Universiteit Utrecht

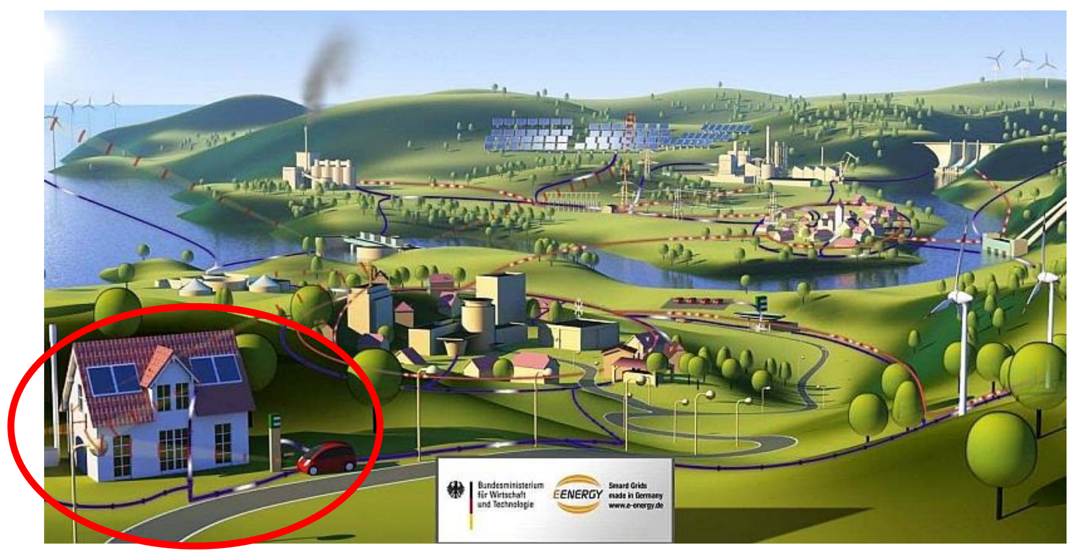
Faculty of Geosciences
Copernicus Institute of Sustainable Development
Connecting knowledge for sustainability

Diffusion of photovoltaic systems and electric vehicles in the Netherlands and implications for the energy transition

Mart van der Kam m.j.vanderkam@uu.nl, Wilfried van Sark w.g.h.j.m.vansark@uu.nl , Floor Alkemade f.alkemade@tue.nl

A key issue in many smart grid visions is integration of the energy and mobility system. Electric vehicles (EVs) can be charged with renewable photovoltaic (PV) solar power, and thus contribute to the integration of PV solar power in the electricity network via flexible demand and storage in bidirectional vehicle-to-grid (V2G) systems. We study the role of consumers in the transition to a smart grid system by comparing the diffusion of PV and EV in the Netherlands. We find large differences in the spatial dependence of the diffusion of these innovations. These differences have implications for the smart grid transition, since vehicle-to-grid systems may not be viable for certain regions and different means of load balancing would have to be implicated.

Background



Role of consumers in smart grids

- In smart grids the role of consumers changes from passive energy users to active ones such as prosumers and traders of flexibility
- Smart homes are envisioned to have technologies such as PV systems, EVs and energy storage

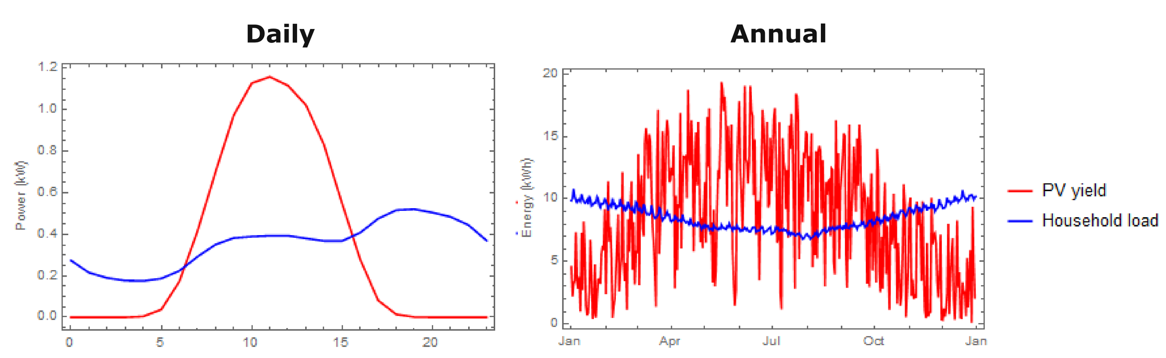


Figure 1 PV yield and household demand profiles

Supply and demand

- Typical household demand is not in line with PV power supply, both on a daily and a yearly scale

