WHEN DEVICES BECOME ‹ENERGY-AWARE›

Each car has a speedometer. Similarly, every electrical appliance could display its real-time power consumption. This basic idea is behind a current research project of the iHomeLab at the Lucerne University of Applied Sciences and Arts. Scientists have investigated various technical solutions for consumption displays in real time - and evaluated potential applications. ‘Energy-aware’ appliances could therefore help to increase self-sufficiency in neighborhoods with decentralized electricity production and aid the provision of balancing energy from household appliances.

The user of a tumble dryer with energy awareness can set the time on the appliance by which the laundry must be ready at the latest. Within the defined time span, the operating time of the tumble dryer can then be freely selected according to the requirements of the microgrid or the balancing energy provider. Photo: HSLU

A technical report about the results of a research project in the field of electricity, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine ET Elektrotechnik (issue December 2018).

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Federal Office of Energy SFOE

Andreas Rumsch (right) is head of the Smart Energy Management research group at the iHomeLab at the Lucerne University of Applied Sciences and Arts - Technology & Architecture. Rumsch spearheaded the project on Energy-Aware devices together with Edith Birrer and Martin Friedli, both senior scientists of the iHomeLab. The photo shows the project team with exhibits of the iHomeLab in Horw near Lucerne. Photo: B. Vogel

For some time now, scientists have been investigating the extent to which people save energy when they are aware of their energy consumption thanks to real-time feedback. One possible starting point is technical solutions that give residents a clear picture of the electricity meter's consumption data. Some years ago, researchers at the iHomeLab at the Lucerne University of Applied Sciences and Arts (HSLU) developed an analysis software (NIALM) that is able to determine from the total electricity consumption (load curve of a household) which electrical appliances in the household are currently switched on and how much electricity they consume (cf. the SFOE technical article 'A Measurement System that Recognizes (almost) all Electrical Appliances,' available at: www.bfe.admin.ch/CT/strom).

Today, NIALM technology is used in commercial products such as Smappee. Andreas Rumsch, an electrical engineer trained at ETH Zurich who is now researching building intelligence at the iHomeLab, is ambivalent about the available solutions: "NIALM basically works well, but the analysis procedure does not always work satisfactorily." On the one hand, connected electrical appliances are not always reliably detected and the heating rod of a boiler, for example, is incorrectly designated as a microwave oven. In addition, the consumption is not always determined with the desired accuracy of 10%. With devices with variable consumption – a drilling machine operated with different numbers of revolutions for instance – the analysis tools are sometimes overtaxed.

Measuring Consumption Directly at the Electrical Appliance

Against this background, a research team led by Andreas Rumsch has set about examining alternative methods for recording real-time consumption. In their latest research project, they are drawing on an obvious idea: to not derive the consumption of electrical appliances from the total load curve, but to determine it directly for each individual appliance. This can be achieved, for example, by equipping an LED lamp or a kettle with a measuring chip that determines consumption. Such measuring chips are available on the market today for just a few Francs. In many cases, the installation of a measuring chip is not necessary: more complex electrical appliances such as dishwashers or washing machines are now equipped with microprocessors. As a rule, these microprocessors are able to determine the consumption of an appliance with little additional effort. Thus, the electronic control of a dishwasher 'knows' at all times whether the appliance is currently being heated, pumped, washed or dried and can show the current energy consumption at any time by referring to the manufacturer's consumption data.

Be it by measuring chips or by targeted reading of the control electronics, electrical devices can be put into the state of 'knowing' their current consumption. In some cases, they can also 'know' their future consumption in the next minutes, hours or even days. In this context, experts speak of "energy awareness" and call correspondingly equipped de-

vices "energy-aware devices". Ideally, these 'energy-conscious' devices are also able to transmit current consumption information to residents, power stations or other recipients via a suitable communication channel (e.g. the Internet). The necessary interfaces are already present in television sets, for example, and more and more electrical appliances are being standardly equipped with them.

Hardly an Additional Benefit when Saving Energy in the Household

"Networked devices are becoming more widespread, which is why we have investigated the application potential of energy aware technology in our study," says Rumsch, referring to the objective of the latest work. The scientists have investigated three possible applications: energy saving, microgrids and balancing power. As anticipated, the scientists arrived at a skeptical assessment of energy savings. The researchers involved say that it is true that real-time feedback generally enables savings of up to 8% and that they put the savings potential of the three categories of household appliances investigated (TV, lamps, white goods including boilers) at 6%.

