IBM **SmartGrid** Vision and Projects

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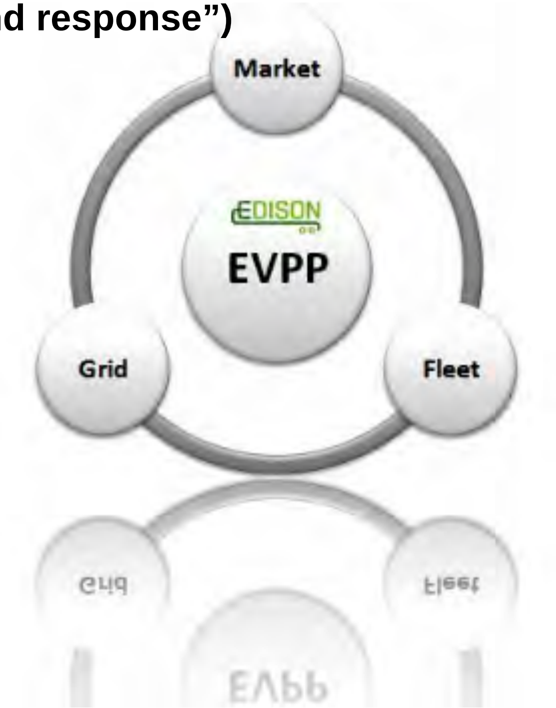
SmartGrid Vision: IBM Virtual Power Plant (VPP) will revolutionize how electricity is produced and consumed, benefiting all parties.

Variable production ("green") = storage + flexible consumption ("demand response")

- The driver's costs are minimized while providing maximum convenience.
- Generation and distribution of electricity is more even since large peaks in consumption are avoided.
- The availability of green energy can be balanced with flexible consumption.



Source: http://www.flickr.com/photos/ibm_research_zurich/4882647022/in/set-72157622238483748/

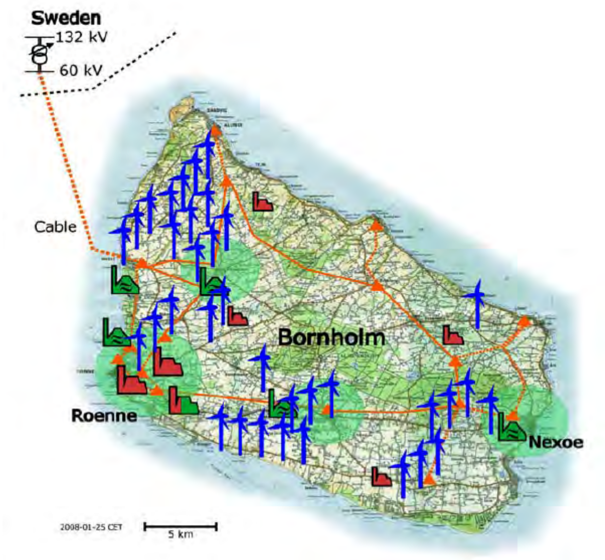
Electric vehicles in a distributed and integrated market using sustainable energy and open networks

EDISON *Symbiosis of Electrovehicles and Grid*

"V2G refers to adding the capability to deliver power from the vehicle to the grid, but "V2G" is also used to imply that power flow, whether to or from the vehicle, is controlled in part by needs of the electric system, via a real-time signal." *[Lund, Kempton, 2008]*

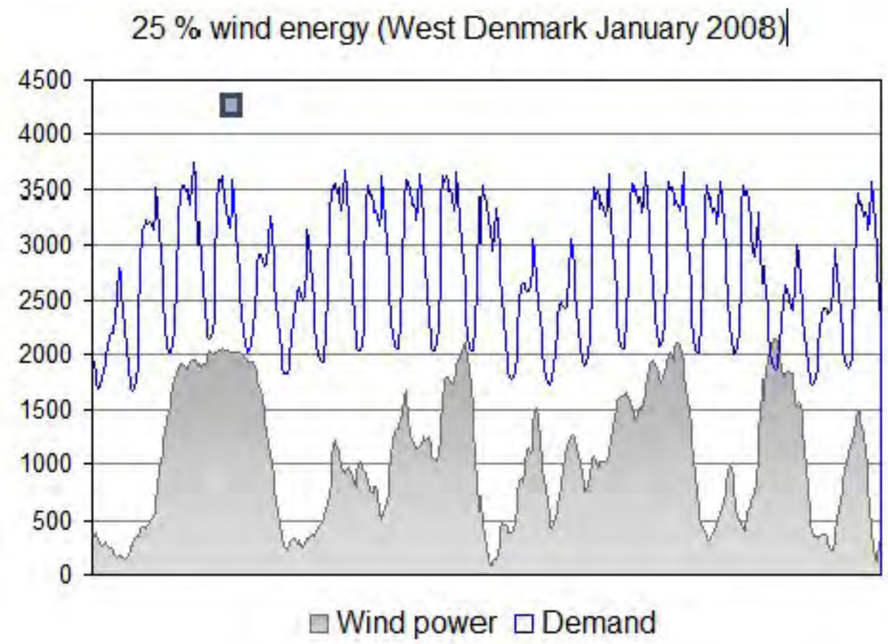
EDISON — Electric vehicles in a distributed and integrated market using sustainable energy and open network

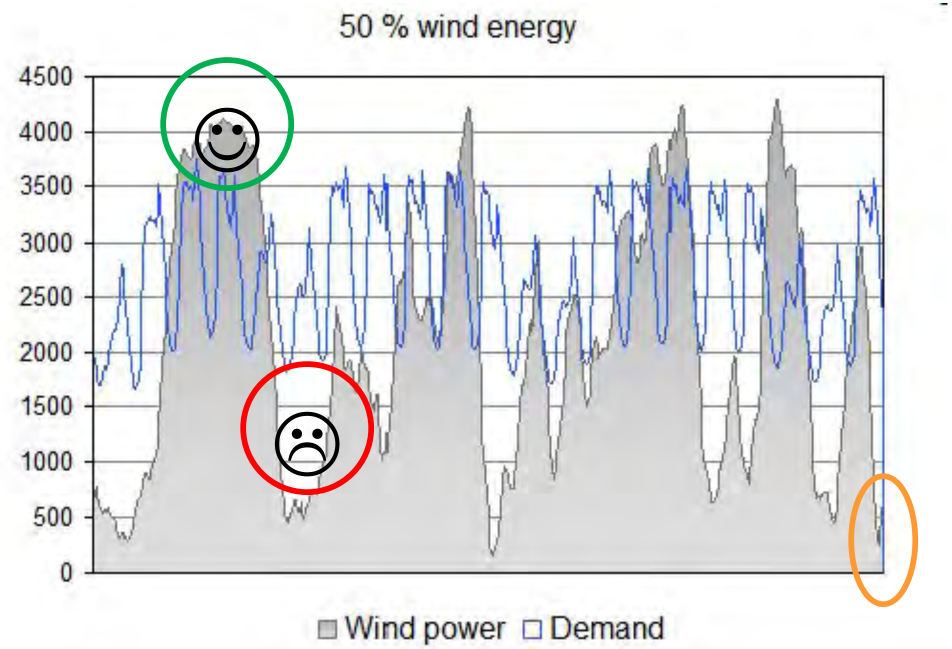
- **Business problem**: Design of an energy system for an entire country that will support a large proportion of EVs, plugged into an electric grid, in private homes or at charging stations in company and public parking lots.
- **Challenge:** How to maintain security of supply in an electric grid that incorporates a high percentage of green, but **fluctuating wind energy** and also has a **significant number of mobile EVs**, which represent both a challenge and huge storage/regulation potential.
- **Solution Approach**: Development of management system to control charging of cars in accordance with the availability of wind energy while enabling **optimal use of the electricity grid**. Develop simulation and prediction technologies.
- **IBM Research's Role:** Develop a simulation environment to understand dynamics of EVs in the grid. Design and implement **EVPP** for server side control when charging EVs and using EVs as storage.



danskenergi IBM EURISCO RESEARCH & DEVELOPMENT SIEMENS DONG energy ØSTKRAFT energi til gode oplevelser DTU