Vehicle-to-grid

- EVs can act as a source of flexible demand, or storage, in V2G systems

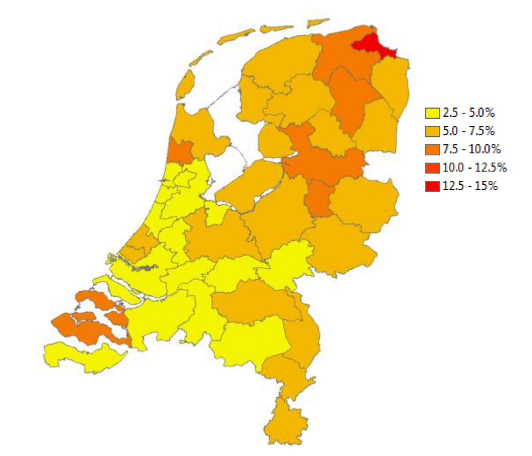


Figure 2 Percentage of household rooftops with PV of COROP (COÖrdinatie commissie Regionaal OnderzoeksProgramma) areas (2015)

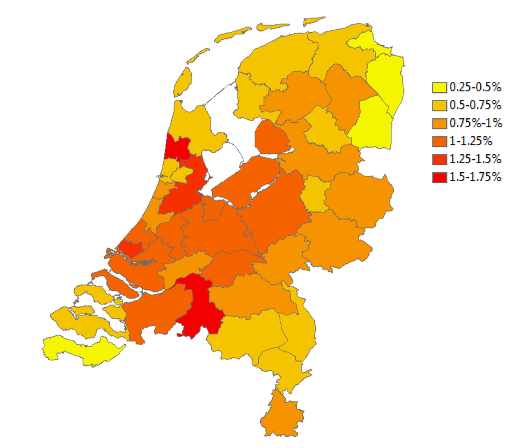


Figure 3 Percentage of EVs in car fleet of COROP areas (2016)

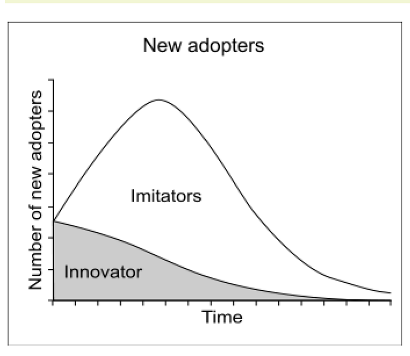
User adoption

- Diffusion of PV and EV show opposite spatial patterns
- PV systems are relatively popular in rural areas, while EVs are more popular in urban areas
- V2G systems may not be viable in certain regions

Method

Bass model of diffusion

- We build scenarios to investigate the potential contribution of households to the energy transition with the combination PV and EV
- The Bass model of diffusion explains innovation diffusion by dividing the population in two groups:
  - Innovators, who decide to adopt independent of others
  - Imitators, who are influenced by others in their decision to adopt



$$\text{Adopters}(t) = m \cdot \frac{1 - e^{-(p+q)(t-t_0)}}{1 + \frac{q}{p} e^{-(p+q)(t-t_0)}}$$

$m \rightarrow$ total market size
$q \rightarrow$ innovator parameter
$p \rightarrow$ imitator parameter
$t_0 \rightarrow$ start time of diffusion

Indicators

- We fit the Bass model on historical diffusion data of PV and EV and link it to the energy system
- We use two indicators to measure the effect of PV and EV diffusion on the energy system:
- $\text{self-sufficiency} = \dfrac{\text{annual PV yield}}{\text{annual energy demand}}$
- $\text{self-consumption} = \dfrac{\text{annual PV yield used locally}}{\text{annual PV yield}}$
  - annual PV yield used locally = PV yield used by local household demand or local storage (in EVs)

