



DREAM-GO

Enabling Demand Response for short and real-time efficient management of smart grids: A multi-agent based approach

Zita Vale

zav@isep.ipp.pt
email.zitavale@gmail.com



14th International Conference on Practical Applications of Agents and Multi-Agent Systems

University of Sevilla - Sevilla (Spain) | 1st-3rd June, 2016 |

www.paams.net

Agenda

- Smart Grids
- People
- Demand response
- Real world application

Smart Grids

Smart Grids

Smart Grid (SG) Definitions

- *European Technology Platform SmartGrids*

“A Smart Grid is an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers, and those that do both - to efficiently deliver sustainable, economic and secure electricity supplies”

www.smartgrids.eu

- **Some notes:**

- “ 'Smart Grid' is today used as marketing term, rather than a technical definition
- “For this reason there is no well-defined and commonly accepted scope of what "smart" is and what it is not.”
- “It is worth noticing that according to the IEC definition a "Smart Grid" is not a grid but a concept”

Smart Grid

Arnold, M.; Rui H.; Wellßow, W. H.: "An Approach to Smart Grid Metrics", IEEE PES Innovative Smart Grid Technologies (ISGT) Europe 2011, Manchester, United Kingdom, 2011

Smart Grids

Smart Grids are closely related with the intensive use of renewable energy sources

FIVE MAJOR DEVELOPMENTS ENABLING THE SHIFT TO 100%



1

**DISTRIBUTED SOLAR
 BECOMES COST-
 EFFECTIVE ACROSS
 GEOGRAPHIES**



2

**UTILITY-SCALE
 RENEWABLES
 GROW UP**



3

**ENERGY STORAGE
 COMPLETES THE
 PUZZLE**



4

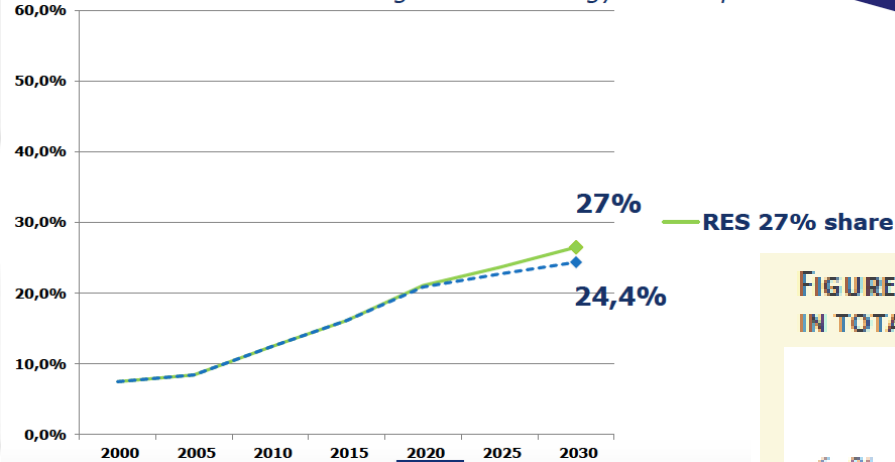
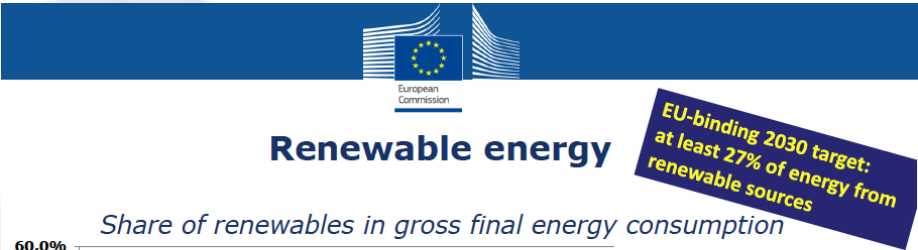
**NET ZERO BUILDINGS
 AND SMART
 CONNECTED DEVICES
 DRIVE EFFICIENCY
 RENAISSANCE**



5

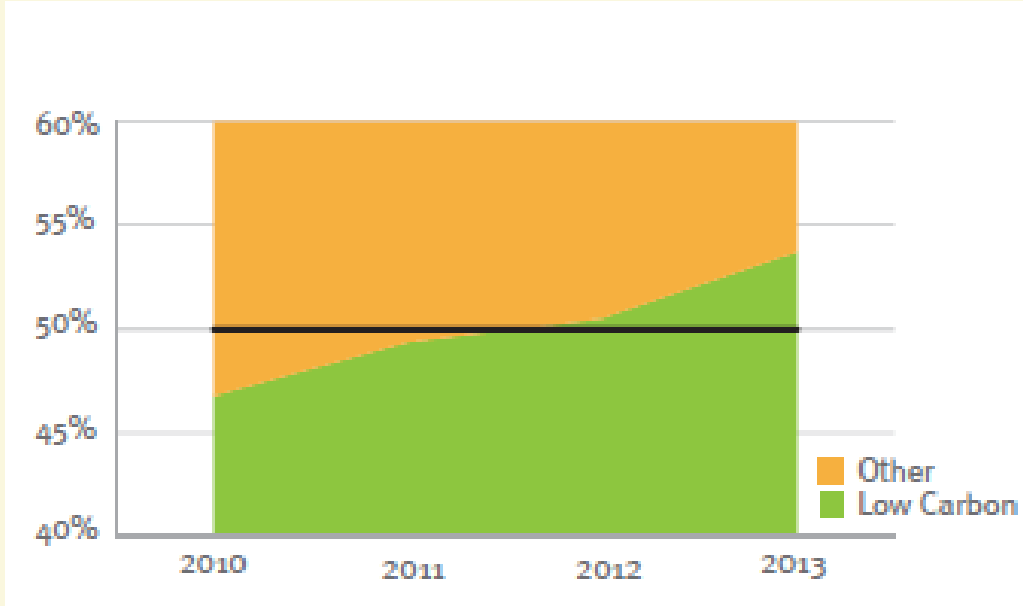
**AN EMBOLDENED,
 RESILIENT GRID
 TAKES SHAPE**

Source: Clean Edge research



A sector in transformation: Electricity industry trends and figures, Eurelectric, January 2015, based on the latest available industry figures (2013)

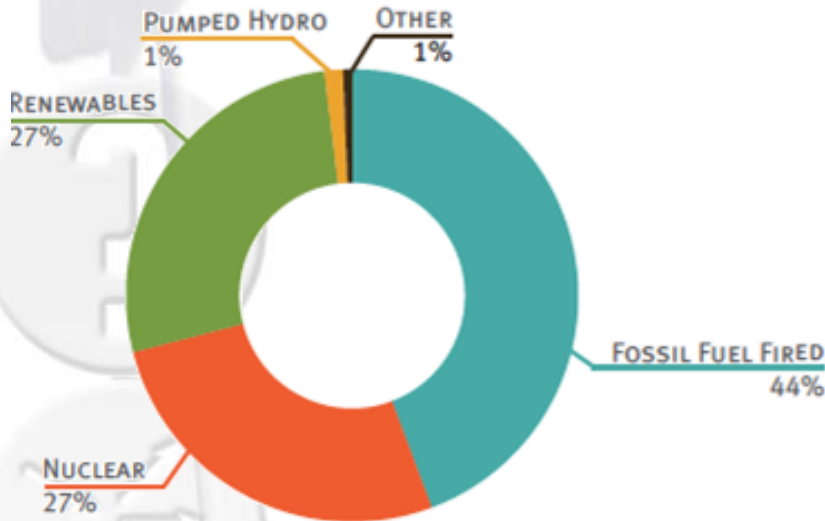
FIGURE 1: SHARE OF LOW CARBON TECHNOLOGIES VERSUS OTHER IN TOTAL ELECTRICITY PRODUCTION IN EU28



Source: EURELECTRIC

Smart Grids

2013



A sector in transformation: Electricity industry trends and figures, Eurelectric, January 2015, based on the latest available industry figures (2013)

