



# › COMPLEXITY IN ELECTRICAL POWER SYSTEMS CONTROL AND COORDINATION

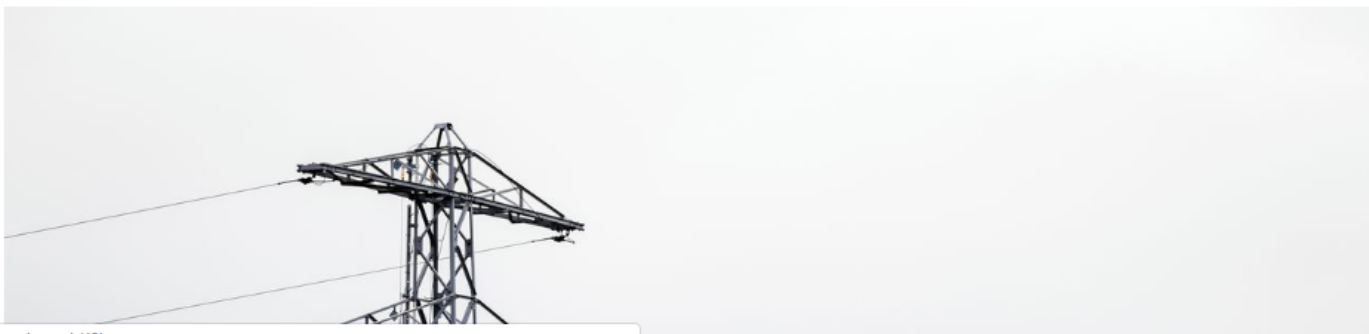
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ECN part of TNO  
Technical University of Eindhoven

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for life

# Netbeheerder Tennet wendt landelijk stroomtekort af

Maandagochtend dreigde een landelijk stroomtekort. Vermoedelijk had dit te maken met een gebrek aan wind en zon.

 **Guus Ritzen**  30 april 2018



<https://www.nrc.nl/nieuws/2018/04/30/landelijk-stroomtekort-afgewend-door-netbeheerder-tennet-a1601355>

# DUNKELFLAUTE ON 30 APRIL 2018 IN NL

- › Unexpected rainy day:
  - › Less Solar infeed than forecasted
  - › More power demand than forecasted (lighting)
- › Windspeed also lower than expected: less wind infeed
  
- › Reserve market close to depletion
- › System Operator TENNET issues an ‘alarm message’ to the power sector to allocate more reserve power.
- › TENNET buys “hundreds of megawatts” from outside NL.