The impact of “more wind” on the grid



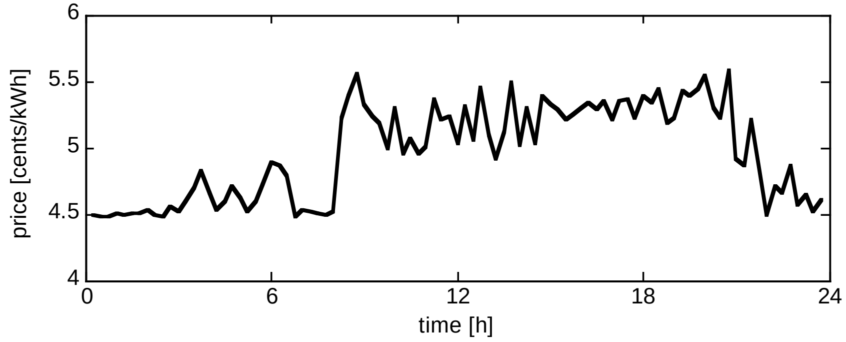


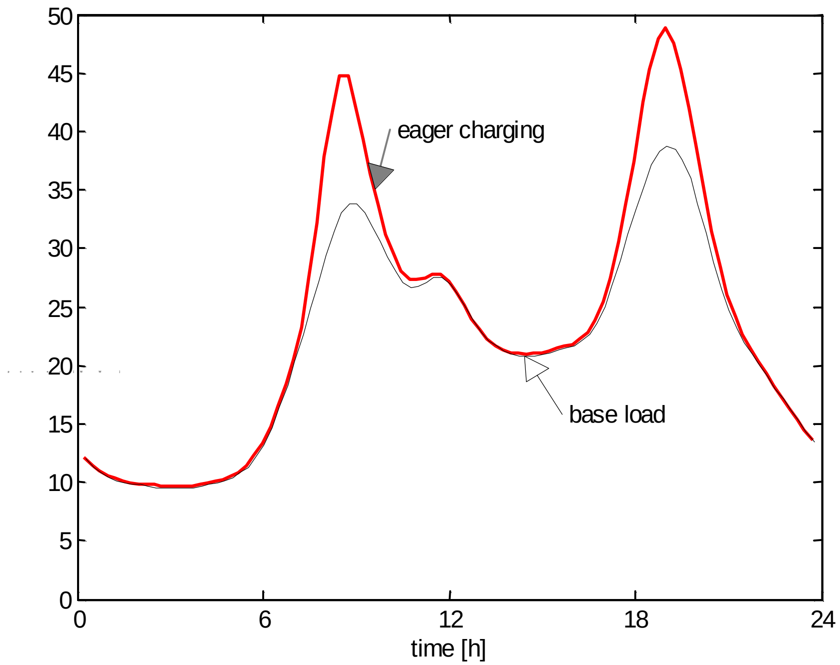
- Buffering **wind energy** avoids having to potentially use **fossil fuel** later → G2V
- And just imagine what happens without storage if the wind **stops** → V2G

Source: Oestergaard, et.al., 2009.

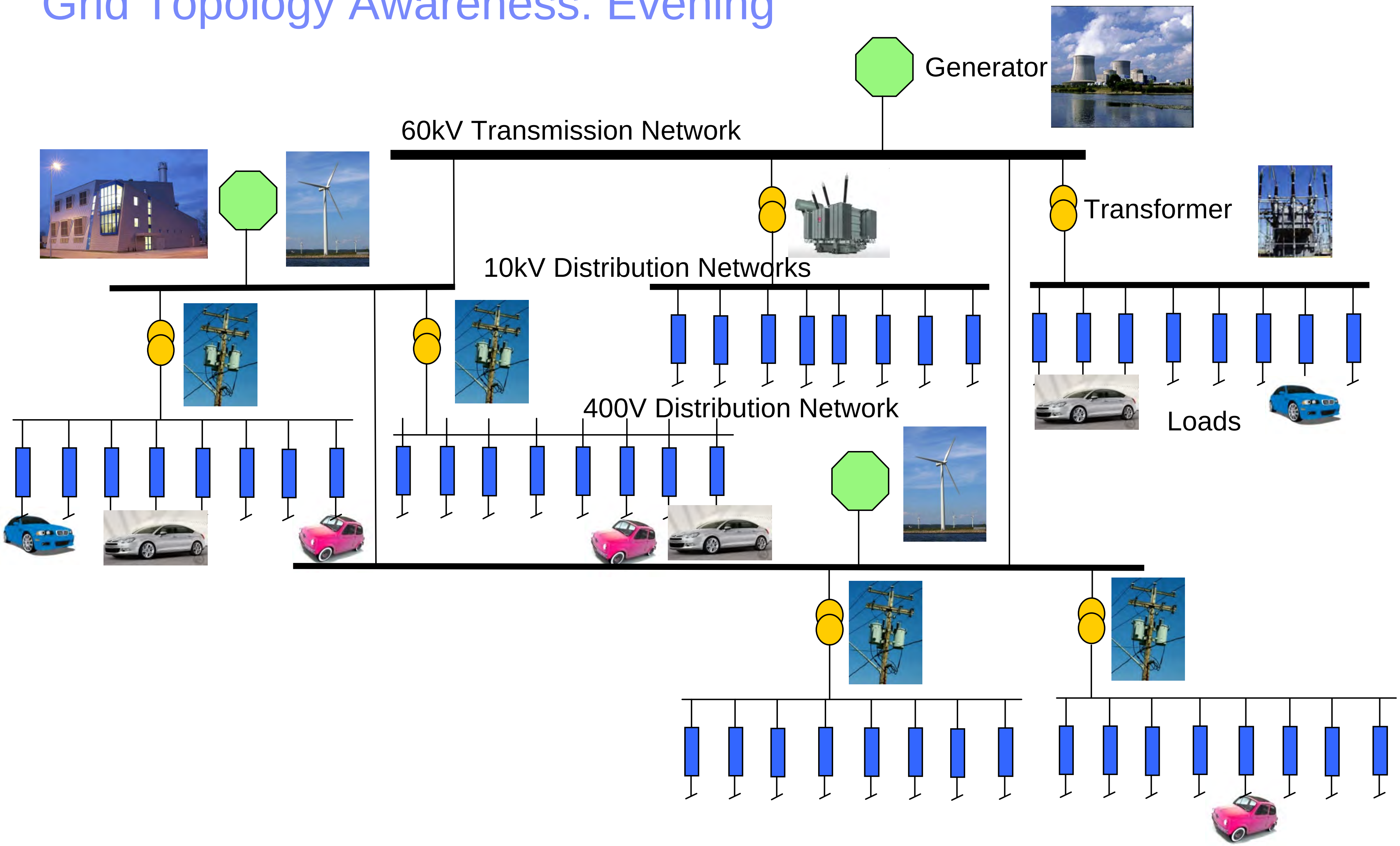
The impact of electric vehicles (EVs) on the grid

- 3'500 commuters / 12'000 400V outlets / 16 kW maximum charging
- Price of electric energy
  - Synthetic but negatively correlated to available wind power
- Eager charging, i.e., charging the EV full when connecting to grid

