

The Value of Smart Appliances in Stressed Electricity Systems

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Intelligent Energy  Europe

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WP Goals

Quantifying the value of Smart appliances from system operation perspective:

Generation:

Provision balancing services: response and reserve



Increase economic viability of intermittent generation

Network Operation:

Congestion management



Increasing the utilization of existing assets

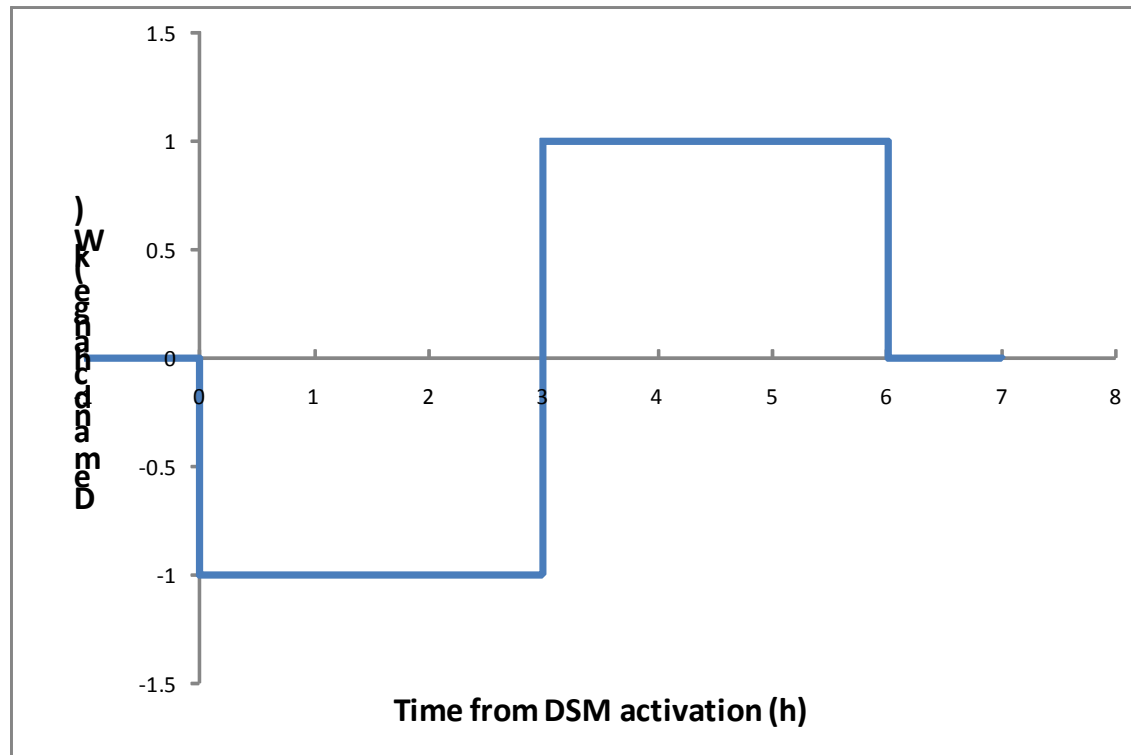
Our Research: What is the value of Smart Appliances to the System?

Tools developed:

1. Generic DSM simulator
2. Specific smart appliance simulator
3. Network constrained simulator

Generic DSM Simulator

Economic Dispatch optimisation is allowed to superpose a fixed number of demand modifications (e.g. 2 million) onto total demand per day:

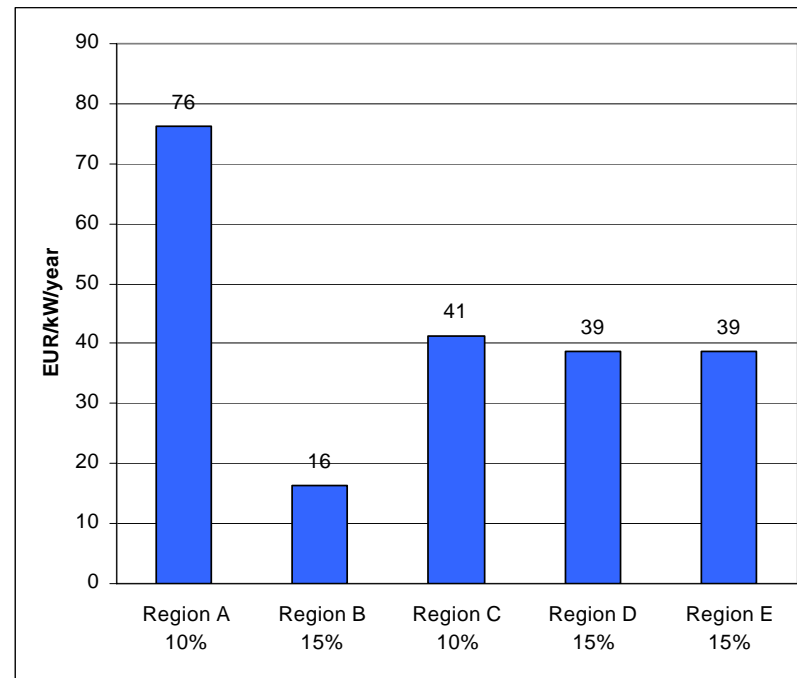


Smart-A Regional Classification

	Region A "South of Europe"	Region B "Scandinavia"	Region C "New member states"	Region D "Germany/ Austria"	Region E "UK"
<i>Generation Flexibility</i>	Low	High	Medium	Medium	Medium
<i>Demand Profile</i>	Summer Peak	Winter Peak	Winter Peak	Winter Peak	Winter Peak
<i>Intermittent Generation Installed</i>	Medium (rising)	Low (rising)	Low (rising)	High	Low (rising)

Generic DSM Simulator: Results Summary

Savings per kW of controllable load



	Region A	Region B	Region C	Region D	Region E
<i>Reduction in fuel costs⁽¹⁾</i>	[3 – 6] %	[0.05 – 0.32] %	[0.1 – 1] %	[3 – 5] %	[0.5 – 3] %
<i>Reduction in wind spillage⁽²⁾</i>	[30 – 50] %	0%	[0 – 70] %	[36 – 70] %	[0 – 70] %

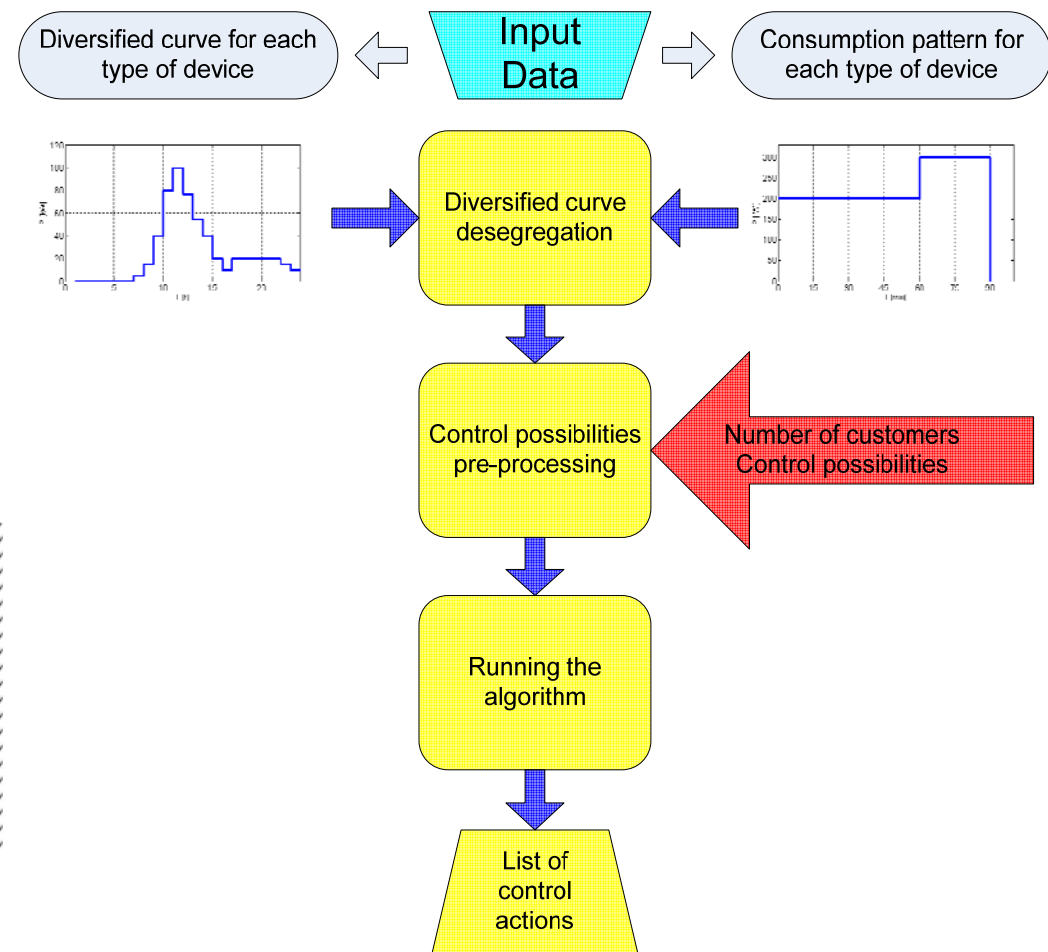
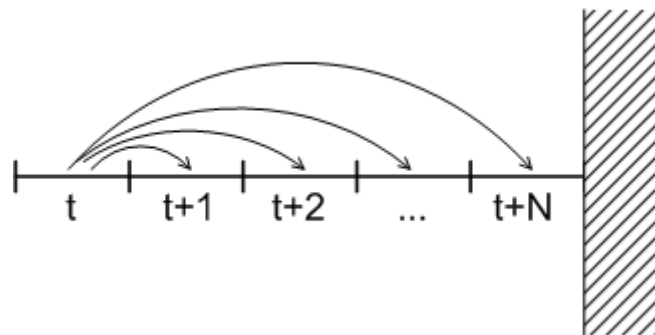
⁽¹⁾ Percentage of the total system fuel costs

