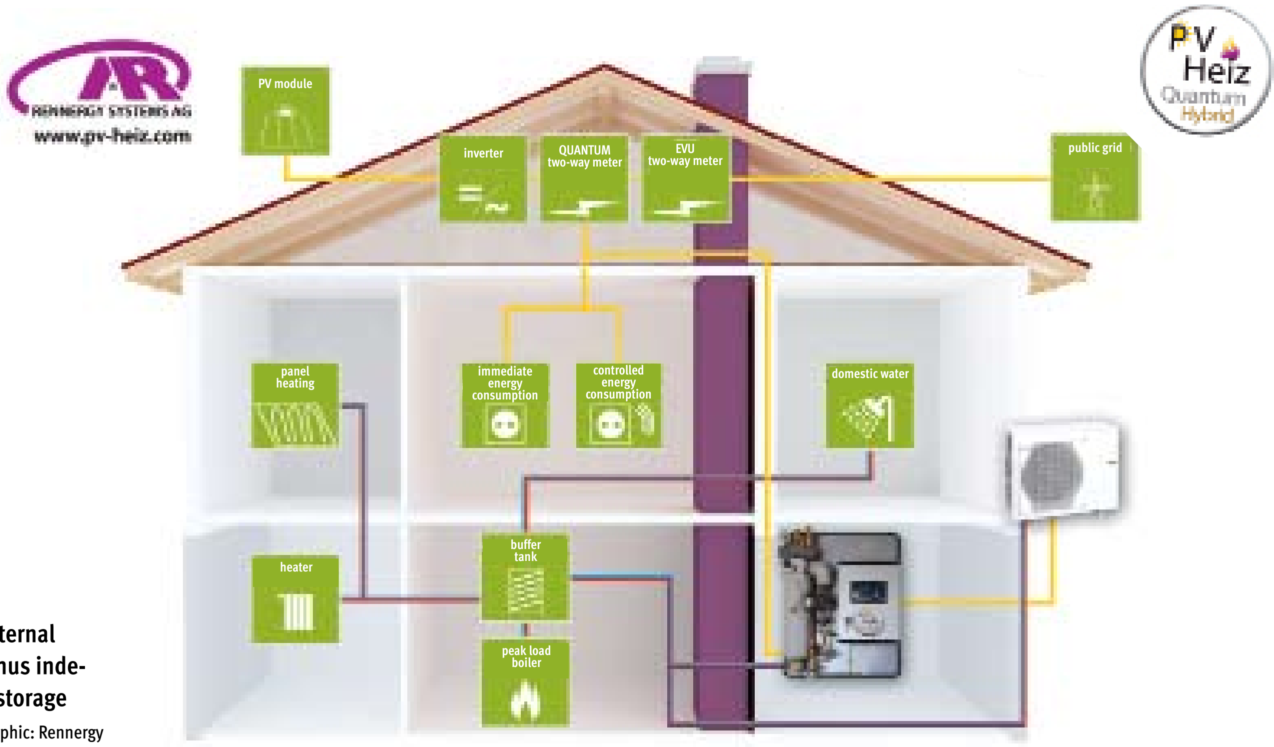
A question of priorities



Rennergy uses an external pump group and is thus independent of the heat storage connections. Graphic: Rennergy

When the household appliances are being supplied, the electricity storage is full and the electric vehicle is ready to go, the excess from the PV system generates heat. In this way, self-consumption rates of 90 % and above can be achieved.

Should you be allowed to use PV electricity for heating to convert high-grade energy into low-grade heat? For a long time this was considered taboo – especially as solar collectors can harvest solar heat more efficiently than PV modules. But the question cannot be answered technologically by the natural sciences or even answered morally. What counts is what the end consumer wants and what is economical for them. PV electricity is becoming evercheaper. In many countries it has already achieved grid parity. At the same time, feed-in tariffs are continuing to drop. Teresa Auciello, Sales Director of the British off-grid specialist Marlec, assumes that there is a market for PV heating systems in all countries in which there is already a mature or expanding PV market. Marlec has so far mainly sold its Solar iBoost system in the UK and Ireland, but is currently expanding its sales in France, Spain, Holland and Northern European countries. 4eco, also from Great Britain, is active not only in Europe, but also in Australia and New Zealand.

