Collaborating Smart Solar-powered Microgrids

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ABSTRACT

This deliverable documents the work as done during the trial period related to monitoring and maintenance of the installed technology and assisting its use, including repair or replacement of faulty hardware, installation of bug fixes and software improvements, and the operation of a help-desk or help-line, where users can get support and solutions for rising problems involved or related to the trials.

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CoSSMic consortium

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2.0	2017-03-31	Released

Table of content

1 About this Document

1.1 Role of the deliverable

This deliverable has the role to document the continuous activities during the trial period related to monitoring and maintenance of the installed hardware and software technology and assisting its use, including repair or replacement of faulty hardware, installation of bug fixes and software improvements and the operation of a help-desk where users can get help with possible problems related to the trials.

1.2 Relationship to other CoSSMic deliverables

D5.4 is strongly correlated with D5.1 which already describes the trial users of the City of Konstanz in Germany and of the Province of Caserta in Italy with their installed PV systems, lists the users and their selected equipment as foreseen for the integration into the trial for each user´s site. D5.3 moreover documents in detail the installed hardware and software at the users trial sites, and describes all restrictions either of technical or legal nature classified by country, type of user and selects single users to address, discuss and define ways to overcome the restrictions.

Relation to WP6
D6.2 describes how the measured data are evaluated with respect to the KPIs defined in D6.1. All the collected and stored data serves as the basis for the simulations as described in D6.4.

Relation to the other WPs
Furthermore D2.1, D2.2 and D2.4 give overviews of how the potential trial users may be integrated and which technologies will be used especially to create a suitable GUI and the requirements of the users as worked out in workshops, D2.5 focuses on community building and D2.3 on applicable Business Models.

WP3 delivers among others the concept to run the trials; first D3.1 describes the technical architecture, D3.2 its realised implementation and D3.3 its complete integration release.

The software development and implementation as documented in D3.3 section 5 Software modules and the topic database of measured data in D6.1 section 4.1 Handling of the measured data are directly implemented in the trials.

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1.3 Relationship to other versions of this deliverable

Only the final version of this deliverable will be published

1.4 Changes of the deliverable due to obstacles

The software development of the optimising scheduler and the integration of the background loads, (consumption of devices, which are not directly measured) have been delayed. However, the basic functionality of the already installed and running software on the Raspberry PIs at the single user sites has been operating stably for more than a year and has collected data more or less as planned. The users are able to store their data and display them by using the developed Graphical User Interface (GUI), furthermore the weather forecast of the upcoming days is displayed and can be used for individual scheduling of device tasks by calculating the predicted PV-yield with the available software. Due to the delay of the optimising scheduler, the load-shifting functionality has not been available to the users, and therefore we have not been able to collect data on its effect. To compensate for that the evaluation design has been modified and relies more on simulation than originally foreseen (see D6.2 for more details).

1.5 Structure of this document

Chapter 1 gives an overview about this document and the links to the other work packages and deliverables of the project. Chapter 2 introduces and summarizes the overall activities during the trial period. Chapter 3 is dedicated to the user specific activities and coming up individual action points at the different user sites. Chapter 4 introduces the users and the installed equipment of the Caserta trial site. Chapter 5 deals in short with the internal and external data flow and data acquisition. Chapter 6 sketches the cooperation with the trial site users followed by Chapter 7 which gives a conclusion.

2 The overall work as done during the trial period

ISC with the support of SST and the Stadtwerke Konstanz has implemented the necessary equipment at the trial locations in Konstanz. SUN supported by the Province of Caserta have done the same within the Caserta trial site. The electricity flow within the neighbourhood of Konstanz and Caserta, both generation and consumption was recorded for at least one whole year for the Konstanz and a shorter time period for the Caserta trial. During this test phase the users got online information about their consumption and generation of energy with the target to consume energy rather during times of high PV generation and low demand as indicated by the displays and supported by their tariff knowledge about cheap or more expensive energy costs. With strong support by simulation tools as developed in WP6.4 also different business models schemes, as worked out in WP2, could be tested at different times within the trials or at an indicated site only.

The work was related to the monitoring and if necessary maintenance of the installed technology with special focus on failure detection of manual as well as automatic data acquisition, their evaluation and discrimination.
During the running of the trial the assistance of its use of the users at their sites has been continuously done by personal contacts either by face to face meetings, telephone calls or email exchange. The main focus was the use of the deployed graphical user interface (GUI) and to a certain extent also the further evaluation of already measured data and the use of the data for individual interests.

2.1 The stability of the installed system

One can state a high reliable stability and functionality of the different types of installed hardware devices over the whole trial running duration time which means that no serious hardware device fault could be reported. The main reason of coming up instabilities of online availability of the running CoSSMic system rises from the data connection lines for the internet access and the acquisition and transfer of the measured data. The RS485 connected devices and the smart meters are running without failure.

Internet access:

It was observed that the internet access by WLAN or LAN was temporarily out of order but always only for relatively low time spans and never originated from a CoSSMic system fault.
Sometimes the recovery of the internet access did not initiate directly the remote access to the Raspberry PI, so manual switch off and on of the system was needed to activate the access to the user again.

Radio frequency based data transmission:

The data transfer was more exposed to temporary interruptions. The smart plugs as installed at the power sockets of the integrated devices like refrigerators, freezers, dishwashers, washing machines, etc. measures the power and energy flow and sends it to the data receiving units, which are attached to the Raspberry PI. The transmission occurred to be down sometimes and must be started again by booting up the Raspberry PI. However, the restart could be done remotely by an operator.

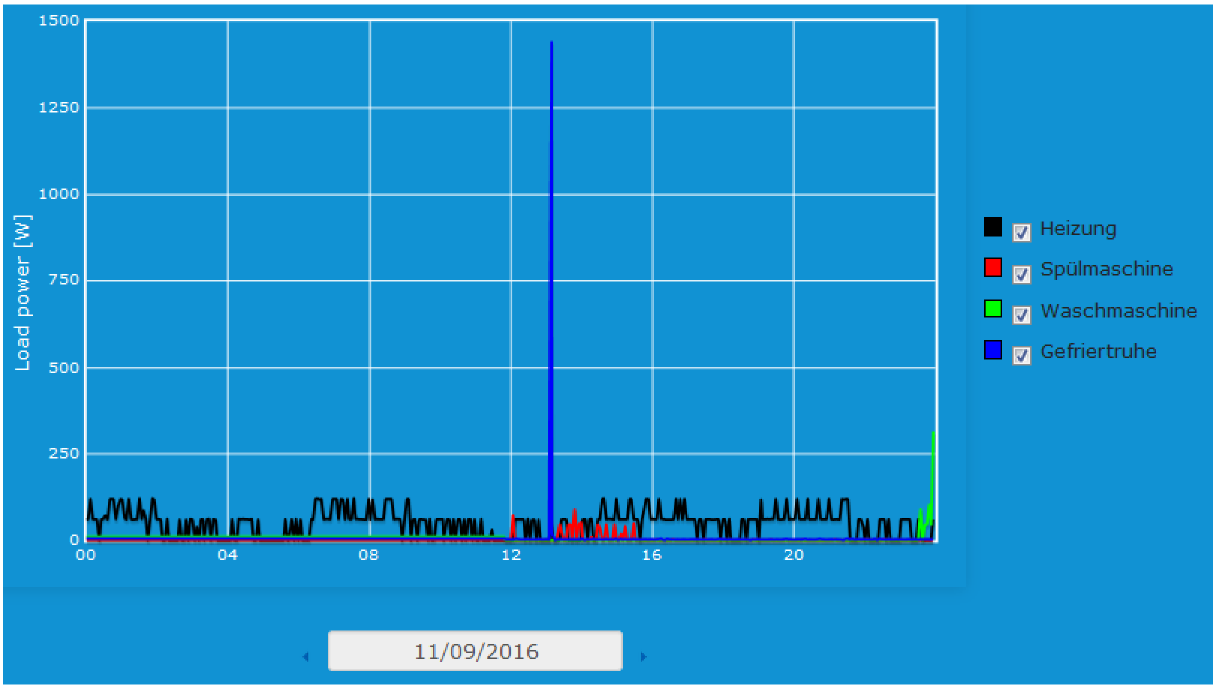

Figure 1: GUI display of KN12. At around 12 o´clock the Raspberry PI was remotely switched off and on again to work in regular mode to receive data via CUL receiver.

In Figure 1 the GUI shows till 12 pm only the RS485 based data transfer to the Raspberry PI of the smart meter measured heating pump electrical consumption. A remote booting of the Raspberry PI triggered the switch-on of the radio frequency based data transfer around 12pm. Then the time traces of the three appliances washing machine (i. e Waschmaschine), dishwasher (i. e. Spülmaschine), which is exchanged by a coffee maker (!), and the freezer (i. e. Gefriertruhe), which is substituted by a micro wave oven (!) are detected again.

<u>UMTS</u>

Sometimes the local conditions do not allow to connect the data acquisition smart meter directly with a cable to the internet connected Raspberry PI. Restrictions can be the long distances between the smart meter and the internet connected Raspberry PI or it would be necessary to manipulate the buildings construction, etc. Therefore the data transfer can also be provided via UMTS technique. The connection from a first Raspberry PI having a RS485 interface for data communication with an installed smart meter via UMTS to a second main Raspberry PI with permanent internet access by LAN may also show disturbances and interruptions, mainly caused by the break-off of net-access as displayed in Figure 2 within the building of installation.

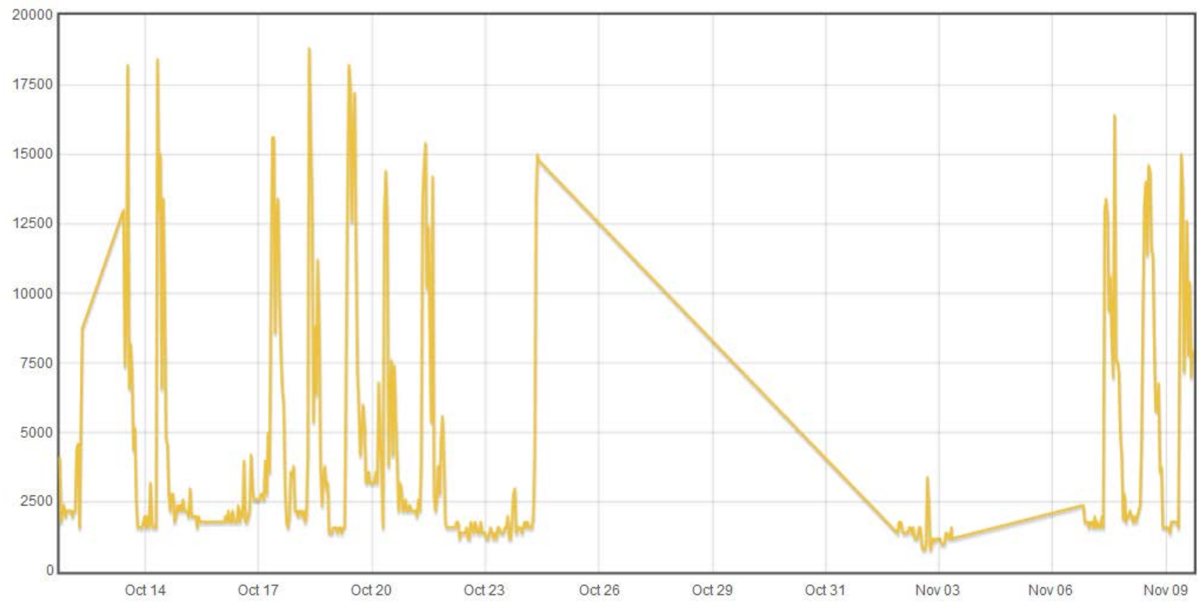

Figure 2: The consumption data of the public user KN05 from Oct. 10th to Nov. 10th 2016.

For both the WLAN service and the radio transmission system precaution must be taken to mount the transmitter and the receiving unit not too far from each other and to avoid faraday shielding, especially when mounted in an electrical switchboard cabinet.

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2.2 The contact to the users

The personal contacts with the users started already in the very early phase of the project in 2013/14 with first workshops on community building as described in WP2 deliverables, and were continued during the different more technical based Smart Energy Workshops as held in Konstanz (07/2015 and 11/2016) and Caserta (10/2016). The users were as well invited before the trials started at the ISC Konstanz to get all necessary information related to the trials.
Furthermore whenever necessary personal visits at the user sites were realized and supported by email and telephone contacts.
See also D5.3 Chapter 6 Training of the users for more details.

