TASK 3 – USERS

Rainer Stamminger/ Jasmin Geppert, Bonn University

Content

- Drivers and barriers for the uptake of smart appliances
- Data protection, data security and consumer rights
- Comfort constraints and consumer objections per appliance category
- User behaviour: typical daily/ seasonal use pattern per appliance category
  - Daily load curves (one average appliance)
  - Hourly profile of flexible load (all appliances)
- Conclusions

Drivers for the uptake of smart appliances

Economic and ecological aspects

- Dynamic pricing (automation)
- Monetary savings (main driver)
- Lower environmental burden (second driver)
- Reasonable pay-back periods

Product related aspects

- Maintenance or enhancement of comfort
- Increase of control (e.g. via smart phone)
- Information on energy use
- New services (e.g. monitoring of or support for elderly people)
- Social factors

Barriers for the uptake of smart appliances

Economic aspects/ regulatory framework

- Incomplete smart meter rollout
- Lack of awareness of smart functions/ price schemes etc.
- Hidden costs (installation or repairs)
- Mistrust in energy suppliers/ scepticism about their motivation
- Data privacy/ data protection issues

Product-/ service related aspects

- Loss of control
- Technical failures/ system reliability
- Safety aspects/ insurances (during unattended operation)
- Lack of interoperability
- Error-proneness of appliances
- Upgradeability/ limited support
- Complicated handling

Additional costs and expected financial gains

- Slightly higher purchase price accepted by majority of consumers
- Acceptance of additional costs depend on absolute price of appliance, payback time, gain in comfort, potential additional costs and future savings
- Payback time of more than 3 years critical from consumers point of view (Mert et al., 2008, Smart-A project)
- Consumers are more convinced by lower energy costs than by reduced purchase prices
- Expected reduction of energy price: 11-20 %
- Savings of 80 €/ a as the point at which changes in behavioural patterns start to be worthwhile for consumers (Paetz et al., 2012)

Privacy aspects – general recommendations

- **Status today:** conditions in member states differ widely (e.g. penetration rate of smart meters, responsible entities for installation of smart meters, involvement of Data Protection Authorities, data paths, etc.)
- General recommendations (based on Task Force Smart Grid Expert Group 2 and the Article 29 Data protection working party):
  - "Privacy by design and default"
  - Length of data retention: related to the purpose
  - Way of data retention: aggregated and anonymised form (as far as possible)
  - Safeguards comprising the whole system
  - Consent of consumer for any disclosure of private data to or processing of data by third parties
  - Flexibility/ mobility (change of provider or location) of costumers enabled

Data security aspects

- Risk of an attack on the **infrastructure** considerably higher than risk of an attack on an **individual appliance**.
- However, measures also recommended for attacks on individual appliances:
  - "Connection on/ off" switch
  - Update capability to tackle known threats and future security needs
  - Limitations for changes in settings
  - etc.

Besides deliberate attacks also potential accidents, e.g. due to equipment failures, user error or natural catastrophes have to be taken into account !

TASK 3 - CONSUMER BEHAVIOUR WITH PERIODICAL APPLIANCES

viegand maagøe energy people

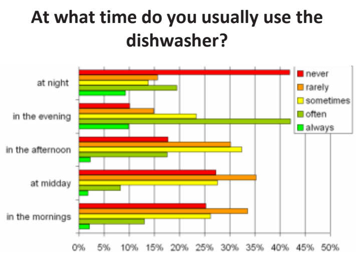
ARMINES

universitätbonn

Wuppertal Institut für Klima, Umwelt, Energie GmbH

Rainer Stamminger/ Jasmin Geppert, Bonn University

Dishwashers – user behaviour

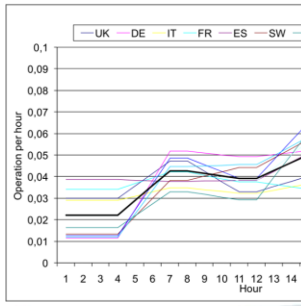


Source: EUP LOT 14

- 50/55 °C and 60/65 °C programmes preferably used
- Average nominal temperature: 59.3 °C (source: EUP LOT 14)
- Use patterns vary on a daily basis
- No seasonal variations

