# Control agents for real Microgrids

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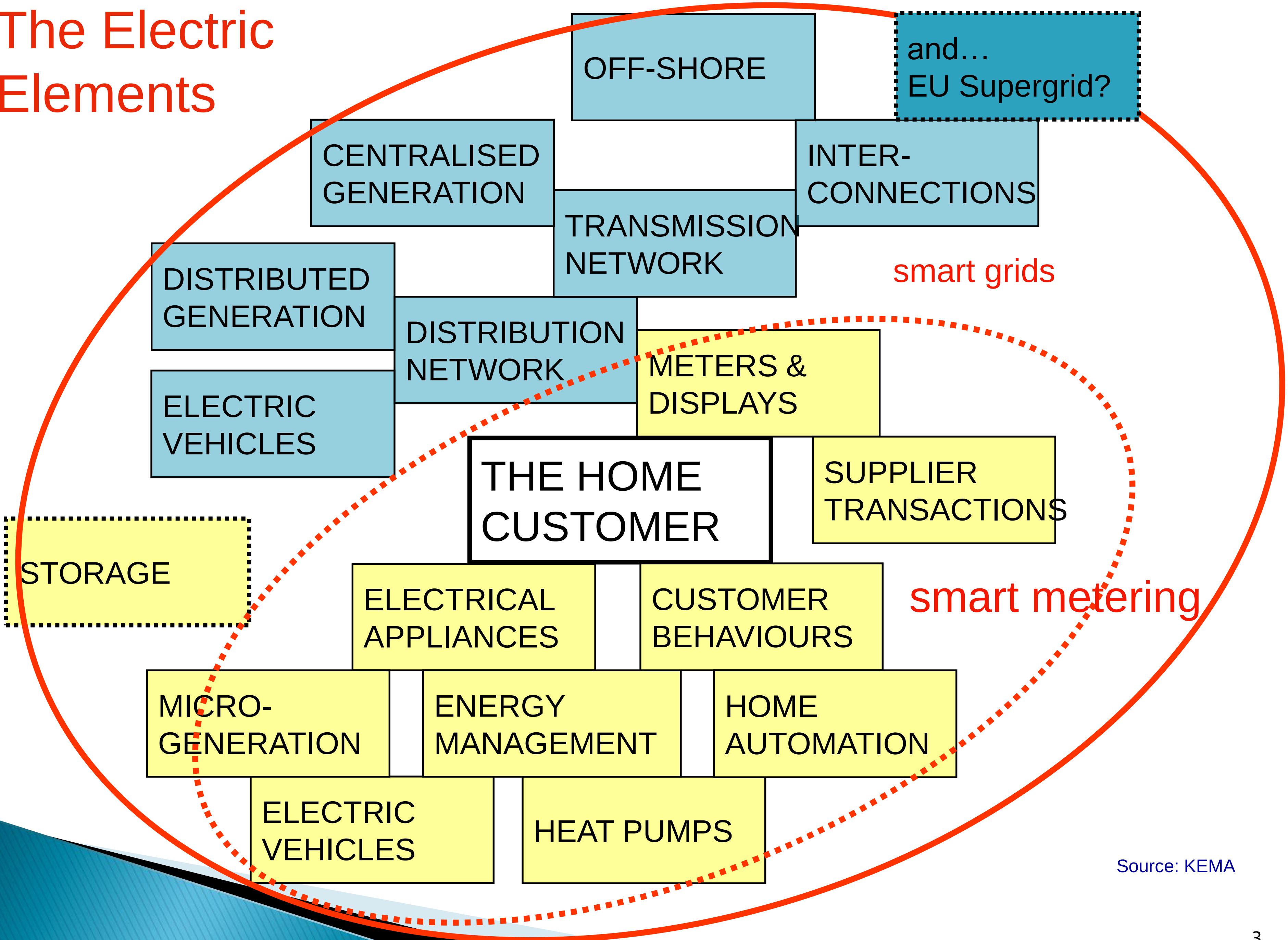
# Outline

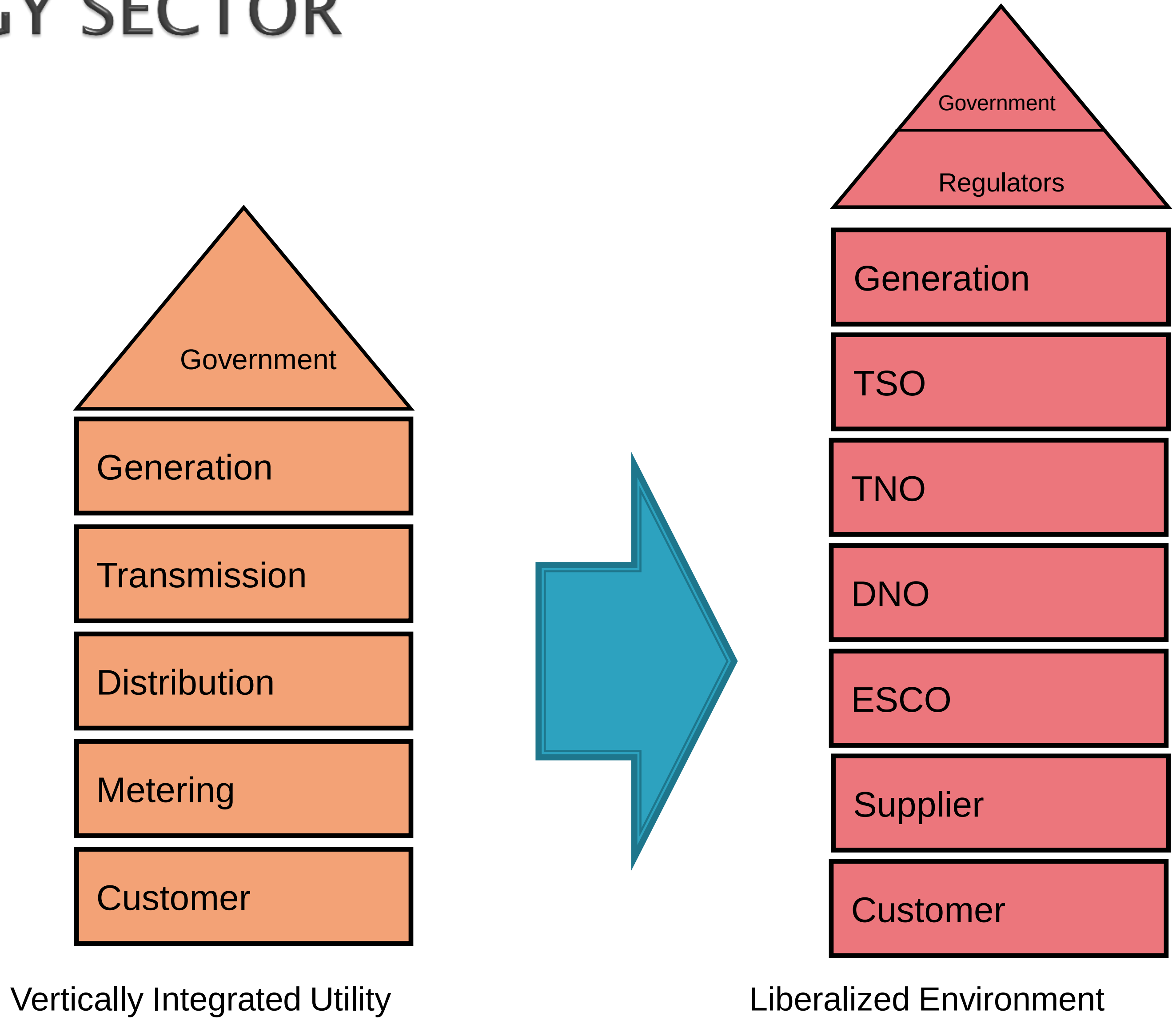
- Introduction– Smart Grids
- Advanced architectures and control concepts for more Microgrids
- Development of alternative control strategies

