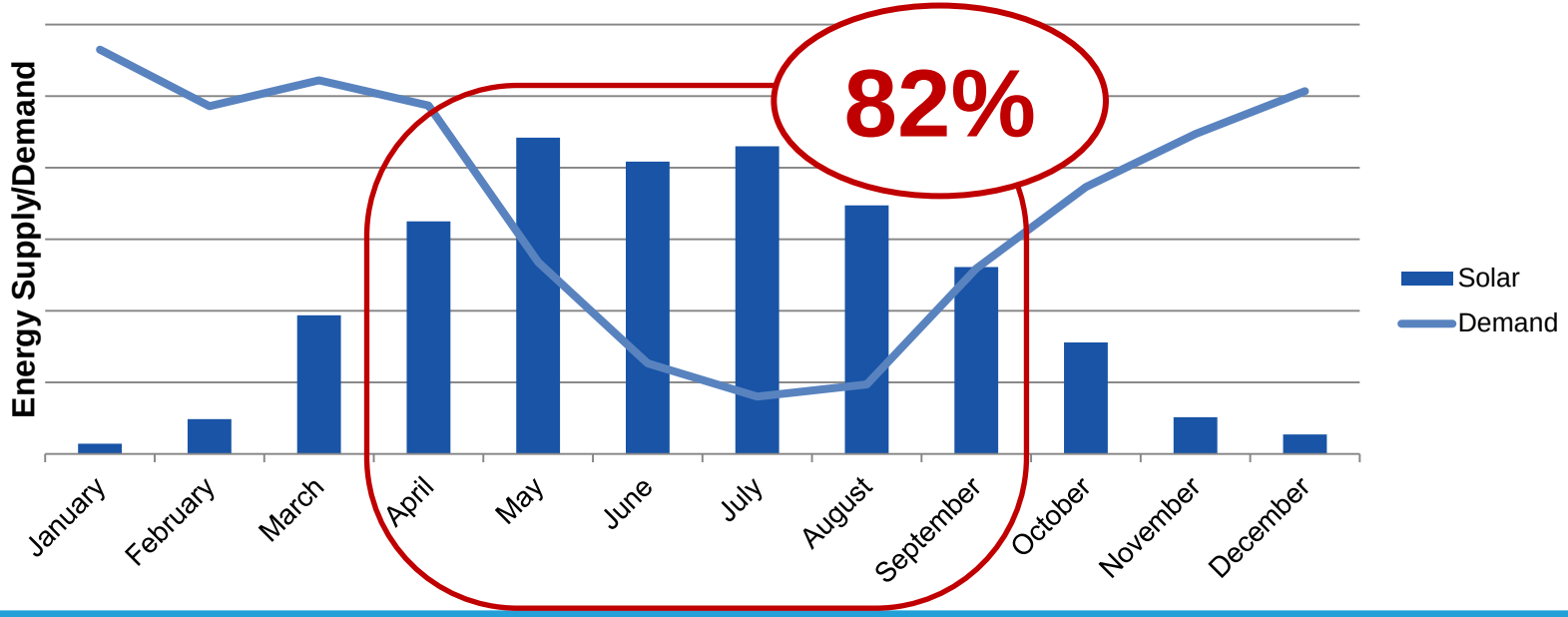

Potential storage solutions

	Strengths	Weaknesses
Batteries	High efficiency (80-90%) Returns electricity	High cost Not for seasonal cycling
Hydrogen	Long storage times Multiple uses	Infrastructure demands Difficult to handle
Thermal	Low cost Daily and seasonal cycling	Application dependent

Previous work – Solar PV + storage

Comparing battery and thermal storage with solar PV

- Single family house equiped with GSHP
- Lead acid batteries and electric resistance hot water tank
- Daily storage cycling
- For each system increasing self-consumption from 58% to 88%
  - LCOE of batteries = 0.4 €/kWh
  - LCOE of thermal = 0.2 €/kWh
  - LCOE of reference = 0.16 €/kWh

Problem: Displacing COP of 3 with a COP of 1

Thygesen R. and Karlsson B. (2014) Simulation and analysis of a solar assisted heat pump system with two different storage types for high levels of PV electricity self-consumption. Solar Energy, 103, pp.19-27.

