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AARHUS UNIVERSITY
DEPARTMENT OF ENGINEERING

SEMIAH

An Aggregator Framework for European Demand Response Programs

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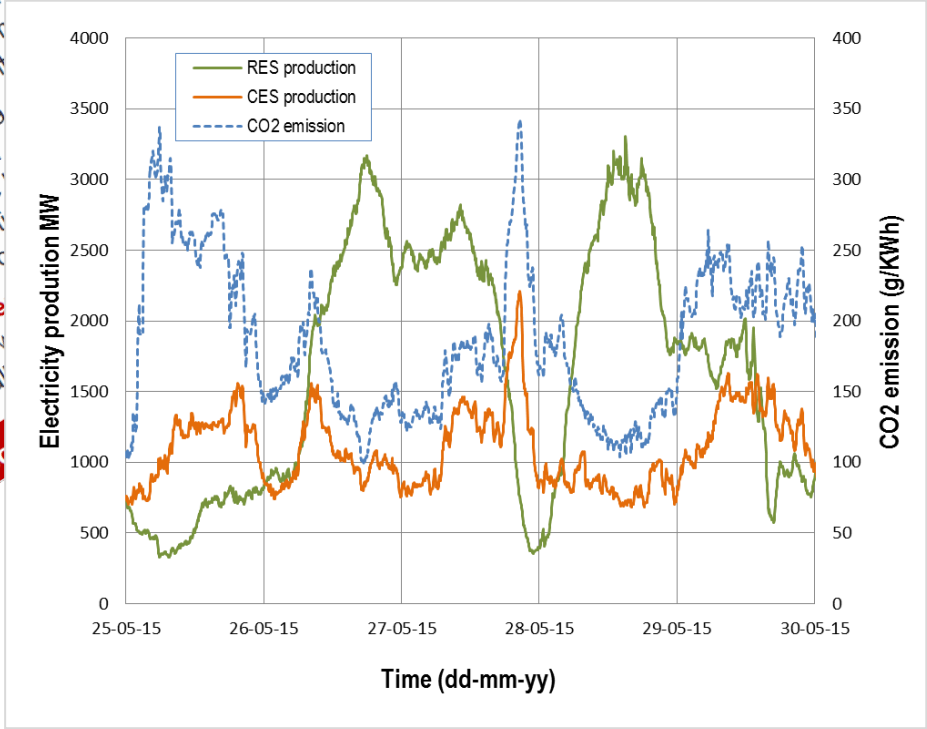
Towards a Low-Carbon Economy

- In the low-carbon economy, electricity production is going to be dominated by renewable energy sources (e.g., wind and solar power).
- Wind and solar power are intermittent forms of electricity generation.
- Electricity demand needs to be flexible and to better balance the supply.
- Electricity demand is increasing.
- Ongoing liberalization and integration of European electricity markets.

Potential of Providing Flexibility with Domestic Appliances

Danish RES and CES production (May 29, 2015)