However, the scientists do not believe that this potential will be better exploited with energy-aware devices, as Andreas Rumsch explains: "When I want to watch TV, I do so independently without considering consumption feedback. The benefits of energy aware appliances are very limited for white goods, because other criteria such as the length of time dishes are lying around or the designated washing day play a more important role than energy consumption." The energy-conscious user is more likely to look for an energy-efficient device when purchasing.

Microgrids

Costs	Communication unit	$	$	$
	Measurement hardware	0	0	0
	Compared to device cost	Ok	Ok	Ok
Benefits	Potential of shiftable energy	40%	10%	3%
	Time-Period of shifting	day	hour	hour
	User acceptance	Yes	?	No
	Benefit of energy awareness	good	med	0

Within microgrids, 'energy-aware' boilers, but also white goods such as dishwashers and washing machines, can be used by means of load shifting to increase their consumption of locally produced electricity. With refrigerators, on the other hand, energy awareness is of little use, as users fear that the quality of their food will be impaired if their refrigerators are not cooled as usual. Table: HSLU

Energy saving

Costs	Communication unit	0	$	$
	Measurement hardware	$	$..0	0
	Compared to device cost	Ok	High	Ok
Benefits	Potential of savings per year	1%	1%	4%
	Will I change behaviour?	No	yes	?
	Benefit of energy awareness	0	low	low

For electrical appliances to become ‹energy-aware›, they need measuring hardware (measuring chip, readout electronics) and a communication unit that transmits the measurement data e.g. via the Internet. In the field of energy savings, iHomeLab researchers believe that ‹energy-aware› devices have no (television) or at least only a small (lamps, white goods) additional benefit. Nevertheless, it remains to be seen: if the savings potential were fully exploited on the basis of real-time feedback, around 6% of household electricity could be saved across the three appliance categories (TV, lamps, white goods). Table: HSLU

Application in Microgrids and Grid Stabilization

iHomeLab researchers see a potential field of application for

Balancing Power

Costs	Communication unit	$	$	$
	Measurement hardware	0	0	0
	Compared to device cost	Ok	Ok	Ok
Benefits	Avg. potential control power [MW]	210	27	75
	Time-Period of shifting	day	< day	hour
	User Acceptance	Yes	?	No
	Benefit of energy awareness	good	med	0

According to the Lucerne scientists, electric boilers and charging stations of e-mobiles could be used to provide balancing power thanks to energy awareness. The contribution of e-mobiles is currently still small, but is expected to increase sharply in the future. Refrigerators, on the other hand, are not suitable because users would not accept deviations in cooling performance. Table: HSLU

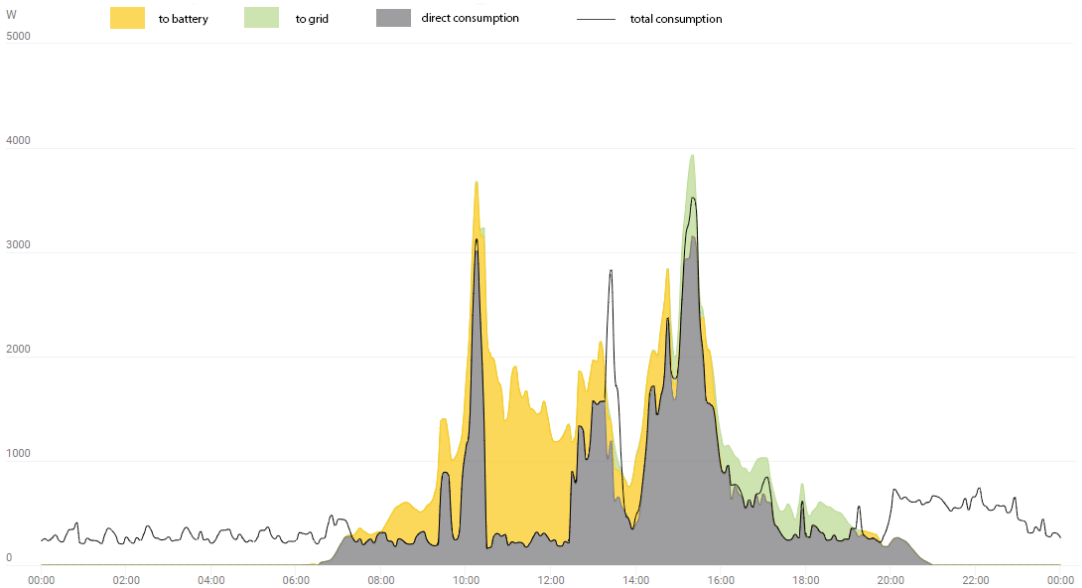
energy-aware devices in residential and commercial districts that have decentralized power production and storage facilities ('microgrids'). Here these devices can provide the data basis for an energy management system that strives for a high degree of self-sufficiency. Thanks to the consumption data, electrical appliances are operated at times when decentralized electricity is produced (e.g. photovoltaic electricity) whenever possible. Suitable for this are boilers or white goods such as dishwashers and washing machines, all of which operate over a specified amount of time. "Energy-aware devices offer an advantage over NIALM technologies because they also provide data on future energy consumption," says Rumsch. According to Rumsch's estimate, around half of household electricity could be to optimized for its own use.

