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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

Project team at Stakeholder Meeting 10 March 2015:
Sarah Bogaert, Koen Vanthournout & Dominic Ectors, VITO
Jan Viegand, Viegand Maagøe
Prof. Rainer Stamminger & Jasmin Geppert, Rheinische Friedrich-Wilhelms-Universität Bonn
Philippe Rivière, MINES Paris-Tech

THE TEAM

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Flemish energy research VITO is part of

EnergyVille

VITO
- Energy Technology
- Sustainable Cities

KU Leuven
- Electa
- Building Physics
- Mechanics

imec
- Photovoltaic Research

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linear
Intelligent Networks

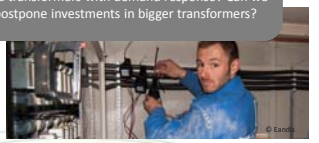
Business/Control Cases

Portfolio Management
Can demand response shift the energy use of families according to the day-ahead markets?

Intraday (Wind) Balancing
Can the energy supplier use demand response to correct intraday imbalances in its portfolio, caused by differences between predicted and actually generated wind energy?

Line Voltage Control
Can demand response help to reduce overvoltages and undervoltages in the distribution grid?

Transformer Ageing
Can we lengthen the lifespan of the distribution grid transformers with demand response? Can we postpone investments in bigger transformers?



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Viegand Maagøe

Ecodesign

Public sector

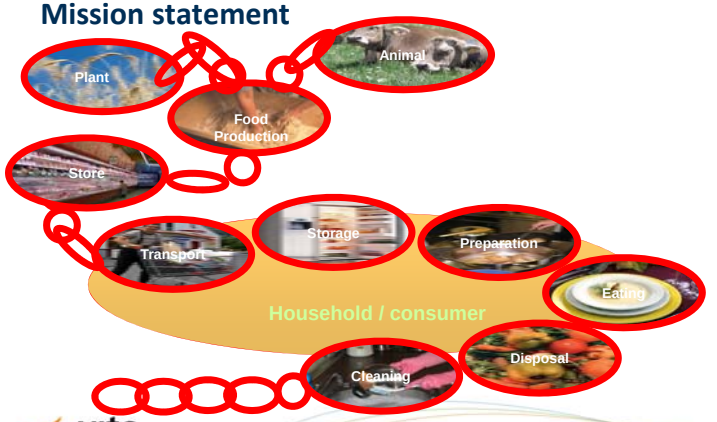
Buildings

Communication

Industry

Viegand Maagøe provides communication and consulting services on energy and climate to public and private organizations and companies

University of Bonn – Household Technology: Mission statement



University of Bonn – Household Technology: mission statement

- Household Appliance Technology Bonn aims to lighten life in domestic homes by applying technology

relieve from heavy works | reduce time consuming activities | increase overall welfare | minimise environmental effects

- **Focus in research on:**
  - Precision in good housekeeping
  - Analysis of the food chain in households
  - Medium of acquired insights

Rainer Stamminger

Jasmin Geppert

Completed projects (selection)

- Organization and evaluation of a European round-robin test of dishwashers 2003 + 2009
- **Acceptance of intelligent and connected appliances at home**
- European habits in storing perishable foods
- Risk assessment of the cold chain from grocery to households
- Keeping food stuff fresh – new ways
- Innovative concepts in catering – Dream Steam
- Consumer behaviour in drying of articles in different tumble dryer types
- Consumer acceptance for innovative drying systems
- Global/ European dishwashing habits
- **Renewable energy use by smart appliances (SMART-A EU-project)**
- Energy consumption and performance of various small appliances
- Filming and spotting on dishes
- Energy consumption of professional coffee machines in Germany
- Washing behaviour of special consumer groups
- Usage behaviour of washer-dryers in 10 European countries
- **Field test of Smart Grid appliances**
- New methodology to assess creases in shirts
- Assistant for cooking
- Washing performance and consumption of old washing machines
- Workshop and training in using EN 50242
- Consumer habits in washing (in general and especially for young families)
- Cleaning performance, drying performance and consumption of old dishwashers
- New rinse-aid formula for dishwashing supporting energy saving
- New ways to measure rinsing performance on washing machines
- Market trends and consumer behaviour on energy using products (WM, DW and Cold) (EuP lot 13 and 14)
- Best practise in manual dishwashing
- Consumer acceptance of TTIs
- Low Temperature washing machines
- Food processing
- Sustainable consumer behaviour
- Comparison of global standards for dishwashing assessment
- Verification of energy label declaration for washing machines (Atlete II)