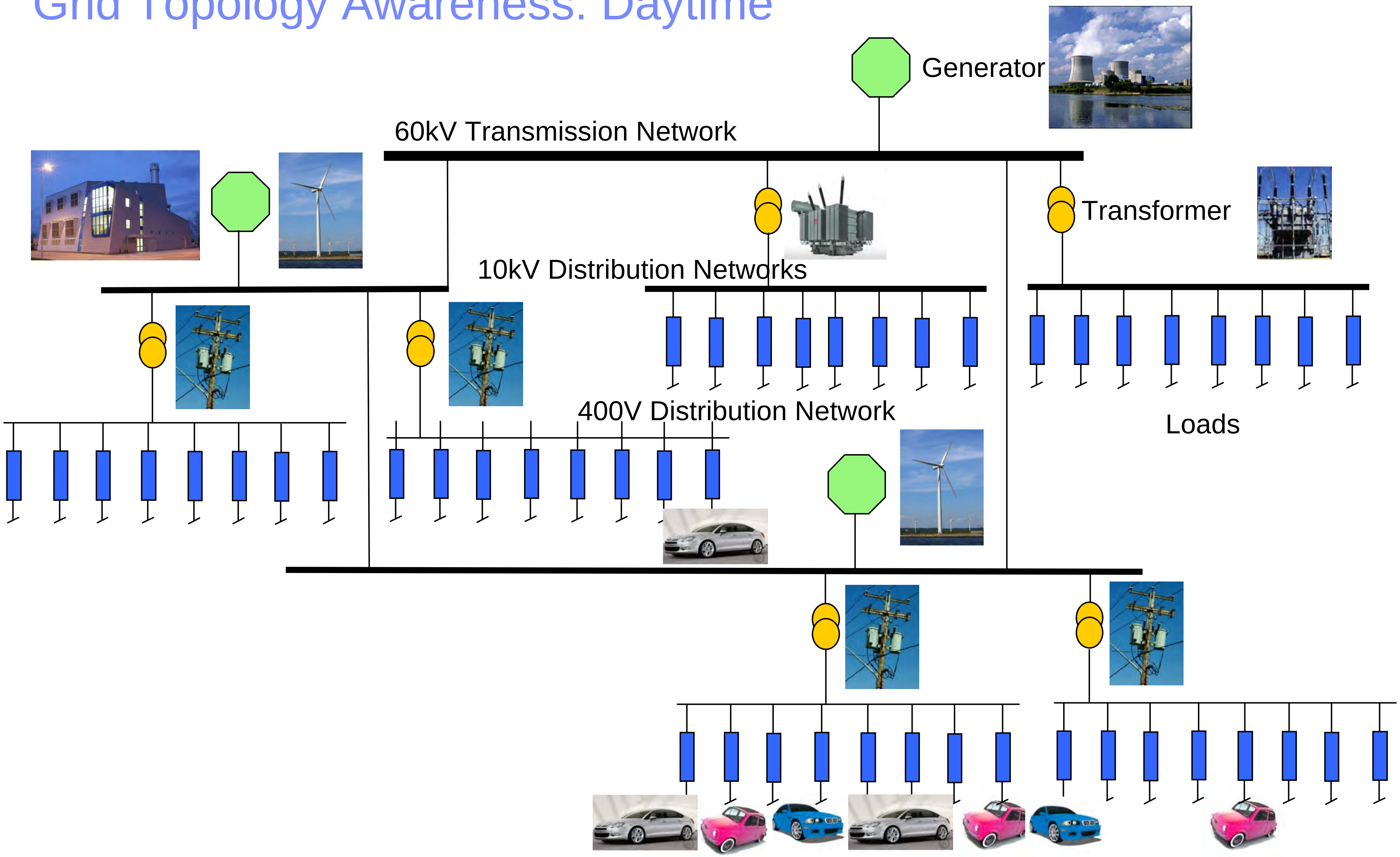




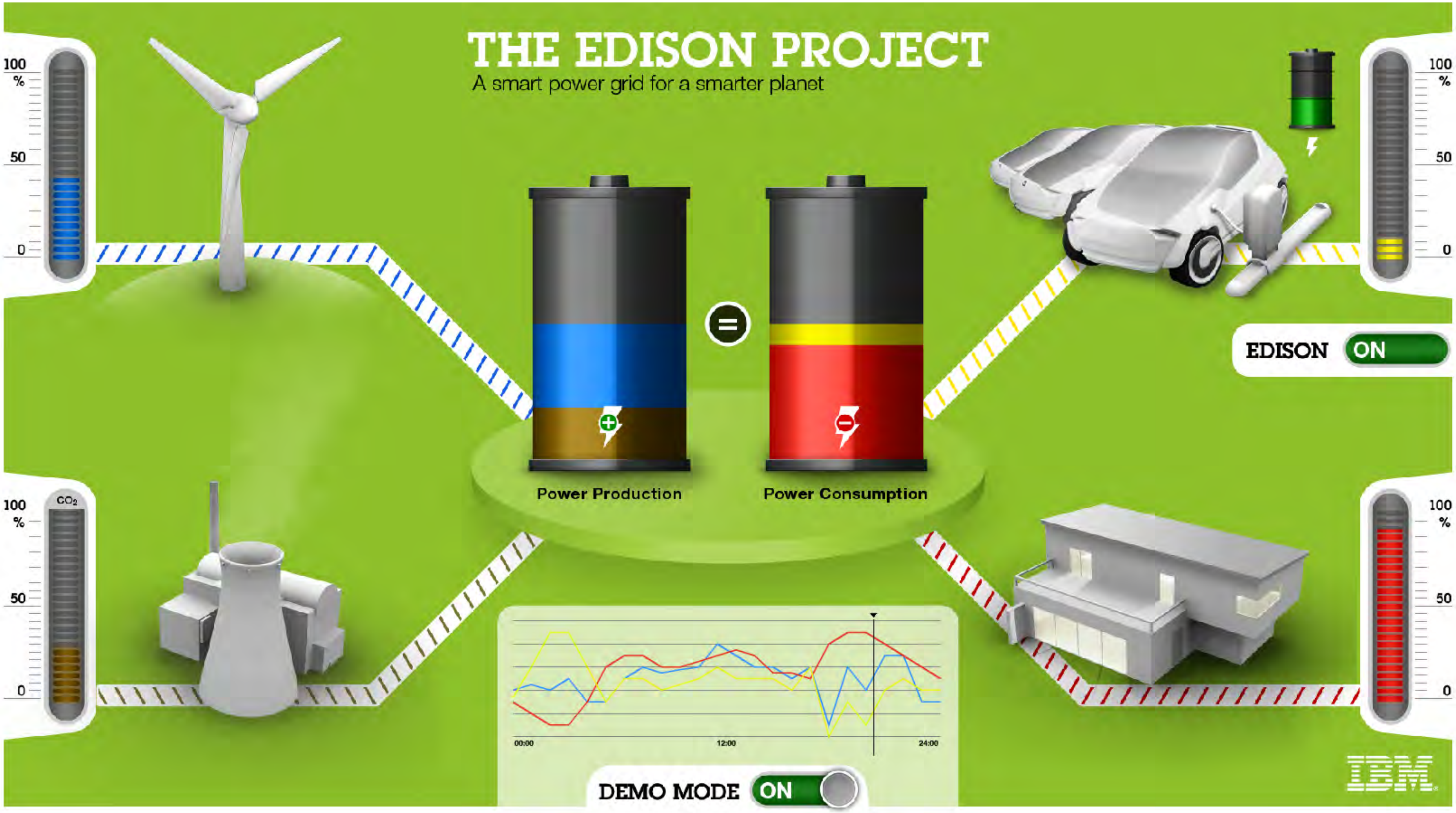
Grid Topology Awareness: Evening



Grid Topology Awareness: Daytime

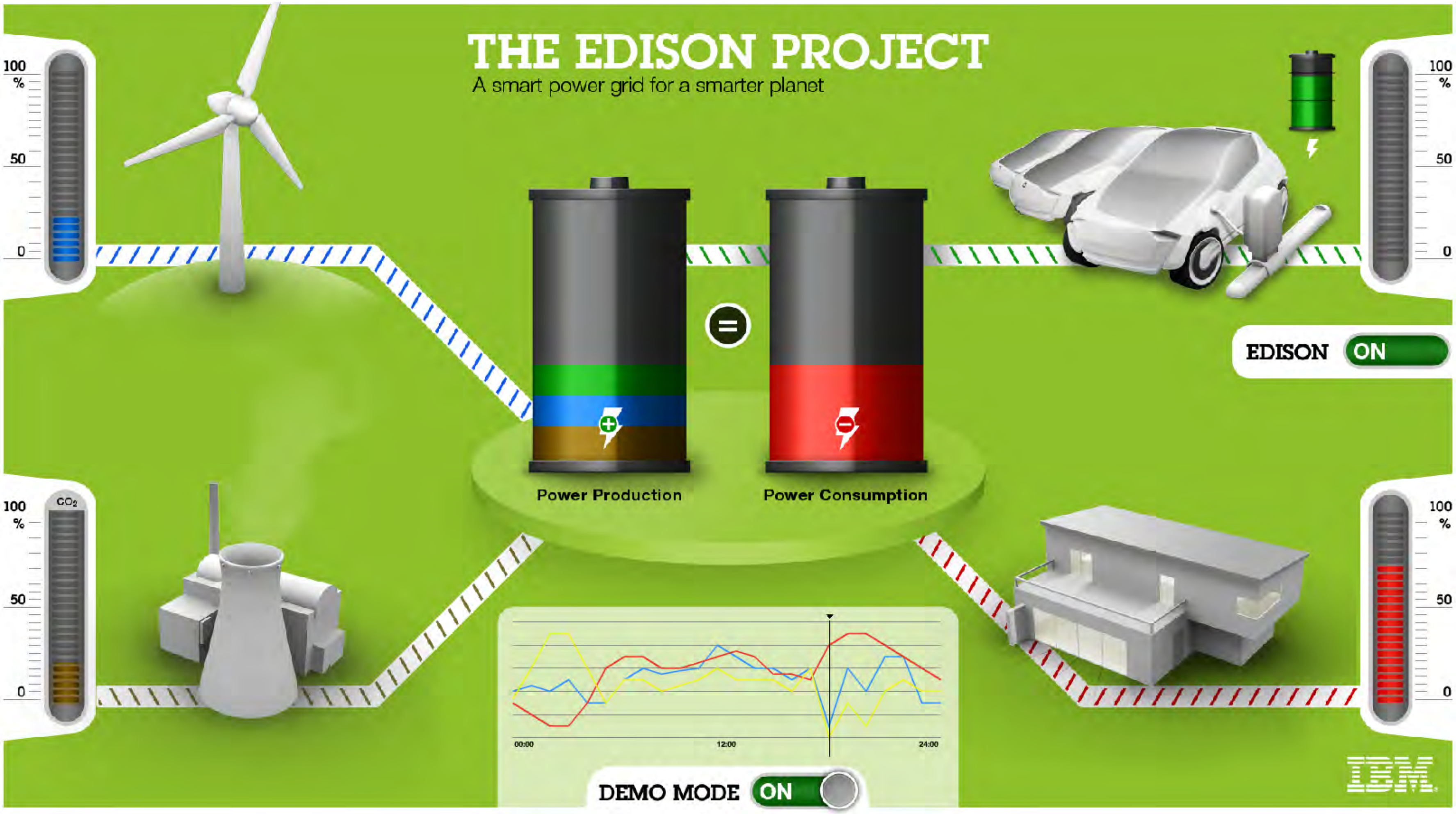


Scenario 1: Green energy-driven smart charging of electric vehicles



Source: https://vpp1.edison-net.dk/DemoDay.2010

Scenario 2: Full V2G to help with power balance and local quality



Source: https://vpp1.edison-net.dk/DemoDay.2010

Vehicle owner's annual net profit from V2G is highest for RS while minimizing battery wear out

Quicker response required

"RS"

	Peak power	Spinning reserves	Regulation services
Battery, full function	$267 (510-243)	$720 (775-55)	$3,162 (4479-1317)
Battery, city car	$75 (230-155)	$311 (349-38)	$2,573 (4479-1906)
Fuel cell, on board H_2	$-50(loss) to $1,226 (2200 - 974 to 2250)	$2,430 to $2,685 (3342 - 657 to 912)	$-2,984 (loss) to $811 (2567 - 1756 to 5551)
Hybrid, gasoline	$322 (1500-1178)	$1,581 (2279-698)	$-759(loss) (2567-3326)

Source: Kempton, et.al., 2001

Optimal operating point for V2G:

- **Short-term power** worth more. And better to provide out of batteries than sustained energy
- **Depth** of battery discharge (DoD). The 3% cycle achieves 10 times the lifetime kWh throughput

