Aalto University
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Potential of PV self-consumption in a residential building with different heating systems

Buildsim-Nordic 2014

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PV in Finland

- Residential PV systems may export excess power to the grid
- Export price is 30-50% of import price
- More economical to use power on-site
- Batteries are expensive

$\Rightarrow$ Store solar electricity as heat.

How are PV economics and self-consumption affected by local electricity-to-heat conversion?

Building description

- Measured electricity demand from a district heated house ($120\,\mathrm{m}^2$)
  - 5300 kWh annual demand
- Simulated thermal demand
  - 2010 Finnish building standard
  - 9500 kWh annual demand
- DHW demand from IEA (200 l/day)
  - 3400 kWh annual demand
- Different heating systems
  - District heating (no PV heating)
  - Heat pump heating (COP 3)
  - Direct electric heating (COP 1)

Energy system

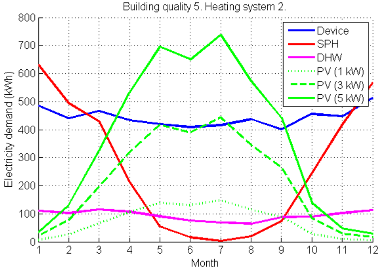
- Simulated PV generation (TRNSYS)
  - Facing south
  - Slope 40 °
  - Practical efficiency 10%
- PV capacity 0 to 10 kW
- PV priority
  1. Operate appliances
  2. Charge thermal storage
  3. Export to grid
- Stratified thermal storage tank

Economic calculations

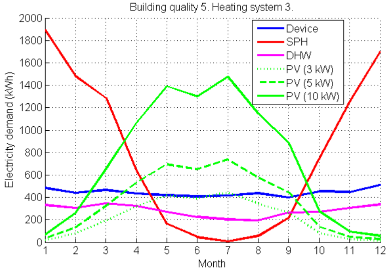
- Hourly electricity price (Nord Pool, 2013)
- 4% real interest
- 4% annual energy price rise
- 2.5% annual distribution price rise

Mismatch of energy demand and generation

Heat pump

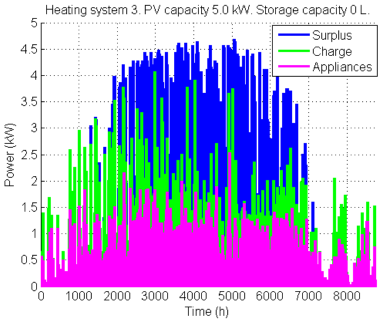


Direct electric heating

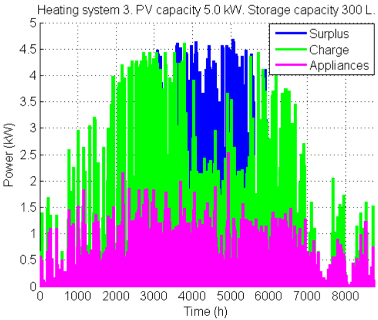


Hourly PV usage

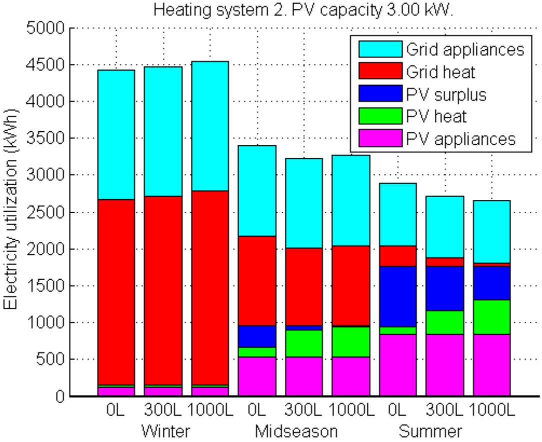
No storage



300 l storage



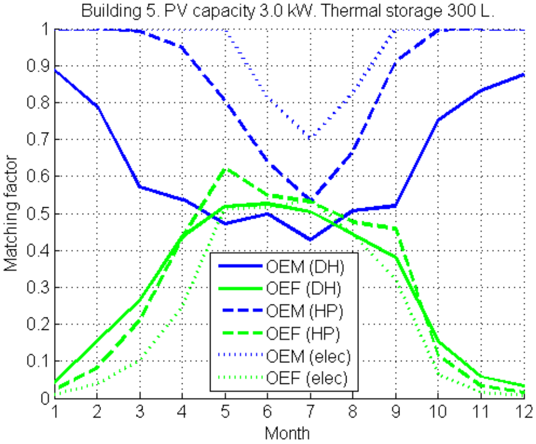
Seasonal energy usage



- Large tank costs energy in winter
- Small tank best in midseason
- Largest tank best in summer

