Microgrids: The secret to unlock the power of distributed energy resources

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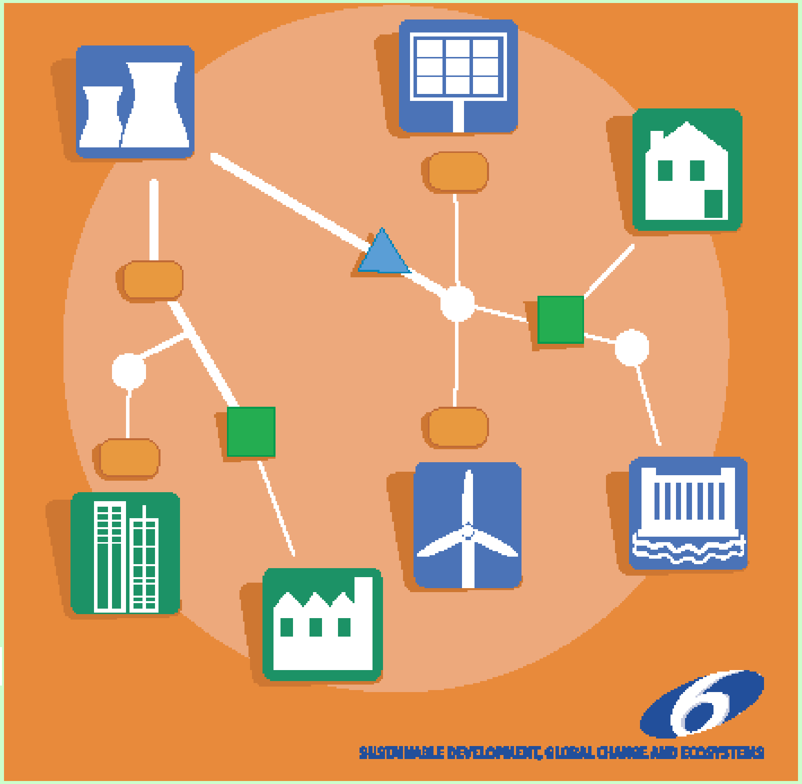
The EU concept of “Smart Power Networks”

- “Smart” coexistence of central and decentralised generation with lower carbon generation and efficient demand/response
- Load trading and cost optimisation by means of dialog towards time-variable tariffs and variable incentives depending on present load
- Customer integration based on bi-directional communication and large flow of information



Micro CHP in the Netherlands

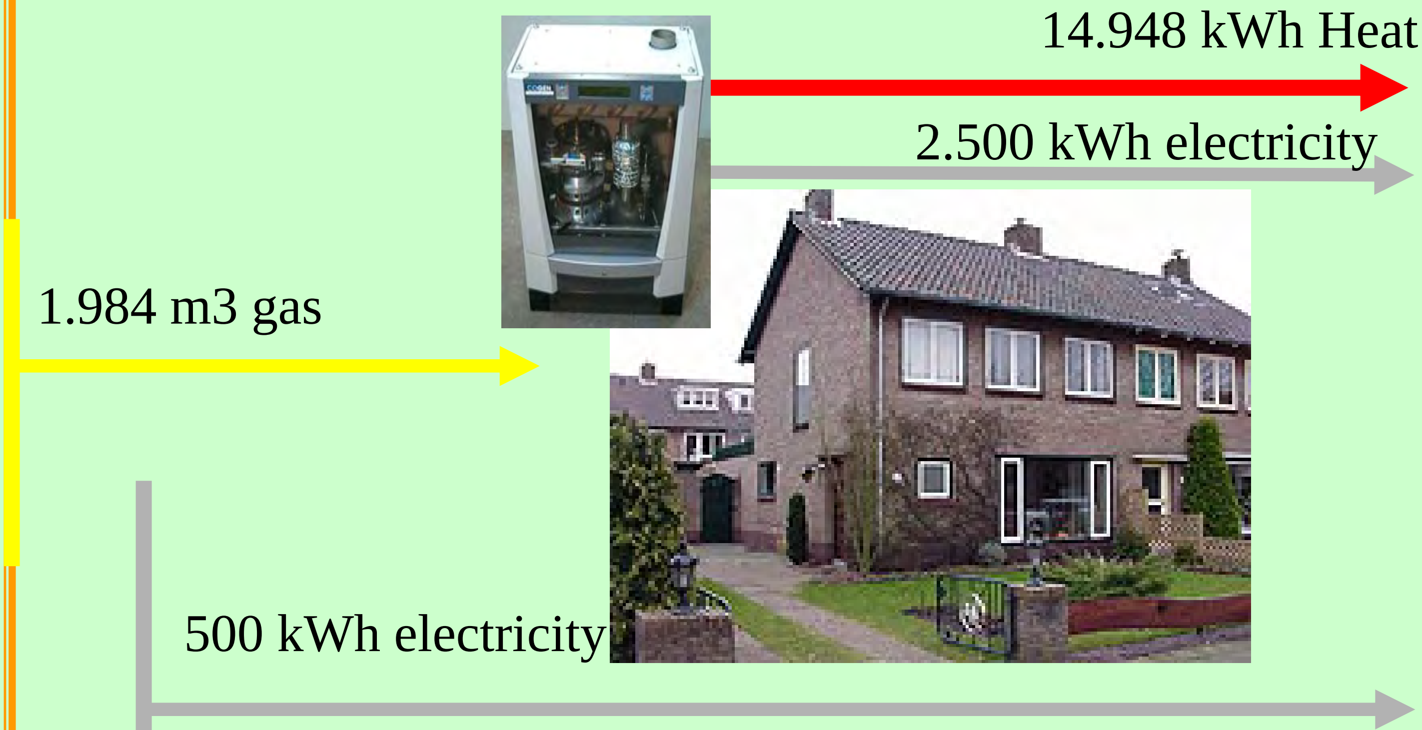
Average Annual Energy Consumption Dutch Households

1.700 m3 gas eq. 14.948 kWh heat

3.000 kWh electricity

Essent Micro CHP
Field Test

Expected Average Annual Energy Consumption Dutch Households with Micro CHP



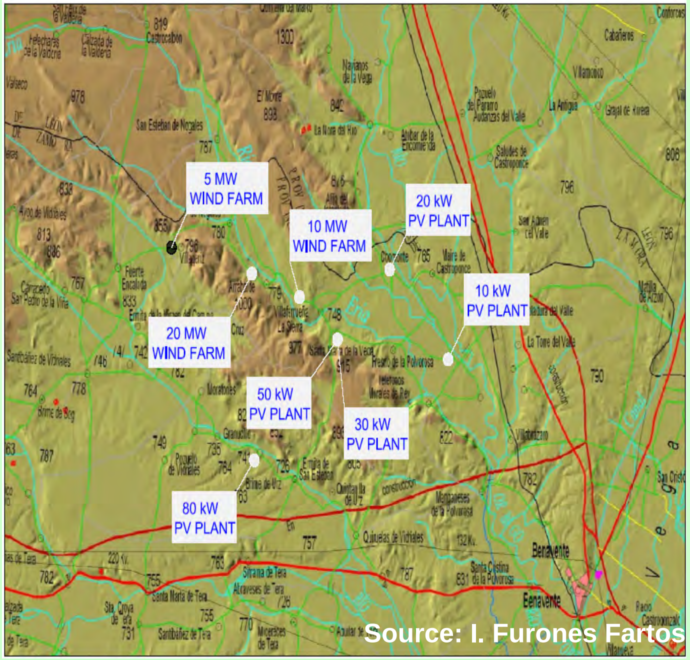
Conclusions:

- decreased electricity supply of 2.500 kWh
- increased gas supply of 284 m3 gas, to produce 2.500 kWh electricity
- electricity generation efficiency of 90%