# The Electric Elements



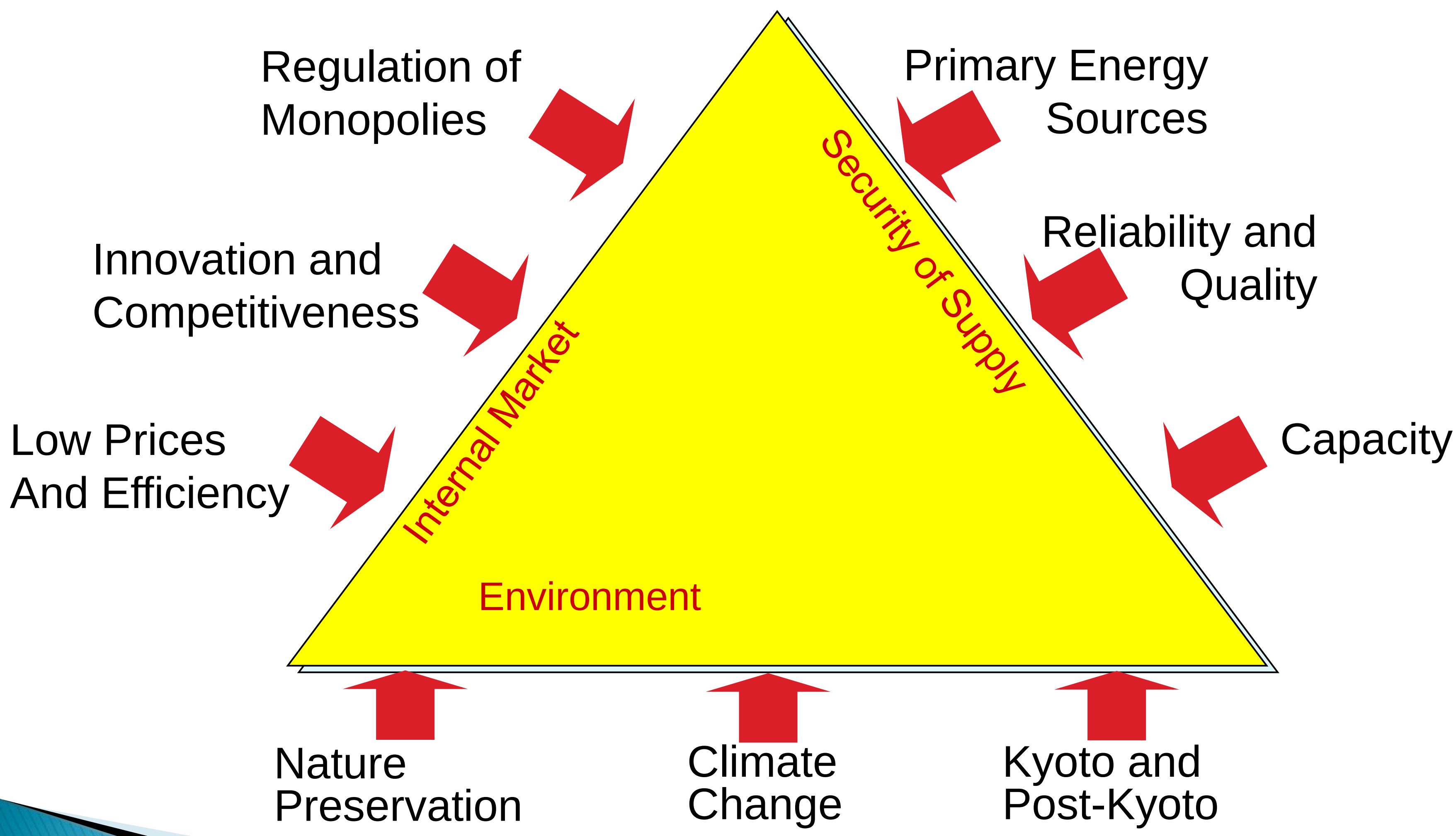

Source: KEMA

# ENERGY SECTOR

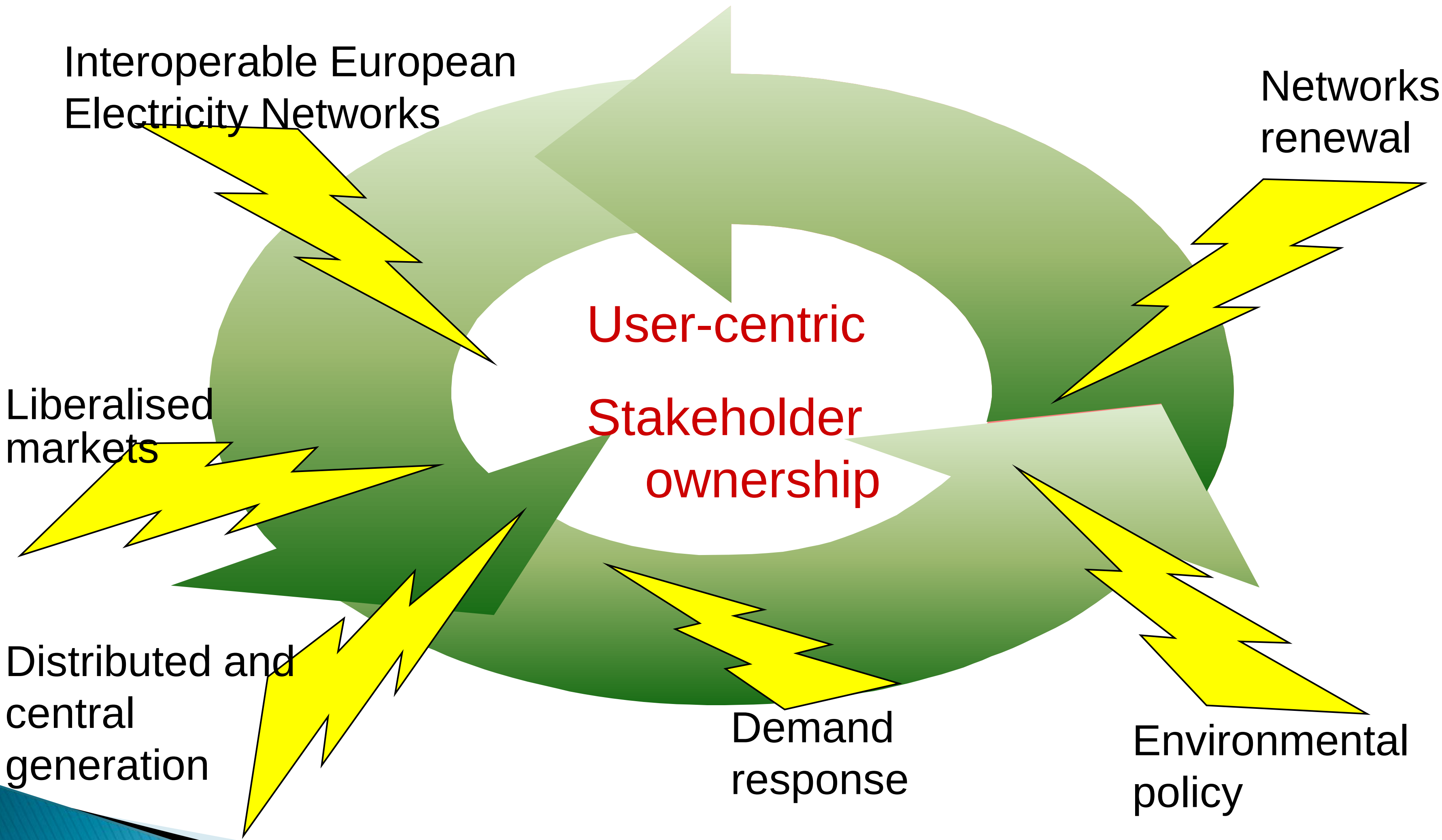


# The Vision

# Drivers towards SmartGrids



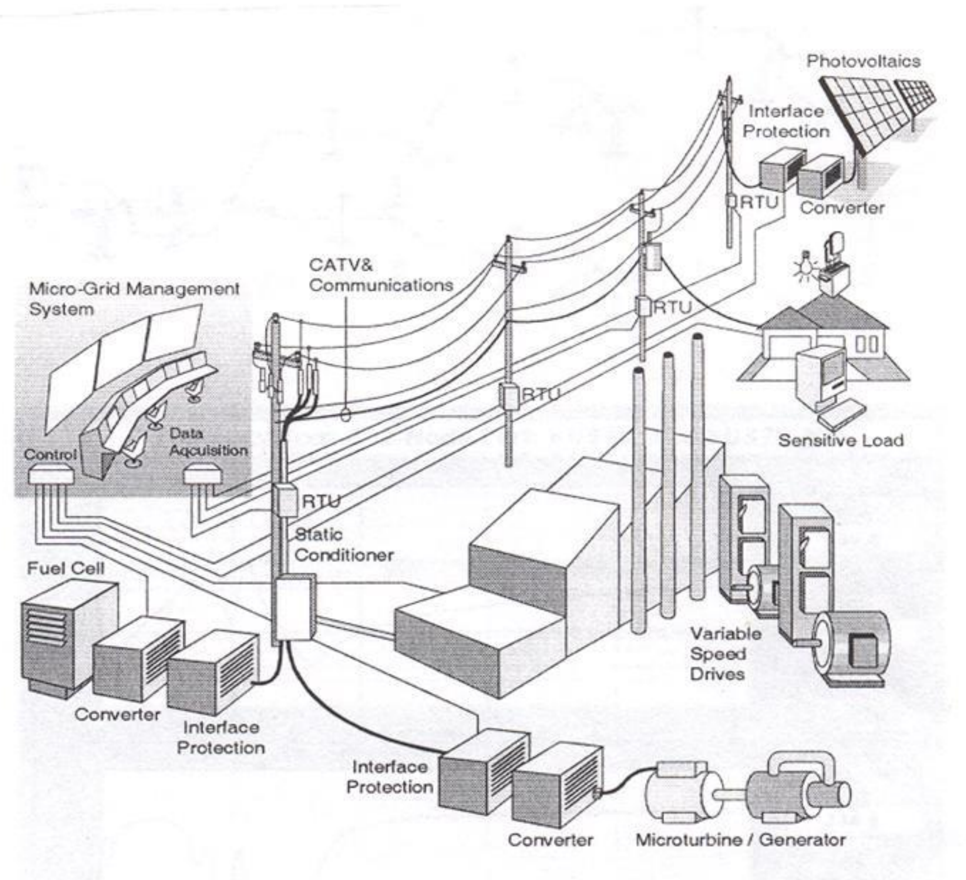
# Why SmartGrids?



# 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.



# Why MICROGRIDS?

**Economy**

- Production near Load
- No Transmission Cost
- DSM Policies

**Reliability**

- Power Quality
- Better Reliability indices
- Advanced Capabilities (island mode)

**Environment**

- Increased Penetration of RES
- CO2 Reduction
- Energy Efficiency

# Technical Challenges

- Control & Coordination of DGs and Loads
- More Efficient and Economic DGs: Batteries, Fuel Cell, Flywheels, etc
- Power Electronics Interfaces
- Protection Scheme / Static Switch
- Communication Requirements
- Standardization

# Control & Coordination: Is it necessary?

- Why suggest that the coordinated operation of several DGs and Loads (Consumers) may increase the efficiency and will provide useful tools to the network management.
- Thus the consumers, the DGs owner and the network may have financial and operational benefits.
- These benefits may derive by applying DSM policies, Congestion Management, Black Start, Postpone Transmission/Distribution Network Investments, etc.

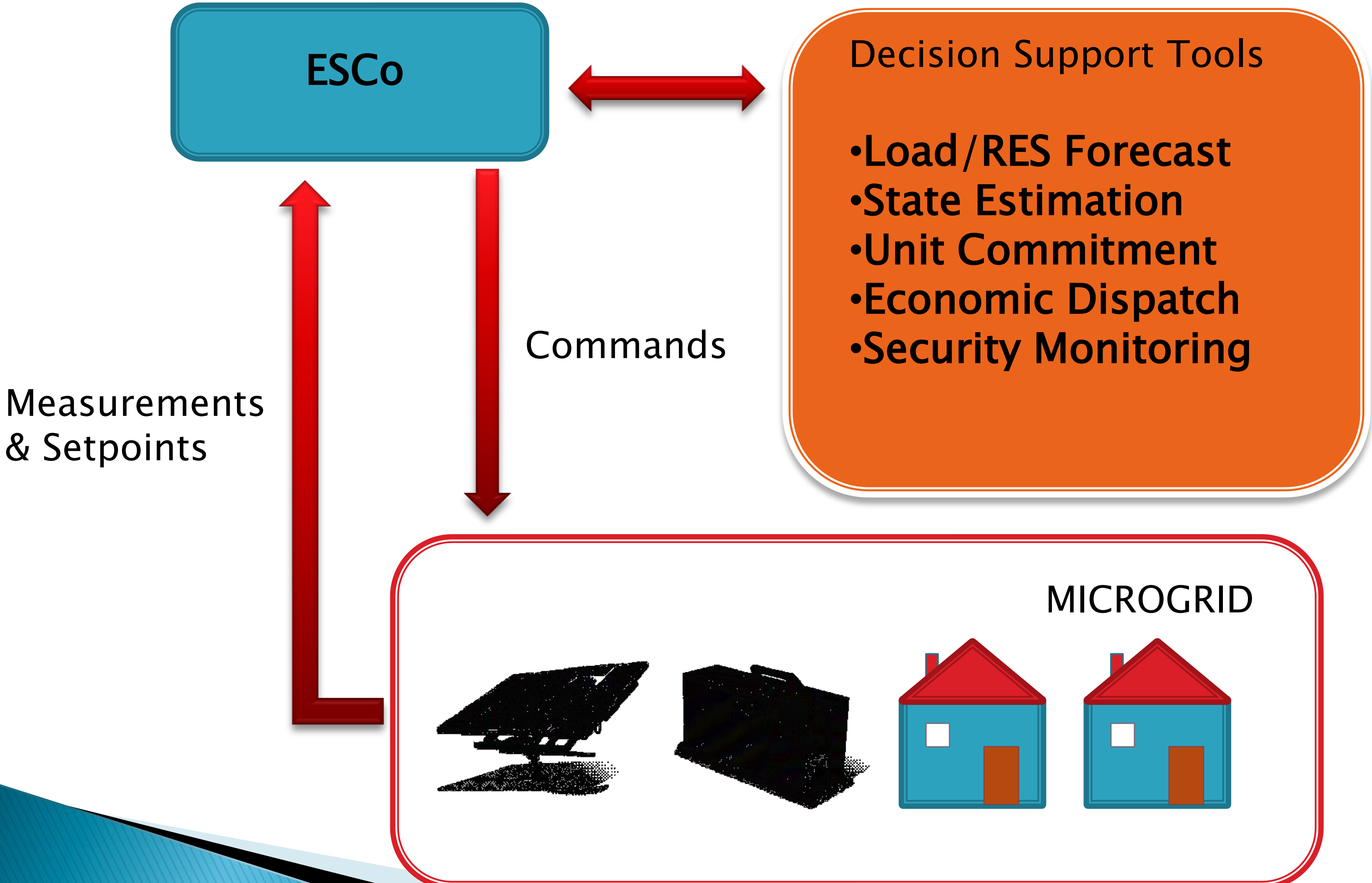
# Basic Challenges for Microgrids Control

- The legal framework/Market Structure
- Larger Number of nodes.
- The solution should have very low cost per node.
- The Microgrid includes all the operations of large systems.
- The system should include DGs from different vendors and different principle of operation.
- The available communication infrastructure should be used in order to reduce the cost.

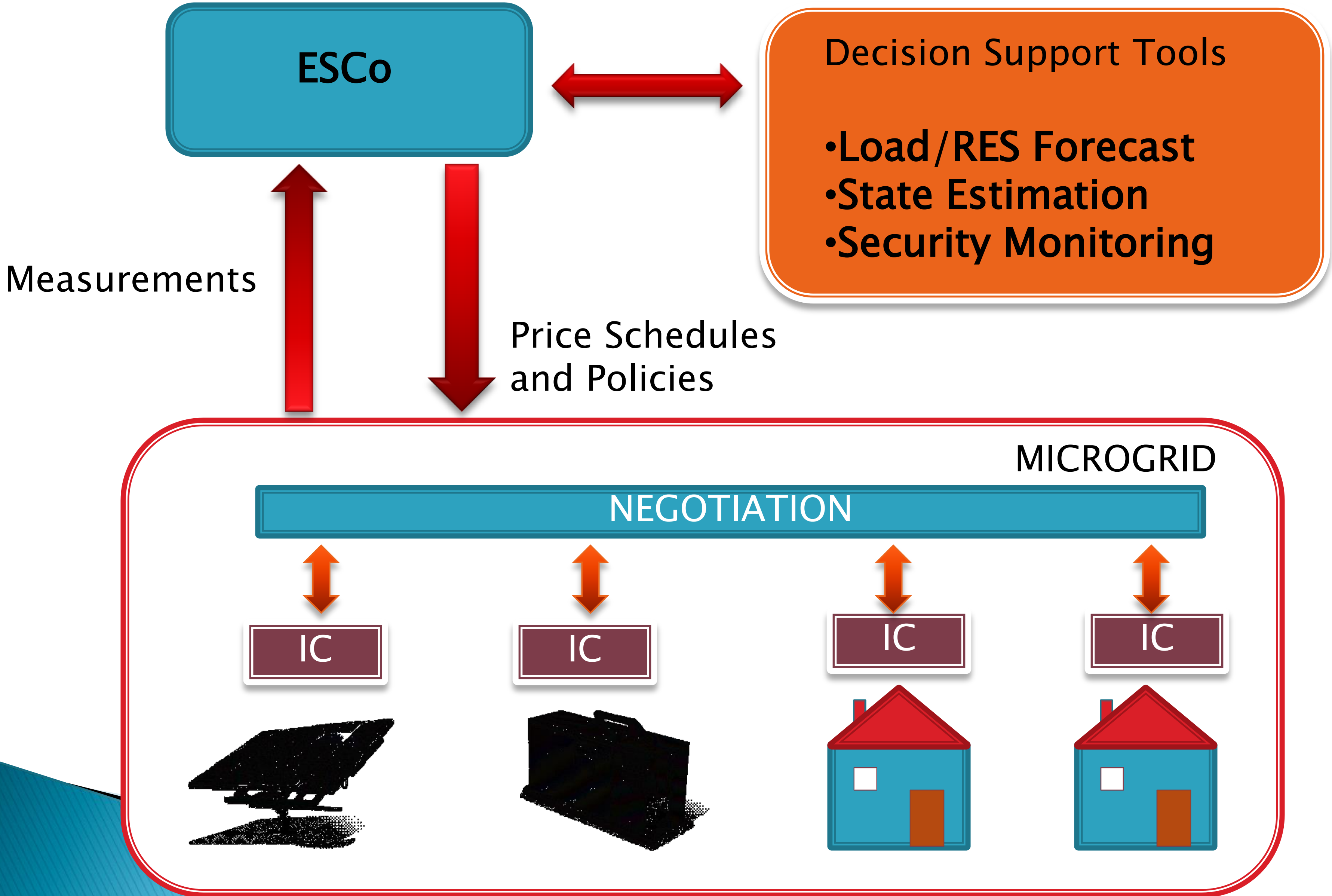
# Centralized & Decentralized Control

- Two possible control architectures may exist.
- The main issue is where the decision is taken
- The **Centralized Approach** suggests that a Central Processing Unit collects all the measurement and decides next actions.
- The **Decentralized Approach** suggests that advanced controllers are installed in each node forming an distributed control system.