Apart from Marlec and 4eco, there are also other suppliers of specialised PV heating systems (see table 1), mainly in Germany and Austria. The suppliers come partly from the PV sector, but mostly from the traditional heating technology sector. Specialist PV heating companies have also been set up, however, to lay claim to this new market.

Especially cheap: heating with direct current

The simplest version of a PV heating system directly uses the DC current from the modules and feeds a DC heating element. Such a system does not require an inverter. The control of the heating element is via MPP tracking. Suppliers of such systems are the German PV wholesaler Krannich Solar, the US-American inverter manufacturer Advanced Energy Industries and my-PV from Austria.

The advantages of these DC systems, which are in direct competition with heat generation using solar collectors, are clear. The installation is very much easier compared to a solar thermal system. Planning approval is not required, nor is maintenance such as checking the solar heat transfer liquid. The DC products are well-suited for retro-fitting existing heating systems if a buffer or hot water storage with the right sort of flange for a heating element is available. According to my-PV, this storage should have a size of at least 200 litres. If the right sort of flange is missing, then the product supplied by Rennergy can play

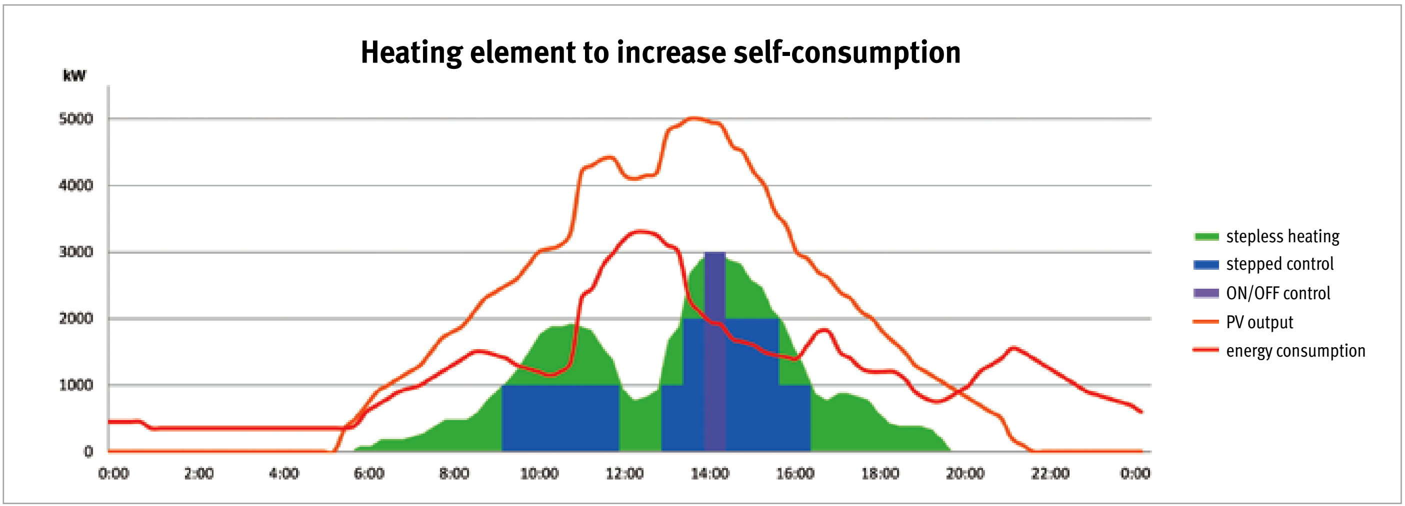


Fig. 1: A stepless heating element converts much more PV energy into heat than a 1- or 3-step one. Framework conditions: power of heating element, 3 kW; PV system power, 6 kW; a sunny summer's day.

Graphic: Klaus Rauch, Consulting Engineer

its trump card. Here, the heating element is contained in an external pump group and can be fitted to any unused storage connection of your choice.

