University of St.Gallen

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Bits to Energy Lab

Mechatronics to drive environmental sustainability: measuring, visualizing and transforming consumer patterns on a large scale

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Bits to Energy Lab, ETH Zurich

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Bits to Energy Lab - Overview

- **Research initiative of 4 chairs at 3 universities**
  - **ETH Zurich** (Chair of Information Management; Distributed Systems Group)
  - **University of St. Gallen** (Operations Management)
  - **University of Bamberg** (Energy Efficient Systems)

- **Mission: We combine IT and social science concepts to motivate households to reduce their energy consumption.**
  - Measure / Retrieve behavioral data
  - Research-based implementation of interventions
  - Data analytics
  - Transfer to practice: startups &industry collaboration

Hot water consumption is the 2nd largest end use in residential energy consumption, which accounts for 27% of the final energy use in the EU.

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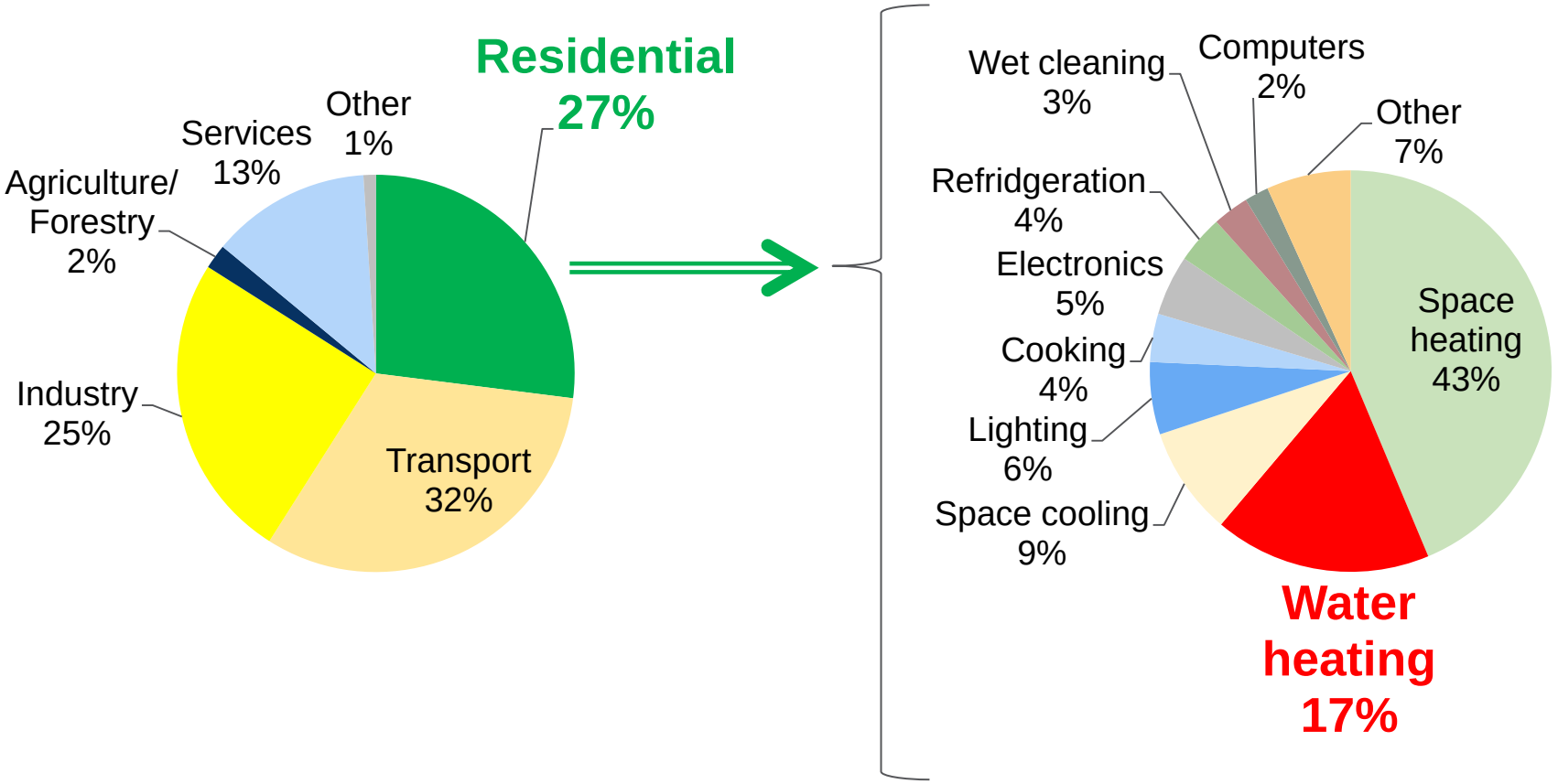
Final energy consumption by sectors (EU-27, 2010)