# The Centralized Approach



# The Decentralized Approach



## Implementing the Decentralized Control Concept

- One approach of implementation adopts the intelligent agent approach
- Next some basic concepts of the agent theory will be presented as well some practical examples.

# 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**

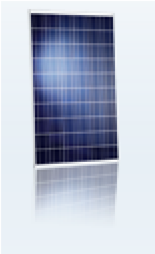
- partial representatio n  of the environment
- autonomy
- possesses skills

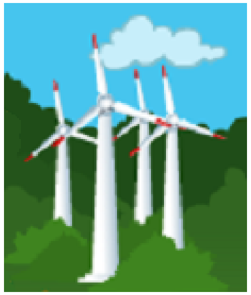
**Cogniti ve**

- Memory
- Environment Perception
- high level communicati on

# Physical entity that acts in the environment or a virtual one

Physical Entity: Any Hardware that acts into the electrical network!




Virtual Entity: Any (software) entity that interacts with other agents and is part of the system!

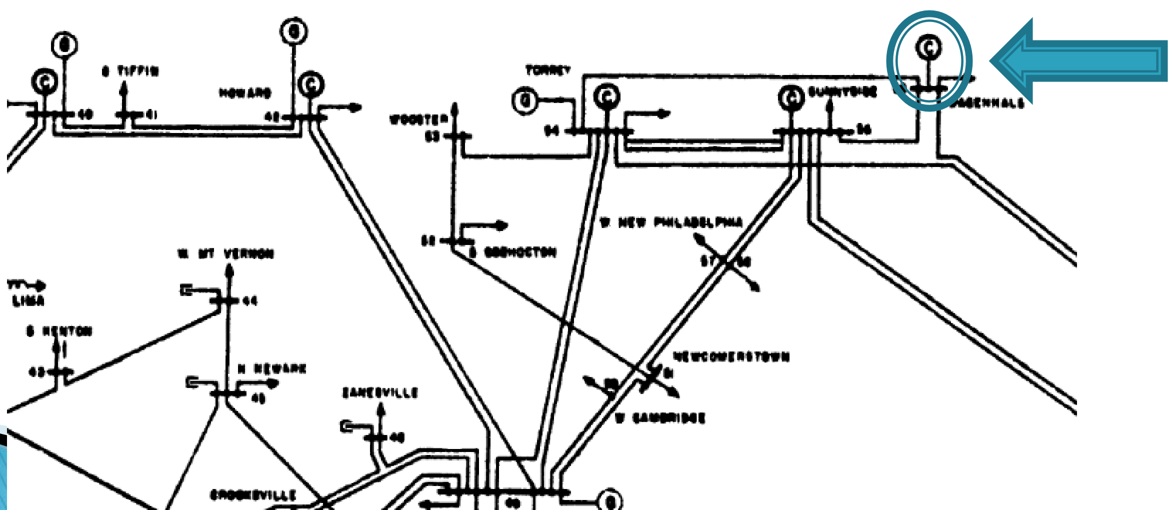
DNO | DATABASE | TSO | MARKET OPERATOR

ESCO | WIND FORECAST | ERP | CRM

# Partial representation of the environment

Environment Knowledge: Important for any control system!

- It is very hard to have knowledge of the whole electrical network.
- This is one of the fundamental problems in any power system control application.
- The agent theory suggests that only part of the knowledge may be available in an agent!



The Agent knows electrical values in the connected bus: Voltage, Current, P, Q, frequency….

# Agent Communication

A significant characteristic of agents. The Agent Communication Language allows the interaction and the knowledge sharing.

One significant part of the agent communication is the auction algorithm

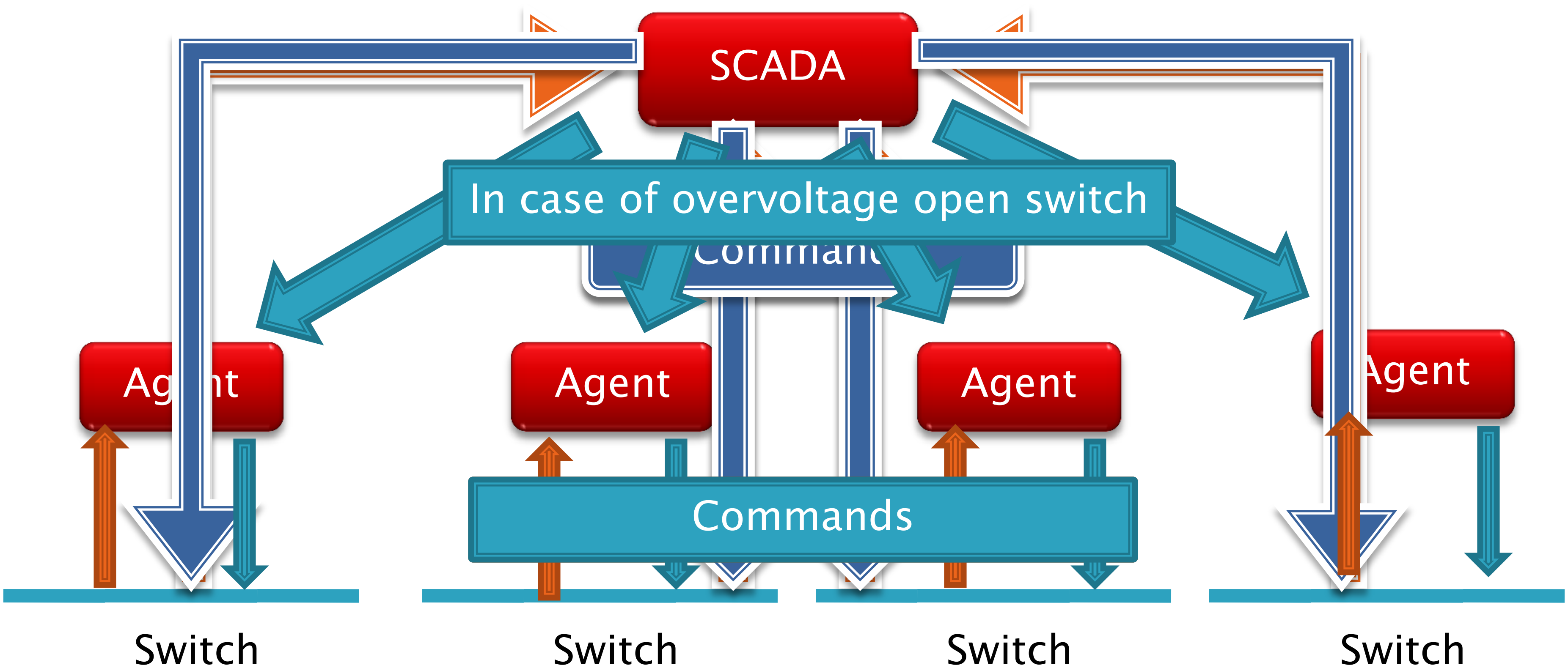
By adopting the fundamental principals of economic theory, thus fair bidding leads to optimal solutions, the auction algorithm is a useful tool for the agent applications.

# Agent Communication Language

- The intelligent agent concept requires a strong language capable to describe knowledge
- This language has a structure and a vocabulary called ontology
- The language allows the establishment of complex dialogues

# Agents have a certain level of autonomy

This characteristic is a consequence of the local intelligence!



# Behaviour ,objectives, resources, skills and services

**Behavior**
- Competitive
- Collaboration

**Objectives**
- Maximize profit
- Minimize cost

**Resources**
- Available Fuel
- Energy Stored in a Battery

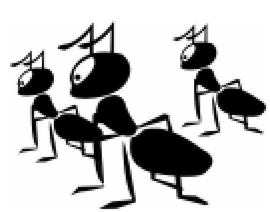
**Skills**
- Load Curtailment
- Black Start

**Services**
- Yellow pages
- Data Storage

# Reactive vs Cognitive

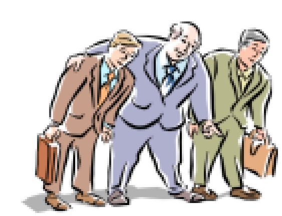
Reactive

- The agent react to certain signals
- The collaboration of several reactive agents may form a intelligent society
- Typical example: the ant colony
- For an electrical network a protection device is a reactive agent.
- Several protection devices may create a self healing network



Cognitive

- The agent has increased intelligence and advance communication capabilities.
- The collaboration is supported by the intelligence and the communication capabilities
- Typical example: the human society