According to calculations by the Austrian research institute ASIC, a 2 kW PV system from my-PV can achieve a solar hot water coverage of approx. 50 % for a four-person household. The ASIC calculation says this is the approximate yield from a 6 m^2 solar heating system. my-PV says their list price of such a system for the end customer is € 2,910. This is less than a solar heating system would cost. But things look very different if a suitable heat storage is not already available. Then there are not only additional costs for the storage unit. There are costs especially for the installation of the hydraulics, and the price advantage quickly becomes a real disadvantage. The maintenance advantage also lessens, for there should certainly be a maintenance of the heating installation to check the sacrificial anode in the water storage unit, for example. Scaling of the heating element could also require maintenance.

50 % solar coverage also means that the other half of the energy for hot water generation must come from other sources. For cases in which no further heat generator such as a gas or pellet boiler is available, my-PV and Krannich can supply an additional AC heating element which can heat the water using electricity from the grid. You can have controversial discussions on whether this form of energetic use of electricity makes sense, but it certainly presents the owner of such a system with the potential to use valuable, solar-generated electricity. He would then be using this for his household electrical appliances: saving more money per kWh and also playing a bigger part in the energy transition.

More uses: grid-connected systems

Those who wish to give their household electricity demands priority need an energy management system that can recognise surpluses from the PV system (see table 2: overview of energy managers). With the Elios4You by 4-noks from Italy, the control variable is the excess feed-in power. The energy manager measures the 3-phase feed-in power at the grid connection point and regulates this to zero by controlling the heating element. At Marlec a signal is transmitted wirelessly from the current transducer clamp to the central unit. This regulates the heating

Overview of PV heating systems

Manufacturer	Type designation	Components [9]	Heating source	Heating source variable	Electricity supply heating sources	Phases electricity supply	Max. heating power [kW]	Min. heating power [kW]
4eco	Power diverter	EMS	EHE	continuously	AC	1	3.0	3.0
