TECHNICAL STUDY REPORT ON MEASURING, REMOTE MONITORING AND REMOTE CONTROLLING FOR SOLAR THERMAL SYSTEMS

UNDP

gef

Cu

ESTIF

European Solar Thermal Industry Federation

ACKNOWLEDGEMENTS

SUMMARY

The market, media and policy arena often neglect solar thermal, because solar thermal energy is seldom accounted for and the amount of solar thermal heat supplied is neither measured nor displayed in a transparent way. This also results in problems/breakdowns not being spotted quickly. This "Technical study report on measuring, remote monitoring and remote controlling for solar thermal systems" aims at contributing to making measuring, monitoring, and remote controlling more mainstream for smaller systems. It also intends to make use of some information from larger systems, where measuring, remote monitoring, and remote controlling are already common. This report shall contribute to make solar thermal stakeholders better aware of the potential to be exploited in terms of measuring, remote monitoring, and remote controlling and its potential to improve solar thermal systems and its application, making it easier to compare and to reduce failures. Parts of the study will generally apply to water and space heating systems, not only those including solar thermal.

This technical study provides an overview on the status on ways of measuring, monitoring and controlling solar thermal in smaller systems, with a clear focus on current methods. It will look into the state-of-the-art for solar thermal, including some components such as sensors, controllers and connectivity. The report will also address the Smart Home and Internet-of-Things as an opportunity for solar thermal water & space heating, the (solar) heating system as part of the Smart Home and additional parameters as input to (solar) heating system.
Finally, it will look into possible service offerings based on the remote monitoring, controlling of (solar) heating systems.

This "Technical study report on measuring, remote monitoring and remote controlling for solar thermal systems" was developed as part of the Global Solar Water Heating (GSWH) Market Transformation and Strengthening Initiative (GSWH Project), and as a result of a joint effort between The European Solar Thermal Industry Federation (ESTIF) and the United Nations Environment Programme (UNEP) through its Division of Technology, Industry and Economics (DTIE) and the Global Environment Fund (GEF).

Funded by the Global Environment Fund (GEF), the GSWH project's main goal is to accelerate the global commercialization and sustainable market transformation of SWH, thereby reducing the current use of electricity and fossil fuels for hot water preparation. It will build on the encouraging market development rates already achieved in some GEF programme countries and seek to further expand the market in others where the potential and necessary prerequisites for market uptake seem to exist.

The GSWH project consists of two components as follows:

• Component 1 - Global Knowledge Management (KM) and Networking: Effective initiation and co-ordination of the country specific support needs and improved access of national experts to state of the art information, technical backstopping, training and international experiences and lessons learned.

• Component 2 - UNDP Country Programmes: Work in the country programmes revolves around addressing the most common barriers to the development of solar water heating: policy and regulations, finance, business skills, information, and technology.

ESTIF, as one of the project's regional partners, is committed to the development of knowledge products and services. And to this end, ESTIF has been entrusted with the task of elaborating this This "Technical study report on measuring, remote monitoring and remote controlling for solar thermal systems"

Note: Mention of the names of firms and commercial products does not imply the endorsement of the United Nations and ESTIF, but just to show different examples of solutions and approaches that are available currently in the market.

CONTENTS

INTRODUCTION / BACKGROUND

Continuous metering and monitoring of solar thermal systems have proven to be a sensible option, already commonly used for large systems. They provide several benefits with regard to the installation, operation, maintenance and use of solar thermal systems. For instance, they ensure that failures or underperformances are spotted early on, thus helping to maximize solar yields.

For years, larger solar thermal systems have been rigorously measured and often connected for remote monitoring and controlling. The rationale is that a failure or under performance of the system can quickly result in high costs – because heat, which could have been supplied by the solar thermal system, must then be generated by electricity, fossil fuels or biomass, all of which are not usually provided free of charge. Moreover, the early identification of a problem may help avoid further problems and associated costs (e.g. in the case of water leakage). In larger systems, the additional costs of the metering/monitoring equipment, network connection and, possibly, service charges are usually small in comparison with the potential costs of problems not detected early.

With smaller systems, this is different: The additional costs of complex (remote) metering and monitoring are proportionally very high. Furthermore, as in smaller systems savings in absolute terms are also smaller, this makes the additional costs of metering and monitoring almost prohibitive. In Germany, a guideline from the Association of German Engineers (VDI 2167) recommends that the additional costs of metering should not be higher than half the expected annual savings. For smaller solar thermal systems this can be a very small amount. Another way of looking at the issue is to compare the additional costs with the overall initial investment: A small thermosiphon solar hot water system in Mediterranean countries like Greece, Turkey or Israel costs less than 1000 EUR. An additional 100 EUR for metering would increase the investment costs by more than 10%.

Today, most small solar hot water systems (especially those of the thermosiphon type) are not metered at all and no information on the actual yield or even the correct performance of the system while in operation exists.

Furthermore, most of the smaller systems are not connected to a communications network (internet, smart meter, mobile / fixed-line telephony) and thus information is available only on-site and not to manufacturers, planners, installers or other service providers.

This study looks at the state-of-the-art in (remote) metering, monitoring and controlling of small solar thermal systems. It analyses how the universal availability of the internet, especially the promises of smart homes (also known as home automation) and the Internet-of-Things (IoT), offers new opportunities for solar thermal and heating supply in general. And it delves into how these changes could leverage new service offerings such as contracting and ESCOs.

STATE-OF-THE-ART *(metering and remote monitoring, remote controlling of small(er) solar thermal systems)*

Large(r) solar thermal systems typical remote monitoring/metering

If and how solar thermal energy is measured and a solar thermal system is controlled depend largely on its size: Large systems such as the many solar district heating systems in Denmark, which often have capacities of several Megawatt (several thousand square meters of collector area), are very strictly measured and controlled. Because the kilowatt-hours of heat are sold and would otherwise have to come from e.g. burning fossil fuels, the owners or operators have a high interest in knowing that everything works as expected. Even much smaller systems, e.g. 100 m^2 of collector area on a residential building block, are usually remote controlled and metered.