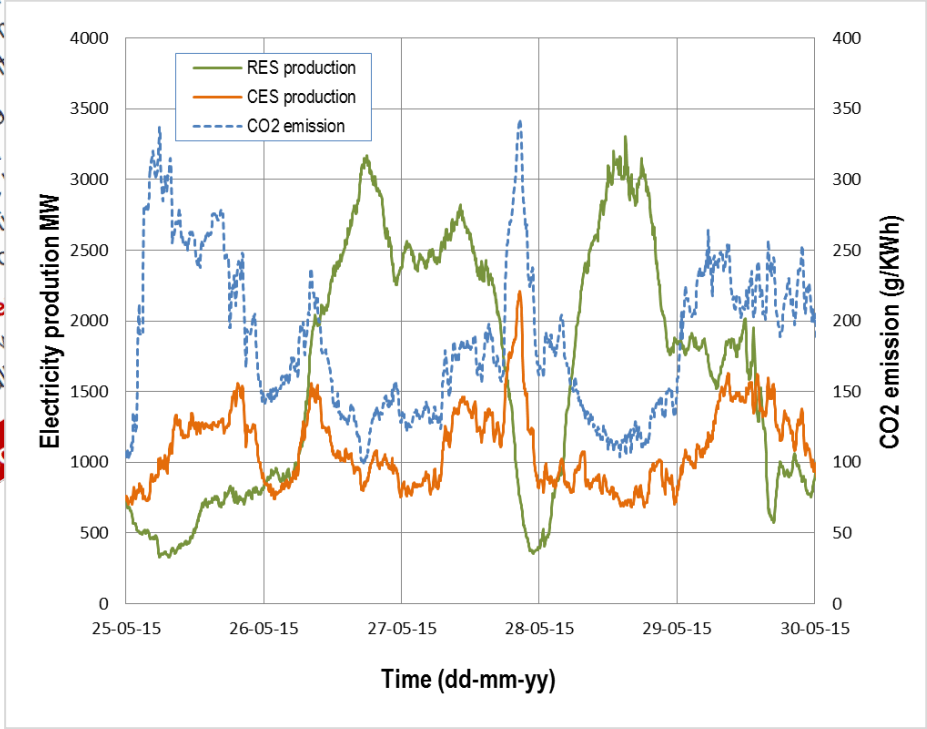


Potential of Providing Flexibility with Domestic Appliances

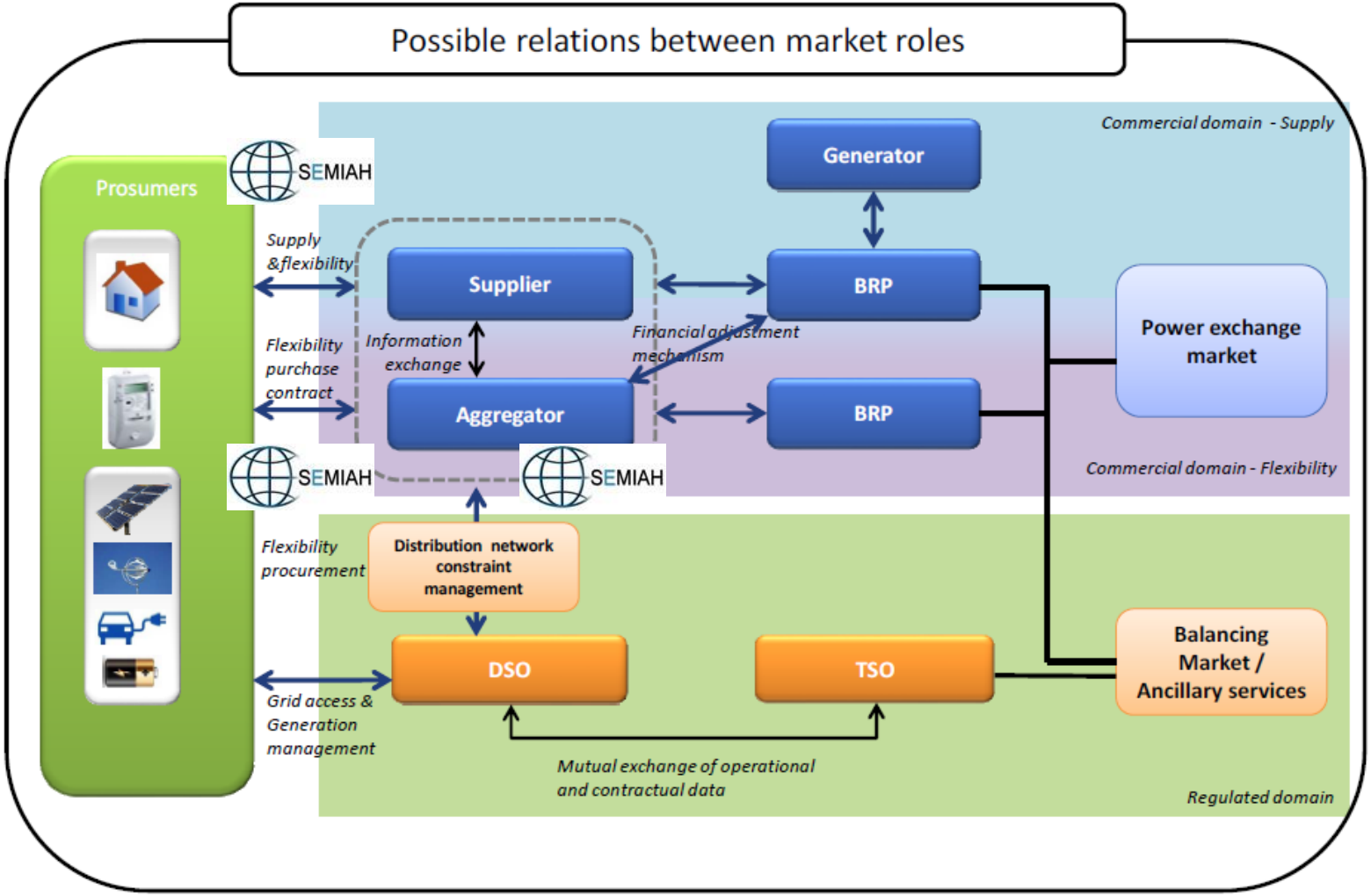
Outline

- Smart grid and regulating power
- Challenges for demand response in households
- The SEMIAH project
  - Flexibility concept
  - Project objectives
  - System model and design
  - Integration framework
  - Load scheduling and load shifting
  - Grid stability analysis

Danish RES and CES production (May 29, 2015)



Impacts – Roles & Regulatory framework



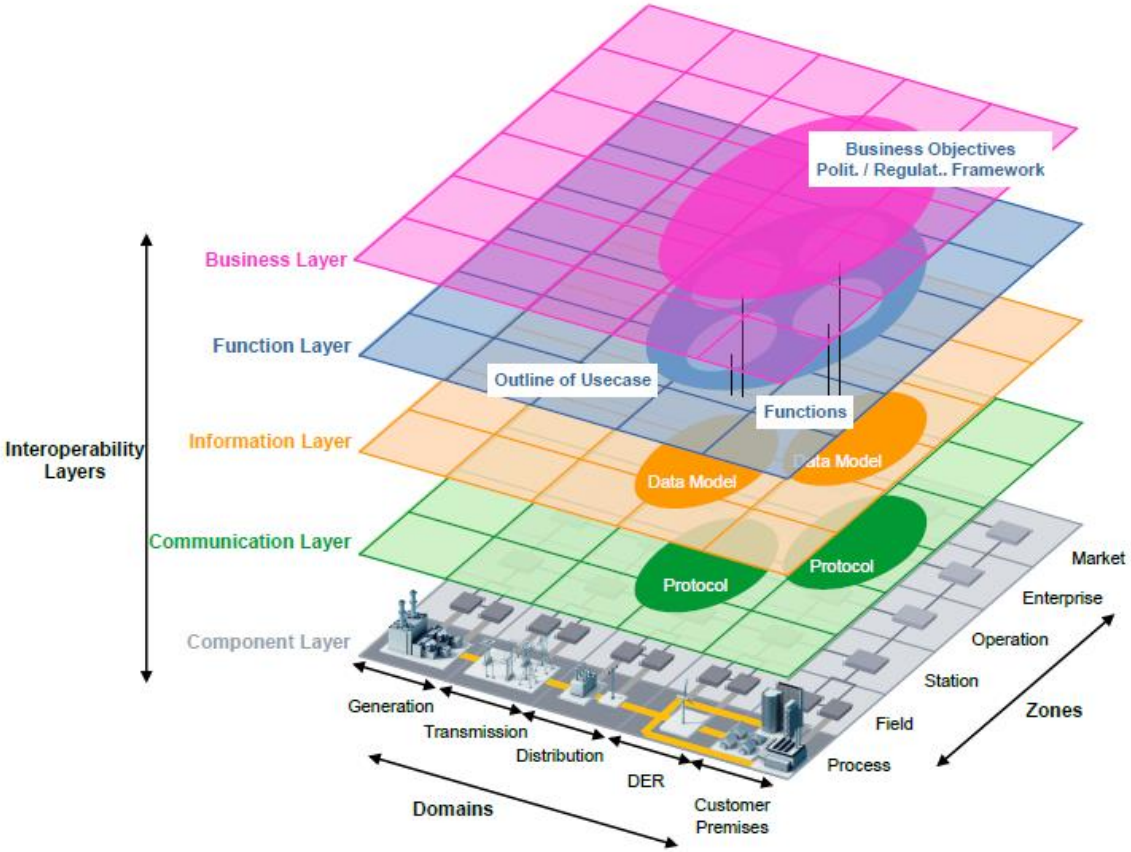
Ref: Regulatory Recommendations for the Deployment of Flexibility, EG3 Report. Smart Grid Task Force, January 2015