Two European examples: Increasing distributed generation in LV and MV grids

Over 100 power plants in
residential, commercial and industrial grids

City of Mannheim (Germany) as of July 2005



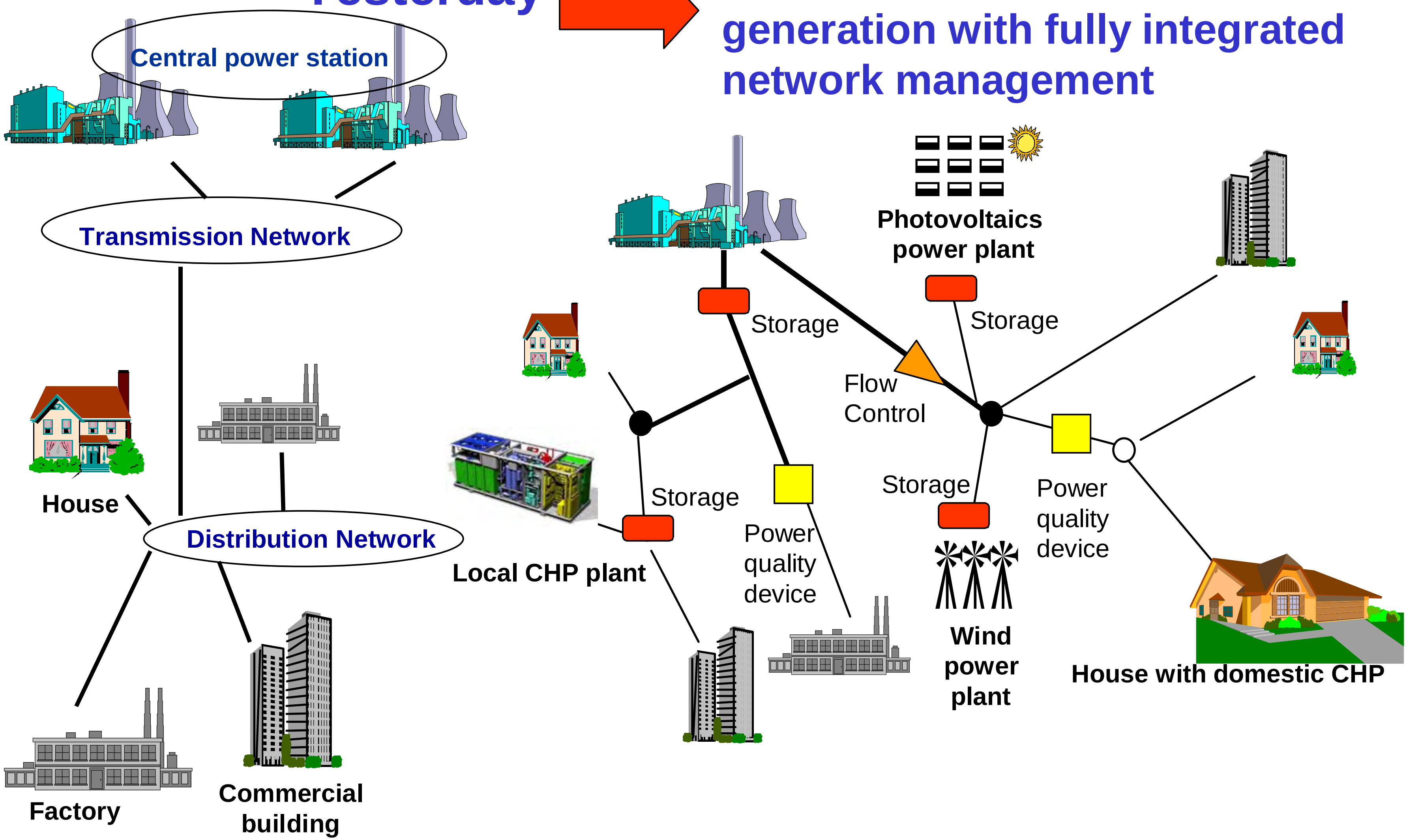
Over 60 small and medium PV Plants in
residential, commercial and industrial grids

Region of Benavente (Zamora, Spain)
as of September 2005

The vision.....

Yesterday

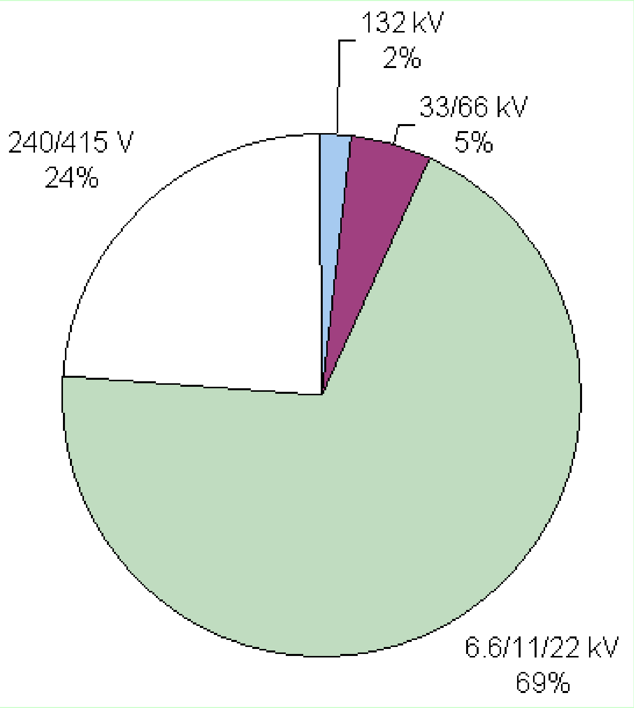
Tomorrow: distributed/ on-site generation with fully integrated network management



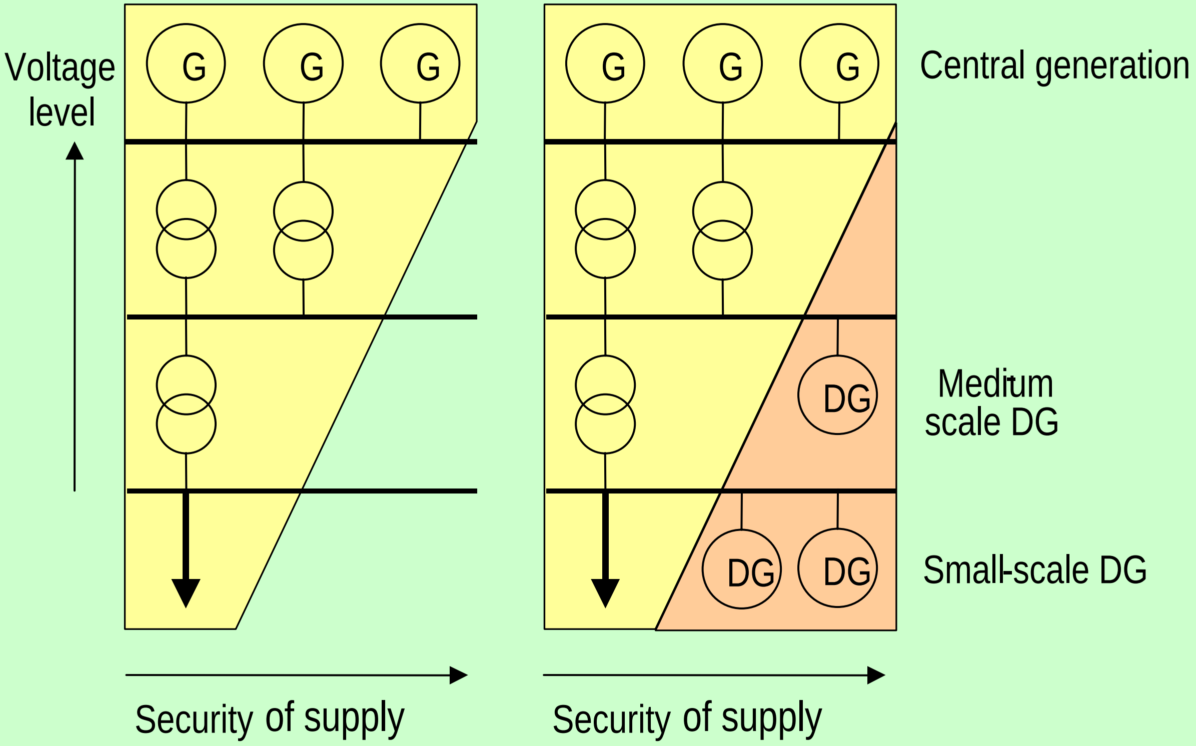
Technical, economic and environmental benefits

- Energy efficiency
- Minimisation of the overall energy consumption
- Improved environmental impact
- Improvement of energy system reliability and resilience
- Network benefits
- Cost efficient electricity infrastructure replacement strategies
- *Cost benefit assessment*

Potential for DG to improve service quality

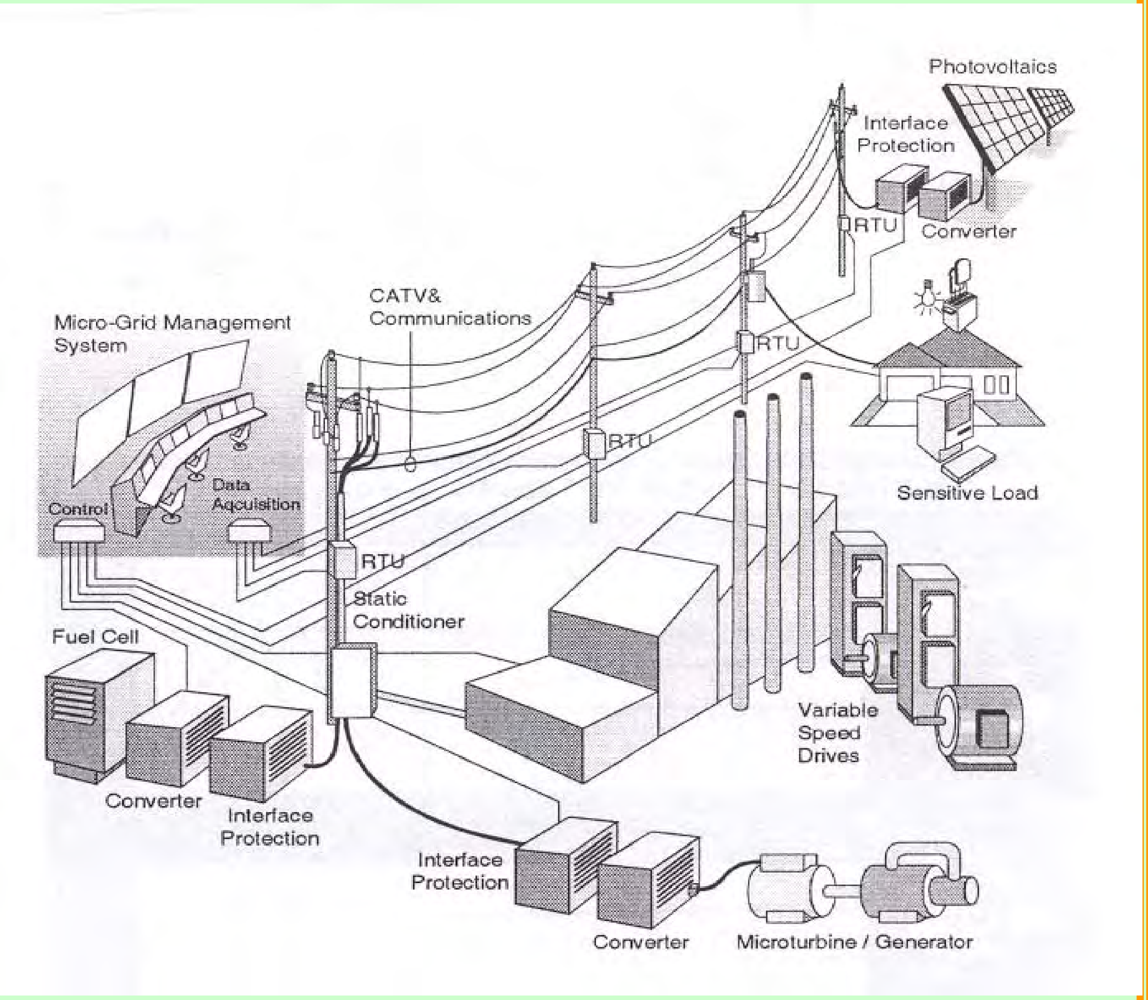


Distribution of CMLs



What are MICROGRIDS?

