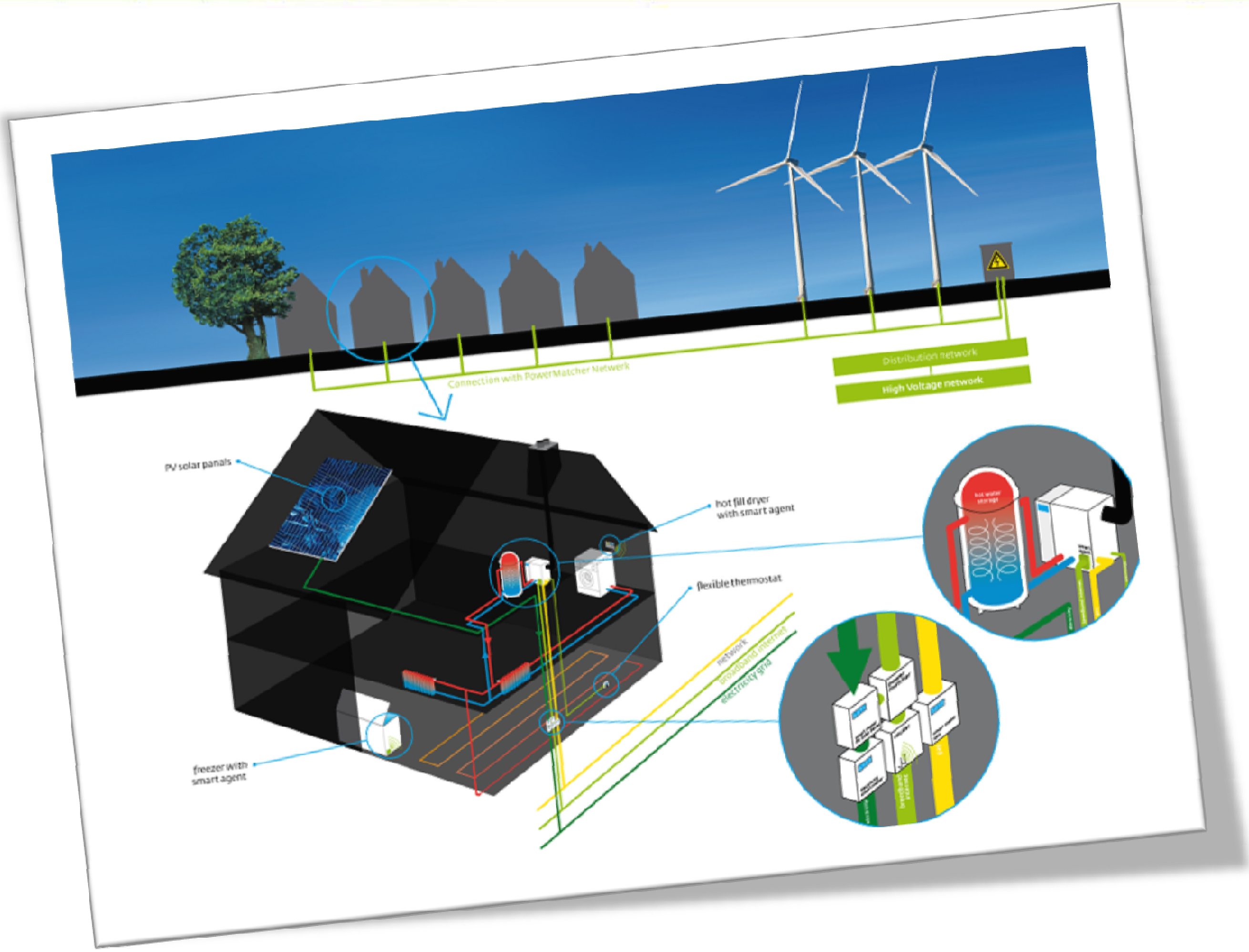
A Living Lab Smart Grid Demonstration

What is PowerMatching City



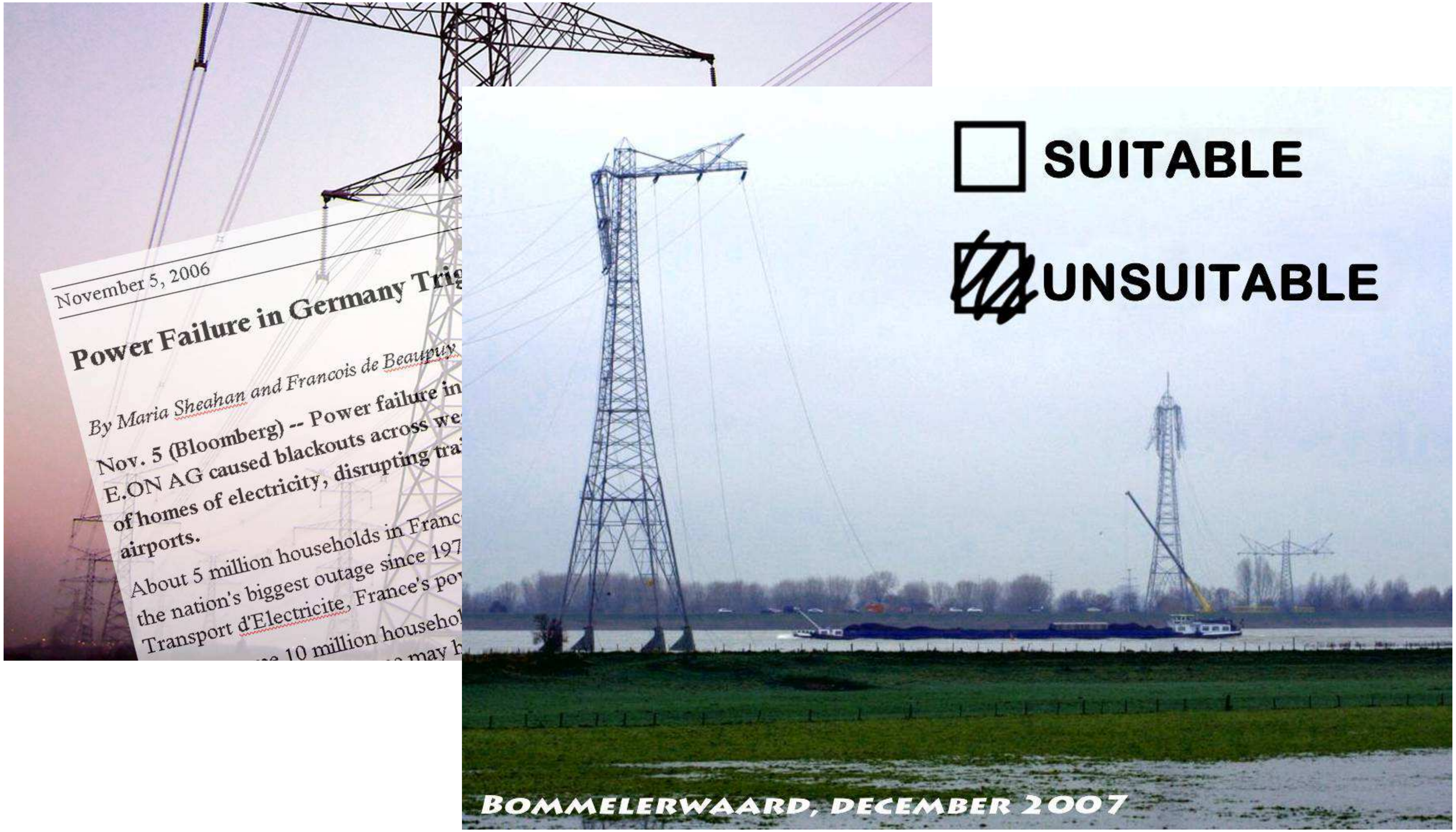
Objectives PowerMatching City

- Design, Build and **Demonstrate feasibility** of a **Smart Energy System**

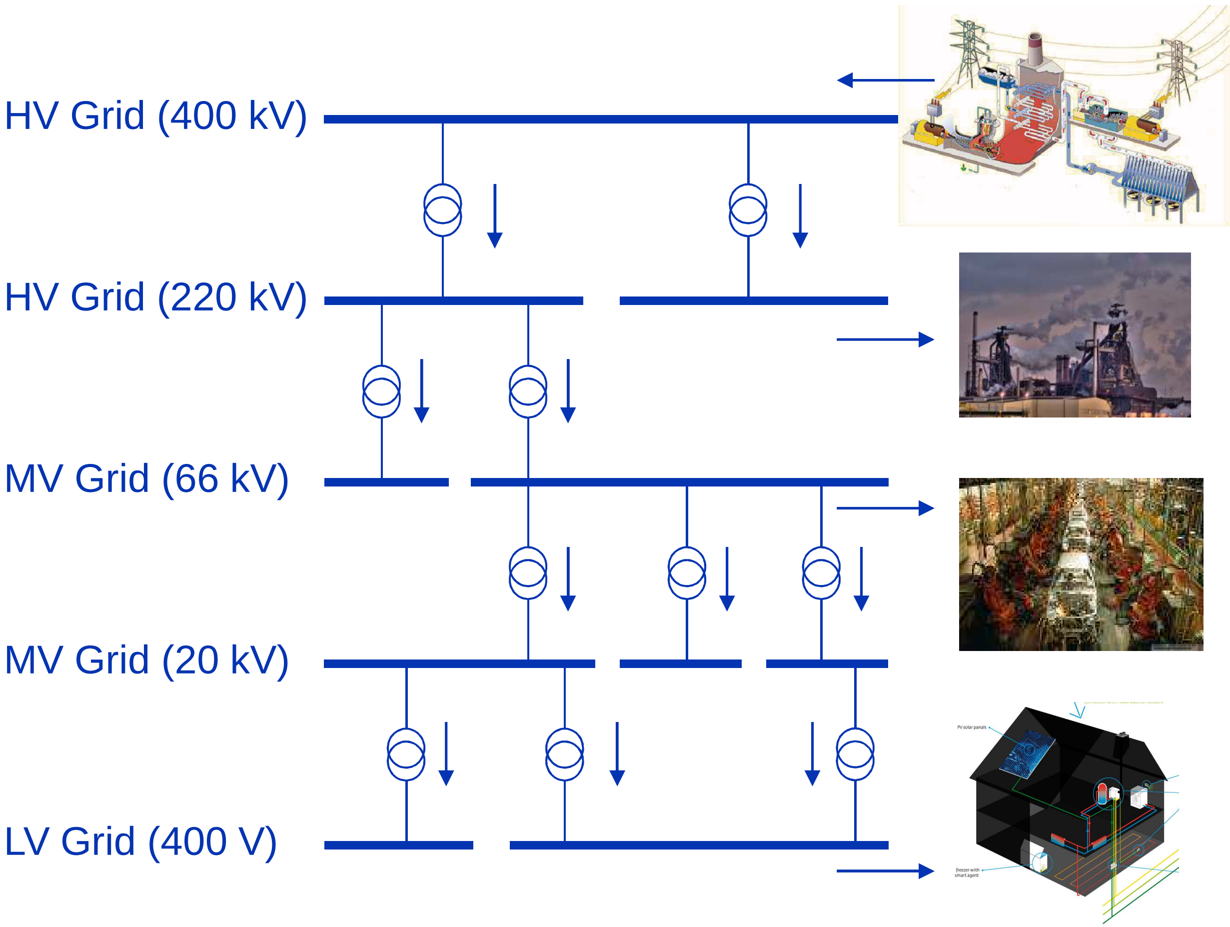
- **Optimization** based on (local) **Energy Markets**
  - **Commodity**
  - **Capacity**