# ELECTRICITY IS A DISSATISFIER

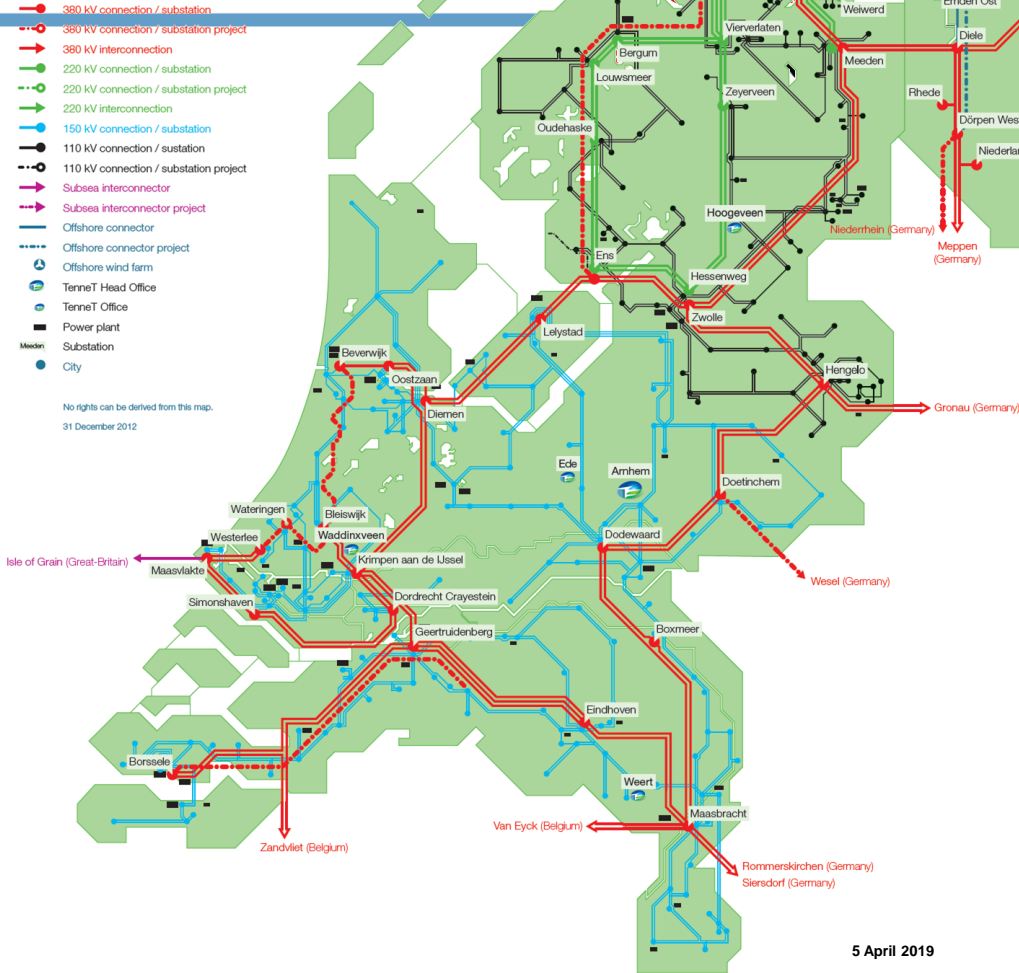


# › POWER SYSTEMS COMPLEXITY

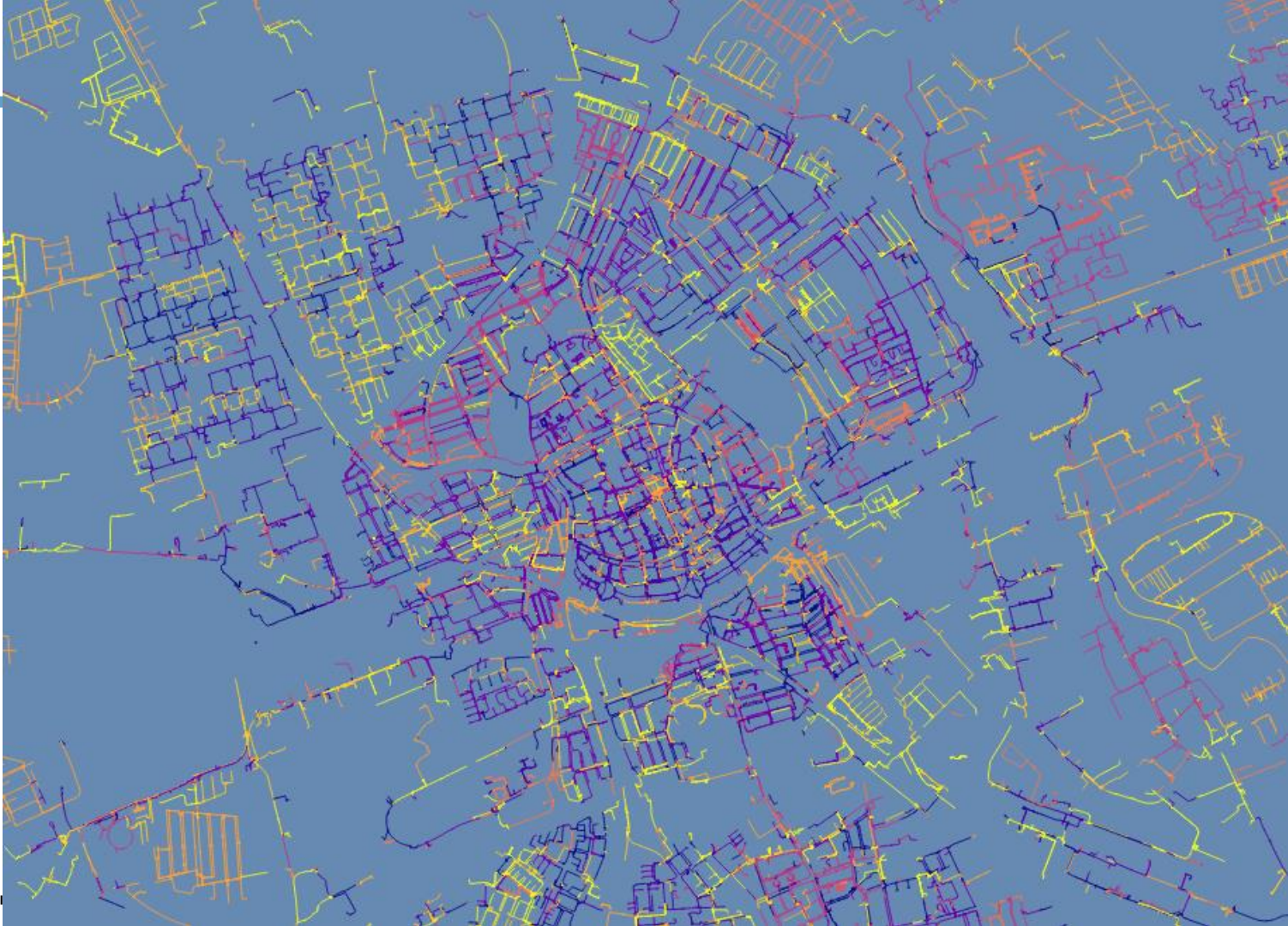


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# HIGH-VOLTAGE TRANSPORT NETWORK