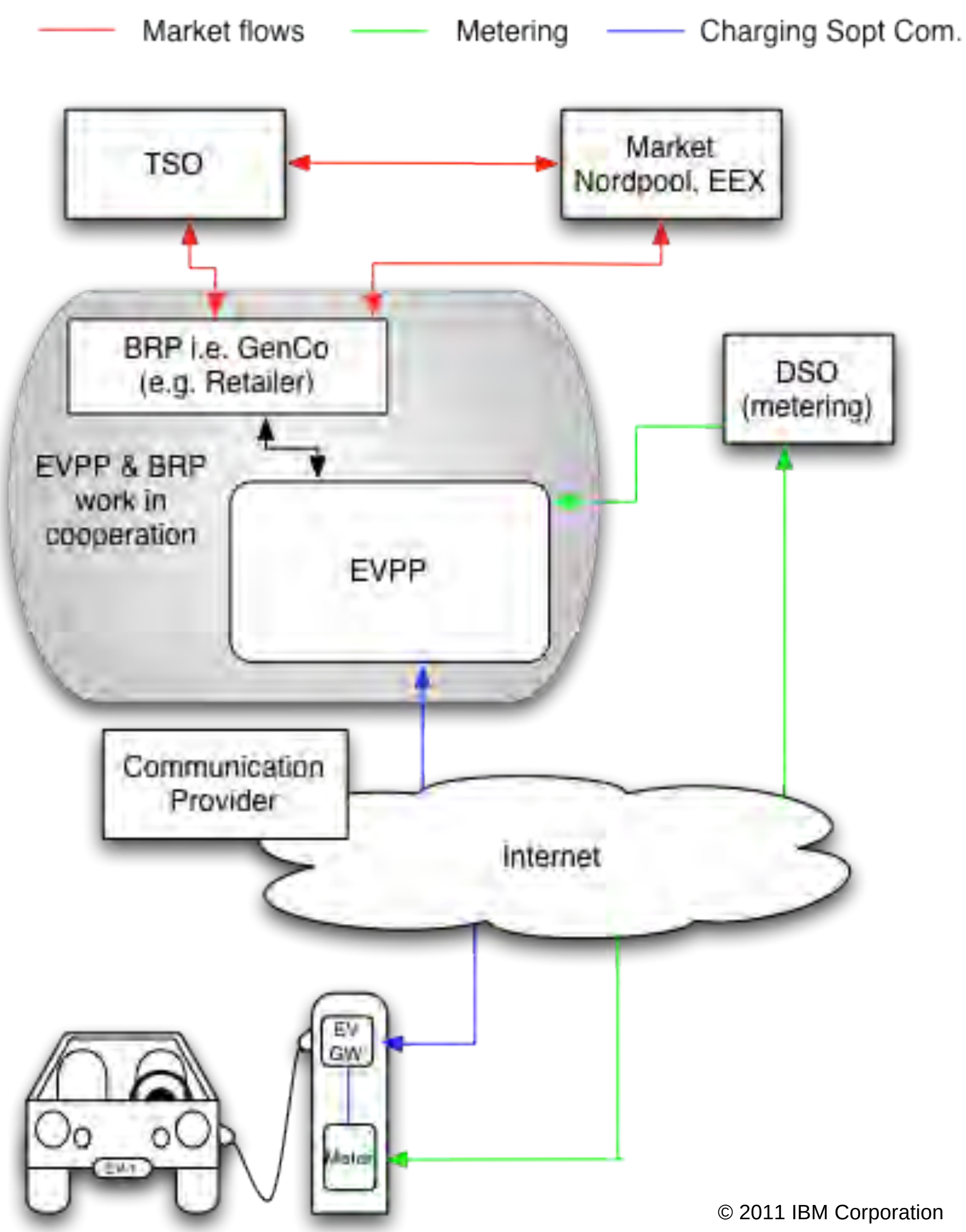
Regulation Power in Switzerland…

Planning Electric-Drive Vehicle Charging under Constrained Grid Conditions

Dr. Olle Sundström and Dr. Carl Binding
IBM Zurich Research Lab, Switzerland

EDISON Virtual Power Plant

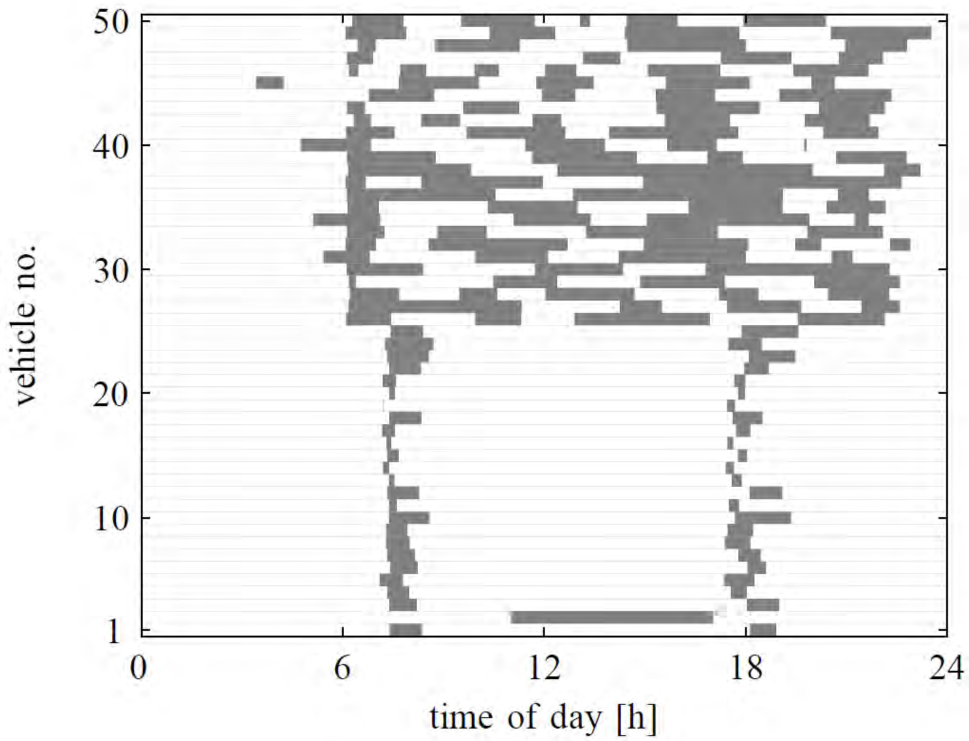
- centralized planning
- aggregates vehicles to act on the energy markets
- creates charging plans for all subscribed vehicles based on
  - trip forecasts (simulation)
  - battery SOC & SOH
  - grid state (DSO input)
  - energy availability & price
  - ancillary services requests
- handles roaming
- handles accounting
- Alternative formulations depending on OF, lead to quadratic or linear models



TSO: Transmission Service Operator
DSO: Distribution Service Operator
SOC: State of Charge
SOH: State of Health
BRP: Balance Responsible Party

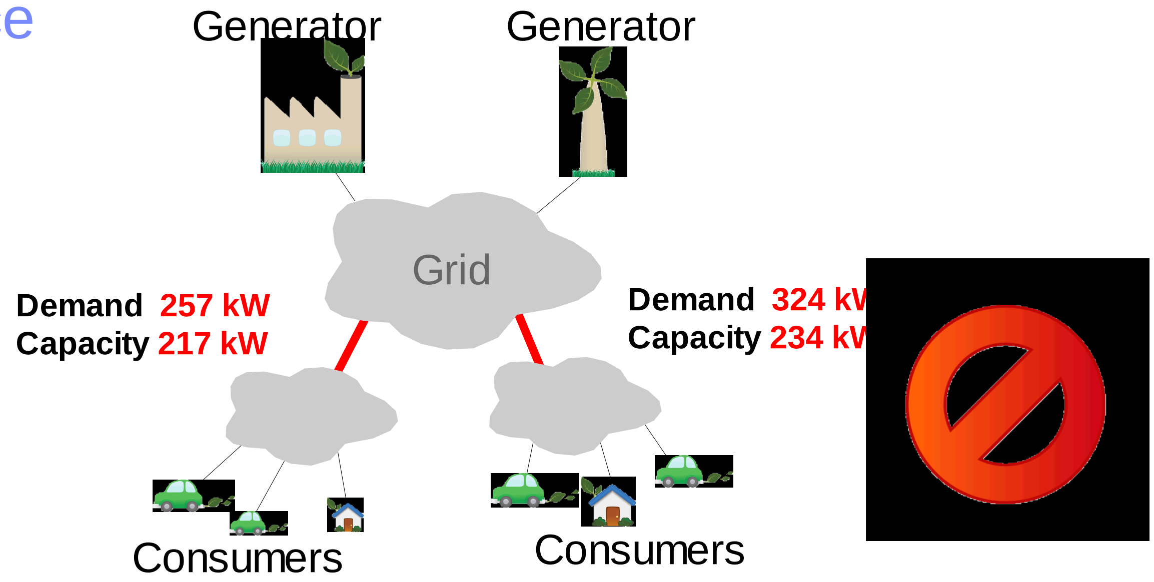
Prediction of Electric Vehicle Trips and Energy Needs

- Collected data
  - Time-of-departure, Time-of-arrival
  - State-of-charge at time-of-departure and at time-of-arrival
  - Location at time-of-arrival
- Future trips are predicted
  - Clustering of historical trip data for different types of EVs, day of the week, etc.
    - Commuter cars
    - Taxis
    - Family cars
- Predicted values
  - Time-of-departure
  - Time-of-arrival
  - Energy need for each trip
  - Location (to handle grid constraints)

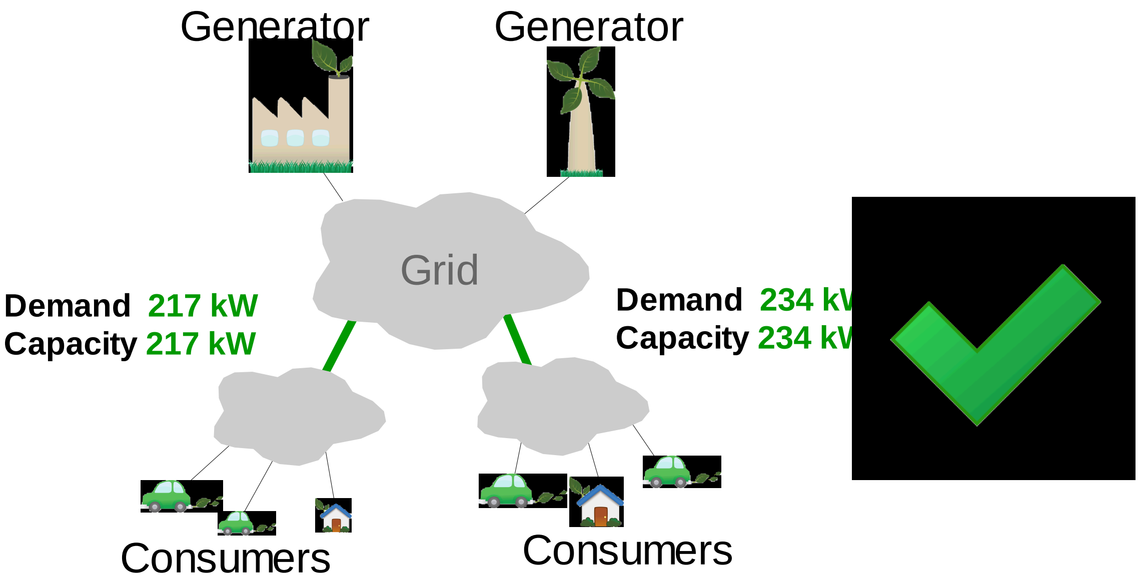


Grid Congestion Avoidance

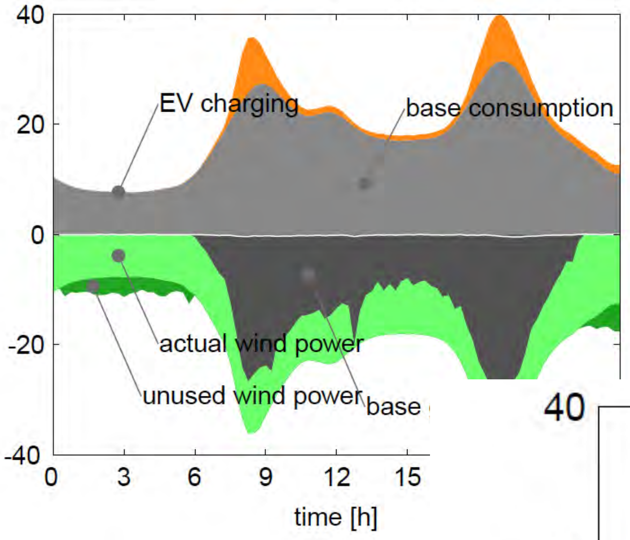
- Grid capacity is limited
  - Distribution lines
  - Transformers
- Enormous costs of replacing infrastructure
- What if many EVs aggregate in "hot-spots"? Can the grid cope with the load?