2.3 Direct implied changes during the trial

Very rarely came up the situation to repair or even to replace of a faulty hardware. Sometimes a broken power supply used for the Raspberry PI of 2nd generation with a maximum current rating of 1.2 A stemming from the Raspberry PI 1st generation had been exchanged by a power supply of higher current rating of 2.0 A. Despite the given ratings of the own power consumption for 1st and 2nd generation Raspberry PI are only deviating by less than 10% (from 3.2 to 3.4 W) under full load according specifications. During the trial phase it has been very clearly seen that the used Raspberry PI 1st generation in the first early installation round was too weak in data storage as well as processor power to handle the occurring data volume. Thus all the firstly installed Raspberry PIs of 1st generation has been exchanged by the Raspberry PIs of 2nd generation.

The creation and then installation of bug fixes and software improvements have been done first at selected user sites before being deployed to all users of the neighbourhood.

3 The action points as done at the different user sites

The individual details of the accomplished work items are listed for each single user by taking into account the changes and modifications during the trial phase of the installed integrated devices as:

- Smart meters
- Storage systems
- PV systems
- Other devices

The adaption and exchange of data acquisition and transfer methods and technologies for availability and quality improvement and optimization as:

- From RS485 interface to S0 data acquisition
- UMTS from Raspberry PI 1 → Raspberry PI 2
- WLAN vs. LAN
- User sites firewalls
- Smart plugs vs. smart meters

An overview of the updated Konstanz trial site hardware installations is given in Table 1. A similar table was already presented in D5.3. The start dates of the integration of the different users and the beginning of continuous monitoring of the household data are given in Table 2.

KN-User →	**KN01**	**KN02**	**KN03**	**KN04**	**KN05**	**KN06**	**KN07**	**KN08**	**KN09**	**KN10**	**KN11**	**KN12**
Device | items	industry	industry	industry	industry	public	public	private	private	private	private	private	private
Installation since	13.05.15	22.09.15	02.09.14	Aug 14	July 15	Aug 15	15.04.15	17.03.15	11.12.14	Aug 14	21.01.15	18.03.15
Elster sm/Devices/T-sensor	3/-/-	-/1/-	3/1/-	1/16/1	3/-/-	1/-/-	3/3/1	1/4/1	2/5/2	3/5/1	1/3/-	2/4/1
Elster sm tot	1 x A1500	8 x diff meters	1x AS1440	1x A1500	1 x AS1440	1 x A1500	1 x AS1440	1 x AS1440	1 x AS1440	1 x AS1440	1 x AS1440	1 x AS1440
for PV	2 x AS1440	4 x A1500	2 x AS1440	different	1 x AS1440	some	1 x AS1440	No PV	1 x AS1440	1 x AS1440	No PV	1 x AS1440
add. sm	-	Nova5//1A	yes for battery	yes for Mbus	1 x AS1440	no	yes	yes	yes	yes	no	yes
T-sensor	-	-	-	yes	-	-	yes	yes	yes(2)	yes	?	yes
refrigerator	-	-	-	SP	-	-	no	no	SP	SM+SP	SP-combi	no
freezer	-	-	-	-	-	-	SP	SP	SP	SM	SP-combi	SP
dish washer	-	-	-	SP	-	-	SP	SP	SM	SM	SP	SP
washing machine	-	-	-	-	-	-	SP	SP	SP	SM	SP	SP
heat pump (=hp) / pump (=p)	-	-	-	-	-	-	AS1440 (hp)	SM for (p)	SM for (p)	AS1440 (hp)	-	SM for (p)
available storage devices	eCar (17.8kWh)+5+1lifters	18*12V *40Ah= 8,65kWh	stationary battery (3.7kWh)	eCar(24 kWh)+stationary batt.(2.3 kWh)	back-up safety battery	back-up safety battery	-	-	-	eCar (15kWh)	-	-

Additional Devices	-	-	16A open charger for 4 employees eCars+all	14 industrial devices via SM (Mbus)	-	-	-	-	-	second refrigerator ventilation	-	aquarium, microwave, coffee-maker

Table 1: The table lists an overview of the installations at the different users in Konstanz. The abbreviations as used in this table stand for: sm: smart meter, hp: heat pump, p: pump, and SP: smart plug.

User	CoSSMic integration started	Continuously data available
KN01	10-2015	07-2016
KN02	07-2016	still pending[1]
KN03	04-2016	04-2016
KN04	10-2015	02-2016
KN05	07-2016	07-2016
KN06	06-2016	12-2016
KN07	05-2015	01-2016
KN08	04-2015	04-2015
KN09	12-2014	02-2016
KN10	11-2015	11-2015
KN11	10-2015	10-2015
KN12	10-2015	02-2016

Table 2: The table gives an overview of the date of start of the integration of the different users and the monitoring and storage of the household data.

3.1 KN-01 (industry, 20 employees, annual consumption: 237MWh)

The DSO at the German trial site is the Stadtwerke Konstanz (SWK) which were unable to read the monthly consumption remotely of the RS485/CLO interfaced Elster A1500 smart meter → so the CoSSMic team had to take off the smart meter from CoSSMic neighbourhood from 1st March about 2pm on and connected the meter´s RS485 data line back on the 3rd March 2016 about 3pm → it didn´t show records even past remote switch off of the Raspberry PI → In order to open the DSO the data path for billing the Smart meter CLO interface must be off latest again on the 24th March for secure remote data reading of the DSO! Thus from this date the Elster S1500 was permanently off-line; → but the PV-yield was still recorded via the two AS1440 Elster smart meters and fed into the CoSSMic system.

On the 4th Jul. 2016 a straight forward developed S0 data acquisition driver was installed, SIM card temporarily missed has been found again...under the rocks...and the system could be switched on to work across a relay for safety reasons to be able to switch-off the output signal whenever necessary!

The A1500 S0 port is already used for the security alert control of some electrical loads (cooling rooms!).

Different voltage levels are used to drive the signal. Access via a safety relay is possible but the system must be switched off during installation work officially by the Stadtwerke Konstanz (DSO).

Now since 15th Jul. 2016 about 10am the total consumption data are available via S0 data port interface.

[1] Based on the mismatch between the user´s own smart meter and the RS485 protocol.

Some further online checks have been done to calibrate the output signal for the right data amount acquisition because in Jul. 2016 the signal was probably by a factor of 2 too high, thus the pulse-factor/kWh was reset from 100 → 200 pulses.
The monitored 16-17 days in Jul. 2016 brought about 31MWh, which is the communicated amount from SWK for the whole July. → i. e. the measured consumed energy amount is by a factor 2 too high. The history of the trial and error is as following: first set 100pulses/kWh with transfer resulted in double energy amount from 15th Jul. to 4th Aug. 2016; then 200 pulses without rounding resulted in only 0.5 times the energy amount till 16th Aug. 2016. Finally and also at present the factor is set to 100pulses/kWh without rounding error, which seems to be ok now. See the history of setting in the Figure 3.

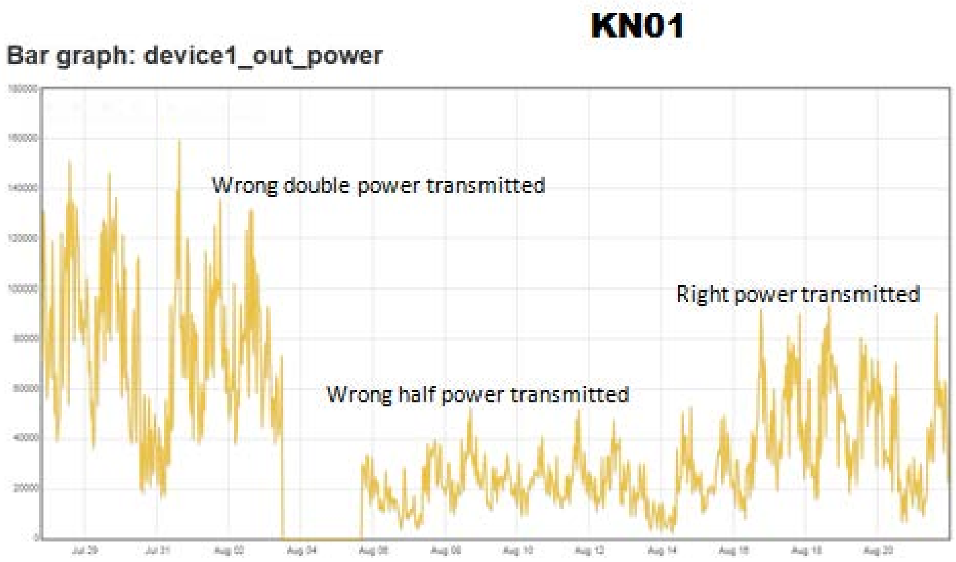


Figure 3: Measured time dependent power consumption for a too high (left), too low (middle) and right set (right side) analogue output signal calibration.

The installed PV panel system on top of the KN01 facility has a power rating of about 12kWp. Its output together with the daily consumption of the 19th Jul. 2016 is shown in Figure 4. The power curve over the day shows often a drop-shift regularly past midday at the sun climax at very sunny days, probably due to the downward regulation of the inverter to 70% of the maximum power rating (Wp_{max}) of the PV system. Compare this observation with the displayed production of the KN10 PV system in Figure 29 without such a capping regulation of the same day and rather same panel orientation to the sun.

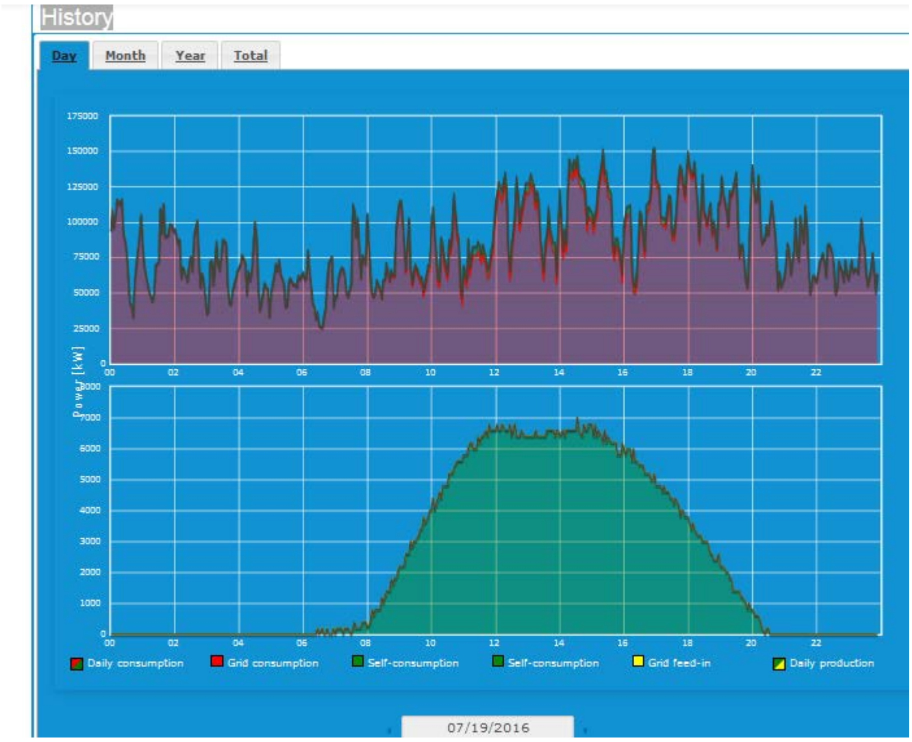


Figure 4: Top shows the power consumption and bottom the power yield of the PV system. The power yield curve vs. time shows often a drop-shift regularly at the sun´s climax at very sunny days probably due to regulation of the inverter to 70% of Wp_{max}.

Remark:

From time to time comments and critics came up from the local utility distributer that it seems for them that the CoSSMic installation disturb the data transfer for the customer billing from the A1500 Elster smart meter to them. But we are confident not to do this because we are using the analogue output S0 while they are using the digital CLO interface.

3.2 KN-02 (industry, 250 employees, annual consumption: 600MWh)

The user side ICT fire wall side was already established against and towards possible invaders and had to be overcome. An official permission agreement has been received for our purpose to establish the intended internet access.

At present the Raspberry PI 2 is connected to the internet via LAN and available via VPN and is connected to the RS485 interface of the installed external smart meter of the type TIP NOVA RS485 MOD-BUS as displayed in Figure 5.