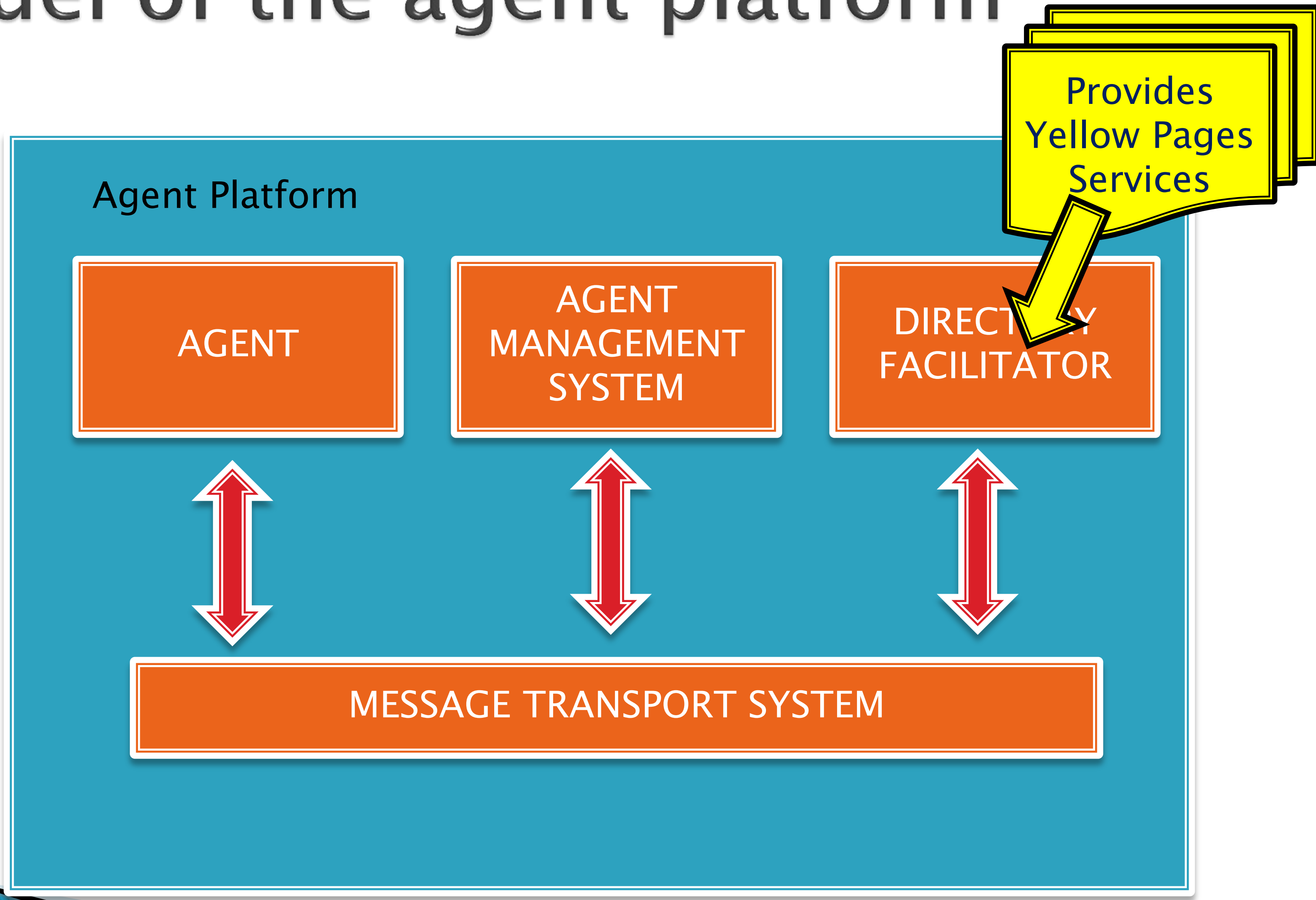


# Examples of Implementations

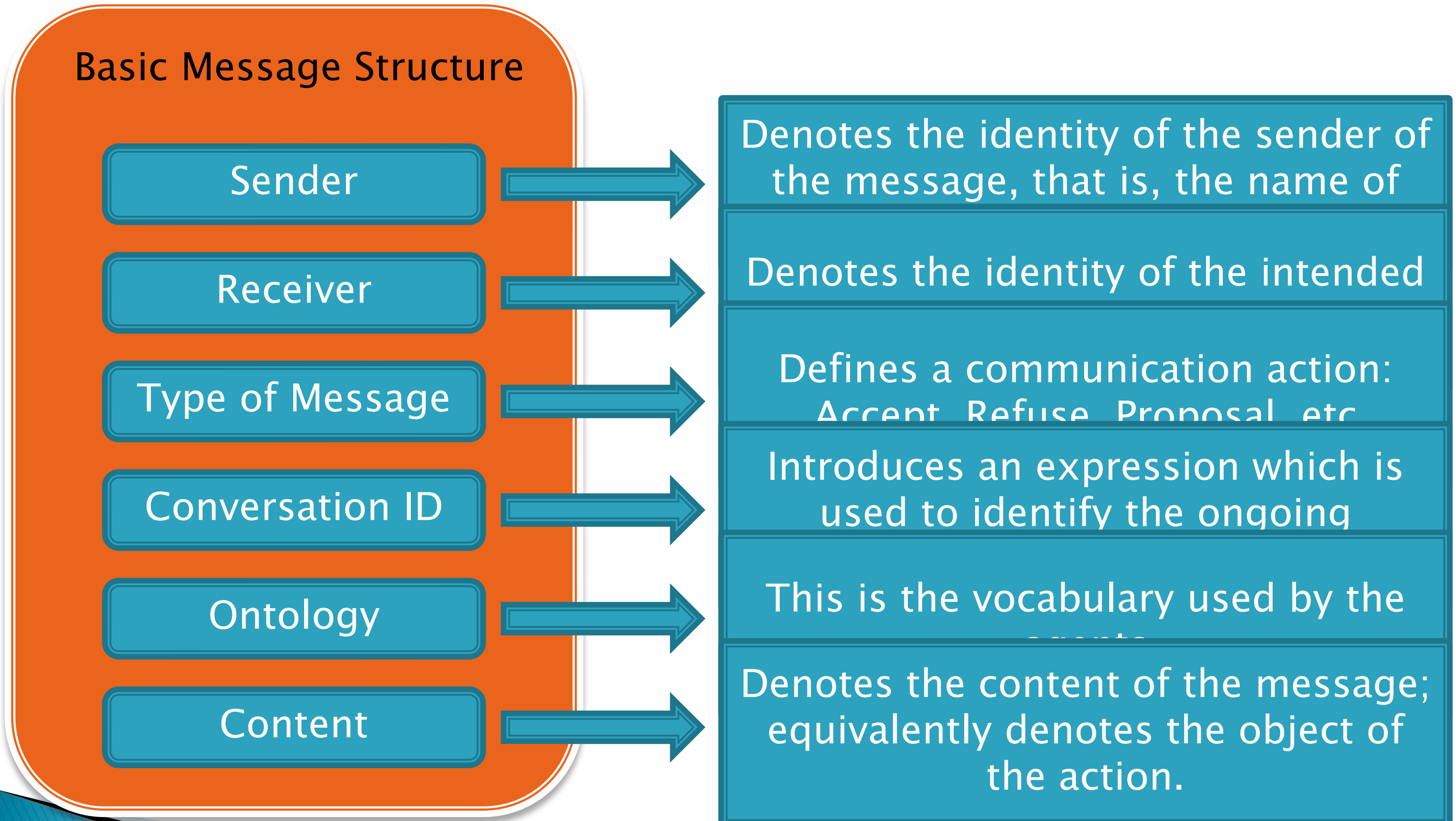
# Example #1
# Implementing Agent with Java-Jade

- Jade is a Java based platform for agent implementation.
- It is compatible with FIPA requirements
- FIPA is the Foundation for Intelligent Physical Agents
- Jade provides a set of libraries that allow the implementation of the agents.

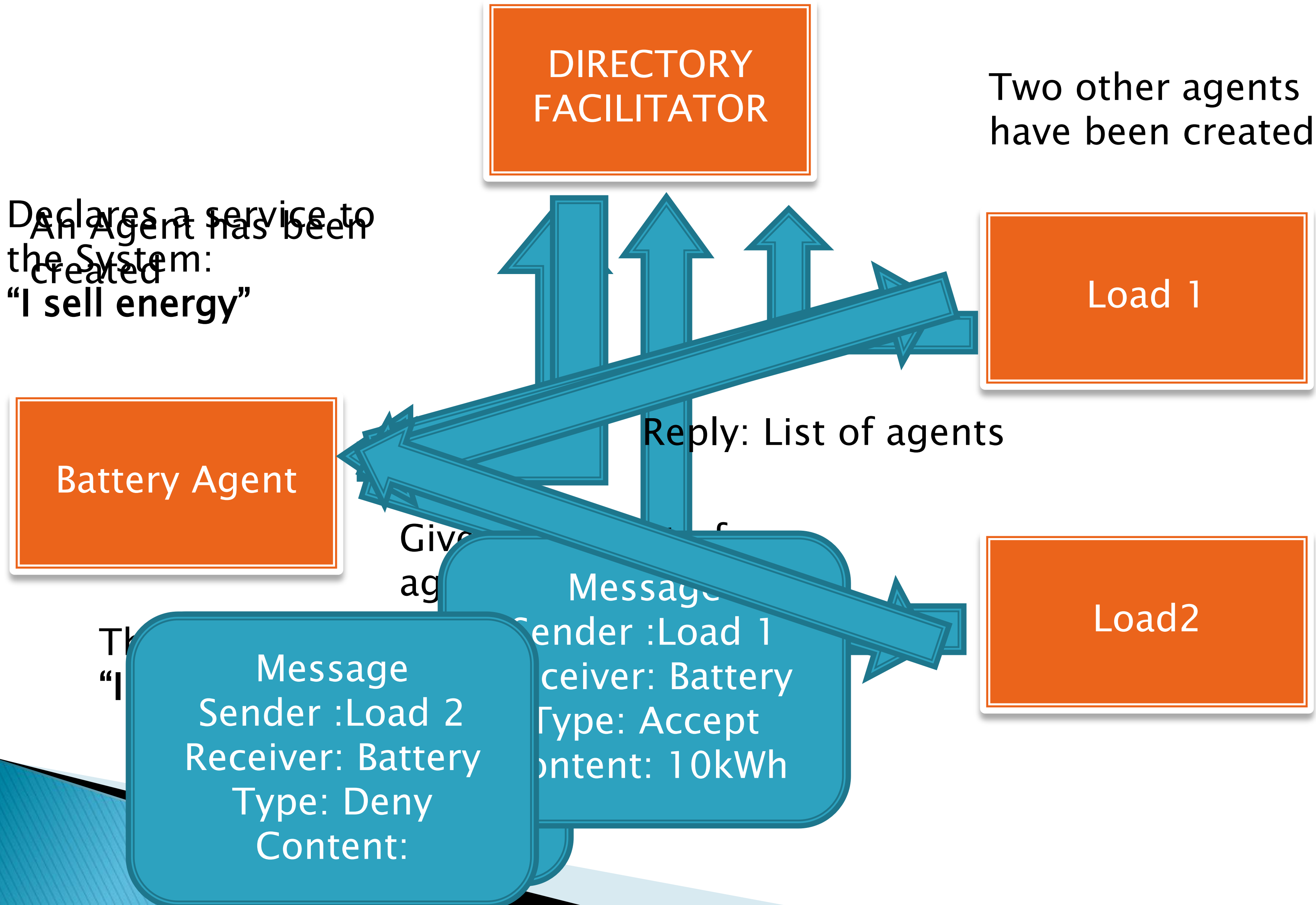
# Model of the agent platform



# Implementation of the dialogues

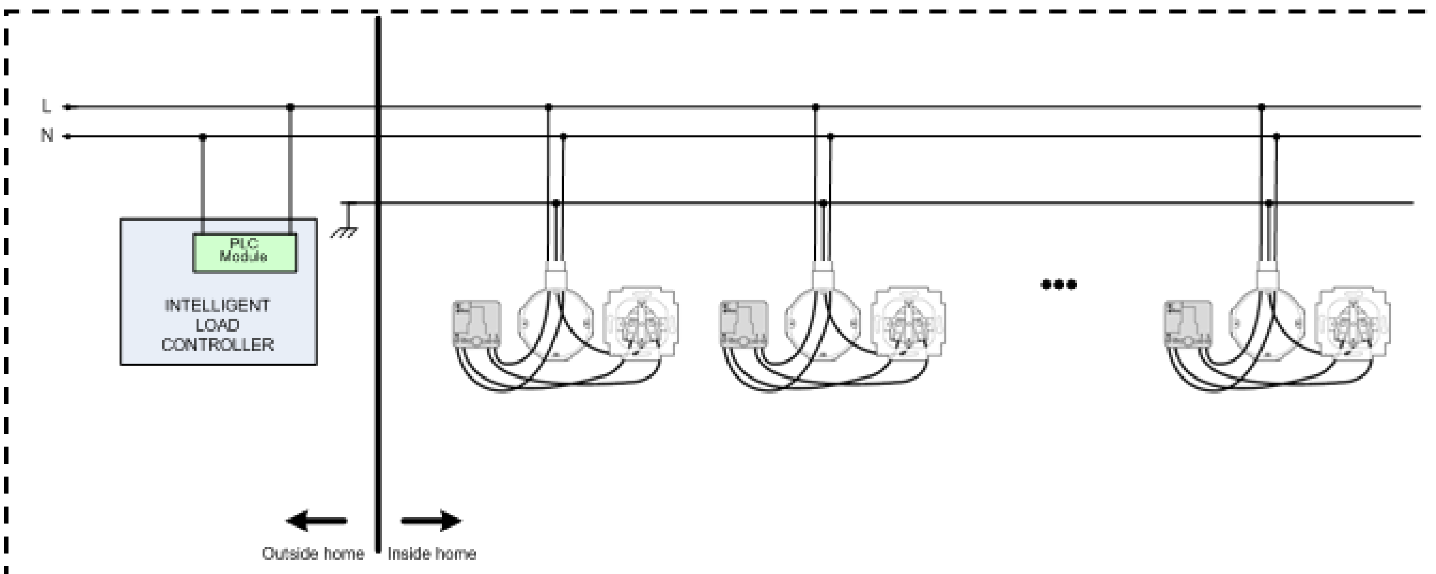


# Simplified Conversation



# The Load Controller

1. Windows CE 5.0
2. Intel® Xscale™ PXA255
3. 64MB of RAM
4. 32MB FLASH Memory
5. Java VM
6. Jade LEAP



# Laboratory Overview

# Panel with Load Controllers

# Example #2
# Agent Based Control in a Real Installation

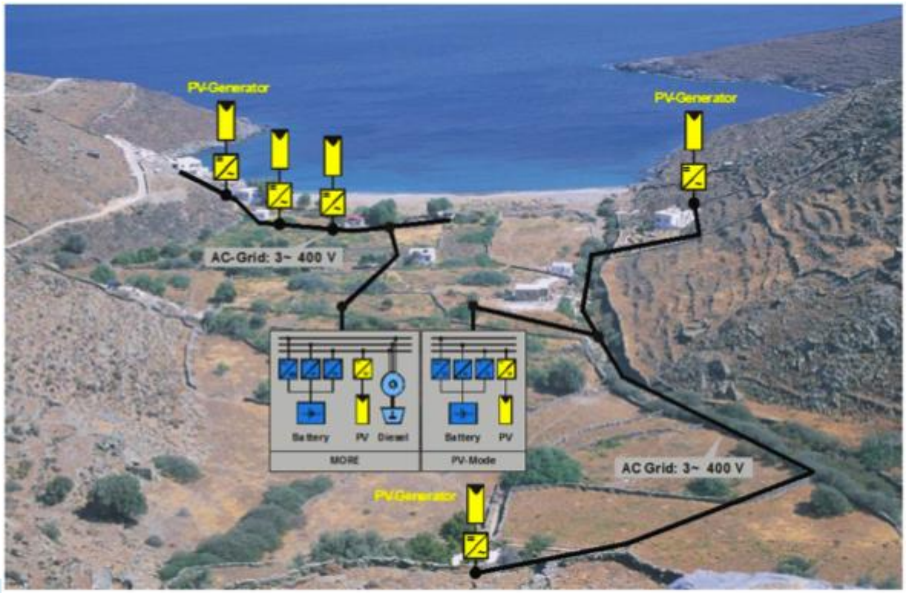
- This is our first implementation of the Agent Based Control
- The installation is in the island of Kythnos
- The goal is to optimize the consumption of the houses

# Short Description of Kythnos Installation

- The test site is a small settlement with 13 houses

The production system includes:

- 12 kW of PV
- 53-kWh  batteries
- 5-kW diesel



# Installation of the Controllers

Outside System House

House 11

House 7

Inside System House

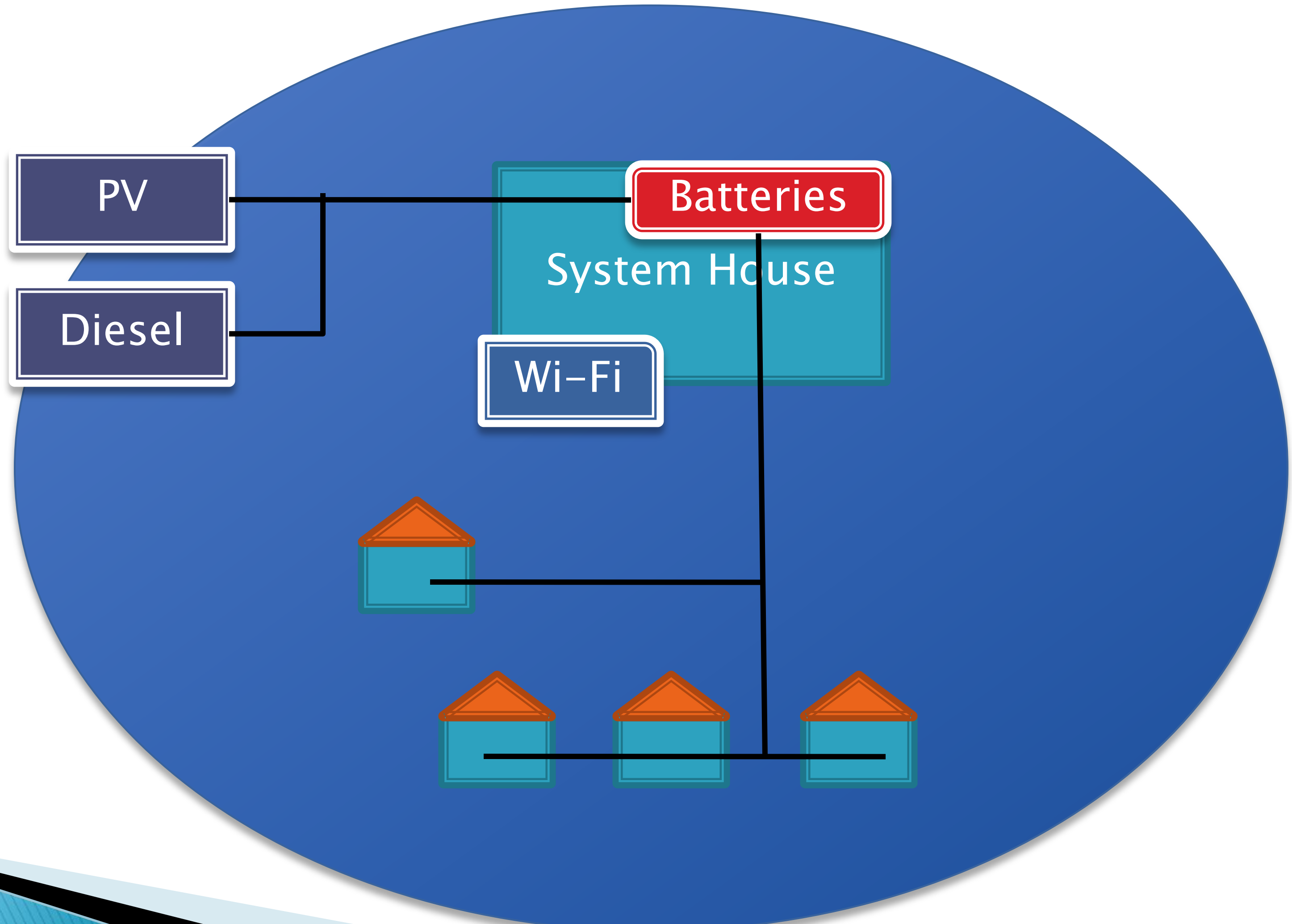
House 5

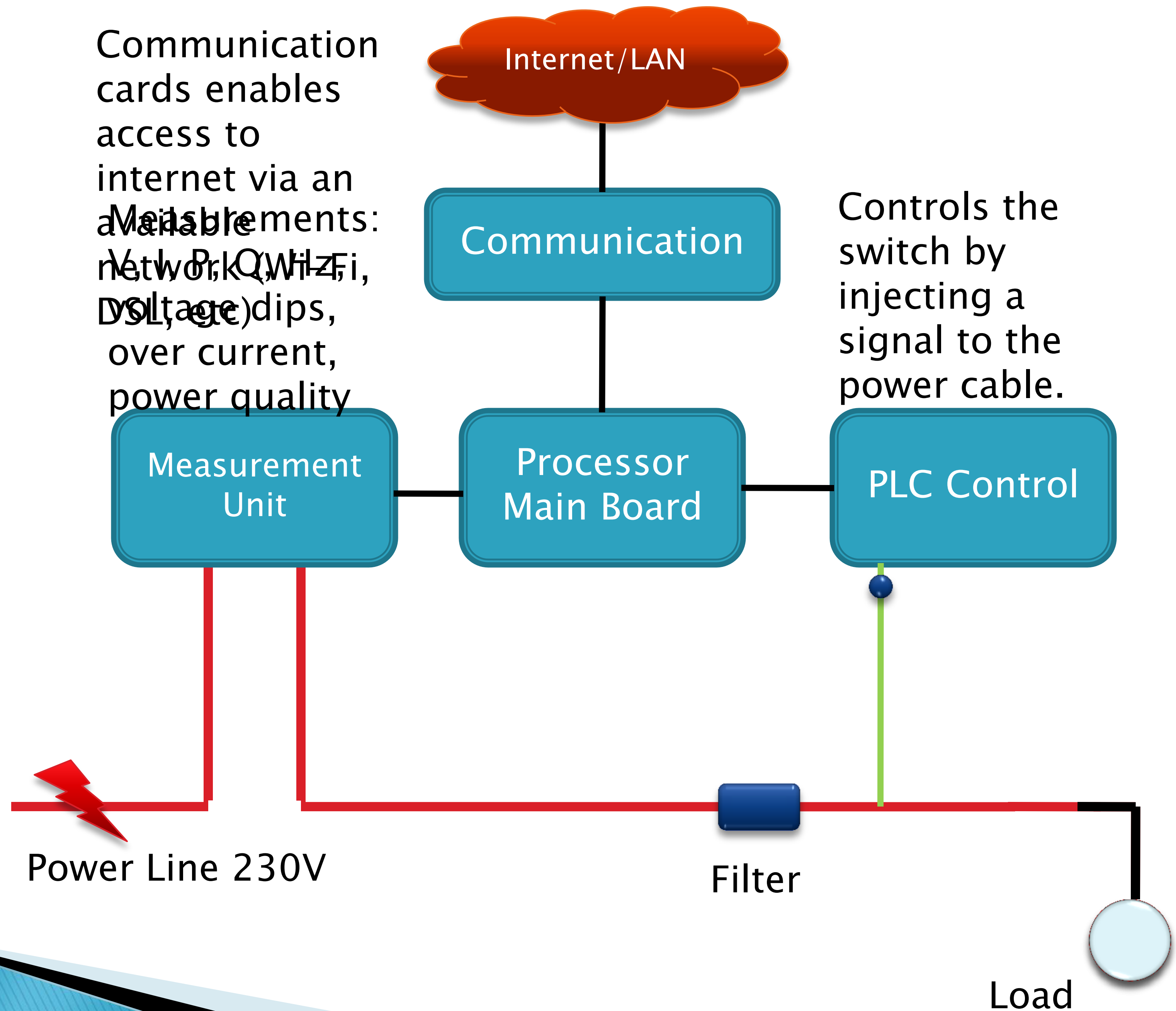
House 4

# Goal of the Experiment

- The Goal of the experiment is to test the agent based control system in a read test site in order to increase energy efficiency.
- The technical implementation will be based on the load controller described in a previous Presentation and the Jade Platform
- The algorithm regarding the increase of the energy efficiency is quite simple and focuses in the limitation of the pump operation.

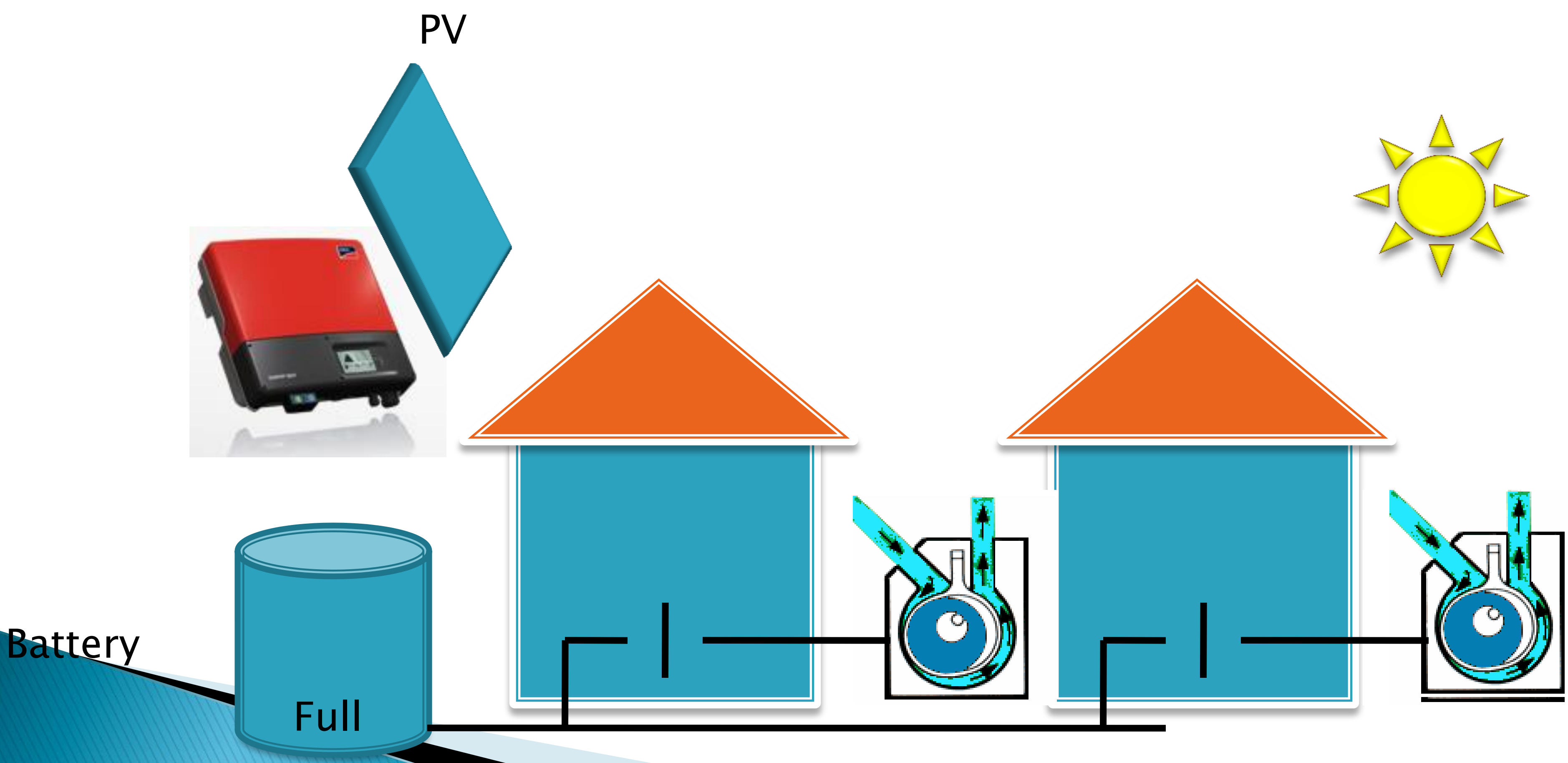
# General Configuration




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
Internet/LAN
Communication
Controls the switch by injecting a signal to the power cable.
Measurement Unit
Processor Main Board
PLC Control
Power Line 230V
Filter
Load

# The general idea:

The main load in each is the water pump.
The goal of the system is to limit the usage of the pumps



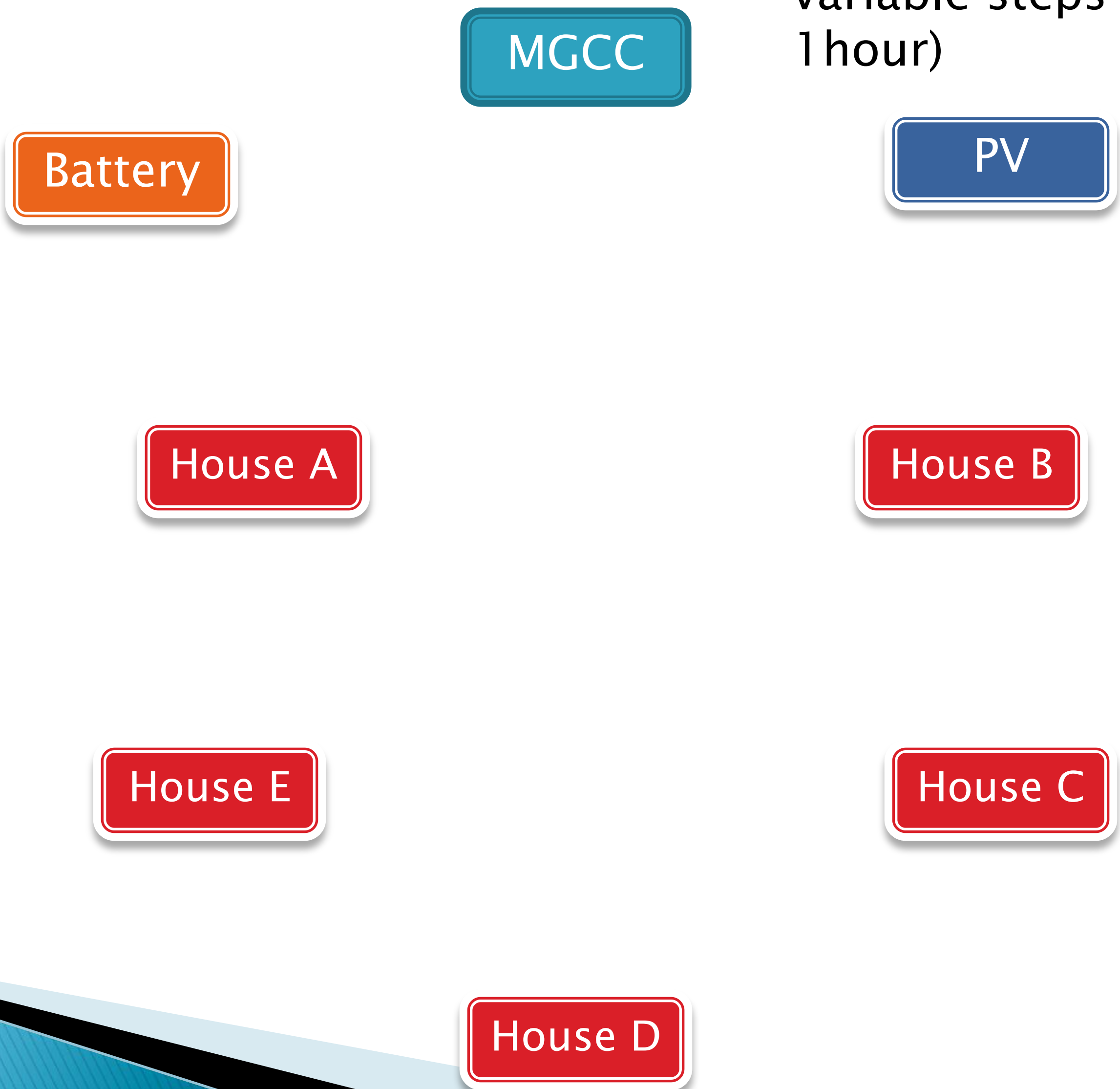
# The MAS System

- The MAS tries to increase the energy efficiency. The steps are the following:

1. The system decides the available energy that can be used by the pumps.
2. The houses decide how to share this energy.

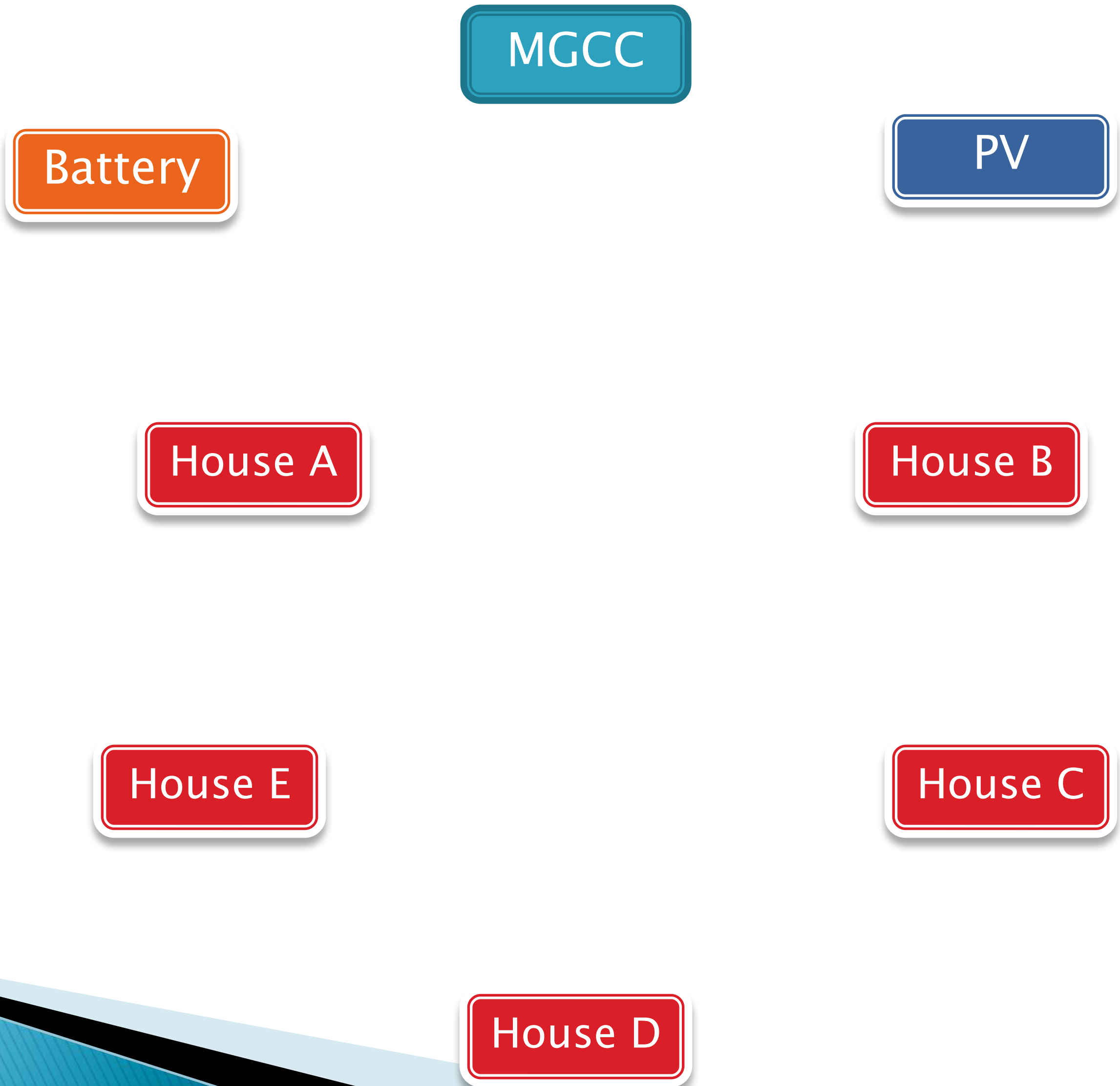
# Negotiation

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



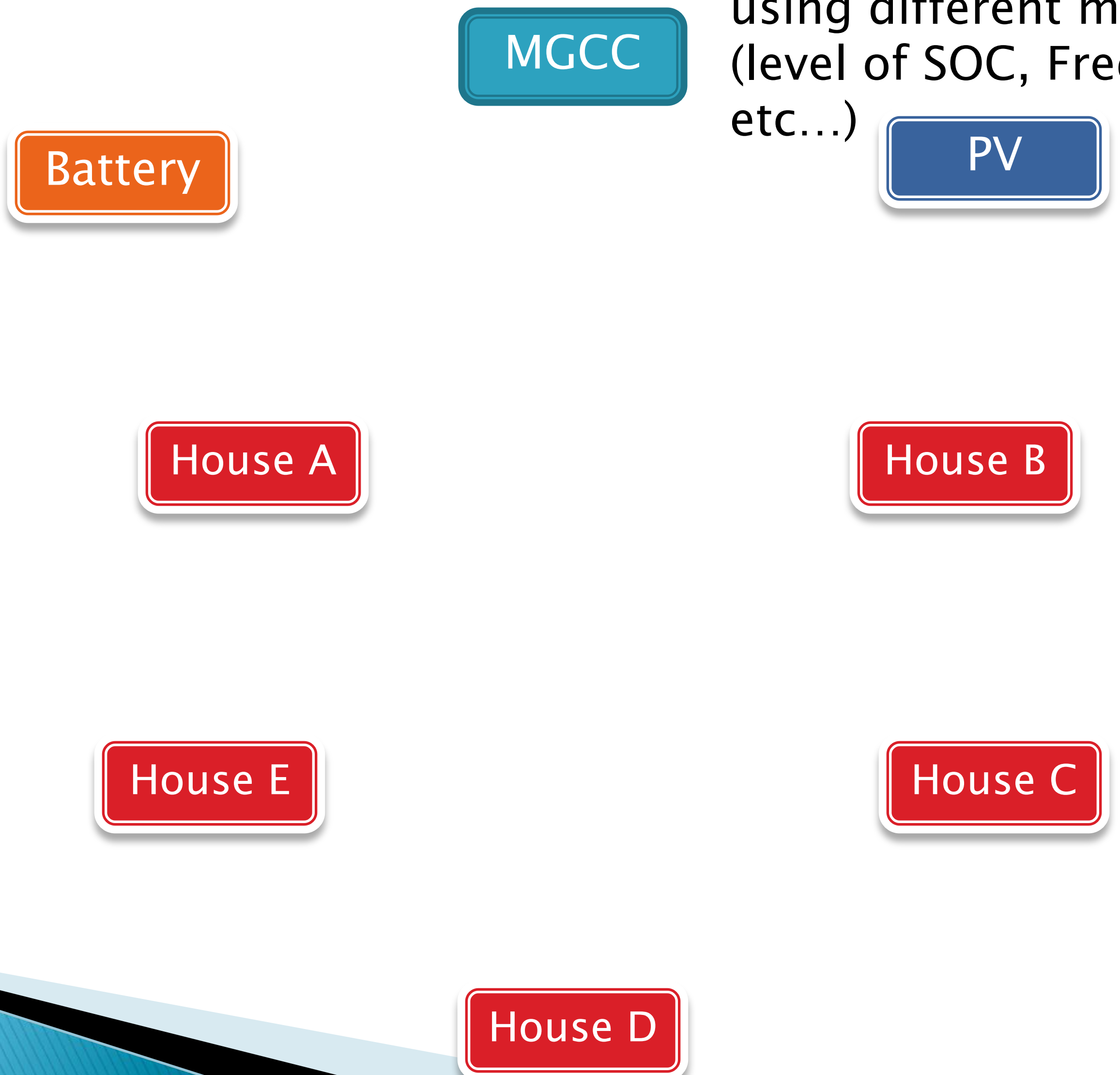
# Negotiation

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

MGCC

Battery

PV

House A

House B

House E

House C

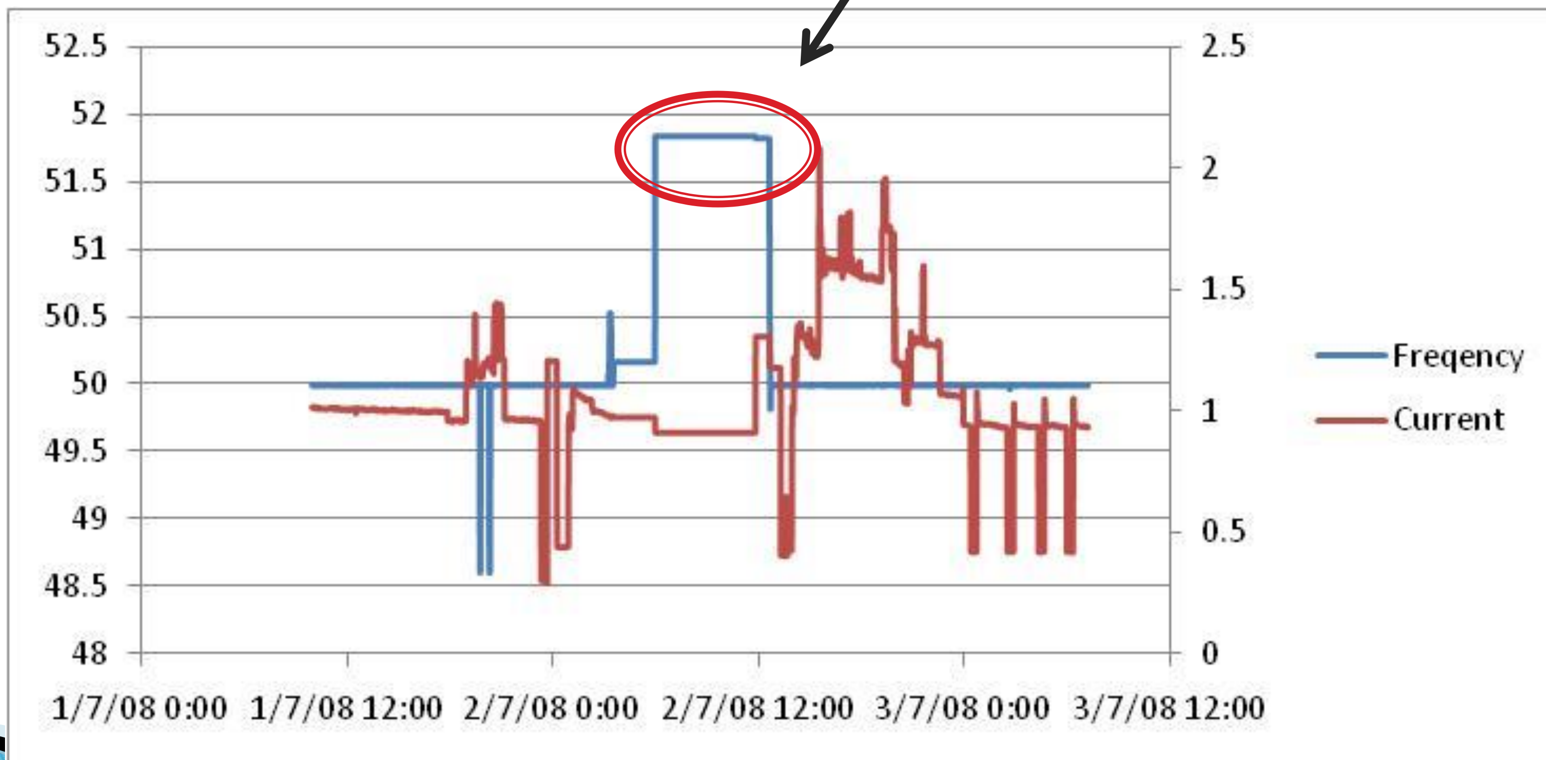
House D

# Policies to estimate the available energy

- SOC of the Battery: This is an indication of the available energy of the system. The amount of energy above a certain level can be used (example >90%)
- The system frequency. If the system frequency is above 50Hz this is an indication that the batteries are full and part of the PV production is rejected