FIGURE 9: THE SHARE OF RENEWABLE ENERGY SOURCES IN THE TOTAL EU-28 RENEWABLES GENERATION MIX FOR 2013

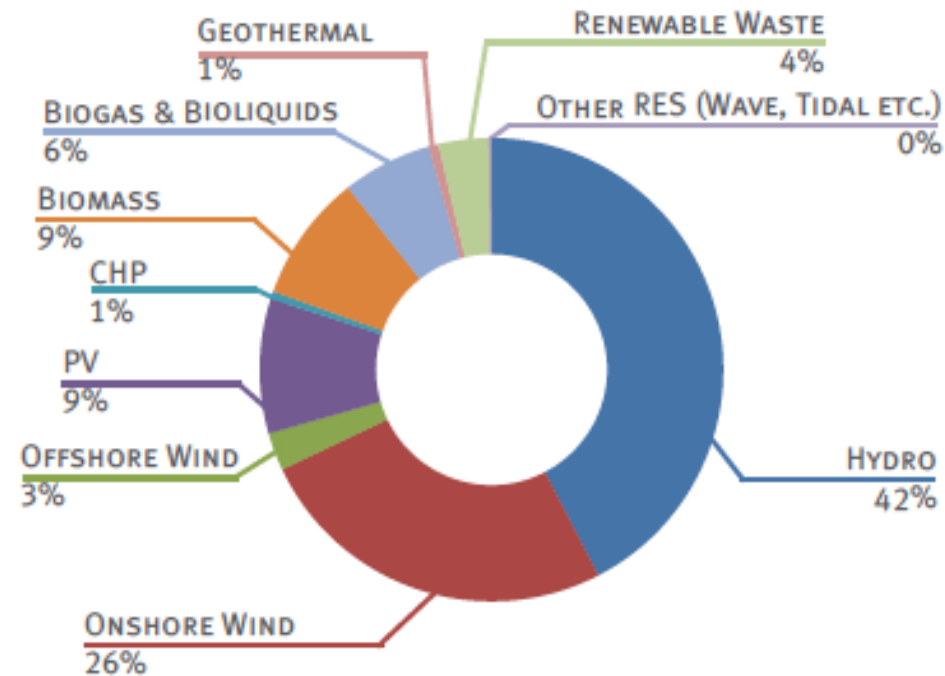


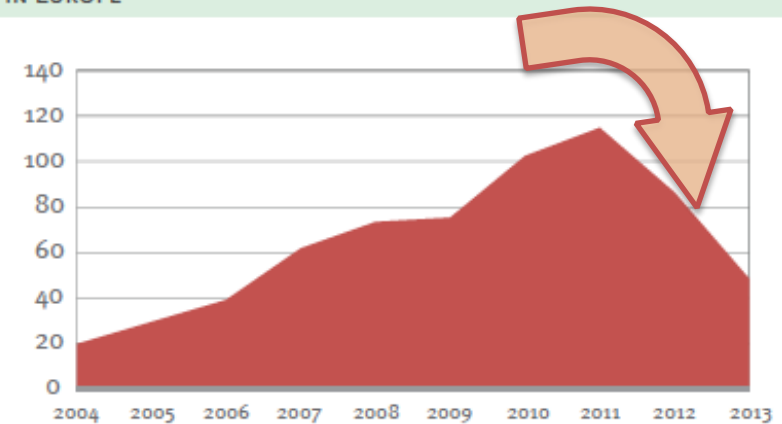
TABLE 2: EXAMPLE OF COUNTRIES WITH A HIGH PEAK SOLAR AND PEAK WIND PRODUCTION

PEAK SOLAR						
	Peak Solar powered generation in 2013 in 15 min interval	Date of Peak Solar generation			Final consumption in the 15 minutes of peak solar production	% covered by Solar
GERMANY	5988	21	Jul	2013	10743	56%
BELGIUM	2.062	20	Apr	2013	7.119	29%

PEAK WIND						
	Peak Wind powered generation in 2013 in 15min interval	Date of PeakWind generation			Final consumption in the 15 minutes of peak wind production	% covered by Wind
DENMARK	4.892	22	Oct	2013	4.914	99%
PORTUGAL	3.864	10	Dec	2013	6.654	58%

Issue / opportunity

FIGURE 11: ANNUAL INVESTMENT (\$BN) IN RENEWABLE ENERGY IN EUROPE



Source: Global Trends in Renewable Energy Investment 2014, Bloomberg New Energy Finance

- Intelligent energy resource management
- New players
- New business models
- ...

TABLE 3: SELECT GOVERNMENTS THAT HAVE ACHIEVED 100% RENEWABLE ELECTRICITY

GOVERNMENT	POPULATION	DATE ACHIEVED
Aspen, Colorado, U.S.	6,700	2015
Carinthia, Austria	550,000	2013
El Hierro, Canary Islands, Spain	10,700	2014
Greensburg, Kansas, U.S.	777	2010
Iceland	317,351	1982
Kodiak Island, Alaska, U.S.	15,000	2015
Schleswig-Holstein, Germany	2,800,000	2014
Tokelau, New Zealand	1,337	2012

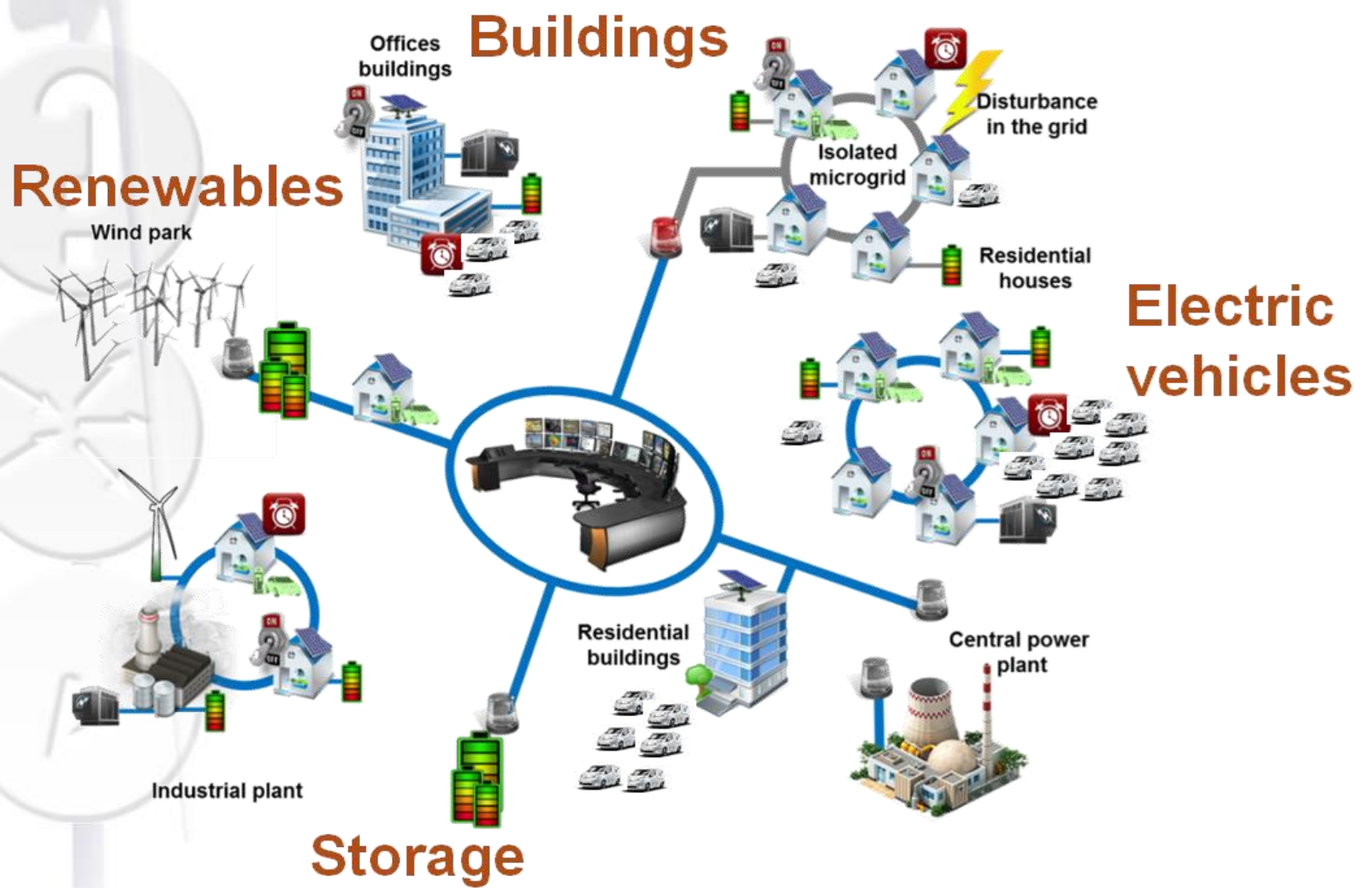
Source: Clean Edge research



April 2013: 136 areas in Germany had already fixed a 100% renewable energy target