- Develop **Application Independent** Solution

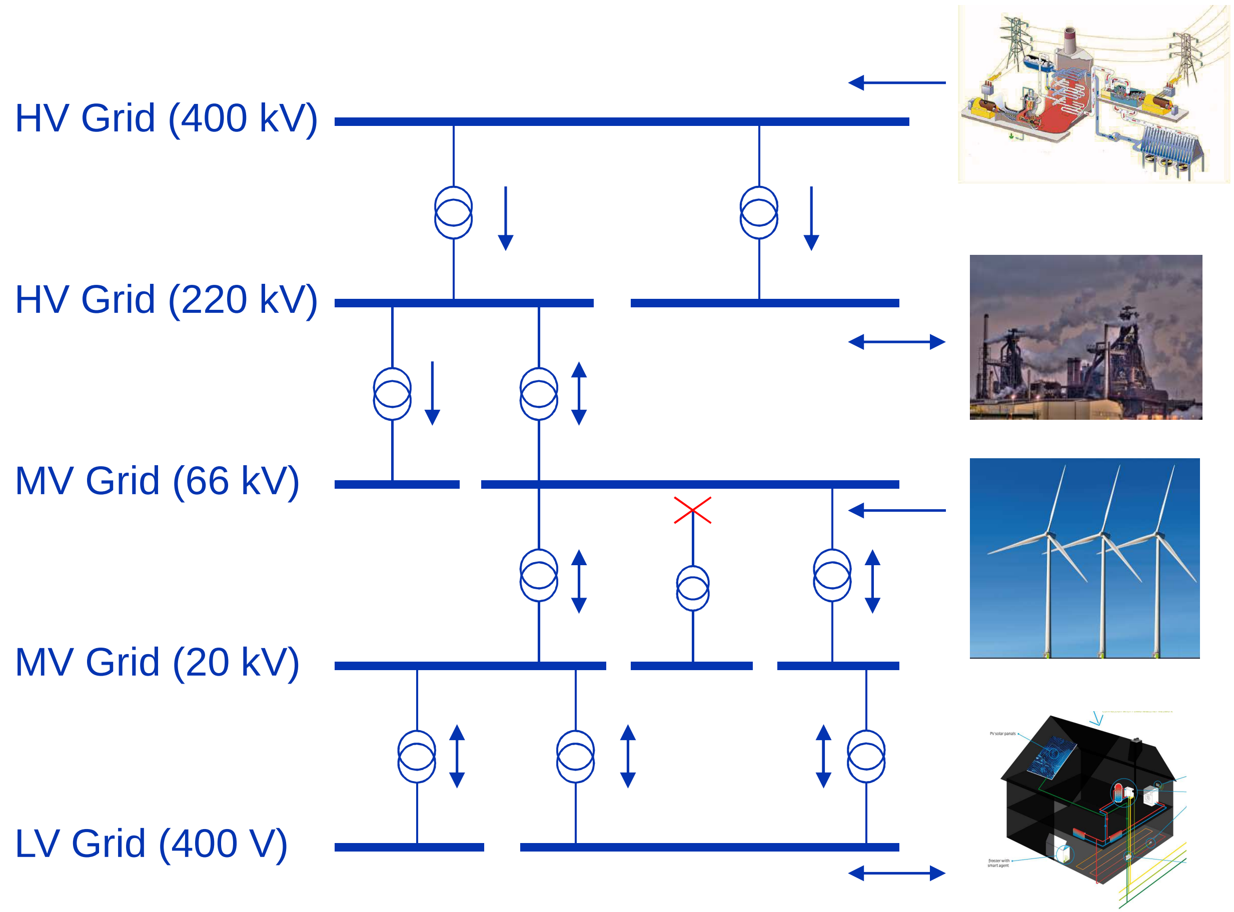
- **Integrate** Local **Generation** and **Demand Response**


November 5, 2006
Power Failure in Germany Trig
By Maria Sheahan and Francois de Beaupuy
Nov. 5 (Bloomberg) -- Power failure in
E.ON AG caused blackouts across we
of homes of electricity, disrupting tra
airports.
About 5 million households in Franc
the nation's biggest outage since 197
Transport d'Electricite, France's po
10 million househol
SUITABLE
UNSUITABLE
BOMMELERWAARD, DECEMBER 2007

One way network



Two way network



User point of view

General assumption:

The end-user is a *'homo economic'*

Its incentives:

- reducing energy costs
- without profit no investments in:
    - Solarcells
    - µ-chp
    - Load management
- free energy market with peer to peer trade
- transparency in tariffs in time and load for energy and transport

User point of view

- Comfort end-user
  - room temperature
  - end time laundery
- Indoor decisions
  - ***People in Power***
    no external ‘big brother’!
  - tariffs are the only means of control
  - forecasted energy tariffs

- Optimization energy costs
  - selling: max
  - buying: min

- Thermal buffer electrical buffer
  - Heating
  - Freezer
  - Fridge
- Automatic time shifting
  - Washing machine
  - Dishwasher
  - Dryer
- Cost-optimal use domestic resources
  - solar cells
  - µ-chp
- Self learning
- Automatic operations

Full Concept Smart Grid Solution

Intermittent Renewable
Energy Sources

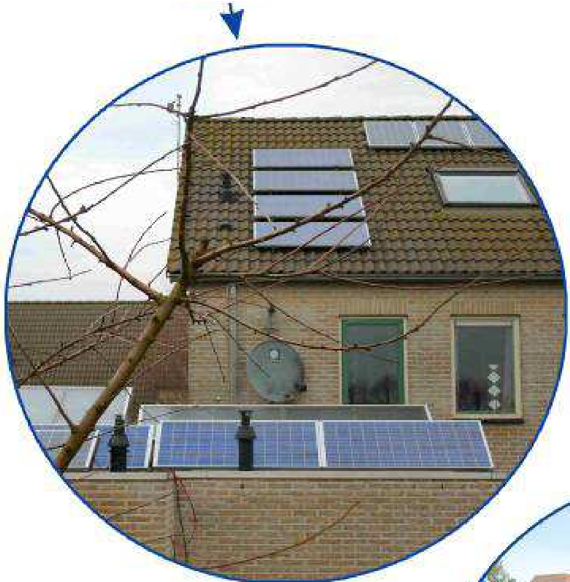
Smart Appliances
for Demand Response

Smart Hybrid Heat Pumps

mCHP for Flexible Power

Smart Charged
Electric Vehilces

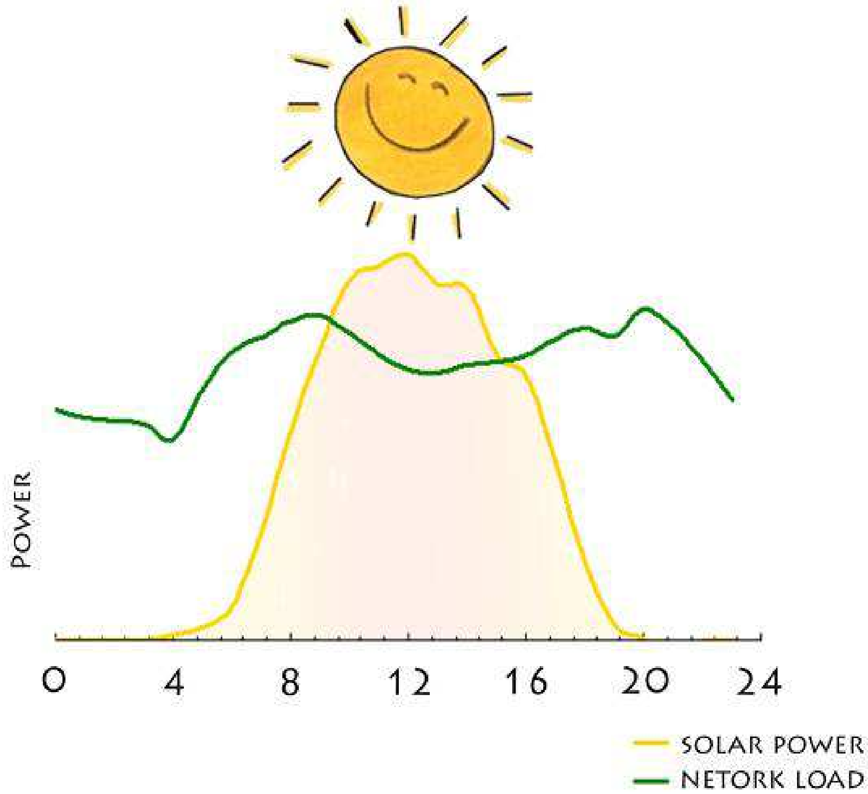
Sustainable Decentralized Energy



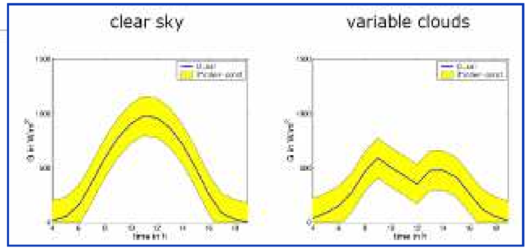
PV – Solar Power
Physical or Virtual
Connected