vito vision on technology

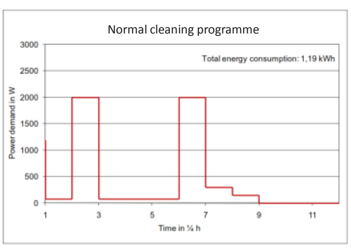
Dishwashers – day curve of operation



- Dishwashers mainly switched on in the afternoon/ evening
- Daily use pattern similar for all countries investigated
- → **Assumption 1:** average daily use pattern valid for all EU-28 countries
- → **Assumption 2:** daily use pattern will not change in near and mid-term future

vito vision on technology

Dishwashers – generic pattern of power demand during operation

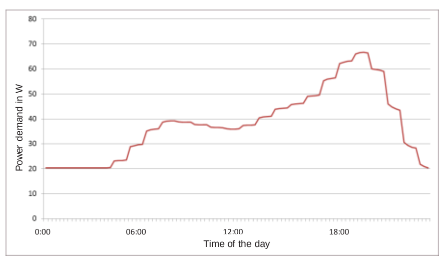


Source: Stamminger et al., 2009; Smart-A project

- Power demand high in heating phases (cleaning, rinsing)
- Future prospect:
  - lower cleaning and rinsing temperatures
  - lower power demand in the cleaning and rinsing phase
  - increased cycle times

vito vision on technology

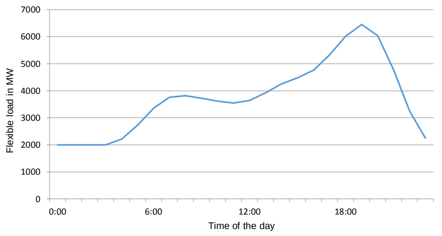
Dishwashers - general pattern of daily load curve (one average dishwasher)



- Day curve of operation x power demand during operation x use frequency (280/365 days)

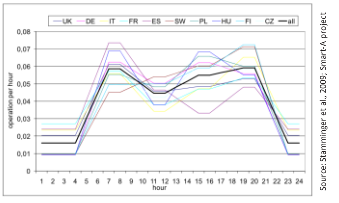
vito vision on technology

Dishwashers - hourly profile of flexible load (all dishwashers)



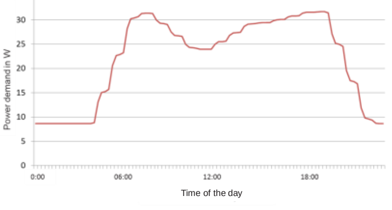
- Assumption: flexibility of dishwashers 3 h
- Number of appliances in stock: 98,345 millions (assumption: 100 % smart)

Washing machines – day curve of operation



- Preference for 40 °C programme
- Average nominal temperature: 45.8 °C (source: EUP LOT 14)
- Two preferred time slots: in the morning and in the afternoon/ evening
- No seasonal variations
- Daily use pattern similar for all countries investigated
- → **Assumption 1:** average daily use pattern valid for all EU-28 countries
- → **Assumption 2:** daily use pattern will not change in near and mid-term future

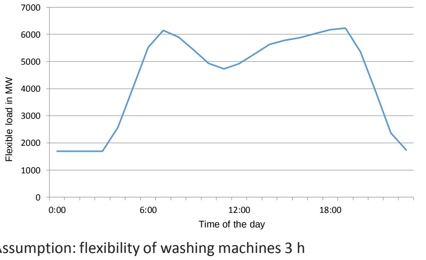
Washing machines - general pattern of daily load curve (one average dishwasher)



- **Future prospect:**
  - total energy consumption expected to further decrease
  - lower power demand in heating phase
  - increased cycle times

Day curve of operation x power demand during operation (normal cotton programme) x use frequency (220/365 days)

Washing machines - hourly profile of flexible load (all washing machines)