Smart Grid Architecture Model (SGAM)

- Holistic view of the smart grid

Domains represent a conceptual grouping of smart grid actors

Zones represent the hierarchical levels of power system management



Ref.: CEN-CENELEC-ETSI Smart Grid Coordination Group – First Set of Standards. Part of M/490. November 2012

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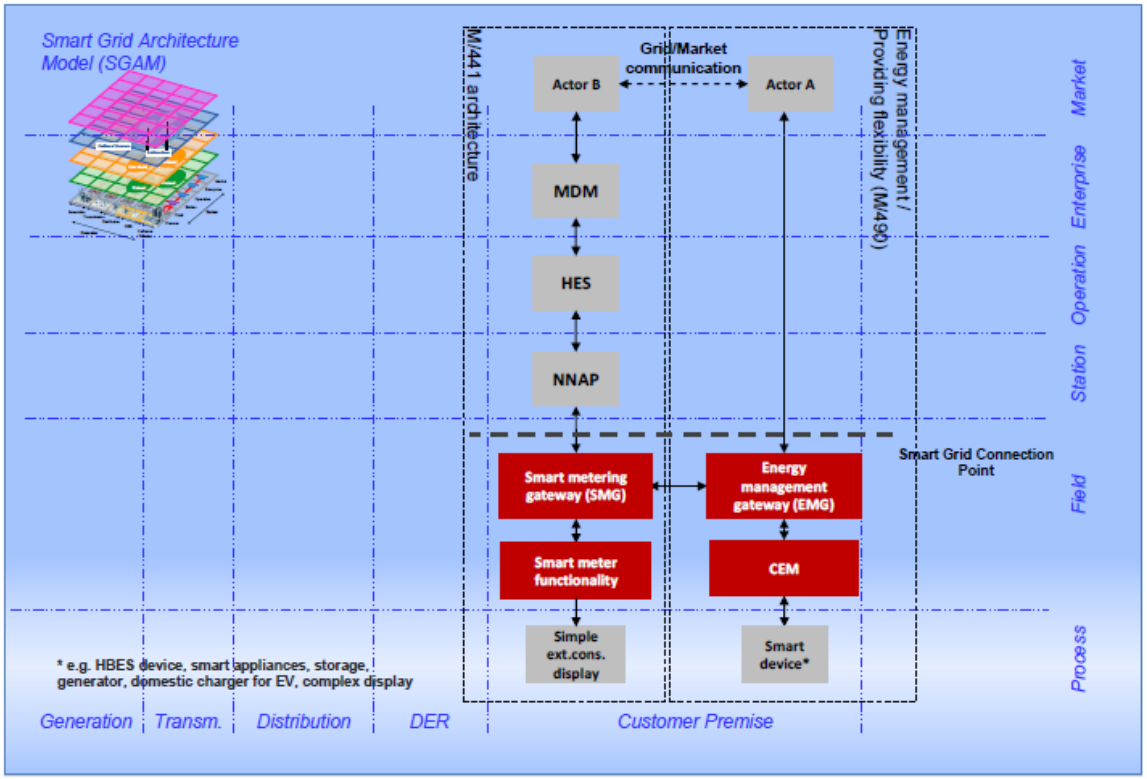

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NNAP - Neighbourhood Network Access Point

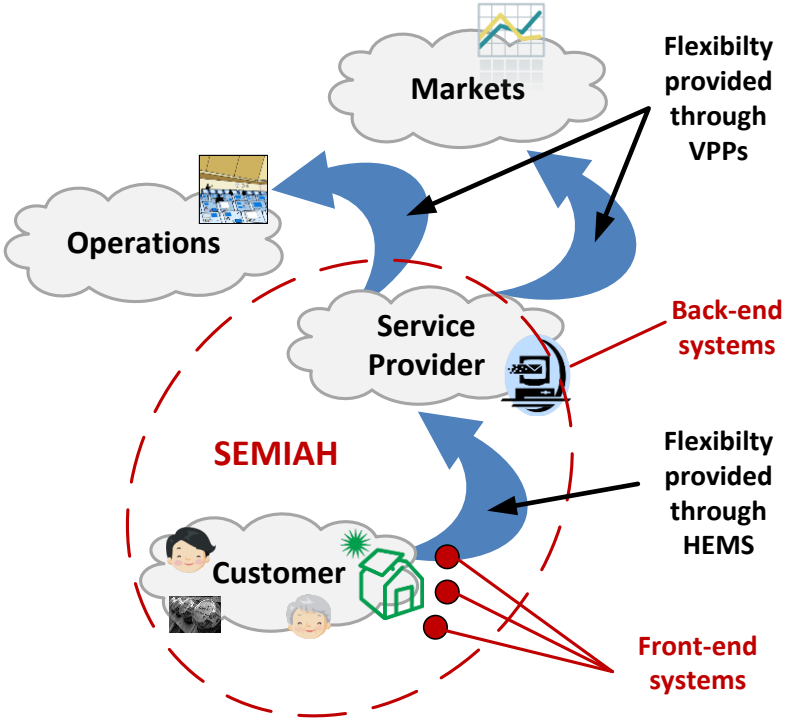
HES – Head End System

MDM - Meter Data Management

CEM – Customer Energy Manager

Challenges for Demand Response

- Scalability
- Prosumer-in-the-loop
- Interoperability
- Market integration
- Low-voltage grid stability
- Reliable and low-cost infrastructure:
  - Home Energy Management System (HEMS);
  - Virtual Power Plant (VPP)
  - Efficient algorithms