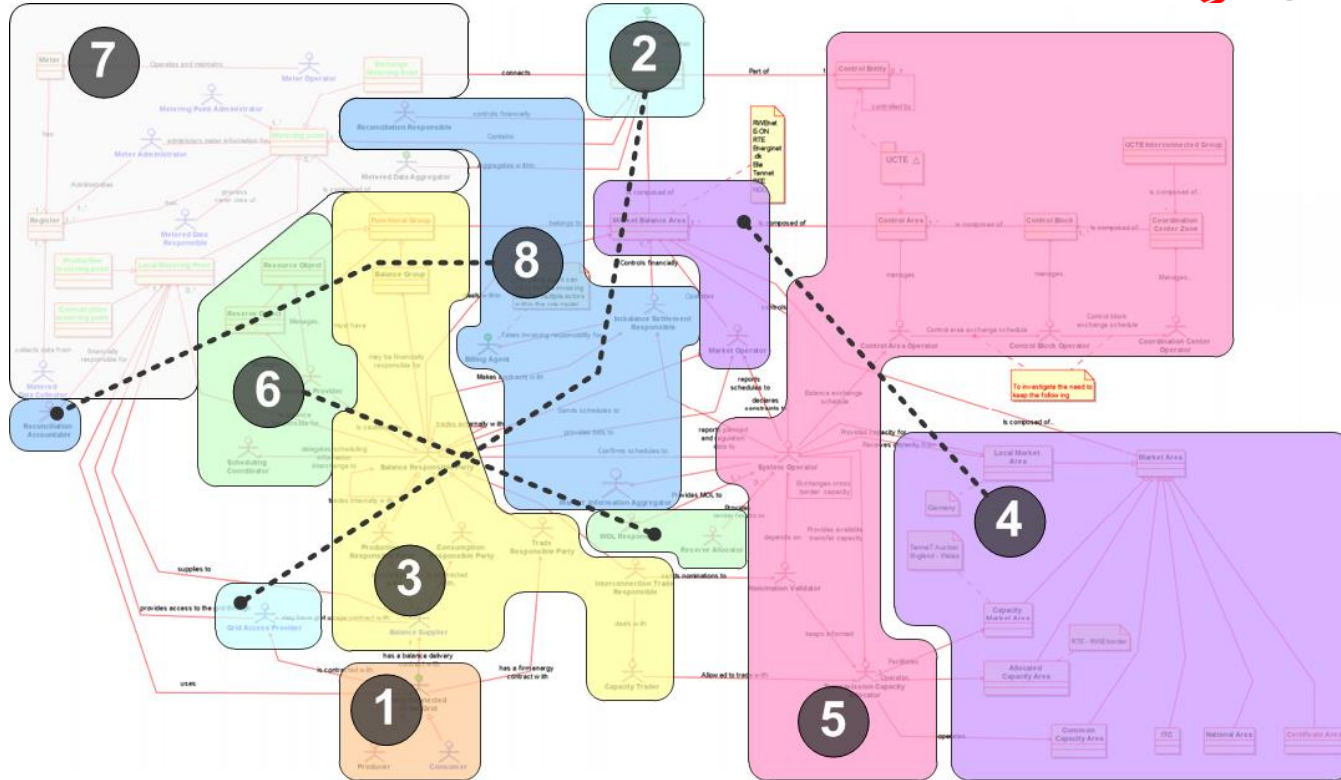
# E-NETWORK IN THE CITY OF GRONINGEN

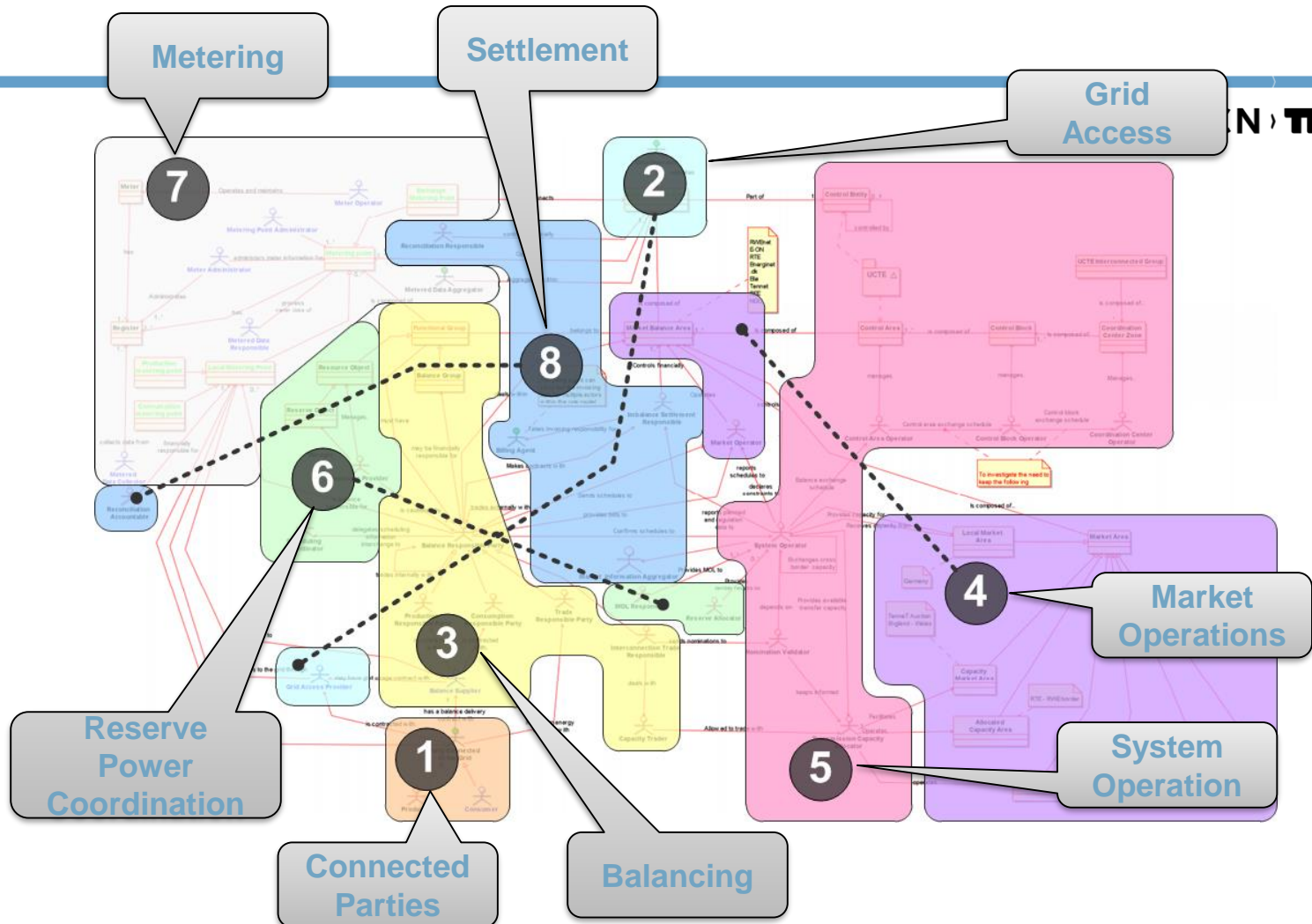






# PARTITIONING THE ELECTRICITY ROLE MODEL





# › CHALLENGES

The background image shows a residential neighborhood with rows of houses. Each house has several solar panels installed on its roof. In the distance, a large wind turbine stands against a clear blue sky. The overall scene is bright and sunny, suggesting a focus on sustainable energy and modern housing.

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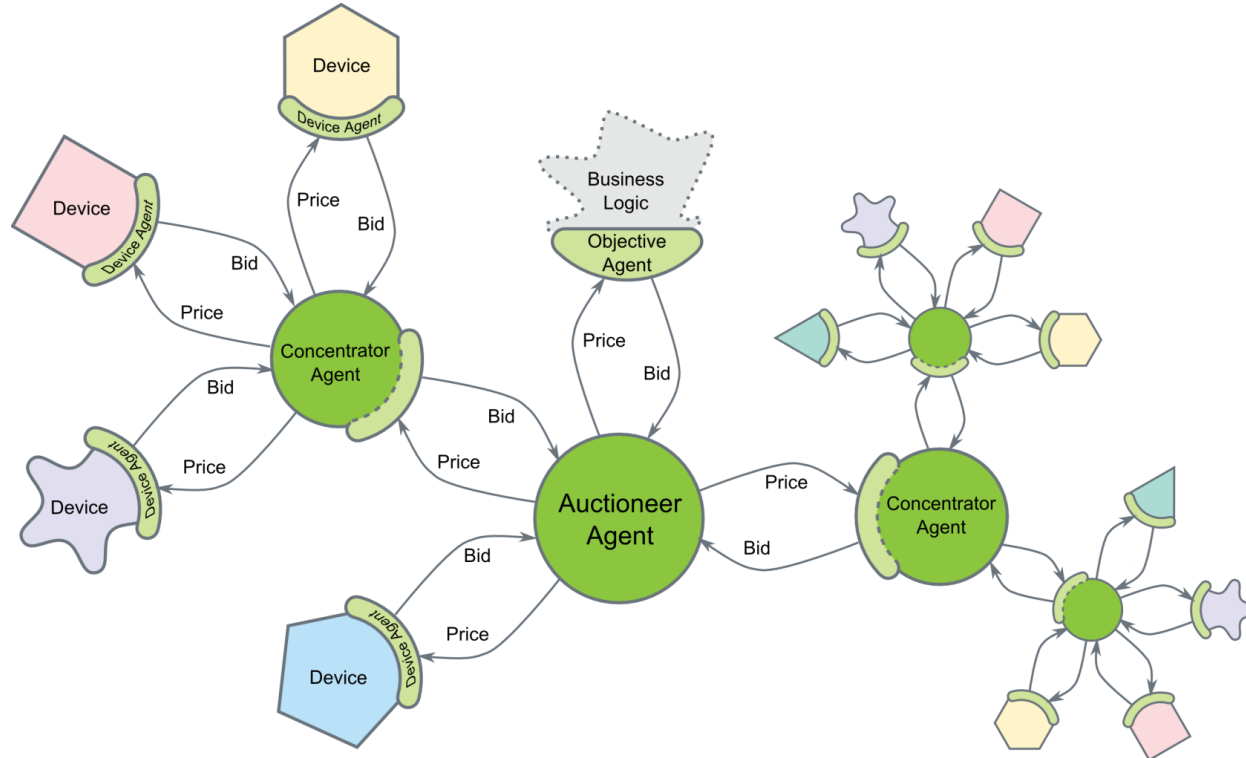
# ELECTRICITY SYSTEM CHALLENGES

- › Renewable energy introduces uncertainty