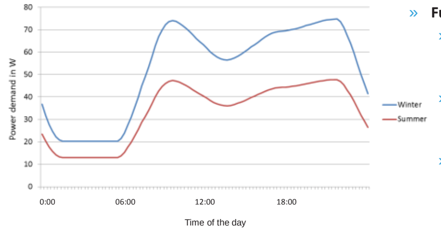


- Assumption: flexibility of washing machines 3 h
- Number of appliances in stock: 196,821 millions (assumption: 100 % smart)

Tumble dryers – user behaviour

- Use patterns vary on a daily basis
  - **Assumption**: daily use pattern are the same as for washing machines, but offset of 2 hours
- Use pattern additionally vary on a seasonal basis
  - Winter: average frequency of 3.6 cycles per household and week (source: EUP LOT 16)
  - Summer: average frequency of 2.3 cycles per household and week (source: EUP LOT 16)

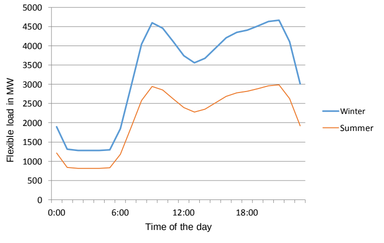
Tumble dryers - general pattern of daily load curve (one average tumble dryer)



- **Future prospect:**
  - higher shares of heat pump dryers
  - lower total energy consumption
  - lower power demand during the whole cycle

Day curve of operation x power demand during operation (normal cotton programme) x use frequency (winter: 93.6/183 days; summer: 59.8/183 days)

Tumble dryers - hourly profile of flexible load (all tumble dryers)



- Assumption: flexibility of tumble dryers 3 h
- Number of appliances in stock: 62,723 millions (assumption: 100 % smart)

Possibilities for consumers to engage in smart *periodical appliances*

- 1. Remote activation: the user selected program is remotely activated before the user deadline is reached.
- 2. Altered electricity consumption pattern: while the appliance is activated, the consumption patterns changed through pausing the operation, changing the temperatures, etc.

Periodical appliances - comfort constraints and consumer objections

- Willingness of consumers to shift loads to off-peak hours is rather high, but inter-personal differences
- Consumers would accept shifts of at least 3 hours
- Concerns include safety aspects (e.g. fear of flooding or fire if appliances are operated unattended or during the night)
- Concerns in view of smart washing machines: textile damage, colour fading
- Concerns in view of smart tumble dryers: textile damages and wrinkles

- Almost no concerns in view of smart dishwashers

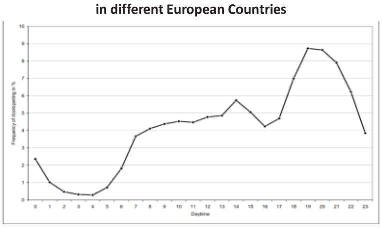
TASK 3 – CONSUMER BEHAVIOUR WITH CONTINUOUS APPLIANCES

viegand maagøe energy people
ARMINES
universitätbonn
Wuppertal Institut für Klima, Umwelt, Energie GmbH

Rainer Stamminger/ Jasmin Geppert, Bonn University

Refrigerators – user behaviour

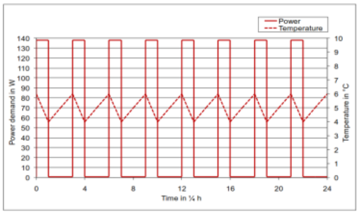
Frequency of door openings of refrigerators during the day in different European Countries



Source: S. Thomas, 2007

- Use pattern vary on a daily basis
- Seasonal variations only weak and neglectable
- **Assumption 1:** daily use pattern valid for all EU-28 countries
- **Assumption 2:** daily use pattern will not change in near and mid-term future

Refrigerators and freezers – generic pattern of power demand

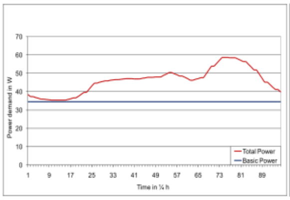


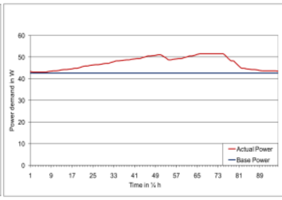
Source: Stamminger et al., 2009; Smart-A project