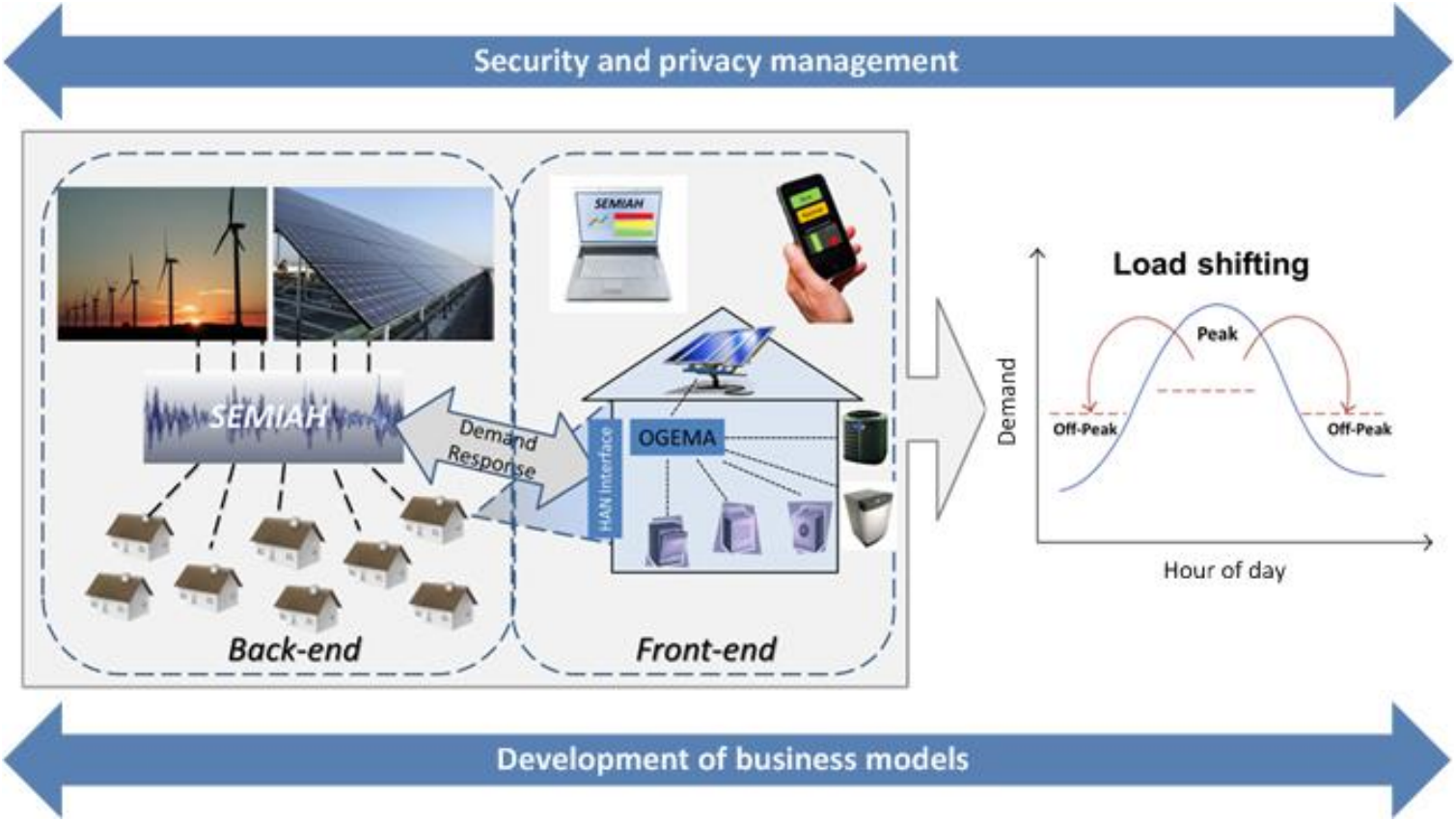


To provide 1 MWh/h of flexibility the need is about:

- Approx. 8.000 households with direct heating;
- Approx. 1.000 households total (i.e., wet appliances + heating + …)

The SEMIAH Project

Scalable **E**nergy **M**anagement **I**nfrastructure for **A**ggregation of **H**ouseholds