- › Electricity generation is being decentralised
- › New types of electricity consuming devices are introduced
  - › For example: electrical vehicles and heat pumps
  - › High electricity demand and high synchronicity
- › Distribution networks are ageing
  - › Replacement in cities is increasingly cumbersome
  - › Technical personnel is diminishing
  
- › Paradigm shifts needed:
  - › From “Supply follows demand” to “demand follows supply”
  - › From centralised control to decentralised self-organisation

# › (FUTURE) SOLUTIONS

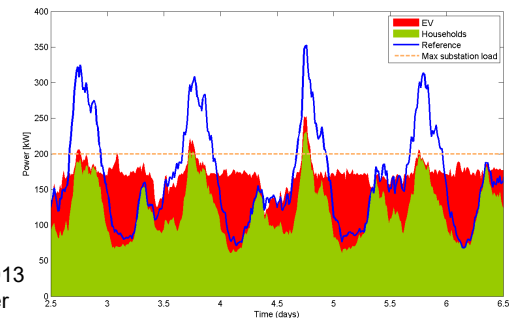
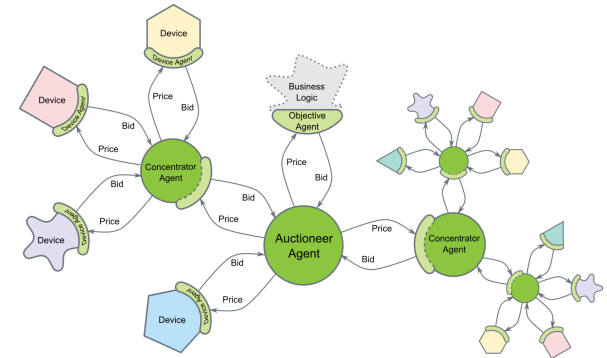
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# DISTRIBUTED MARKET-BASED COORDINATION