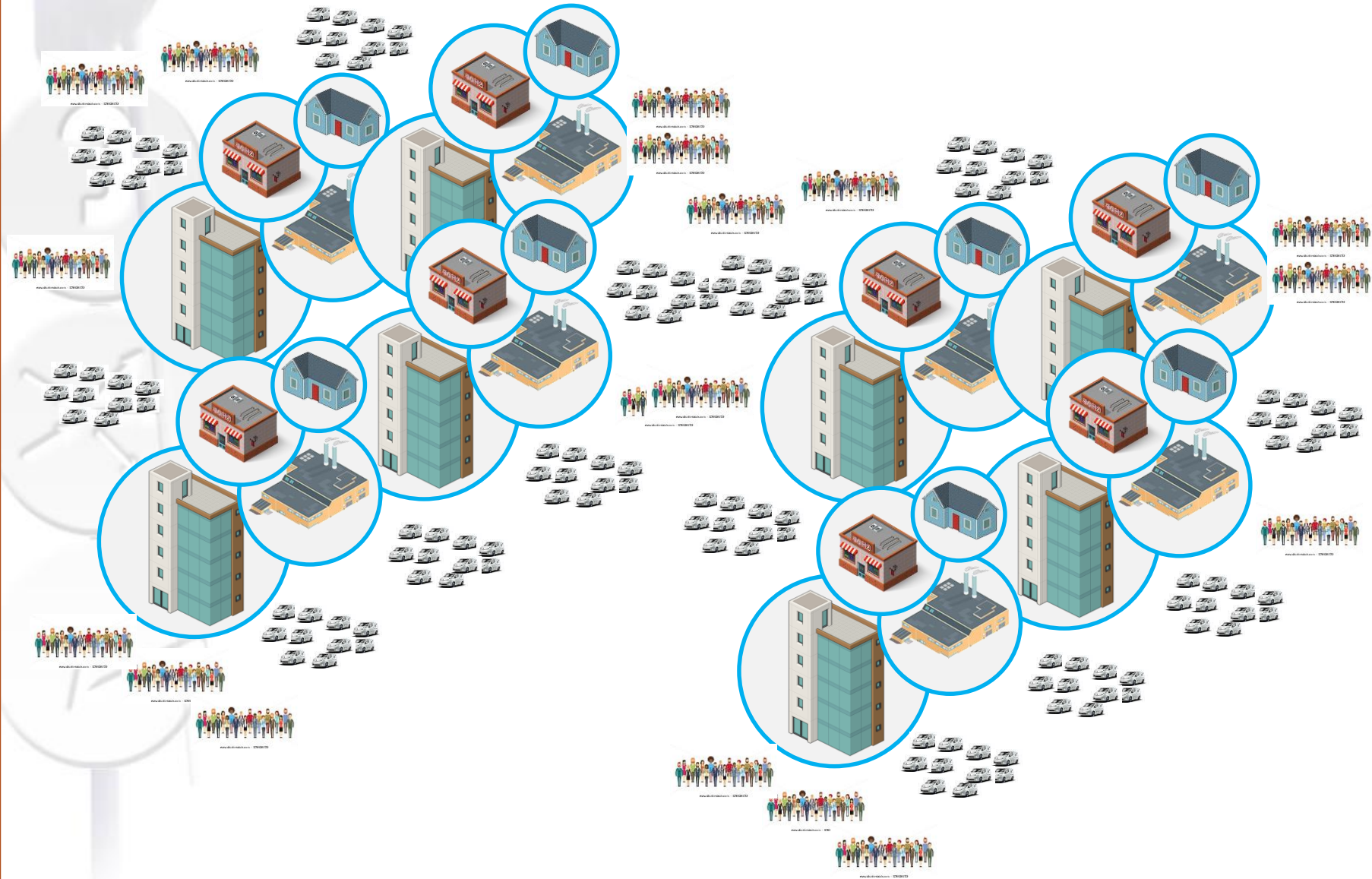
Smart Grids

Smart grids & microgrids



What are we missing???

People



- Citizens (smart cities)
- Customers (retailers)
- Consumers (utilities)
- ...

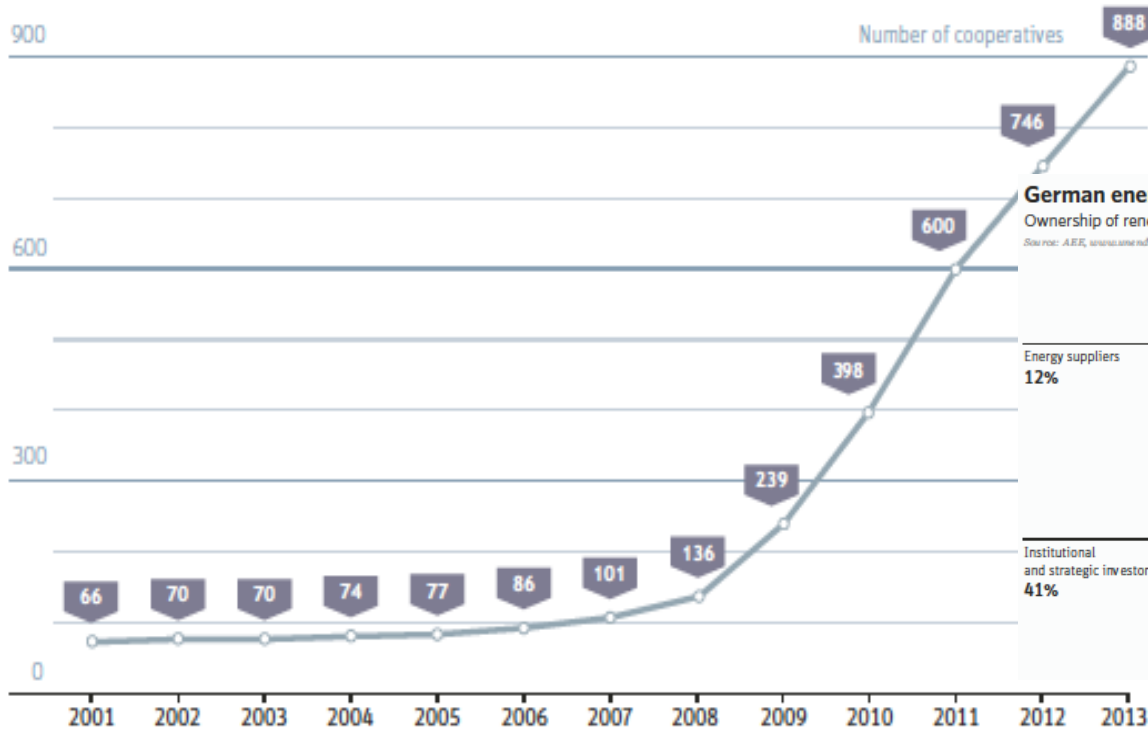


- **Active consumers**
 - Demand response
- **Resource/player aggregation**

Citizens form cooperatives to drive the energy transition

Number of energy cooperatives in Germany, 2001-2013

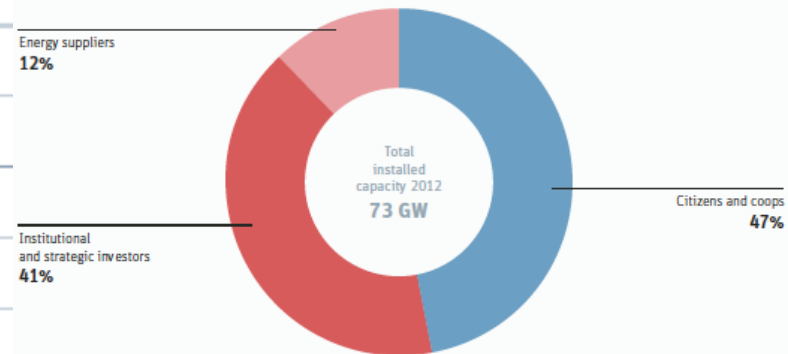
Source: www.unendlich-ich-ist-energie.de



German energy transition is a democratic movement

Ownership of renewables in 2012

Source: AEE, www.unendlich-ich-ist-energie.de



Energy Transition, The German Energiewende, By Craig Morris, Martin Pehnt

An initiative of the Heinrich Böll Foundation

Released on 28 November 2012, Revised July 2015

www.energytransition.de

New York REV (Reforming the Energy Vision)



S&C High-Speed Fault-Clearing Systems
Minimize or Eliminate Power Outages for
Military Bases



Markets Policy Players Microgrids Infrastructure Regions Resources W

Moody's on New York REV: Winners, Losers and What's Next

October 21, 2015 By Elisa Wood [Leave a Comment](#)

SHARE: [Twitter 18](#) [Facebook 2](#) [LinkedIn 54](#) [Google](#) [More](#)

New York utilities would not become obsolete, but may actually see their value increase under New York's Reforming the Energy Vision, or REV, according to a report issued this week by Moody's Investors Service.

REV is a regulatory remaking of electricity markets being watched carefully by other states as a possible model to manage the growing decentralized grid. The sweeping industry restructuring would give new status on the grid to local energy and likely heighten microgrid development.



This would disrupt the conventional business model of the state's major utilities: Consolidated Edison, National Grid, Iberdrola and Fortis.

However, New York is looking at ways to reconfigure and preserve the investor-owned utility role on the disrupted electric grid. Rather than becoming obsolete, utilities may in fact "see their value increase," Moody's said.

"By proactively encouraging utilities to adopt a business model that supports new technologies, a long-term plan like REV could prove to be an orderly and economic response to the technology risk facing the utility industry," said Moody's senior vice president Mihoko Manabe in the report, "Regulated Utilities — US: NY's REV: Seeking a Greener Utility Grid for the Environment and Investors."

Power to the people - the blockchain's consumer energy revolution begins in New York



By Ian Allison

April 11, 2016 17:00 BST

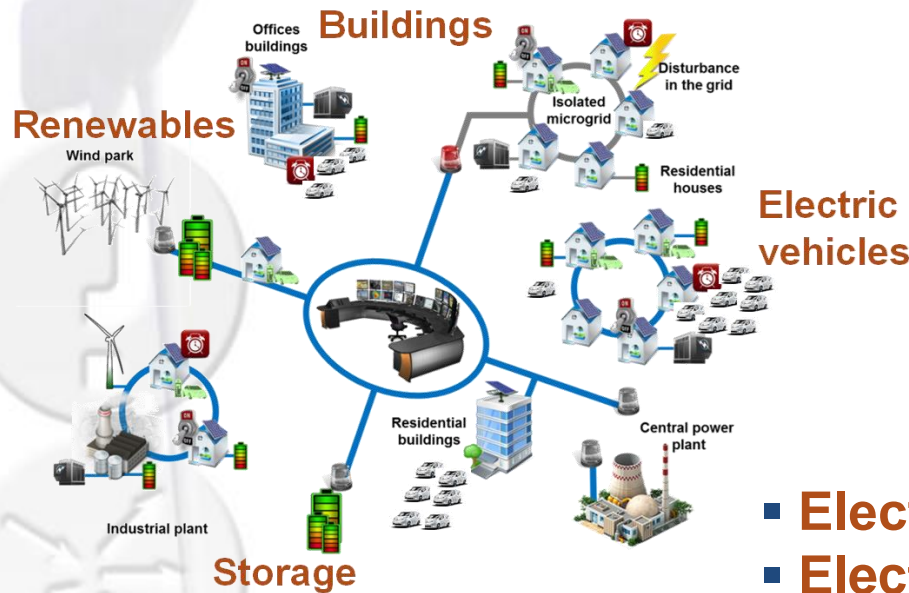
[f 265](#) [Twitter](#) [g+](#) [Reddit](#) [in](#)



Power to the people - the blockchain's consumer energy revolution begins in New York (iStock)

The energy industry took a giant step towards a consumer-run future today (Monday April 11) when New York start-up TransActive Grid enabled the first ever peer-to-peer paid transaction of energy in the USA.