Interconnection of small, modular generation to low voltage distribution systems forms a new type of power system, **the Microgrid**.
Microgrids can be connected to the main power network or be operated **islanded**, in a **coordinated, controlled** way.



Technical Challenges for Microgrids

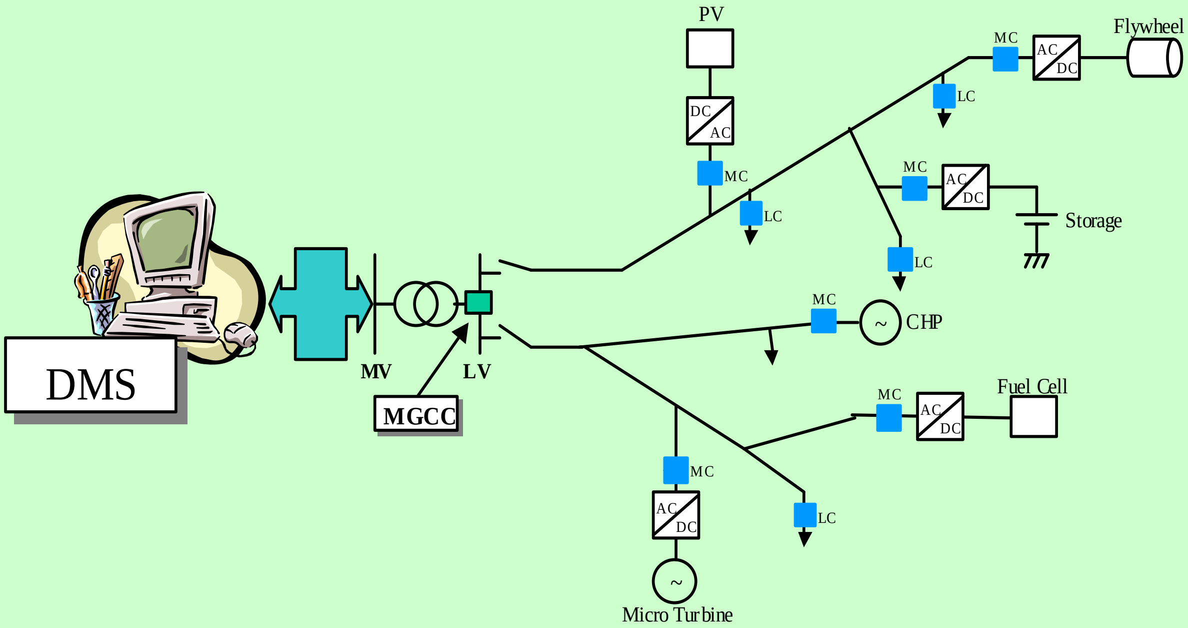
- Relatively large imbalances between load and generation to be managed (significant load participation required, need for new technologies, review of the boundaries of microgrids)
- Specific network characteristics (strong interaction between active and reactive power, control and market implications)
- Small size (challenging management)
- Use of different generation technologies (prime movers)
- Presence of power electronic interfaces
- Protection and Safety

Market and Regulatory Challenges

- coordinated but decentralised energy trading and management
- market mechanisms to ensure efficient, fair and secure supply and demand balancing
- development of islanded and interconnected price-based energy and ancillary services arrangements for congestion management
- secure and open access to the network and efficient allocation of network costs
- alternative ownership structures, energy service providers
- new roles and responsibilities of supply company, distribution company, and consumer/customer

Microgrids – Hierarchical Control

MicroGrid Central Controller (MGCC) promotes technical and economical operation, interface with loads and micro sources and **DMS;** provides set points or supervises LC and MC; **MC and LC Controllers**: interfaces to control interruptible loads and micro sources

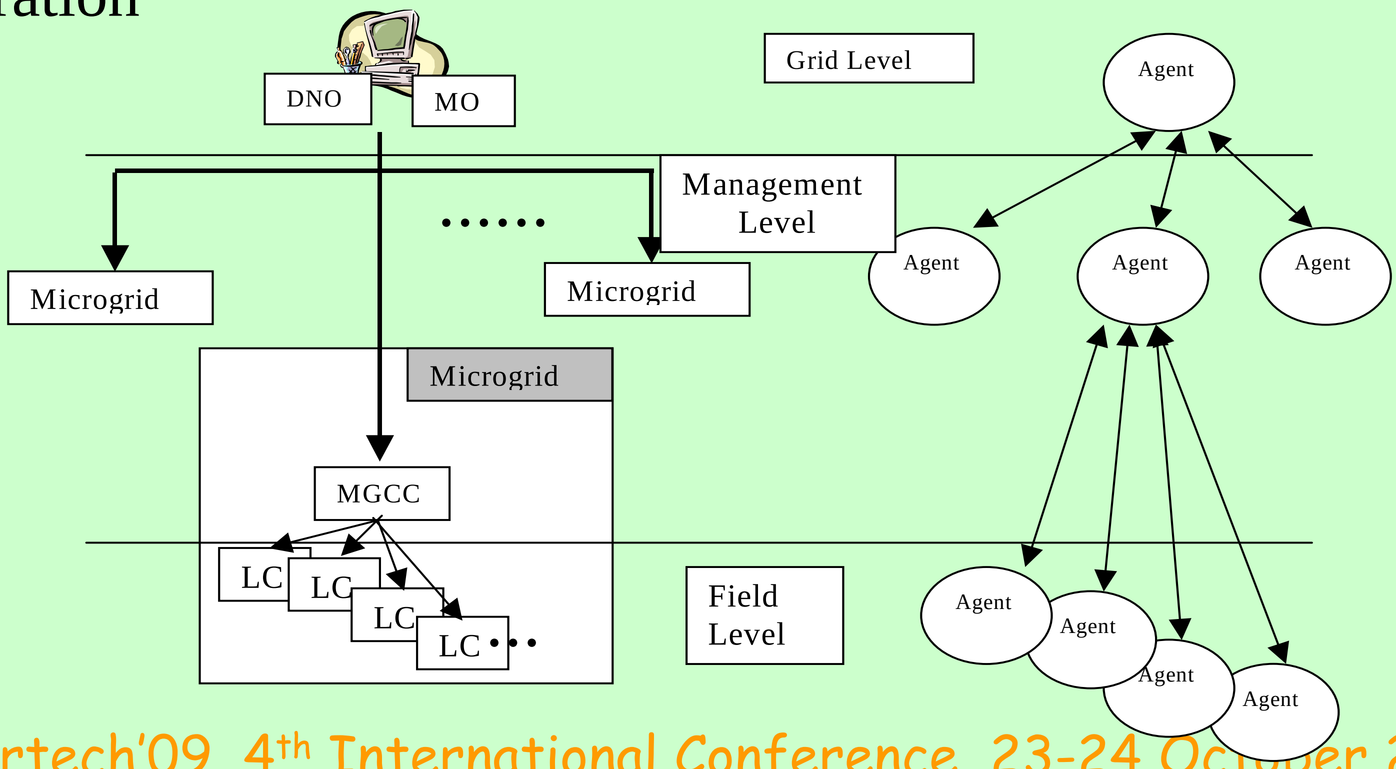


Centralized vs. Decentralized Control

MultiAgent System for Microgrids

- Autonomous Local Controllers
- Distributed Intelligence
- Reduced communication needs
- Open Architecture, Plug n' Play operation