Some more hardware was needed for the smart meter integration. There was an MBus interface +/- 5 V supply via data line but w/o RS485 and thus an additional converter was needed like a ModBus or Solvimus GmbH MBUS-PS80 converter. In the following time period it needed a longer time coordination phase to get access to a direct 230 V / 50 Hz power supply for the TIP NOVA RS485 MOD-BUS inside the distribution cabinet which is property of the Mainau AG.
It seemed to be a never ending story with the indicated voluntary responsible persons, a lot of phone calls, email contacts and personal visits on the island of Mainau and the involved facilities.
But just on the 17th Nov. 2016 we could install the ModBusRS485 Interface but had still to wait for the 230 Vac driving voltage supply for the unit, as can be seen in Figure 5.
By the way, the already installed and by LAN internet connected Raspberry PI failed probably due to data transfer overload, which overloaded also the 1.2 A maximum current limited power supply while the system was busy and searched but could not find the already introduced but not activated TIP NOVA RS485 MOD-BUS device. This thermal overload was probably additionally driven by the dense packed mounting inside the distribution cabinet as can be seen from Figure 6.

On the 23rd Nov. 2016 finally the TIP NOVA RS485 MOD-BUS could be connected with 230Vac driving power and the Raspberry PI generation 2 with a new 2A maximum current rated power supply.

Figure 5: It shows the not connected M-Bus TP device (left), the TIP NOVA RS485 MOD-BUS interface (middle with red and blue power supply cables) and the Mainau AG owned smart meter TIP NOVA 5//1 MID-4L (right).

Figure 6: It shows the Raspberry PI 2 in its housing with its power supply right on top as plugged into a power socket, the red almost hidden LAN internet access behind the RS485 to USB converter in front of the picture for the data exchange between the smart meter and the Raspberry PI 2.

3.3 KN-03 (industry, 10 employees, annual consumption: 30MWh)

During the trial start period only minor problems came up, e. g. In the GUI the weather forecast was displayed but not the community generation and consumption of the present day in the GUI view History the daily self-consumption was ok in the legend but did not show the right colour. For the monthly and annual History view the colour was ok but not the legend and furthermore the daily contour did not fit exactly. But finally all the problems could be fixed and are mentioned here exemplary.

The battery smart meters were finally embedded on the 26th Apr. 2016 and could monitor loading and discharging cycles of the battery. The GUI as displayed in Figure 7 shows the daily loading of the battery for Jul. 2016 and of one day, i.e. the 20th Jul.. The charging of the discharged battery starts already early in the morning and the following discharging typically, in the summer season, at late evening from about 8pm as can be seen in Figure 8.

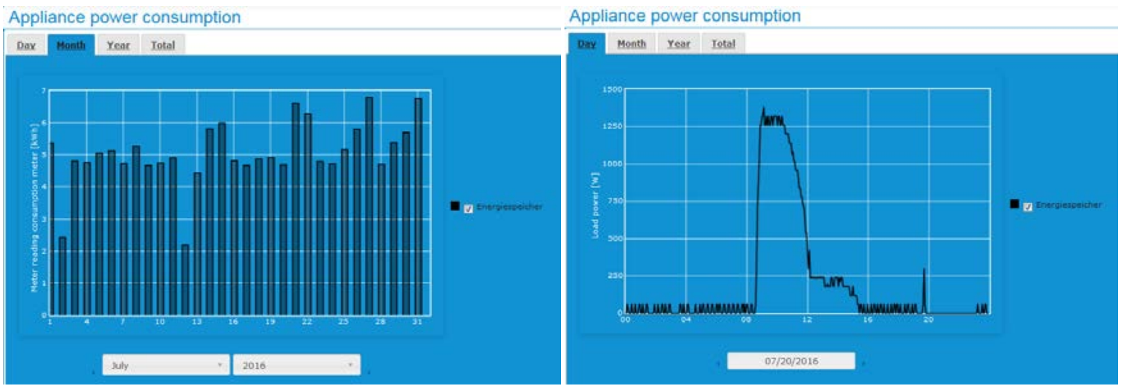


Figure 7: Battery loading in kWh of the entire July 2016 (left) and the power flow in Watt of the loading run of the 20th July 2016 (right).

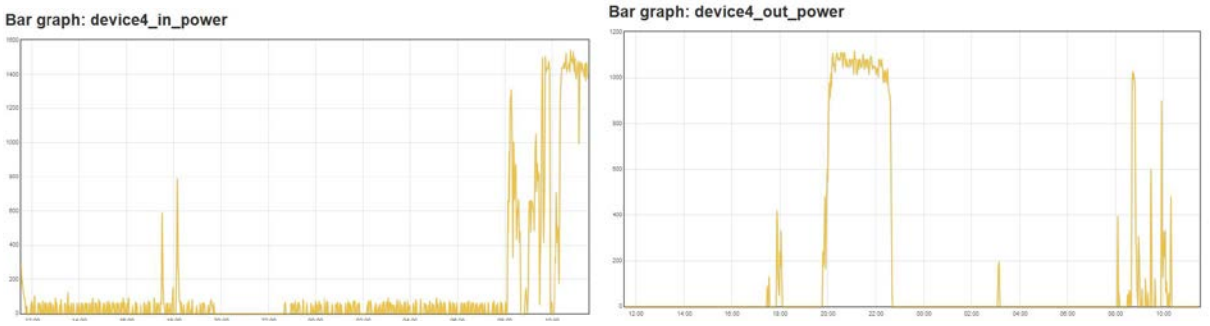


Figure 8: The power flow into (left) and out (right) of the Engion stationary battery of KN03 between 11.30 and 11.30 from the 8th to the 9th May 2016.

There has been a serious electrical fault probably forced by weather lightning from the 17th May 2016 on. The connection to the internet was interrupted from that date and also the data flow to the Raspberry PI was disconnection. Finally the system was back again and connection as from 28th May 2016 at 6pm, see Figure 9.
At the beginning of Sep. 2016 occurred a server break down but for this case the Raspberry PI was still fully reachable, and only off sometimes for a rather short time period of about hours.

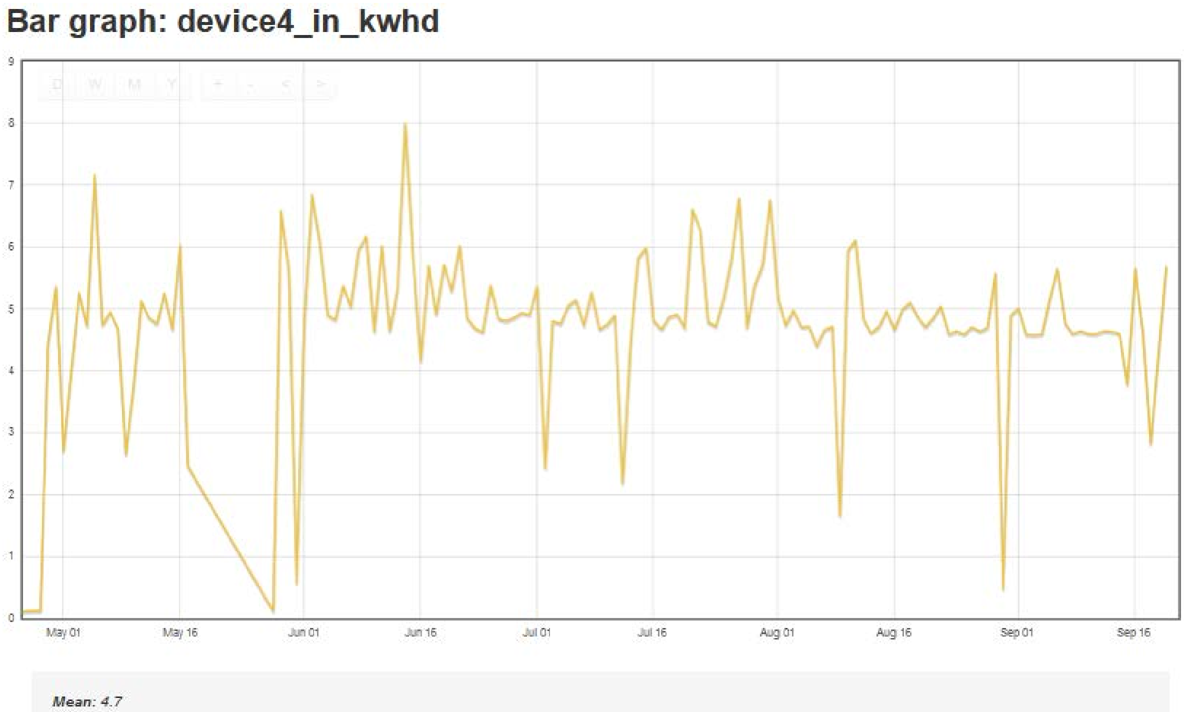


Figure 9: The daily charging in kWh of the stationary battery from May to Sep. 2016. The data loss from 17th to 28th May is clearly seen.

It is worth to mention that sometimes disturbances were monitored stemming from the data acquisition port already present at the corresponding feed and in the GUI as can be seen from Figure 10.

Figure 10: The total consumption over the 3rd Jan. 2017 (top), the PV generation over the same day (middle) with a strong short lasting peak and again the disturbance signal for a higher time resolution at around 11.40 am (bottom).

3.4 KN-04 (industry, 50 employees, annual consumption: 730MWh)

During the trial it appeared only after system power drop that the MBus data acquisition interface was in the off state and had to be reset and also the CUL radio frequency data transfer worked stable and was found just once without detected reason from the 3rd Jun. 11am till 6th Jun. 2016 11.30am, in the off state and was on duty well again after a refresher start of the Raspberry PI.

At this user all together 19 devices were monitored, i. e. two PV panels systems, two household appliances (refrigerator and dish washer), an electrical automobile charger and fourteen industrial consumer devices. The power consumption of all 17 consumers is shown in Figure 11 for the 19th Dec. 2016.

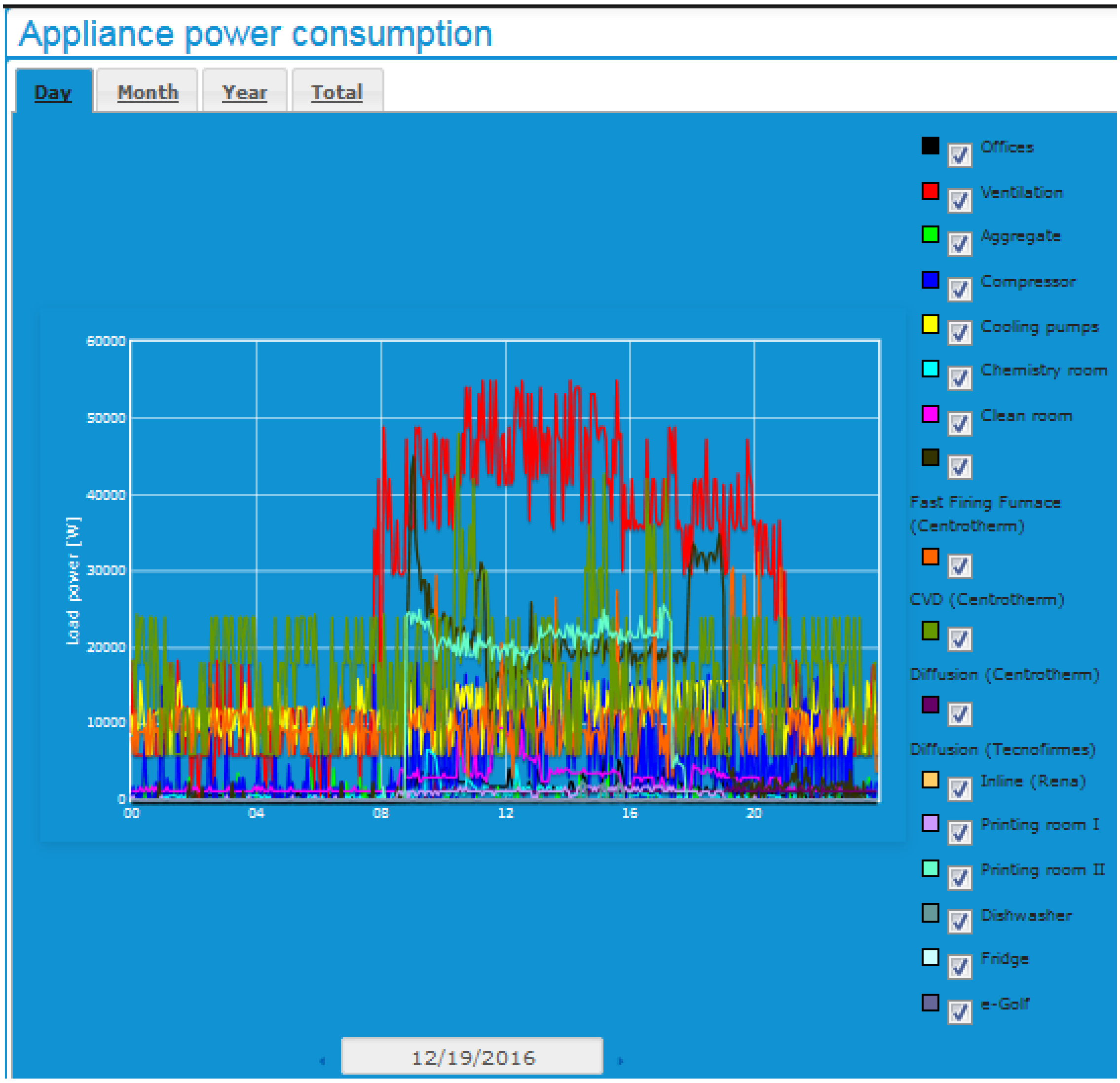


Figure 11: Power consumption of all at KN04 integrated consuming devices, i.e. 14 industrial devices, two household appliances and one electrical car charger.