Giant step



Smart grids & microgrids + Electricity market(s)

- Electricity market ≠ wholesale market
- Electricity market ≠ wholesale retail market

**NEW
ERA**

- Energy transactions and service provision
 - Transactive energy
 - Transactions among neighbors
- Business Models
 - Contracts
 - Tariffs
 - Demand response



**Artificial Intelligence
&
Intelligent systems**

**Optimization and Computational
Intelligence**

Machine learning

Knowledge discovery

Big data

Intelligent Interfaces

Affective computing

**Power
&
Energy systems**

User modeling

Cyber-physical systems

Multi-agent systems

Context Awareness

Semantic web

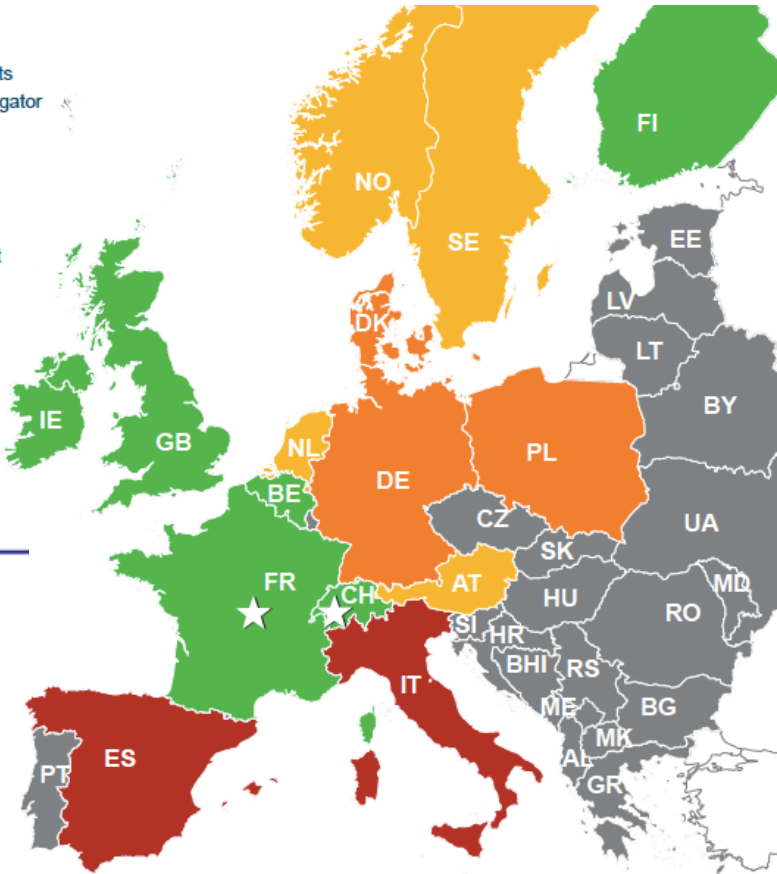
Ambient intelligence

Ontologies

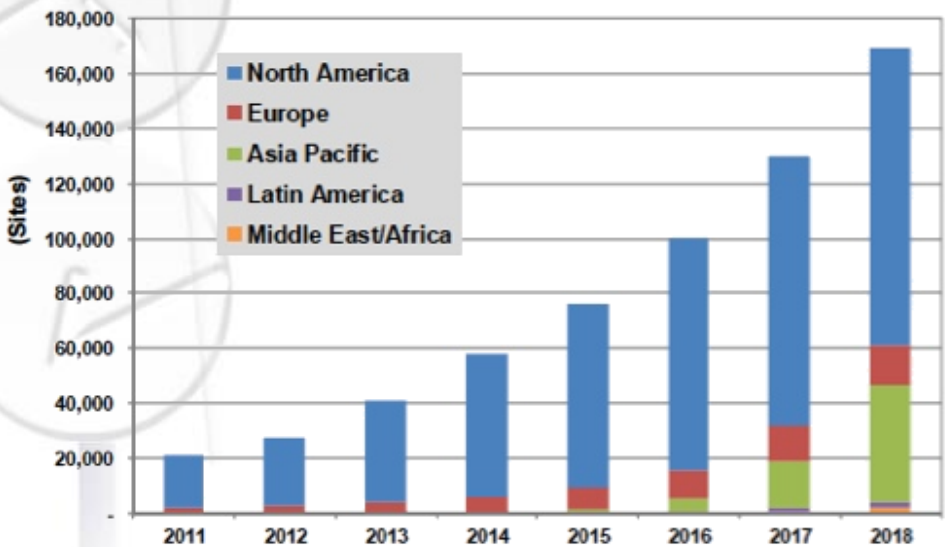
Demand response

Demand Response

- ★ Commercially active, standardised arrangements between BRP and aggregator in place
- Commercially active
- Partial opening
- Preliminary development
- Closed
- Not assessed



ADR-Enabled Sites by Region, World Markets: 2011-2018



SEDC. Mapping Demand Response in Europe Today, Sept. 2015

(Source: Pike Research)

Enabling Effective Demand Response

DREAM GO

DREAM-GO – Enabling Demand Response for short and real-time Efficient And Market Based smart Grid Operation - An intelligent and real-time simulation approach



Leader: GECAD (Portugal)
3 EU countries,
5 EU institutions
1 US institution
3 companies

2015-2018

Enabling Effective Demand Response

DREAM-GO

DREAM GO

P.PORTO

gecad ? ✖ ✓
Research Group on Intelligent Engineering and Computing
for Advanced Innovation and Development



**VNIVERSIDAD
D SALAMANCA**
CAMPUS DE EXCELENCIA INTERNACIONAL



Sal
800 AÑOS
1218 ~ 2018



RESEARCH GROUP
BISITE.usal.es

V P S
Virtual Power
Solutions



nebusens




European Union




HORIZON 2020
MARIE CURIE

CLEMSON
UNIVERSITY



CLEMSON UNIVERSITY
SOUTH CAROLINA
1889



Real-time Power and Intelligent Systems
RTPIS

DISCOVERGY
ENTDECKE DEINE ENERGIE

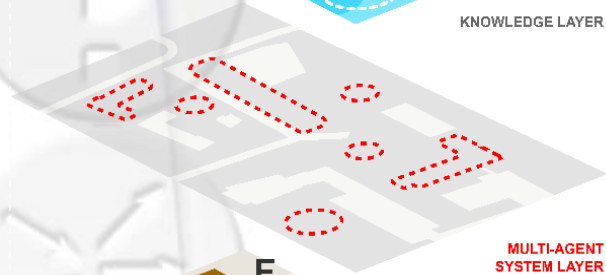
Real-time smart grid management and simulation platform



KNOWLEDGE LAYER



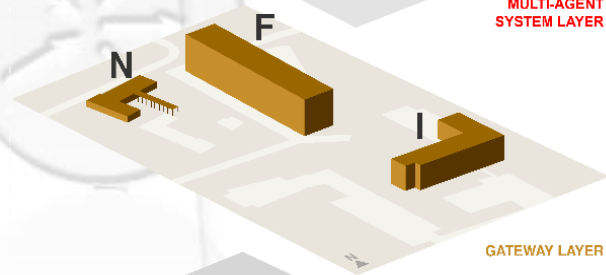
Intelligent applications and services



MULTI-AGENT
SYSTEM LAYER



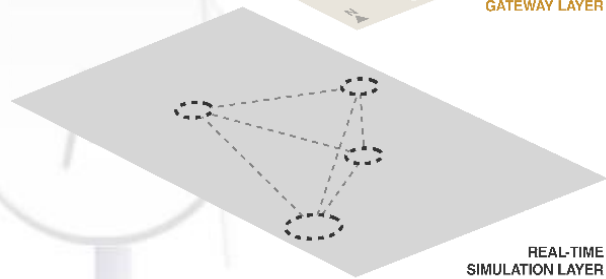
Multi-Agent System(s)



GATEWAY LAYER



Real buildings and equipment Developed gateways for real-time data acquisition and control

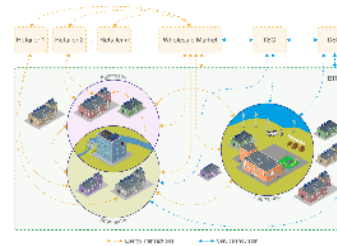
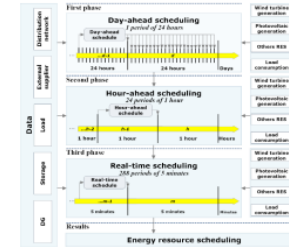
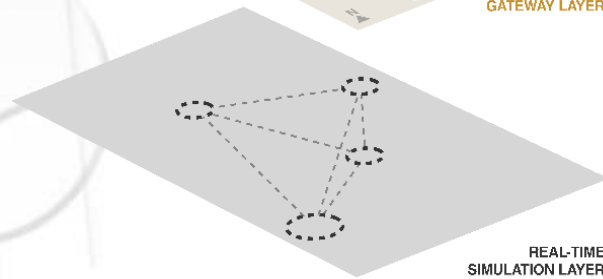
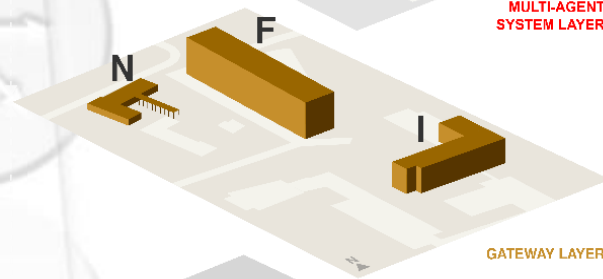
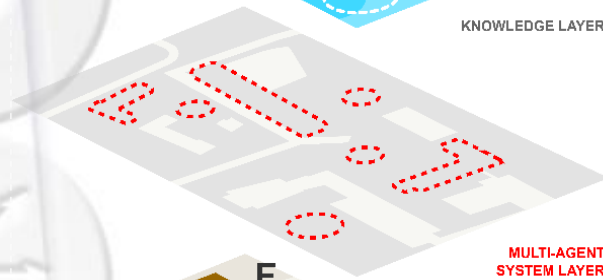