Source: European Commission: Energy Efficiency Status Report 2012

Source: DoE Buildings Energy Data Book 2011

Promising results of a pilot study motivated further R&D to move from prototype to mass production.

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Pilot study (2011) with promising results:

- Prototype of smart shower meter
- Energy and water consumption: 22% reduction

However:

- Sample size (N=61)
- Sampling bias

→ **Further research and development, cleaner & larger study**

Users can install the smart water meter amphiro a1 in three simple steps.

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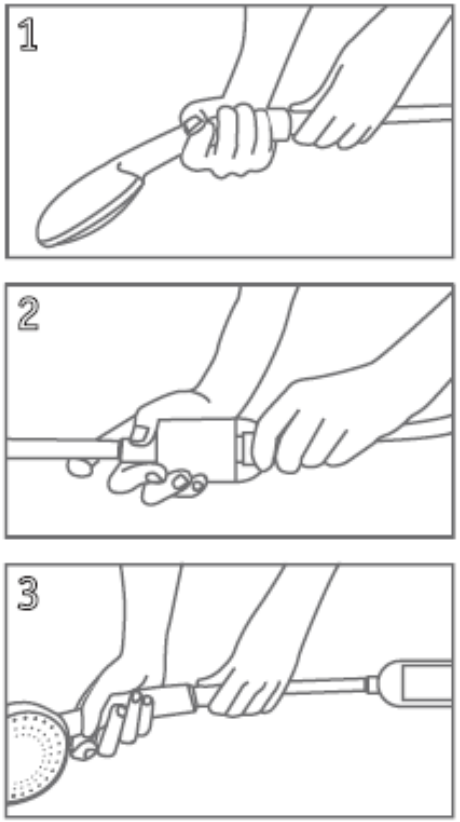

What the smart water meter measures and displays

Measures

- Flow rate
- Temperature (1 Hz)
- Duration (shower, interruptions)

Derived from that

- Water volume
- Energy consumption

Display (standard)

- Temperature
- Water volume
- Energy efficiency class
- Polar bear animation

per shower

Cross-section of the device: A built-in generator harvests energy from the water flow.

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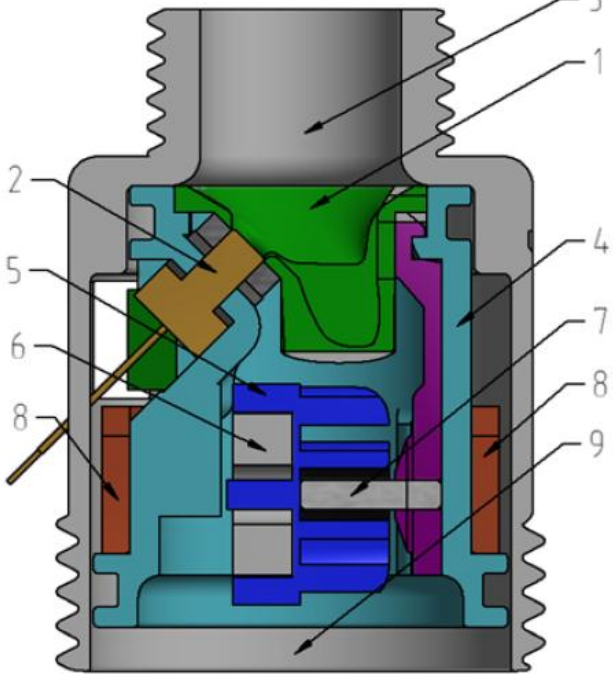

Water inlet

Turbine nozzle

Thermistor

Micro-generator tube

Turbine wheel

Generator wheel axle

Generator magnet

Generator coil

Water outlet

Amphiro a1 harvests its energy from the water flow. Its electronic components are optimized for intermittent energy supply.