C.E.S. Centre Efficacité énergétique des Systèmes

- **ARMINES / CES : Energy Efficiency research center** of one of the leading engineering schools in France, Mines ParisTech, part of PSL Research University .
- 6 research teams: Process thermodynamics, thermal systems, structural thermal design, CO2 capture, Building physics and LCA, **Demand side management**
- 6 main application themes : Buildings, Industry, Process, Low emission vehicles, Energy storage, Energy policies

- **Demand side management** (team part of this project):
- Long experience regarding energy efficiency policies (SAVE, Ecodesign); strong physical and technical background of energy systems in buildings ;
- Present evolution towards: **heating/cooling networks** design and evaluation, evaluation of shaving/curtailment programs with use of **smart meters/grids**, modelling and measurement of savings, **end-use energy consumption** local to global models.

Philippe Rivière, Assistant Professor, philippe.riviere@mines-paristech.fr
MINES ParisTech, PSL Research University, CES – Center for the Energy Efficiency of systems

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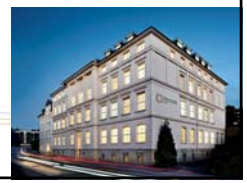
Wuppertal Institut

Wuppertal Institut für Klima, Umwelt, Energie GmbH

- Founded in 1991, non-profit limited company, about 250 staff members
- Trans-disciplinary research and development of models, strategies and instruments for transitions to a sustainable development at local, national and international level
- Four research groups with focus on different research fields:
  - Future Energy and Mobility Structures
  - **Energy, Transport and Climate Policy**
  - Material Flows and Resource Management
  - Sustainable Production and Consumption
- Strong focus on evaluation of technical and economic aspects to support the development of effective and sustainable policy strategies



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WORK PLAN

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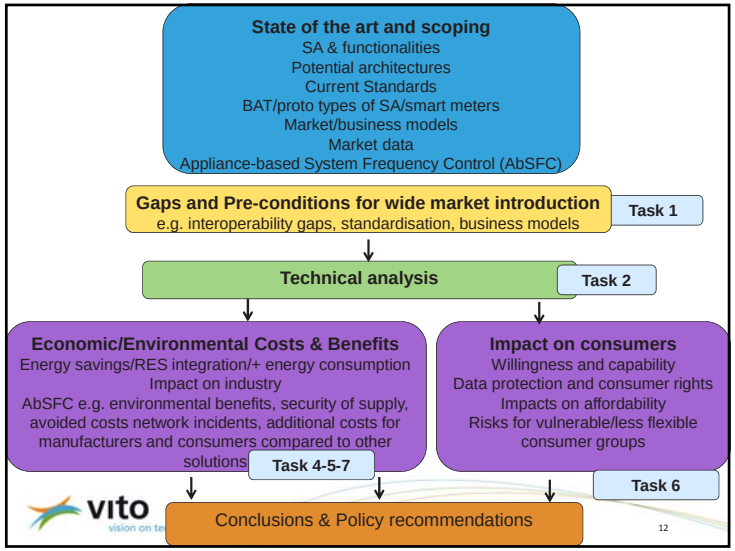

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Next meetings & reporting

- Study runs until Sept 2016
- Report on scope/interoperability/standardisation to be submitted in April for written comments
- 2 additional Stakeholder Meetings – provisional plan:
  - Task 1-5: September 2015
  - >Task 6: June 2016
- Register for updates on http://www.eco-smartappliances.eu

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WHAT ARE 'SMART APPLIANCES' – SCOPE OF THE STUDY: FUNCTIONALITIES APPLIANCE TYPES

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Philippe Rivière, MINES Paris-Tech
Dominic Ectors, VITO

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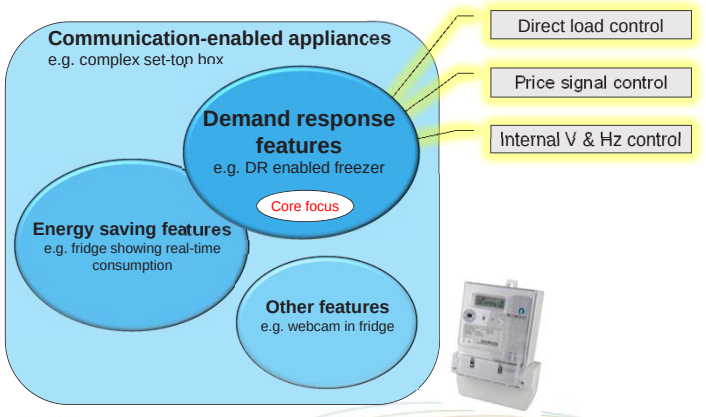
Appliance focus