REAL-TIME
SIMULATION LAYER

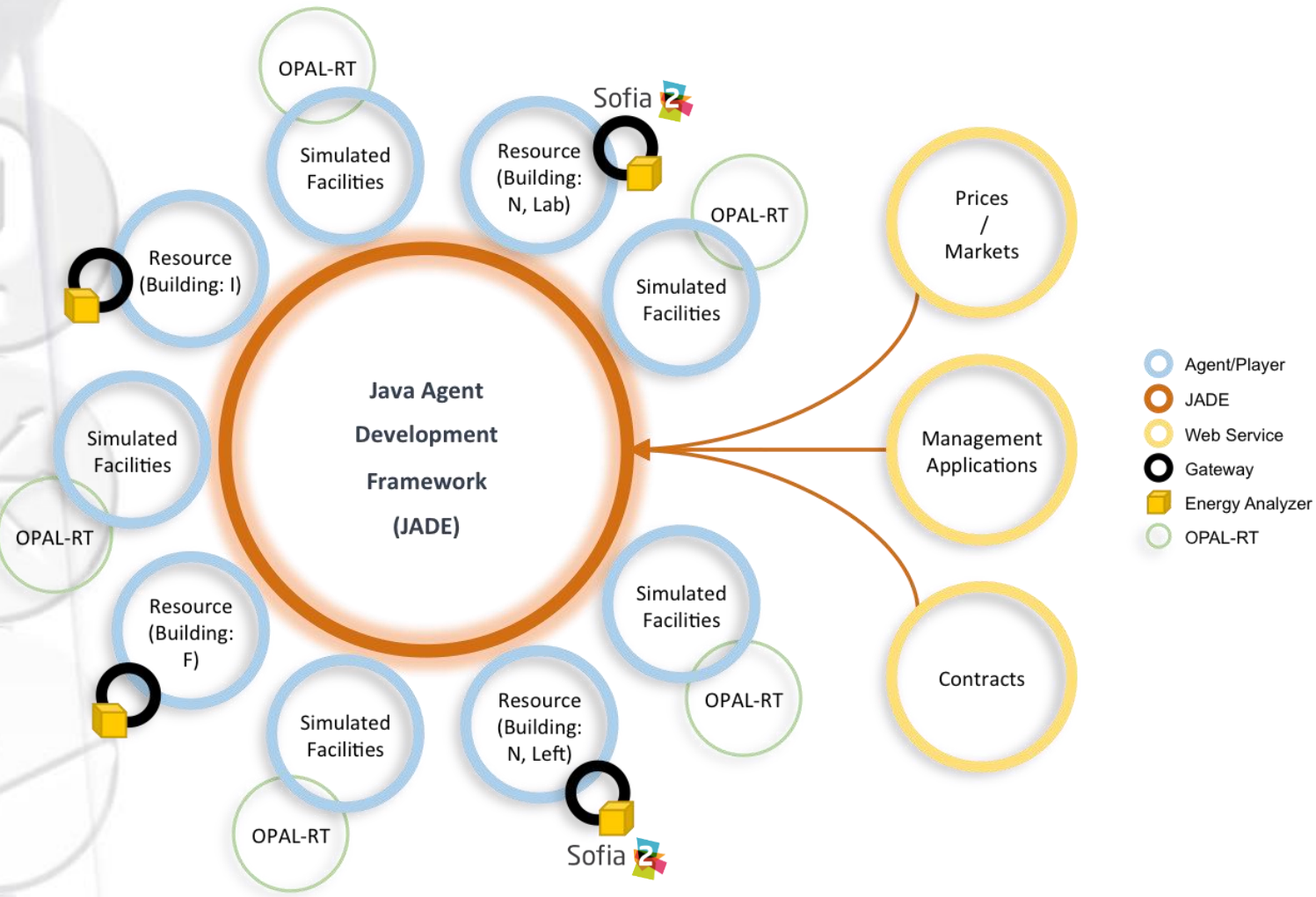


Real-time simulator for all the components that we miss in our system

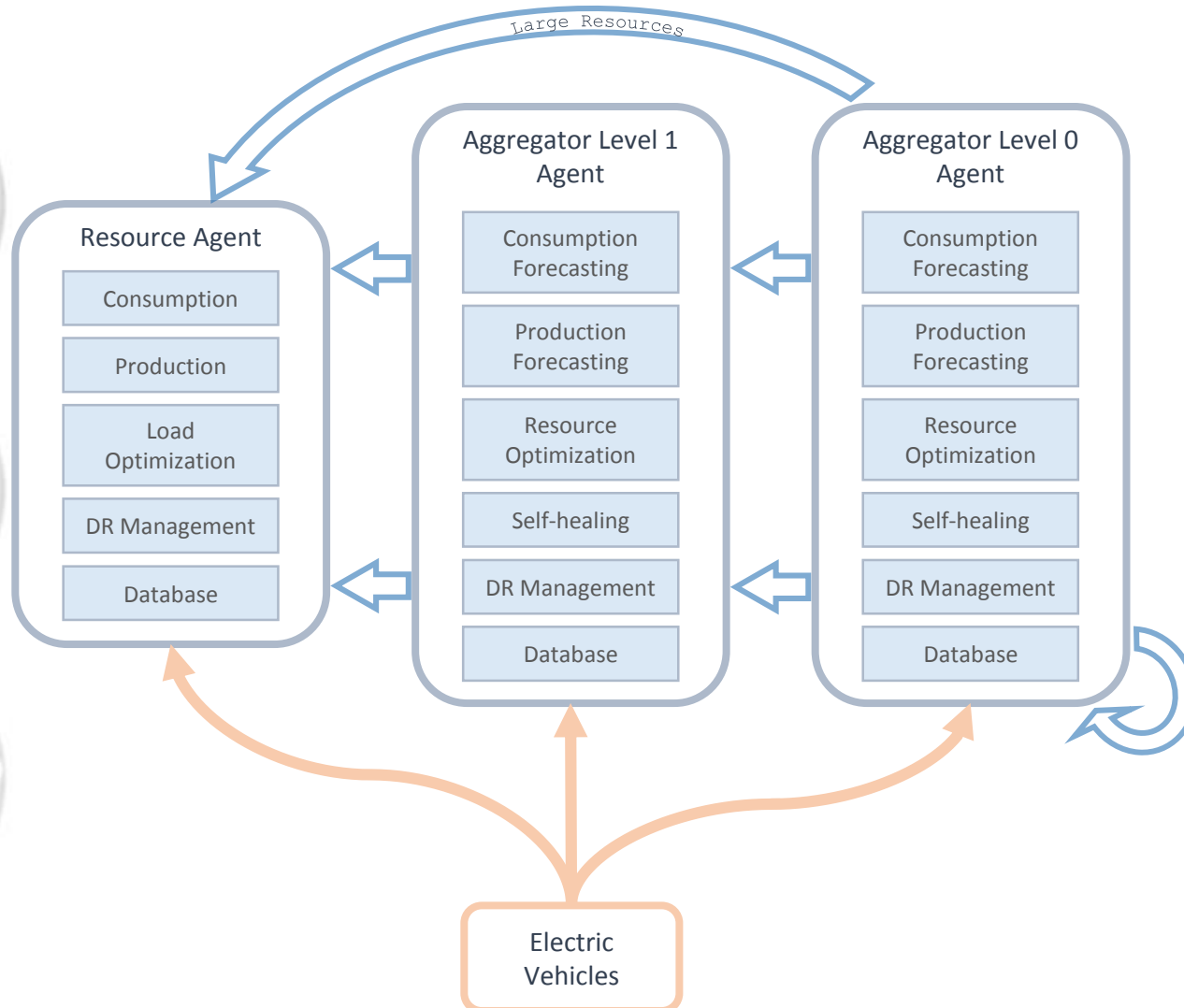
Real-time smart grid management and simulation platform