Metering, monitoring, controlling small solar thermal systems

For the purpose of this study, small solar thermal systems will mean: Systems providing hot water, possibly also supporting space heating, for private houses/dwellings for 1 or 2 families. Depending on the application and climatic conditions, such systems usually have a collector area between 3 and 20 m^2.

Small thermosiphon systems

Among these there is the small thermosiphon system, in which one or a few collectors are closely connected to a tank and the whole system is usually placed on the roof of a house. Thermosiphon systems work without pumps and in general without any controller. Instead, they use natural circulation with cold water entering at the bottom of the collector, heating up and the warmer water rising to the top of the collector, and then at the upper part of the tank. From the bottom of the tank, colder water flows back to the bottom of the collector(s) – just through the forces of gravity. Where electricity or gas is available, these systems are typically used in conjunction with a backup heater, which is often integrated into the tank (immersed electrical resistant heater), but can also be e.g. an instantaneous water heater placed inside the building.

As the tank is usually placed outside the building envelope, this type of solar thermal system is used primarily in warmer regions, where frost is rather uncommon. Where needed, frost protection is achieved with the electrical backup heater in the tank.

Because of its simple principle – without the need for sensors, controllers or pumps – and because they are normally used in rather sunny regions and thus do not need to be very efficient, small thermosiphon systems can be very cheap. In the world's largest market, China, systems are available for less than 100 EUR; even in Mediterranean countries; the cost of a newly installed thermosiphon system often does not exceed 1000 EUR.

The only controllers sometimes used with thermosiphon systems, do not control the solar thermal part but the backup heater. These controllers can be simple timers (e.g. switched on for the night or morning) and/or temperature controllers, with a sensor in the tank. In any case, they do not measure solar thermal energy.

Small forced circulation systems

Pumped systems (also called forced circulation systems) can be used anywhere and are the predominant system used in colder climates, e.g. in Central or Northern Europe. There, the tank is generally placed further away from the collector field and the circulation in the collector loop is achieved by powering an electrical pump. That pump is controlled by a solar thermal controller, which is normally connected to at least two temperature sensors, one in the storage tank and one at the collector field outlet. If the tank is not yet fully loaded (maximum intended temperature reached) and if the temperature at the collector outlet is higher than in the tank, the pump is activated to transfer heat from the collector to the storage tank.

Figure 1 Examples of solar thermal controllers[1]

Energy metering and remote monitoring/controlling

Solar thermal heat can be measured with a dedicated heat meter, but many controllers can also measure solar thermal energy production. To this end, temperature sensors measure the flow and return flow temperature and the volume of the heat transfer fluid flowing in the collector loop. The energy is calculated from these measurements.

For many years, mechanical flow meters (i.e. an impeller or turbine in the fluid stream) were the only option. Later, vortex sensors entered the market, which gave accurate measurements without movable parts. Both continue to be deployed in today's solar thermal systems.

Today, typical costs for flow meters are in the region of 20-40 EUR (wholesale price, with larger solar thermal manufacturers paying even less) and temperature sensors cost 10-15 EUR.

In a new system, in which the controller can already be connected to additional sensors, the additional costs for heat metering can be quite low (ca. 80-100 EUR for the end-consumer: for

---

[1] Photos: Copyright RESOL - Elektronische Regelungen GmbH, left DeltaSol ES, right DeltaSol SL

one or two additional temperature sensors and one flow meter, plus some additional installation work). However, if retrofitted in a system which was not designed for heat metering, it remains expensive (ca. 300- 500 EUR, plus installation costs).

Considering the total end-consumer costs of a small forced circulation solar domestic hot water system (ca. 3500-5000 EUR, incl. VAT and installation), an extra 300-400 EUR would appear unacceptably high (>10% of the system costs). But for only an additional investment of 100 EUR, the benefits of measurement could outweigh the additional costs. This calculation would be even more favourable if slightly larger systems (e.g. combi-systems which also cover part of the space heating demand) were considered. There, the additional costs from metering could be less than 1% of the total initial investment costs and the benefits from better data would be even higher.

Another interesting approach would be to compare the additional costs of measurement with the expected cost savings from e.g. a problem spotted earlier than otherwise. For example, if the pump in the solar circuit failed and this problem was not detected for three months, the system operator would incur higher costs for conventional energy. Better measurement/monitoring could have prevented those costs. However, because these costs depend largely on the climate, the solar thermal system considered, the type of conventional energy used as back-up and its local price, it is impossible to quantify them. Such cost-benefit calculations would have to be carried out for specific use cases at specific locations.

Even where flow meters are not deployed, many controllers offer some kind of control function, allowing a user to see if the system operates correctly or receive an alert if not: e.g. if the pump fails, the controller would indicate that the temperature in the collector is increasing but not so in the tank.

While the vast majority of solar thermal controllers use only current sensor values for its control algorithms, some offer also the possibility of storing past data – and even to use them where other data are missing. For example, in a situation where the temperature sensor at the collector fails, the controller can take the data from the preceding days and estimate the operation for the current day. The controller would then assume that the temperature at the collector outlet was similar as in the previous days and operate the pump accordingly – that is when the storage tank is not fully loaded and the temperature at the collector exceeds the temperature in the tank.

Solar thermal controller can often be extended with additional modules to add functionalities. Typical modules include data loggers (to store and retrieve past operation data) and network interfaces (wired or wireless). However, as this is not yet a standard option, the (end-consumer) costs are often around 300-400 EUR. Some manufacturers offer the option to connect the solar thermal controller to an online portal, making the data (and possibly analyses) available via the WWW or a mobile app.

