Preparatory study analysing the technical, economic, environmental, market and societal aspects with a view to a broad introduction of smart appliances and developing adequate policy approaches

Under multiple framework contract N°ENER/C3/2012-418-Lot N°1

TASK 4 REPORT - TECHNICAL ANALYSIS

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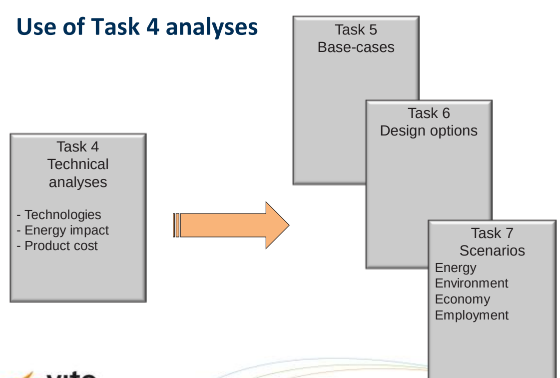
Introduction and approach - Task 4 objective

What
- Technical analysis of products in scope
- Assessment of technical parameters related to life cycle performance
- Focus on use phase – very little impact on production, distribution and end-of-life phases

Which products
- Products currently on market and in future – with potential for DR
- Focus on the selected product group examples

Why
- Input to next tasks

Use of Task 4 analyses



Limitations and how to overcome them

- Only few smart appliances on market
- Limited data received on current products
- Analyses based on estimations and data available
- Can improve report with more precise and updated data
- Request data from industry

Technologies

Traditional appliances modified for DR e.g.:

- Network connection
- Other control systems to process and react on the DR response signals
- Other components for DR e.g. energy storage, safety circuits, measurement circuits, sensors etc.
- Modifications in existing control system programming
- Additional power supply to electronics

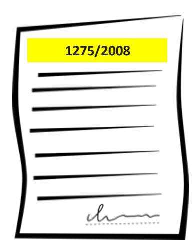
Use phase – Energy consumption impacts

Use phase – Energy regulation

Network standby horizontal requirement:

- From 1 January 2015: 6.00 W
- From 1 January 2017: 3.00 W
- From 1 January 2019: 2.00 W (subject to review)

Vertical requirements such as lamp control gear: 1 W (0.5 W Sept. 2016)



Use phase – Network connections

Network type	Power consumption, Watt		
	Min	Max	Average
Bluetooth Classic			1
Bluetooth 4.0	0.000147	0.5	0.250074
Wi-Fi	0.51	1.9	1.205
ZigBee	0.068	0.589	0.3285
Z-Wave			0.07
Ethernet, active link, 1000 Mbps	0.425	1.64	1.0325
Ethernet, active link, 100 Mbps	0.22	0.65	0.435
Ethernet, active link, 10 Mbps	0.22	0.69	0.455

APPLIANCE EXAMPLES

Appliances:

- Dishwashers, washing machines, tumble dryers, washer-dryers
- Radiators and built-in inertia radiators
- Boilers
- Heat pumps
- Circulators
- Residential air conditioners
- Ventilation
- Residential energy storage system
- Lighting

Assessments:

- Network connection
- Additional components
- Appliance modifications
- Demand response mechanism
- Cost impact (product price = manufacturer cost + mark-up)
- Energy impact (cost, environment)

Periodical appliances (dishwashers, washing machines, tumble dryers, washer-dryers)

- **Network connection** possibilities comprise:
  - Wi-Fi connection
  - Connection via Gateway
  - Frequency sensing
  - → Some models are already available from a few manufactures in the European market
- **Additional components** needed:
  - Respective network connection device
  - Switch to activate / deactivate smart operation

Periodical appliances (dishwashers, washing machines, tumble dryers, washer-dryers)

- **Appliance modifications**: Enabling periodical appliances for DR-functions requires new control software (dependent on level of smartness anticipated) and an extension of memory capacities.
  - **Signal activation:** software to recognize signals from the grid and to activate device before a predefined deadline is reached.
  - **Remote activation:** software allowing bidirectional communication and activating the machine in response to the remote signal.
  - **Altered electricity consumption pattern:** signal recognition software and an energy management software to find the most suitable reaction in response to signal and transform it into action.