Windfarm Kreileroord

Embedding Solar Power



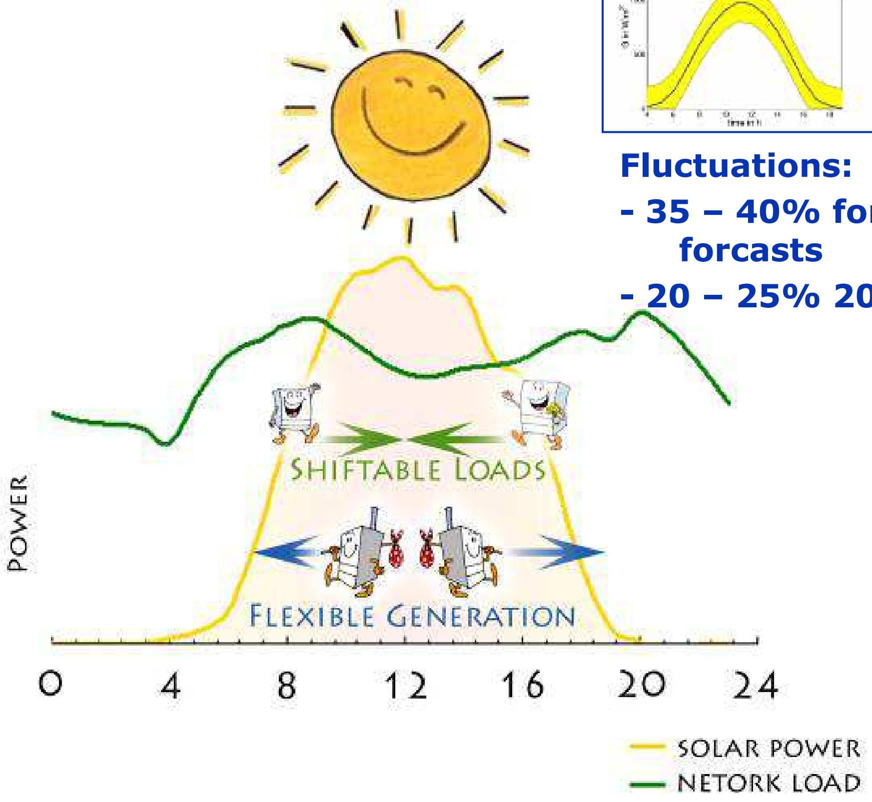
Embedding Solar Power II



Fluctuations:

- 35 – 40% for local forcasts

- 20 – 25% 200 km²



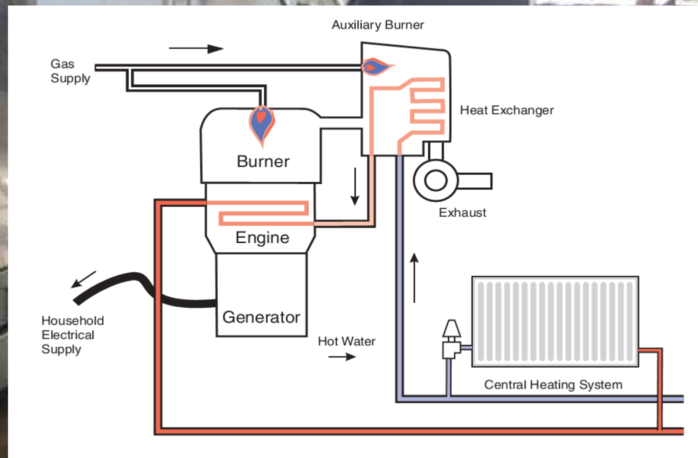
Smart Appliances

Micro-CHP – decoupling electricity and heat

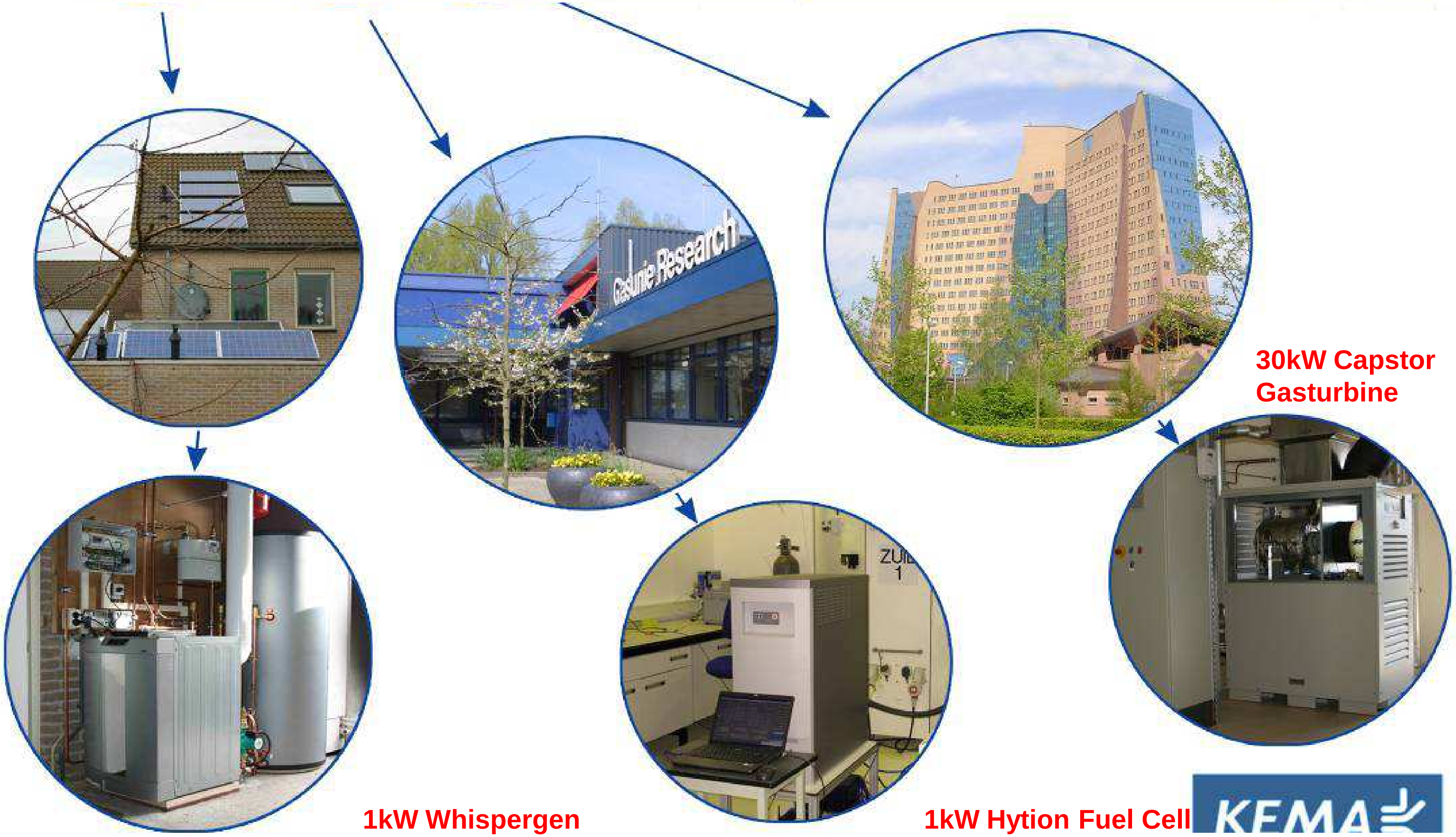
WhisperGen Micro-CHP

Electrical output
- Nominal mode: up to 1000W

Thermal output
- Minimum: 5.5 kW
- Nominal mode: 7 kW
- Maximum: 12kW



Scalable CHP production



30kW Capstor Gasturbine

1kW Whispergen

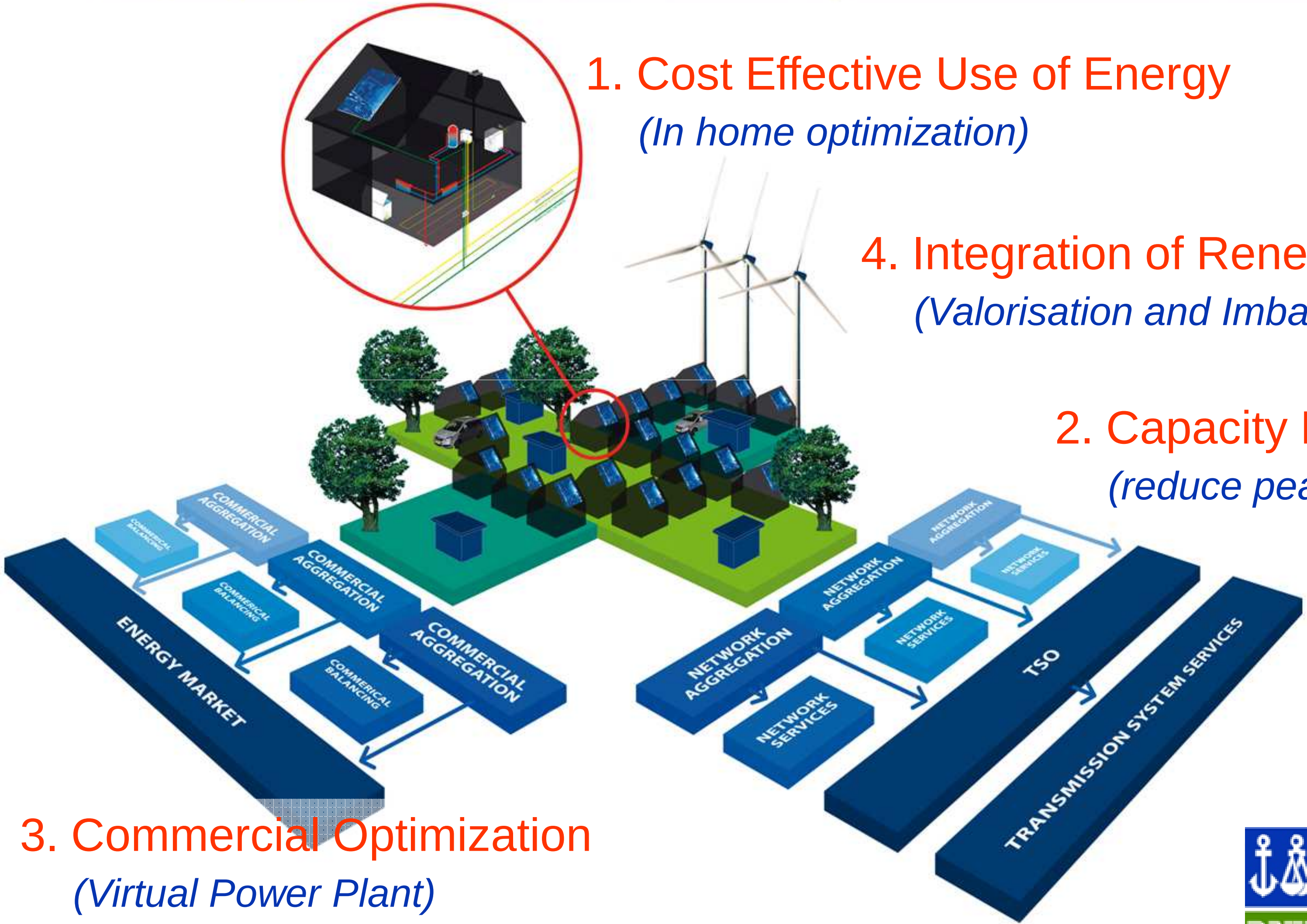
1kW Hytion Fuel Cell

Multi Goal Optimization

1. Cost Effective Use of Energy
(In home optimization)

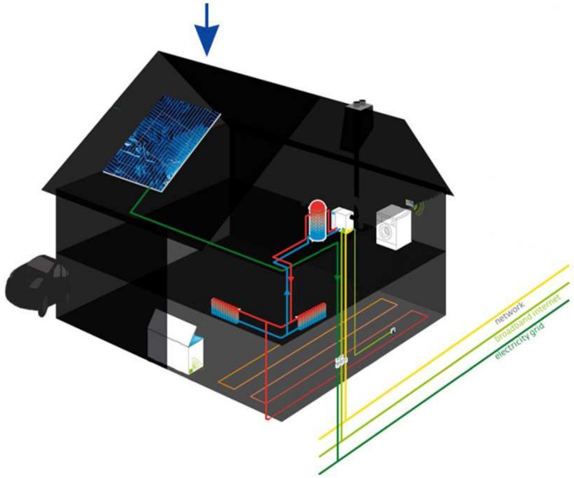
4. Integration of Renewable Energy
(Valorisation and Imbalance Reduction)