⁽²⁾ Percentage of the total wind spilled

Smart Appliance Simulator

Features:

- Shifting algorithm
- Flexible shifting of devices
- Individually controlled devices



Case Study

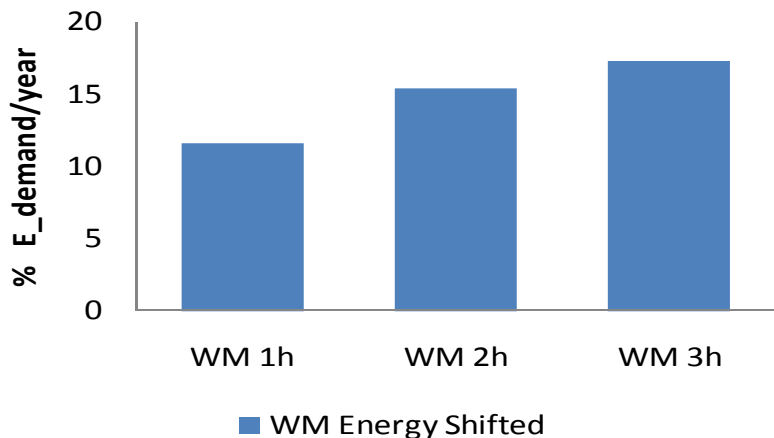
110 generator system: $P_{\text{INSTALL}} = 20.5 \text{ GW}$ $P_{\text{g,max}} = 700 \text{ MW}$