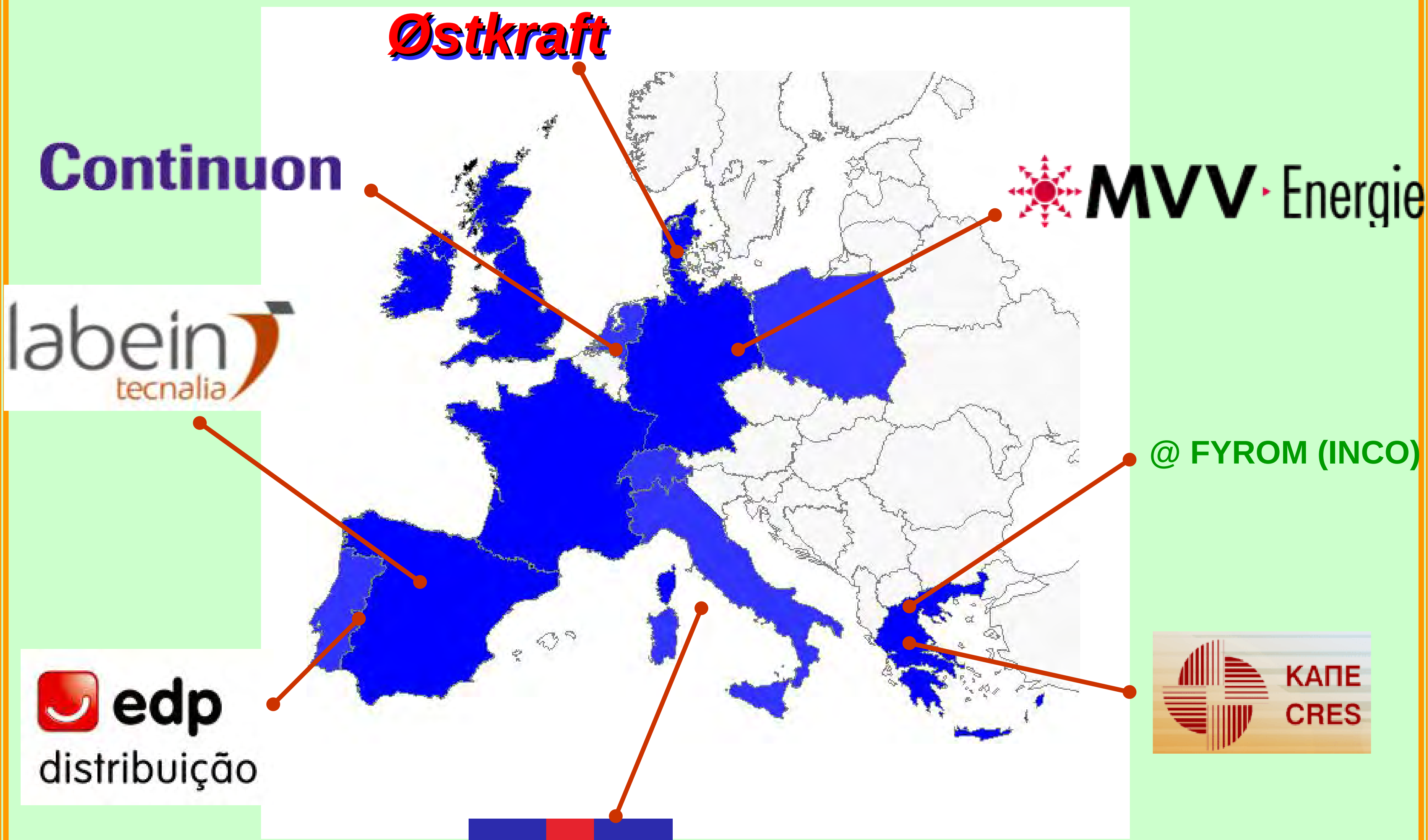
- FIPA organization
- Java Based Platforms
- Agent Communication Language



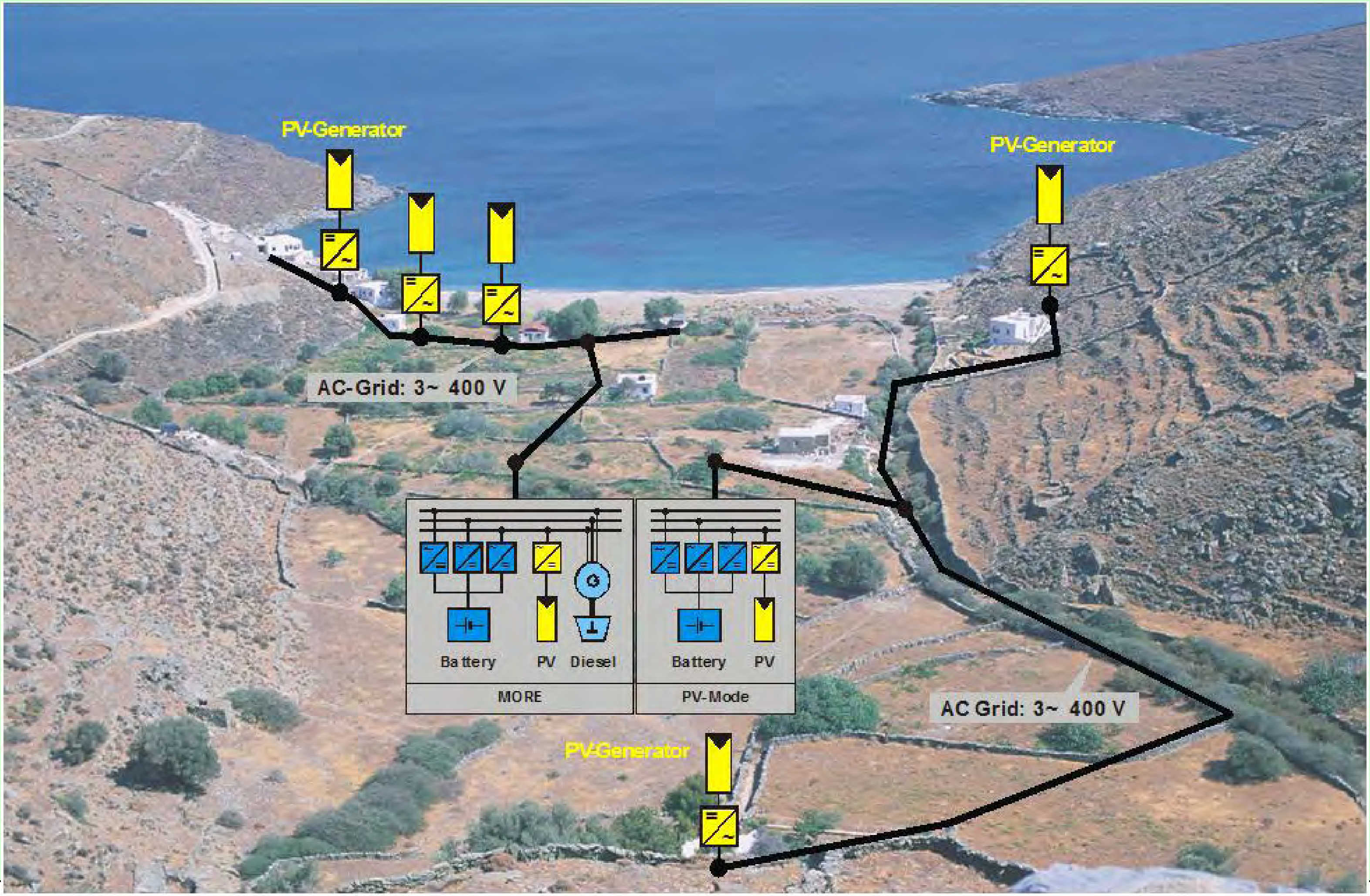
MORE MICROGRIDS Project

Budget: 8M€

Eight Pilot Microgrids



Kythnos (Gaidouromandra) Microgrid



Supply of 12 buildings (EC projects MORE and PV-Mode)

Typical House

Systems added:

Next generation Sunny Island inverters, to deal with islanded mode control

Intelligent Load Controllers

The test site is a small settlement of 12 houses

Generation:

5 PV units connected via standard grid-tied inverters. A 9 kVA diesel genset (for back-up).

Storage:

Battery (60 Volt, 52 kWh) through 3 bi-directional inverters operating in parallel.

Monitoring: Data logging equipment

The Kythnos System House

Experiment Goals

- Test decentralized control in a real environment with the aim to increase energy efficiency
- Technical challenges of the Multi Agent System – test negotiation process
- Test novel features in MAS implementation including communication capabilities
- Test of new inverters

The Agent

- Physical entity that acts in the environment or a virtual one
- Partial representation of the environment
- Agents communicate - cooperate with each other
- Agents have a certain level of autonomy
- The agents have a behaviour and tends to satisfy objectives using its resources, skills and services