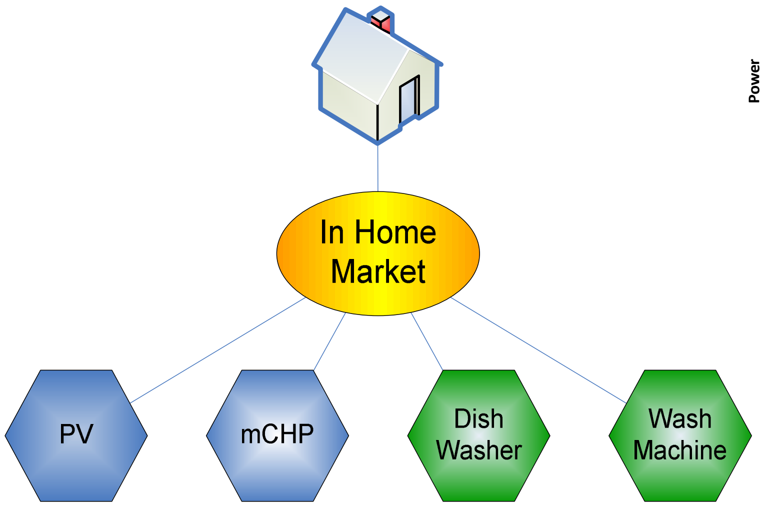
2. Capacity Management
(reduce peak loads)

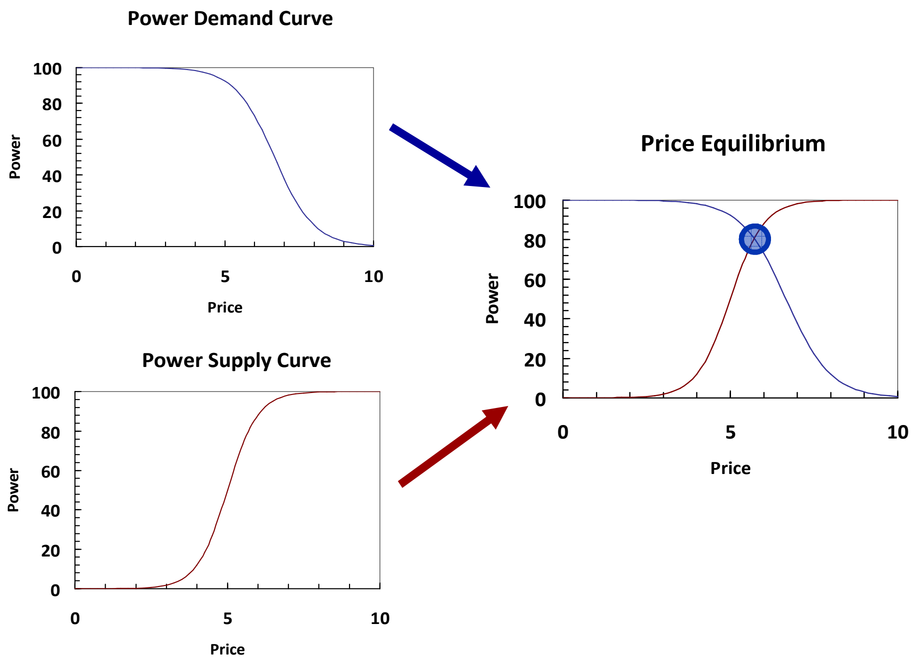


3. Commercial Optimization
(Virtual Power Plant)

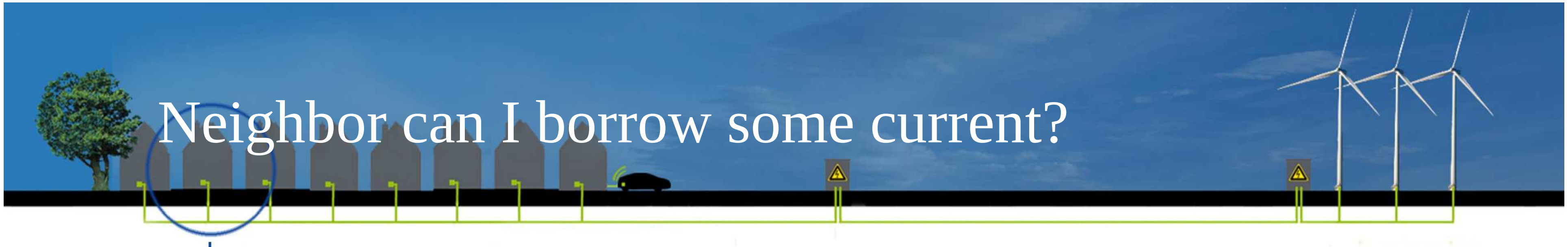
Your own local energy market at home

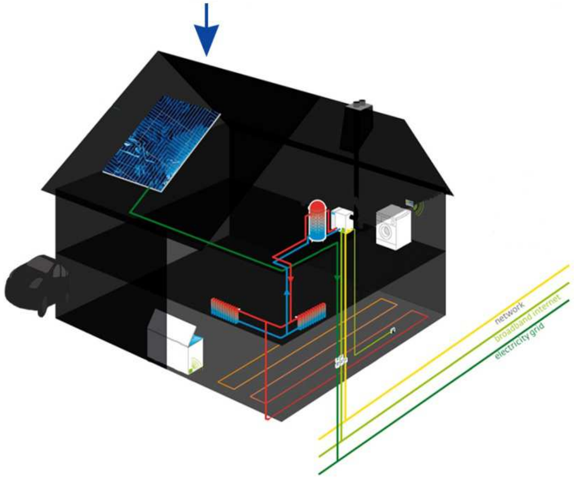


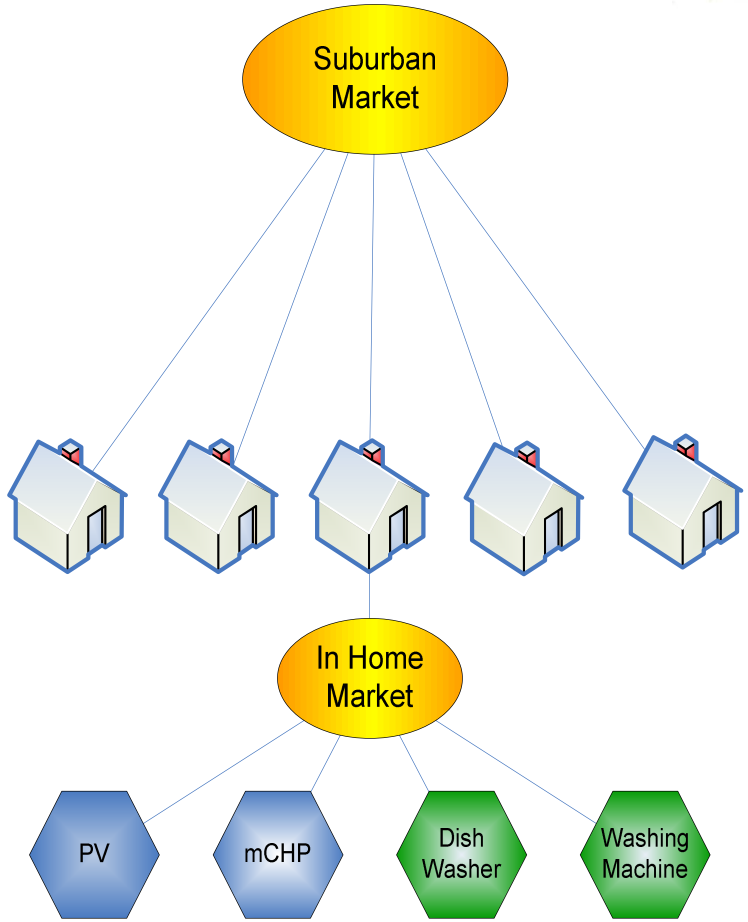




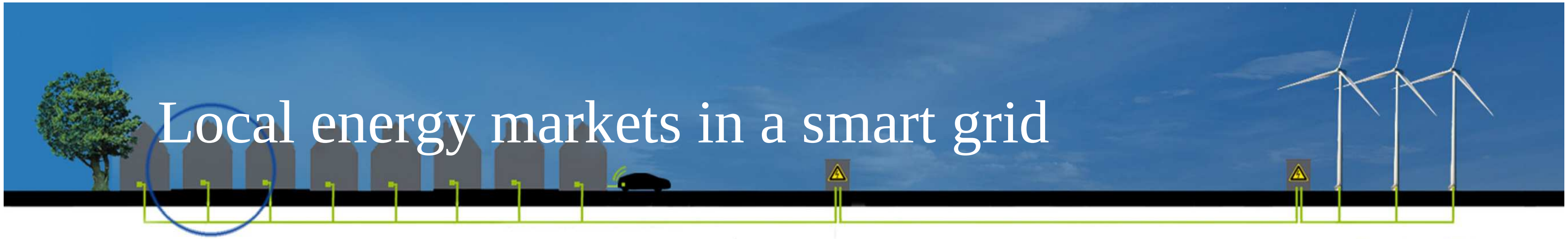
Neighbor can I borrow some current?