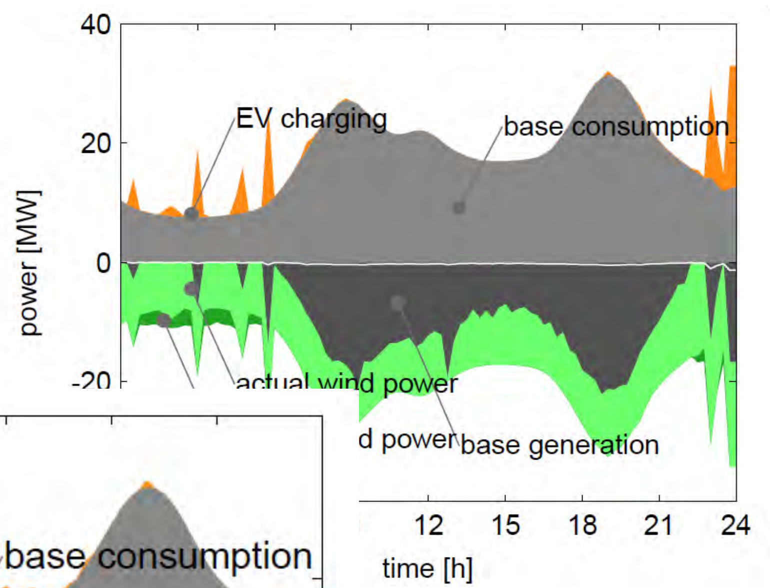


- Method based on iteratively solving a maximum flow problem
  - A fast maximum flow implementation is essential
  - Generating a new set of constraints to include in the basic charging schedule optimization