AEI Power	AE PV Heater	Con	EHE	continuously	DC	-	1.5	0.0
Austria Email	ES-PV	HST, EMS	EHE	6-stage	AC	1 or 3	6.0	1.0
B+S Wärmetechnik	Master Solar	HST, EMS, PV, In [1]	HP	continuously	AC	1	13.0 [18]	2.0
Buderus	Logaplus (WPL AR-3 + PV2) + battery storage	HST, EMS, PV, In, BS	air-to-water-HP	continuously	AC [21]	1	6.0	2.0
Buderus	Logaplus (WPL AR-3 + PV1)	HST, EMS, PV, In	air-to-water-HP	continuously	AC	1	6.0	2.0
Buderus	Logasys SL 580	HST, EMS, PV, In	hot-water-HP	no	AC	1	3.7 [18]	2.0
Dimplex	HPL 6TUW Plus-Aktion	HST	air-to-water-HP	continuously	AC	3	6.4	4.0
Dimplex	LAW 9IMR Plus-Aktion	HST	air-to-water-HP	continuously	AC	3	9.0	6.7
Dimplex	LAW 14ITR Plus-Aktion	HST	air-to-water-HP [11]	continuously	AC	3	14.7	13.9
Juratherm	Reparco dynamica	EMS	EHE [2]	31-stage	AC	3	6.2	0.2
Juratherm	Reparco maxima	EMS	EHE [2]	31-stage	AC	3	24.8	0.8
Krannich	Ziggy PV-Thermie	EMS, PV	EHE	no	DC	-	3.0	3.0
Marlec	SolariBoost	EMS	EHE	continuously	AC	1 [4]	3.0	0.2
my-PV	Elwa	Con, PV	EHE	continuously [19]	DC [22]	-	2.0	0.0
my-PV	Elwa	Con, PV	EHE	continuously [19]	DC [22]	-	2.0	0.0
my-PV	AC-Elwa	EMS	EHE	continuously	AC	1 or 3	3.0	0.0
Ratiotherm	Oskar Smart Energy	HST, EMS	HP	continuously	AC	1 or 3	15.0	0.2
Rennergy	PV-Heiz Eco	Con [3]	EHE [2]	7-stage	DC	-	9.0	0.1
Rennergy	PV-Heiz Premium	EMS [3]	EHE [2]	7-stage	AC	3	9.0	0.1
Rennergy	PV-Heiz Quantum	EMS [3]	air-to-water-HP	continuously	AC	3	14.0	1.0
Rennergy	PV-Heiz Quantum Hybrid	EMS [3]	air-to-water-HP	continuously	AC	3	14.0	1.0
SolarInvert	Stromhamster	HR, EMS	EHE	continuously	AC	3	6.0	0.0
SolarInvert	Stromhamster	EMS	boiler	continuously	AC	3	6.0	0.0
Solarwatt	Energy Manager	EMS	BW-HP	n/a	AC	1	3.0 [18]	1.5
Soleg	Brauchwasser-WP-Set	EMS, HST	hot-water-HP	2-stage	AC	1	3.4	1.9
Soleg	Zusatzheizung WP	EMS, HST	air-HP	no	AC	1	3.0	3.0
Soleg	Zusatzheizung Heizstab	EMS, HST	EHE	continuously	AC	3	6.0	0.1
Soleg	Brauchwasser-Set	EMS, HST	EHE	7-stage	AC	3	3.5	0.5
Solare Datensysteme	Solar-Log 1200 + Ego Smart Heater + 3 phases electricity meter	EMS	EHE	8-stage	AC	1	3.5	0.5
Stiehle Naturenergie	Sunbrain	n/a	EHE, HP	4-stage	AC	3	16.0	0.0
Varista	Energyguard - Heater 9.75 kW	EMS, PV, In	EHE	continuously	AC	1	6.0	0.1
Viessmann	Vitocal 200-S	HST, EMS, PV, In [1]	air-to-water-HP [11]	continuously	AC	1 or 3	16.5	1.2
Viessmann	Vitocal 200-A	HST, EMS, PV, In [1]	air-to-water-HP	continuously	AC	1 or 3	10.0	3.0
Viessmann	Vitocal 161-A	HST, EMS, PV, In [1]	hot-water-HP	no	AC	1 or 3	1.7	1.7
Viessmann	Vitocell 100-B CVE	HST [4]	EHE [14, 20]	continuously	AC	1	2.7	0.1