Model assumptions

- Every rooftop is suitable for a PV-installation
- The average nominal power of PV systems is 4 kWp, and this stays constant over time
- The specific PV yield is 875 kWh/kWp
- Total household electricity demand stays constant over the years
- Every passenger vehicle can be replaced with an EV
- The total car fleet stays constant over time
- EVs stay within the same COROP area
- EVs are available for V2G all the time
- Charging and discharging efficiency of the EV-batteries is 92%
- EVs have on average 5 kWh of storage available for V2G, and this stays constant over time

Results

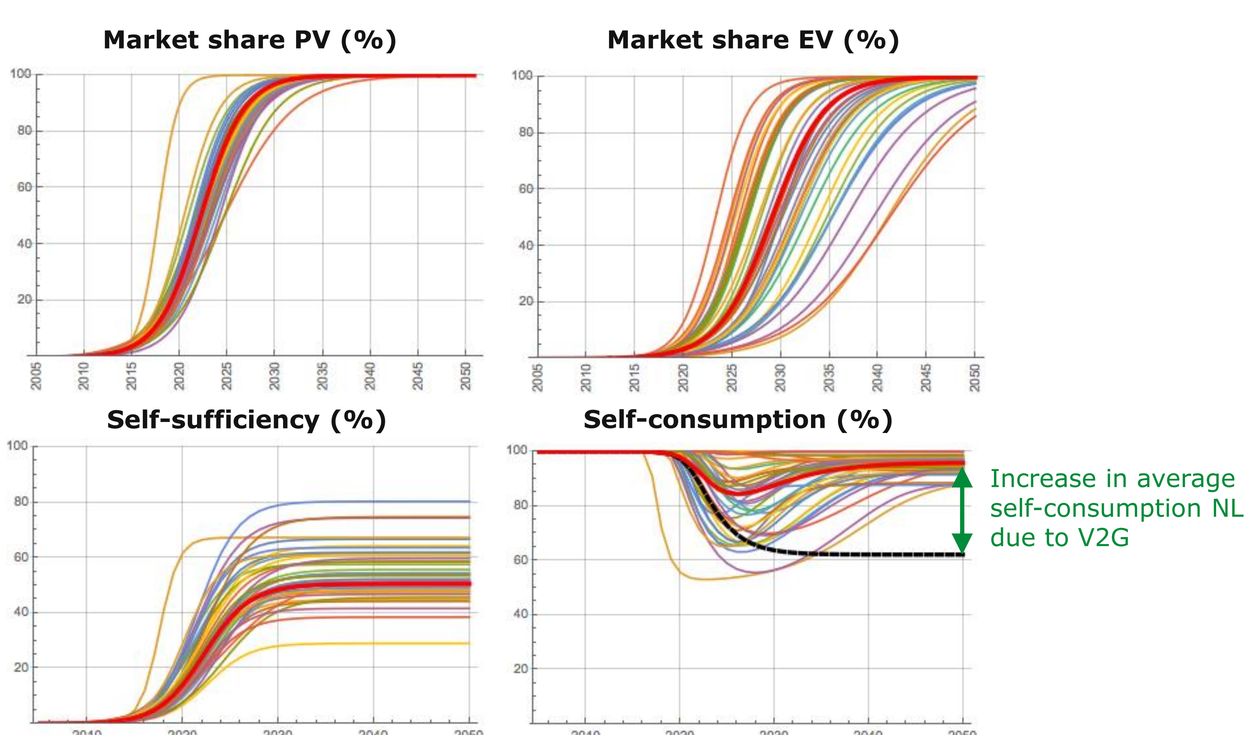


Figure 4 Model results. The thick red line represents the average value for the Netherlands, the thin coloured lines represent the different COROP areas and the dashed black line represents the average self-consumption of the Netherlands in case if no storage is used