For our 2-month field trial with 700 households, the devices were reconfigured to customized operation modes.

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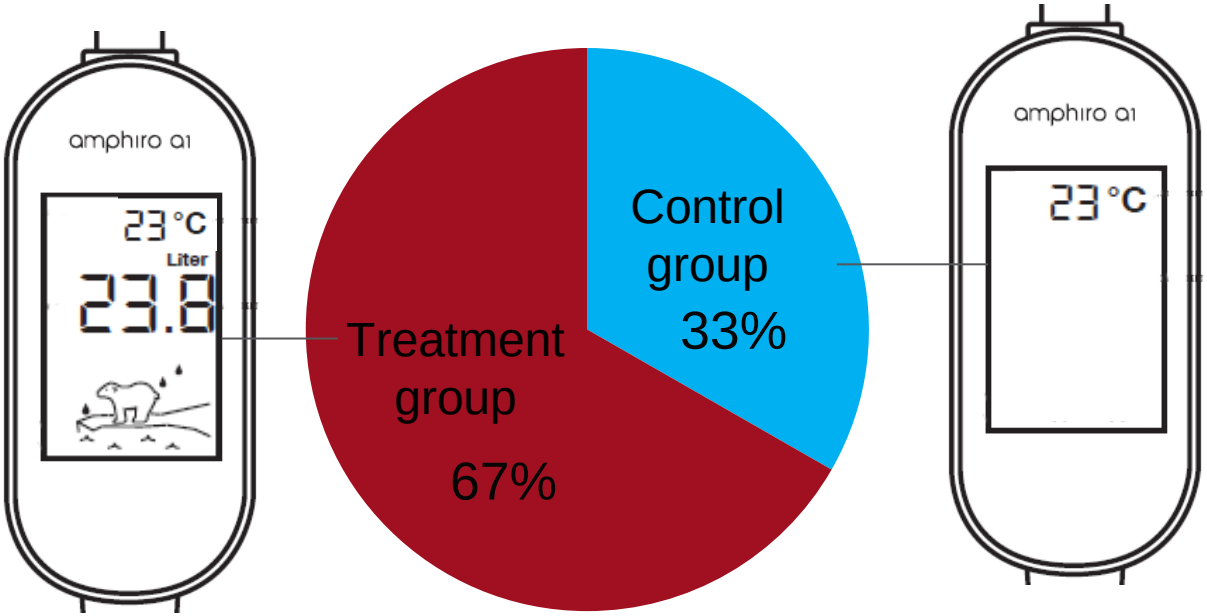
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Energie BFE

ewz Die Energie

- Generic software for all devices
- Random group assignment



For the visual data readout we built a readout terminal with a webcam.

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- 685 devices read out
- Data of 46’835 showers (T, vol, showertime, breaktime)
- Supplemented with survey data (demographics, attitude, personality)
- 629 complete datasets

The vast majority of study participants was overall satisfied with the device (83%) and intended to continue using it (79%).