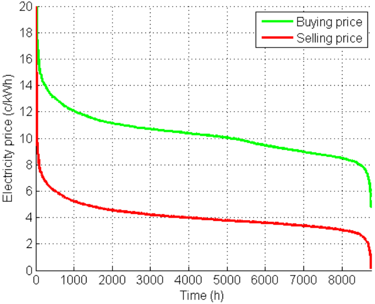
No nighttime heat scheduling utilized

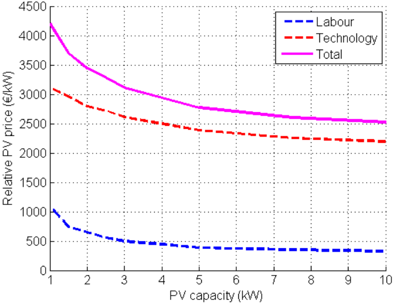
Monthly energy matching



- OEM = portion of PV energy used on-site
- OEF = portion of energy demand met by PV

Electricity and PV system price

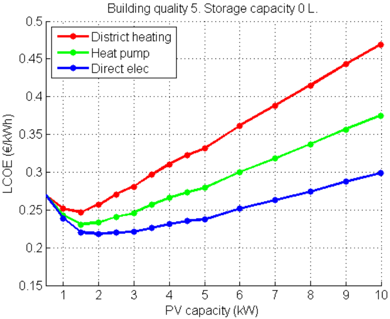




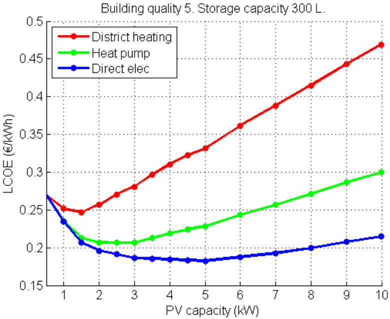
Levelized cost of PV electricity over 20 years, 1/2

LCOE = (PV price - Discounted savings and exports) / Self-consumed energy

No storage



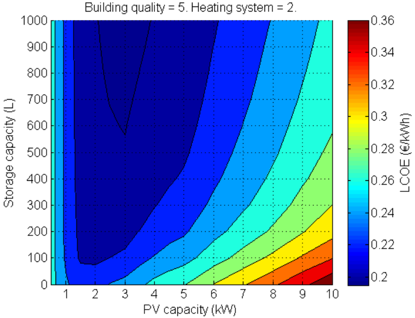
300 l storage



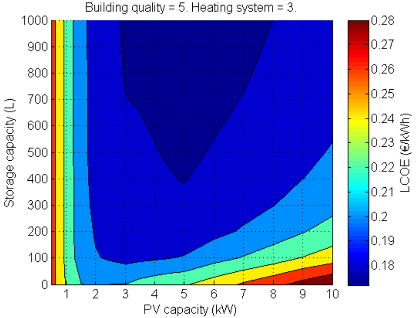
Levelized cost of PV electricity over 20 years, 2/2

LCOE of grid electricity: 0.09 €/kWh

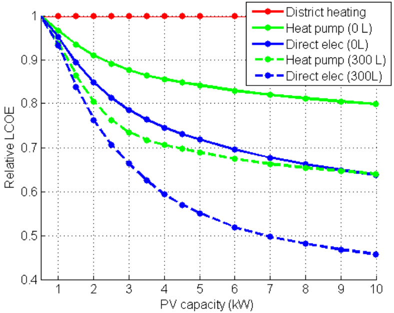
Heat pump



Direct electric heating



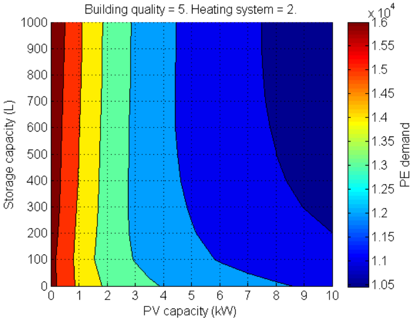
LCOE relative to no PV heating case



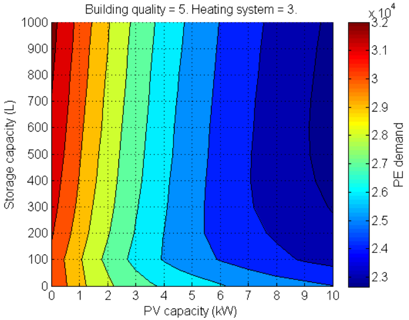
LCOE drops by 25 to 35% with a 3 kW PV system

Primary energy demand

Heat pump



Direct electric heating



Conclusions 1/2

- Usage of excess PV power for heating increases self-consumption
  - by 0.15 to 0.25 with HP
  - by 0.30 to 0.45 with direct electric heating
- A 100 l thermal storage is enough to gain most benefits
- PV heating improved LCOE by at least 10%, when PV capacity was 2 kW or more
  - ...but not enough to beat grid prices (17 c/kWh vs. 9 c/kWh)
- 20 years was not enough for system payback

Conclusions 2/2

- Optimal charge control could improve the situation a little
- Economic residential PV would still need incentives or much higher electricity prices
  - Feed-in tariffs do not encourage self-consumption
  - Self-consumption incentives encourage energy waste
- Future: Communal energy systems?
  - Economies of scale
  - Seasonal storage
  - Shared heat pump or CHP
  - New incentive related to self-consumption and energy demand reduction

THANK YOU FOR LISTENING!