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Environmental self-identity as the basis for consumer behaviour in agent-based models of energy technologies

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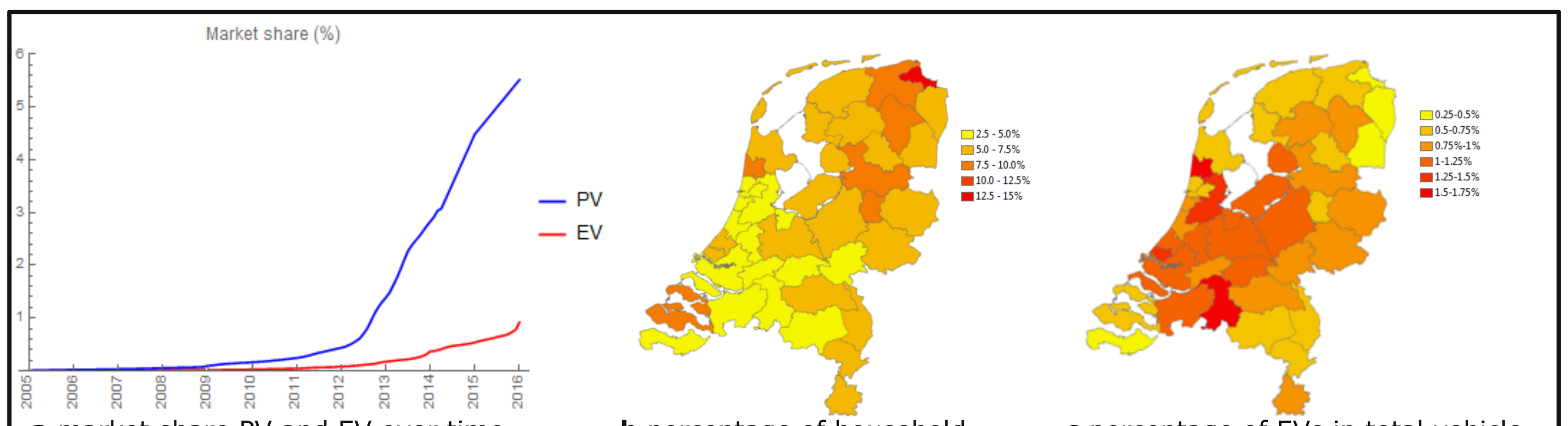
Because of recent trends in energy, such as the rise of photovoltaic (PV) solar panels and electric vehicles (EVs), it is more and more important to understand the increasingly diverse energy behaviours of consumers. Agent-based models (ABMs) are a suitable tool for building bottom-up, spatially explicit scenarios of consumers in energy systems. In ABMs agents can follow behavioural rules based on a thorough understanding of (psychological) factors underlying pro-environmental behaviour. Previous attempts to model consumers in ABMs do not capture the moral dimension of pro-environmental behaviour, which appears to be an important factor underlying pro-environmental actions. We model the adoption and use of PV and EVs in the Netherlands, using recent theoretical developments in environmental psychology.

Adopters of PV and EV in the Netherlands



a market share PV and EV over time **b** percentage of household rooftops with PV-installations **c** percentage of EVs in total vehicle fleet

Figure 1 Market share PV and EV in the Netherlands
Adoption levels of PV and EV are rising rapidly in the Netherlands; these technologies are not spread evenly over the country (Figure 1). With the rise of these technologies, the heterogeneity of consumers is expected to increase.