Table 1: Whether DC or AC heating element, hot water or heat pump for the heating system: the customer decides how he wishes to convert his PV electricity into heat.

Source: company data

Con = controller; HP = heat pump; HST = heat storage tank; EMS = energy management system; PV = PV system; In = inverter; BS = battery storage; DHW = domestic hot water; SH = space heating; EHE = electric heating element; HR = heating rod

	Heating used for	Volume heat storage tank [litre]	Priority electricity consumers	Grid electricity for heating	Power measurement to grid	Battery storage included	Visualization of energy flows	PV power [kW] [23]	PV self-consumption rate [%]	Net list price [€] [24]
	DHW, SH	by customer	yes	yes	1-phase	no	display, internet portal	starting from 2	100	513
	DHW, SH	by customer	-	no	-	no	App, internet portal	1.5 up to 2.7	up to 100	798
	DHW	80/100/120	yes	yes	no	no	n/a	n/a	100	n/a
	DHW, SH	1,000	selectable	yes	1-phase	yes	App, display internet portal	n/a	80	10,000
	DHW, SH	50 up to 500 [17]	no	yes	3-phase	yes [6]	App	5.8	80	n/a
	DHW, SH	50 up to 500 [17]	no	yes	-	yes	App	3.5	60	n/a
	DHW	270	no	yes	-	yes	App	3.5	60	6,845
	DHW, SH	400 [16]	selectable	yes	3-phase optional	yes	App	starting from 3	80	11,573
	DHW, SH [12]	400 [16]	selectable	yes	3-phase optional	yes	App	starting from 3	80	9,077
	DHW, SH [12]	400 [16]	selectable	yes	3-phase optional	yes	App	starting from 3	80	11,060
	DHW, SH	by customer	yes	no	3-phase	yes	no [12]	starting from 5	90	5,778
	DHW, SH	by customer	yes	no	3-phase	yes	no [12]	starting from 5	90	n/a
	DHW, SH	by customer	-	optional	-	n/a	display	1.5	100	1,856
	DHW, SH	no maximum	yes	yes	3-phase [10]	no	display, separate monitor	starting from 1	95	n/a
	DHW, SH	by customer [15]	-	yes	-	no	software	1.5	100	2,092 [7]
	DHW, SH	by customer [15]	-	yes	-	no	software	2	100	2,445 [8]
	DHW, SH	by customer [15]	yes	no	3-phase	no	software	starting from 2	60 up to 70	n/a
	DHW, SH	750	selectable	no	1- or 3-phase	yes	display [13]	10	n/a	7,795
	DHW, SH	by customer	yes	no	-	no	internet portal	starting from 3	60 up to 90	starting from 2,427
	DHW, SH	by customer	yes	no	3-phase	no	internet portal	starting from 3	60 up to 90	3,739
	DHW, SH	by customer	yes	no	3-phase	no	internet portal	starting from 3	60 up to 90	4,705
	DHW, SH	by customer	yes	yes	3-phase	no	internet portal	starting from 3	60 up to 90	7,983
	DHW, SH	by customer	yes	no	3-phase	no	internet portal, display	2 up to 10	80 up to 95	n/a
	DHW, SH	by customer	yes	no	3-phase	no	internet portal, display	2 up to 10	80 up to 95	n/a
	DHW	290	selectable	yes	3-phase	yes	internet portal	4	> 80	2,857
	DHW	300	yes	optional	n/a	no	no	3 up to 10	up to 90	3,156
	DHW, SH	1,000	yes	optional	n/a	no	no	5 up to 10	up to 90	4,878
	DHW, SH	1,000	yes	optional	n/a	yes	yes	3 up to 10	up to 90	2,827
	DHW	300	yes	optional	n/a	no	no	3 up to 10	up to 90	1,816
	DHW, SH	by customer	yes	no	3-phase	yes	App, computer, internet, display		n/a	1,099 [25]
	DHW, SH	by customer	yes	optional	3-phase	yes	display [14]	starting from 3	80	starting from 1,786
	DHW, SH	by customer	yes	no	3-phase	yes	App, internet portal	5	up to 70	14,284 [5]
	DHW, SH	170 up to 300	yes	yes	1- or 3-phase	yes	yes	n/a	up to 80	n/a
	DHW, SH	170 ut to 300	yes	yes	1- or 3-phase	yes	yes	n/a	up to 80	n/a
	DHW	300	yes	yes	1- or 3-phase	yes	yes	n/a	up to 80	n/a
	DHW	300	yes	no	1- or 3-phase	yes	no	3 up to 8	up to 100	n/a

[1] battery storage optional; [2] EHE integrated in hydraulic station; [3] heat storage tank and PV system optional; [4] 3-phase option planned for late 2015; [5] sales only to plumbers, no end-consumer price, [6] 4.4 kWh battery included; [7] price for crystalline modules, also with 1.4 kWp CIGS modules for € 2,410; [8] price for crystalline modules, also with 2.1 kWp CIGS modules; [9] heating source in next column; [10] 3-phase available from Q4 2015; [11] split heat pump; [12] in development; [13] peripheral device for web; [14] planned App; [15] min. 200 litre; [16] 100 litre DHW 3300 litre buffer; [17] extension with DHW possible; [18] with power of EHE; [19] MPP tracking; [20] dry heater for resistance to lime; [21] battery storage DC; [22] additional AC heater optional; [23] recommended power when the PV system is not included; [24] list price in Germany; [25] special offer

Data recording during the partial solar eclipse in Germany in March. Solar-Log records the yields and calculates the self-consumption rate.

Graphic: Solar-Log

element proportionally to the electricity available and responds to changes in PV electricity generation and consumption by the household appliances.