Proposed concept – PV/T + GSHP

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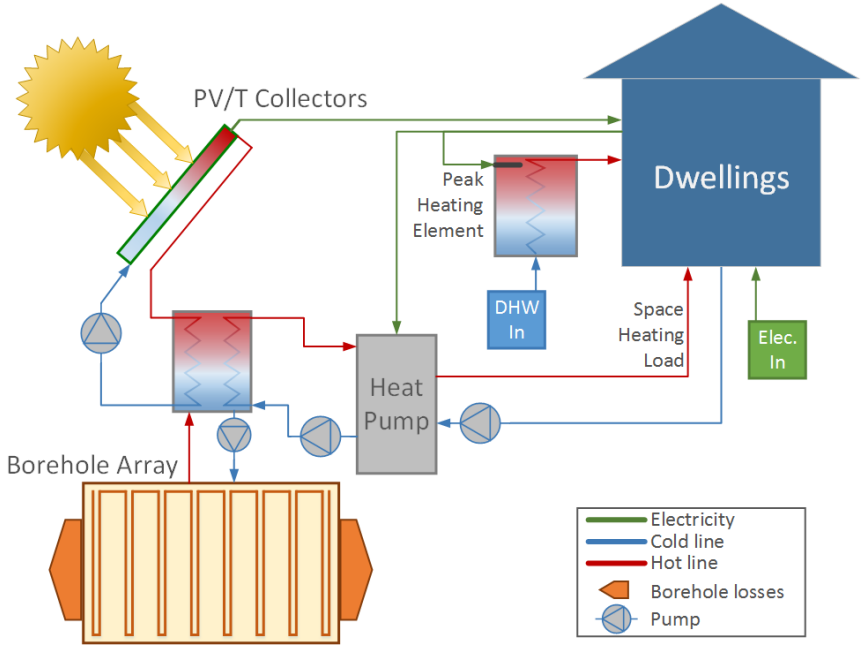

- Mutually beneficial
  - Requires low-temp strategy
  - Cool PV and warm boreholes
- Potential performance gains
  - 4-6% increased PV gen.
  - 20-35% less HP demand
  - 80-90% storage efficiency
- May only partially solve the demand/supply imbalance

Previous work – Seasonal thermal storage

<u>Drake Landing - Okotos, Alberta, Canada</u>

- Original design
  - Solar thermal stored in 144 borehole field w/ 2.25m spacing
  - 45-70 °C mean store temp, 98% solar fraction, 40% efficiency
- Recalculated with low-temperature strategy with heat pump
  - ¼ collector area, 4x BTES volume (4.5m spacing)
  - 10-16 °C mean store temp, 78% solar fraction, 86% efficiency
  - SCOP of 4.5

Chapuis S. and Bernier M. (2009) Seasonal storage of solar energy in borehole heat exchangers. 11th International IBPSA Conference, Glasgow.

Previous work – PV/T + GSHP

Single family house – Frankfurt, Germany

- Ground source boosted by PV/T (when advantageous)
- Single borehole which turned out to be undersized
- Measured PV output increase of 4%
- Measured GSHP performance not possible
  - Calculated SCOP increase of 0.36-0.56 with undersizing
  - Equal to 15% annual electricity savings

Bertram E., Glembin J., Rockendorf G. (2012) Unglazed PVT collectors as additional heat source in heat pump systems with borehole heat exchanger. Energy Procedia, 30, pp.414-23.

Previous work – PV/T + GSHP

Multi-family, low-exergy house – Zurich, Switzerland

- Design description of building under construction
- PV/T actively cooled with boreholes
- Calculated PV/T results
  - 12-14% increase in electrical output
  - 65% total energy efficiency (15% el, 40% th)
- Calculated GSHP results
  - SCOP of 7.9
- Holistic solution could limit applicability to non-optimized buildings

Meggers F., Ritter V., Goffin P., Baetschmann M., Leibundgut H. (2012) Low exergy building systems implementation. Energy, 41, pp.48-55.

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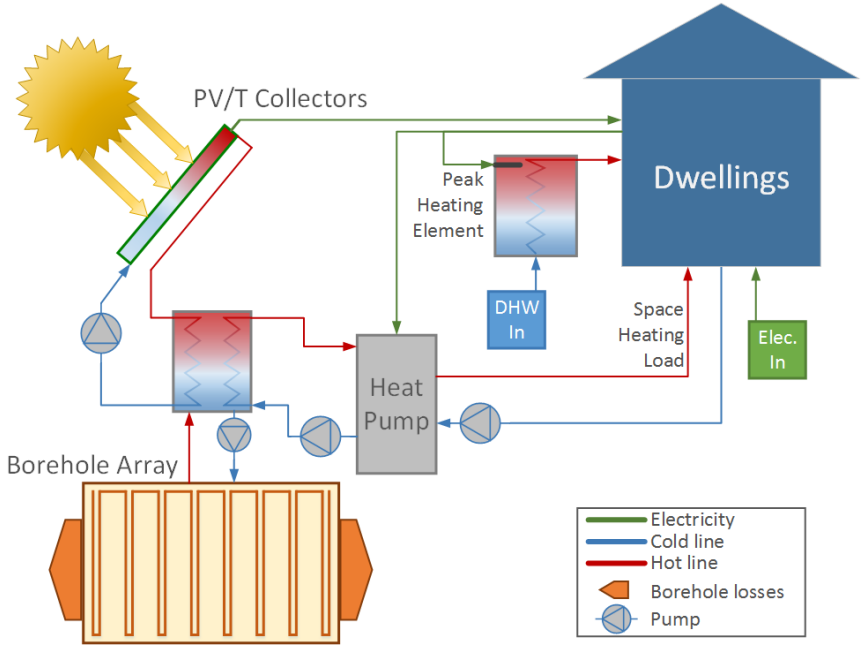

Effsys expand proposal

- Identify barriers and opportunities
- Measured data analysis
- TRNSYS model development
- Control strategy optimization

Student project

- PV/T cost reduction

Tack för mig

Source: http://www.allbatteries.com.ph/2013/10/my-second-post/