- **Future prospect:**
  - efficiency of compressors still increasing
  - trend towards higher capacities
  - average power demand is expected to remain constant in near future

Refrigerators and freezers – generic pattern of daily load curve (one average refrigerator/ freezer)

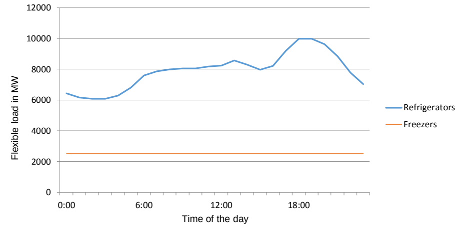
Refrigerators **Freezers**





vito
vision on technology

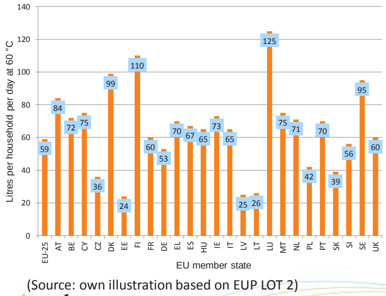
Refrigerators and freezers - hourly profile of flexible load (all refrigerators and freezers)



- Assumption: flexibility of refrigerators and freezers 10 min
- Number of appliances in stock: 236,496 (RF) and 66,704 (FR) millions (assumption: 100 % smart)

vito
vision on technology

Electric water heaters – user behaviour



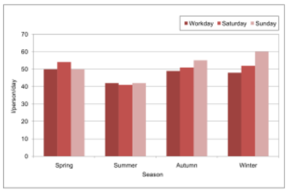
- Considerable differences in hot water consumption between member states
- Daily and seasonal variations in use pattern

(Source: own illustration based on EUP LOT 2)

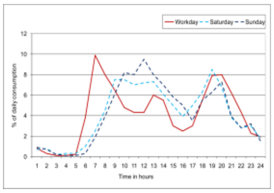
vito
vision on technology

Electric water heaters – seasonal and daily use pattern

Seasonal variations in hot water consumption **Daily variations/ use pattern of hot water**



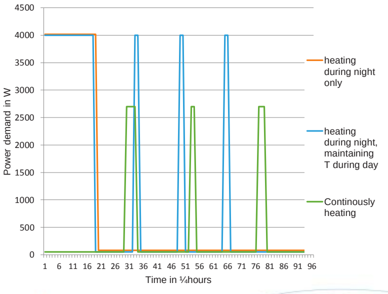
(Source: BfK, 1993)



(Source: BfK, 1993)

vito
vision on technology

Electric water heaters – general pattern of power demand



- Three main types of electric storage water heaters
- **Lack of data**
  - on types in stock
  - rated power
  - frequency of each type in different member states
- **Input requested!**

Possibilities for consumers to engage in smart *continuous appliances*

- 1. Power line triggered operation (e.g. frequency control): changes in frequency are detected by appliances and transferred into action (activation or delay of cooling or heating).
- 2. Altered electricity consumption pattern: changes in the operational parameters of the appliance (motor speed, temperature settings, etc.) allow modification of the consumption pattern.

Continuous appliances - comfort constraints and consumer objections

- **Refrigerators and freezers:** load shifts/ short-term interruptions limited in order to prevent microbial growth and quality losses of food
- **Refrigerators and freezers:** storing energy by cooling to lower than normal storage temperatures possible for freezers, but not for refrigerators (risk of freezing sensitive food and loosing food quality)

- **Water heaters:** Consumer acceptance and comfort constraints dependent on the storage capacity

TASK 3 – CONSUMER BEHAVIOUR WITH BEHAVIOURAL APPLIANCES

viegand maagøe energy people
ARMINES
universitätbonn
Wuppertal Institut für Klima, Umwelt, Energie GmbH

Rainer Stamminger/ Jasmin Geppert, Bonn University

Behavioural appliances – description of category

- Behavioural appliances are appliances where the operation is linked to its functionality and whose operations require the active involvement of consumers.
  - Instantaneous water heaters
  - Vacuum cleaners
  - Range hoods
  - Hobs
  - Ovens