If all of the excess is channelled to the heating element and a sporadic appliance such as a fridge switches on, there would be a flow of grid electricity for a short period until the energy manager readjusts. For this reason, the PowerDog by ecodata from Germany allows an excess control point to be set. This could be 100 W, for example. "Everything above 100 W of excess goes into the heating element. If household appliances switch on then the heating element throttles back immediately," explains ecodata General Manager Gerhard Hütter. The Solar-Log by Solare Datensysteme from Germany also has self-consumption as the main focus for system operation. "The Solar-Log control unit ensures that only PV-generated power and no grid electricity is used for heating," says Gerd Edelmann, Head of Product Management.

For consulting engineer Klaus Rauch, who advises several companies on the development of PV heating systems, it is generally important to set the excess power, not the PV power, as the control value. Otherwise there would be the danger of using grid electricity for heating, especially if the power of the heating element is not variable, or only variable in a few steps. A stepless regulation is also important energetically. Klaus Rauch has studied a PV system with 6 kW of rated power. The excess power on a sunny summer's day is only enough to supply an unregulated 3 kW heating element for a few minutes (see fig. 1) and the increase in own PV consumption is minimal. Things look somewhat better if the heating element consists of three 1 kW rods, but a steplessly controlled heating element stores about twice as much solar electricity in the form of heat over the 3-step solution.

Most systems in this overview are based on steplessly controlled heating elements. It is important that the control is not via phase cutting, as the technical connection regulations of the energy suppliers only permit this for heating elements up to 0.2 kW of power.

The requirements for using the Solar-Log system, for example, are a grid connection with 230 V and 16 A. Additionally, a storage is required with a 1.5 inch flange. Some suppliers, such as Rennergy or Juratherm (both German), supply a heating element which is built into an external pump group. The German fittings specialist Tuxhorn also recently presented such a unit at the ISH international heating exhibition. Apart from the independence of flange sizes, this also has the advantage that you can specifically target a heating of the top part of the boiler. This is especially important for a large buffer storage that supplies a house with hot water and heating. An internal heating element must heat up all of the water volume above it. On cloudy days not enough energy is always available to reach a useable temperature level, however, and the conventional secondary heating must switch on. This would not be necessary if only a little hot water were generated directly right at the top. The system with the AC heating element from my-PV, though, does also allow layer heating with the heating elements built into the boiler. For this the company offers the option of fitting two heating elements at different levels of the boiler.

Dream team: PV and a heat pump

Heating element systems are well suited for retro-fitting in existing heating systems due to their simple installation and low costs. It is just important to have a boiler which is large enough. Home owners who already have a PV system on the roof can also retro-fit such systems without a lot of effort in order to increase their own consumption.

But if the old heating is on its last legs and a new installation is required, then there is the opportunity for switching completely to electricity by installing a heat pump system. Systems designed to get as much own PV consumption as possible are available from the large heating technology companies such as Viessmann, Vaillant, Stiebel Eltron and Bosch Thermotechnik, or heat pump specialists such as Dimplex.

With heat pumps, an additional function of the energy management system comes into play. When there is a PV excess, the Solarwatt Energy Manager of the heat pump, for example, sends a signal to switch the buffer or hot water storage to a higher temperature level. It is also possible to follow a higher heating curve. "The house thus becomes a heat storage," says Solarwatt Product Manager Stefan Peeck: "With this stored heat you are able to lessen or even entirely do away with the drawing power of at night." Solarwatt works closely together with Dimplex, but generally all SG-Ready heat pumps – i.e. those for smart grids – are compatible. Other systems, such as those by Viessmann and 4-noks, are also able to superelevate the temperature using heat pumps.

Hot water heat pumps are also mostly SG-Ready. These are a more efficient alternative for hot water generation than a heating element. These units cannot generally be regulated, but only consume approx.