EU FP7 project started 2014/3 (36 months dur). 12 partners from CH, DE, NO, DK

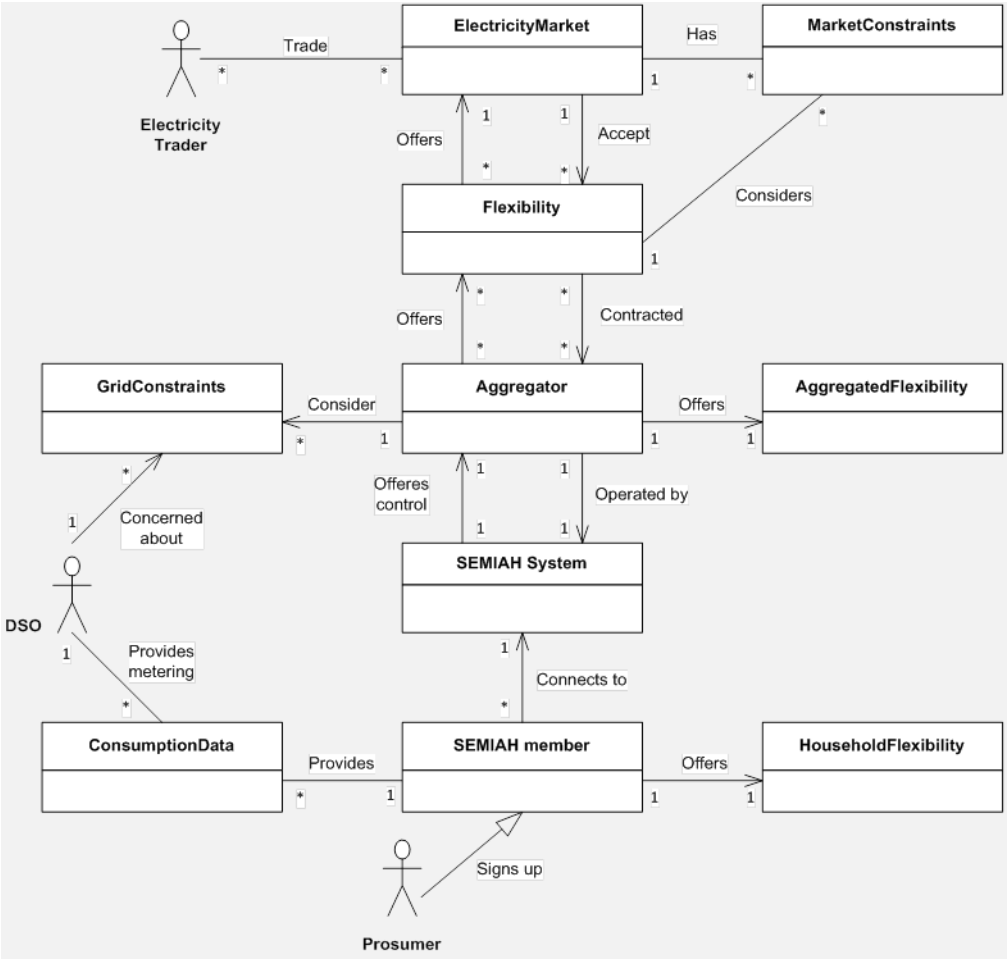
SEMIAH Project Objectives

1. To define the technical and functional specifications of SEMIAH – including **front-end** and **back-end systems**, as well as the specification and design of TSOs/DSOs and users' interfaces.
2. To develop an **open ICT infrastructure and architecture** for the implementation of a **demand response function** in **households** and in order to bring together as many services for smart grids.
3. To develop the **SEMIAH system intelligence** for the **control** of electrical loads in households.
4. To **integrate** the back-end and front-end systems and to **verify** that all interfaces are operating as expected.
5. To carry out **pilot-testing and validation** of SEMIAH in real end-user environments.
6. To ensure that **security and privacy** issues are effectively integrated in all elements of SEMIAH.
7. To develop **new business models** for the implementation of demand response in households.

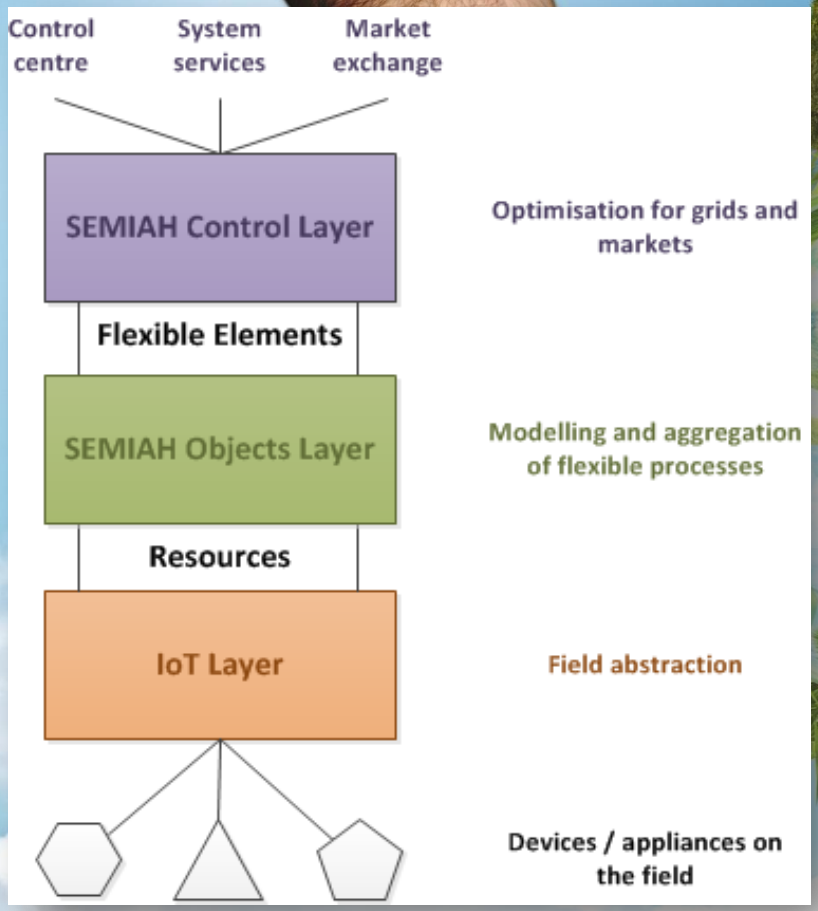
SEMIAH Domain Model

- Flexibility concept
  - Thermal inertia of buildings
  - Delayed operation of home appliances

Aggregators pool flexibility from a large number of households and offer flexibility to the electricity market