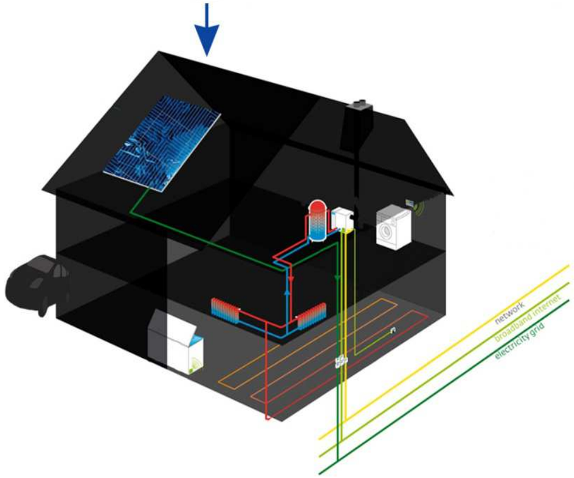


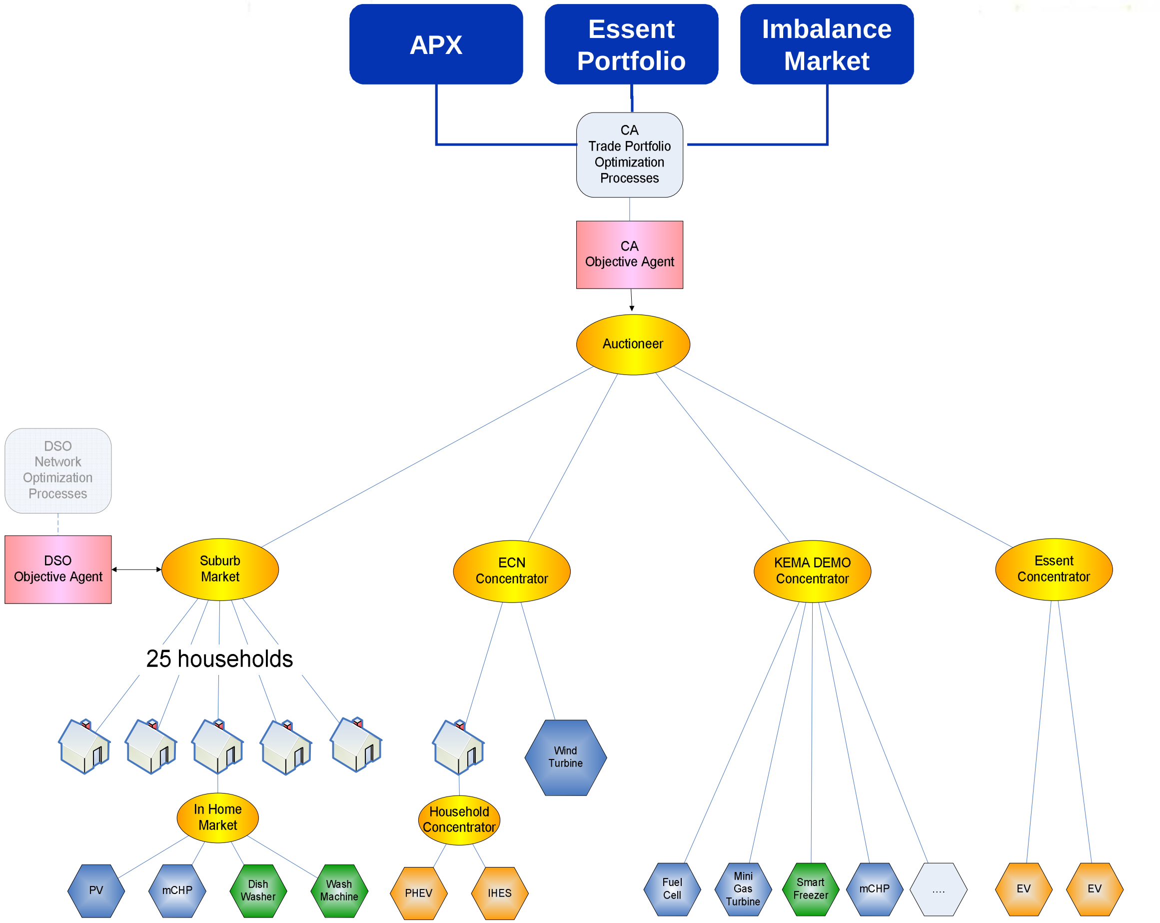




Local energy markets in a smart grid

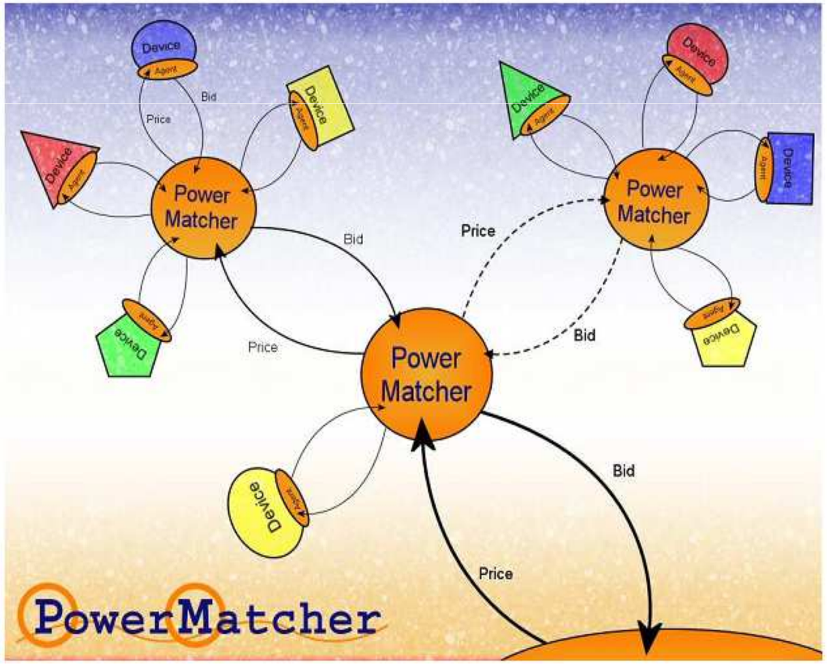






The PowerMatcher

The PowerMatcher is a market-based control concept fo supply and demand matching (SDM) in electricity networks with a high share of distributed generation



Each device is represented by a control agent which tries to operate the process associated with the device in an economical optimal way

The only information exchanged between the agents and the agent platform are bids. These bids express to what degree an agent is willing to pay for a certain amount of electricity. Depending on that, the agent will start producing (or consuming) or wait for the next bidding round

Device agent types and Strategies

Stochastic operation devices

- Solar and wind energy. The output cannot be controlled

Shitable operation devices

- Washing and drying processes. Can be shiftable up to a certain limit

External resources operations devices

- Heating and cooling systems. Produce a resource, other than electricity, and have a shifting operation to economically attractive moments

Electricity Storage devices

- Conventional batteries, flywheels and super-capacitors.