Suppliers of energy management systems

Manufacturer	Type designation	Heating sources	Heating source variable	Priority electricity consumers	Grid electricity for heating	Battery storage charging	Visualisation of energy flows	Net list price [€]
4-noks/enerquinn	Elios4You	EHE, HP	continuously	yes	no	no	yes	419 [3]
Austria Email	EBH PV	EHE	6-stage	yes	yes	no	no	n/a
Dimplex	Smart Eco Zentraleinheit	HP, DHE	yes	selectable	yes	yes	App	585
ecodata	PowerDog	EHE, HP	continuously or 3-stage	yes	selectable	yes	internet portal	998 [4]
Schletter	SmartPvCharge2.0	EHE [1]	continuously	yes	no	yes	internet portal	n/a
Schuler	Energiemanager SC 460	EHE, HP	continuously or multi-stage	selectable	selectable	no	software	n/a
SIB Energy	PV Immersion Controller	EHE	continuously	yes	yes	no	display, separate monitor	375
SMA	SMA Smart Home	HP [2]	no	selectable	selectable	yes	App, internet portal	n/a
SolarInvert	Stromhamster	EHE, HP, boiler	continuously	yes	no	no	internet portal	n/a
Solar-Log	Ego Smart Heater	EHE	8-stage	yes	no	yes	display, computer, internet portal	545 [5]
Solarwatt	Energy Manager	EHE, HP, DEH, boiler	multi-stage	selectable	selectable	yes	internet portal	747
Soleg	Smart Home PVH	EHE, HP	continuously	yes	selectable	yes	yes	1,300

DEH = direct electrical heater (convectors, IR heating, night storage, etc); HP = heat pump, EHE = electric heating element

[1] heat pump planned; [2] also other heating sources via wireless socket; [3] price for device up to 15 kW PV, device up to 50 kW PV costs 587 €; [4] price with Energyanalysator, power controller, temperature sensor and internet portal; [5] price for Ego Smart Heater without Solar-Log

Table 2: The energy manager ensures that as much PV electricity as possible is optimally used in the household.

Source: company data

500 W and can thus use excess PV electricity for many hours of the day similarly to a steplessly controllable heating element. If we stay with the example from Klaus Rauch (see fig. 1), the hot water heat pump really cannot use much of the excess power, however. This is because more than 500 W of excess is available pretty much right across the day. Heating elements are thus better for a higher self-consumption rate.

Heating is the last in line

Energy management systems can do more than just divert excess electricity into heat generation. Most can also control electricity storage. The SmartPvCharge2.0 by Schletter from Germany serves mainly to charge an electric vehicle. The self-consumption of solar electricity in the household always has priority here. Excesses first go to charging the battery storage: only then is it the electric vehicle's turn. “It may be that the current excess power is not yet enough to begin charging the electric vehicle without drawing power from the grid,” says Hans Urban, Deputy CEO at Schletter. “In such a case the heating element is switched on. This uses the excess energy until power is enough for the higher-priority use, i.e. charging the vehicle,” he continues. The user can change these priorities. If he wants to use the electric vehicle that evening, for example, he can press a button to immediately charge at full power. “Precisely the use of solar electricity for electric mobility has the highest economic gain. If you replace 1 kWh of household electricity through self-consumption, then in Germany this has an economic value of 28 €-ct/kWh. If 1 kWh of PV electricity is used in an e-vehicle then the economic value is a whopping 38 €-ct. Right now you cannot use solar electricity in a better way than that,” says Urban.

Not only Schletter but also the Solarwatt Energy Manager and the SMA Smart Home System can charge electric vehicles. SMA Smart Home adjusts the household electricity demand to the solar electricity generation via radio-controlled sockets. The company incorporates weather forecasts into this as well. What the energy managers can primarily do is visualise the energy flows, for which there are apps, web portals and special PC software. The occupants can not only monitor their PV system, they can also see which appliances are currently using electricity and how much. “Through the direct visualisation of consumption there are savings effects of 10 to 20 %,” says Stefan Oexle-Ewert, Head of enerquinn, which sells the 4-noks system in Germany. This is not least because the occupants can easily track down otherwise hidden consumption.

The aim of heating with PV is maximising self-consumption. DC systems have to get as close to 100 % as possible in order not to waste any PV electricity generation. But what can grid-tied systems achieve? “We have customers who achieve up to 80 % self-consumption rates with our Sunbrain system,” says Fritz Stiehle, owner of Stiehle – Küche Bad Naturenergie.

Jens-Peter Meyer