Reactive

- partial representation of the environment
- autonomy
- possesses skills

Cognitive

- Memory
- Environment Perception
- high level communication

Technical Description

Software

- Java/Jade implementation
- CIM based ontology

Hardware

- Embedded Controller
- Measurements
- Communication
- Control via PLC

Technical

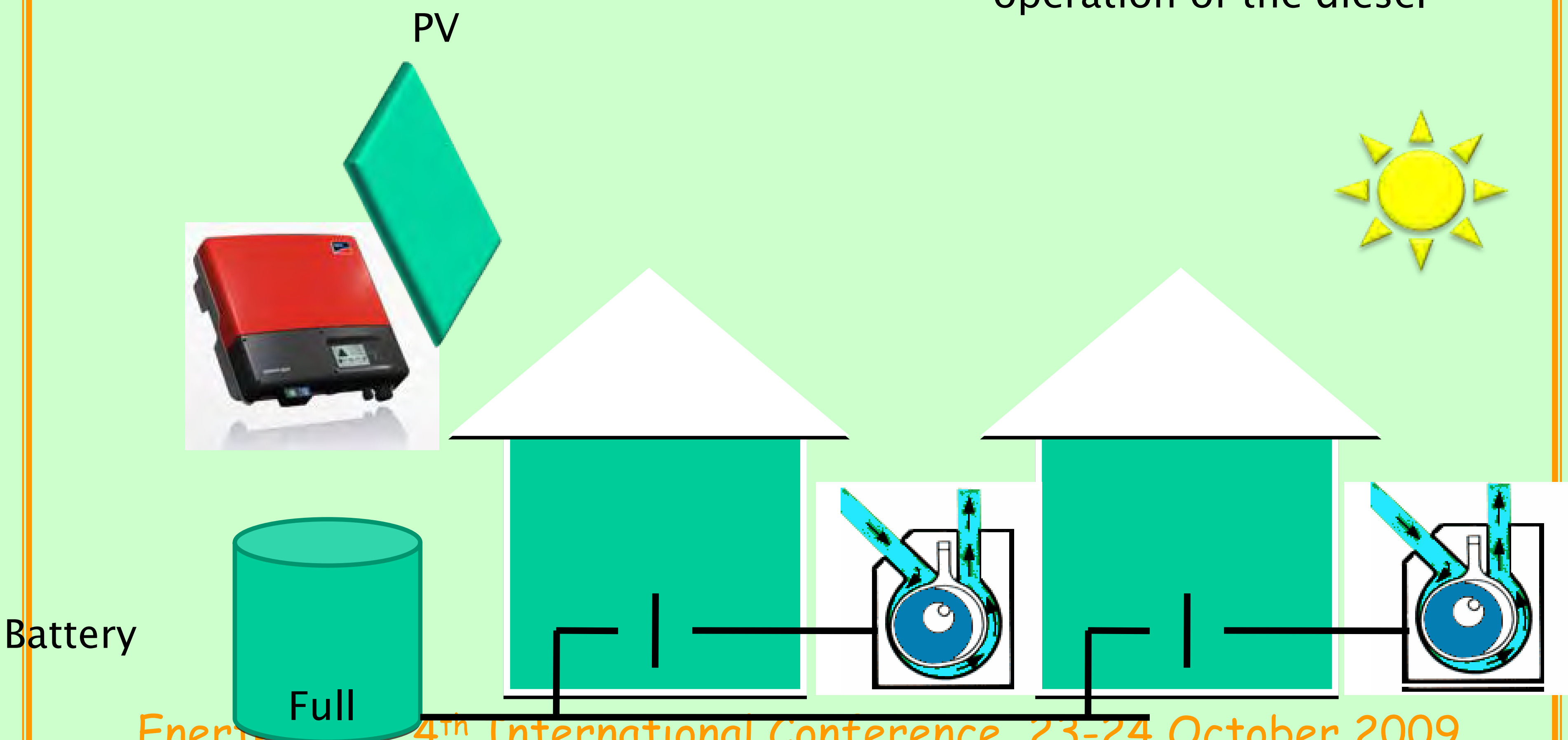
- Implement Distributed Control
- Test in real Environment

Electrical

- Increase energy efficiency
- Manage Non Critical Loads

The general idea:

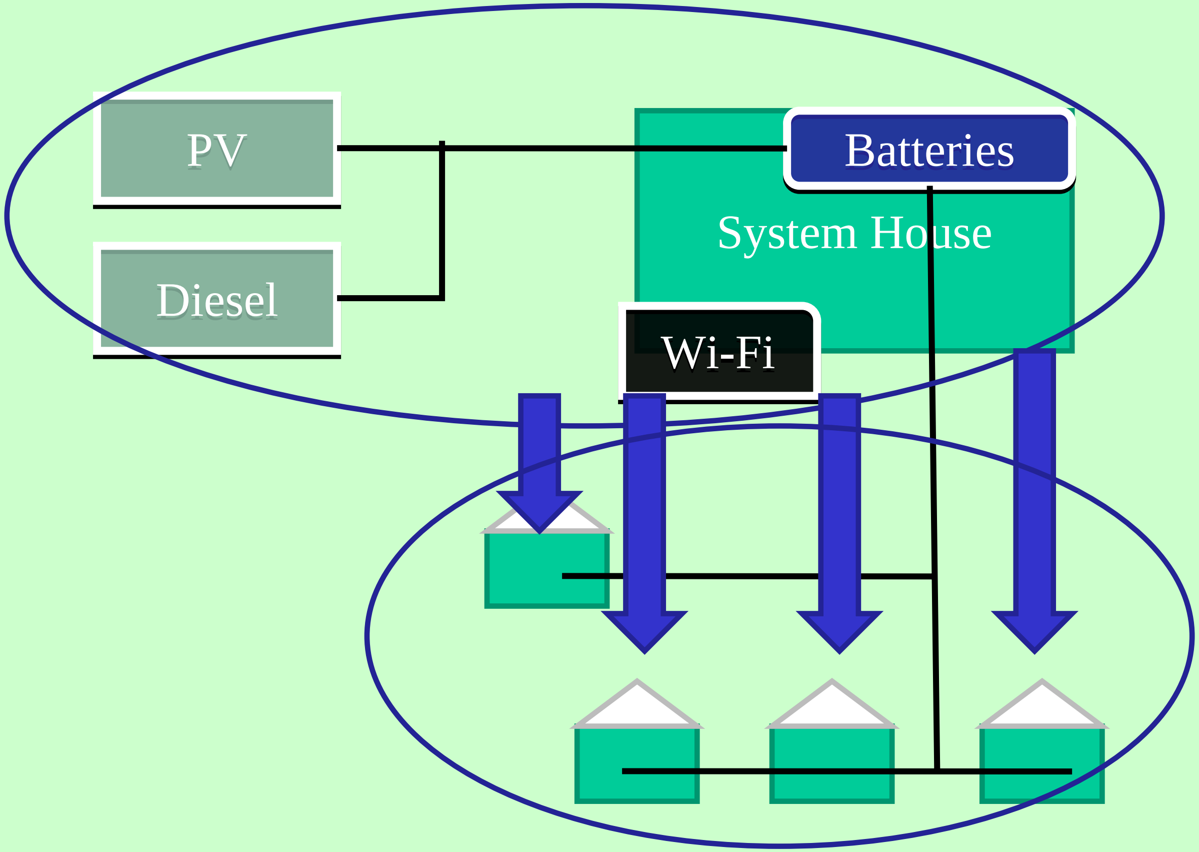
The main load in each house is the water pump. The goal of the system is to optimise the usage of the pumps by limiting the operation of the diesel



The Process of the experiment

Step 1: The agents identify the status of the environment

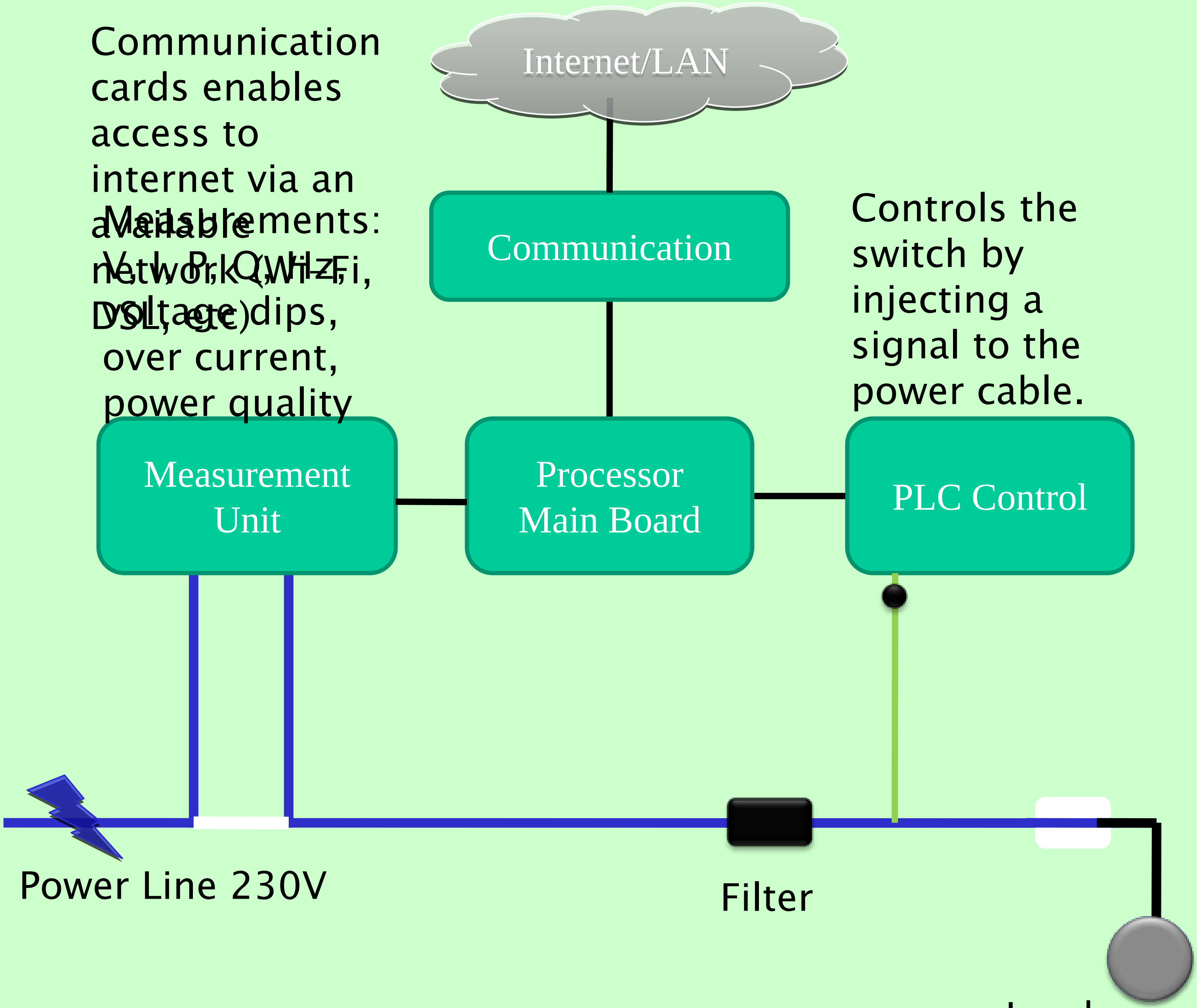
Step 2: The agents negotiate on how the share the available energy



Communication cards enables access to internet via an available network (Wi-Fi, DSL, etc)