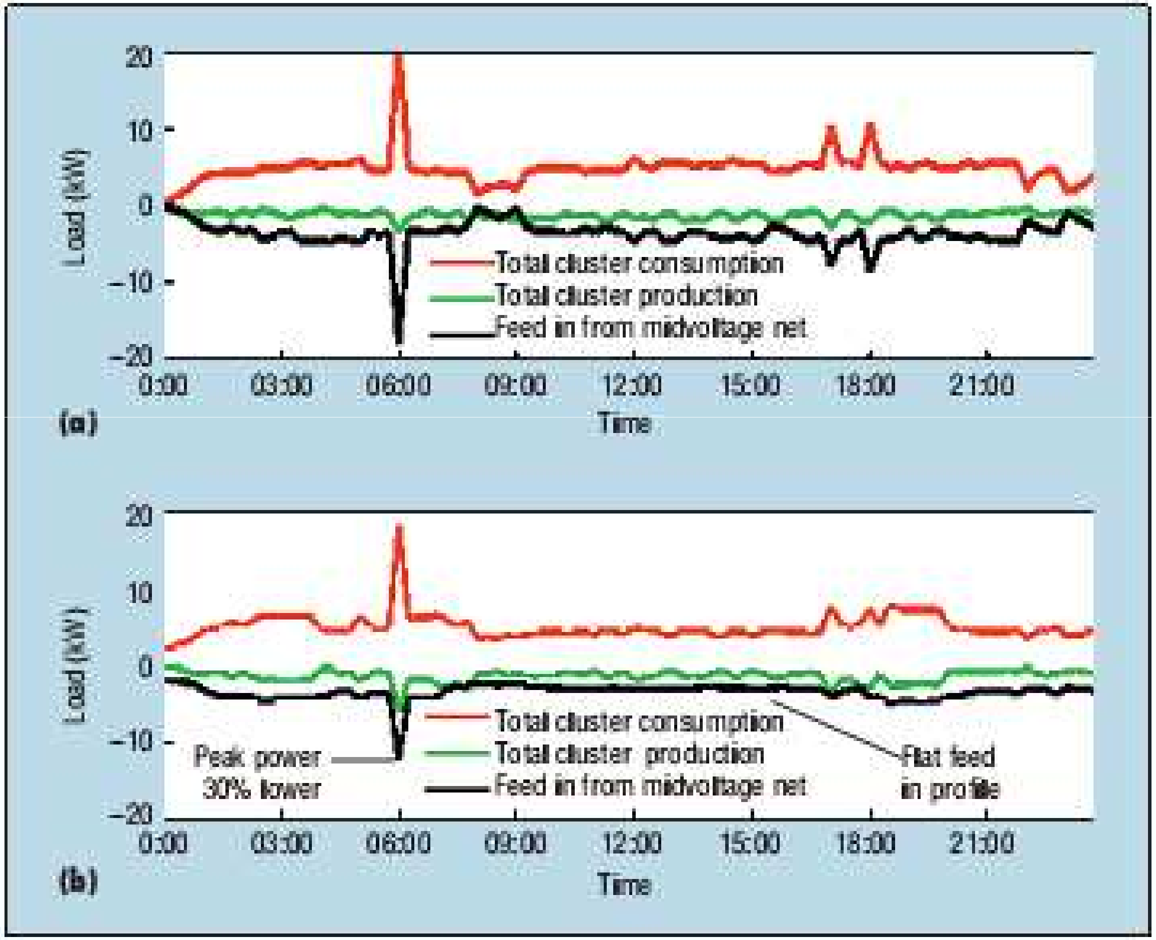
Freely-controllable devices

- Diesel Generator. Devices that are controllable up to certain limits

User Action devices

- Audio, Video, Lighting, computers. Stochastic operation devices

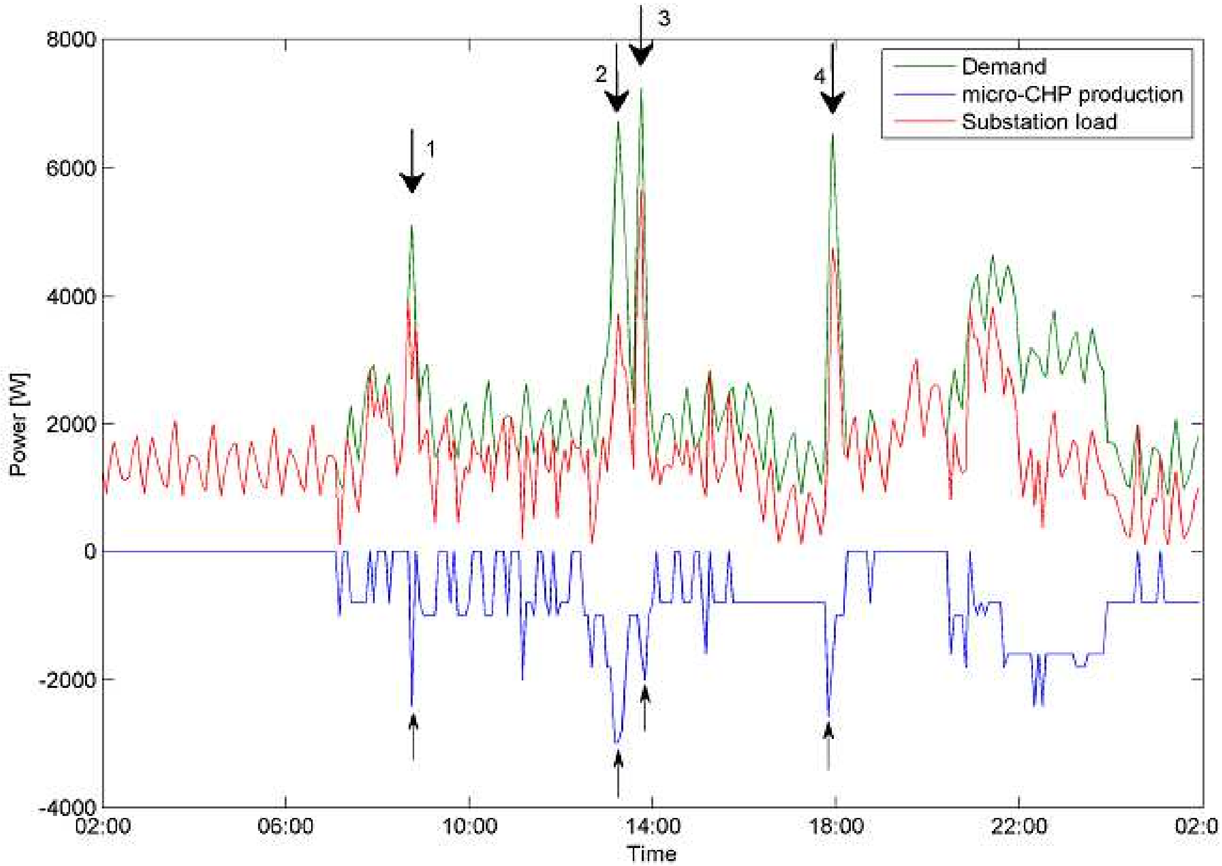
Field Test 1



20
10
0
−10
−20
Load (kW)
Total cluster consumption
Total cluster production
Feed in from midvoltage net
0:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time
(a)
20
10
0
−10
−20
Load (kW)
Total cluster consumption
Total cluster production
Feed in from midvoltage net
Peak power 30% lower
Flat feed in profile
0:00
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Time
(b)

Field Test 2

Field Test. May 2007. Warm wheather.



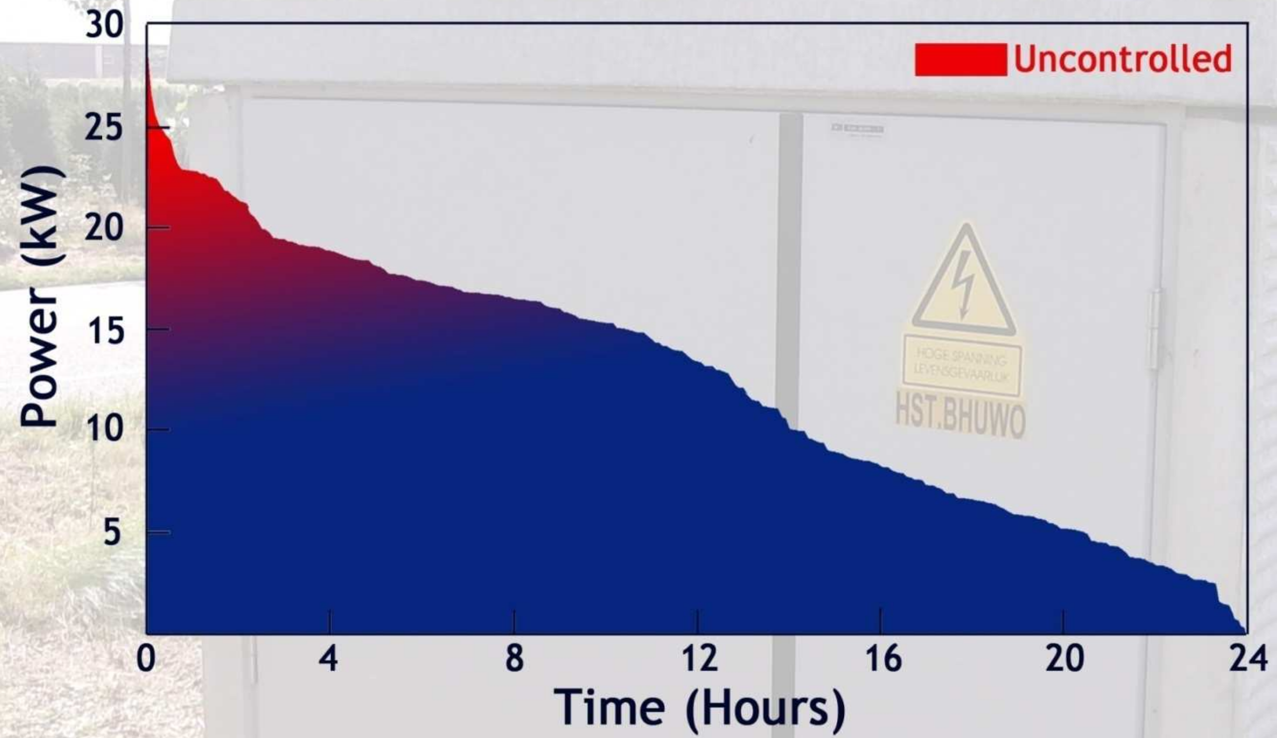
The substation load is reduced due to the energy produced by the micro-CHP

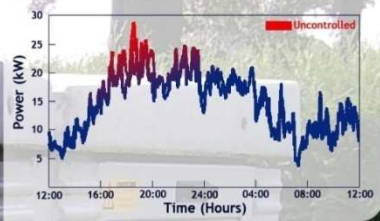
There was a demand of tap water on peak 2 so in the third peak is was largely satisfied

