

Solar power profitability with demand response and carbon-corrected electricity prices

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Research questions

- What is the economic profitability of small-scale PV systems in the northern conditions?
- How much the profitability improves by utilizing electric hot water heater (EHWH) as an energy storage?
- How much the profitability increases if the social costs of carbon are internalized in the electricity prices?

Framework

- The profitability is modelled in three locations in Finland: Helsinki, Jyväskylä and Sodankylä
- Flexibility is provided by the EHWHs in detached houses
- Carbon emission prices are scaled according to the emission allowance prices and social cost of carbon estimates



Results

- Household hot water heating profile changes by the solar power generation and heating optimization
- Savings vary between 5–33 euros per year across regions and PV system sizes

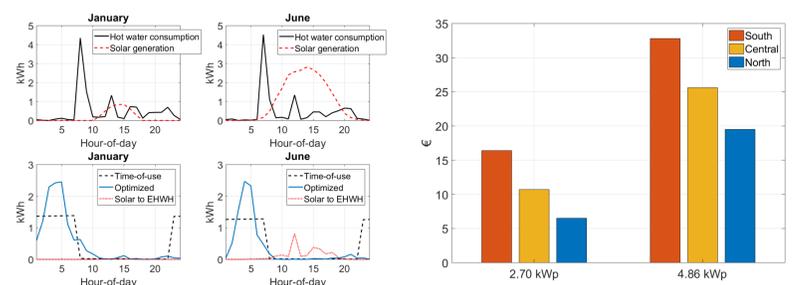


Figure 2. Average heating profiles and annual extra savings from the hot water heating optimization

Model

- Discrete time dynamic optimization model
 - Control the charging of the heater, given the energy content in the heater and solar power output
- Econometric modelling of the emissions
 - Marginal emissions are derived from this model
 - Divide the electricity price to "carbon-related" and "non-carbon-related" parts

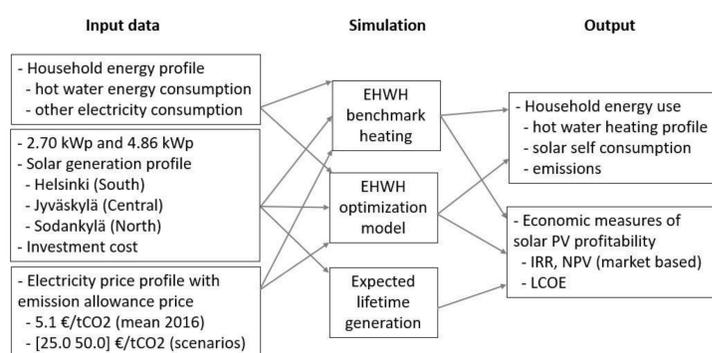


Figure 1. Model overview

- Internal rates of return (IRRs) of solar PV investments vary from 0.6 to 1.4 % without any consumption optimization
- Optimization improves the IRRs up to 2.1 % in the southern location

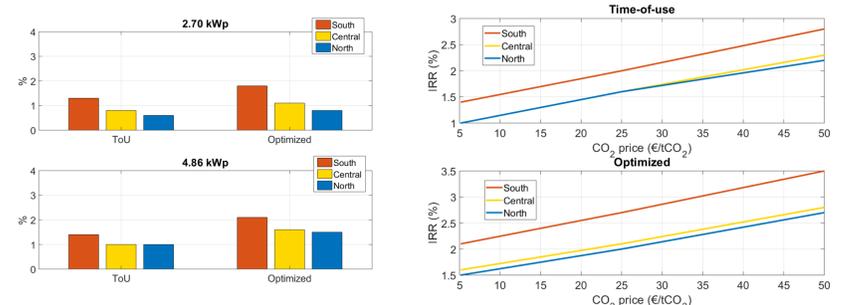


Figure 3. Internal rates of return with original (left) and scaled (right) carbon prices

- Higher carbon emission allowance prices increase the IRRs, on average, by 0.3 % points per additional 10 €/tCO₂
- Note that other price components, such as taxes and distribution tariffs, have similar impact on the IRRs

Conclusions and policy implications

- Solar power profitability is fairly low in the Finnish context
- Optimization of household water heating improves the profitability marginally
- Savings are larger from the optimization the higher the solar generation compared to the electricity consumption
- Higher emissions allowance prices increase the profitability
- Technologies enabling the consumption optimization and control should be promoted