Measurements: V, I, P, Q, Hz, voltage dips, over current, power quality

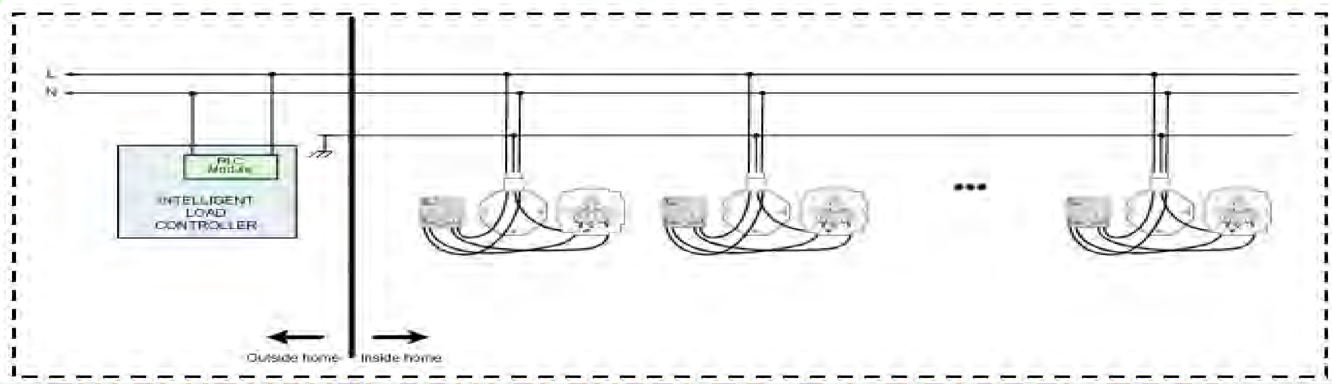
Controls the switch by injecting a signal to the power cable.



Intelligent Load Controllers

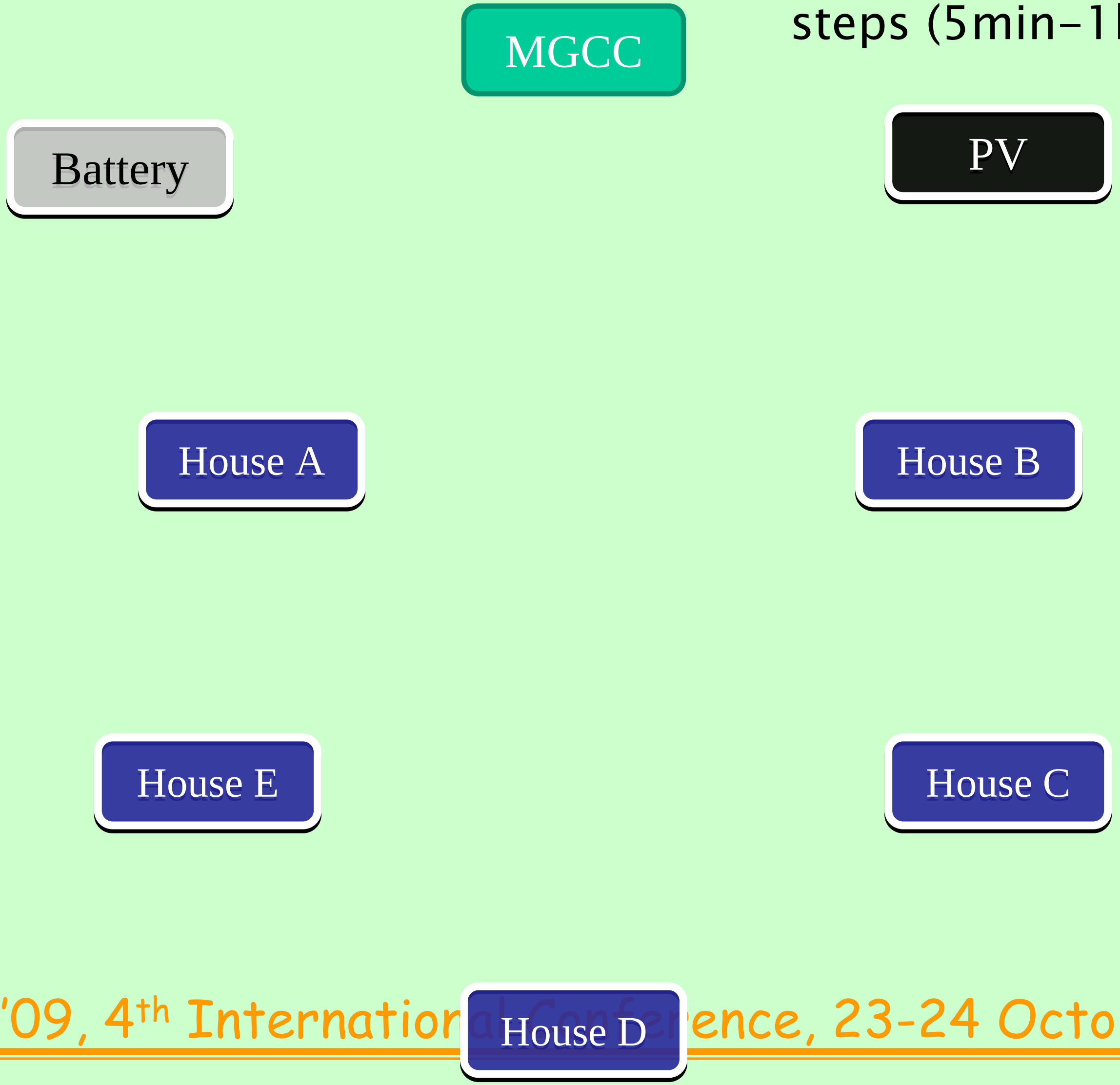
In each house an ILC is installed:

- Windows CE 5.0
- Intel® XscaleTM PXA255
- 64MB of RAM
- 32MB FLASH Memory
- Java VM
- Jade LEAP



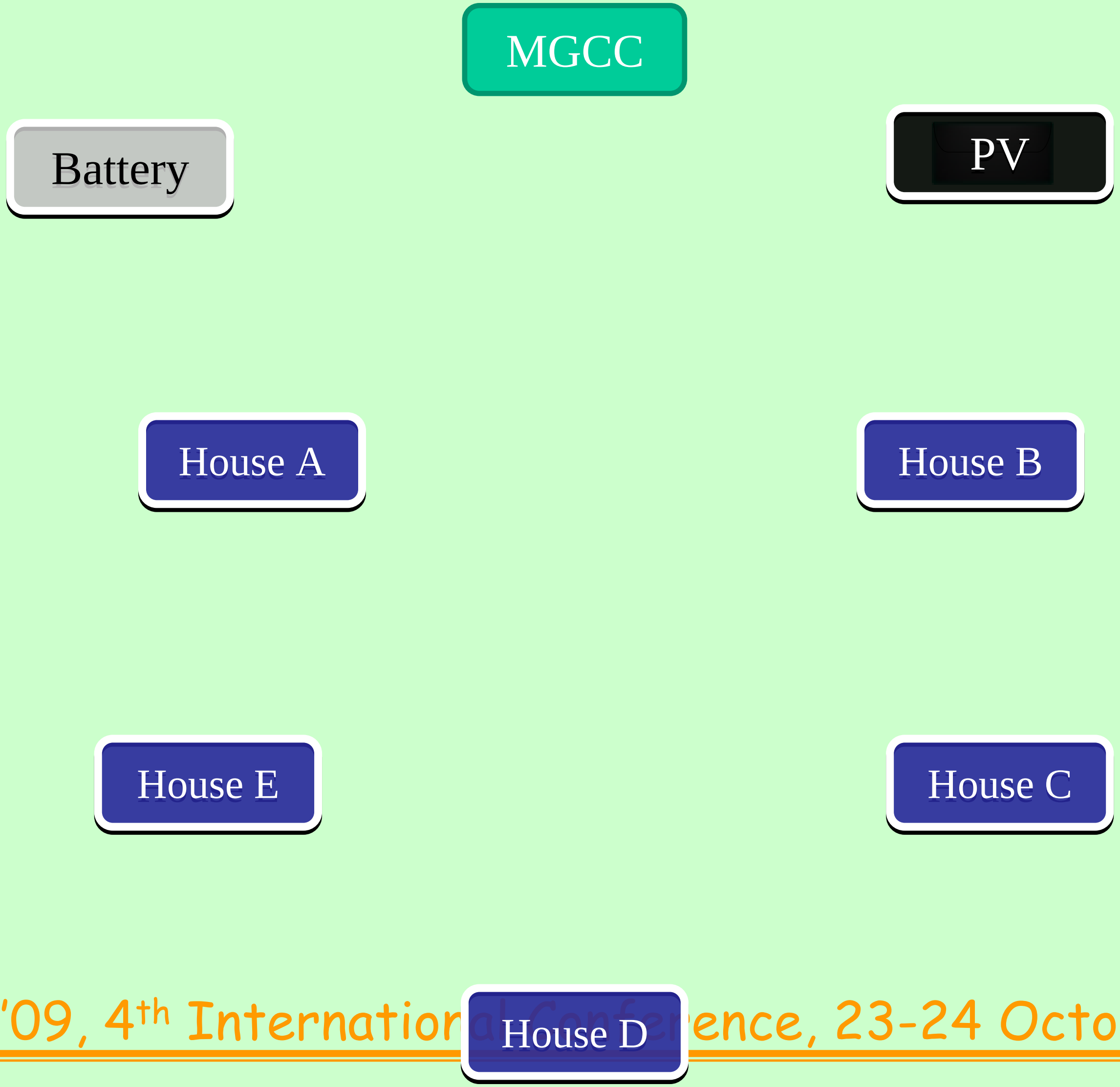
Negotiation

Start Negotiation.
The MGCC orders the system to start a new cycle. This can be done in variable steps (5min-1hour)