The sequence of peaks will be more effciently compensated in winter season

End-Result: Uncontrolled Load Duration

on a Distribution Station

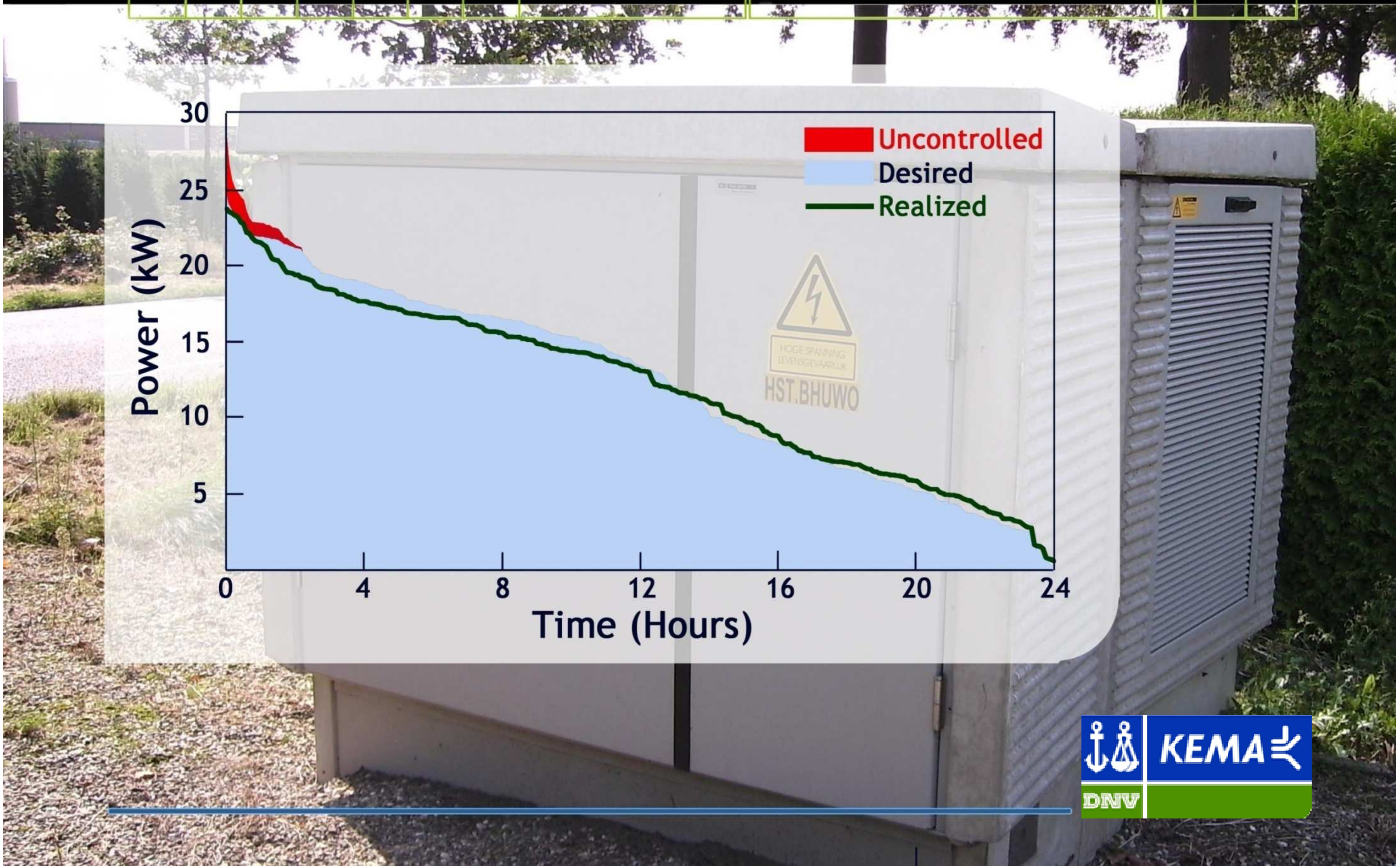




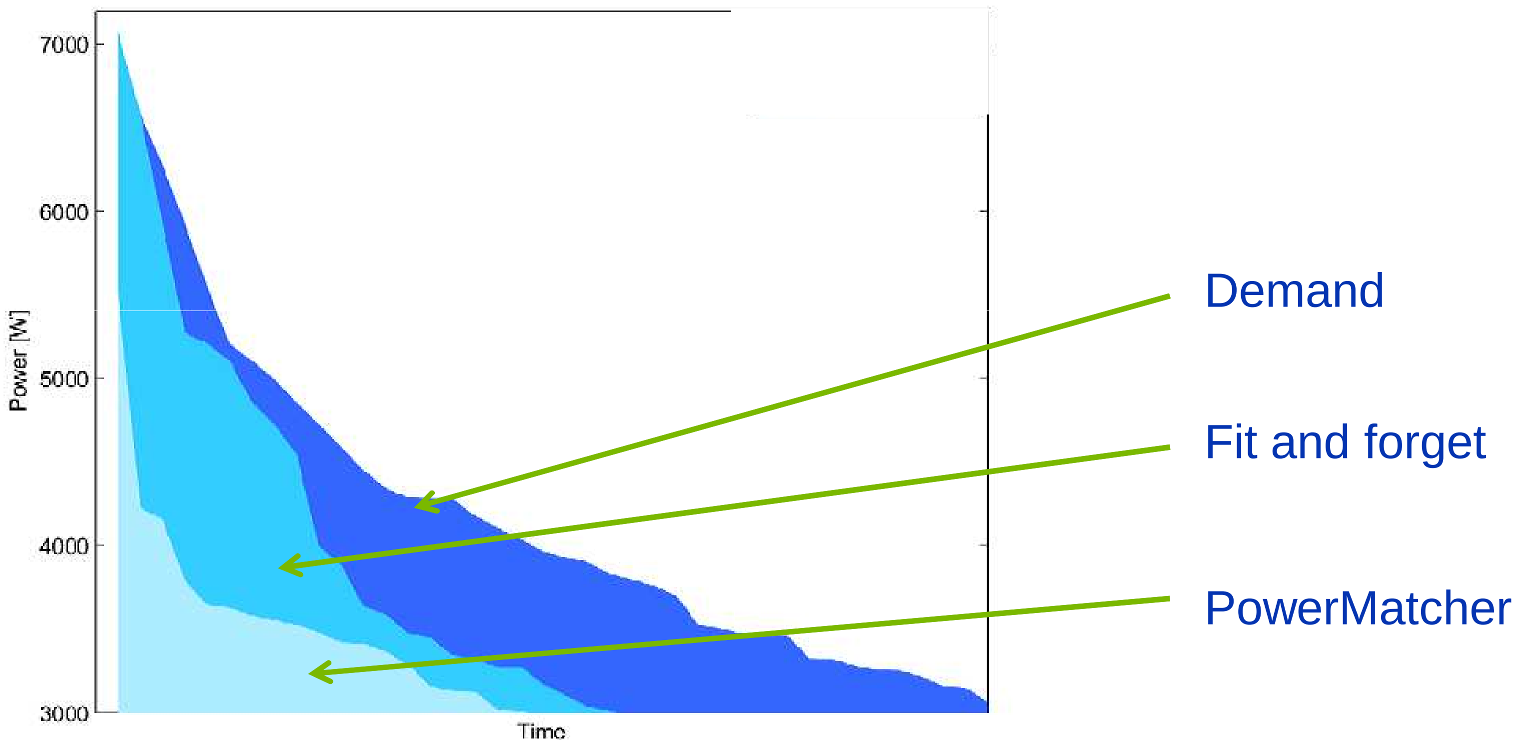
KEMA DNV

End-Result: Realized Load Duration

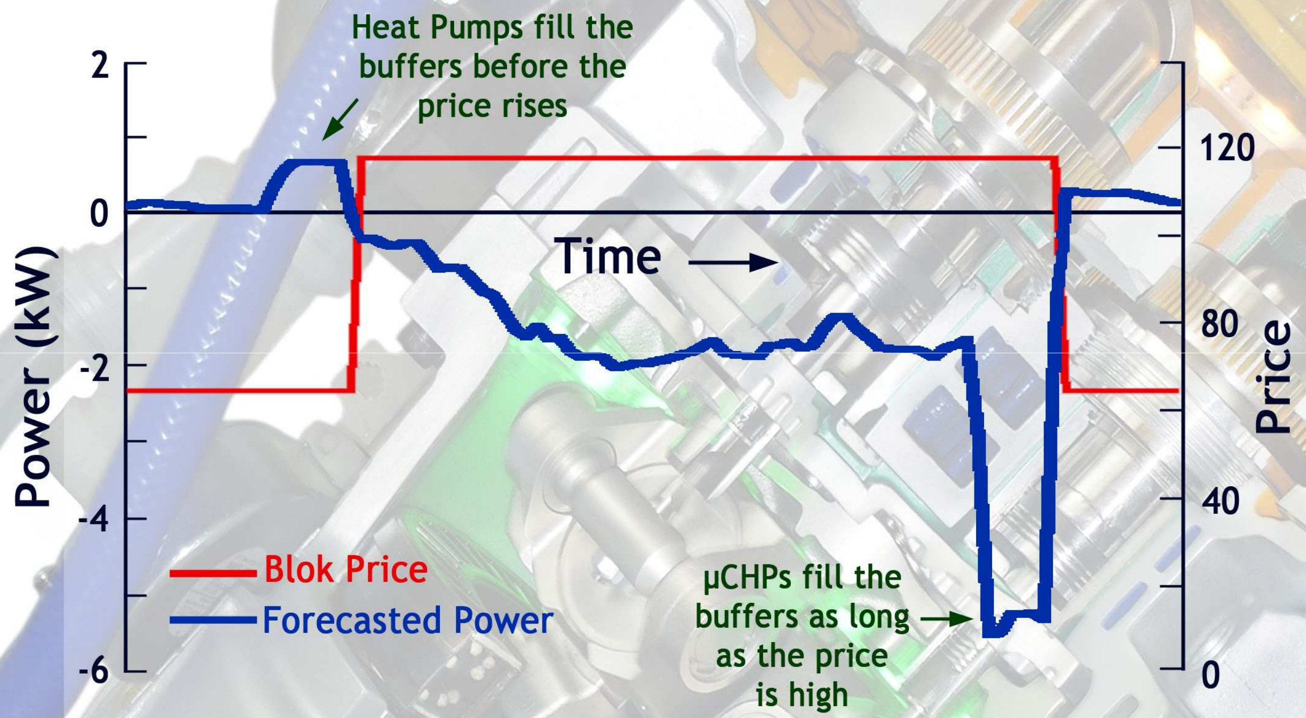
and Load on Distribution Station



Load duration curves of the net substation



VPP: Forecast 24 hours ahead
based on external block profile



Insight into Energy Consumption & Production

People in PowerMatching City

ADVANCE USER
Theo (Environmental Safety consultant, Gasunie)

“Gas usage increase in about 15% meanwhile electricity went down”

“Time delay of approximately 5 minutes in the energy portal”

“Dashboard to that shows energy usage day by day per appliance”

“Freedom to generate electricity”

“Hability to control the whole system remotely”

People in PowerMatching City

FAMILY 5 MEMBERS
Pouwla (Housewife)

"We are more aware of our energy use: Computer, lamps, shower"

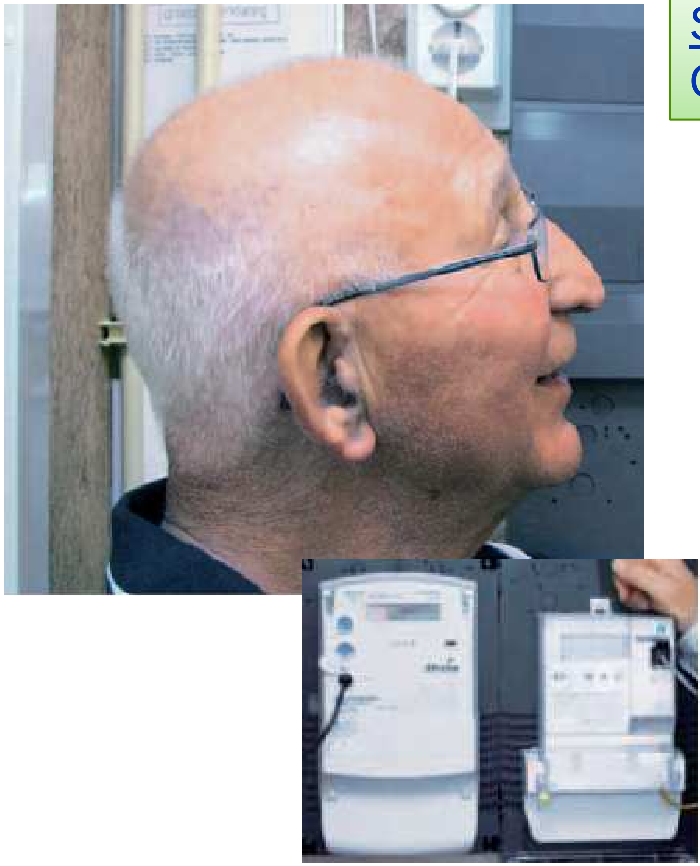
"Despite the constant demand the system is performing well"

"Gas consumption increase while electricity requirements has fallen 50%"

"The thermostat for the central heating cannot work as a timer"

"It just does work"

People in PowerMatching City



<u>SINGLE APARTMENT</u>
Geert (pensioner)

"Energy bill remains about the same"

"I do a wash tiwice a week, on Sunday, because electricity is cheaper"

"He now uses more electricity than in the past. Gas usage decrease"

"It just does work"

Making the Smart Grid real:
Smart Grid Interop Lab (SGIL)

Overview: DNV KEMA created the Smart Grid Interoperability Lab (SGIL), one of the first in the United States. The initial lab is co-located at the Duke Energy Envision Center in Erlanger, KY and at the existing DNV KEMA –Powertest lab in Chalfont, PA.