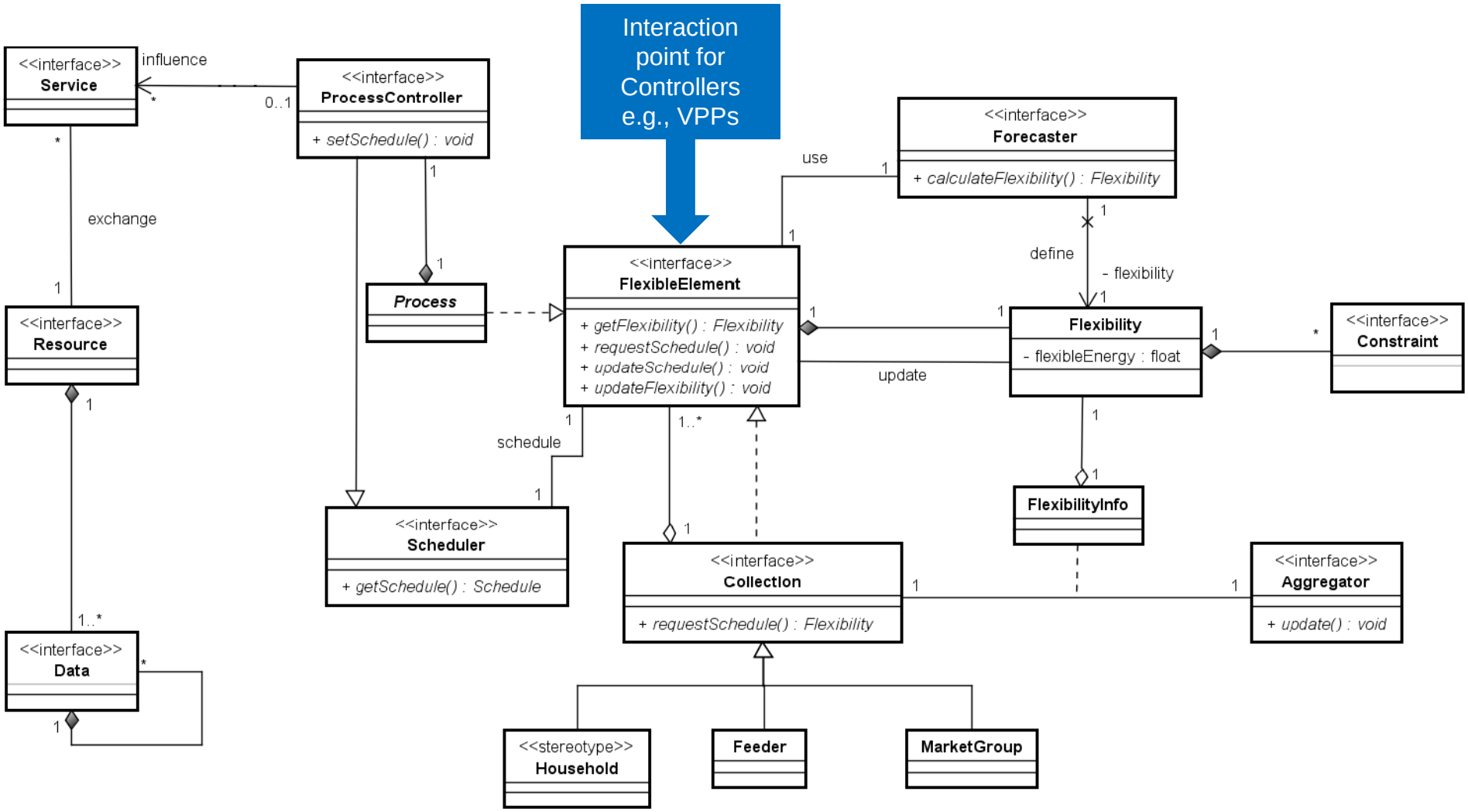
System Model and Design



System design principles:

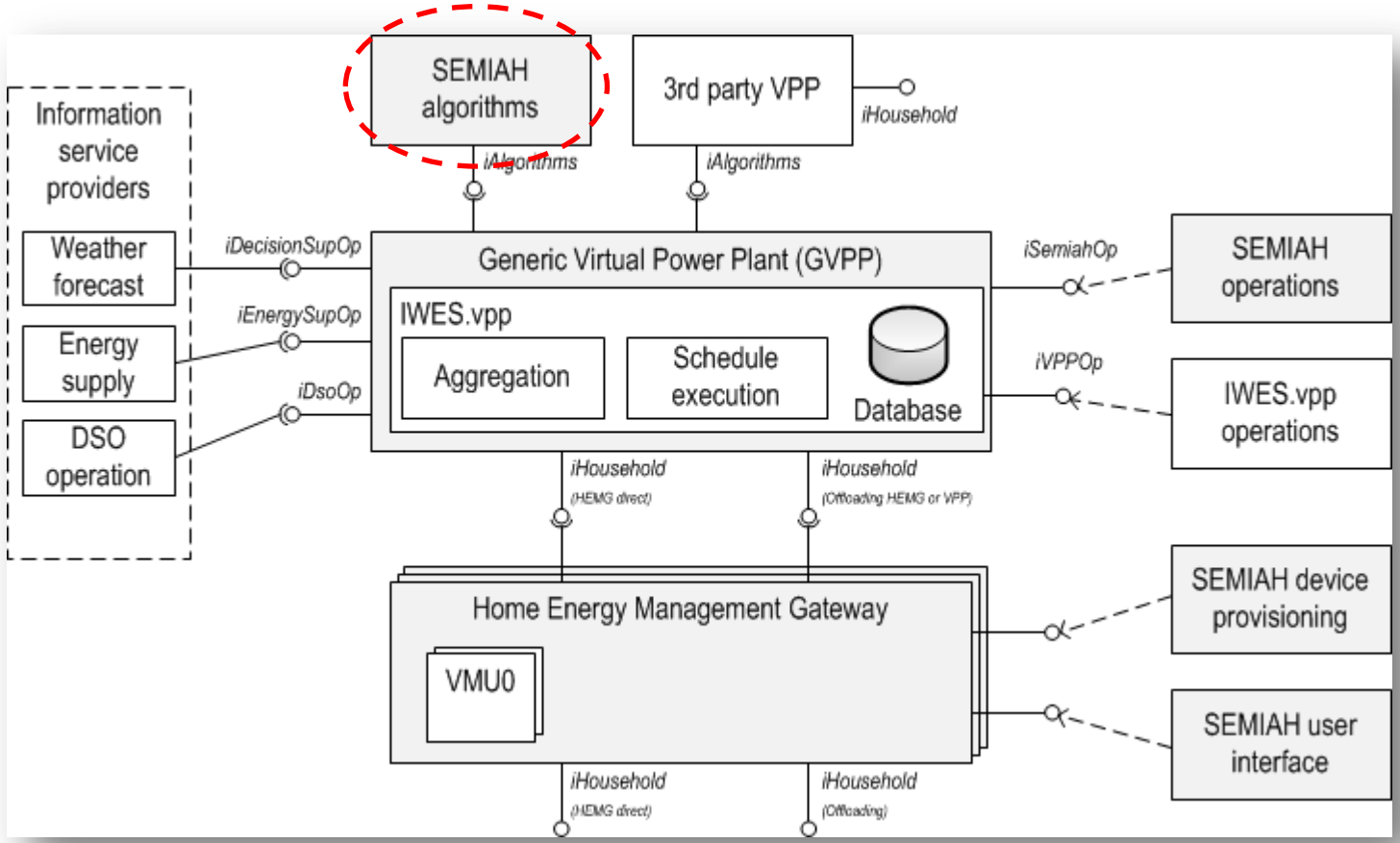
- Service-oriented architecture
- Loosely coupled systems
- IEC compliant data models as the level of interoperability
- Web-services technology: Restful; HTTPS over TCP/IP.