Max. forecasted demand: 19.8 GW Installed wind capacity: 5 GW

Nr of households: 8 million

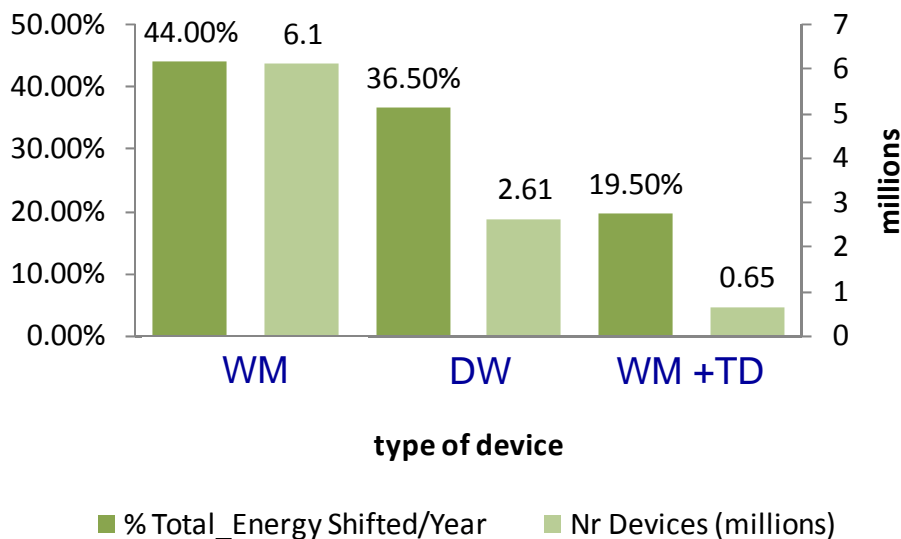
Type of Appliance	Penetration Factor	Shifting capabilities	Consumption pattern lasting
Washing Machine 1h	32%	<1 h	2 h
Washing Machine 2h	32%	<2 h	2 h
Washing Machine 3h	32%	<3 h	2 h
Aggregated WM	96%	Up to 3 hours	2h
Dish Washer	30%	6 h	2 h
Washing Machine + Tumble Dryer	20%	3 h	4 h

Activity per Device Type



The amount of energy shifted increases with the flexibility provided by the consumer.

The WM with larger delayed start time are more used.

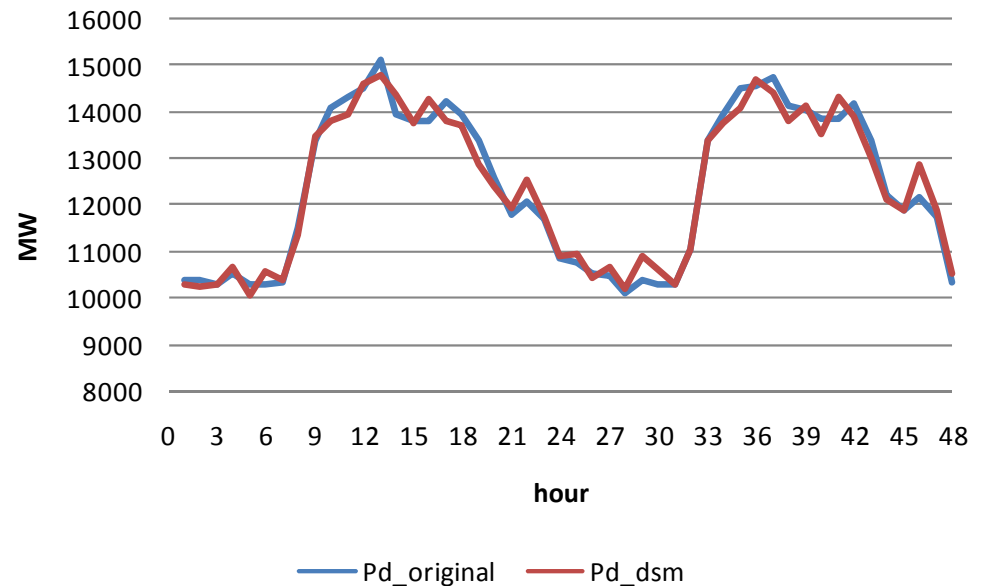


When comparing different appliances the utilisation is driven by:

- Flexibility of delayed start time
- Amount of energy consumed by the appliance.

Value per Type of Appliance

Type	Value per appliance and year
Washing Machine	3,0 EUR
Dish-washer	6,0 EUR
Washer +Dryer	13 EUR