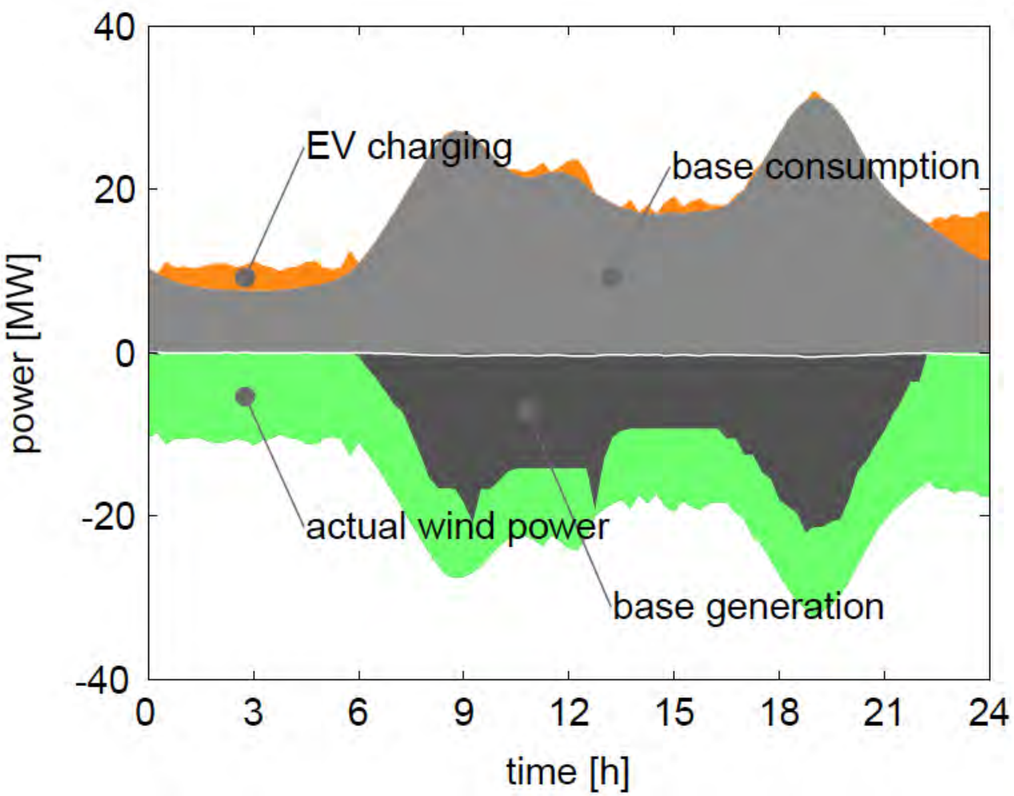


Optimal smart-charging by communication between grid and consumer



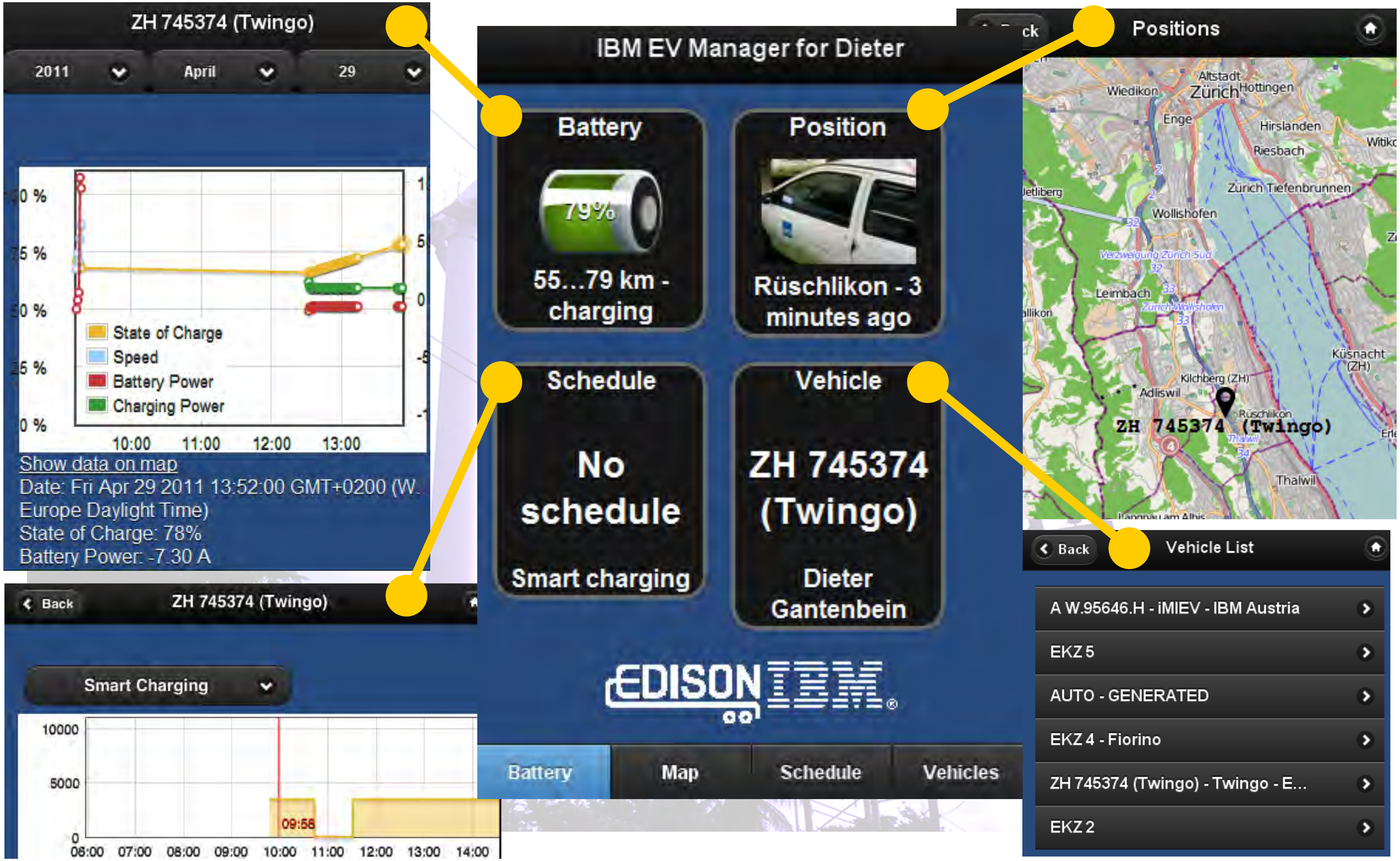


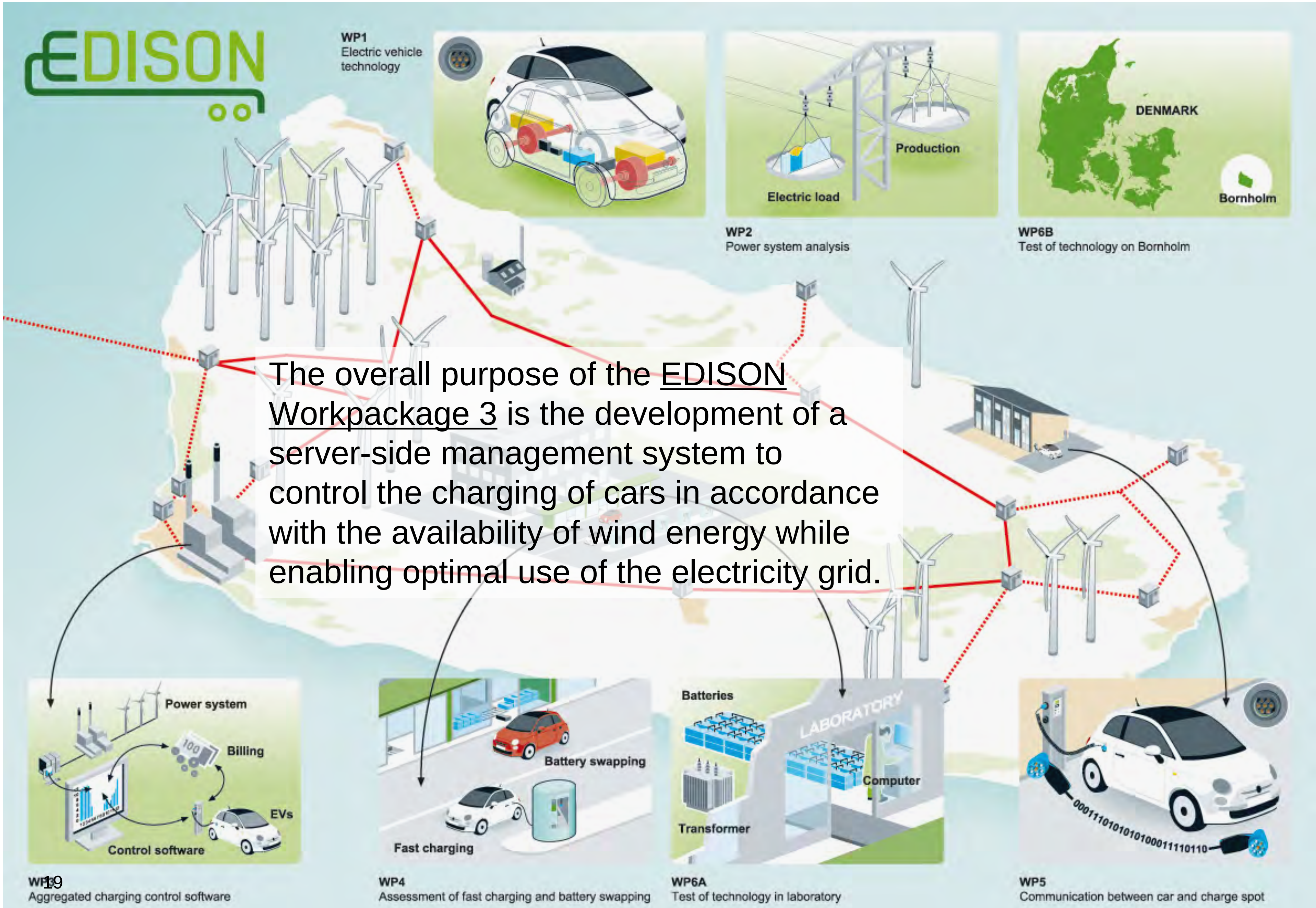
With constant power prices charging is immediate and peaks increase. Required grid enforcement.



Dynamic prices provide good economies but not yet stability.