Real-time smart grid management and simulation platform

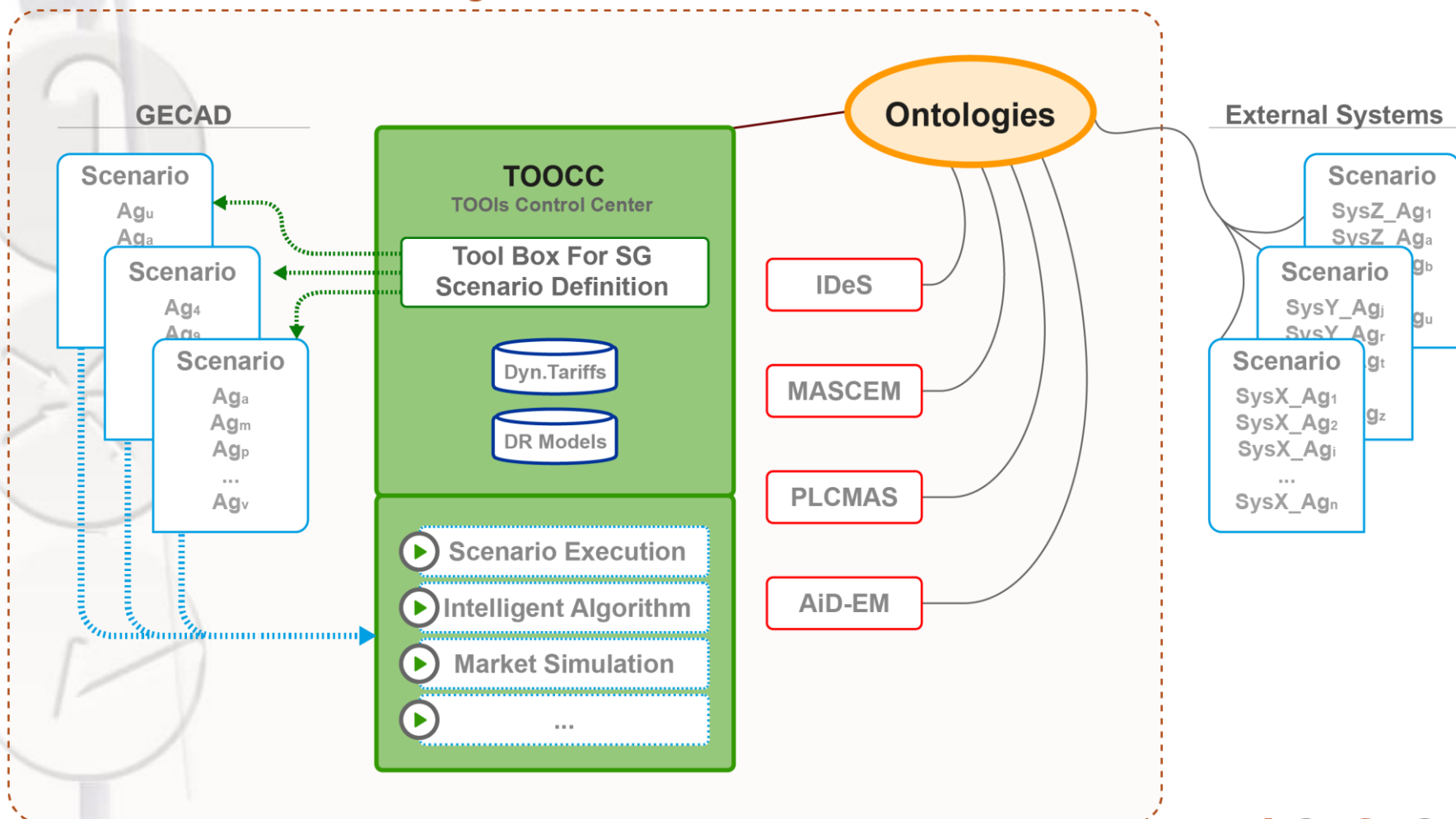


Real-time smart grid management and simulation platform



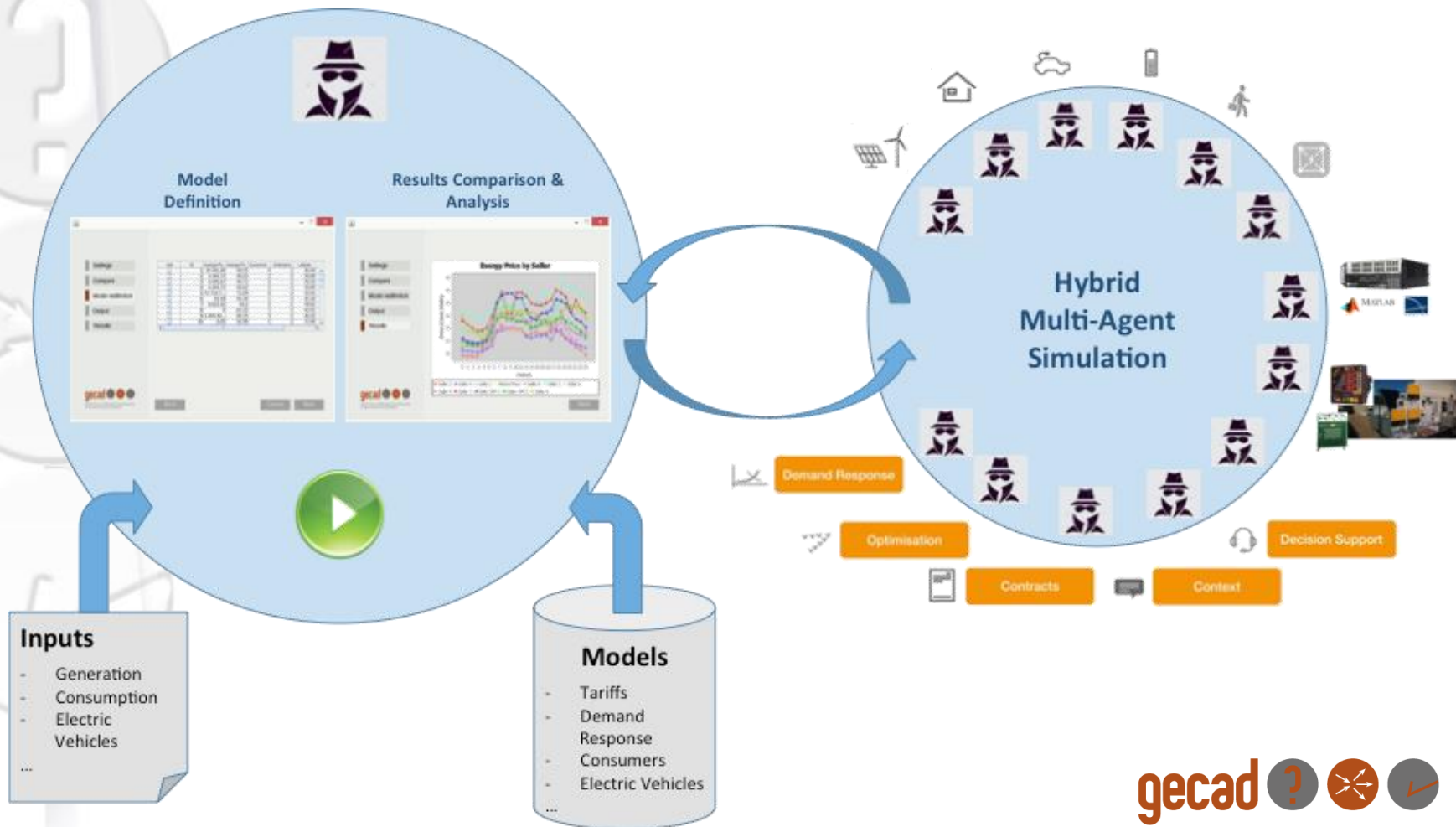
Real-time smart grid management and simulation platform

Multi Agent Smart Grid Tools



Real-time smart grid management and simulation platform

TOOls Control Center (TOOCC) Model, Setup, Execution, and Analysis



Real-time smart grid management and simulation platform

Implementation tools

Agents are implemented in JAVA

www.java.com

using the JADE framework

<http://jade.tilab.com/>

Several of the decision support methodologies are developed in Prolog

www.lpa.co.uk

Calculation and metaheuristics algorithms are mostly programmed in MatLab

www.mathworks.com/products/matlab/

Deterministic optimization models are implemented using GAMS and/or TomLab

<https://www.gams.com/>

<http://tomopt.com/tomlab/>

Several models are implemented in SIMULINK

www.mathworks.com/products/simulink/

Real-time smart grid management and simulation platform

Databases are currently implemented in SQL SERVER

<http://www.microsoft.com/es-es/server-cloud/products/sql-server/>

Several data-mining models (clustering, forecasting and classification) are implemented in R and in IBM SPSS Modeler

<https://www.r-project.org/>

<http://www-01.ibm.com/software/analytics/spss/products/modeler/>

Automation devices are programmed in C

<http://www.cprogramming.com/>

Web services are implemented in C# / .NET <https://msdn.microsoft.com/en-us/library/z1zx9t92.aspx>

Ontologies can be written in any language supported by JENA (e.g. RDF, RDF/JSON, JSON-LD, Turtle, RDF/XML)

<https://jena.apache.org/>

Real-time smart grid management and simulation platform

Some communications with physical devices are done through the MODBUS protocol using TCP/IP, RS485 and ZigBee