# POWERMATCHER

- › PowerMatcher is a Smart Grid Coordination Technology
- › PowerMatcher uses automated market mechanisms implement efficient and scalable coordination
- › Field deployed in 10+ pilots in The Netherlands, Germany and Denmark.
- › Functionalities:
  - › Balancing unpredicted wind power variations → Uncertainty reduced by 60 – 80%
  - › Solve overloading of distribution networks → Typically around 30-35% peak reduction
  - › Combination of the above.



- Koen Kok, "The PowerMatcher: Smart Coordination for the Smart Electricity Grid". PhD thesis, VU University Amsterdam, 2013
- Kok & Widergren, "A Society of Devices: Integrating Intelligent Distributed Resources with Transactive Energy." In IEEE Power and Energy Magazine, May-June 2016.

# FIELD IMPLEMENTATIONS





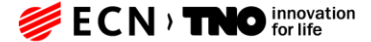
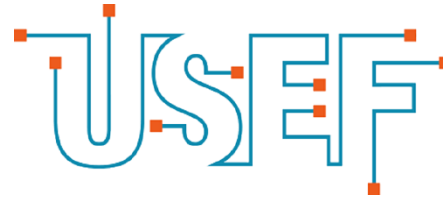


› RECENT PILOT:  
HEERHUGOWAARD

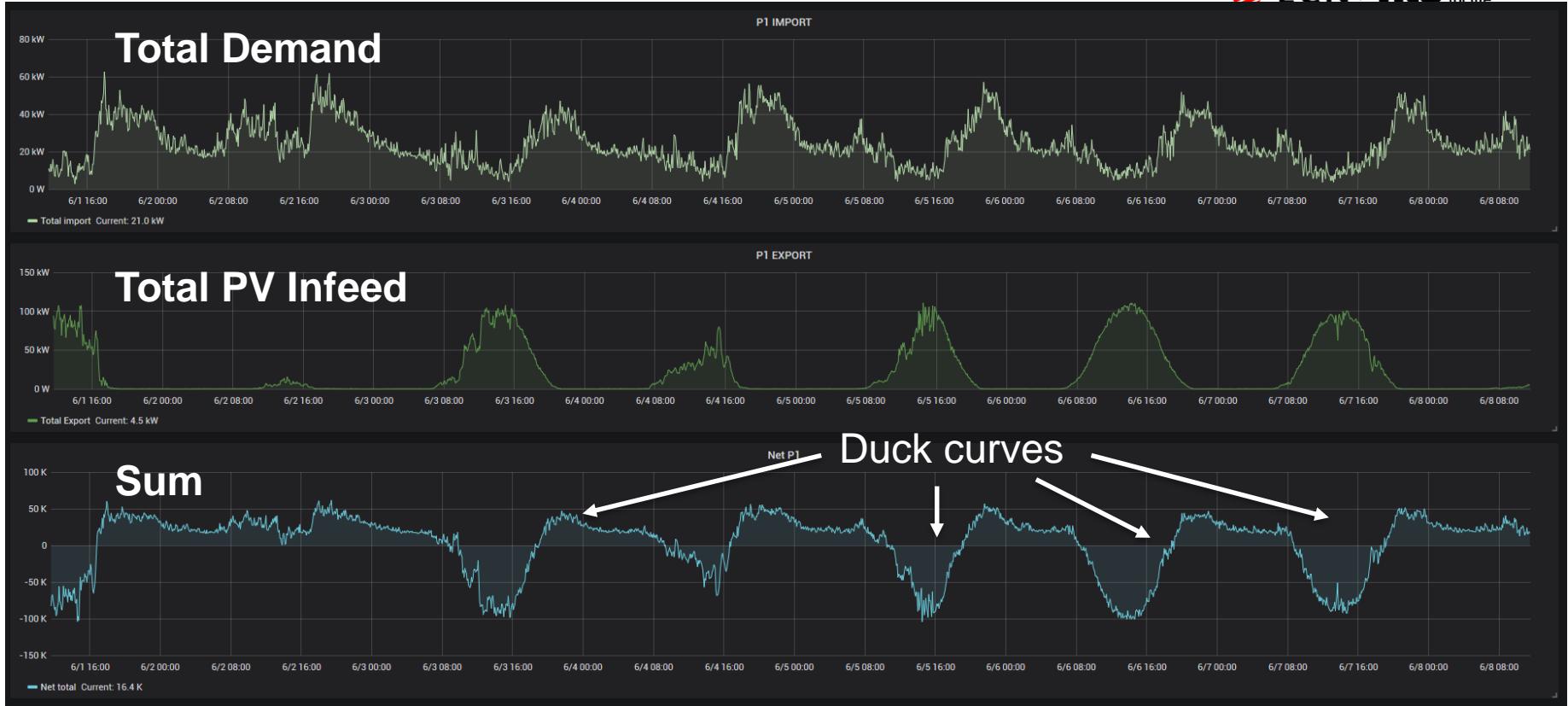
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# HEERHUGOWAARD PILOT