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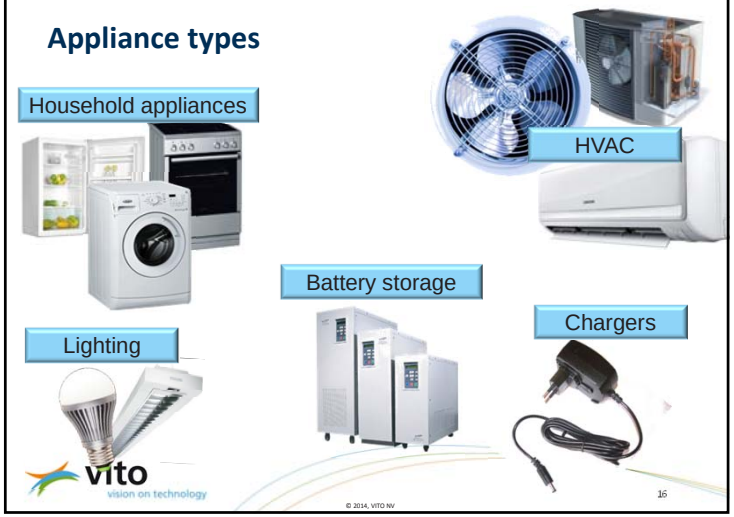
Appliance types



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Appliance types

Periodical use	Batch E.g. washing machine
Permanent use	Always on E.g. ventilation
Behavioural use	On when needed E.g. lighting

Analysis of appliances

- Appliance category
- Shifting & modulating possibility
- Shifting potential GW / GWh
- User impact
- Gaps & pre-conditions
- Functionalities energy efficiency

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HOUSEHOLD APPLIANCES

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Prof. Rainer Stamminger, Bonn University

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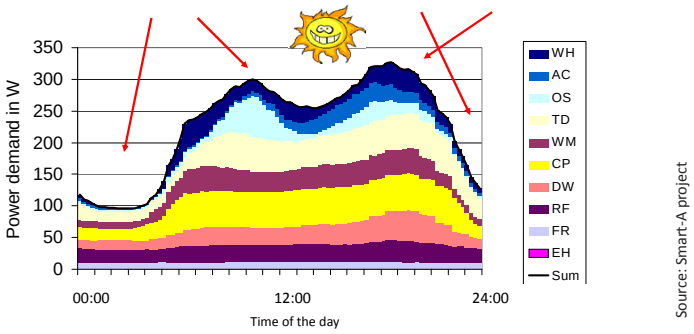
Estimated daily load curve of an average household in region "Germany/Austria":



Source: Smart-A project

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Installed base

(source: R. Kemna, ECODESIGN IMPACT ACCOUNTING, 2014)

	2010	2015	2020	2025	2030
Washing machines	185.828.000	196.821.000	200.805.000	202.648.000	204.744.000
Dishwashers	82.799.000	98.345.000	115.036.000	131.797.000	148.553.000
Tumble Dryers	62.723.000	68.018.000	71.801.000	75.767.000	77.778.000
Washer-Dryers	700,000 units sold in 2012 in EU (4 % of washing machine market, growing)				
Refrigerators/ freezers	297.800.000	303.200.000	308.000.000	312.800.000	317.600.000
Water heaters	157.293.000	161.740.000	165.192.000	168.688.000	172.268.000
Electric hobs	133.781.000	149.114.000	163.566.000	176.468.000	188.544.000
Electric ovens	191.823.000	199.332.000	209.502.000	220.505.000	232.059.000
Range hoods	92.371.000	97.111.000	102.060.000	107.267.000	112.741.000
Vacuum cleaners	364.226.000	388.857.000	419.407.000	487.849.000	545.178.000

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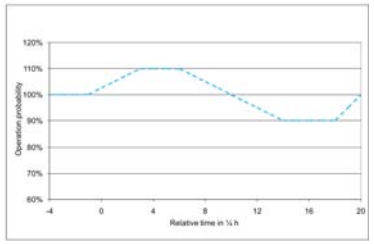
Shifting or capacity modulating potential

1. **Power line triggered operation** (e.g. frequency control)**:** doesn't influence power demand curve of a single appliance. With regard to the day curve of power demand of all appliances, a 10 % shift of operation at any time in any direction is estimated.



Source: Smart-A project

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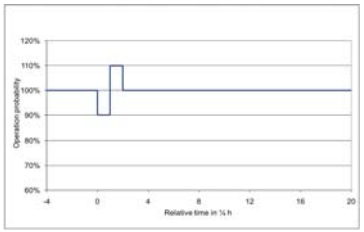
Shifting or capacity modulating potential

2. **Internal energy manager agent:** triggered by an external signal, appliances being in an appropriate state may change its operation (e.g. delay in start or interruption of heating phase, changes in programme run, lower temperatures). The external signal should include information on the shortage of energy and how long it will last. Recovery peak may be relevant.