Virtual Power Plant: User Control



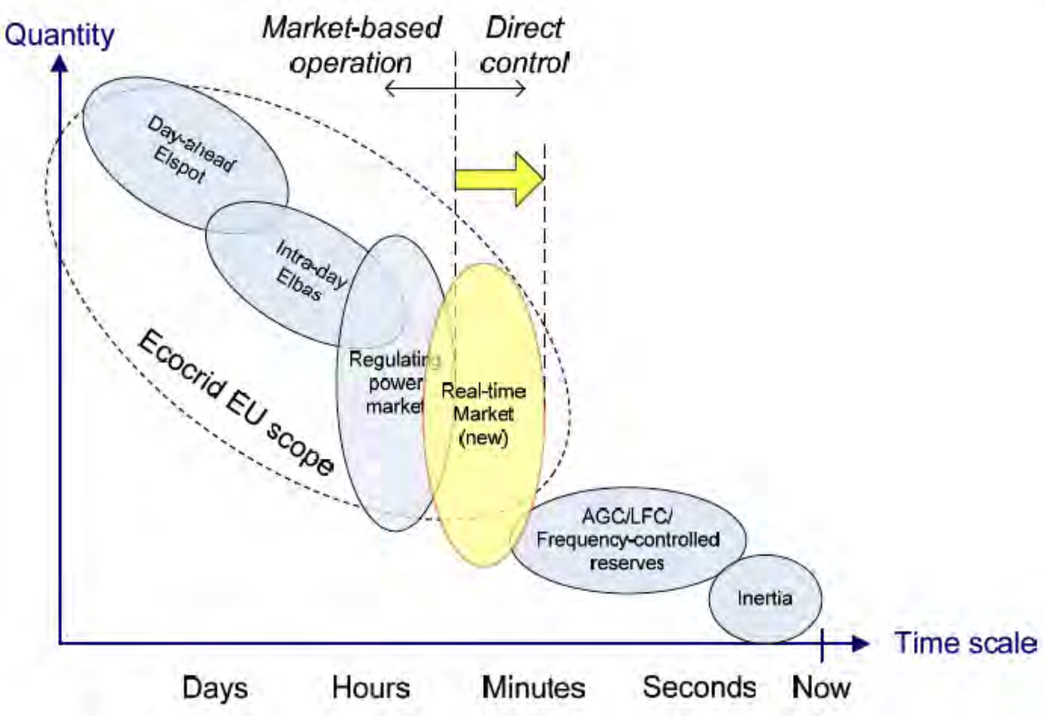


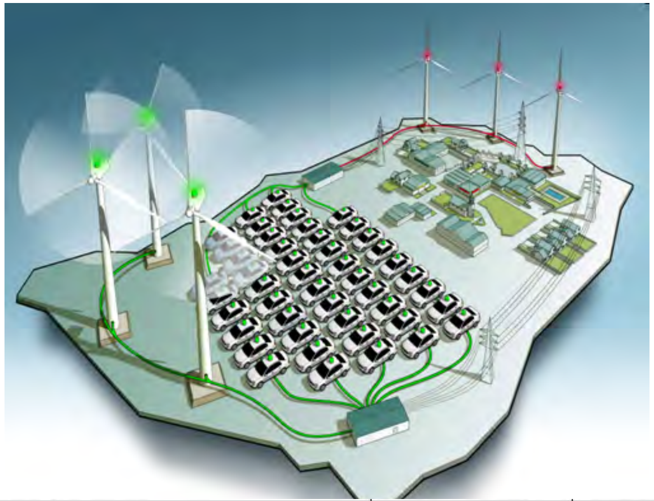
The overall purpose of the EDISON Workpackage 3 is the development of a server-side management system to control the charging of cars in accordance with the availability of wind energy while enabling optimal use of the electricity grid.