- › 90+ Flex Households:
  - › PV Panels
  - › Batteries
  - › Water heaters
  - › Heatpumps
- › Connected using End-to-end Open-source Solutions
- › Coordination:
  - › Avoid grid overloading
- › Second Phase was operational during 2018



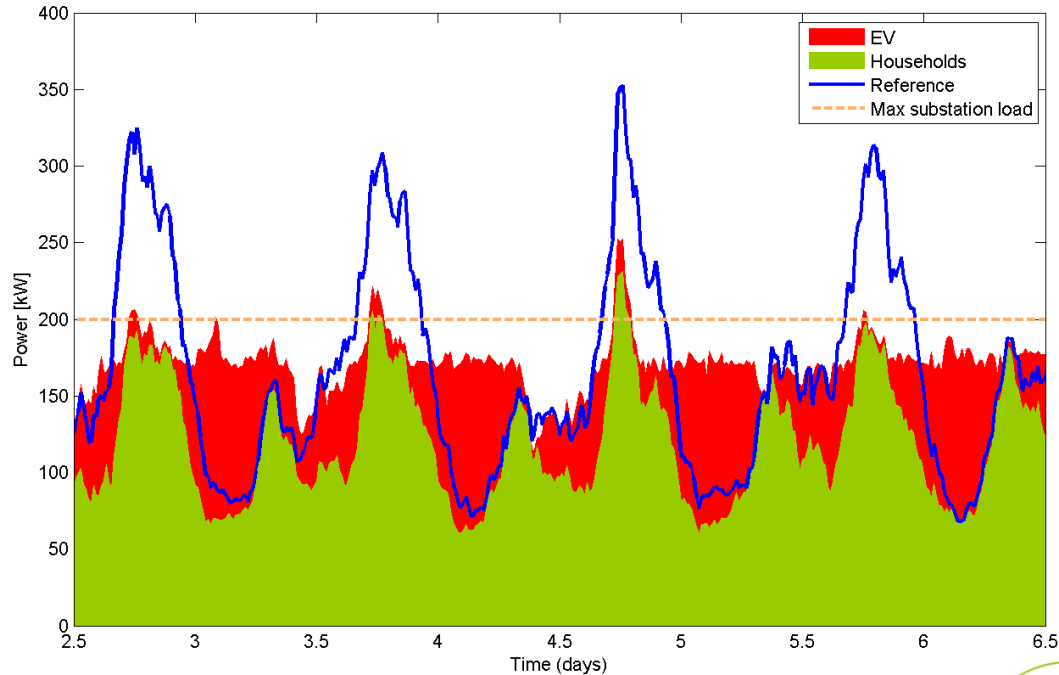