The different industrial devices were monitored to get an overview about the distribution of the different energy consumptions in amount and time duration. Because it is mandatory for a research centre working on new products and processing, first to take care about the right timing of the process routines and also the predefined necessary energy amounts. Thus at this stage there was only little freedom for load shifting possible.

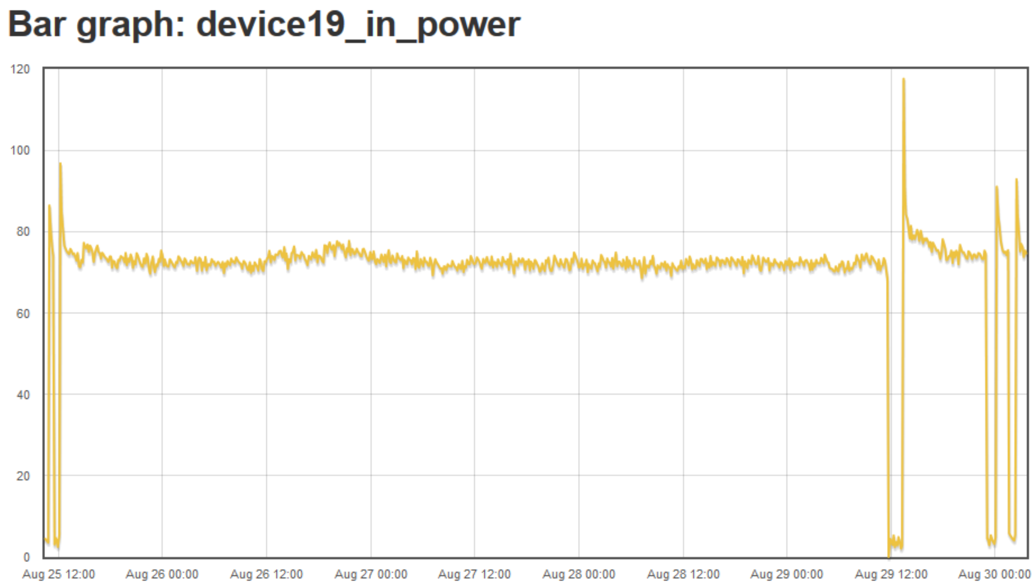


Figure 12: Power consumption of the refrigerator KN04 between the 25th and the 30th Aug. 2016 which shows the transitions from regular to continuous to regular cooling mode back again.

Interesting to mention that the monitored refrigerator sometimes went into a continuous cooling mode and stayed there for a certain time period and came back again by accident as can be seen in the GUI screen view of Figure 13, which gives a clear advice that the refrigerator internal T-sensor system is not working properly and has to be exchanged.

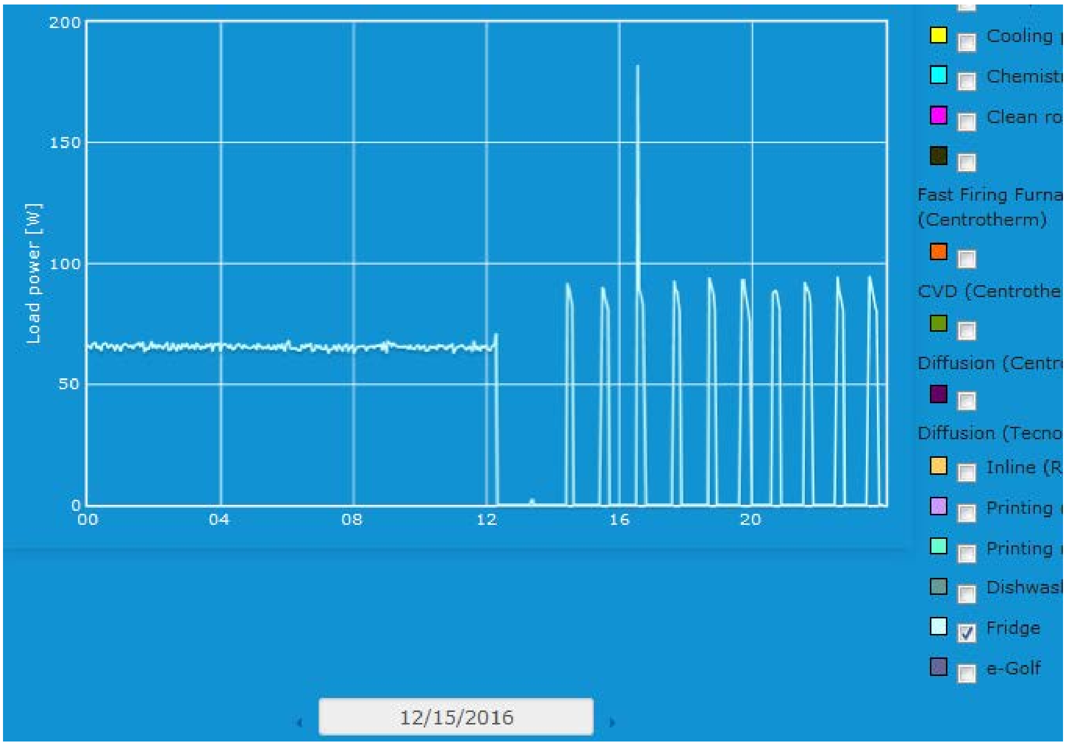


Figure 13: The power consumption of the integrated refrigerator of user KN04 shows a transition in the power consumption from a continuous mode to a chopped mode.

In the morning of the 28th Nov. 2016 an only few seconds lasting outage of the overall power supply forced a switch off of the installed safety switches of the rooftop PV installation to secure each of the three strings of the PV system.

Due to bad weather conditions with very low sunshine over the whole Dec. 2016 into the New Year and a cover by a snow layer, the summarized displayed generation yields of the facade and the top roof PV installation together on the GUI, the switch off of one system was detected late on the 3rd Jan. 2017. This switch off of the rooftop PV panel system resulted in a total feed-in energy loss of about 250 kWh. This value corresponds to the average PV yield of 8 kWh/d measured for the same seasonal period one year ago, for the roof top PV installation.

Remark:
By the way is it worth to mention, that the history view is ok but the colours have to be changed and also the units from kW to W, which should be done at the uploading of the next software version.

3.5 KN-05 (school, about 100 pupils, annual consumption: 25MWh)

There have been some problems in the beginning on internet and VPN access which could be solved in cooperation with the external company (Comformatik AG, Geschäftstelle VS-Schwenningen, Eichendorffstraße 33, D-78054 Villingen-Schwenningen) and the Stadt Konstanz as the official carrier and technical responsible for intra and inter network access at schools in Konstanz.
The installed hardware, one Raspberry PI -2 was connected by LAN to the internet and one Raspberry PI -1 via UMTS to the Raspberry PI -2 seemed to be not open due to a firewall of SWK for UDP but for ICMP protocol. Tests showed that trace route is possible from gateway “schulen” to gateway “ISC” and the responsible VPN-server.

It seemed one get through the firewall, but the Raspberry PI-2 didn´t hold its dedicated IP (IP 172.17.8.237) anymore or got and held afterwards an unknown one provided from the network access provider Comformatik.
Now the Raspberry PI 2 is available via VPN and is working but the second Raspberry PI 1 installed close to the Elster AS1440 was still not connected to the main Raspberry PI 2 as connected to LAN.
On the 19th Apr. 2016 the service crew recognised with opened electrical cabinet door that the UMTS stick “finds” 3G/3G+ net and can be seen via internet but no data transfer between the Elster AS1440 and the Raspberry PI-2 via UMTS was realised with closed cabinet door.
From the 17th May 2016 the UMTS stick was mounted outside the cabinet and on duty as can be seen from Figure 14. The consumption pattern during one regular school day, the 2nd June 2016, is shown in Figure 15.

Figure 14: The opened electrical cabinet with the cable connection between the Raspberry PI, mounted in the left part of the picture and the UMTS data port which is mounted on top and outside the electrically shielded cabinet.

Nevertheless there were continuously ongoing data transfer failures to complain which drove some consecutive days without data transmission from the data collecting Raspberry PI-1 wired with the AS1440 Elster smart meter and the LAN-connected Raspberry PI-2.The transmission was off for example from 2nd August 2pm till 9th August 3am 2016
.On a wider displayed time range clearly visible are the weekly school days between two weekends during a month monitoring time span as shown in Figure 16.

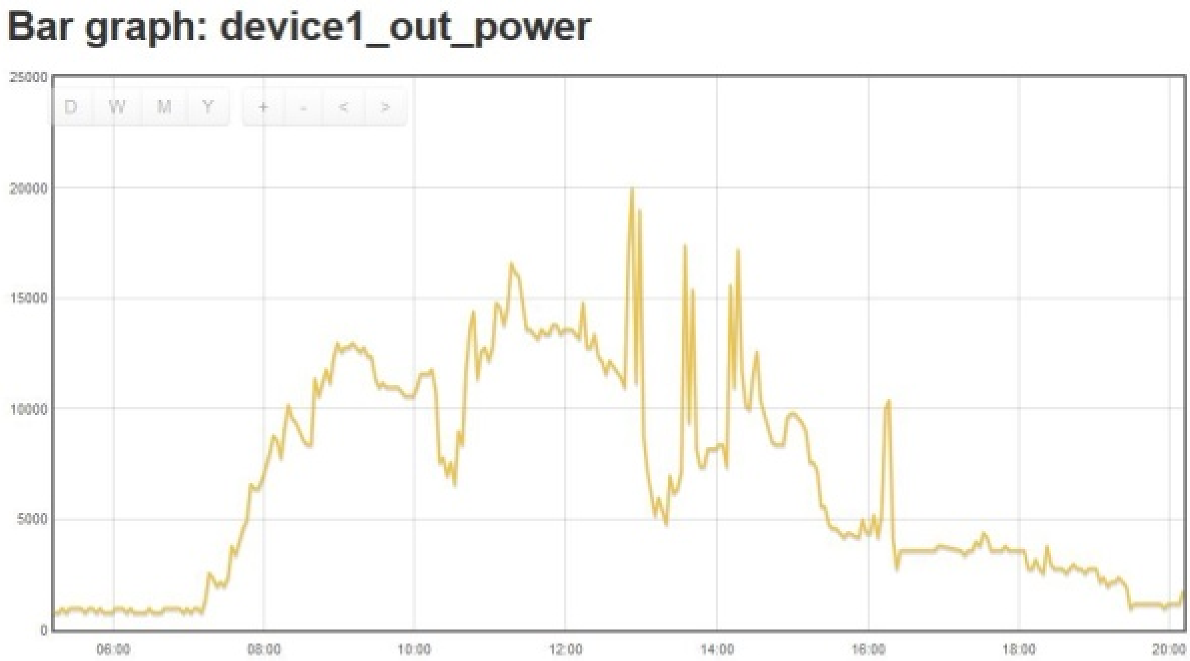


Figure 15: The entire electrical power consumption flow over the 2nd June 2016, a regular school day.

The data transfer between the Raspberry PI -1 close to the smart meter and the Raspberry PI -2 connected to the internet by LAN did not work continuously well, sometimes interruptions occurred of about some consecutive days. See Figure 16 which shows a data transfer interruptions of three time periods, from the 12th -14th Oct, 24th Oct – 2nd Nov and 3rd – 7th Nov. 2016.
For the data transfer from the Elster AS1440 smart meter a first Raspberry PI sends the data by UMTS to the LAN connected second Raspberry PI, which turned out to be time dependent not continuously available, which is mainly based on the local building conditions. This fact results in lacking of available measurement data.