Source: Smart-A project

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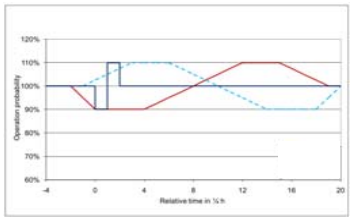
Shifting or capacity modulating potential

3. **Remote control by an energy demand manager:** the energy demand manager decides about starting time of appliances within a predefined time interval and tries to harmonise the available power on the grid with the demand. The power demand curve of a single appliance may or may not be affected by this option.



Source: Smart-A project

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Total shifting potential

Washing machines	4.86 GWh*
Dishwashers	8.17 GWh*
Tumble Dryers	3.03-9.47 GWh*
Washer-Dryers	n/a
Refrigerators/ freezers	1.56 GWh*
Water heaters	2.5-9 GWh**
Electric hobs	n/a
Electric ovens	n/a
Range hoods	n/a
Vacuum cleaners	n/a

Source: own calculations based on Smart-A project, Puranik, 2014

Referring to: * All European households ** Swedish households

Comfort and user impact

Motivations

- Economic Incentives
- Environmental benefit
- Enhanced safety functions (e.g. overloading signal, temperature surveillance, water stop, detection of technical faults)
- Enhanced comfort and usability
- High quality service & support
- Attractive design

Objections

- Concerns about safety (especially during absence) and noise (during the night)
- Concerns about quality (food spoilage, damages in clothes, …)
- Loss of control (remote control)
- Doubts about maturity of the technology
- Scepticism about the ecological benefits (add. energy con.)
- Additional costs

HEATING, VENTILATION AND COOLING

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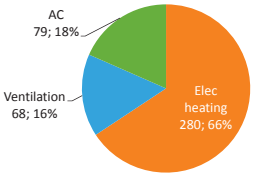
Philippe Rivière, ARMINES Paris-Tech

HVAC – Installed base (1/2)

- Space heating
  - Radiator
  - With built-in inertia
  - Heat pump
  - SH circulators
- Air conditioning
  - Room
  - Central
- Ventilation
  - Residential
  - Commercial
- Humidity control

EU HVAC electricity consumption in TWh and %

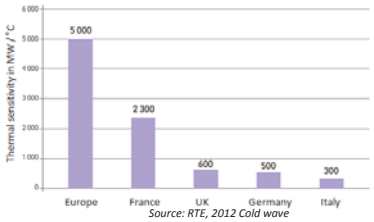


Source: ErP preparatory studies Ener Lot 10 & 21, ENTR Lot 6

15 % of EU electricity consumption

HVAC – Installed base (2/2)

	GW
SH	**261**
SH: Radiators wo inertia	166
SH: Radiators w inertia	37
SH: Boilers (El.)	10
SH: HP	40
SH: circulators	8
AC	**198**
AC: residential	86
AC: commercial	112
V	**12**
V: residential	2
V: commercial	10



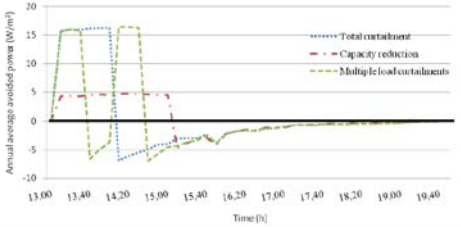
Source: RTE, 2012 Cold wave

Cold wave 2012 : - 1 °C -> + 5 GW
About 100 GW seen from the grid versus > 210 GW SH thermosensitive installed base !

HVAC – Modulating potential

SH & AC

- Using the building mass for SH and AC. Potential of **1 to 2 hours.**



Example of different cooling curtailment strategies

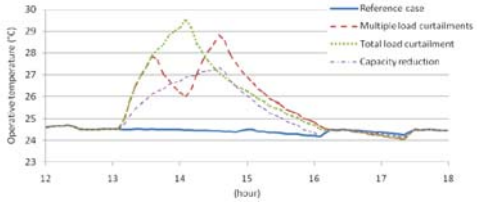
Source: Da Silva, 2010

- Using built-in inertia. **From 1 h to 12 hours (night tariffs)**
- Hybrid heat pump / AC.

Ventilation. **Maximum 1 h** and 50 % capacity for commercial (NREL, 2013).