	Reduction %
Total Fuel Costs	4.35 %
Wind Curtailed	53 %

Network-constrained Simulator IEEE 30 Bus Network

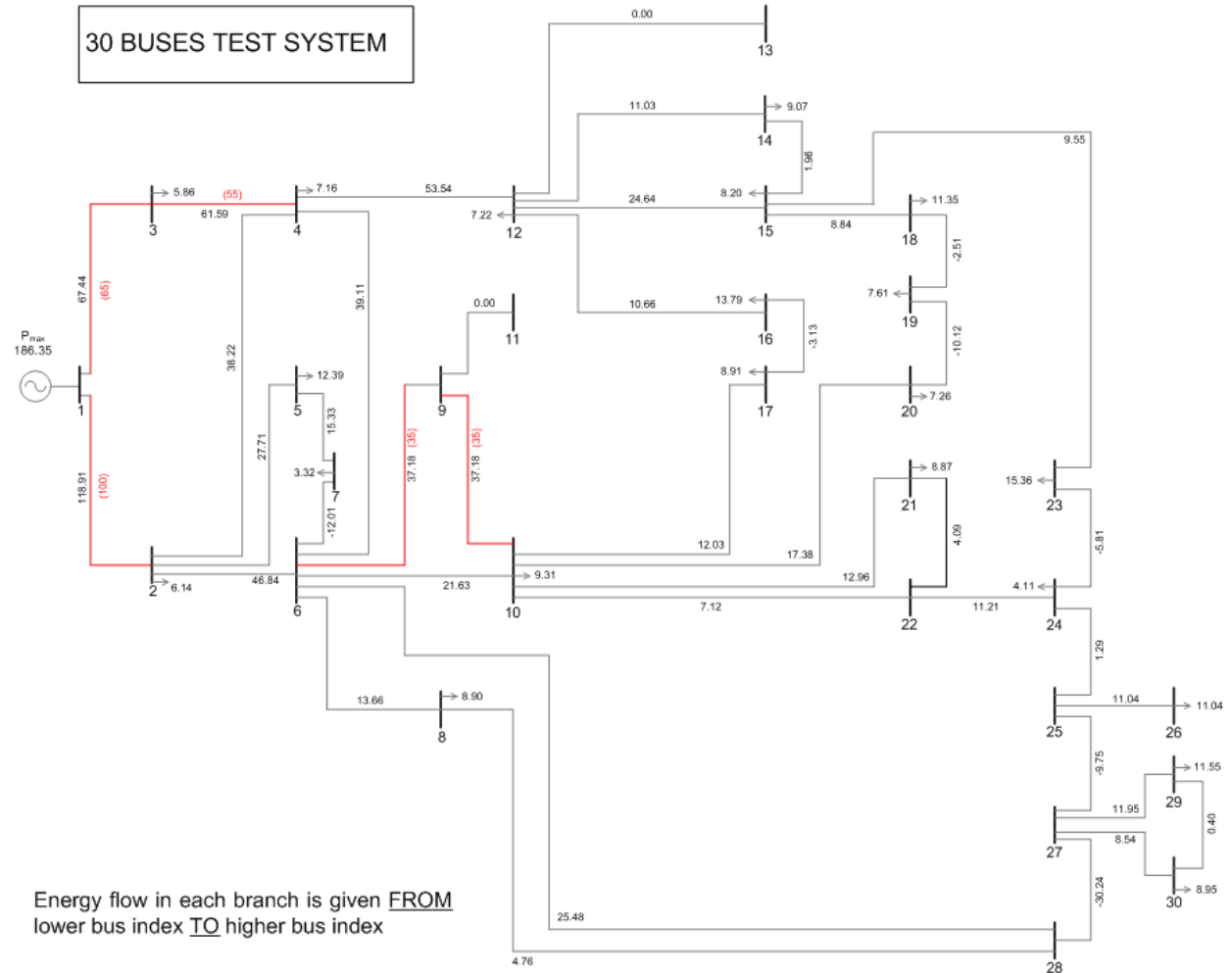
Power flows for the case:

- Maximum demand
- No line limits

Numbers in brackets are imposed line limits.