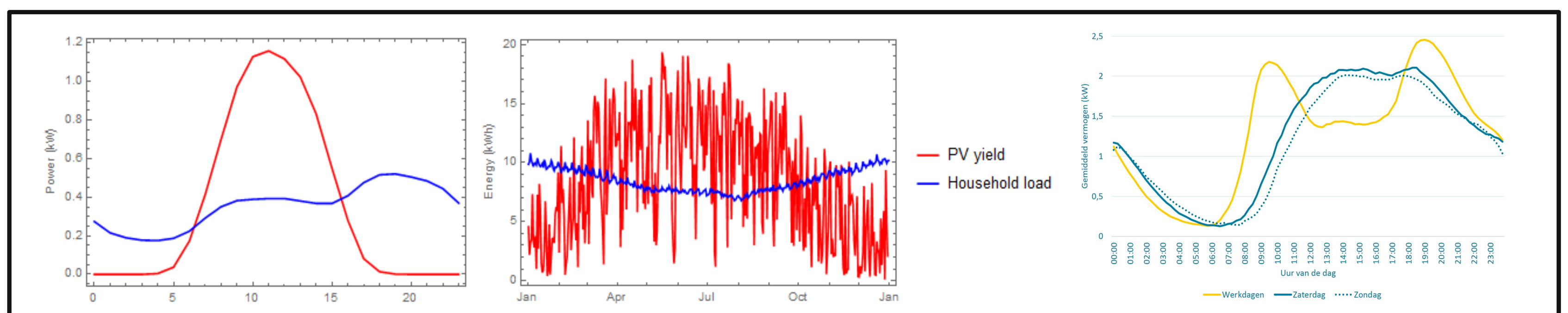
PV adopters and EV adopters have different characteristics. Table 1 presents results from a regression analysis of PV adopters and EV adopters at neighbourhood level.

Table 1 Differences between PV adopters and EV adopters
Signs indicate whether a variable is a positive or a negative predictor for PV/EV adopters

Variable	PV adopters	EV adopters
Address density	-	
Age 25-45	-	+
Age 45-65	+	-
Household income	-	
Household rooftops (per person)	+	
Family size	+	-
Education level	+	
Passenger vehicles (per person)		+
Public charging stations (per person)		+
Rooftop area (per person)	+	

Adoption ≠ smart use

To make the transition to a sustainable energy system, it is not sufficient to simply adopt clean energy technologies; they must also be used in a sustainable way. For instance, to achieve clean transport PHEV owners should predominantly use the electromotor. Furthermore, to deal with the intermittency of renewable energy sources solutions such as flexible demand or storage must be used.



a daily **b** annual **c** EV charging profile (source: e-laad)

Figure 2 Profiles for PV yield, household load and EV charging demand
Typical household demand is not in line with PV power supply, both on a daily and a yearly scale. EV charging can further increase peak demand

Visions of a sustainable future couple the widespread diffusion of electric vehicles to energy supply from renewable sources. In these visions, EVs act both as a source of demand and a storage option for excess renewable energy in vehicle-to-grid (V2G) systems. The adoption and use of renewable energy technologies and electric vehicles by consumers will determine the characteristics of the future electricity grid.

Environmental self-identity

When people adopt smart energy technologies for environmental reasons this will signal that one is a pro-environmental person, thereby strengthening environmental self-identity and promoting consistent sustainable energy behaviours. In contrast, when these technologies are adopted for other reasons than the environment (e.g. financial or technological) this behaviour will not signal that one is a pro-environmental person and therefore not strengthen environmental self-identity and subsequent sustainable energy behaviours.

Environmental self-identity:
- captures the moral dimension of pro-environmental behaviour
- links adoption of energy technologies to its use.

Table 2 Correlations between environmental self-identity and EV charging
The correlations are based on a survey set out among EV owners in the Netherlands (N = 245). The results show a relation between the environmental self-identity of EV adopters and their charging behaviour. EV adopters with a higher environmental self-identity are more likely to charge their EV with sustainable energy and to charge outside peak demand hours, thereby contributing to the integration of both EVs and renewable energy sources in the existing infrastructure.

	EV charging with sustainable energy	EV charging outside peak demand hours
Environmental self-identity	.40**	.20*

Note. **Correlation is significant at the .01 level; *Correlation is significant at the .05 level

Our model

In our model, the agents are households can decide to adopt PHEVs and/or PV. Agents with PHEVs commute, and have to decide to fuel their vehicle with gas or (green) electricity. Agents with high environmental self identity are more motivated the charge their vehicle with green electricity.