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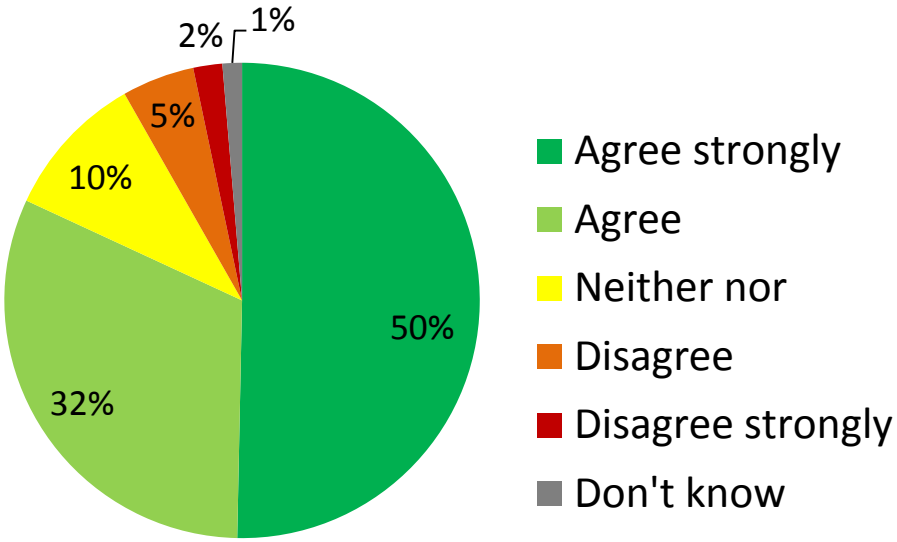
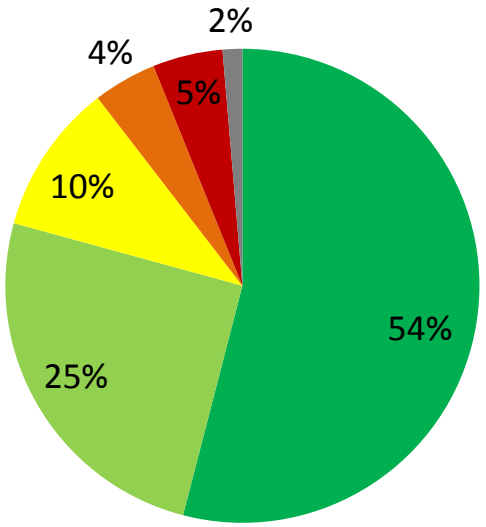
"I'm overall satisfied with the shower meter."



N=445 (Participants of final survey excl. control group)

"I / We intend to continue using the device after the study."



N=665 (Participants of final survey incl. control group)

The smart shower meter reduces shower consumption by 23% – a much higher impact than electricity smart meters typically have.

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- **2-month study with 700 households**
  - 23% (!) reduction
  - The impact exceeds electricity smart meters by far:

Reduction	Electricity smart meters	Smart shower meter
Energy – relative consumption change	3.2% of household electricity	23% of shower energy
Energy – absolute change	86 kWh	443 kWh
Water reduction per yr	/	8500 liters
Cost savings per year	22 €	106 €

Our study also covers demographic and contextual factors shaping the impact of the feedback intervention.

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- **Young people (20-29) use 227% as much energy and water as elder people**
  - Higher shower frequency
  - Consumption per shower +72%
- **Younger people respond more strongly to the feedback intervention**
- **Environmental attitudes don't have a significant impact on the response to the intervention**

Key contributions of our paper

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- **Work extends domain scope beyond electricity**
- **Design of an energy-autarkic,micro-mechatronic device that offers in-situ consumption feedback on hot water usage**
- **Easy-to-deploy, low-price, and mass-market-compatible application**
- **Accompanying large-scale field study: insights can be applied to many other feedback technologies**
  - Direct feedback at the point of consumption as key
  - Insights into contextual factors shaping response to feedback

Key points, outlook and thank you for listening

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- Developed device for consumption feedback on hot water usage
- Energy-autarkic and easy to install
- Deployed in >10.000 Swiss households
- Field study shows high impact: 23% reduction
- Long-term study ongoing (1 year)

Thank you very much for your attention.

Contact
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BACKUP SLIDES

As the device harvests its energy from the water flow, its electronic components are optimized for intermittent energy supply.

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- **Low-power micro-controller**
- **Low power LC display**
- **1024-byte EEPROM (up to 507 showers)**
- **Voltage preconditioning for stable 3.3V operating voltage**
  - Full-wave bridge rectifier
  - Buffer capacitor (330µF)
  - Low voltage dropout regulator

Some more details on the readout process

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- **Micro-generator coil put in close proximity of 2nd coil**
- **→ Air-core electrical transformer**
  - Trigger readout (amplifier, 1.6 kHz excitation signal)
  - Power the smart meter during readout
- **Screen displays encoded data (6Hz → data transfer rate of 3 bytes/s)**
- **Camera: 30 frames/s**
- **Self-written software to locate device, decode and validate the shower data, data stored as .csv-file**

The data readout process also included several other tasks:

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- Visual data read-out
- Data sanity and consistency check
- Linking with survey ID
- Functionality check
- Device-wanted check
- Resetting the memory
- Parts-completeness check
- Repackaging for reshipping