The advantages of (remote) monitoring and remote controlling solar thermal

- ### *Detecting failures early*
  As mentioned, most solar thermal systems are equipped with a (conventional) backup-heater. This is necessary to have sufficient warm water or space heating even at (extended) times of low or no sunshine. However, as long as hot water or space heating are available, the user cannot know whether or not the solar thermal system is working properly, e.g. the pump in the collector loop may have failed but because the backup heater provides the required heat, the consumer is not aware of the problem. This is a very real drawback, and failures are often detected only after weeks or months (e.g. when the annual energy bill shows a higher than usual electricity consumption).

  A controller, which at least provides a basic control function, can help overcome this problem. However, often the solar thermal controller is tucked away in a heating cellar or storage room and a flashing red light will not be noticed by the consumer. This is where more advanced solutions, such as remote monitoring of the system offer big advantages. Failures can be detected early and the system repaired. This benefits the environment and reduces cost for the system owner or user.

- ### *Detecting underperformances*
  While a complete failure is relatively easy to detect, it is much more difficult to identify situations in which a solar thermal system is not fully functioning. This situation can happen from the time of installation/commissioning (e.g. due to planning or installation mistakes) or it can happen during the system operation (e.g. degradation of the heat transfer fluid, lime stone on heat exchangers etc.). The challenge is to have reference values to compare the measured data against. If the planning was already faulty, reference values may also be wrong and underperformances remain hidden. It is easier to compare against earlier values – e.g. the solar yield in one year compared with the previous ones (of course, factors other than real problems may have an impact, such as less solar irradiation or different consumption patterns).

- ### *Optimizing solar thermal yields by adding external data to the control algorithm*
  As will be shown below (section *Increasing the usable solar thermal energy*, p.20), solar thermal yields could be increased by adding external data to the control algorithms, e.g. weather data, expected occupancy times of the house, the living schedule and temperature preferences of the occupants.

SOLAR THERMAL IN THE SMART HOME AND INTERNET-OF-THINGS (IOT)

The rapid development and adoption of new ITC technologies have reached building technology and even (small) heating systems. More and more products are connected to a "Smart Home" network and/or the internet. This is also known as "home automation" and is often seen as part of the" Internet-of-Things" or short "IoT", in which devices communicate with each other allowing functionality, which would have been impossible without this connection.

When remote heating systems monitoring used to mean an additional fixed-line telephone connection or a module (and consequent subscription) to connect to mobile telephony networks, today wireless networks are available in almost every household. And connecting another product to them and thus to the internet comes at no or little additional costs.

Understanding the "Smart Home" hype

The notion of "home automation" or the "smart home" is already several decades old. Over the years there have been several waves of new developments and products, but only recently has this notion really gained traction. This market sector is expected it to increase dramatically over the coming years[2]. This is due to three things having become widespread and available at low costs:

- Wireless connections (Wi-Fi, Bluetooth) have largely done away with the need to install additional network cables in buildings
- Mobile devices (smart phones, tablet computers) are increasingly becoming the de-facto remote control for many very different devices and services.
- Internet connection: The number of households with access to the internet in most industrialised countries has risen to 60-95% (average in the EU in 2014 was >78%[3], in the US in 2013 74%[4])

In order to understand the opportunities and challenges for solar thermal in a smart home environment, one has to look not only at heating and cooling but at the whole smart home ecosystems, its drivers and the interests behind them.

---

[2] In a recent report market research company MarketsandMarkets concluded: "The global smart homes market was valued at $20.38 billion in 2014 and is expected to reach $58.68 billion by 2020;" see http://www.marketsandmarkets.com/PressReleases/global-smart-homes-market.asp
[3] Source:
http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=tin00073&language=en
[4] Source: http://www.census.gov/content/dam/Census/library/publications/2014/acs/acs-28.pdf

Drivers for the "Smart Home"

In North America, the largest market for "Smart Home" products, the drivers are very clear[5]:

- energy,
- security and
- comfort/convenience

In other markets the order may be different but the topics are similar.

"Security" involves surveillance cameras, motion detectors, and door locks. In this category, one could also add other safety devices such as smoke/fire alarms, baby monitoring, and water leak detection. Many of these offerings have already been available in the past, but the "news" is that they are now networked and often available as part of a larger smart home platform, which can be monitored/controlled via a smart phone or tablet. The benefits are rather obvious: The house can be easily monitored (and possibly) controlled from your desktop or smart phone, devices can speak to each other – e.g. the smoke detector on the second floor can set off the alarm also on the first floor and send an SMS to the owner or neighbour. The baby monitor can interrupt the (streaming) TV and show the live video from the child's bed room. The humidity sensor in the basement could start a ventilator and/or inform the owner of a problem.

"Comfort" or "convenience" can be anything which promises to make one's life easier: From opening the garage door, shutting the blinds on the windows, switching or adjusting the lights, to controlling the media centre (TV, radio, music etc.). Controls can be triggered via a smart phone or through some kind of "events", e.g. the lights flashing when the doorbell rings, or lights switched on when a room is occupied. Through web services such as "If This Then That (ITTT)", one can even trigger events in the house, depending on arbitrary events somewhere else – you could have your lights flash green when your favourite team scores and red for the opposing team; or alarms when certain stock prices reach a threshold. In the kitchen, the hob or oven can be controlled by both, the (digital) cooking recipe and sensors in the cooking pot.

"Energy" is currently the biggest driver, and it encompasses energy and cost savings as well as improved comfort. Most of the "home energy management" development is aimed at reducing or time-shifting electricity demand. And, it goes hand in hand with – partly mandated – activities of US utilities to increase energy efficiency, or to influence electricity consumption as a means of Demand Response (DR). Because many of the concepts are applicable or are adaptable also to thermal energy usage, more details and some examples are given below. The thermal aspect has received much attention with the advent of the "learning thermostat" of US company NEST, which was founded by several Ex-Apple employees and acquired in 2014 for 3.2 billion USD by Google[6].

Barriers for the "Smart Home"

The biggest barrier to-date is the lack of interoperability. While there exists a vast number of smart home devices and services, most of them are insular and unable to "talk to each other".