We base our consumer characteristics on regression analyses (Table 1) and a survey set out among EV owners (Table 2).

The goal of our model is to explore different scenarios for charging infrastructure, aiming at decreased peak demand and integration of renewables, accounting for consumer behaviour. Scenarios will be evaluated on impact on the environment and grid reliability

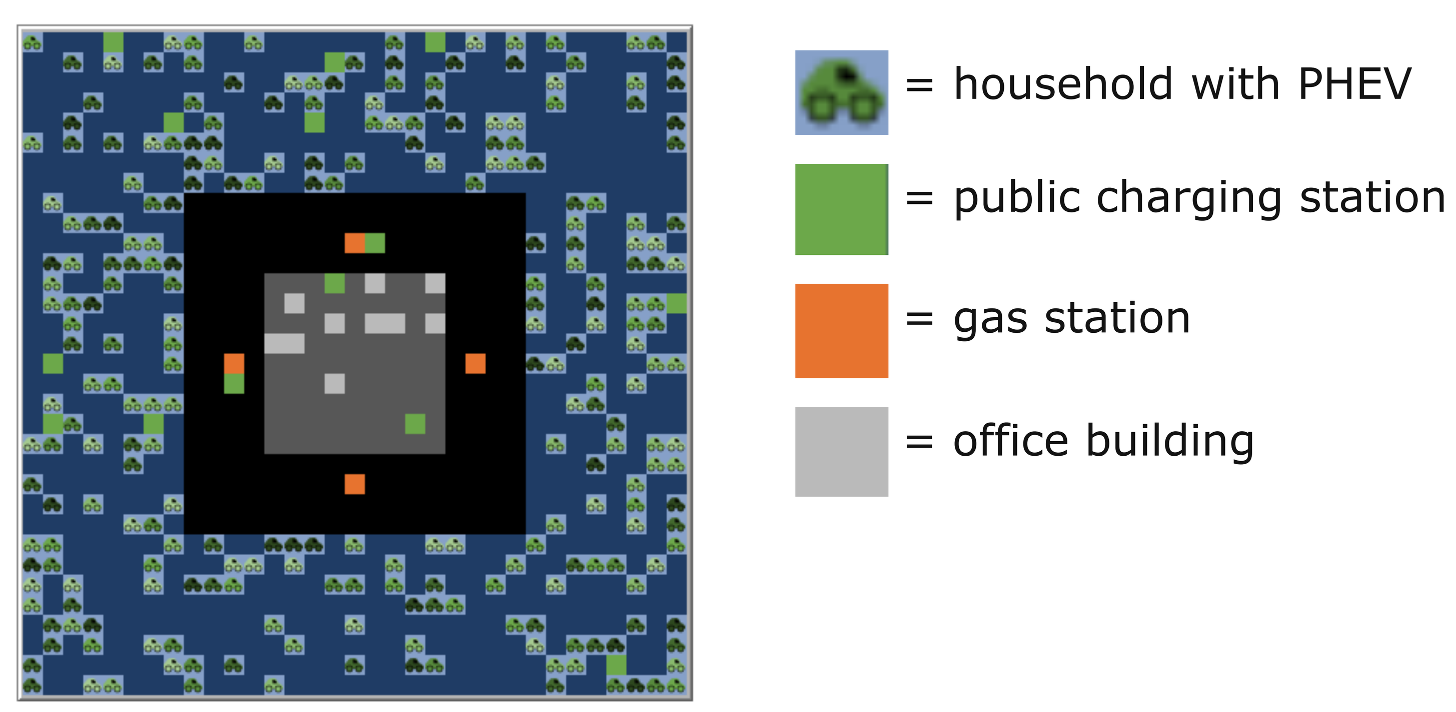


Figure 3 Setup of our proposed model in Netlogo

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