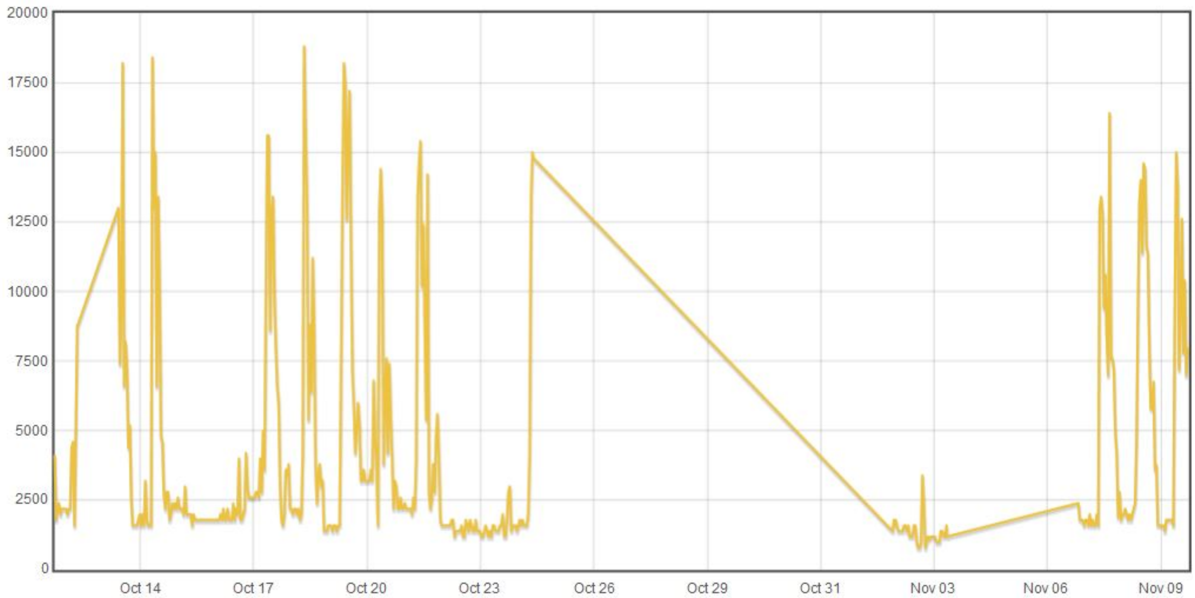


Figure 16: The power consumption of about one month with three longer lasting periods of failure of data transmission.

3.6 KN-06 (school, about 1000 pupils, annual consumption: 300MWh)

The Raspberry PI-2 and the UMTS stick were first installed from end of Feb. 2016 after a first test phase at the ISC in the electrical cabinet house about the 300m apart from the LAN internet access. In Figure 17 are seen the Raspberry PI with the UMTS stick and the A1500 smart meter.
The access to the KN06 facility was established by the cooperation with different responsible persons, Mr. Gheorghiou from the Stadt Konstanz for the facility, Frau Schäfer from the external company Comformatik AG for network access, the Stadtwerke KN for the Elster smart meter maintenance case with different people from the maintenance crew of Mr. Schöller, the School Director Ms. Wehinger-Schwörer and the janitor / house keeper Mr. Bunten of the Geschwister-Scholl-Schule as the public facility and the ISC for the coordination and the Raspberry PI setups.
For the data access from the smart meter A1500 Elster, still equipped with two digital interfaces RS485/CLO we use the same analogue S0 interface access as already established at the KN01 user site.
The data transmission from the Raspberry PI-1 as connected directly by cable to the main smart meter A1500 Elster we use in the same manner, as already proofed and applied at the KN05 user site a Raspberry PI-1 to UMTS to Raspberry PI-2 (with 16GB SD-card) data link. The Raspberry PI-2 is permanently connected to the internet by LAN.
Now from the 27th Sept. 2016 the Raspberry PI-2 at KN06 hanging on LAN is available by VPN. The Elster smart meter A1500 connected to the raspberry PI-1 and the UMTS access stick are seen in Figure 17.

Figure 17: The picture of installation from the 17th Oct. 2016, when the Raspberry PI-1 is again connected via S0-Interface with the A1500 Elster smart meter in the MV-LV distribution cabinet.

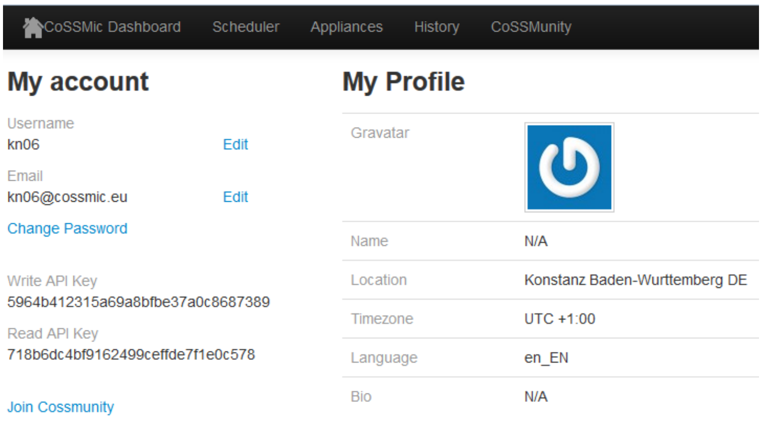


Figure 18: The account view of KN06 with its email address as displayed on the GUI.

The consumption of this user could be integrated into the CoSSMic data acquisition very late, because of technical and administrative delays, during the trial phase in Nov. 2016, an example of monitored data flow of the month Jan. 2016 can be seen in Figure 19.

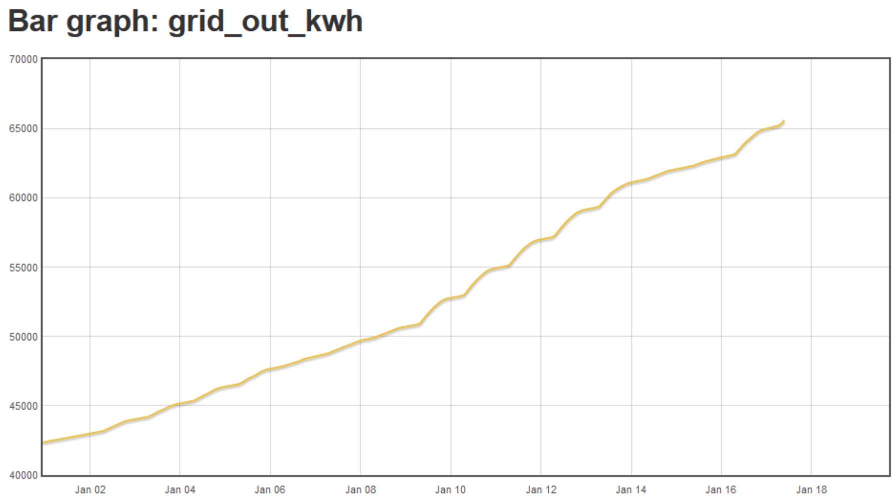


Figure 19: The monitored energy consumption in kWh of KN06 for Jan. 2017 until SD card break down.

<u>Remark:</u>
Few days after the official end of the project the Raspberry PI integrated SD memory card broke down, due to high service load on the 17^{th} Jan. 2017.

3.7 KN-07 (private house, 2 persons, annual consumption: 10MWh)

The user KN07 served as a test user for the integration of a device consumption control by automatic detection of the fulfilment of a preset threshold value. In the open source used data acquisition software emoncms a feature is available to send out an alert message when a certain predefined threshold condition of a measured data value is fulfilled.

In a first test it was ok to set the threshold to a relative value. Here the thresholds of the online fault detection were probably set to relative levels of two times above and 5% below the average power, as measured in the last elapsed hour.
It was working as expected. The configuration was set in the way that any data point higher than two times or lower than 0.05 times the average for the time interval of one elapsed hour. In a first run the threshold values were chosen arbitrarily and were easy to modify.
With the result to receive a feeds failure message via email continuously each hour the email with the information:

The following feeds: set (['70'])
Set (['70']) are acting suspicious and should be investigated

Figure 20 gives an example of a detected data transfer break. The measured data of a smart plug to be transmitted to the Raspberry PI by means of radio frequency failed and was missing since about 16:07 h!

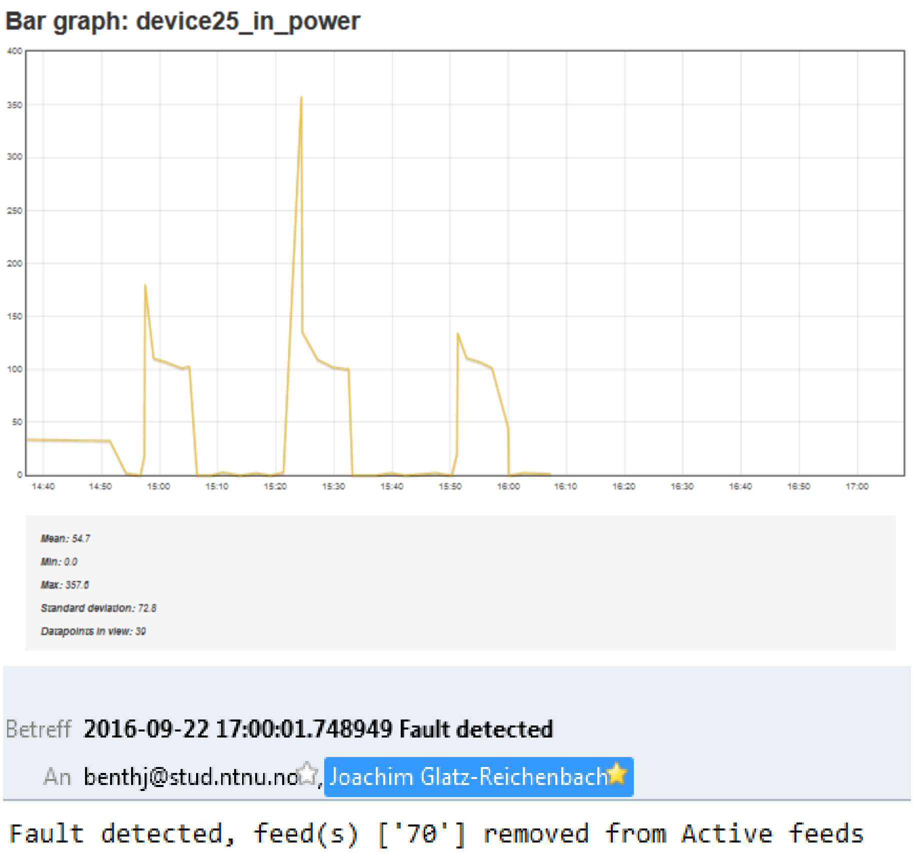


Figure 20: Power consumption trace of the freezer of KN07 from the 22nd Sep. 2016 (top) and the automatically generated and sent message by emoncms interface to a pre-defined email addresses (bottom).

At present the failure detection threshold level is set for the lower and upper level to discrete power values of 20W and 250W, respectively.

As another example the data transmission via radio frequency of the freezer consumption was off for just longer than 2 hours between right before 1pm and some minutes past 3pm of the 17th Nov. 2016, see top of Figure 21 and with a more precise time resolution shows the same situation the middle part of Figure 21. This failure behaviour created two messages at 2pm and 3pm to report the failure. In the bottom part of Figure 21 one can see, the email from 3pm of the 17th Nov. 2016.