<http://www.modbus.org/>

Some resources are modeled using PSCAD

<https://hvdc.ca/pscad/>

Actual equipment control

- PLCs (Programmable logic controllers)
- Hardware prototyping with

- Arduino

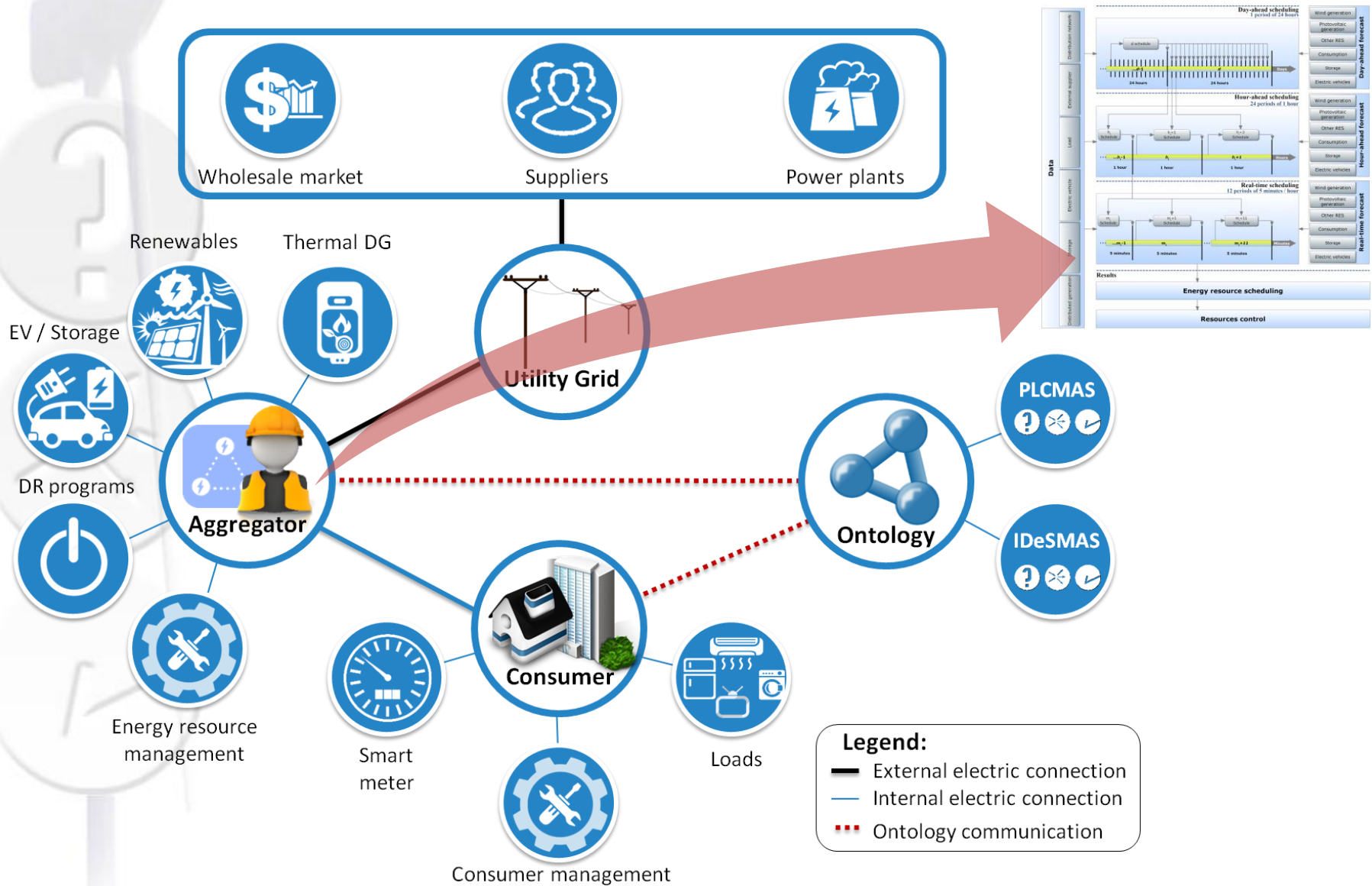
<https://www.arduino.cc>

- Kubietruck

<http://www.cubietruck.com>

Real world application

Enabling Effective Demand Response



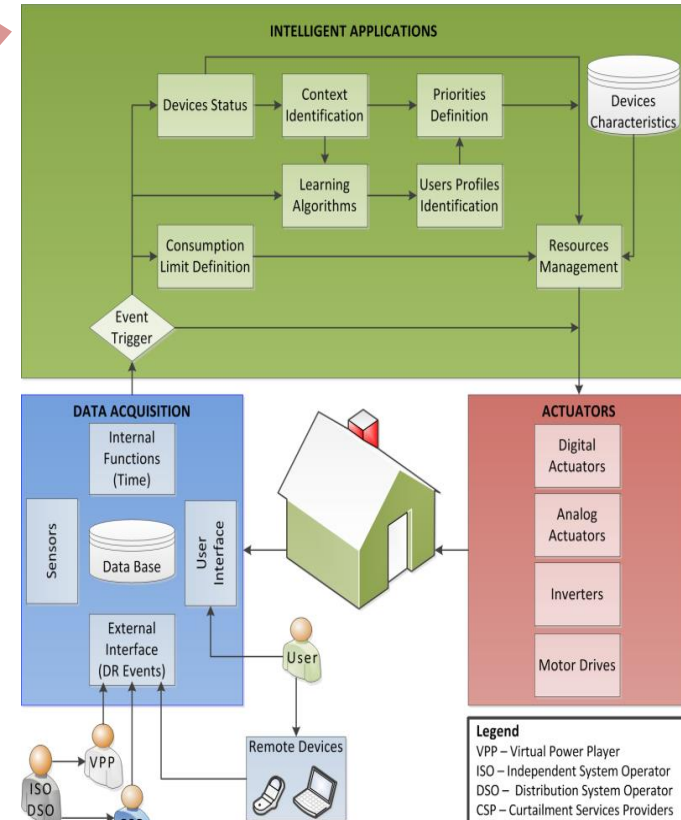
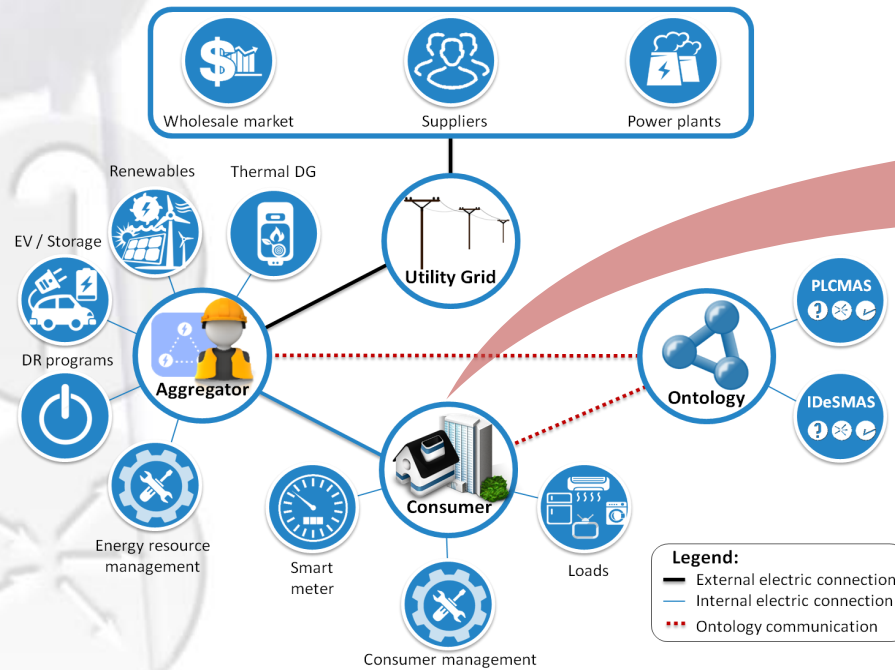
DREAM-GO



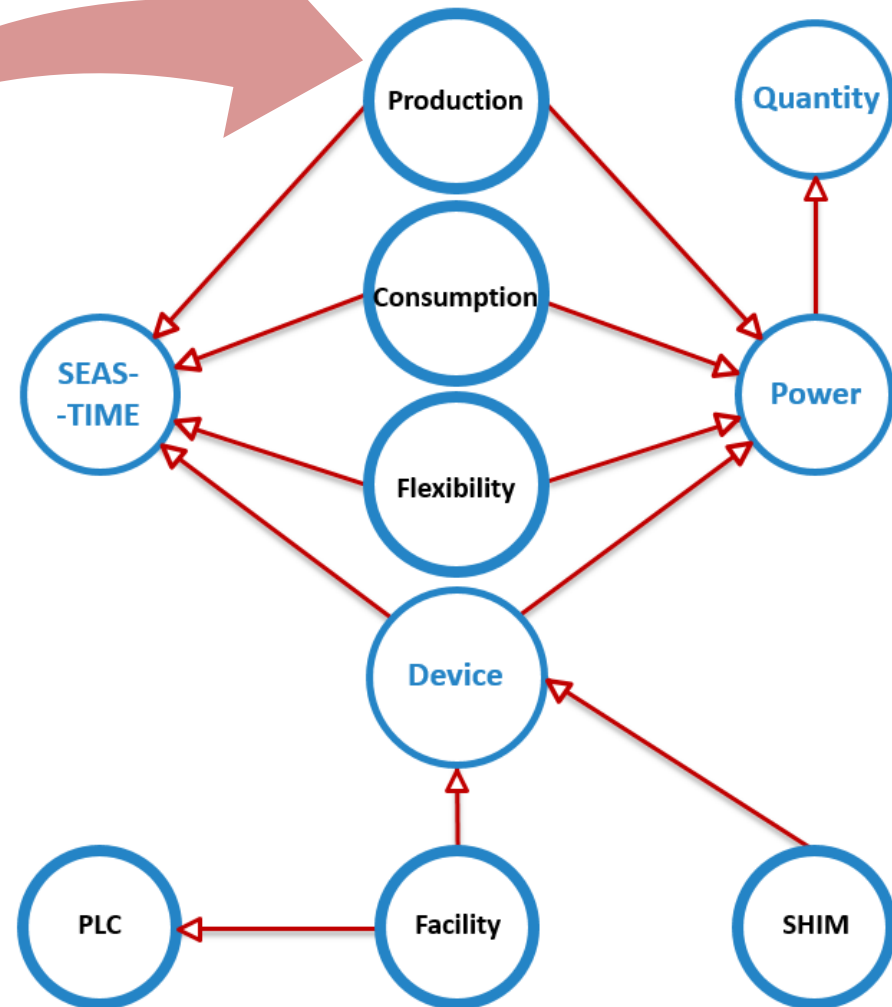
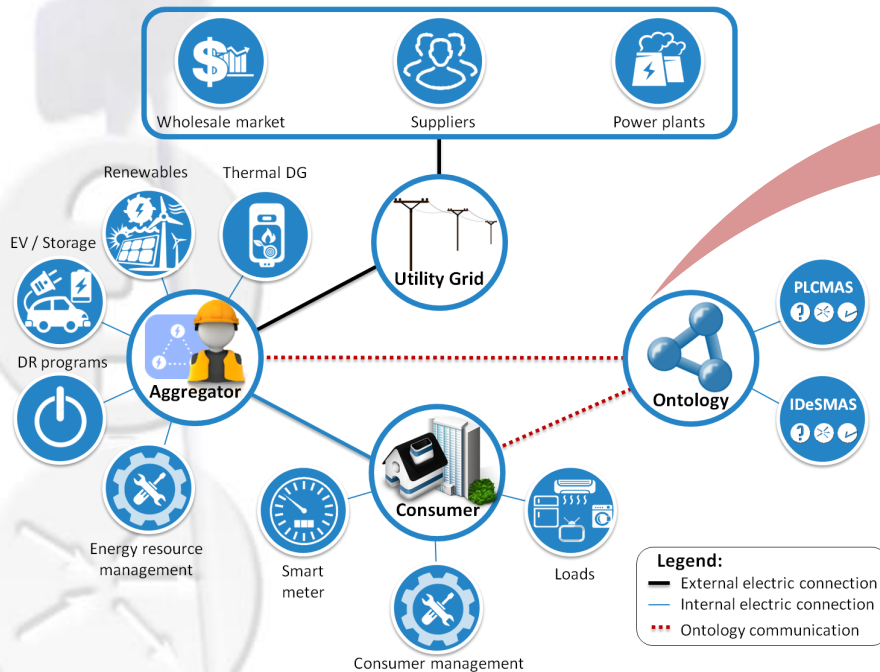
HORIZON 2020