The Lucerne scientists have identified a second area of application in the allocation of balancing power from household appliances. The Swisscom subsidiary tiko, for example, already generates balancing power - i.e. electricity to stabilize the electricity grid - today by accordingly controlling the operating time of heat pumps, for example. In the opinion of the iHomeLab researchers, boilers, dishwashers, washing machines, tumble dryers and charging stations in electric vehicles could also be increasingly used in the future to provide balancing power by exploiting their load-shifting potential (in principle as shown above for microgrids). "A balancing power system based on energy aware devices has the advantage of knowing the future energy consumption of individual consumers," emphasizes Andreas Rumsch.

INTERNATIONAL EXCHANGE OF EXPERTS

From 2014 to 2016, scientists from the Lucerne University of Applied Sciences and Arts - Engineering & Architecture had investigated the energy efficiency of the Internet of Things (IoT) (cf. the SFOE technical article 'Networking also Works with Low Power,' available at: www.bfe.admin.ch/CT/strom). As a follow-up project, the researchers carried out the study on the potential of energy-aware devices described in the main text. Both studies were conducted as part of the international Technology Collaboration Program 'Energy Efficient End-Use Equipment' (TCP 4E for short) of the International Energy Agency (IEA). This is one of 39 programs in which an international group of experts exchanges views on a specific energy topic and initiates research projects.

In the 4E program, experts from 12 countries, including Switzerland, exchange information and experience and develop proposals for the efficient use of energy. The 4E program has three sub-programs (Annexes). One of these is the Electronic Devices and Network Annex (EDNA), in the context of which the two studies mentioned above were developed. The study results are discussed in the Executive Committee of the 4E program. They serve the political authorities in Switzerland and the other countries involved as a stimulus for regulatory or other steps that will have an impact on implementation. BV



The aim in a microgrid is to control consumption in such a way that it corresponds as closely as possible to the energy produced (grey areas). If more energy is produced, it can be stored in a battery (yellow areas). Local storage then makes it possible to supply consumption peaks from the battery (white area). When the battery is full and no more consumption can be added, the excess energy must be fed into the grid (green areas). Photo: HSLU

Developing Control Systems

Rumsch and his research team are encouraged by the results of the current study to continue research into the further development of energy aware technologies. For each application, the next step is to develop control algorithms and communication protocols. Real time controls are also important, such as those that incorporate weather data, for example. In the short term, iHomeLab researcher Rumsch suspects that the potential of energy awareness devices can best be realized in microgrids: "When a building owner sets up a superstructure with rental apartments, he can determine which electrical devices he will install and thus lay the foundation for an energy management system that works particularly efficiently thanks to energy awareness."

- The **final report** on the project can be found at: https://www.aramis.admin.ch/Texte/?ProjectID=40188
- **Information** on the project can be obtained from Roland Brüniger, Head of the SFOE Electricity Technologies Research Program: roland.brueniger[at]brueniger.swiss
- Additional **technical articles** on research, pilot, demonstration and flaghsip projects in the field of electricity can be found at www.bfe.admin.ch/CT/strom.

Author: Dr. Benedikt Vogel, on behalf of the Swiss Federal Office of Energy (SFOE)
Version: January 2019