Behavioural appliances - comfort constraints and consumer objections

- Behavioural appliances require an active involvement of consumers during operation
- Cooking and cleaning activities are time-bound
- Instantaneous water heaters cover an immediate need – cannot be stored
- Large comfort impacts

- In case of hobs and ovens: short term interruptions would be rather accepted if the cooking or baking results are not compromised
- Load shifts and short-term interruptions are improbable for all other behavioural appliances

Possibilities for consumers to engage in smart *behavioural appliances*

- Altered electricity consumption pattern: pause between heating cycles, interrupt the heating phase, etc. (hobs and ovens)

Conclusion *periodical/ continuous/ behavioural appliances*

- Load shifting potential high for **periodical appliances** because of high level of rated power, high (or increasing) numbers of installed appliances and manageable comfort constraints
- Medium potential of **refrigerators and freezers** despite high numbers of appliances in stock because of low levels of rated power and limitation to short term interruptions
- Input needed in view of **storage water heaters**: types in stock, rated power, frequency of each type in different member states
- Low/ no potential of **behavioural appliances** despite the large installed base and partly high levels of rated power because of very serious impacts on user's comfort

TASK 3 – CONSUMER BEHAVIOUR WITH COMMERCIAL REFRIGERATION

Rainer Stamminger/ Jasmin Geppert, Bonn University

Commercial refrigeration

- Lack of data on:
  - Number and types of appliances in stock
  - Typical use patterns (daily/ seasonal)
  - Average rated power of appliances in stock
  - Comfort constraints
  - Lifespan
  - Flexibility

- **Input is requested!**

TASK 3 – CONSUMER BEHAVIOUR WITH HVAC

Philippe Rivière/ Marcel Perret-Gentil, ARMINES Paris-Tech

HVAC – User behaviour

- Seasonal periods
  - Winter season : 7 months for EU28
  - Summer season : 5 months for EU28

- Occupation Schedules
  - Different for residential & tertiary sectors
    - Residential: Working population (absent during the day) and full time population
    - Tertiary: Depends on the commercial sector (offices, hospitals, shopping mall, factories…)
      - Weekly patterns, weekends, night shifts…

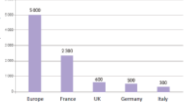
HVAC – comfort constraints

- **Heating (EN 15251)**
  - Temperature of 18 °C (19 °C for tertiary buildings
  - Temperature variation < 2°C/h
- **Cooling (EN 15251)**
  - Maximum temperature : 27°C
  - Temperature variation < 2°C/h

HVAC – Heating period

Member State	Heating Degree-hours	Group by heating season average	Heating Season (months)	Number of days in heating season	Days in heating season
Finland	5849	Group 1	10,8	323	288
Sweden	5444		10,2	306	
Estonia	4445		8,8	265	
Latvia	4265		8,6	257	
Lithuania	4094	Group 2	8,3	250	214
Poland	3616		7,7	231	
Austria	3574		7,6	229	
Czech Republic	3571		7,6	229	
Denmark	3503		7,5	226	
Slovakia	3453		7,5	224	
EU 27 Average	**3254**		**7,2**	**216**	
Germany	3239		7,2	215	
Luxembourg	3210		7	214	
Romania	3129		7	211	
United Kingdom	3115		6,9	210	
Slovenia	3053		6,7	208	
Hungary	2922		6,7	202	
Ireland	2906		6,7	202	
Netherlands	2902		6,7	201	
Belgium	2872		6,7	200	
Bulgaria	2687		6,4	193	
France	2483		6,1	284	
Italy	1970	Group 3	5,4	163	138
Spain	1842		5,3	158	
Greece	1663		5	151	
Portugal	1282		4,5	135	
Cyprus	782		3,8	114	
Malta	560		3,5	105	

- Focus on representative countries that represent the main installed base (France, Germany, UK…)



Temperature sensitivity of electricity consumption in France and other countries in Europe in 2012, from (RTE, 2012)