---

[5] Source e.g. https://www.greentechmedia.com/articles/read/smart-thermostat-is-the-most-wanted-connected-home-device
[6] Source: https://investor.google.com/releases/2014/0113.html

Several different (wireless) communication standards (Wi-Fi, Bluetooth LE, ZigBee, Zwave and others) as well as a lack of common control protocols make it difficult for the consumer to build a really smart home, in which devices intelligently interact and which can be controlled through a common interface (e.g. a single app on the smart phone or tablet computer). The situation is not unlike the early internet, when companies like Compuserve or AOL had closed messaging services for their subscribers, which were not able to communicate with subscribers of other services.

Several competing hub solutions exist – either free (open source) or proprietary – which try to connect different devices from different manufacturers and to "translate" between them. However, so far none of them has gained enough traction in the market to be seen as "the" smart home platform of the future. The industry is still waiting for the emergence of a common and open standard, just like e-mail increasingly replaced individual messaging solutions from various internet companies. Until then, many consumers will remain reluctant to make large investments in long-term solutions (e.g. door locks, light switches, radiator thermostats) for fear that the technology could still change and their new devices become obsolete in just a few years (e.g. because the apps which control them might not be available anymore).

It is generally believed that the network effect of connected devices will result in a gravitation toward one platform (or a very small number of platforms): The more devices are available for one platform, the more relevant it will become and the more consumers will chose that platform and buy even more devices, which in turn will lead device makers and service providers to target that platform even more.

Interests and Players in Home Energy Management (HEM)

- #### *Energy utilities and grid operators*
  Energy utilities naturally have a high stake in this market and its development, but generally their area of interest was mostly on the generation, transmission and distribution side – just up to the meter. With the roll-out of smart meters in many countries, they gained better insights into real-time energy consumption of individual households and companies. Nevertheless, they had little insight into what was happening behind the meter, which applications were used when, how much and how consumers could possibly reduce (or shift) their consumption to reduce costs and/or overall energy usage. This is slowly changing –partly because many utility regulators require them to work on improving the energy efficiency of their customers.

- #### *Specialised Demand Response or Energy Data companies*
  In many cases the utilities co-operate with the second big group of players in the HEM market: companies measuring, analysing and disaggregating energy consumption data in order to show consumers where they spend most of their energy and generate the highest energy costs. These companies usually measure energy usage behind the meter and frequently upload user's data to online ("cloud") services, which use big data analytics to dissect them. Often, they rely also on past utility data for each customer, but increasingly they are able to analyse consumption data in (almost) real-time and make

recommendations without the need to analyse past bills. In the beginning they were able to identify only the largest electricity consumers in the household: they could detect when the washing machine was started, when the air-conditioning was switched on or off etc. Nowadays, their tools can detect even small consumptions and – with the help of the user – label them. These tools are now able to record with increasing accuracy, which device in the household was used when and for how long. Together with price information they can show how much money was spent on which (type) of activity or device, e.g. "for laundry" (washing machine, dryer, iron) or "for entertainment" (TV, stereo, game console). Some of the companies have developed their own hardware, while others are focussing on software and services, leveraging existing hardware or data sources (i.e. meter or billing data from the utility). Big names in this market are Opower and Tendril. However, many start-ups and also large tech companies like Siemens, Honeywell or Toshiba have entered the market and it remains to be seen which formula proves the most successful.

A few years ago, a wave of "energy dashboards" emerged: many companies – and investors – believed that consumers would change their usage patterns just by showing them their energy data, sometimes coupled with recommendations for improvements –. What seemed to work in the beginning soon wore off and the novelty factor, which made many home owners frequently review their energy dashboards, faded. Such dashboards are still an important part of the offering, but more and more they are only one tool in a tool box which helps home owners and even tenants reduce energy consumption. And, in many cases the real "dashboard" is still a printed report, often distributed together with the energy bill.

Apart from incentives (information, sometimes lower energy rates), there are also increasingly more solutions available allowing a utility, device manufacturer or third-party service provider to actually control building technology and appliances

> **Example: How Opower helps consumers and utilities to lower their energy usage**
>
> The company Opower was founded on the premise of behavioural science and touts itself "the largest behavioral science experiment in the world": In a 2003 experiment, university students tried to influence the energy consumption of 1207 households in a middle-class residential city north of San Diego. They went around and distributed small messages, which people found hanging at their door. They tried several different arguments to see, which one worked best (in short):
> - Save Money by Conserving Energy
> - Protect the Environment by Conserving Energy
> - Do Your Part to Conserve Energy for Future Generations
>
> But none of them showed success in the sense that energy consumption decreased. However, a fourth argument really worked:
> - Join Your Neighbors in Conserving Energy. Summer is here and most people in your community are finding ways to conserve energy at home.[...]
>
> Based on these findings, Opower provides reports to consumers, which relate their energy usage to those of similar households in the same area. With emoticons they signal how well they are doing and give actionable advice on how to reduce the household's energy consumption.

remotely to reduce or time-shift energy consumption. So far, this is used almost

exclusively for large(r) buildings; however, the trend toward more and more connected devices in the building will almost certainly result in this becoming a market also for small(er) buildings and possibly even individual flats.

A related approach aims at automatically communicating energy price signals to the systems of the users, so that they can be programmed to respond accordingly. In order to facilitate the interoperability of products and services from different companies, a broad alliance of companies have agreed to cooperate within the OpenADR Alliance. Their goal is to provide "a non-proprietary, open standardized DR [Demand Response] interface that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the Internet"[7]. Members of the OpenADR Alliance include inter alia energy utilities, (building) technology manufacturers and service providers.