UML Model

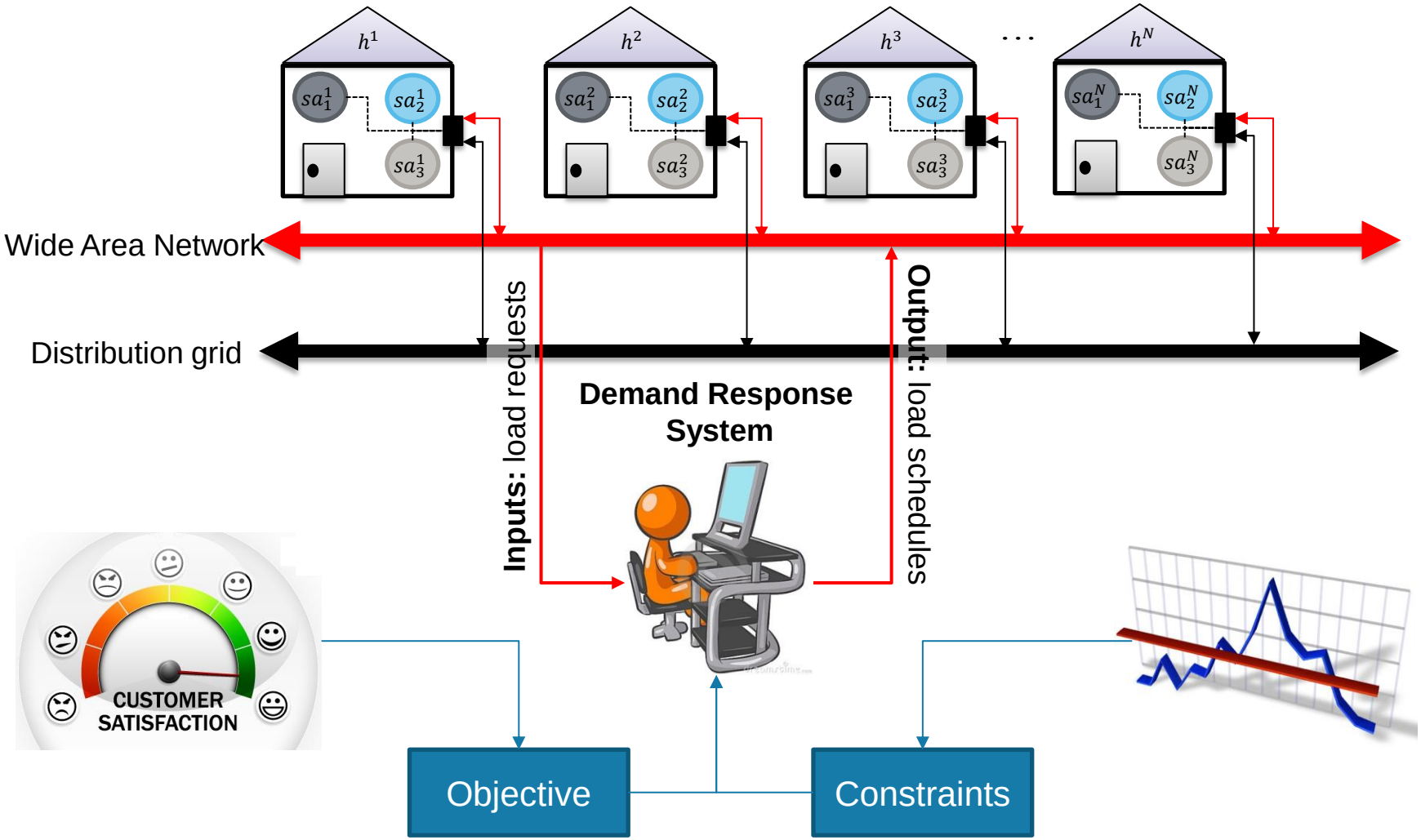

Interaction point for Controllers e.g., VPPs
<<interface>> Service
influence
0..1
<<interface>> ProcessController
+ setSchedule() : void
exchange
<<interface>> Resource
Process
<<interface>> FlexibleElement
+ getFlexibility() : Flexibility
+ requestSchedule() : void
+ updateSchedule() : void
+ updateFlexibility() : void
use
<<interface>> Forecaster
+ calculateFlexibility() : Flexibility
define
- flexibility
Flexibility
- flexibleEnergy : float
<<interface>> Constraint
update
schedule
1..*
<<interface>> Scheduler
+ getSchedule() : Schedule
FlexibilityInfo
<<interface>> Collection
+ requestSchedule() : Flexibility
<<interface>> Aggregator
+ update() : void
<<interface>> Data
<<stereotype>> Household
Feeder
MarketGroup