Periodical appliances (dishwashers, washing machines, tumble dryers, washer-dryers)

- **Demand response mechanisms:**
  - **Remote or signal activation:** the user selected programme is remotely activated or activated by a signal coming from the grid before the user deadline is reached.
  - **Altered electricity consumption pattern:** while the appliance is activated, the consumption patterns changed through pausing the operation, changing the temperatures, changing heating power, changing spinning speed (in the case of washing machines and washer dryers) etc.

Periodical appliances (dishwashers, washing machines, tumble dryers, washer-dryers)

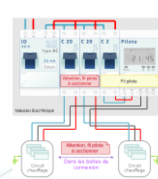
- **Cost impact:** dependent on the level of smartness anticipated:
  - **Signal activation:** a signal recognition unit as well as a start-time delay function/ time function are needed (assumed additional costs 10-50 €)
  - **Remote activation:** a switch is needed to signal activation and a communication module is required enabling bidirectional communication (assumed additional costs 30-130 €)
  - **Altered electricity consumption pattern:** a signal recognition unit and an energy management software are necessary (assumed additional costs 10-100 €)

Periodical appliances (dishwashers, washing machines, tumble dryers, washer-dryers)

- **Energy impact:**
  - Network connection: maximum energy values stipulated in the amended standby regulation (COMMISSION REGULATION (EU) No 1275/2008) are assumed
  - Standby energy consumption (signal or remote activation): while waiting for start of machine or at the end of a cycle (standby power max. 0.5 W, 1 W in case of informative displays)
  - Short-term interruptions: may increase energy consumption due to the need to recover heat losses
  - Lowering process temperature: may reduce energy consumption
  - Pausing of operation: may require energy consuming measures to maintain performance of the process (e.g. drum rotation etc.)

Radiators and built-in inertia radiators

- **Network connection**
  - Pilot wire to smart meter, wireless networks
- **Additional components**
  - Electronic thermostat capable of sending/receiving external signals (i.e. from the grid, the user)
- **Appliance modifications**
  - Adaptability between the electronic thermostat and the radiator (Nest → Heat Link i.e.)



Radiators and built-in inertia radiators

- **Demand response mechanism**
  - Radiators work on/off. Modulating programs (Comfort, Eco, Cold) by varying indoor temperature set point i.e.
- **Cost impact**
  - Due to energy consumption: (4.5W/1000*8760h*0.20€/kWh=8€).
  - Installation of demand response: electronic thermostat (Wi-Fi enabled =~ 200€, Honeywell, Nest …)
  - RTE approximation (receiving only) 35/85€
- **Energy impact**
  - If wireless enabled, estimation of 6W (3W by 2019, EU regulations). Manufacturers estimate nowadays an average consumption of 4,5W for a communicating device

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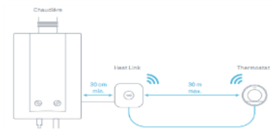
Electric Boilers

- **Network connection**
  - Wireless technologies via electronic thermostat
- **Additional components**
  - Electronic thermostat that controls the water drained from the boiler to the radiators.
- **Appliance modifications**
  - Adaptability between the thermostat and the boiler (i.e. Nest → Heat Link)



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Electric Boilers

- **Demand response mechanism**
  - On/off. Possibility to store energy in a tank and use it afterwards
- **Cost impact**
  - Due to energy consumption: (4.5W/1000*8760h*0.20€/kWh=8€).
  - Installation of demand response: electronic thermostat (Wi-Fi enabled =~ 200€, Honeywell, Nest …)
  - RTE approximation (signal receiving only) 35/85€
- **Energy impact**
  - If wireless enabled, estimation of 6W (3W by 2019, EU regulations). Manufacturers estimate nowadays an average consumption of 4,5W for a communicating device

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Heat pumps

- **Network connection**
  - Wireless technologies via electronic thermostat
- **Additional components**
  - Electronic thermostat, capable of modulating the charge?
- **Appliance modifications**
  - Adaptability between the thermostat and the heat pump (intermediate device between the thermostat and the heat pump, software). If the heat pump is used for hot water supply, a storage tank could be used to gain more shifting potential
- **Demand response mechanism**
  - On/off, modulating the charge of the compressor, signals to storing water in a storage tank. According to (Delta Study), must manufacturers agree that variable tariffs is the way to optimize profits from a DR program