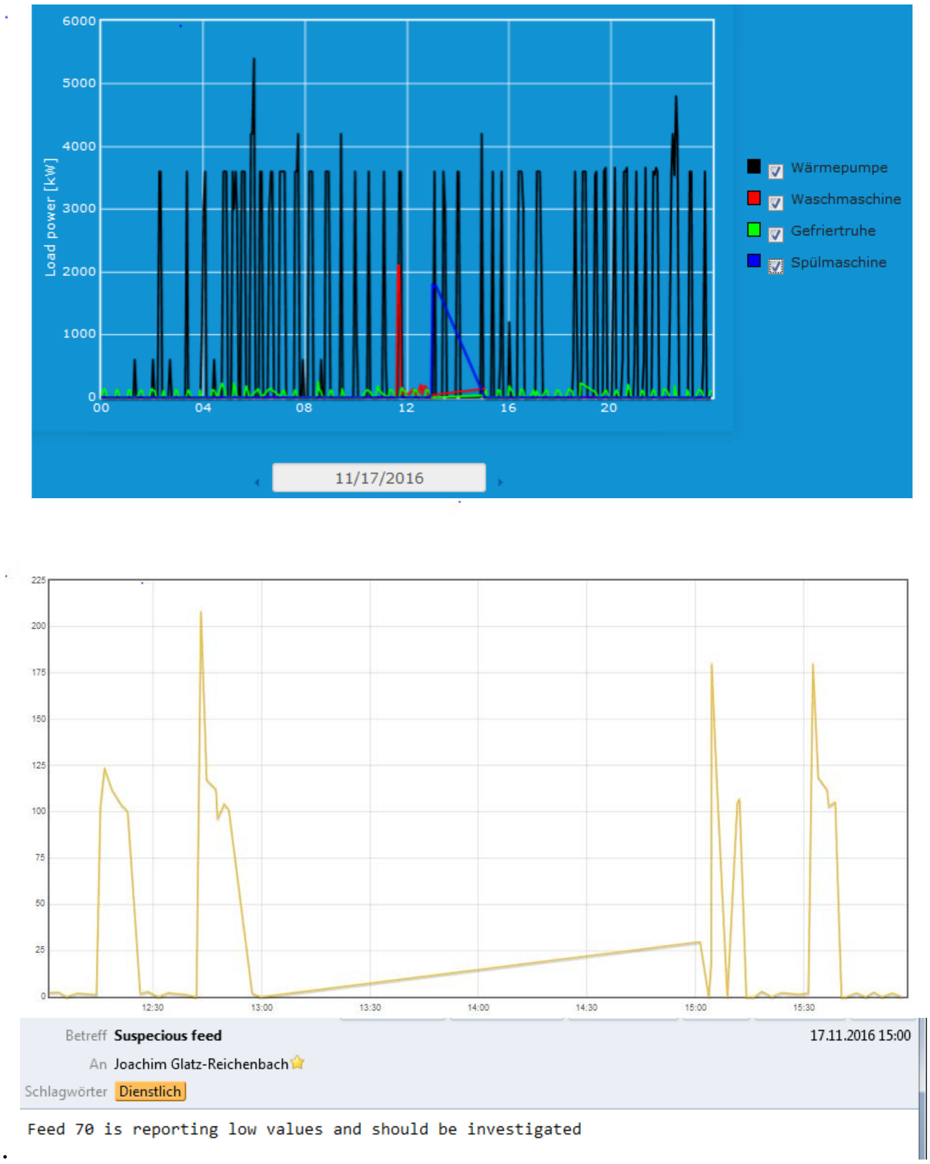


Figure 21: The monitored power consumption of the freezer in the top graph in green together displayed with other monitored appliances, and only the power consumption of the freezer in the middle graph and the sent out alert email message in the bottom part.

Starting from 1st Nov. 2016 with a high repeating rate bad freezer signals were detected which were caused as we found out later by a not communicated freezer´s position change!
So we recognized by remote failure detection that the power signal was not transmitted in the right way, but the measured and also transmitted T-sensor signal worked well, so the frozen food and goods were in no danger!
And furthermore there was no washing machine signal at all. The last washing run was detected on the 1st Nov. 2016, see Figure 22. A visit at the user-site location on the 16th Nov. 2016 cleared up the situation and we could restore the smart plug washing machine connection.

Due to the movement of the freezer the corresponding smart plug was not fully plugged into the power socket, the transmitter of the T-Sensor signal was inside the freezer, however, well working, and the smart plug belonging to the washing machine was off duty, just laid aside. Now smart plug and transmitter of T-signal were well mounted as can be seen from Figure 23.

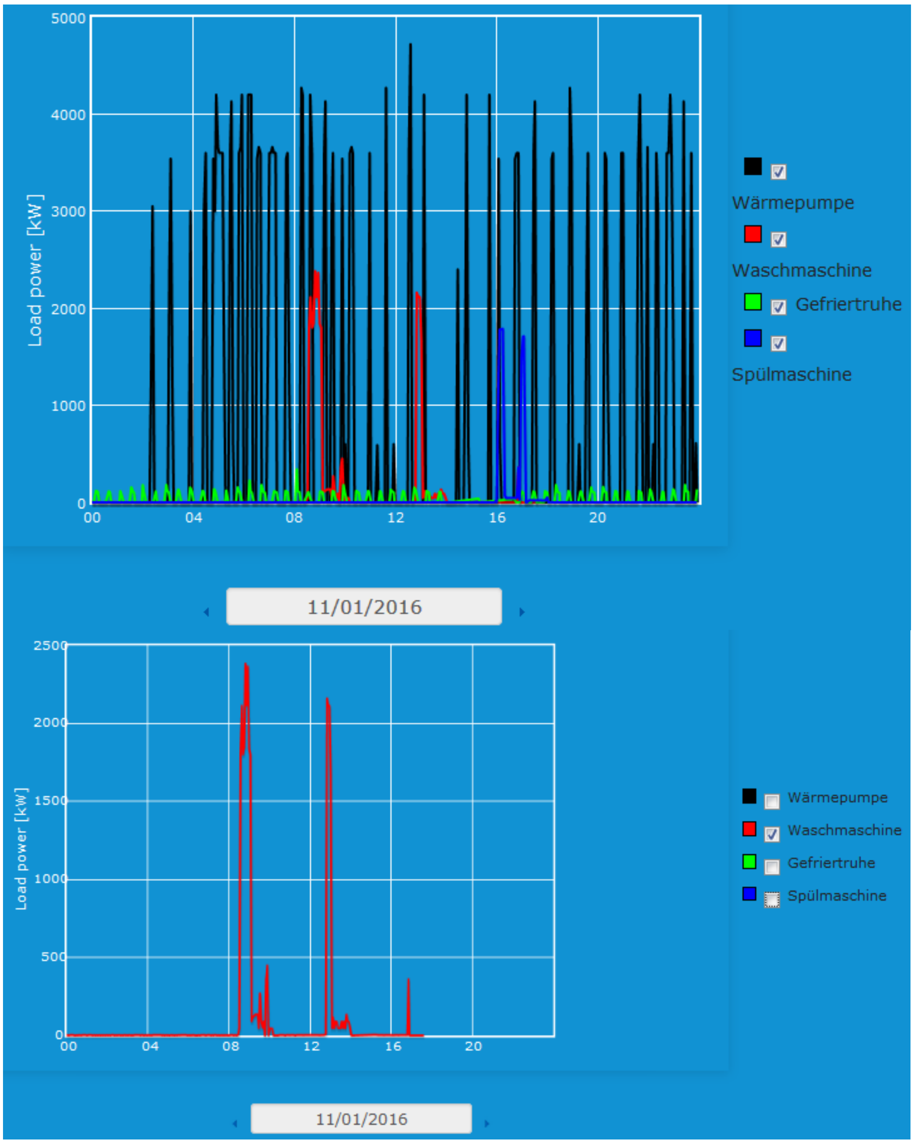
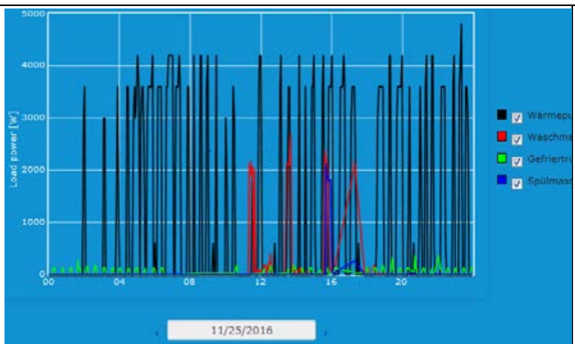


Figure 22: In the top part the power consumption of all four monitored appliances are displayed and in the bottom part only the washing machine consumption trace as stopped on the 1st Nov. 2016 at around 5pm.

Figure 23: Smart plug as plugged into the socket to measure the consumption of the freezer and the radio transmitter of the T-sensor inside the freezer on top of the socket.

Remarkable is for example, which occurs from time to time, that on the 23rd Mar. 2016 at around 10am the recorded appliances have a total power consumption of 4kW but the overall household consumption shows a value of about 7kW, which is not a resolution failure but obviously an additional not individually recorded consumer.

In this household from time to time very high power consumption up to 10kW could be measured which is probably the result of stacked power consumption of heat pump, dishwasher and/or washing machine and the not directly measured kitchen stove, see Figure 24.



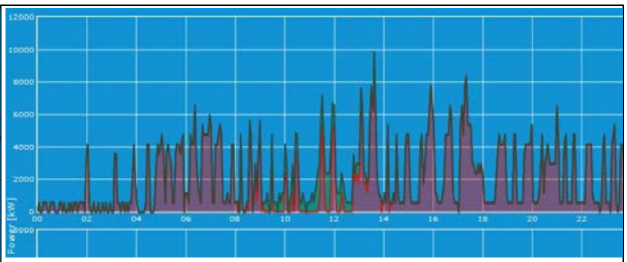


Figure 24: Left side shows the individually measured appliance consumptions and on top the overall household consumption of the 25th Nov. 2016.

Remark:
Interesting to mention the basic load of about 500W all over the year without heat pump consumption, which is of course clearly reduction for the non heating time period.

3.8 KN-08 (private house, 4 persons, annual consumption: 4MWh)

The Raspberry PI 1st generation run unstable with short lasting interruptions, but it was even worse that its working power was too low and therefore the system was very slow when displaying data by the GUI! From time to time the microcomputer was really overloaded and delivered the message: Can't connect to database, please verify credentials/configuration in settings.php Error message: Can't connect to local MySQL server through socket '/var/run/mysqld/mysqld.sock' (2) is fixed.
With the 8th Apr. 2016 a Raspberry PI 2nd generation was installed and from that date on was working fine and also the CUL radio transmission data transfer seemed to be more stabile.

On the 26th Apr. 2016 the CoSSMic team proposed by a telephone contact to switch the smart socket from the freezer and connect the smart socket to the laptop for safety reasons, that an undetected switch off of the freezer by the radio transmission data link won´t lead to warming-up of the freezer.

Furthermore to have more consumption power integrated in the household on the 10th Jun. 2016 at about 12pm a heater was installed instead of the freezer.

Another phone call with the user on the 22nd Sep. 2016 informed the CoSSMic team that the user wanted to have direct access to consumption loads of single devices, which could be done by direct access to emoncms feeds within a certain time resolution of i. e. < 180s. But one has to pay attention on the fact that we are measuring energy and differentiate these values in time to get the power values! Anyway a better resolution shows the energy feed.

During another phone call on the 23rd Nov. 2016 were two items mentioned and discussed:
A; The freezer which was taken from the trial already in Jun. 2016 and exchanged by a heater showed up for one day on the 23rd Nov. 2016, with an energy consumption of 0.6kWh.
B: There was no way to retrieve in the History view data from the past. But it was possible for the appliances view.

<u>Remark:</u>
The basic load of the user is about 550W which comes from stand-bys (phone, router, etc.) and freezer, fridge, heater pump, etc.

3.9 KN-09 (private house, 5 persons, annual consumption: 5MWh)

Due to individual household reasons the LAN access was not freely available because the network access point was buried under wall covers and a heavy board. So we had to install an own CoSSMic initiated WLAN for data transfer and communication at the users site.
Sometimes the internet access to the household´s Raspberry PI was interrupted for short time periods up to hours but could be recovered by remote reset by the CoSSMic maintenance team or manual switch off and on of the Raspberry PI by the user, himself.

The smart plug for monitoring the freezer was connected in Mar. 2016 but didn´t show current flow because the freezer´s power plug was connected to another socket. Smart plug was re-connected to the freezer from the 12th March 2016, 8pm on.
A check of the GUI on the 26th Apr. 2016 showed that weather forecast was ok, but still no device control active, appliances/day in W ok, and also grid feed and self consumption ok now for data displayed per day, per month and per year. Minor changes of the History display was necessary to rename the scale from kW to W of the daily display.
The system worked very steady and stabile, but with the 22nd Aug. 2016, the Raspberry PI was not available via internet anymore (internet access at user was ok!) → personal visit oat the user´s site on the 23rd Aug. 2016 was necessary for some clarifications and fixing. → Raspberry PI was switched manually off and on via externally installed circuit breaker as the switch. One possible reason was discussed that the Raspberry PI went off during the last contact session, probably due to internal overload with the result of data lost for the time period between 10am 22nd Aug. and 2pm 23rd Aug. 2016, see Figure 25.