SEMIAH Framework Architecture

- Component-based framework for scalable aggregator infrastructure

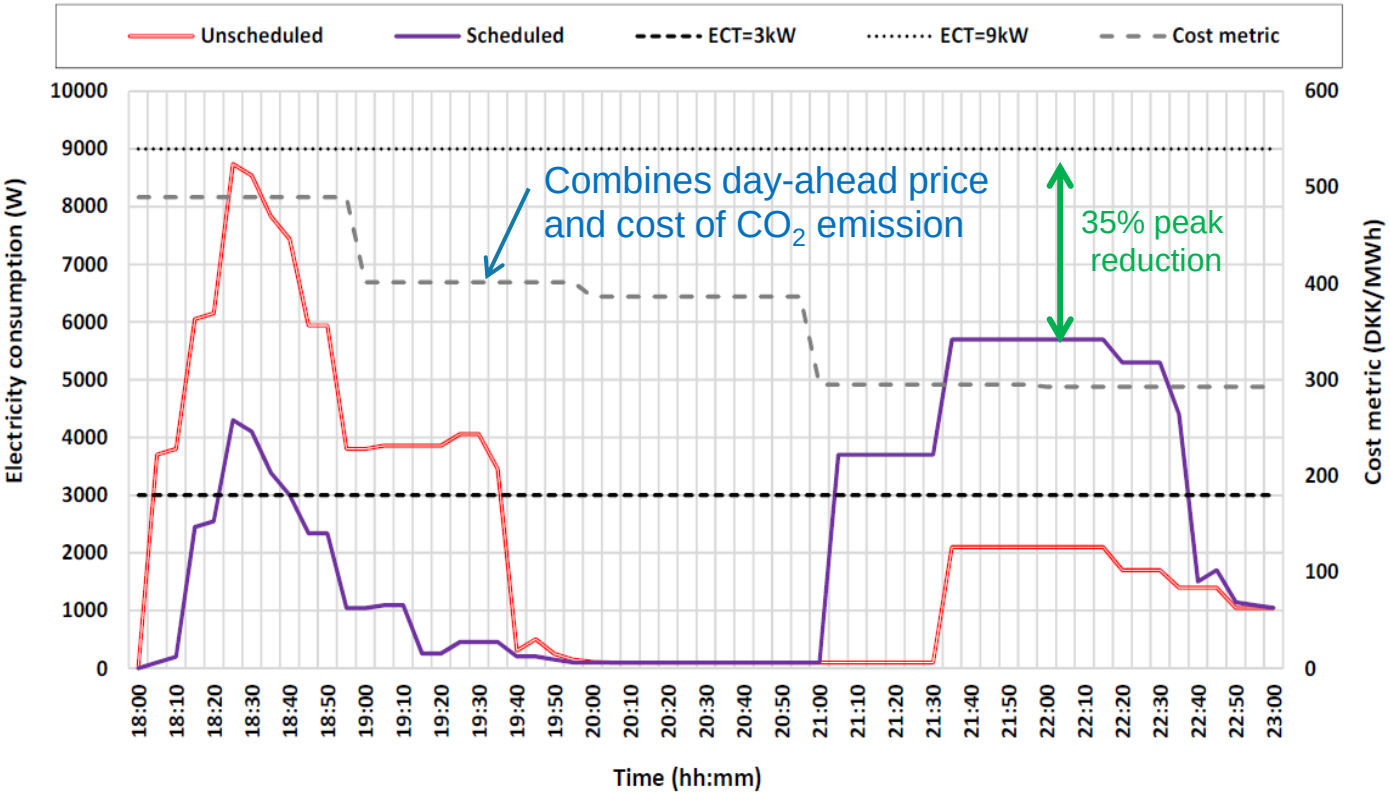


Load Scheduling (event based)



Reference: Azar, AG, Jacobsen RH; Zhang, Q. Aggregated load scheduling for residential multi-class appliances: Peak demand reduction. 12th International Conference on European Energy Market. 2015

Peak Demand Shifting



Scenario:

Time	Activity
18.00 – 23.00	Lights
18.00 – 20.00	EV charging
18.05 – 19.50	Washing machine
18.10 – 18.50	Oven
18.20 – 18.50	Stove
19.00 – 19.45	TV
21.30 – 23.00	Laundry dryer

Test case:

- single household;
- scenario based;
- assigned individual Electricity Consumption Threshold (ECT)

Ref.: Jacobsen, RH; Azar, AG; Zhang, Q, Ebeid, ESM. Home Appliance Load Scheduling with SEMIAH. SMART 2015, The Fourth International Conference on Smart Systems, Devices and Technologies. 2015

Low-Voltage Grid Assessment

Risk factors

- Instability and increased volatility (feedback)
- Loss of diversity (coincidence factor)

Grid constraints must be taken into account in the load scheduling.

Low-Voltage Grid Assessment

Early assessment of the grid stability in the SEMIAH pilot sites

Issue	Expected	Present	Root cause	SEMIAH potential impacts
Overvoltage	Yes	No	Net power injection from buildings. Cable sizes	Positive: alignment between generation and consumption in buildings
Harmonic distortion	Yes	Only in Skarpnes, Norway	Power converters	None
Reverse power flows	Yes	Online in Visp, Switzerland, to LV feeders; expected to MV side in summer time	Instant generation in excess of instant consumption in feeder	Positive: alignment between generation and consumption in feeder
Power factor	Yes, at night times	At times of PV generation in Visp, Switzerland	Power converters Cable sizing	None

Conclusions

- Demand Response is one possible way to provide a more flexible electricity consumption and to improve the stability of the LV grid.
- Residential demand response brings several system design challenges
  - scalability, interoperability,
  - grid stability, user engagement,
  - new business models, security & privacy
- SEMIAH targets an ICT infrastructure solution that scales to 200,000 households with the aim to produce aggregated flex-offers that can be traded in the electricity markets.

Thank you

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