- *Consumer tech, internet and telecommunications companies in the Home Energy Market*

  In the late 2000s, recording, reporting and sometimes analysing home energy consumption became an interesting topic for tech giants such as Google and Microsoft. Google's "PowerMeter"[8] allowed consumers to link their energy meter to the internet and watch their consumption at anytime from anywhere via the internet. Microsoft started to offer its "Hohm" energy management tool, which was set to become a whole platform for home energy management. Microsoft had even teamed up with the renowned Lawrence Berkeley National Laboratory and licensed their Home Energy Saver energy stimulation programme to provide solid recommendations based partly on the location of the consumer. Both, PowerMeter and Hohm were launched in 2009 and for both of them the end was announced in mid-2011, due to low consumer numbers. The reasons for the failure are manifold, the most important one being that they may have been "too early" in the market. Apple's iPhone, which revolutionized the mobile device market, only came out in 2007 and in 2009 the use of smart phone was far from widespread. The whole wave of "smart home" devices and services took off only when smart phone usage skyrocketed and seemingly everyone had a "remote control" in his or her pocket.

  In 2011, Google announced "Android@Home", which was to be a hub for everything home automation, based on Googles Android operating system. The company even wanted to launch a new low-power wireless protocol for this service. However, to-date this has not happened and the Company does no longer mention Android@Home. Nevertheless, Google re-entered the smart home market in 2014 with the acquisition of NEST, a company which offered a smart thermostat with high appeal to consumers with a liking for beautifully designed and simple to use products. NEST has since also launched a smart smoke detector, a surveillance camera and a programme for other products to

---

[7] *Source:*
http://www.openadr.org/assets/docs/understanding%20openadr%202%200%20webinar_11_10_11_sm.pdf ,
accessed 22 July 2015
[8] *Idem*

interact with the NEST platform. While the functionalities of the devices are not so different from existing offerings, they started a momentum in the market because – mostly due to their aesthetics – for the first time, consumers really wanted to have a heating controller on the wall of their living room. More on NEST and its products/services in the section Smart Heating (p.16).

Another aspiring player in the smart home market is Apple. With their mobile operating system 8th edition (released in 2014) the company introduced HomeKit, a kind of framework on which device and software developers can build their offerings. All communications would go through an Apple product working as a central hub at home: An AppleTV, or a software app on one of the company's mobile devices (e.g. iPhone, Apple Watch). Currently, it is too early to predict what role Apple can and will play in the smart home market. Given the company's large user base and its track record with introducing new – sometimes even revolutionary – products, it seems possible that Apple HomeKit will become one of the more important platforms for the smart home. HomeKit offers interesting features, such as voice control (using "Siri") and strong encryption. The latter is sometimes quoted as a major factor for the small number of HomeKit certified products so far (by July 2015, only a handful of devices received certification).

Lastly, telecommunications providers are an important player in the smart home market. Many telcos and cable companies are offering home networked solutions. Their experience in networking and their interest in offering value added services on top of their networks have made them also strong players in the market.

Smart Heating

So far, most of the focus on "energy" in the smart home was on electricity. Electricity utilities and grid operators have a strong interest in reducing expensive peak load, operators of PV plants or electrical storage devices aim at optimising their use in the grid etc.

Thermal energy usage has already been included in this, as far as electricity is the main or even only energy source: Turning down the electrical heater – including electrical heat pumps – in winter or the air conditioning in summer can significantly contribute to lowering expensive demand at peak load times. Electrically heating or cooling rooms or producing domestic hot water can be optimised to coincide with off-peak electricity prices (e.g. starting the heating or cooling two hours earlier and reducing the load, when load peaks result in higher prices in the grid). Where thermal storage exists, they can be loaded at times of overcapacities to reduce loads at high price times. Increasingly, the relevant parameters are not only signalled to the consumer, but the systems automatically adjusted accordingly.

These same incentives (price variations throughout the day) do not exist for other energy sources used for heating. Households depending on heating oil or wood pellets normally order new supplies once or twice every year. Shifting demand in between deliveries does not have any influence on the overall cost. For households this is also true for natural gas: whether they use gas at night, in the morning or sometime during the day, consumers always pay the same price.

Therefore, the incentive to integrate non-electrical heating in the smart home comes not from shifting but from the potential to reduce the overall heating consumption and/or from a new functionality increasing the comfort (e.g. easier to use, better control of temperature in the house).

Lowering overall energy consumption for heating & increasing comfort

People tend to be lazy, and for heating or cooling this can be expensive (both environmentally and monetarily): They forget to switch off the heating or air conditioning when they open the windows. Or, they do not lower heating or cooling in rooms not in use for some time (e.g. when they leave for work in the morning, or when they go to bed at night). The latter should have

Example: The NEST "learning" thermostat

The learning thermostat was the very first product offered by NEST and the one which really started the smart thermostat hype. The key feature was the "learning" mode: Every time a person changes the set temperature, the thermostat "learns" a bit more about the preferences and schedules of the household members. After about a week the thermostat "knows" when people get up, when they leave for school or work, when they return and when they go to bed – and which temperatures they would like to have during each phase.

The device even "learns" how long it takes to heat up or cool down the house – and it aims at reaching the desired temperature at the right time: If the persons in the house get up at 6am and expect a temperature of 20°C, the thermostat might increase the heating already an hour earlier.

The NEST learning thermostat also tries to detect if people are present in the house. If not it can automatically activate an "away" mode, typically setting the temperatures lower (when heating).

The currently available version of the learning thermostat can be controlled also over the internet via a smart phone app. And it lets the users review their "energy history": When was the heating on at what temperature?

Today, NEST also offers a smart fire alarm and a (surveillance) camera. When combined with the learning thermostat, the latter can automatically switch on when "away" mode is active, and switch off, when the inhabitants return.

Like other companies, NEST tries to make their offering a complete platform, which other devices can connect to. One of the many possibilities mentioned on the website: The learning thermostat signals a washing machine, that "away" mode will likely end soon. The washing machine, which has already run, starts a short "refresh" program to prevent wrinkles in the clothes – just in time for the return of the occupants of the house.

