Smart Appliances?
- Focal point study is Demand Response
- Smart Appliance = appliance that offers the flexibility in its electricity profile as a service
- What are the interactions with the outside world, from the point of view of the appliance

**Flexibility uses**
- Congestion Management
- Balance
- Flexibility

**Target** is always balancing and/or grid congestion management, flex buyers are always TSO, BRP or DSO

**BRP**: Balancing Responsible Party
**TSO**: Transmission System Operator
**DSO**: Distribution System Operator
**But this translates to a high number of technical objectives**

- Frequency containment, automatic frequency restoration, manual frequency restoration, grid congestion management, wholesale market, intra-day balancing, day ahead portfolio optimization, reactive power ancillary services, PV grid injection minimization, etc.

- What is today’s highest value application of residential flexibility?
- What is tomorrow’s highest value application of residential flexibility?

- Smart appliances should support as many as possible

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**Control architecture**

- 3 approaches: (= generalized use cases)
  - External control & external objectives
  - Internal control & external objectives
  - Internal control & internal objectives

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**External control & external objectives**

- Use case example: use the flexibility of smart appliances to maintain the intraday balance between electricity production and consumption
- New/ altered BC (Business Case) ➔ no impact on appliances

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**Internal control & external objectives**

- Use case example: smart appliances respond directly to day ahead energy market prices
- Control logic required in appliance for all supported BC’s
- Mainly open loop control cases
- New/altered BC ➔ Impact on appliances ➔ Impact on interfaces
- Day ahead energy market prices ➔ Start or delay Operation i.f.o. the prices
**Internal control & internal objectives**

- Use case example: automated frequency restoration based on local frequency measurements
- No communications required
- Control logic required in appliance for all supported BC’s
- Only open loop control, but very fast
- New/altered BC
  - Impact on appliances
  - Potentially hardware impact

Control Objective

Control Logic

Frequency measured

Increase/decrease power i.f.o. frequency

**In house communications are difficult**

- No plug&play solution that works for the majority of the households
- No dominant technology
  - (power line, wireless P2P, wireless meshed, wired, …)
- No technology may be excluded

**Cloud vs. Central Energy Manager**

Central Energy Manager
- Easier to manage/guarantee security and privacy
- Open and interoperable interfaces required on the appliance

Cloud
- No extra hardware
- Each appliance must be able to establish extra-house communication
- Open and interoperable interfaces required at the servers

**Contents**

- Control architectures
- Communication architectures
- Conclusions
A common data model

A shared data model is crucial.

All models require continuous data translation

Conclusion

» Control architectures
  » 3 models, none dominant
  » Large impact on smart appliance functionality and data model
  » Can/should this be limited?
  » Today’s initiatives often partly support both internal and external control

» Communication architectures
  » 2 models, none dominant
  » Can co-exist and impact on appliance can be limited
  » Provided a common data model is used

» Many data model/ontology initiatives:
  SAREF, EEBus, SEP2, OpenADR 2.0, CIM, ...

End consumer business models

» A wide variety of business models for the end consumer are possible
  » Variable pricing
  » Capacity/activation fee
  » PV injection minimization
  » Energy services bundle offer
  » Rebate or subsidy scheme at purchase
  » Obligatory

» Smart appliances should accommodate as many as possible
» Limited public available information
Variable pricing

- Vattenfall/Sweden
  - Retail contracts with Nordic power exchange based hourly prices
- France Option Tempo
  - Blue, white and red days
- Eneco SlimLaden
  - Smart charging of Tesla’s based on energy market prices

Variable pricing – research project experience

- Linear:
  - 6 fixed time blocks per day with variable prices set per day
  - Variable pricing with automated control works well, but non-controlled (peak) loads represent financial risk
  - Too complex for manual demand response (response fatigue)
- PowerMatching city Hoogkerk
  - Automated control preferred over manual control
  - No response fatigue for manual control, as fixed price patterns render price consultation redundant

Capacity/activation fee

- Traditionally used for balancing reserves
- Typically used for industrial demand response based reserves
  - R3-DP and SDR products of Ella in Belgium
  - FCDM and STOR of National Grid in the UK.
- Load management program for airco’s in the US (FPL, BGE, ...)
- Research project experience: Linear
  - Capacity fee was well received by users: simple, no financial risk

Other examples

- PV injection minimization
  - Feed in tariffs for PV production in Germany and Belgium
- Free thermostat or thermostat rebate in exchange for airco control
  (Austin Energy and CPS Energy in Texas, US)
Call for information

» Important that no revenue model is excluded
» Limited public information

» What are your experiences on business and remuneration models for smart appliances?