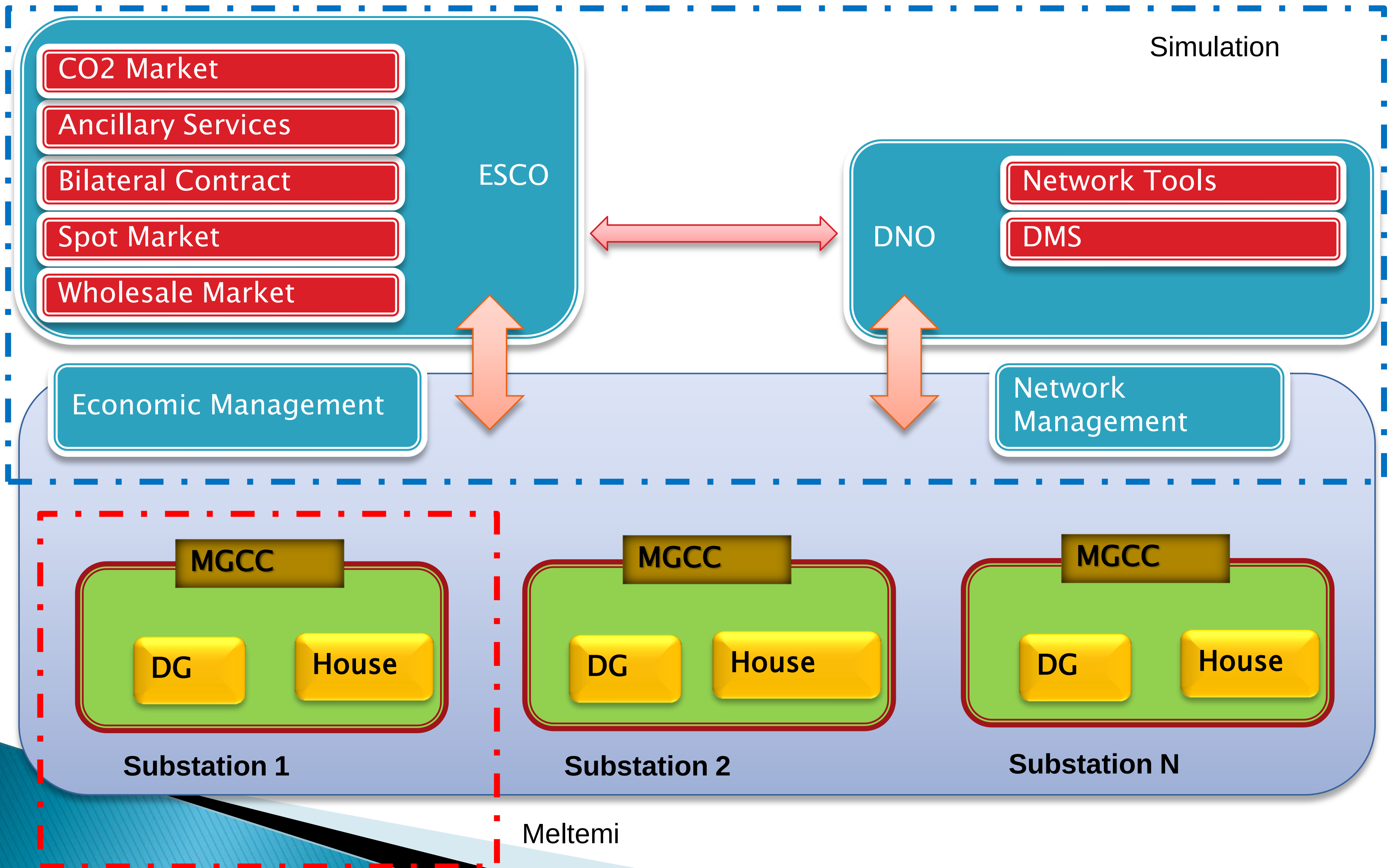
# Example

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.