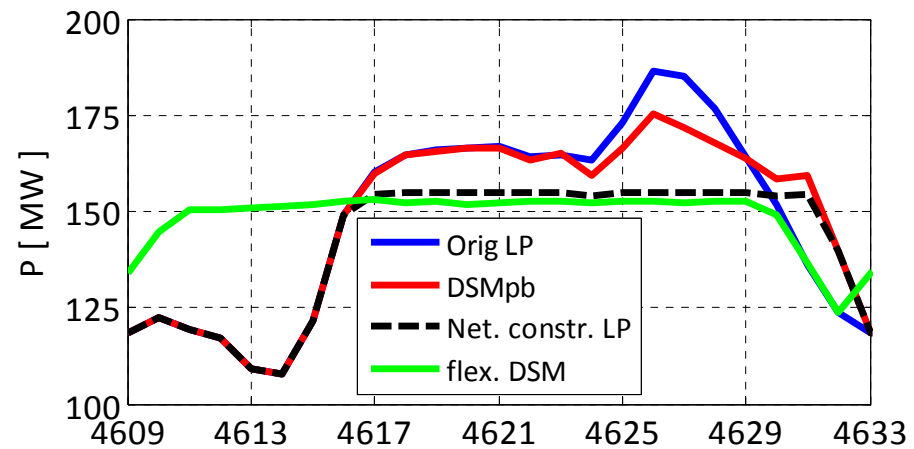
Congested lines are coloured in red

Nr of Buses	30
Nr of Branches	41
Nr of Loads	21
Peak Load	186 MW
Network Capacity	155 MW

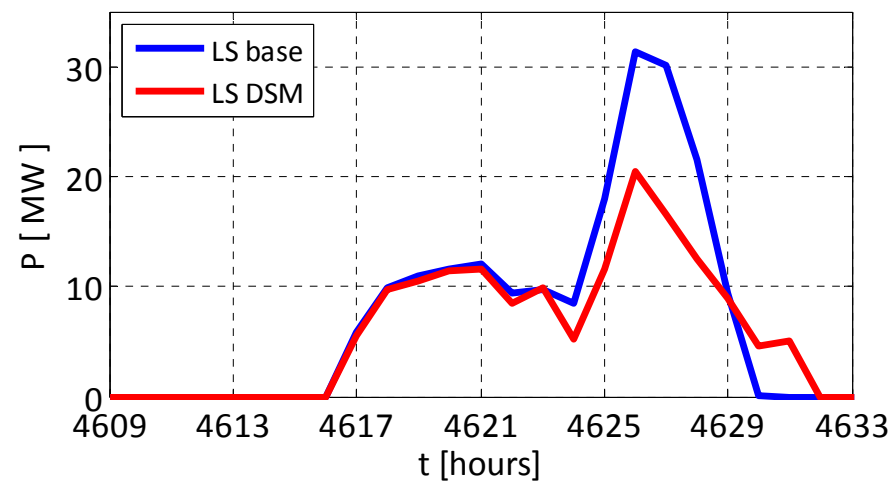


Daily Load Profile and Load Shed

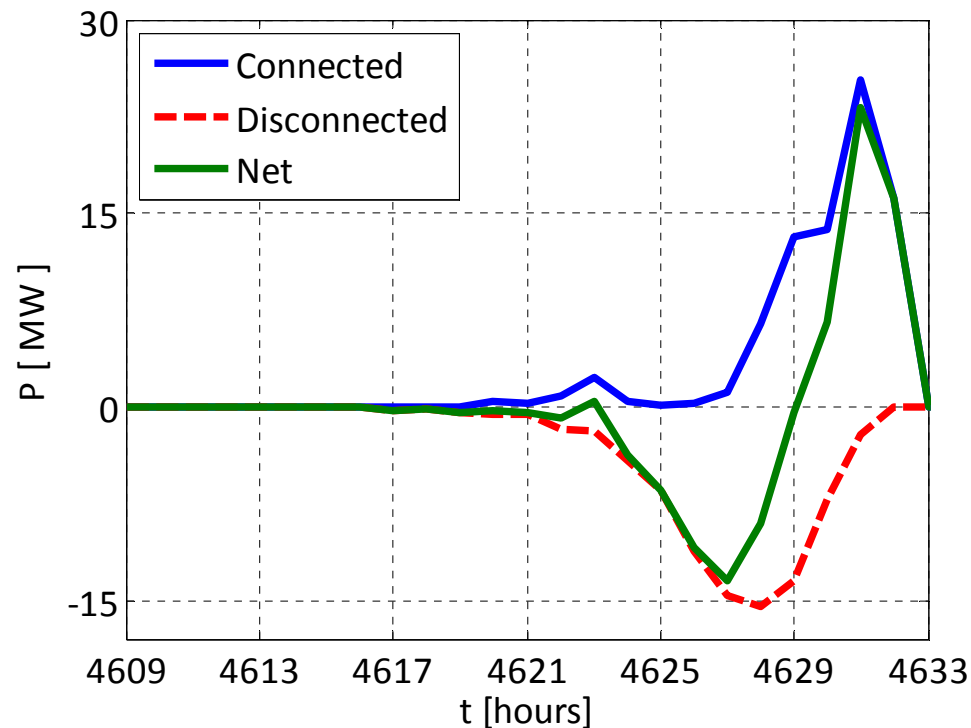
Daily load profile:



Load shed:



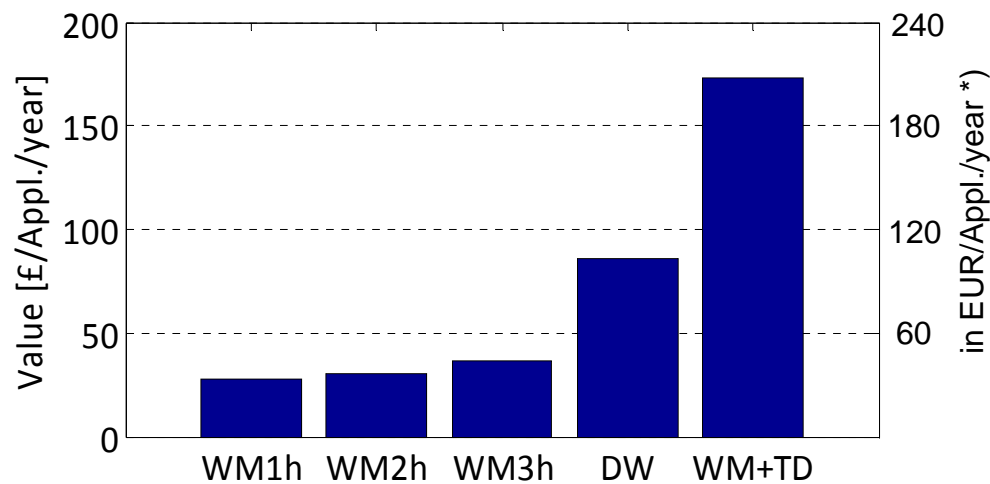
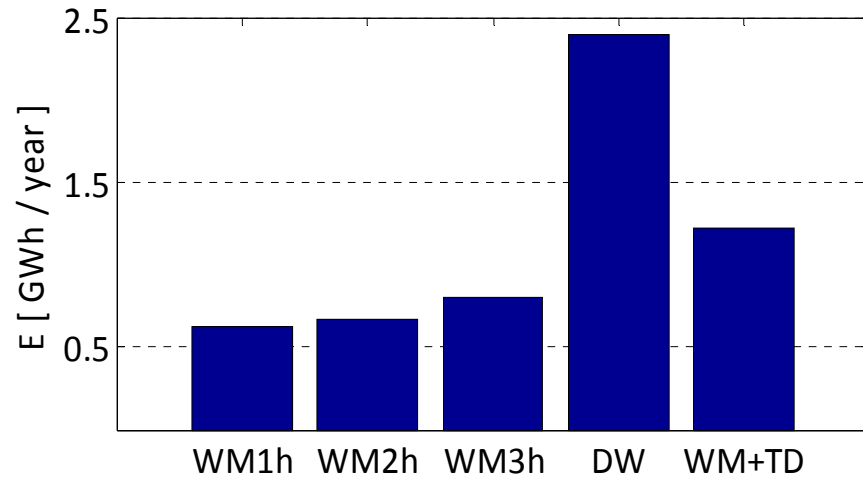
DSM Activity During a Winter Day



Power of managed devices for the whole network:

- Disconnected (around the peak hours)
- Connected (after the peak)
- Net = Connected - Disconnected

Activity and Value Per Device Type



Type	Value*) per appliance and year
WM _{1h} +WM _{2h} +WM _{3h}	37,9 EUR
Dish Washer	103 EUR
Washer + Dryer	208 EUR

*) assuming a 3.600 EUR/MWh penalty for load shed.

Key Findings

Balancing Model

From system perspective the value of Smart Appliances is driven by:

- Penetration of intermittent generation,
- Flexibility of the conventional generation mix, and
- Flexibility of the appliances shifting times provided by the consumer.

Network Operation

- Smart appliances can contribute to congestion relief, reducing congestion costs, depending on the level of congestion on the network.
- The role of Smart appliances will be especially relevant in urban areas where space constraints hinder asset replacement