# HOUSEHOLD DEMAND AND PV INFEED



# SMART CHARGING OF ELECTRIC VEHICLES

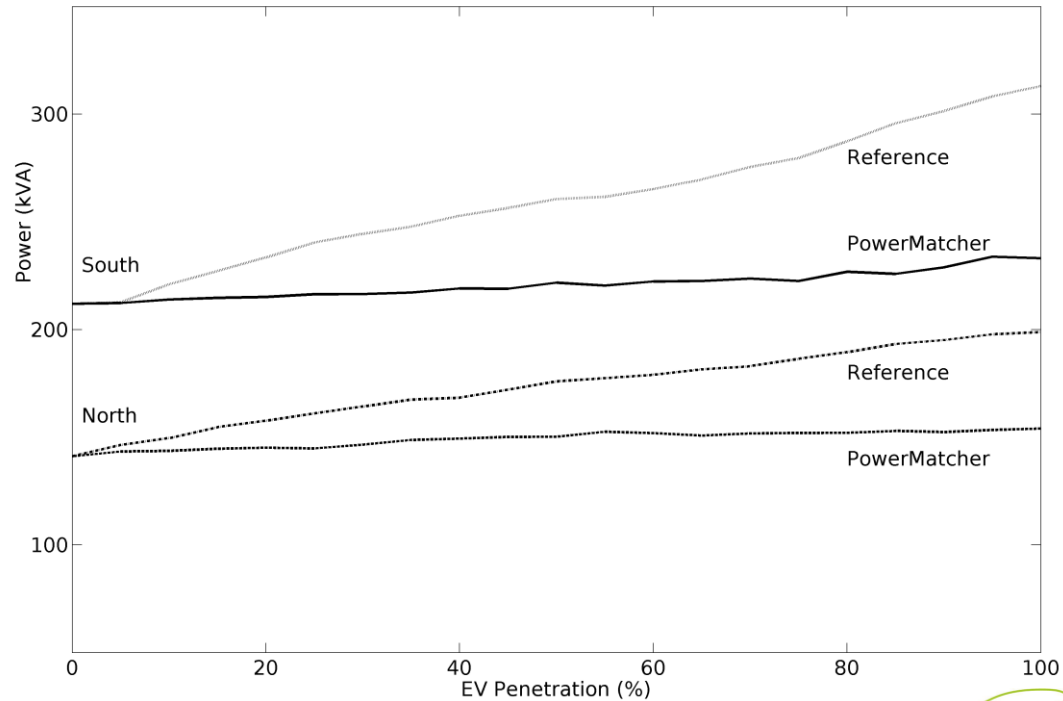


# INTELLIGENT CHARGING RESULTS

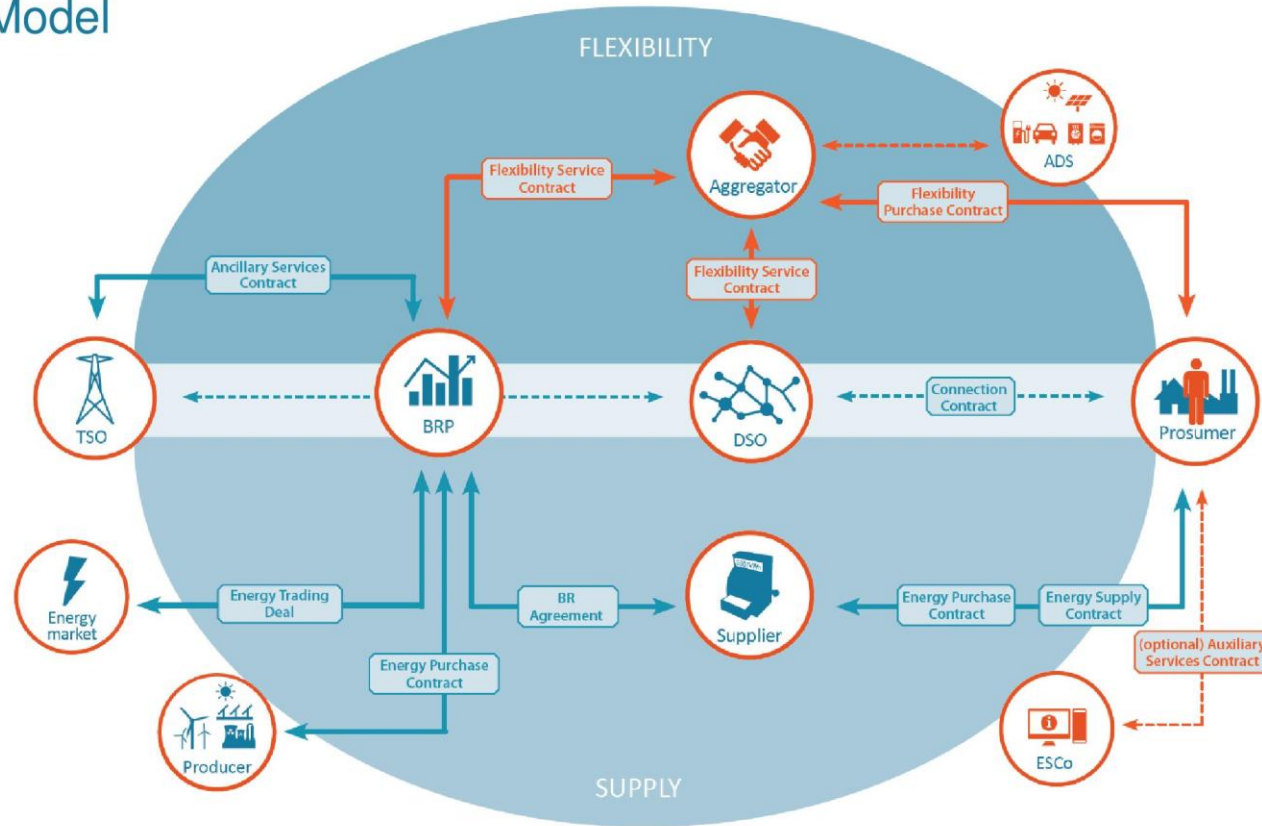


Kok et al., "Dynamic pricing by scalable energy management systems — Field experiences and simulation results using PowerMatcher", 2013