- Total market saturation PV could be reached around 2035
- Total market saturation EV could be reached around 2045
- PV could cover 50% of total household demand
- V2G can increase self-consumption from 60% to 90%
- There are large differences between COROP areas
- Potential for V2G to increase self-consumption is lowest in 2020-2030

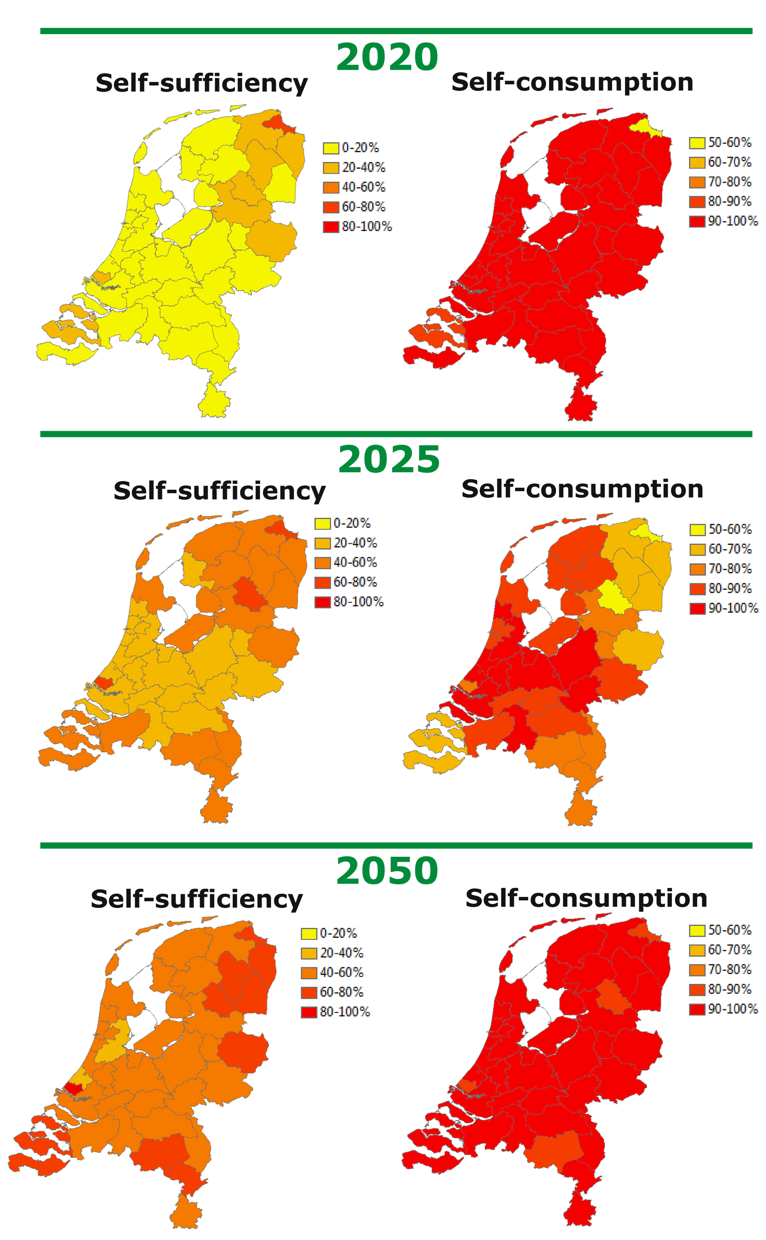


Figure 5 Maps of model results

Conclusions

- **Heterogeneity energy consumers expected to increase:**
  - Currently fast growth of PV and EV
  - Adoption levels of PV and EV show opposite spatial patterns
- **V2G systems can significantly contribute to increasing self-consumption, but:**
  - Self-sufficiency and self-consumption are expected to have a large variation between different areas
  - EV diffusion lags behind PV diffusion

- **We demonstrate the importance of taking user adoption into account in energy system modelling**

This study is part of the NWO URSES project SMARTER - Realizing the smart grid: aligning consumer behaviour with technological opportunities

http://www.nwo.nl/en/research-and-results/programmes/URSES+-+Uncertainty+Reduction+in+Smart+Energy+Systems/realizing+the+smart+grid