Enabling Effective Demand Response

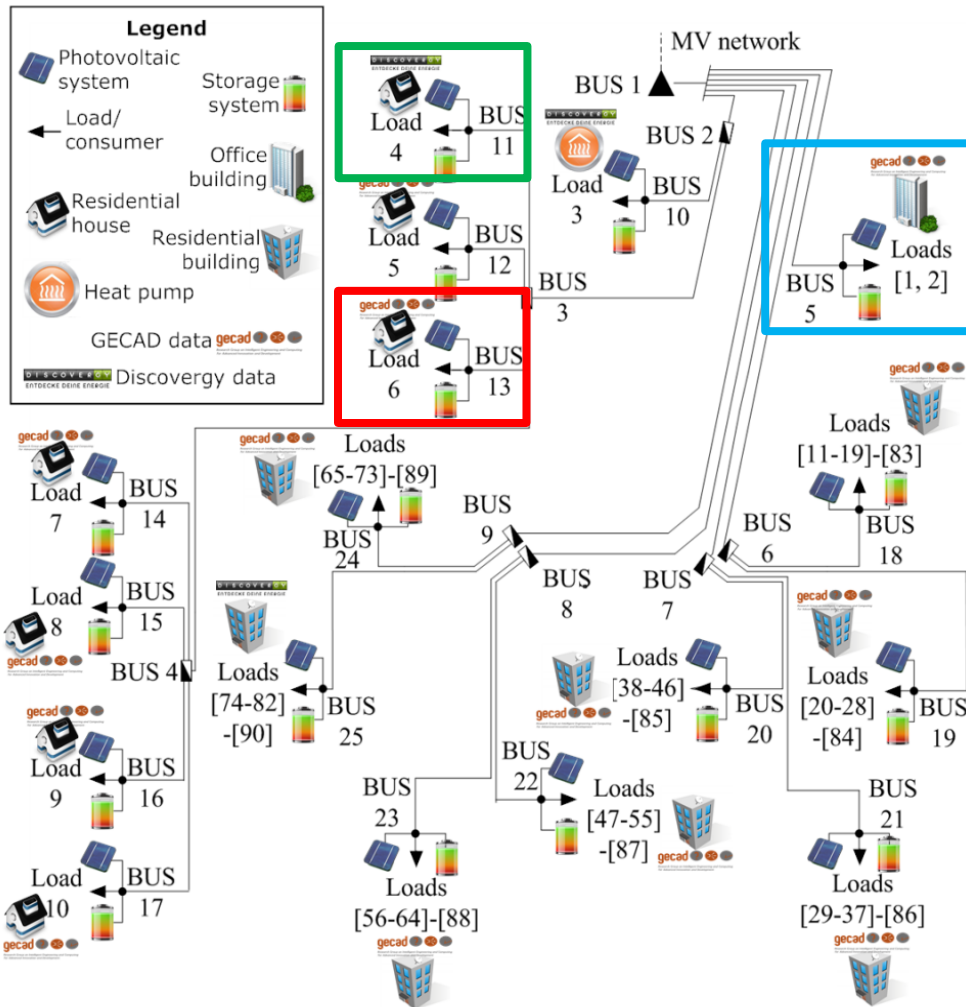


Enabling Effective Demand Response



Ontologies for the Interoperability

Enabling Effective Demand Response



Real-Time Monitoring Loads

Load 4: residential consumer

DISCOVERY
ENTDECKE DEINE ENERGIE

Load 1: GECAD office building

gecad 
Research Group on Intelligent Engineering and Computing
for Advanced Innovation and Development

Load 6: GECAD smart home lab

gecad 
Research Group on Intelligent Engineering and Computing
for Advanced Innovation and Development

Enabling Effective Demand Response

Residential consumer (Load 4):

- Aggregator scheduling → Consumers

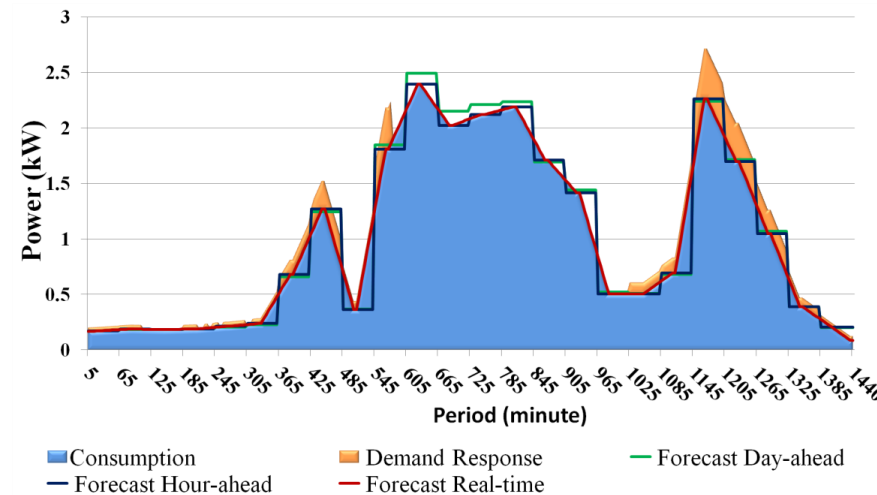
GECAD office building (Load 1):

- Aggregator scheduling → Consumers
- Local scheduling

GECAD smart home lab (Load 6):

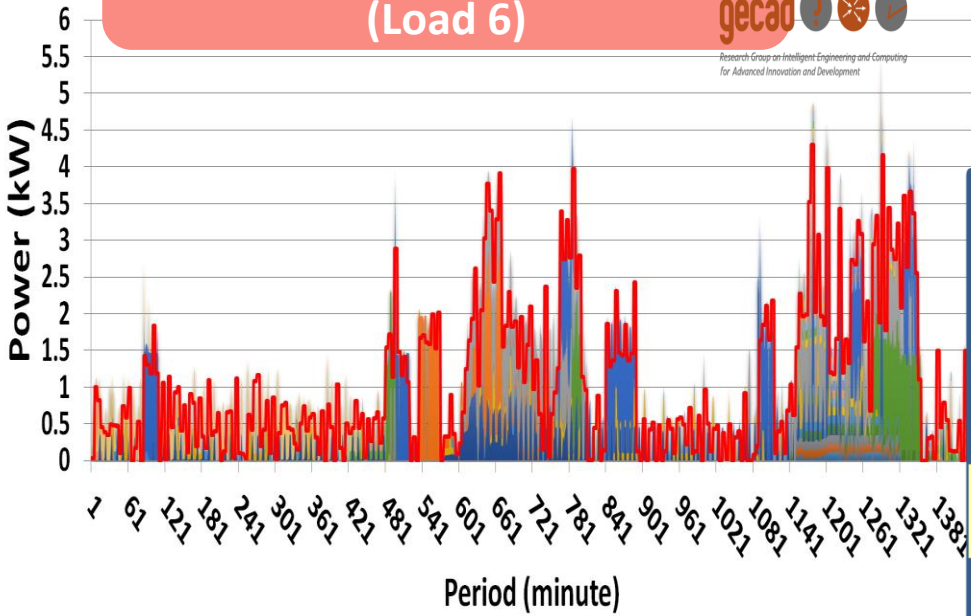
- Aggregator scheduling → Consumers
- Local scheduling
→ Direct load control via PLC

Aggregator scheduling results Residential consumer (Load 4)



Enabling Effective Demand Response

Local scheduling results
GECAD smart home lab
(Load 6)



- Light 1 Hall

HVAC Ro

Microwave Ki

Refrigerator Ki

Water heater Ba

Window 3 LV
- Light 2 Ro

TV Ro

Water cooler Ki

Washing machine Ki

Light 6 LV

HVAC LV
- Light 3 Ro

Light 4 Ki

Kettle Ki

HVAC Ki

Light 7 LV

TV LV
- Window 1 Ro

Window 2 Ki

Coffee machine K

Light 5 Ba

Light 8 LV

ERM Limit



Thank you



*Research Group on Intelligent Engineering and Computing
 for Advanced Innovation and Development*



Enabling Demand Response for short and real-time efficient management of smart grids: A multi-agent based approach

Zita Vale

zav@isep.ipp.pt
email.zitavale@gmail.com