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Heat pumps

» **Cost impact**
  » Due to energy consumption: (4.5W/1000*8760h*0.20€/kWh=8€).
  » Installation of demand response: electronic thermostat (Wi-Fi enabled =~ 200€, Honeywell, Nest …)
  » RTE approximation (receiving only) 35/85€
  » Manufacturer information: 100€/200€ to enable DR (software adaptability, intervention)
» **Energy impact**
  » If wireless enabled, estimation of 6W (3W by 2019, EU regulations). Manufacturers estimate nowadays an average consumption of 4,5W for a communicating device

Boiler Circulators

» Network connection
  » The pumps are integrated to the boiler's control system, and will operate when the boiler according to the demand
» Additional components
  » Control interface capable of sending a signal from the boiler to the pumps according to the demand requested.
» Appliance modifications
  » Communication between the pump and the boiler, variable speed drives pumps to enable part load regimes
» Demand response mechanism
  » On/off, part load regime
» Cost impact: Communication between the circulators and the boiler 0€
» Energy impact : 0

Air conditioners

» Network connection
  » Electronic thermostat (via wireless technologies)
» Additional components
  » Electronic thermostat (capable of receiving external signals), software adaptability
» Appliance modifications
  » Adaptability between the thermostat and the air conditioner (intermediate device between the thermostat and the A/C).
» Demand response mechanism
  » On/off, part load regime via inverter A/C

Air conditioners

» **Cost impact**
  » Due to energy consumption: (4.5W/1000*8760h*0.20€/kWh=8€).
  » Installation of demand response: electronic thermostat (Wi-Fi enabled =~ 200€, Honeywell, Nest …)
  » RTE approximation (receiving only) 35/85€
  » Manufacturer information: 100€/200€ to enable DR (software adaptability, intervention)
» **Energy impact**
  » If wireless enabled, estimation of 6W (3W by 2019, EU regulations). Manufacturers estimate nowadays an average consumption of 4,5W for a communicating device

Ventilation

- Ventilation potential in the residential sector is negligible (very low energy consumption from the extractor fans in kitchen and bathrooms). In addition, most of the time there's no control from the users.
- **Network connection**
  - Mechanical ventilation units do only have an on/off switch, the connectivity to the network must be done via a hardware installation (wire between the electric meter to the ventilation unit)
- **Additional components**
  - New circuits that can receive signal from the aggregator/utility and can turn on/off the ventilation, must be installed.
- **Demand response mechanism**
  - On/off, part load regime via variable speed drive
- **Appliance modification**: variable speed drive, on/off circuit

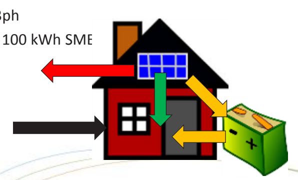
Ventilation

- **Cost impact**
  - No available information
- **Energy impact**
  - No available information

Residential energy storage system

System characteristics

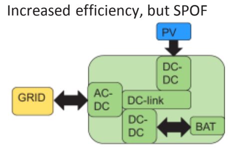
- Current markets in Europe: Germany, Austria, Switzerland
- +40 suppliers, +200 systems
- 25,000 systems installed in GE: 13 ct/kWh feed-in, 30 ct/kWh electricity price => 17 ct/kWh "self-consumption incentive"
- Increase self-consumption from 20-40 % to 60-70 %
- Grid connection: 1ph or 3ph
- E: 2-10 kWh residential – 100 kWh SME
- P: 1,5-10 kW



Residential energy storage system

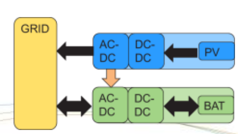
Network connection: Integrated system

- Input = PV array / Output = Grid connection
- Extensive power electronics:
  - Dc-dc converters for PV
  - Dc-dc converter for battery
  - Grid-inverter
- Increased efficiency, but SPOF



Network connection: Separate AC

- First system: Battery & dc-dc converter & grid-inverter
- Second system: PV-string (& dc-dc converter) & grid-inverter
- Requires PV measurement comm to battery system
- More conversion losses



Residential energy storage system

Inherent grid services: ~ Peak shaving

» Store PV peak, supply demand peak

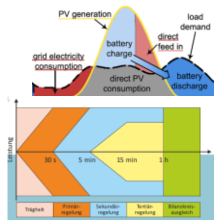
=> voltage support

» Overvoltage: PV peak

» Undervoltage: demand peak

=> Q support

» Voltage support by Q injection (grid losses)