Figure 2: NEST "Learning" thermostat, another modern, albeit more classic looking thermostat from Siemens and an "old" analog thermostat by Cewal

Photos (from left to right): Copyright Nest Labs, Inc., nest.com/press/; Siemens AG, www.siemens.com/press, Uwe Trenkner

been mostly solved long ago with programmable thermostats, but studies have found that consumers do not take the time to programme them or they do not do it correctly. These are typical cases for use of modern smart home technology relating to heating/cooling: instead of manually adjusting or turning-off heating or cooling, smart home technology assists or takes over the control of the temperature levels. One of the simplest solutions is a wireless sensor, which monitors whether a window is open or closed. If the window is open, a thermostat at the radiator(s) in the room is informed and switches it off. After the window is closed, the thermostat switches on the radiator(s) again. But smart thermostats can offer much more functionalities. Smart thermostats from other vendors often offer similar features, but although they are not as prominent as the NEST product, the overall market has grown significantly. According to new market research, smart thermostats will account for over 40% of the nearly 10 million thermostats sold in the U.S. this year[9].

A key differentiating factor of various offerings is the level to which online ("cloud") services are used to deliver the service. Many smart thermostats, such as the NEST product, can operate without any access to the internet. The internet may

Example: Hans Scharler's Location Aware Home Automation

At some point in the late 2000s, Hans developed his own remote control for the home's heating systems. Via his smart phone he could start, stop and adjust the heating or cooling as he liked. But after some time he got tired of this: Switching off the heating when he left the house, switching it back one before he left his work.

So he developed a "Location Aware Home Automation" system from a mesh of different services. Via Google's Latitude service and his smart phone, he was able to constantly track his own position. Via different weather services, he tracked the current weather as well as the forecast. And via his own company's solution he was able to remotely measure his home temperature and control heating and cooling.

His system worked like this: When he (or rather his smart phone) left the house, the heating (or cooling) was automatically turned down. When he left his work place in the evening, the system would notice it, check the indoor temperature of his house, consult the weather data and switch on the heating (or cooling) accordingly.

In this example, the devices themselves were not very "intelligent", e.g. unlike the NEST learning thermostat, this solution would not "learn" the usual living schedule of Hans. But it would connect enough different data – from the sensor(s) at home, from the sensors in the smart phone, and from various internet services (weather data) – to come up with a very useful control strategy.

The same idea can nowadays be found also in commercial offerings, e.g. the tado° smart thermostat.

Figure 3: tado° smart thermostat, including smartphone app

Photo: Copyright tado° GmbH, www.tado.com/de/presse#bilder

Sources: http://nothans.tumblr.com/post/97826188358/automatic-thermostat-control-based-on-location (accessed 23 July 2015); http://origin.conversationsnetwork.org/ITC.TM-ScharlerWinters-2012.06.04.mp3

---

[9] http://www.parksassociates.com/blog/article/pr0715-smart-thermostats (accessed 22 July 2015)

provide additional features, such as working as a remote control, but the internet connection is not necessary *per se*.

Other offerings are more software/cloud oriented: very little intelligence is required in the device itself (e.g. the thermostat or smart home hub), and the main benefits come from its connection to some cloud services.

Like many ideas on the internet, many smart home ideas were tried out first by Do-It-Yourself enthusiasts: makers, programmers and hackers. Sometimes, good ideas and concepts are later implemented in commercial products and services.

In the future, it is likely that smart heating systems will take many more data sources into account: The booking of a flight or train ticket, the reservation of a hotel room, scheduled meetings may – via one's online calendar – influence the system's decision to heat, cool or do nothing. If the heating system knows that the house occupant goes to a restaurant right after work, it can start the heating/cooling later. Or, if friends are expected for a visit, the system could already pre-cool the house and make it more comfortable for a hot summer evening. Other devices could be controlled to influence the temperature level as well: in a heating/cooling situation, windows could automatically be opened, when the outside temperature is higher/lower than inside. Sun shades could be activated to prevent rooms from heating up too much. Such solutions are already in use in larger (commercial) buildings. With the widespread availability of wireless communication, the costly installation of a physical network for home automation has become obsolete. Consumers can chose and exchange devices without having to think about (re-)wiring the whole house. However, they will still have to ensure that the new device can "talk" with the existing smart home system to take full advantage of the opportunities.

Limits to the smart thermostat "hype"
The actual energy savings from adjusting the temperature level at night or when away (lower temperature in the heating case, higher temperature in a cooling situation) can vary significantly. Many reports are based on data from the United States, where the thermal mass is low as many buildings are heated or cooled with electrical devices and because of their light-weight design, The low thermal inertia means that the building can be heated up or cooled down rather quickly and thus the savings from starting heating/cooling as late as possible can be rather significant.

However, the same savings are not achievable in regions where houses are of solid construction (bricks, concrete). There, it can take a while before an adjustment of the thermostat translates into real temperature changes in the rooms. This is especially true for renovated older buildings, with thick walls and good insulation on the outside. The impact of significant variation between days and night temperatures may even create problems with humidity/condensation within the building.

Other benefits of a connected HVAC system

HVAC systems, which are connected to the internet can be remotely monitored and possible problems spotted early on or analysed without a site-visit. Some heating equipment manufacturers have begun offering to installation companies to connect the end-customer's heating/cooling systems to the manufacturer's online service. This way – and with the permission of the owner – the installer can remotely monitor the system and possibly identify the cause of a problem.

> **Example: Bosch Thermotechnik supports installers with a remote monitoring service**
>
> Bosch Thermotechnik (BTT) is the largest manufacturer of heating equipment in Europe. It sells their products under several different brands in- and outside of Europe. In March 2015, BTT presented a new online service for installation companies: Those can have their client's systems connected to BTT's online system. Should a malfunction occur, the installer could retrieve information on the likely causes, which replacement parts would be needed and how much time should be foreseen for the repair.

While this offering is mostly interesting for larger installation businesses, it shows the trend: Remote monitoring/controlling is becoming available to smaller buildings and individual households. The main benefit is not necessarily energy savings, but better comfort (or what marketing would call "peace of mind"). For the installation business it can help plan and dispatch installers/technicians more efficiently and to avoid unnecessary calls on site.