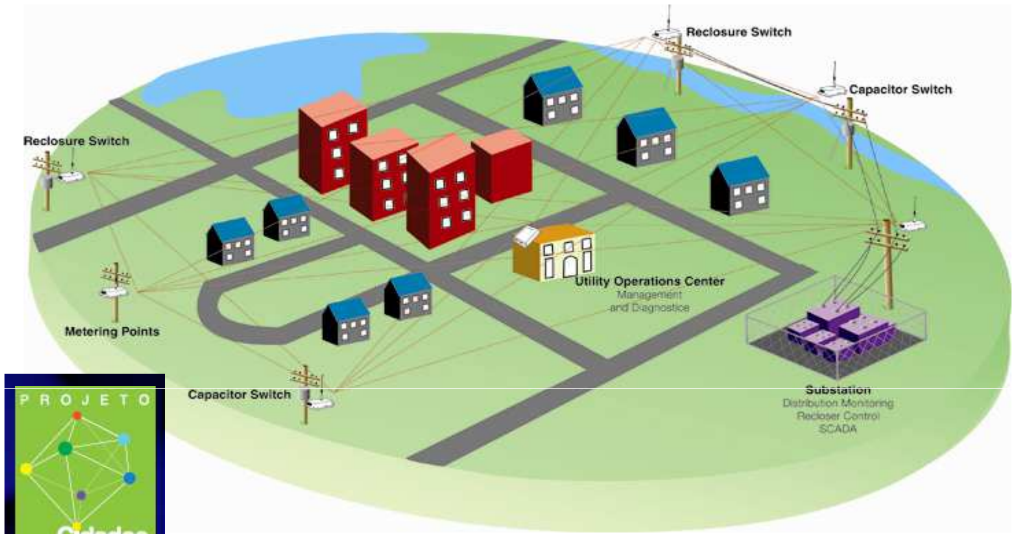
- **Location:** Erlanger, Kentucky, and Chalfont, Pennsylvania, United States
- **Challenges:** Supplement ongoing industry demonstration projects to understand and resolve risks of scaling smart grid networks.
- **Results to date:** Testing can be performed by utilities based on their smart grid designs – use cases that will be exercised in the real world.

Making the Smart Grid real:
The US Navy Advanced Metering Infrastructure

Overview: The AMI project uses the “Navy’s Public Safety Network (PSNet),” a very secure network that can transmit data between the regions in a timely, reliable way, using the advanced Multiprotocol Label Switching (MPLS) technology. Inside each base, the communication network to transmit data from meters to the DAS (the local area network) is designed as a hybrid network of wired and wireless solutions, considering a number of factors such as: security, safety near ordnance, line of sight, available infrastructure, etc.

- **Location:** Worldwide
- **Size:** 120 naval bases in 10 Navy regions around the world
- **Participants:** U.S. Navy, DNV KEMA, URS, American Systems, Square D (Schneider Electric), Weston Solutions
- **Challenges:** Metering practices and electric service standards with naval regions; Dealing with 100+ utilities; DoD’s security and safety rules and regulations; DoD’s requirements on information assurance; Avoiding power outages and wireless interference with activities; Navy’s requirements to save energy.
- **Results to date:** Deployment of AMI projects have been awarded to three multi-award contract (MAC) contractors in six naval regions. Installation of meters and communication networks has also begun in most of these regions, while additional projects in are scheduled for the current and next fiscal year.

Making the Smart Grid real:
Cemig's Cities of the Future

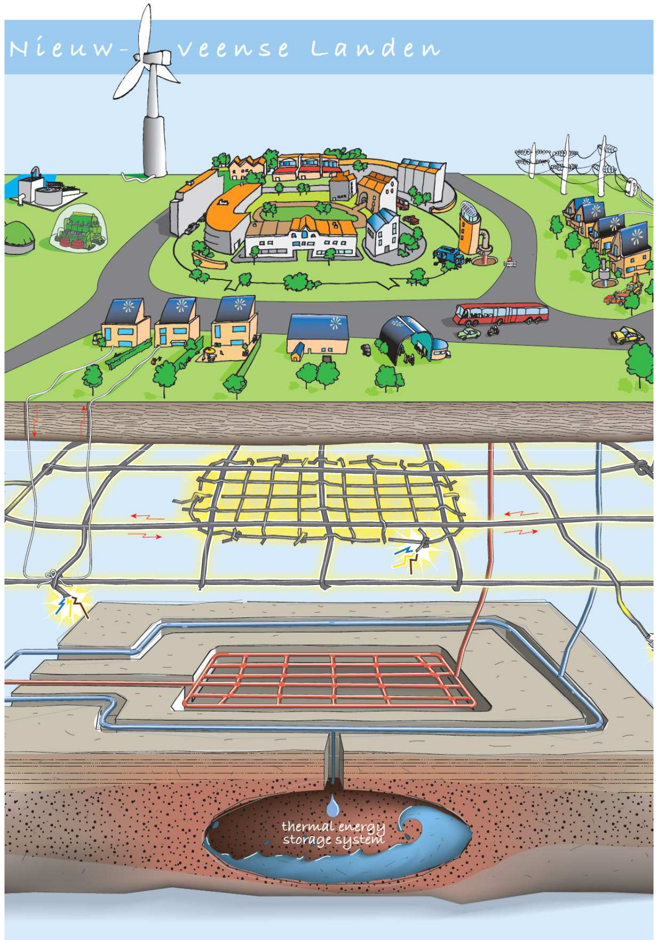


PROJETO Cidades do Futuro CEMIG Sete Lagoas

Overview: Smart grid architectural scope includes Smart metering; Substation automation; Distribution automation; Advanced telecommunications; IT analytical and operational systems; Management and integration of distributed generation

- **Location:** Sete Lagoas, Brazil
- **Size:** Implement a Smart Grid demonstration with ideal size (approx. 75,000 customers)
  - Ideal geographical location (70km north of Belo Horizonte, capital of Minas Gerais state)
  - Technological infrastructure available
  - Collaborative opportunities with local universities and government entities
- **Challenges:** Integrating Renewables, Integrating Gas and Electricity, Consumer Acceptance.

Making the Smart Grid real:
Meppel – Nieuwveense Landen



- **Location:** Meppel, the Netherlands
- **Size:** 3,400 “prosuming” households
- **Participants:** DNV KEMA, Municipality of Meppel, Province of Drenthe, the Reest & Wielden Water Authority, Rendo Duurzaam B.V.
- **Challenges:** Neighborhood-level energy balance; Living in a “pleasantly sustainable manner;” Increased comfort level; Heat and cold storage; Micro-CHP on bio-gas.
- **Results to date:** Niewveense Landen designated as icon project by Dutch Ministry of Infrastructure and Environment; Plans developed; Base case shown to be technically feasible; Currently in decision-making stage.

One form of promoting the smart grid concept is being pursued through Duke Energy's UoF demonstration center

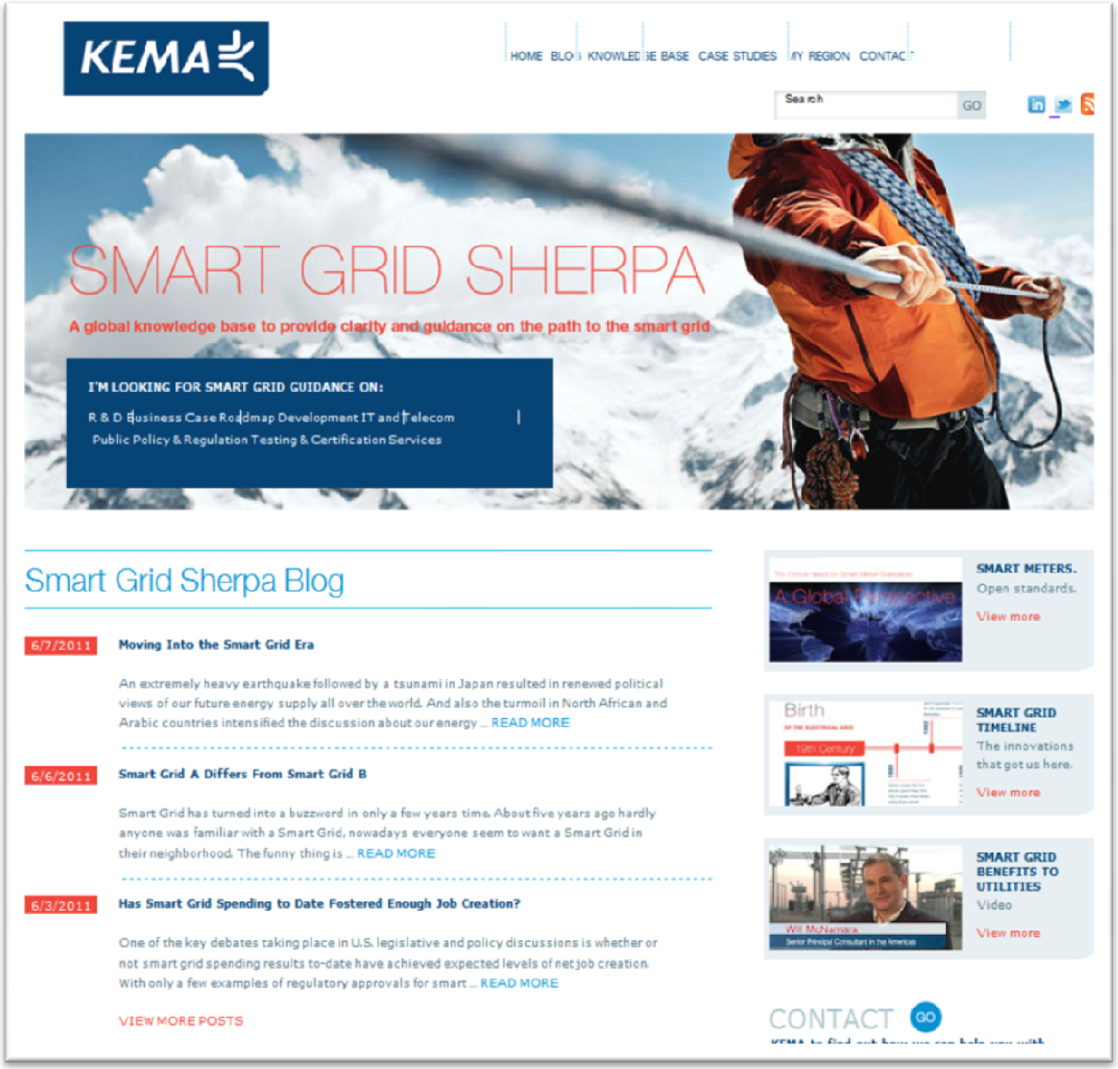
Envision Center

- Cincinnati-based, technology demonstration center that showcases features and benefits of the "Utility of the Future" to various stakeholder groups
- Demonstrates key components of the smart grid vision and how it operates
- Integrates the work at the center with related promotional, educational and marketing activities targeted for various stakeholder groups

KEMA is pleased to be Duke's exclusive partner in designing and operating Envision as the premier smart grid demonstration center in the world

Duke Energy

Please join us in the conversation



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