Grid frequency services:

» Primary frequency reserve: Emphasis on power, discharging and charging of battery BUT limited energy exchange

» secondary frequency reserve (down-regulation): battery charged with e.g. excess wind energy if frequency too high

Residential energy storage system

Current capabilities

- Drastically increase self consumption
- Local weather forecasting
- Home energy management ~ local demand response:
  - Remote control of HH appliances: start washing machine at PV peak
  - Remote control of heat pump or airco
  - EEbus protocol, OpenHab Protocol
- Ready for VPP and dynamic pricing
- Internet connection for
  aggregator communication

Residential energy storage system

Current concerns

» All systems capable of grid energy storage, sometimes forbidden by legislation

» System efficiency:

  » 98 % grid-inverter, 97 % dc-dc converter [+ 0,1-0,4, ++ 0,4-1 P_{nom}]

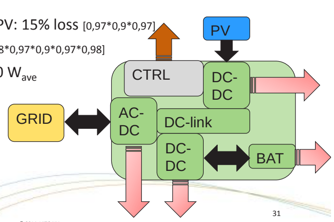
  » 90 % battery

  » Integrated system storing PV: 15% loss [0,97*0,9*0,97]

  » Grid storage: ~20% loss [0,98*0,97*0,9*0,97*0,98]

» Standy losses: up to 5-80 W, 30 W_{ave}

=> 263 kWh per year



Residential energy storage system

» **Additional components**

- Hardware: none
  - Bidirectional currents possible for integrated and separate systems

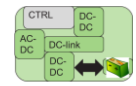
» **Appliance modifications**

- Software: from basic to advanced
  - Basic: I to grid, V/f off-grid, f support > 50,2 Hz, PV peak shaving
  - Energy mgmt: power settings PV, battery, heat pumps, EV, white goods & advanced weather forecasting
    - ⇒ Integral part of residential storage or separate system
    - ⇒ Internal SP or external SP aggregator

Residential energy storage system

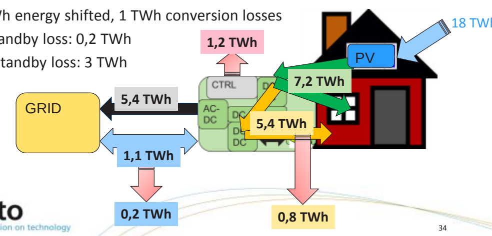
- **Appliance modifications**
- Software: from basic to advanced
  - Self-learning algorithms: distributed measurement, flexibility, near-term power requirements
  - Grid interaction software:
    - Advanced frequency support: primary [49,8-50,2 Hz]
    - From aggregator: Secondary down-regulation
    - Voltage droop: active power curtailment
    - Reactive power support
    - Current redistribution between phases
- **Cost impact:** Not predictable, ~ complexity, ~ extensiveness

Residential energy storage system



Energy impact

- Increase in self consumption: 5,4 TWh
  - 15 % lost in conversion losses: 0,8 TWh gone
- Available flexibility: 1,1 TWh
  - 20 % losses in grid E-storage: 0,2 TWh gone
- 6,5 TWh energy shifted, 1 TWh conversion losses
- 5 W standby loss: 0,2 TWh
- 80 W standby loss: 3 TWh



Lighting

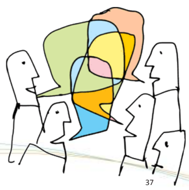
- Network connection
  - Wired (mainly Ethernet)
  - Wireless connections (Wi-FI, Bluetooth, Zigbee etc.)
- Additional components
  - Electronics for communicating with central energy manager (CEM)
  - Some systems include control box for LED bulbs
- Appliance modifications
  - None or few (assuming communication with CEM)
- Demand response mechanism
  - Reduce light intensity or switch off
- Cost impact
  - Substantial costs today on remote managed systems
- Energy impact
  - Energy for electronics
  - Products within 1194/2012: Lamp control: < 1 W

Commercial refrigeration

- Network connection
- Additional components
- Appliance modifications
- Demand response mechanism
- Cost impact
- Energy impact

Discussion

- Can we get closer to real life data – incl. for commercial refrigeration?
- Will costs of DR enabling of appliances be reduced over time with more integrated solutions?
- Will we see a DR System on Chip with reduction of price and consumption?



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