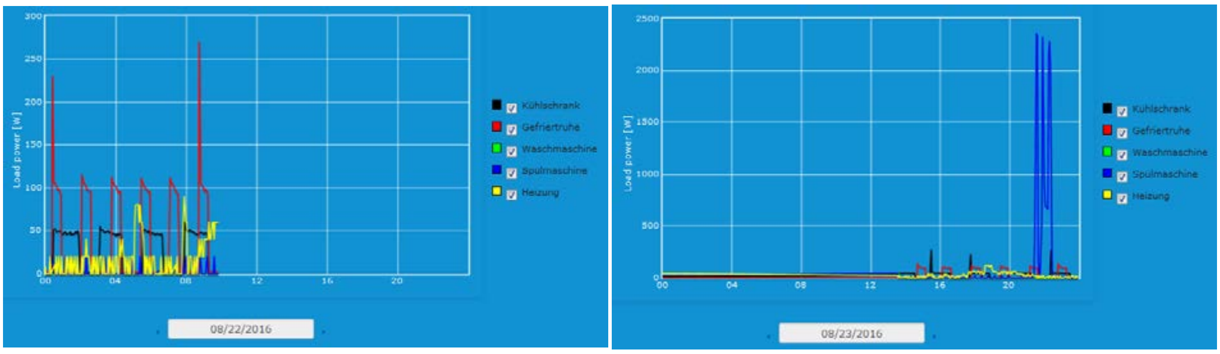


Figure 25: Appliances power consumption for the 22nd (left) and 23rd (right) Aug. 2016.

Sometimes users interruptions of the power flow of some devices could be monitored as for example the maintenance switch off of the freezer in order to clean the device, see Figure 26.

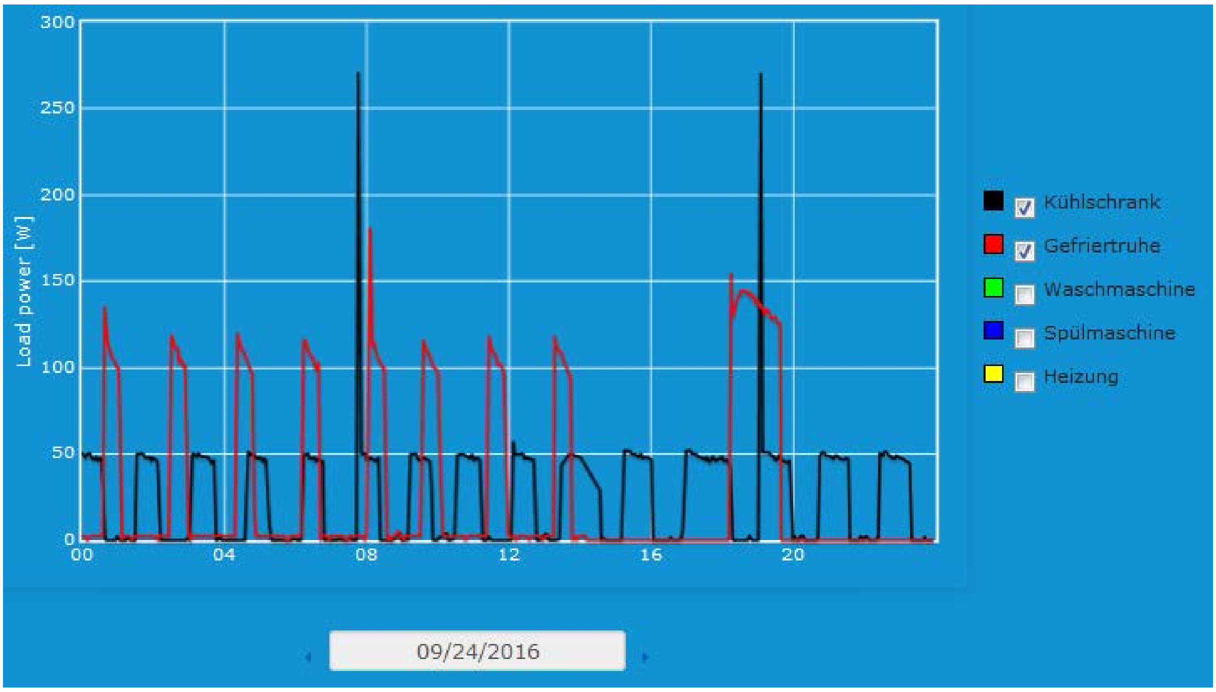


Figure 26: The consumption trace of the freezer (Gefriertruhe) as it was switched off without pulling from the smart plug for maintenance (i. e. cleaning purpose).

A change of the IP-Address might happen deliberately from time to time!
As it happened on the 10th Oct. 2016, the Raspberry PI had afterwards IP 192.168.1.109 as changed from IP 192.168.1.113. With the used WLAN broadcaster it was not possible to assign a static IP-Address.
But in order to get an easy access even with changing IP-Address it is necessary and possible to install Apples Bonjour, https://support.apple.com/kb/DL999?locale=en_US, which enables the user inside the local network to address via hostnames instead IPs, and so it is possible to reach the Raspberry PI via http://cossmic.local/emoncms for any IP-Address.
Sometimes the Raspberry PI was not found via VPN-internet access due to bad WLAN connectivity at the user´s site.
Sometimes single high value data points occurred probably triggered from internal disturbances of not yet known origin as e. g. monitored in the time period from 7th to 12th Nov. 2016, see Figure 27.

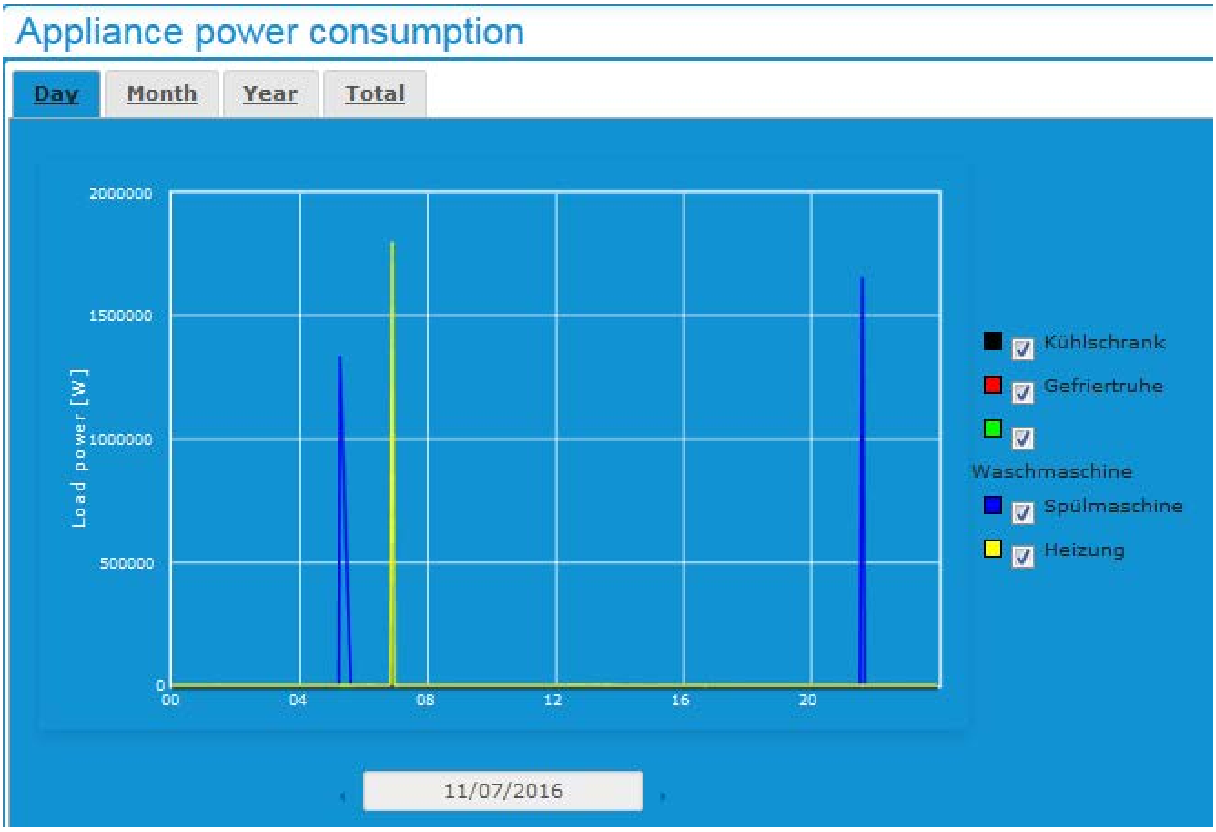


Figure 27: Displayed disturbances on the 7th Nov. 2016 on the data branches for the pump of the heating system (i. e. Heizung) and the dishwasher (i. e. Spülmaschine).

Remark:
One feature came up, which the user found remarkable: The measured fact that the pump of the household heating system needs during the not heating seasonal time period still about 30% of the power of the winter months, which seems to be surprisingly high in consumption!

3.10 **KN-10 (private house, 4 persons, annual consumption: 4.5MWh)**

The private user KN10 was selected to run the developed software first before it could be implemented into the entire neighbourhood. On the 8th Mar. 2016 the external input of weather information as an icon was running, and an early version of the scheduler with task detection was established, continuously tested, and updated. The displayed consumption of the appliances/day in W was ok, also the grid feed and self consumption in the History view was ok in colour and also the scaling was shifted from kW to W.
The refrigerator showed an anomaly between the 10th 8pm and 17th 12pm Jun. 2016 but w/o power consumption correlation.
Also the freezer showed non typical power consumption between 7pm 12th and 8am 24th Sep. 2016.

Furthermore a comparison of the energy consumption of freezer and refrigerator brought up the interesting detail that they have the same and reasonable energy integral values on a daily basis for example on the 14th Jul. 2016 but when comparing the monthly consumption $E_{freezer} = 1/5\ E_{refrigerator}$ (!), which seemed to be a wrong integration behind the values and had been fixed in the meantime.

What were the major changes during the trial?
The detection of the single run devices with smart plugs worked at other user sites, but had been transferred for smart meters as used at KN10. According to the observations, we did not need to tune

the parameters. The failed detection was caused by a communication problem with the meters, based on signal cable reflection, and resulted sometimes in failure of writing the measured data into the local storage of the Raspberry PI. Furthermore the sampling period was set to 15s, well known that it had to be more frequent for our purpose. Thus the cabling was improved by adding end cap resistors.

In the course of the trial single point arbitrary large value data occurred, which were probably caused by internal cable reflexions between the small device monitoring smart meters and the main AS1440 Elster smart meter. They could be almost completely eliminated just by introducing a capping end resistor for improved impedance matching.

One example can be seen from Figure 28 that occasionally disturbances manifested as power sparks in the total consumption path (24kW) and in the PV generation path (4kW) were created, for example on the Sylvester day 2016.

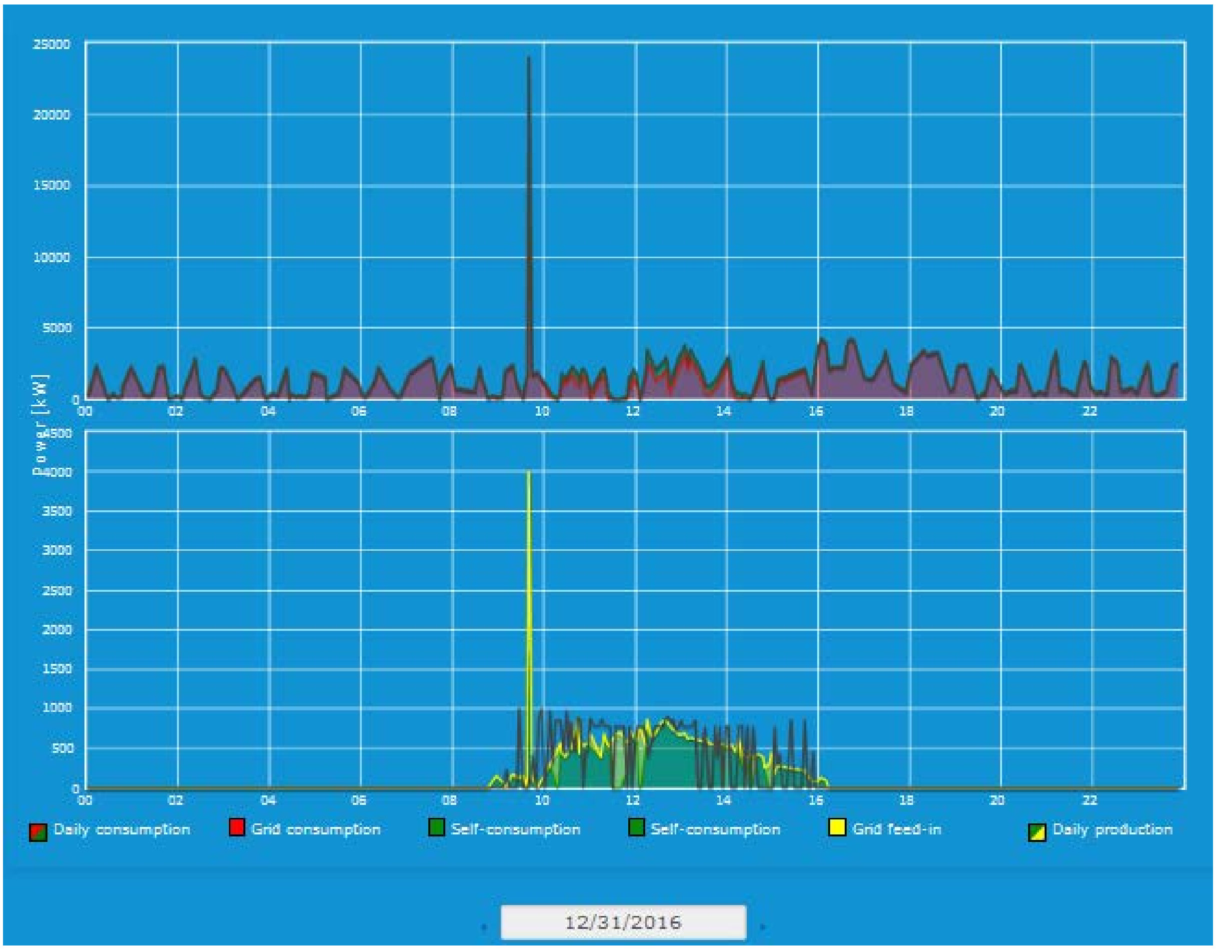


Figure 28: Total consumption (top) and PV production (bottom) of the 31st Dec. 2016 with disturbances at around 9.30am in both feeds, input from grid (top) and input into grid (bottom).

