Universiteit Utrecht
Geosciences
Copernicus Institute of Sustainable Development
Energy & Resources

PV, EV and selfconsumption

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PV, EV, self consumption

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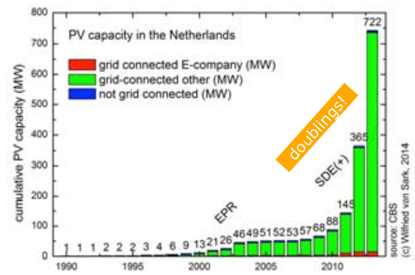
PV is booming in the Netherlands (finally)
Sept 2014: 1 Gigawatt



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PV systems are dispersed over the Netherlands

~200.000 systems

in built environment

Produktie Installatie Register (PIR)

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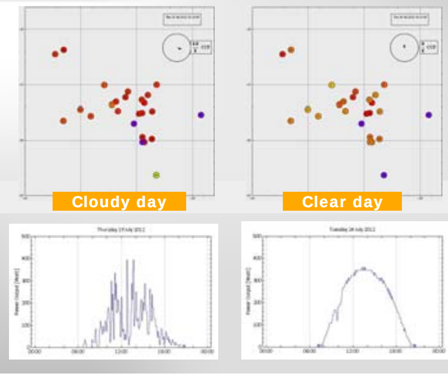
Variation in PV-generation (Utrecht)



[Elsinga, van Sark, 2012]

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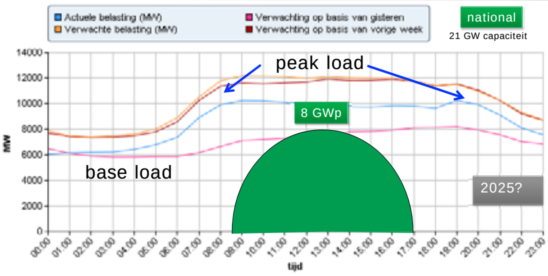
Not a problem now, but what if….



…and what if we also add multi GW wind?

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Smart energy management provides the solution

- Bidirectional power
- Potentially highly variable
- Demand developments?
  - Demand side management
  - Electrical mobility
  - Heat pumps (gas-free heating scenario)

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Demand of wet appliances, controllable?

- Analysis of household and appliances demand data for houses including 3 kWp PV
- Wet appliances: washing machine, dish washer, tumble dryer
- Analysis of possible power
  - shifts effects on peak
  - power effects on average
  - power
  - effects on self consumption of PV

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Demand of wet appliances, controllable?

- Preliminary results:
- Effects only limited

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Pilot Lombok: E-car4all en Storage4all

Objective
Develop and evaluate algorithms for a smart grid system that can **increase self-consumption** of PV-power by storing electricity in EVs in the residential sector while **meeting the demands** posed by the use of the **EVs**

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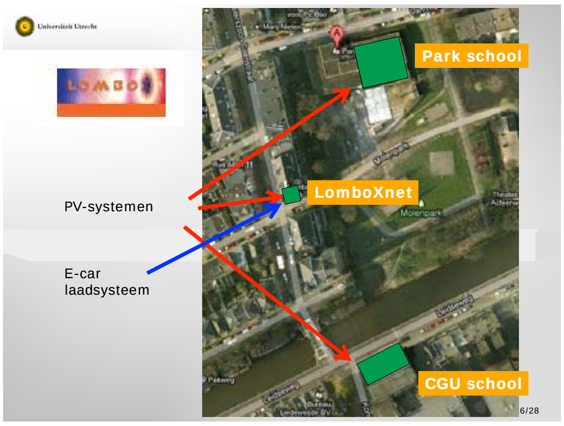
PV-systemen

E-car laadsysteem



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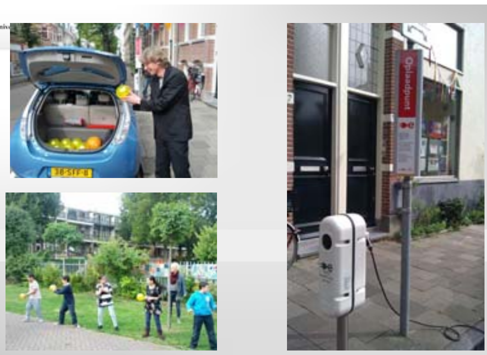

Smart solar charging in Lombok: E-car4all en Storage4all

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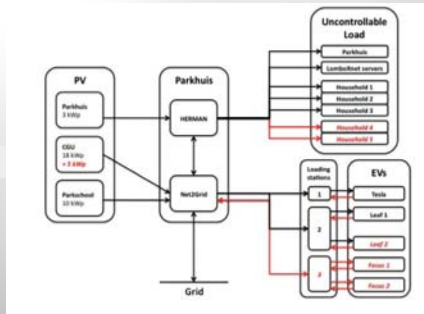
modeling EV-charging systems