The (potential) role of solar thermal in the smart home

Solar thermal has a lot to gain from the trend toward connected devices in the home (smart home). With moderate additional costs, the system operation could be monitored and the solar yield be recorded and analysed.

Monitoring to optimise solar yield and to spot problems

In the case of photovoltaic, it has become very common to remotely monitor the electrical output of the system, especially where feed-in tariffs apply, each day the PV system is not working to its full potential means lost income for the owner of the system. The same monitoring principles could be applied to solar thermal: Systems could be monitored for unusual behaviour (low or no solar heat available, unexpected overheating etc.) and even be checked against weather data and/or compared with the measured output of systems in the same region. This would allow spotting abnormal operation, which may need the attention of a technician/installer.

Increasing the usable solar thermal energy

A smart home controller could even increase the amount of usable solar thermal energy. Often on sunny days, the solar thermal system could produce more thermal energy than can be stored in the storage tank. Usually, the circulating pump in the collector loop is switched off before the temperature in the tank reaches potentially dangerous levels. If sunshine continues, the temperature in the collectors will rise until the heat transfer fluid evaporates and the collector enters a phase which is called "stagnation". During this time, no additional solar heat can be harvested from the system. To shorten the stagnation time and to increase the usable solar heat, a smart home controller could start hot water using household appliances such as washing

machines or dishwashers. In a 2010 experiment by German consumer magazine "test", dishwashers were supplied not with cold water but with warm water at 50°C. The cleaning level was at the same level as it was with cold water, but the electricity consumption was reduced by ca. 30%[10]. If the controller could start the dish washer before the solar thermal system goes into stagnation, the stagnation time could be shortened and additional thermal energy be harvested from the sun.

Similarly, the system could benefit from "knowing" not only the current weather conditions, but also the short term forecast and the expected hot water or space heating demand. Today, installers sometimes wrongly programme the hot water controller so that the conventional backup-heater immediately tops-up the storage tank to have sufficient hot water available on tap. This means lost opportunities for solar thermal: If the gas or electrical boiler heats up the tank immediately after the household members have taken their shower in the morning, the solar thermal system has less or no possibility to store heat in the tank later in the day, when enough solar irradiation becomes available. In an ideal system, the controller would "know" how much hot water would be needed and when, it would also estimate the amount of solar thermal energy produced by the collectors until then. Therefore, it could decide if and how much conventional backup heat was needed. Again, additional input data could improve this "estimate" by the controller: if it "knew" that the grand children are staying for the weekend, it could then increase its expected hot water demand (and space heating demand in winter). If it was aware of other changes to the schedule it could again try to optimise the production of solar and conventional heating. Some of this could come from giving the controller access to the (online) calendars of the occupants.

Tying financial incentives to the solar thermal energy produced
In many countries or regions, solar thermal systems can benefit from public financial incentives. The most common type of financial incentives is an investment grant, offered to the home owner when he/she invests in a solar thermal system. In this case, the incentive is generally related to the size of the system (i.e. the size of the collector field). This is simple and relatively easy to administer, but it has two distinct disadvantages: firstly, the collector area is only a rough indicator of the actual solar thermal energy production and systems of the same size but with different solar thermal yield will still receive the same level of incentives. This is unfair and may create the wrong incentives. Secondly, investment grants provide little (or no) incentive to maintain the system or to optimise its output. This is distinctly different from e.g. a feed-in-tariff for PV electricity, when only fed-in kilowatt-hours are incentivised and the owner of a PV system has a high interest in ensuring good operation.

As shown earlier, the additional cost of measuring solar thermal yields of smaller solar thermal systems can be quite low – if included at installation time in a forced circulation system. With the new developments in the smart home, it would become possible to tie financial incentives to the actually remotely measured solar thermal yield. This would incentivise owners to keep their systems in good working order and to have any problems quickly dealt with. Of course, it

---

[10] *Source (in German): www.test.de/Geschirrspueler-mit-Warmwasseranschluss-Ein-Drittel-Strom-sparen-4127686-0/*

is not as simple as it sounds: it would likely require "approved" meters, possibly an initial check-up by an independent auditor and additional administrative overheads compared with an investment grant (annual payments vs. a one-time payment).

New challenges for non-electrical heating solutions (including solar thermal)

As explained above, a lot of the energy related smart home / IoT development is focussed on electricity. Today, electricity already receives most attention by policy makers, media and the general public. These two factors encourage a trend in many countries towards more electricity consumption for heating purposes. Electric heat pumps, in particular, have seen increases in many national markets and the combination with photovoltaic systems is seen by many as the future of heating. Of course, this downplays future problems from the discrepancy between availability of solar irradiation and heat demand. Peak electricity demand in winter will continue to rise and PV electricity will often not be available then. These are challenges solar thermal has had to deal with for decades and R&D in (seasonal) thermal storage was one answer to address these. If backed up by a non-electric energy source (e.g. gas, biomass) solar thermal heating only marginally adds to (peak) electricity consumption – for controllers and pumps.

Nevertheless, manufacturer of electric heating systems, together with grid operators and utilities are focussing very much on optimising the electricity grid, sometimes viewing thermal electricity usage as a way to shift peak loads.

This focus on electricity and the rapid market development are a challenge for solar thermal as well as all other non-electrical heating solutions.

NEW SERVICE OFFERINGS BASED ON CONNECTED SOLAR THERMAL SYSTEMS

The new opportunities arising from being able to remotely monitor even smaller solar thermal systems at reasonable additional costs could help create new types of service offerings and even business models.