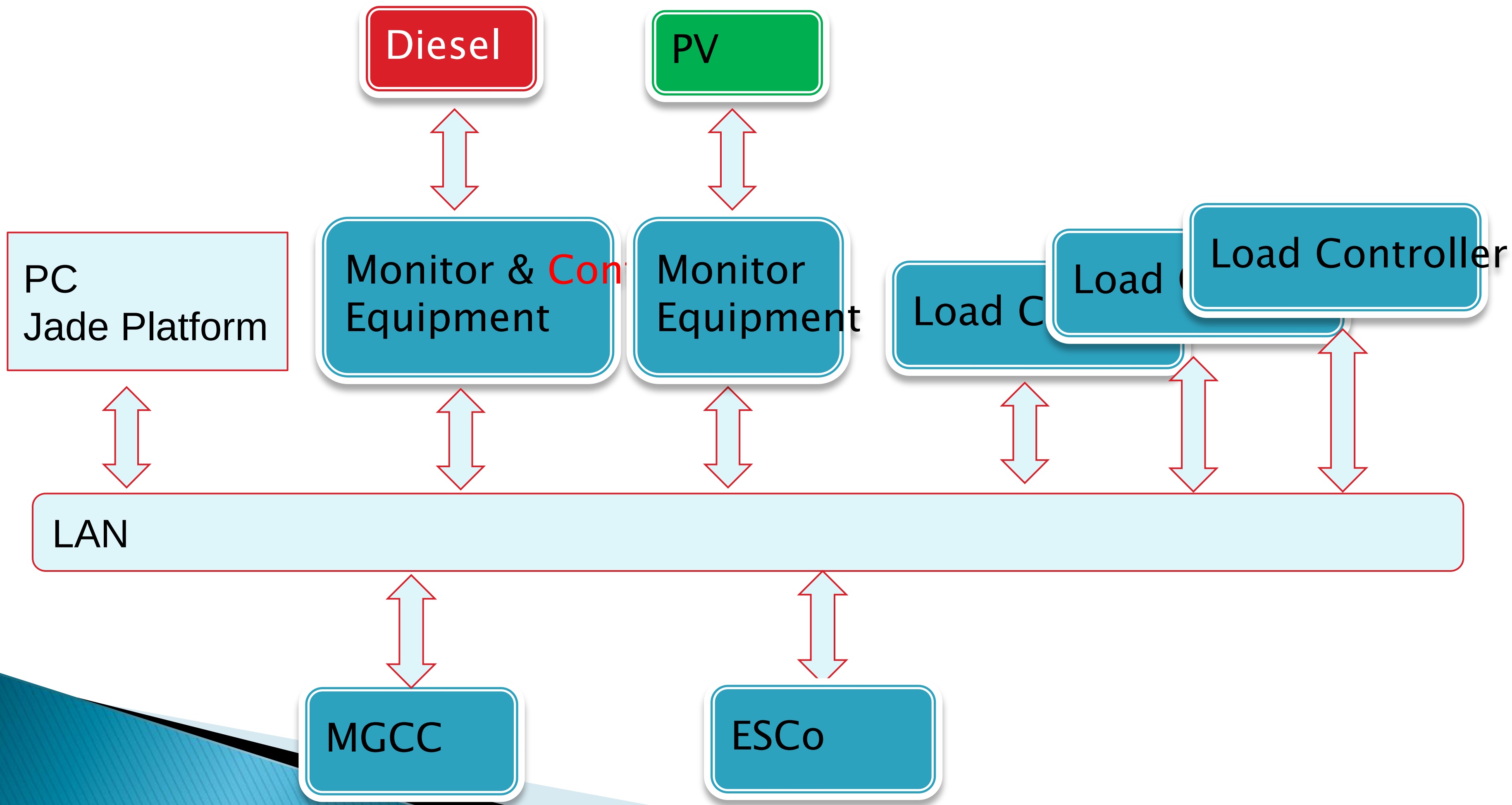


# Real-life field test

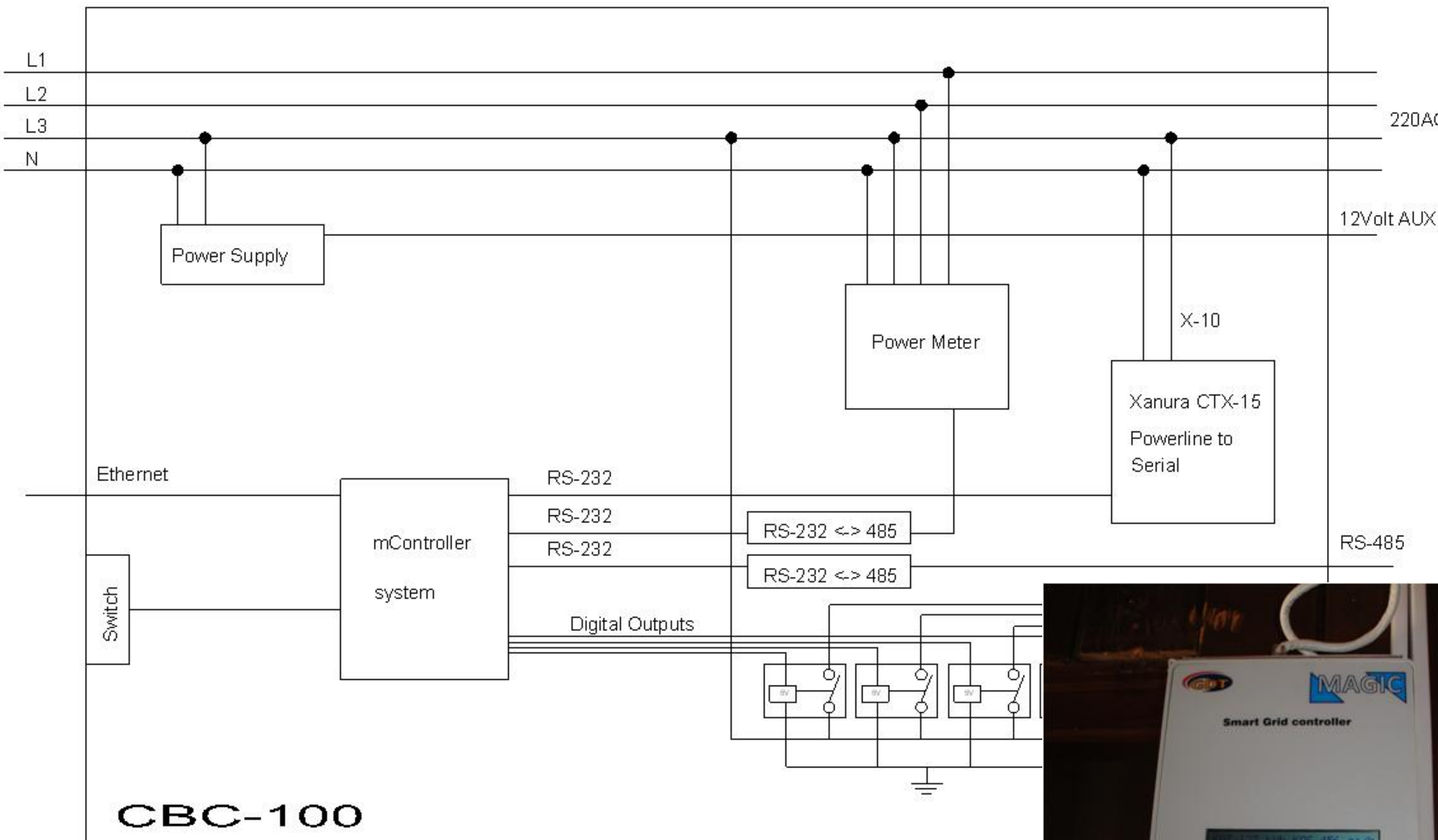
# System Overview



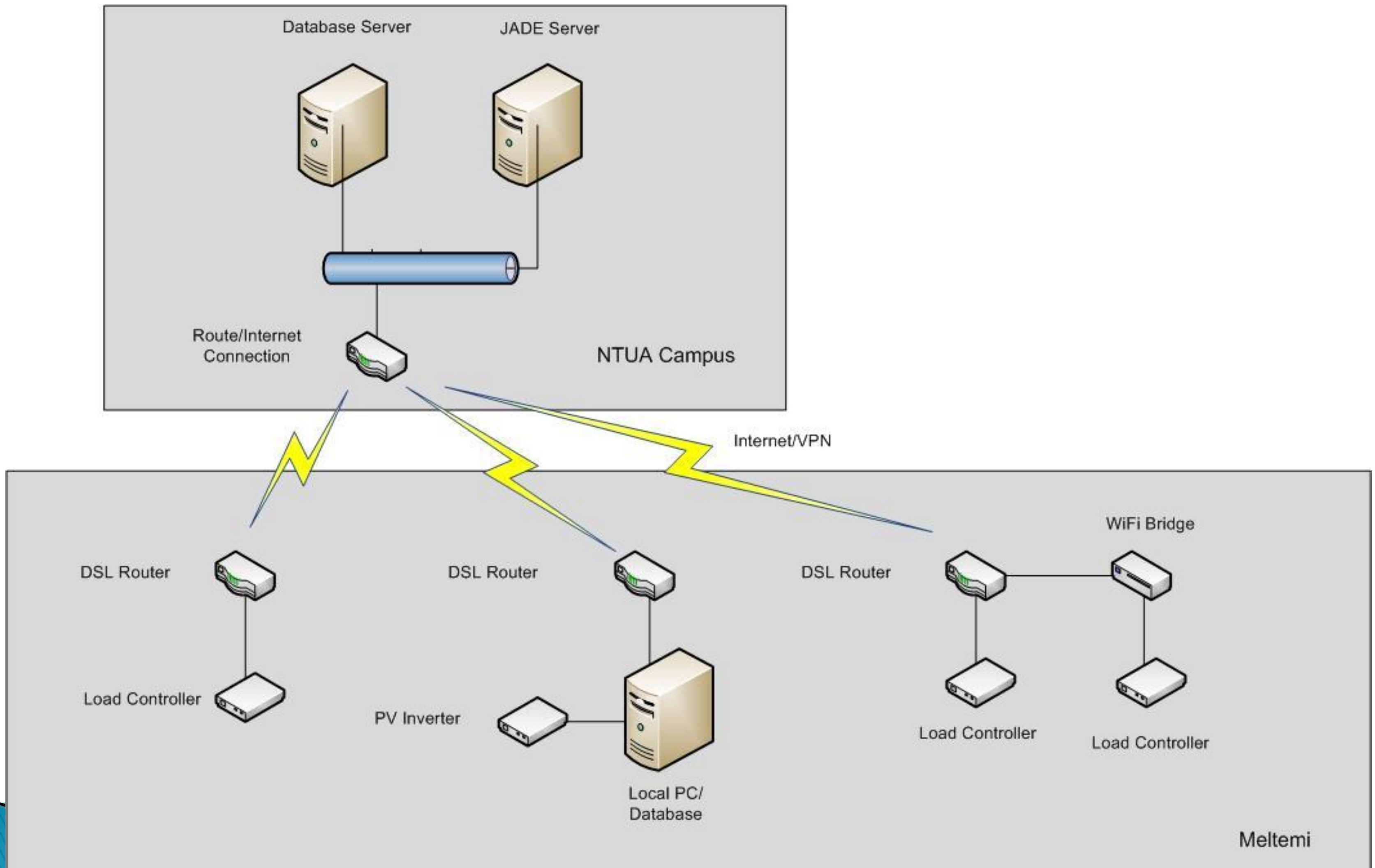
# Field Test Schematic



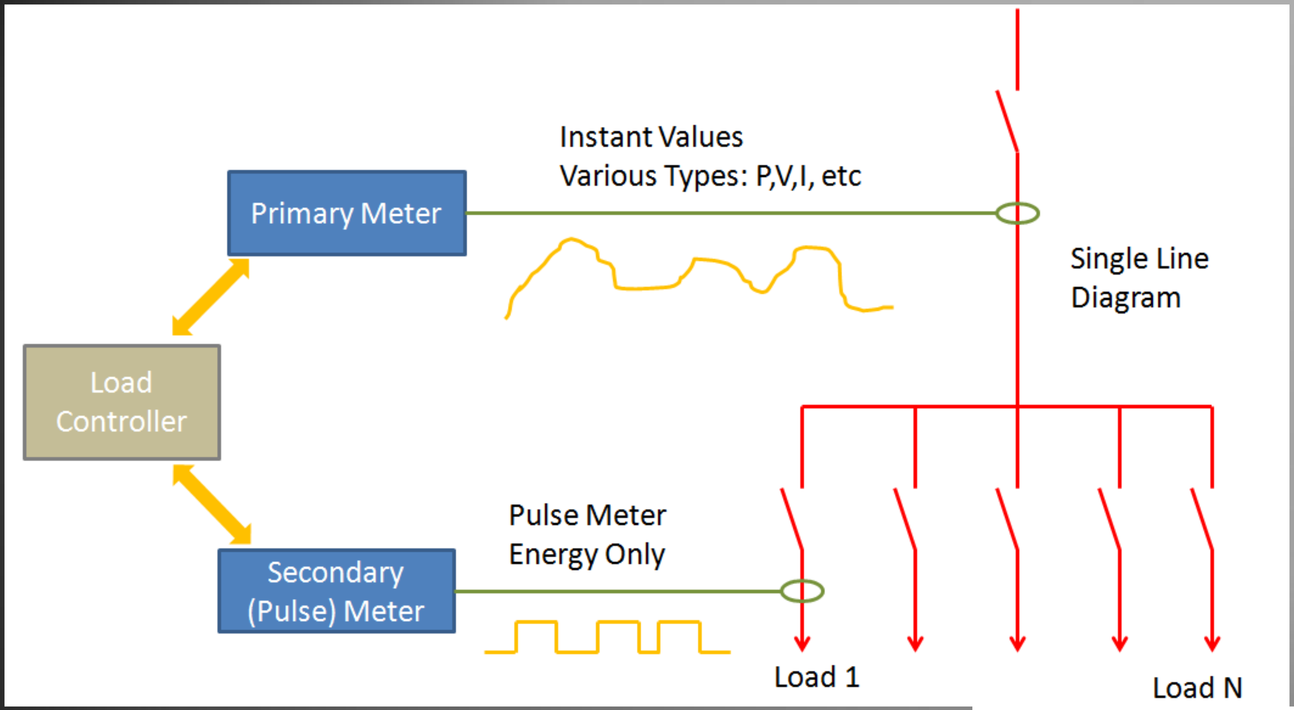
# Load Controller

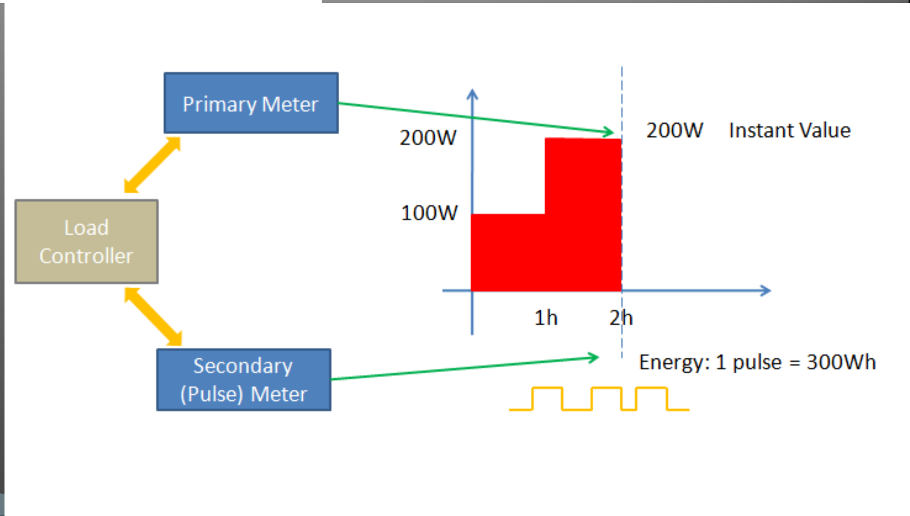



# Actual Network Architecture

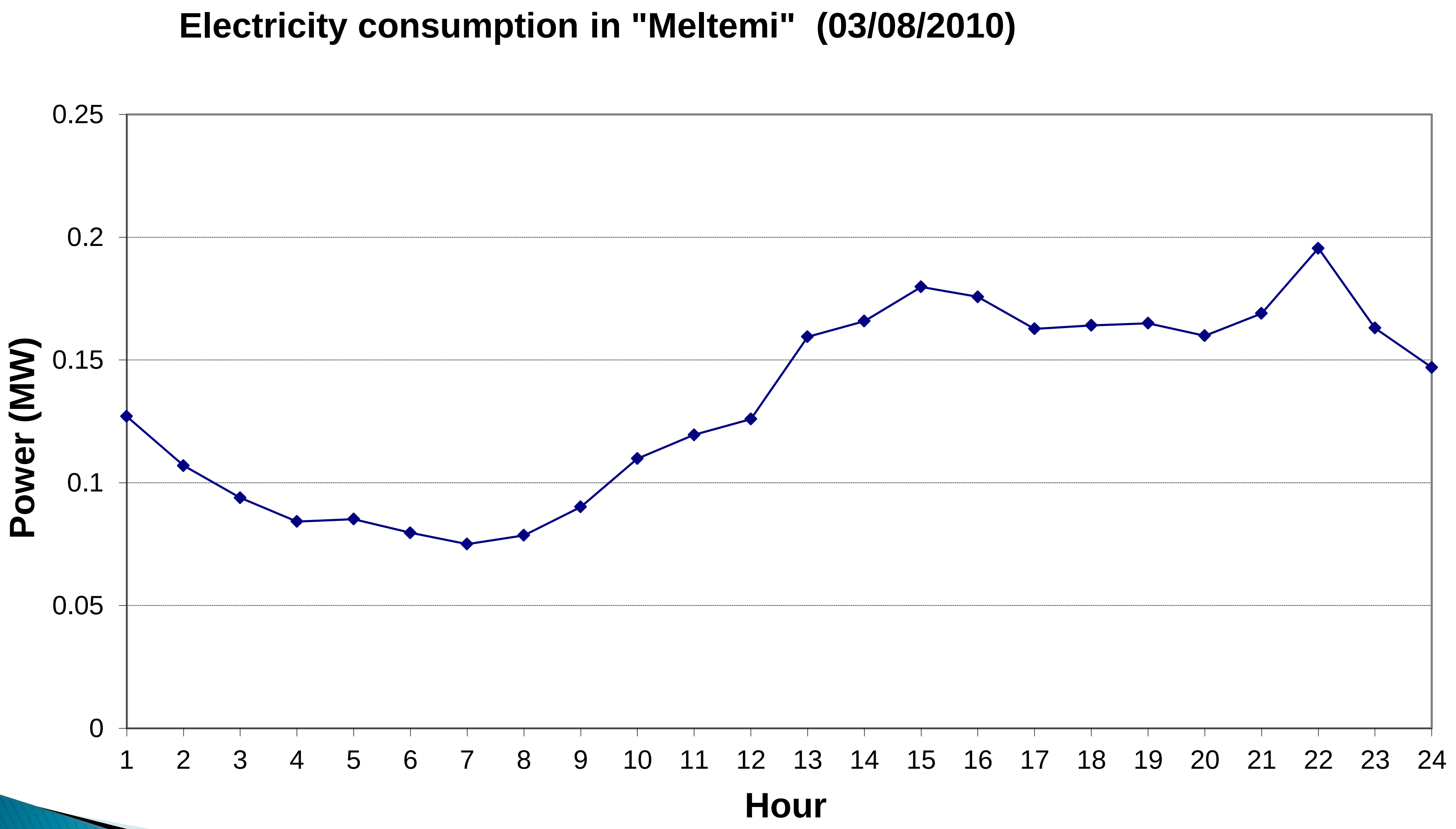


# The operation of Load controller



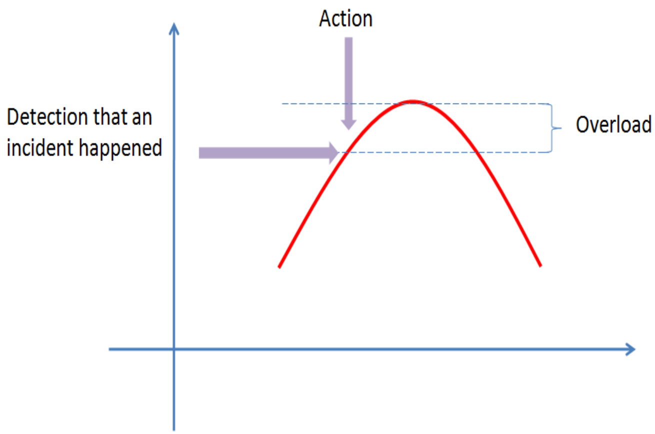
# Typical consumption of the whole camp



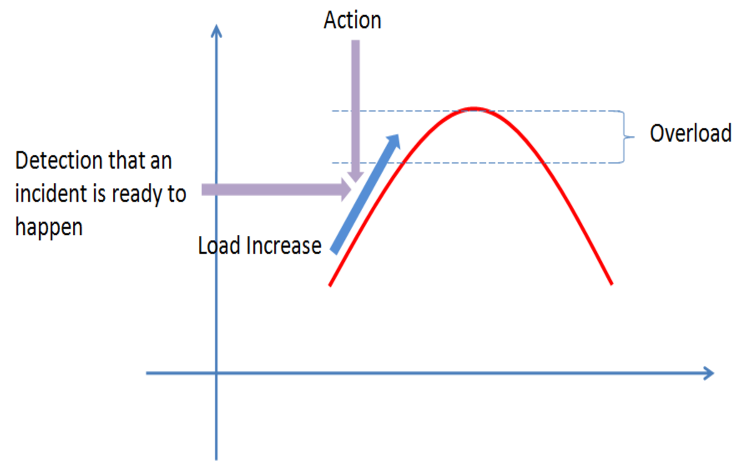
# Overview: Solution Approach

- Key question: How much energy can be used per house

(actual

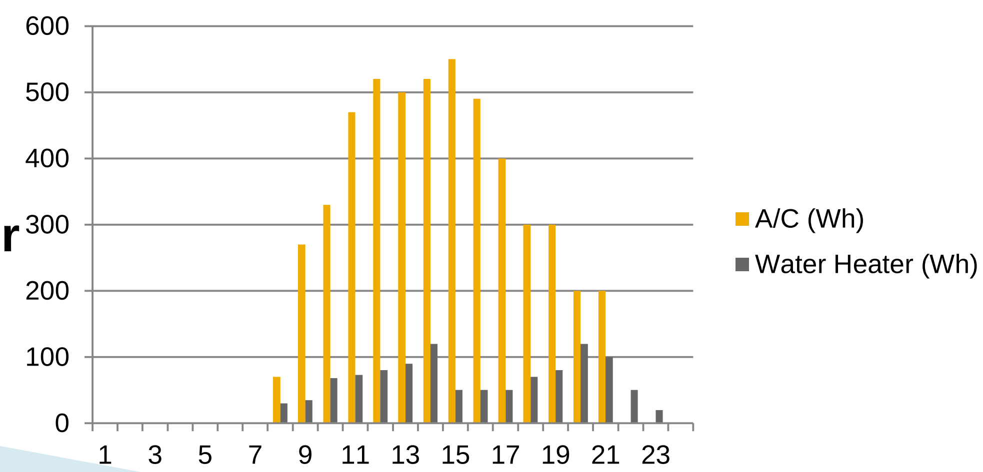



**Simple Algorithm**




**MAGIC Algorithm**

**Knowledge of the of the consumer behaviour**



# Summary

- The usage of SOA and internet based technologies is important
- Legal framework & Flexible Tariffs
- Further explore the consumer behavior
- Forecasting modules are important
- Hardware and installation cost is related to the system capabilities

# Thank You!!!

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