# EV PENETRATION AND DISTRIBUTION PEAK LOADING

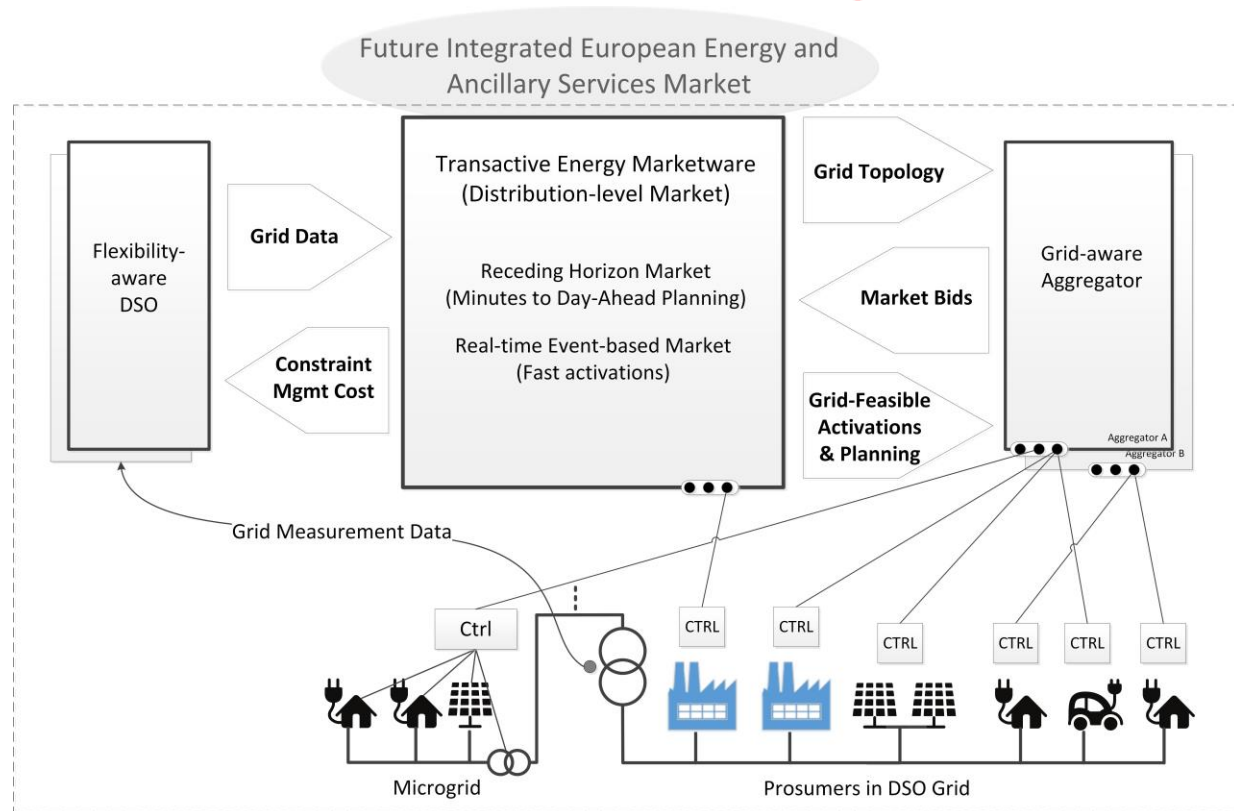


# Interaction Model (standard)



# BLUE PRINT

- › Transactive Energy Marketware (TEM)
- › A local automated market system that optimally matches energy demand and supply with available network capacity on multiple time scales.
- › System Blue print developed with industry (REstore, Expektra) and research partners (DTU, VITO, Uni of Strathclyde).

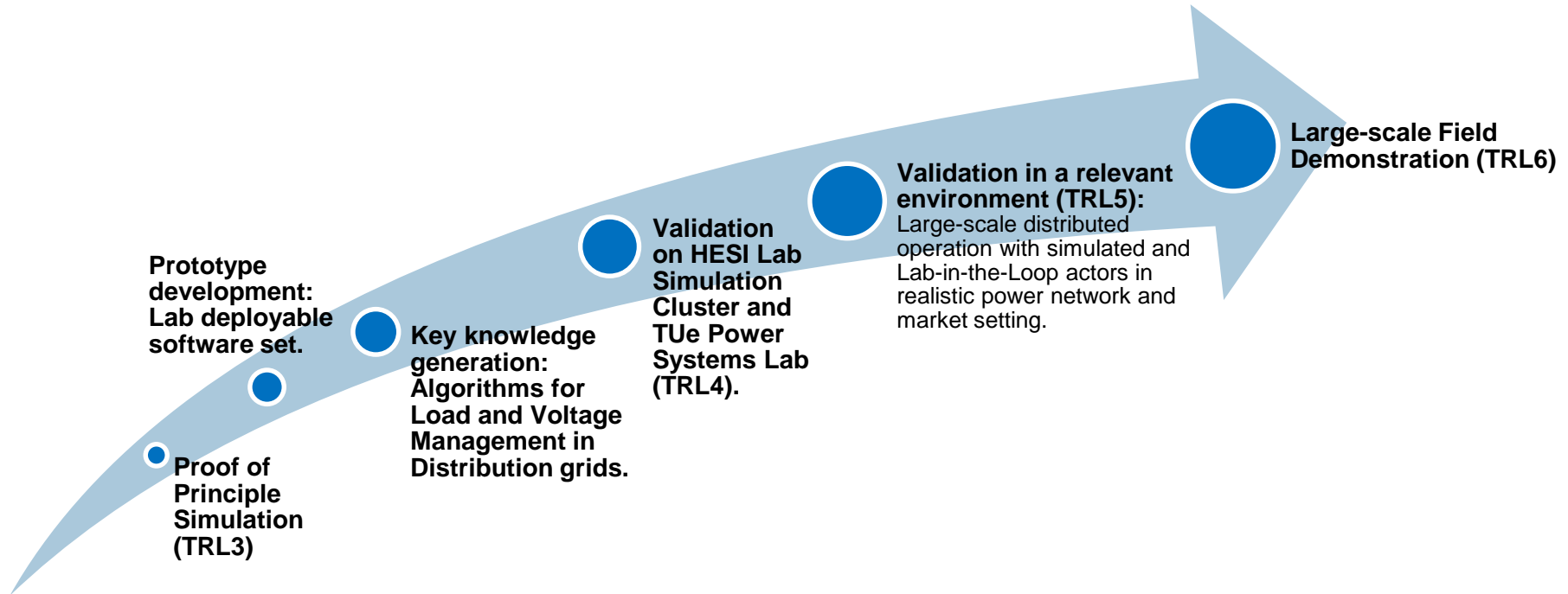




# FUTURE COMPLEXITY RESEARCH

- › AGILE project:
  - › Self-organisation in local energy market mechanisms
  - › UT, TU/e, CWI, TNO, Alliander, IPSUM, EXE
- › Open Wise Edge:
  - › Achieving local energy market scalability using Edge Computing
  - › TU/e, TNO, KPN, Phillips, Johan Cruijff Arena
- › BD4NRG: Big Data for Energy
  - › Combined market systems for energy services and energy data
  - › International consortium (submitted)

# TRANSACTIVE ENERGY MARKETWARE ROADMAP



› **THANK YOU FOR YOUR  
ATTENTION**

**TNO.NL/ECNPARTOFTNO**

**TU/e** EINDHOVEN  
UNIVERSITY OF  
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