EcoGrid eu

www.eu-ecogrid.net

March 2011 to 2014
Final Negotiations in progress





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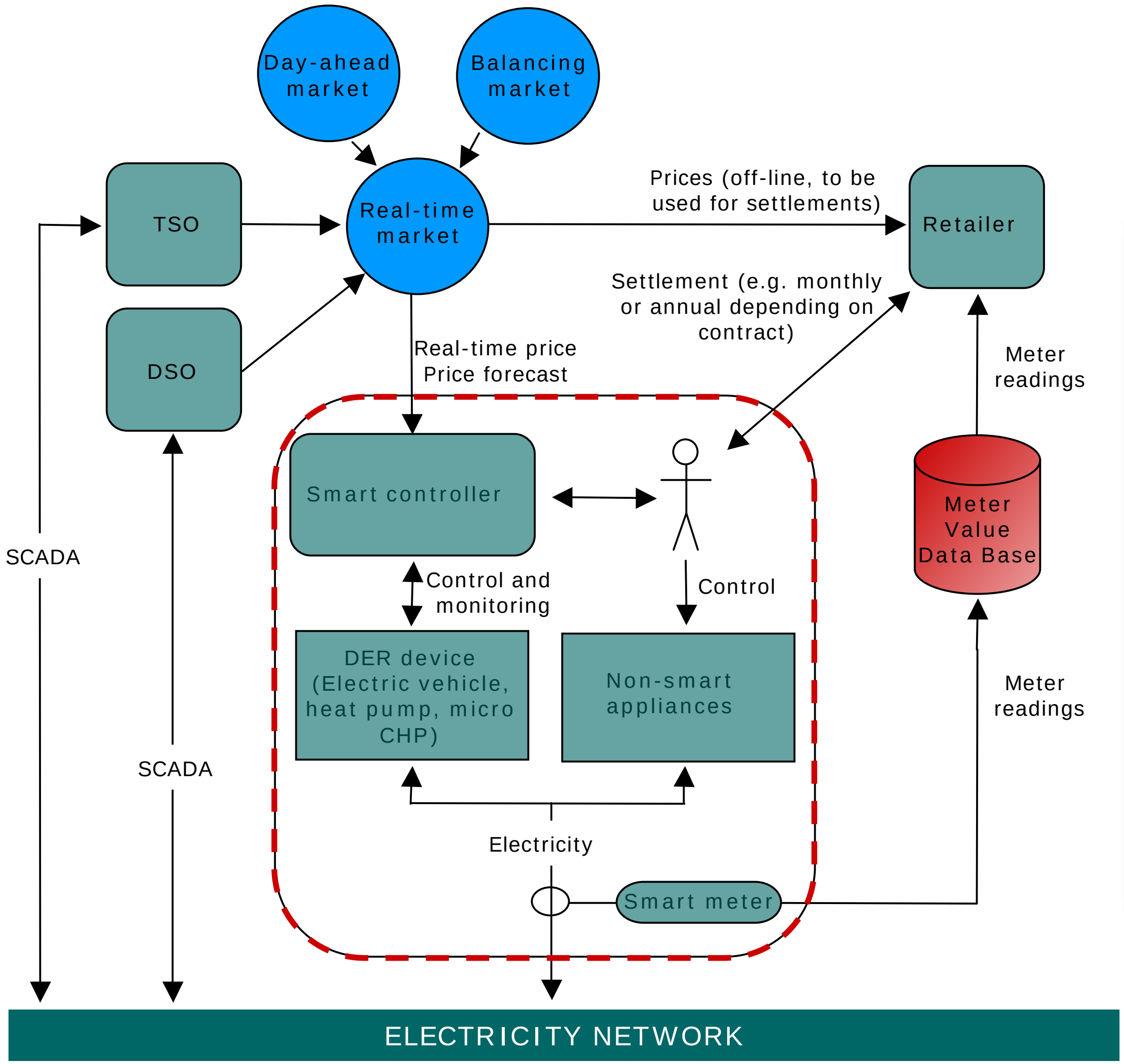
Stichting Energieonderzoek Centrum Nederland	ECN	Netherlands
Eandis cvba	EANDIS	Belgium
Tallinna Tehnikaülikool	TUT	Estonia
Operateur De Reseaux D'energies	ORES	Belgium

Large scale Smart Grid demonstration of real time market-based integration of Direct Energy Resource (DER)

The EcoGrid EU Architecture

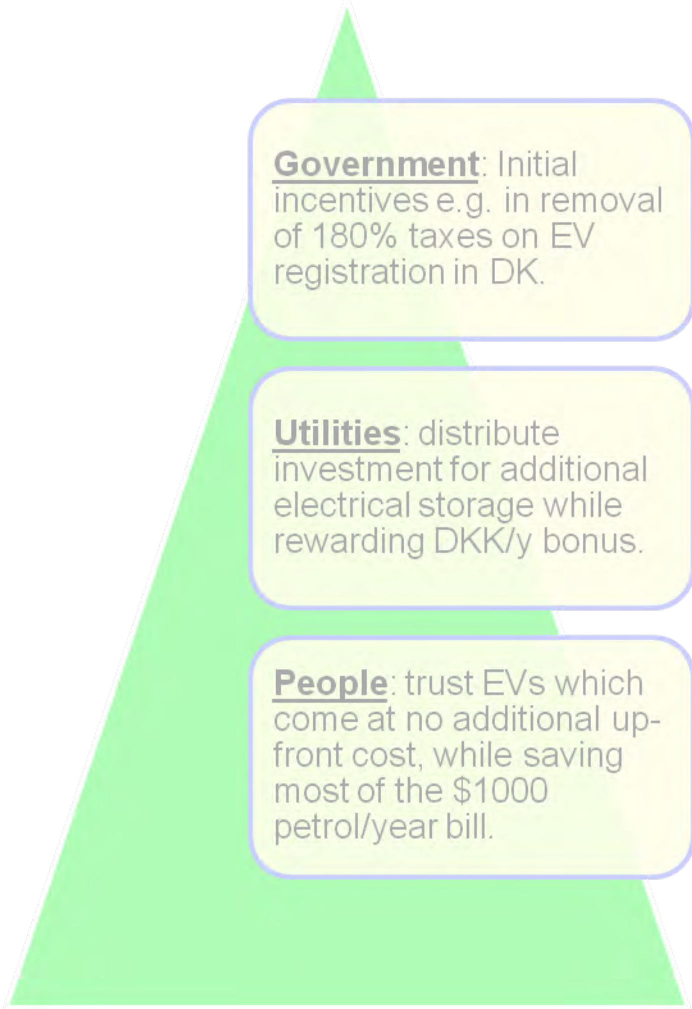


Price-based distributed planning:

- More scalable (?)
- Installation of automatic end-user "smart controllers" in Direct Energy Resource (DER) devices
- Smart Meters to manage "real-time" price signals
- Modern communication infrastructure to transmit price signal to market participants and operational units

Summary

- The future is close but not here yet: essential learning and development phase.
- Proper management of charging is an essential prerequisite to a roll-out of EVs.
- Growing renewable production but distributed dynamics challenge grid.
- Crucial set of projects with key players focused on finding the optimal match of charging schemes and grid operation (EDISON, EcoGrid, Green eMotion)



Questions ?

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