Remote monitoring of solar thermal systems by the manufacturer, installer, third-party service provider

So far, solar thermal – and heating/cooling systems in general – are mostly a one-off business: The installer sells the home owner a piece of hardware (i.e. a heating system) and installs it. Afterwards the customer will usually contact the installer only when problems arise (malfunction of the system). The installer has an interest in a problem-free operation of the system, which often means that he will not optimise it for low energy consumption or high solar thermal fractions. Instead, he will tend to over-dimension the conventional boiler (so that even on the coldest day in years, the system will provide enough heat so that the customer does not call the installer) and choose a control strategy that guarantees constant availability of hot water, thereby often reducing the solar thermal yield, because the tank is always immediately heated up by the conventional boiler.

The widespread use of remote monitoring as a service could slowly change this behaviour. The installer would enter into a longer-term relationship with his customer and continuously ensure the correct operation of the (solar thermal) heating system. He would not get most of his income from the initial installation of the system, but would rather have continued revenues from the service he provides: Detecting problems early; analysing existing problems remotely to determine the likely cause and possible remedy; overall optimising the system operation.

To get an idea of what services could be offered for (solar) heating systems, one can have a look at what is available for PV, today. There, many companies with different backgrounds offer services around monitoring and operation & maintenance (O&M). Services offered include:
- Monitoring of PV system operation, including individual components
- Yield reports including comparisons of actual vs. expected yields
- Pro-active fault detection
- Regular site-inspections
- Exceptional maintenance (e.g. replacement of faulty components)
- Yield improvement through onsite cleaning of PV panels and/or vegetation control

Remote monitoring/metering as a step towards (solar) heat as a service

Large heat consumers already have the option of adopting thermal energy. In this case, they normally do not pay for the initial investment in the heating system and do not even own it.

Instead, they pay the contractor for the kilowatt-hour of heat provided. Such arrangements exist also for small houses or even households, but are still very rare. Often the administrative overheads of such arrangements create costs too high to make it a viable option. However, if

remote monitoring became a common service – offered by the manufacturer, the installer or a third party service provider – the additional step towards charging only for the kilowatt-hour does no longer seem so far. Consumers are more and more used to leasing contracts (e.g. for their cars), or subscription models (streaming TV or music) which replace traditional sales contracts.

So far, such business models are only available for larger installations. The main reason is that the cost of operation and maintenance (O&M), as well as the administrative

Example: Nextility's Skybox

The US based company Nextility is a good example, what is already possible and offered to owners/operators of larger buildings (starting at a daily demand of ca. 5700l of hot water):

Nextility (founded in 2009 under the name "Skyline Innovations") has planned and built solar thermal water heating systems on a variety of residential and commercial buildings – ranging from multi-family apartments blocks to university buildings. The company not only installs the systems, but fully finances, owns and operates them. Like the customers of an energy utility, customers of Nextility are not billed for the initial investment but for the (thermal) energy they use. To this end, the company measures the temperature of the water coming from the water utility and the temperature coming out of the solar thermal system. From these, Nextility calculates the solar thermal energy provided to the client. Furthermore Nextility continuously calculates the hot water costs the customer would have paid without the solar thermal system and ensures that costs do not exceed them. As Nextility is paid only for the solar thermal energy provided, the company has a high interest in a well working system. With their "SkyBox" they continuously monitor ca. 15 different system parameters and their technicians are automatically alerted, if a problem is detected. At the end of the contract period, the customer can chose to renew the contract, to take over the ownership of the system or to have it removed from his roof at the expense of Nextility.

Source: http://www.nextility.com/solar/solar-faq/

overheads do not much depend on the system size. Larger installations are thus much better suited to them than small systems[11].

---

[11] *Source: http://www.sonnewindwaerme.de/solarthermie/erfolgreiche-geschaeftsmodelle-fuer-solarthermie-gewerbe*

STEPS TOWARDS BETTER INTEGRATION OF SOLAR THERMAL IN THE SMART HOME / IOT

The "smart home" eco-system is a fast moving target. It is therefore difficult for the (solar) heating industry to align their products and systems – which are often expected to operate for 20+ years – with current smart home developments.

Possible ways to address the challenges include:

- Accepting and foreseeing that the solar thermal or heating controller will be exchanged before the end of the lifetime of the system has been reached. A new controller could interface with current systems and connect with them using prevailing standards.

- Alternatively, controllers could increasingly be built modular and with the possibility to simply and possibly automatically update the software. If the networking module remained a separate component which now "speaks" Wi-Fi and Bluetooth LE, it could be exchanged later with a new version supporting protocols which today do not even exist.

- Similarly, controllers could increasingly rely on cloud services, thus providing only basic (but rather fixed) functionalities by itself. The more advanced options could be provided externally by online services, which can be updated and expanded continuously.

- Manufacturers of solar thermal controllers should also aim at providing basic functionalities via open protocols. In the heating equipment market, the Opentherm protocol has become widely used. Many products support (parts of) the specification, thus allowing their heating systems to be controlled by Opentherm compatible controllers. A similar approach could be useful in solar thermal.

However, the trend towards more connectedness should not come at the expense of privacy and security. Manufacturers and service providers are well advised to take into account the possible breach of their systems – either by the local controller, a smart home hub or a cloud service. Safeguards against dangerous system conditions (e.g. overheating of the storage tank) must be implemented in a way that it is (almost) impossible to remotely exploit. Users should also have the option not to have their information accessible remotely or even stored in cloud.

NOTES

....

....

....

....

....

....

....

....

....

....

....

....

....

....

....

NOTES

"Technical study report on measuring, remote monitoring, and remote controlling for solar thermal" aims at contributing to making measuring, monitoring, and remote controlling more mainstream for smaller systems. This report should provide a good overview of the state-of-the-art and the main trends in the market regarding also water and space heating systems, not only those including solar thermal. This report shall contribute to make solar thermal stakeholders better aware of the potential to be exploited in terms of measuring, remote monitoring, and remote controlling and its potential to improve solar thermal systems and its application, making it easier to compare and to reduce malfunctions.

This "Technical study report" was developed as part of the Global Solar Water Heating (GSWH) Market Transformation and Strengthening Initiative.