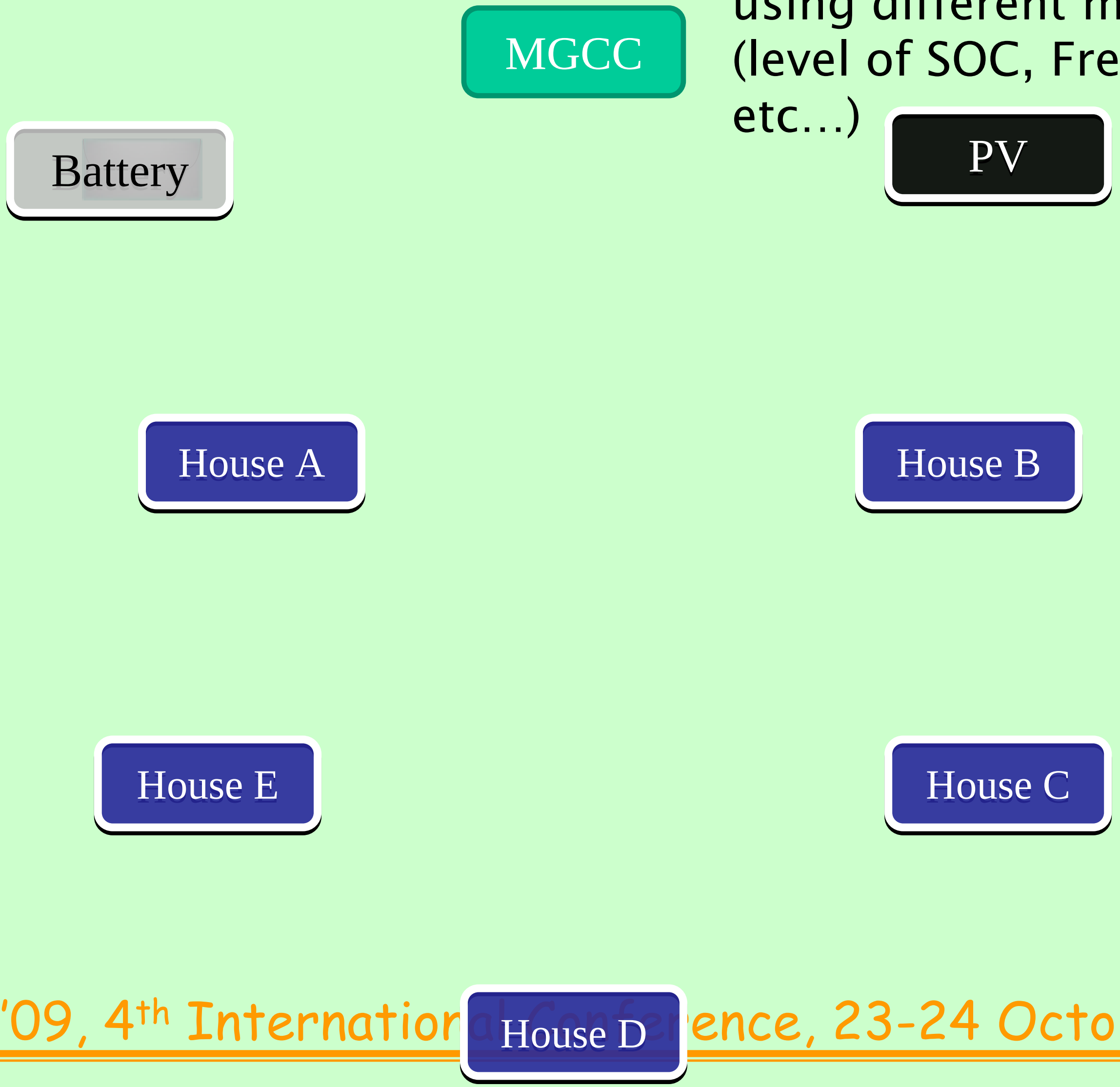
Negotiation

PV agent Announces Production



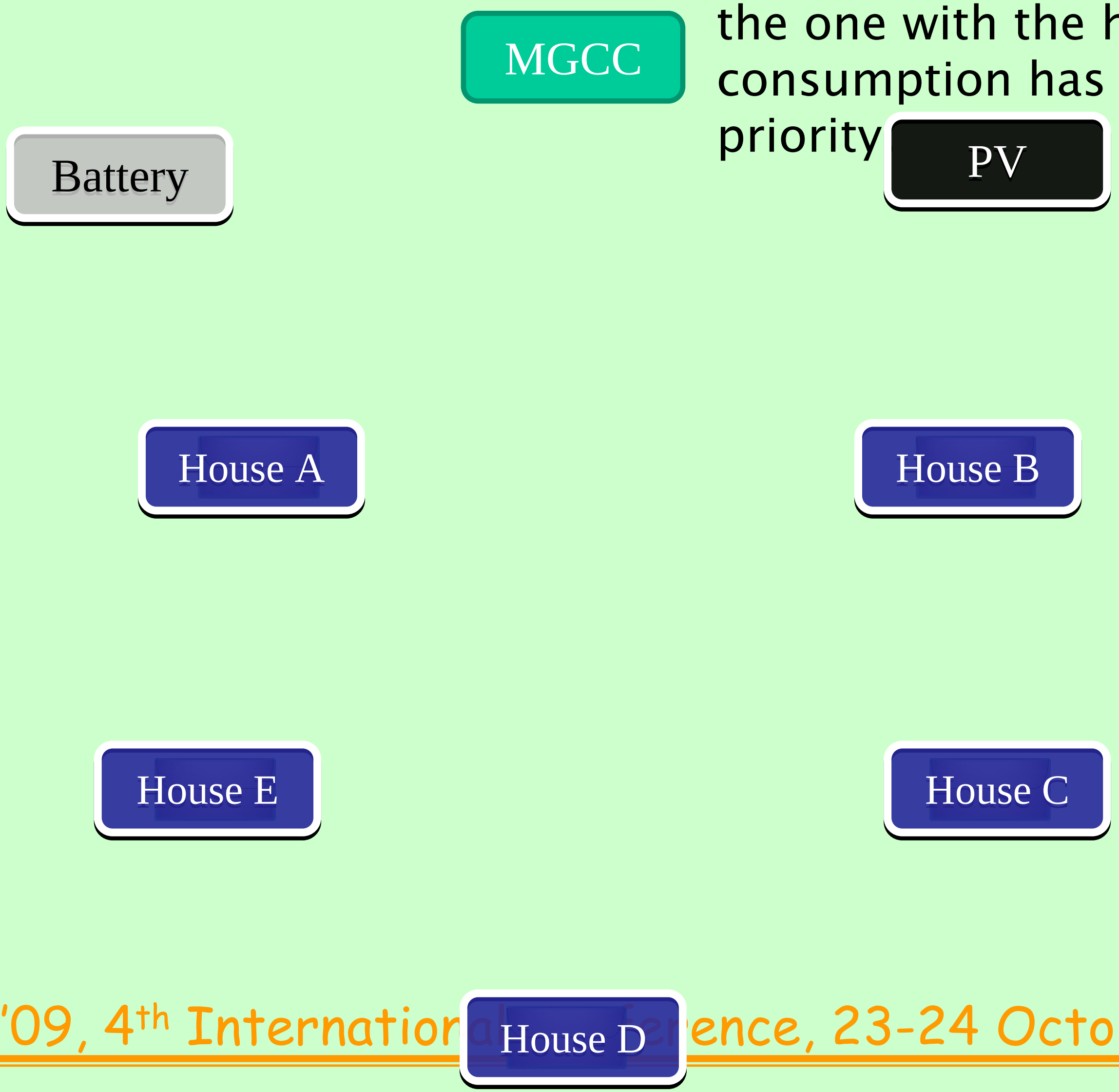
Negotiation

Battery agent Announces Production & SOC.
The estimation of the available energy can be done using different methods (level of SOC, Frequency, etc…)



Negotiation

Agents Start Negotiating. The simple algorithm suggests that agents should consume equally. Therefore the one with the higher consumption has the lower priority