HVAC – Comfort and user impact

- **SH and AC**
  - Indoor (radiative) temperature criteria. Comfort standard EN15251.
  - Variation slope of indoor temperature.



Example of different cooling curtailment strategies

Source: Da Silva, 2010

- **Ventilation**
  - Health limits DR potential due to pollutant concentrations (CO2)

HVAC – Conclusion

Potentials preliminary estimates

- Heating. **100 GWh/day** in the coldest winter months.
- Cooling. **65 GWh/day** in the hottest summer months
- Ventilation (commercial). Max **10 GWh/day**. Competition with energy efficiency.

Gaps / data required

- Data on dehumidifiers / humidifiers
- Feedback on appliance figures
- Information on already smart units (AC & HP)
- Validation of potentials per appliance type (feedback from experimental DR projects) including user acceptance

CHARGERS

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Dominic Ectors, VITO

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Appliance: chargers (low power)

- Category: charging of battery equipped low power appliances
  - Smartphone, toothbrush, laptop, rechargeable power tool, camera,…
- Shifting or capacity modulating possibility
  1. Minimum state of charge (SOC)
  2. Fully charged target time
- Shifting or capacity modulating potential
  - Smartphone (3-5kWh/year), tablet (12kWh/year), power tool (38 kWh/year)
  - Large installed base, low peak/average power consumption
  - Almost no figures (average charging times, times connected)
- User/comfort impact
  - Minimum SOC -> limiting mobility
  - Fully charged target time -> User interaction required

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Appliance: chargers (low power)

- Gaps & preconditions
  - Functional extension needed (connectivity, SW)
- Functionalities supporting energy efficiency
  - Depending on battery technology (some higher between certain SOCs)

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Appliance: battery storage systems

- Category:
  1. UPS for residential and small business
  2. Battery energy storage systems (standalone / integrated)
- Shifting or capacity modulating possibility
  1. UPS: goal is high SoC -> limited shifting possibility
  2. Battery energy storage systems: store excess energy/provide when demand is high/peak power shaving/power smoothing/ islanding
- Shifting or capacity modulating potential
  1. UPS: 100 KVA – 5000 KVA bridging small periods expressed in minutes
     - Due to nature -> low potential
  2. Battery energy storage systems: 1-10 kWh
     - Small installed base

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Appliance: battery storage systems

- User/comfort impact
  - Battery lifetime ?
- Gaps & preconditions
  - Battery technology
- Functionalities supporting energy efficiency
  - Reduction of power losses in the grid (lower peak, less transport)

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LIGHTING

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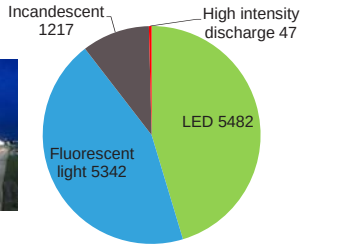
Lighting



Stock 2020: 12088 mill. units

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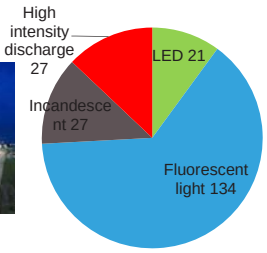
Lighting



Stock 2020: 210 TWh/year

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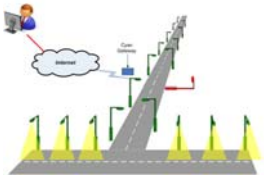
Lighting – DR possibilities

- Dimming
- Switching off



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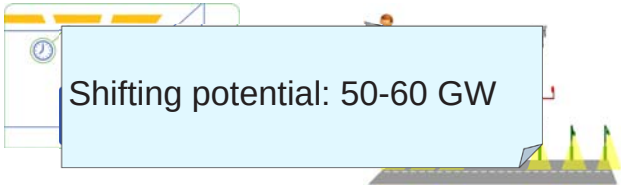
Lighting – DR possibilities

- Dimming
- Switching off



Shifting potential: 50-60 GW

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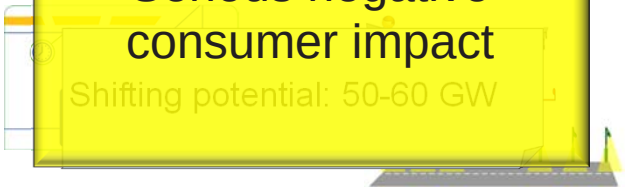
Lighting – DR possibilities

- Dimming
- Switching off

Serious negative consumer impact

Shifting potential: 50-60 GW



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Conclusion – so far

+++ High flexibility potential with few comfort impacts

\+ Smaller flexibility potential and/or larger comfort/health impact

! Only emergency flexibility potential

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