HVAC – Cooling period

Member State	Cooling degree-days Total (1)	Population Share (EU28) (2)	Penetration Rate 2010 (%) (3)	Pondering (1) (2) (3)
EI	5	1%	7%	0,00
DK	57	1%	7%	0,05
NL	75	4%	6%	0,17
EE	78	0%	7%	0,02
SE	81	2%	6%	0,10
BE	84	2%	7%	0,12
UK	94	13%	7%	0,84
FI	97	1%	6%	0,07
LT	102	0%	8%	0,03
LU	103	0%	7%	0,01
LI	105	1%	7%	0,05
CZ	116	2%	1%	0,03
FR	138	13%	7%	1,22
DE	168	18%	2%	0,49
SI	187	0%	24%	0,14
AT	213	2%	5%	0,17
PL	216	7%	1%	0,08
SK	260	1%	30%	1,02
BG	275	1%	28%	1,07
HR	277	1%	n/a	n/a
HU	282	2%	1%	0,07
PO	324	2%	3%	0,16
RO	379	3%	29%	3,75
IT	420	12%	43%	22,22
ES	652	7%	42%	19,28
MT	714	0%	29%	0,21
GR	893	2%	73%	12,41
CY	972	0%	100%	0,97
EU 27 Mean	**263**	**100%**	**18%**	

Countries with higher demand for residential/tertiary a/c

Principal factors taken into account:

•Cooling-degree days
•Population share and
•Penetration rate of a/c in residential

HVAC – Energy Consumption

- ***Heating:***
  - Peak power: 95 GW (2010)
  - Energy consumption: 280 TWh/year
  - Potential energy to be shifted: 30 TWh/year or about 100 GWh/day in the coldest winter day (heating off for one hour)
- ***Cooling:***
  - Peak power: 160 GW
  - Energy consumption: 80 TWh/year (2010)
  - Potential energy to be shifted: 65 GWh/day (this corresponds a the mean demand over the summer for an off-period of one hour

Load Diversity - *HVAC*

- **For EU28**
  - Building stock is heterogeneous
  - Climate conditions are different
  - Different use patterns across the continent

- Single scenario (one building, one average climate, one use pattern) will not give a realistic input for EU28 energy consumption, shifting potential

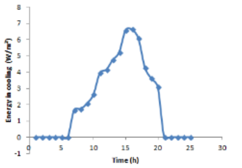


Figure 1. Load curve for an office building in Nice, France (16th July)

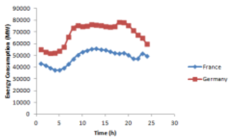


Figure 2. Electricity demand curve for the July 16th 2014

vito vision on technology

Approach for base cases - *HVAC (cooling)*

- **Simplified model**
  - P(MW) α ΔT (+humidity? , solar irradiance?)
  - Known installed units and repartition (ENER Lot 10 / ENTR Lot 6)
  - Simultaneous weather data for EU 28 or representative countries
  - Different use patterns (residential, tertiary uses…)
- **Validation**
  - Grid curve (thermal sensibility)
  - Energy consumption (per country, per appliance type…)

vito vision on technology

Approach for base cases- *HVAC (Heating)*

- **Simplified model**
  - P(MW) α ΔT (solar irradiance?)
  - Known grid thermal sensibility for France
  - Simultaneous weather data for EU 28 or representative countries
  - Different use patterns included in observations from the grid
- **Validation**
  - Energy consumption (per country, per appliance type…)

vito vision on technology

Potential for consumers to engage in smart *HVAC*

- Possibility to enable DR
  - No cycle constraints (on/off whenever)
  - High potential
  - On/off or modulating operation (part-load)

vito vision on technology

Main constraints for consumers to engage in smart *HVAC*

- According to an inquiry from 1 manufacturer
  - Equipment is expensive, investment recovery is not assured
  - Customer will prevail comfort
  - Interoperability from appliances is not enough
  - Additional power consumption of network interface and sensors may be large

Conclusions and perspectives - *HVAC*

- Specific load curves / use profiles cannot be used for estimating a EU28 consumption profile / shifting potential
- Base cases estimated from grid observations and simplified models that will allow to get smoothed functions MW(t)
- Inputs needed: grid observations for cooling/heating and weather data
- Intermediary meeting with experts to validate the model (January 2016)

