Simulation testing of the Cardiff grid
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Cardiff Reference Grid

Area of Pontypool (Cardiff)
- 6 substations
- About 2000 users (98% domestic)

*Data available*
- Average consumption profile per type of user (24h profiles with HH granularity for typical weekday, Saturday and Sunday during the 4 seasons and high summer)
- Annual consumption profile of each user during the period 07/2014 – 06/2015
- Grid physical parameters (feeders size and length, transformer size and type, schematics)

The reference grid only included a single portion of LV grid with 184 domestic users supplied by a 500 kVA transformer
Scenarios Characterization

The available data have been diversified and projected to reflect potential future energy scenarios (based on UK National Grid’s report)

- 2020 Business as Usual
- 2020 Green
- 2030 Business as Usual
- 2030 Green

Each scenario is associated to expected level of penetration of PV systems, Electric Vehicles, Heat pumps

In addition, 3 further levels of penetration of smart appliances (Low, Medium and High) have been considered.

This makes a total of 12 tested Smart Grid Scenarios
Scenarios Characterization

For each scenario, each prosumer of the reference grid has been characterised in terms of:

- Allocation of **smart technologies**
- Allocation of **deferrable loads**
- Allocation of **interruptible loads**
- Definition of appliances cycles
- Categorization of prosumers (to emulate their behaviour)
- Definition of typical shifting intervals
- Creation of PV generation profiles
- Definition of Time-of-Use tariffs
Simulation activities

Period
- Autumn
- Winter
- Spring
- Summer
- HSummer

Day
- Weekday
- Saturday
- Sunday

PV generation
- Low
- Medium
- High

Annualised data

Scenario
- 2020BAU
- 2020 Green
- 2030 BAU
- 2030 Green

Smart appliances penetration
- Low
- Medium
- High

Available flexibility

User
- Individual prosumer (184)
- LEC (1,3)
- LVG (1)

Optimization
- In-home
- LEC
- LVG

ToU tariff
- Actual tariffs
- Smart tariffs

A total of 99,360 optimizations

project co-funded by the European Commission within the 7th Framework Program (Grant Agreement No. 619682)
Simulation activities

For each scenario:

INPUT

- Expected load
- Expected generation
- Available flexibility
- ToU tariff
- Export tariff

MAS Optimization Platform

OUTPUT

- Optimised load

KPIs
### Key Performance Indicators

<table>
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<tr>
<th>Quantified objective</th>
<th>KPI</th>
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<td>Peak load reduction due to local management of flexibility</td>
<td>Peak Shaving</td>
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<td>Reduced grid losses due to local management of flexibility</td>
<td>Grid losses reduction</td>
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<td>Increased renewable hosting capacity of the LV grid due to local management of flexibility</td>
<td>PV penetration</td>
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<td>Number and amount of avoided curtailments; Reduced over-voltages conditions</td>
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<td>Maximization of prosumers revenue with in-home optimization and local management of flexibility</td>
<td>Bill &amp; Revenue</td>
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<td>Maximization of self-consumption with in-home optimization and local management of flexibility</td>
<td>Self-consumption</td>
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These are all calculated comparing the optimised results with a baseline without optimization.
Key Performance Indicators

Example 1: Bill & revenue KPI – In-home optimization – Winter weekday

Smart washing machine
Scheduled at 17:00
Shifting interval 10:30-19

PV + storage

Prosumer 1

Heat pump
Consumption based on heating requirements
Max interruption: 30 min

Smart dish-washer
Scheduled at 19:15
Shifting interval 19–23:30

Input data
- Cycle of appliances;
- Programmed use;
- Shifting interval;
- Interruption capability (for heat pump);

ToU tariff
- Export tariff: 0.0491 £/kWh
- Daily consumption: 27 kWh

project co-funded by the European Commission within the 7th Framework Program (Grant Agreement No. 619682)
Key Performance Indicators

Example: Bill & revenue KPI – In-home optimization – Winter weekday

Cost of electricity for the prosumer: 2.6 £
Key Performance Indicators

Example: Bill & revenue KPI – In-home optimization – Winter weekday

After optimization

Cost of electricity for the prosumer: 2.13 £
Key Performance Indicators

Example: Bill & revenue KPI – In-home optimization – Winter weekday

KPI_HAN_HAN_R_day : 0.47 £/day

Flexibility provided by shiftable appliances: 2.05 kWh

Flexibility provided by interruptible appliances: 4.65 kWh

Cost saving = 18%
Key Performance Indicators

Example 2: Trade of PV surplus – LEC optimization – Winter weekday

- Export tariff: 0.0491 £/kWh

Generation surplus: 2.82 kWh
Example 2: Trade of PV surplus – LEC optimization – Winter weekday

Key Performance Indicators

Smart washing machine
Scheduled at 17:45
Shifting interval 11:30-19

Smart tumble-dryer
Scheduled at 13:15
Shifting interval 11:30–21:30 (but after washing machine)

Smart dish-washer
Scheduled at 16:00
Shifting interval 16:00–23:30

Input data
- Cycle of appliances;
- Programmed use;
- Shifting interval;

ToU tariff

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Key Performance Indicators

Example: Trade of PV surplus – LEC optimization – Winter weekday

With no optimization

Cost of electricity for the prosumer: 3.6 £
Validation plan

Example 2: Trade of PV surplus – LEC optimization – Winter weekday

Cost of electricity after in-home optimization: 3.34 £
Revenue: 0.26 £ (7.1%)
Key Performance Indicators

Example 2: Trade of PV surplus – LEC optimization – Winter weekday

It has 2.82 kWh of energy surplus that wants to sell at a higher price than the export tariff (0.0491 £/kWh)

It currently pays 0.16 £/kWh when there is PV production;
It can also move flexible load (dishwasher) to the time of generation surplus

The MAS optimization sets the negotiation price for PV surplus at 0.1 £/kWh
Key Performance Indicators

Example 2: Trade of PV surplus – LEC optimization – Winter weekday

After LEC optimization

Cost of electricity for the prosumer: 2.9£
Cost of purchased surplus: 0.28£
Revenue: 0.43£ (11.3%)
Key Performance Indicators

Example 2: Trade of PV surplus – LEC optimization – Winter weekday

**After In-home optimization**

- Dishwasher after in-home optimization
- Tumble dryer after in-home optimization
- Washing machine after in-home optimization
- Consumption after in-home optimization

**After LEC optimization**

- Dishwasher after LEC optimization
- Tumble dryer after LEC optimization
- Washing machine after LEC optimization
- Optimised consumption
- Purchased surplus

Revenue Prosumer 2: 0.26 £ (7.1%)

Revenue Prosumer 1: 0.24£ (+104% with respect to simple export)

Revenue Prosumer 2: 0.43£ (11.3%)
Results assessment - ongoing

% gross cost saving

1st step of opt.  
2nd step of opt.  
3rd step of opt.

Annual saving (€)

1st step of opt.  
2nd step of opt.  
3rd step of opt.

Annual saving (€)

% flexible load

% flexible load

2020BAU – Low Penetration

2020BAU – Low Penetration

Annual saving (€)

Annual saving (€)

scenario

scenario

Number of prosumers

% gross cost saving

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2020BAU – Low Penetration

2020BAU – Low Penetration