[Van der Kam, 2014]

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Strategies EV-charging

- Uncontrolled charging: plug&charge
- Controlled charging
- Controlled charging and discharging
- Linear optimization
  (Dis-)charging profile established through mathematical optimisation
  Predictions for PV and demand necessary
  Evaluation with and without perfect information
  (ideal vs. realistic)

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Baseline:
Uncontrolled charging

- **No smart grid or storage**

$$P_{EV,in}(t) = \begin{cases} P_{EV,in,max} & \text{if} \quad E_{EV}(t-1) < C_{EV} \text{ and } t \in t_{EV,I} \\ 0 & \text{else} \end{cases}$$

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Real-time controlled charging

Charging when PV-power is available including override function

$$P_{EV,in,PV}(t)=\begin{cases}\eta_{EV,in}\left(P_{PV}(t)-P_{load}(t)\right) & \text{if } P_{load}(t)<P_{PV}(t) \text{ and } E_{EV}(t-1)<C_{EV} \text{ and } t\in t_{EV,I}\\ 0 & \text{else}\end{cases}$$

$$P_{EV,grid}(t)=\begin{cases}E_{EV,req}(t)-E_{EV}(t-1)-P_{EV,in,PV}(t) & \text{if } E_{EV}(t-1)+P_{EV,in,PV}(t)<E_{EV,req} \text{ and } t\in t_{EV,I}\\ 0 & \text{else}\end{cases}$$

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Linear programming

(Dis-)charging profile established through mathematical optimisation

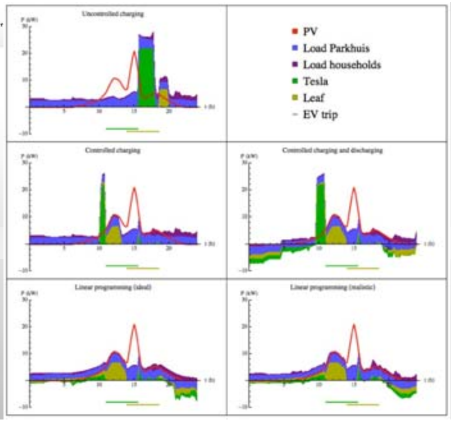
Predictions for PV and demand necessary

Evaluation with and without perfect information (ideal vs. realistic)

Objective function: $\sum_t P_{EV,in,PV}(t)$

Constraints:

- Maximum (dis-)charging power
- Minimum/maximum energy in EV
- No more energy (dis-)charged than shortage/excess PV-power



Van der Kam, 2013

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Performance indicators

Self-consumption:

$$SC(T)=\sum_{t=T0}^{T}\frac{\min\left[P_{PV}(t),P_{load}(t)+P_{EV}(t)\right]}{P_{PV}(t)}$$

Relative peak reduction (RPR)

$$RPR(T)=\frac{\sum_{t=T0}^{T}\left|P_{grid,tot,control}(t)-\overline{P_{grid,tot,control}(t)}\right|}{\sum_{t=T0}^{T}\left|P_{grid,tot,no\,control}(t)-\overline{P_{grid,tot,no\,control}(t)}\right|}$$

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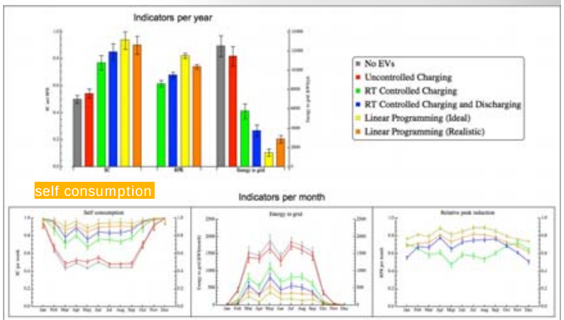

Van der Kam, 2013

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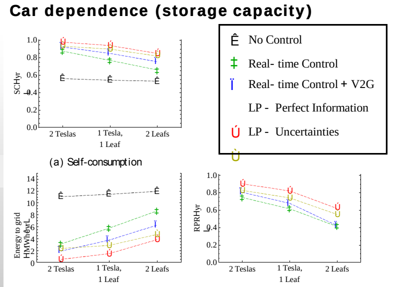
Car dependence (storage capacity)



(a) Self-consumption

(b) Energy to grid

(c) Relative peak reduction

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Conclusions

- Smart grid control algorithms developed for managing the (dis)charging profile of multiple EVs, either in real-time or using linear optimization with predictions for PV-power and electricity demand
- Results show that smart storage of electricity in EVs can increase self-consumption with 23% to 38%, reduce energy sent to the main grid with 3 to 9 MWh per year and reduce peaks with 27% to 67%

NOW: time for experimental data!

- Demand side management options limited
- Are EVs are needed to make DSM a success?!

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