TASK 3 – BATTERY OPERATED RECHARGEABLE APPLIANCES

viegand maagøe energy people
ARMINES
universitätbonn
Wuppertal Institut für Klima, Umwelt, Energie GmbH

Sven De Breucker/ Sven Claessens, VITO/ EnergyVille

Battery operated rechargeable appliances – description of category

Low power appliances equipped with battery charging function :

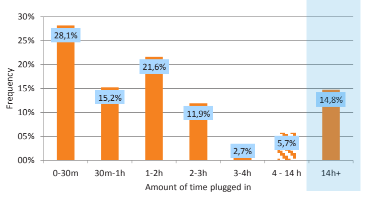
- **Multimedia devices**
- Household appliances
- Power Tools

- Selection based on balance between :
  - Power consumption
  - Installed base
  - Flexibility in charging behaviour

- Selected appliances :
  - laptops, smartphones and tablets

Battery operated rechargeable appliances – user behaviour

» Smartphones



Source : Denzil Ferreira, Anind K. Dey, Vassilis Kostakos. Understanding Human-Smartphone Concerns: A Study of Battery Life. Pervasive Computing. June 2011.

Battery operated rechargeable appliances – comfort constraints

» Battery performance : Constraint on the smart charging to be able to predict very accurately and reliably the next usage.

» If the flexibility would need to be increased, the devices should be connected to their charging stations(wired or wireless) for longer periods.
  - *limiting the mobility that usually is the key feature of these appliances.*

» Drawback is that the energy (demand) shifting potential is a balance between flexibility and energy saving, where longer connection leads to more shifting potential , but also to more energy consumption due to power losses (little, but present) when devices are connected.

Battery operated rechargeable appliances – energy consumption and shifting potential

» **Power consumption :**
  - » Smartphone: 3 to 5 kWh/year
  - » Tablet: 12 kWh/year
  - » Laptop: between 150 and 300 kWh/year

» **Shifting Potential (Quick calculation) :**
  - » 281 GWh per year or 0.77 GWh/day in Europe for smartphones.

Conclusion - *Battery operated rechargeable appliances*

» Battery Operated Rechargeable Appliances, need to be available in large numbers to be able to provide sufficient flexibility.

» In this category we selected smartphones, tablets and laptops as possible candidates.

» They already have sufficient control logic and communications features available, so that the implementation will be mainly limited to software.

» A quick calculation shows that sufficient flexibility (hundreds of GWh per year) can be gained without any change in user behavior. **But it is also clear that for correct calculations, there is still a general lack of available and reliable studies on this subject.**

» The shifting potential is a balance between flexibility and energy saving :
  - » more shifting potential -> more energy consumption (power losses)

» The lifespan of the devices is rather short, 4-5 years.

TASK 3 – CONSUMER BEHAVIOUR WITH RESIDENTIAL ENERGY STORAGE SYSTEMS

viegand maagøe energy people

ARMINES

universitätbonn

Wuppertal Institut für Klima, Umwelt, Energie GmbH

Sven De Breucker/ Grietus Mulder, VITO/ EnergyVille

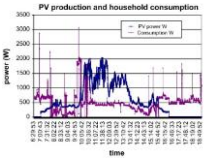
Residential energy storage systems – description of category

- Larger battery storage systems (2 to 10 kWh)
- Two different set-ups exist:
  - Back-up power
  - Electric energy storage
- UPS out of scope due to application (maximum charge at all time)
- Different implementations :
  1. Residential energy storage systems combined with a separate PV installation.
  2. Fully integrated residential energy storage systems with PV
  3. Setup 2 combined with smart control of appliances
  4. Standalone residential energy storage systems

Residential energy storage systems – user behaviour

- Main goal for setup 1, 2 and 3 is maximization of self-consumption
  - Avoid revenue loss due to feed in.

- Setup 4 focusses also on :
  - the difference in pricing in time.
  - reservation and activation fees for other services.



- Installed base :
  - Germany 25,000 in 2015.
  - For other countries figures not known.

