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

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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.

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


Source: DoE Buildings Energy Data Book 2011
Promising results of a pilot study motivated further R&D to move from prototype to mass production.

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.
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.

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.

- Generic software for all devices
- Random group assignment

<table>
<thead>
<tr>
<th>Treatment group</th>
<th>Control group</th>
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<tr>
<td>33%</td>
<td>67%</td>
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For the visual data readout we built a readout terminal with a webcam.

- 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%).

"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.

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

<table>
<thead>
<tr>
<th>Reduction</th>
<th>Electricity smart meters</th>
<th>Smart shower meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy – relative consumption change</td>
<td>3.2% of household electricity</td>
<td>23% of shower energy</td>
</tr>
<tr>
<td>Energy – absolute change</td>
<td>86 kWh</td>
<td>443 kWh</td>
</tr>
<tr>
<td>Water reduction per yr</td>
<td>/</td>
<td>8500 liters</td>
</tr>
<tr>
<td>Cost savings per year</td>
<td>22 €</td>
<td>106 €</td>
</tr>
</tbody>
</table>
Our study also covers demographic and contextual factors shaping the impact of the feedback intervention.

- 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

- 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

- 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.

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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.

- 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

- 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:

- 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