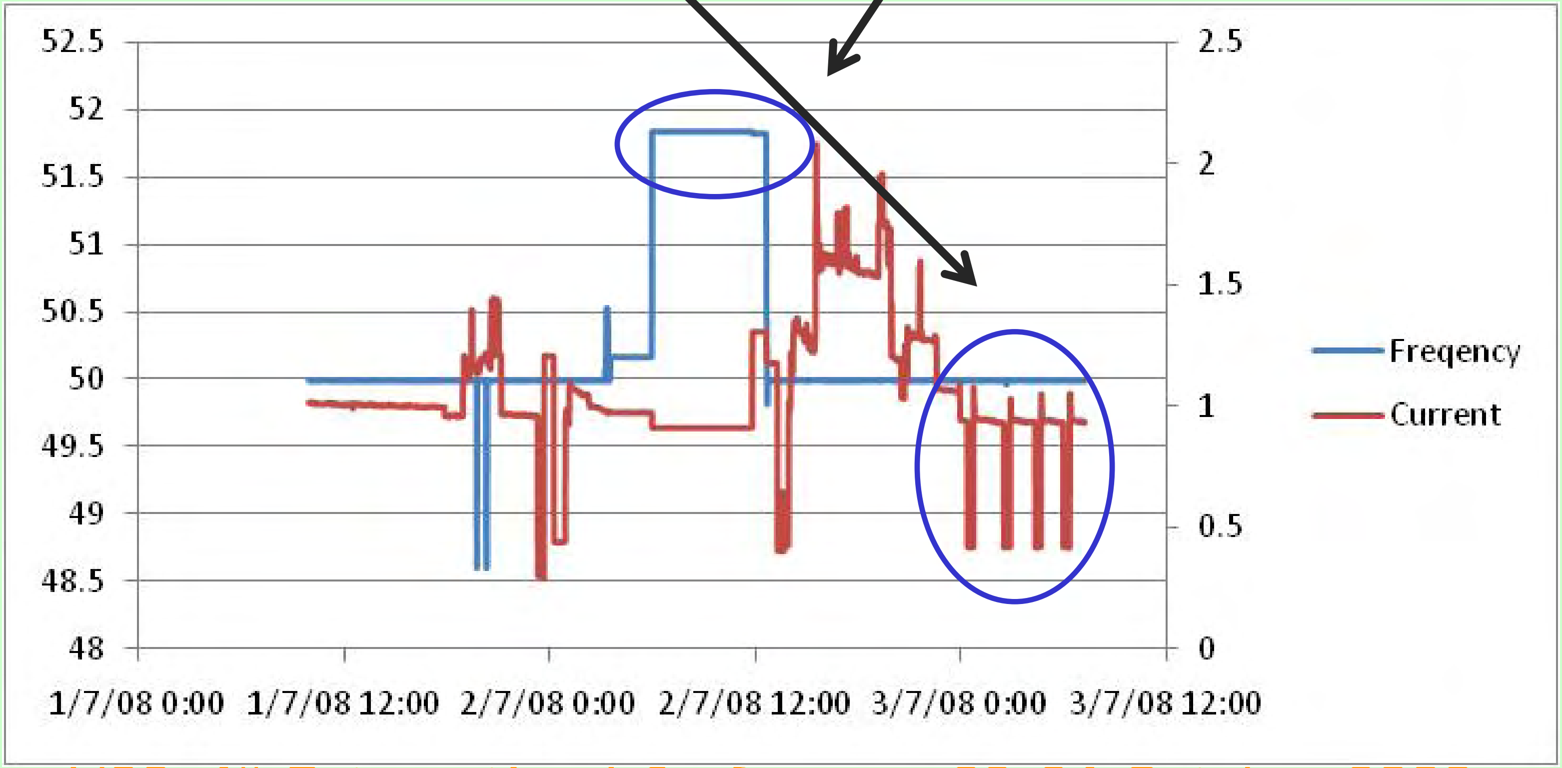


Auction Algorithm: The English Auction

Example

The shedding procedures start later

In this case the frequency if almost 52Hz. This is an indication that the batteries are full and the PV inverters via the droop curves limit their production.



The Kythnos Microgrid

Conclusions

- Microgrids operation – the way to unlock the full benefits of DER in isolated systems. The coordinated operation of several DGs and Loads (Consumers) increases the efficiency and provide opportunities for better network management.

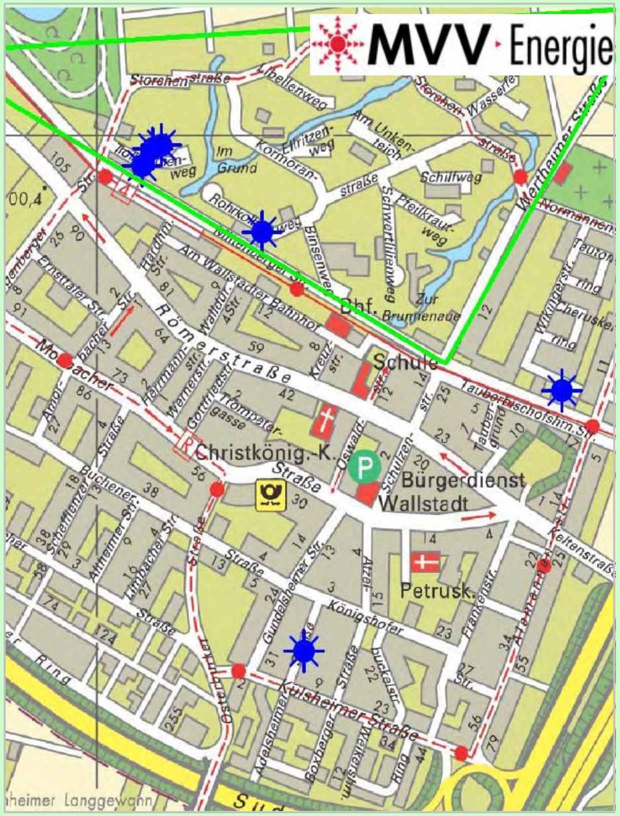
- Decentralized MAS based control well suited to manage multitude of DERs and flexible loads with conflicting objectives and different ownerships

- Decentralized control provides cheap solutions,
with low communication requirements,
without need for central operator

- The solution provides ‘plug and play’ capabilities

- The approach is suitable for large scale systems

Pilot installation: Residential Area „Mannheim-Wallstadt“, Germany



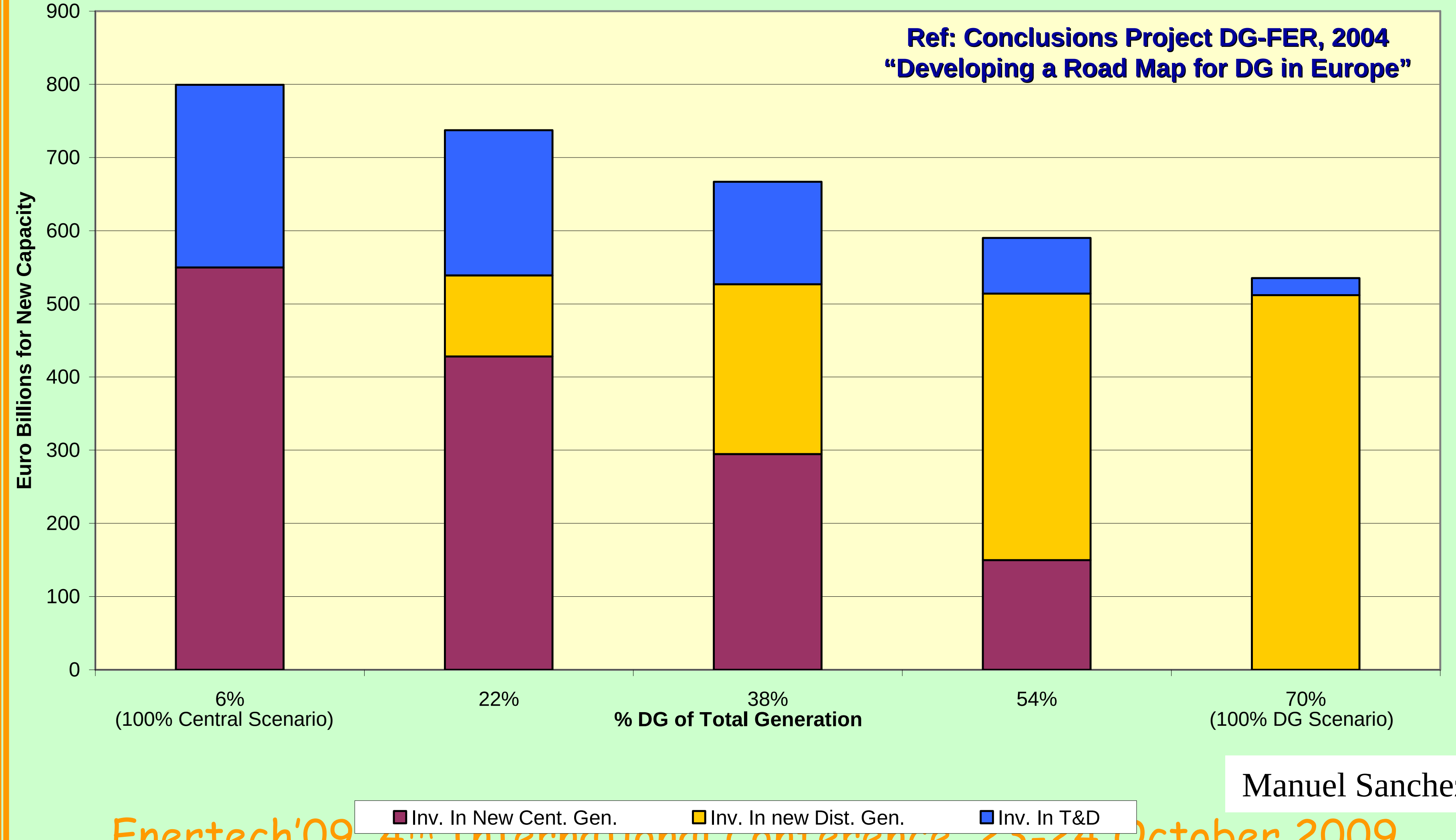
Duration	**Starting August 2006**
Pilot profile	■ **DG capacity el.** **ca. 40 kWp** ■ **DG Technology** **PV, CHP** ■ **Classification** **residential** ■ **Grid Operator** **MVV Energie**
Tasks	■ **Microgrid operation** ■ **Socio-Economic evaluation**

Pilot installation: Bronsbergen Holiday Park, The Netherlands

Duration	**Starting August 2006**
Pilot profile	**DG capacity el.** 315 kWp **DG Technology** PV, storage **Classification** residential, 210 cottages **Grid Operator** Continuon
Tasks	▪ **Islanded operation, automatic isolation and reconnection** ▪ **Harmonic voltage distortion** ▪ **Energy management and lifetime optimization of storage system** ▪ **Black start**

Thank you!

Capital Cost to Supply 2020 Electric Load Growth



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