Residential energy storage systems – comfort constraints

- Most operate fully automated.
  - Can make use of advanced algorithms taking into account price variations, solar predictions based on regional weather information, self-learning techniques to predict expected consumption, etc.
- Minimal or no user interaction.
- Capacity needed is dependent on consumption patterns and installed appliances (E.g. heat pump or not) and installed PV capacity.
- An additional advantage, but certainly not the main goal, is that the residential energy storage system can provide in backup power when the grid is not available.

Residential energy storage systems – lifespan

- Estimate lifespan of 15 to 20 years.
  - Dependent on operations conditions like :
    - Battery type
    - Temperature
    - Charging and Depth of discharge limits.
    - Number of cycles

vito vision on technology

Residential energy storage systems – energy consumption and shifting potential

- Calculations for energy storage systems combined with PV :
  - Based on :
    - 18 GW of installed residential PV capacity in Europe
    - Average capacity of residential installations is 4 kW
    - 30% extra self-consumption if storage applied
    - average consumption of a household : 3,500 kWh/year
  - Result :
    - Shifting for self-consumption: 5.4 TWh/year
    - Additional shifting using the remaining full load cycles : 1.2 TWh.

    => 0,21% of the total electricity consumption (3,101.3 TWh) in EU28 in 2013

vito vision on technology

Conclusion - *Residential energy storage systems*

- Residential Energy Storage System, are ideal appliances for providing flexibility in the electric grid.
- Today we mainly systems in combination with PV installations. (maximum self-consumption of the PV generated energy)
- Operate fully automatic and have no impact on the users comfort.
- Can also be used for different other business case like dynamic pricing, peak shaving from and to the grid and aggregator services.
- Still very small in numbers and only common in Germany (25.000).
- The individual flexibility however is large.
- The lifespan of installations is expected to be between 15 and 20 years.
- A quick calculation on the PV case shows a shifting potential of about 6,6 TWh per year.

vito vision on technology

TASK 3 – CONSUMER BEHAVIOUR WITH LIGHTING

viegand maagøe energy people

ARMINES

universitätbonn

Wuppertal Institut für Klima, Umwelt, Energie GmbH

Jan Viegand, Viegand Maagøe

vito vision on technology

Lighting – User behaviour

- LFL: Linear fluorescent lamp
- CFL: Compact fluorescent light
- Tungsten
- HID: High intensity discharge lamp
- LED: Light emitting diode

Lighting – User behaviour

- LFL: Linear fluorescent lamp
- CFL: Compact fluorescent light
- Tungsten
- HID: High intensity discharge lamp
- LED: Light emitting diode

Usages:

- Homes:
  - Manual on/off and dimming
  - Automatic (time, presence, ambient light)
  - Smartphone control
- Commercial:
  - Manual on/off and dimming
  - Control systems (time, presence, ambient light)
- Public street lighting:
  - Automatic (time, ambient light, presence)

Lighting – comfort constraints

- Lighting covers an immediate need – cannot be stored
- Large comfort impacts
- Only very short periods of dimmed or off time could be accepted for part of the lighting services
- Public street lighting: Less comfort impacts, though safety issues occur

Lighting – energy consumption and shifting potential

- Total energy consumption (2013): 279 TWh/year
- Very little data on demand response potential
- Estimations on potential based on - for each type of light source:
  - Number of installed light sources
  - Lumen output
  - Operating hours
  - Efficiency
  - Simultaneity factor
  - Comfort factor

- **Total DR reduction potential: 28 GW – 4 GWh/day**

Conclusion - *Lighting*

1. Technical potential high
2. Lighting should be produced simultaneous as the needs occur
3. Very serious user impacts and safety issues
4. Demand response potential mainly for short periods of emergency load reduction

!

Conclusion - *all appliances*

High potential	Medium potential	Low/ no potential
Washing machines	Refrigerators/ freezers	Electric water heater (instantaneous)
Dishwasher	Battery operated rechargeable appliances (smart phones and tablets)	Vacuum cleaners
Tumble dryer		Range hoods
Washer-dryer		Battery operated rechargeable appliances (others)
Electric water heater (storage)		Lighting
HVAC		Hobs
Battery storage systems		Ovens