As a good example for comparison for the acquisition of consumption and generation data one may consult Figure 29 for a summer day in 2016.

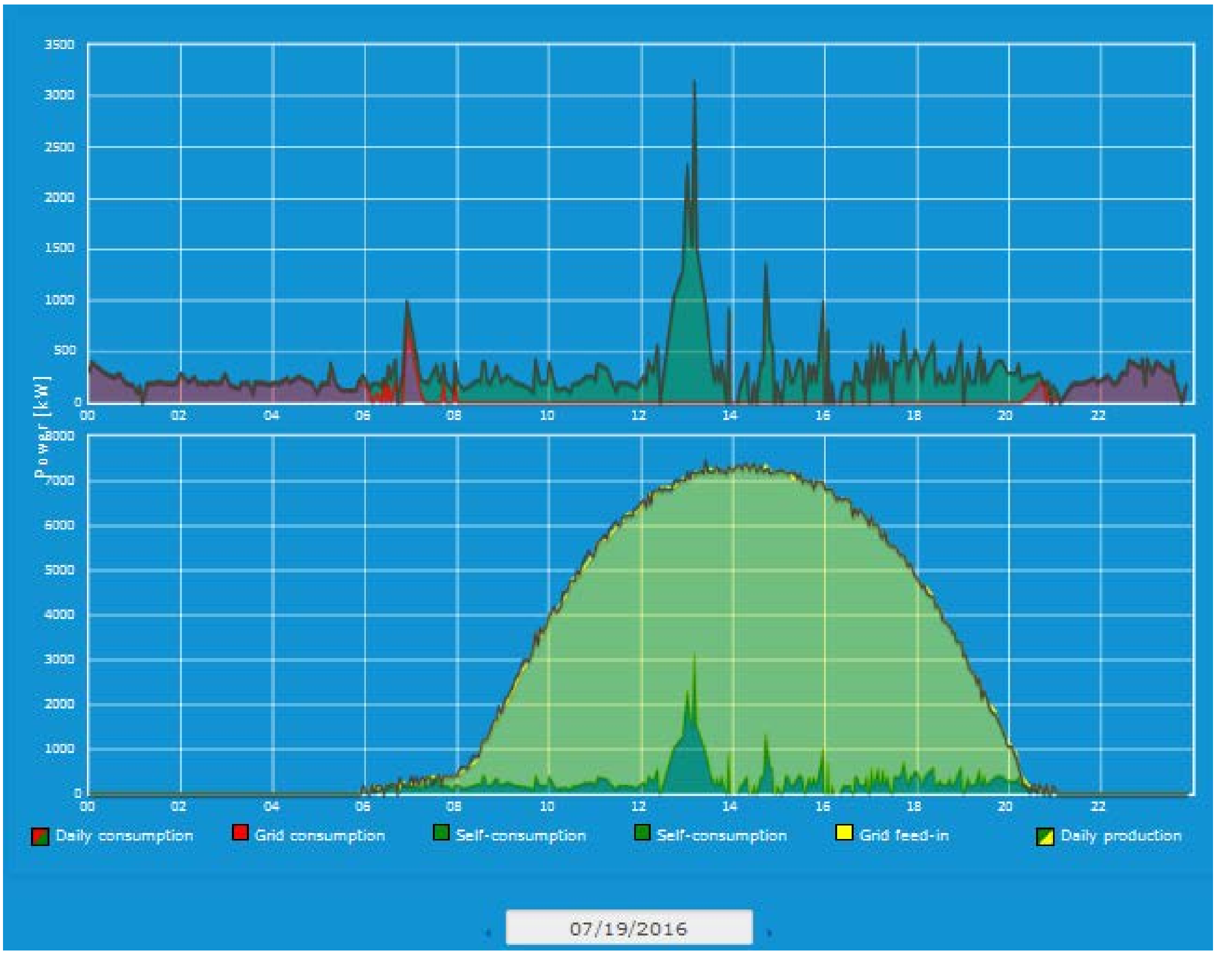


Figure 29: The top part shows the total consumption (red from grid, green from own PV system). The bottom part shows the total PV production again in green the self consumption and in yellow the part fed into the grid.

Finally the CoSSMic team received on the 5th Jan. 2017 the email from the user:

Dear colleges,
Yesterday evening KN10 had to deal with a non finished washing machine (less than 20% of the program was done). The electricity was still off in the evening. We had to use an extension cable to another (not related to CoSSMic) plug to finish the program.
Therefore, because this was not for the first time and because CoSSMic is over now, we disassembled the switches and removed also the smart plug for the fridge. Only the switch for the heat pump is still active. The meters are still active (besides that one for the fridge) so that the energy consumption can still be tracked.

Best regards,
Kristian

3.11 **KN-11 (private apartment, 6 persons, annual consumption: 2.4MWh)**

The overall detection storage and display of the appliances consumption was continuously running well.
Nevertheless it occurred sometimes that the WLAN access to Internet was cut down, e. g. off since 17th until 29th May probably due to unforeseen switch off at the vacations! Thus ok again after the Raspberry PI had been reset on site off/on and was on duty again since 3rd Jun. 2016 about 1pm. Again such a downtime this occurred on the 24th Aug. 2016, and was back again after hours without loss of data
By the way as it is a household with several pupils as members the Pentecost holidays were clearly visible from the dishwasher and washing machine activities.

From the 10th Oct. 2016 the user installed a new WLAN access, which is working up to now without break down again with access as can be seen in Figure 30.

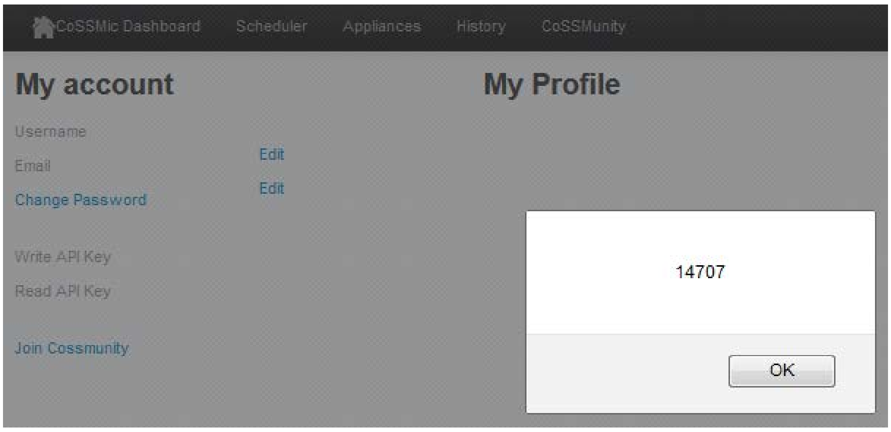


Figure 30: The new start page of the GUI for the new internet provider/modem access.

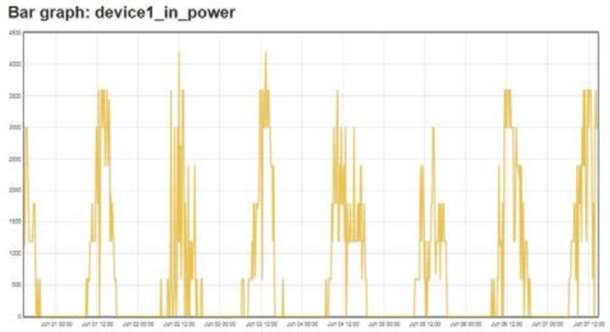
3.12 **KN-12 (private house, 4 persons, annual consumption: 5.5MWh)**

Right from the trial start i instabilities were continuously observed during the data transmission from the smart plugs to the receiver at the Raspberry PI which was mounted in a metallic electrical switchboard cabinet.
On the 15th Apr. 2016 from 9.30am on the CUL was switched off for the reason to shift the Raspberry PI from the shielded metal cabinet to an external plastic made box. Afterwards it has been forgotten to reset manually the smart sockets to be switched on again.
So from this time on the freezer was off and reached slowly temperatures above freezing point and the content started thawing and finally to rotten.
We could arrange a solution with the involved user to his satisfaction to overcome the uncomfortable situation.
This experience triggered our activities to integrate power control of the monitored devices and was initially started by the integration in the freezer´s feed of KN07, see for example Figure 21.

On the 10th May 2016 a Tesla Energy Powerwall battery system with 7kWh (i.e. exactly 6.4kWh) maximum energy rating and 3.3kW power rating was installed together with a 6.36kWp partly flat and to the north oriented PV system and an inverter and control system from solaredge™.
Additional to these already mentioned 12x265Wp flat on a garage rooftop mounted PV modules with 2° inclination and 205° orientation, see Figure 32, 12 more of the same modules were installed and oriented almost to the north (25°east) with 35° inclination.

Access to the data of the storage-PV-system could be realised via a protected account to the portal of solaredge™ (https://monitoring.solaredge.com/solaredge-web/p/site/249379/#/dashboard).

Since this time almost no daylight grid consumption has been observed, consult Figure 33, up to autumn in this household and a comparison of the overall grid consumption shows a reduction of about 100-150kWh/month, which is about 3.3-5.0kWh/day.
Up to now no direct integration of the Tesla Powerwall / SolarEdge™ system into the CoSSMic system was possible. But the generation and storage data were available by solar edge controlling system also in csv-format.



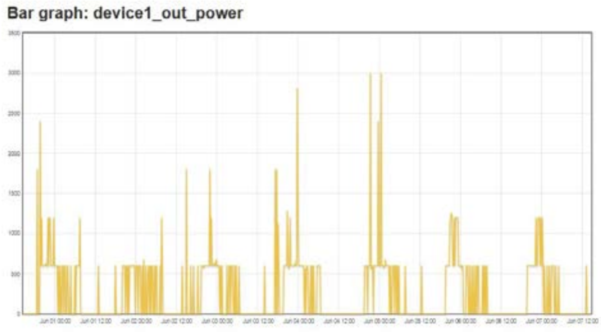


Figure 31: Left picture shows the PV power generation of the 6.34kWp system which does not go into the new installed 3.3kW Tesla battery and the right picture shows the power as delivered from the public grid to KN12.

Figure 31 shows the power flow in/out as measured with the main smart meter Elster AS1440 between 2.30pm and 2.30pm from 31st May to 7th June 2016, with the already installed stationary Tesla Power battery. We see only the power generated part by the recently installed new PV panels which doesn´t go into the Tesla battery and the part which comes from the grid always during the time span of two PV generation peaks.

After the installation of the 7kWh Tesla Power battery one can see a clear drop in the grid consumption, see Figure 33 and Figure 34.

Figure 32: Right: The Tesla Power battery with integrated solaredge™ interface and inverter; left: The flat roof top mounted PV module as recently mounted in May 2016 during the trial period.

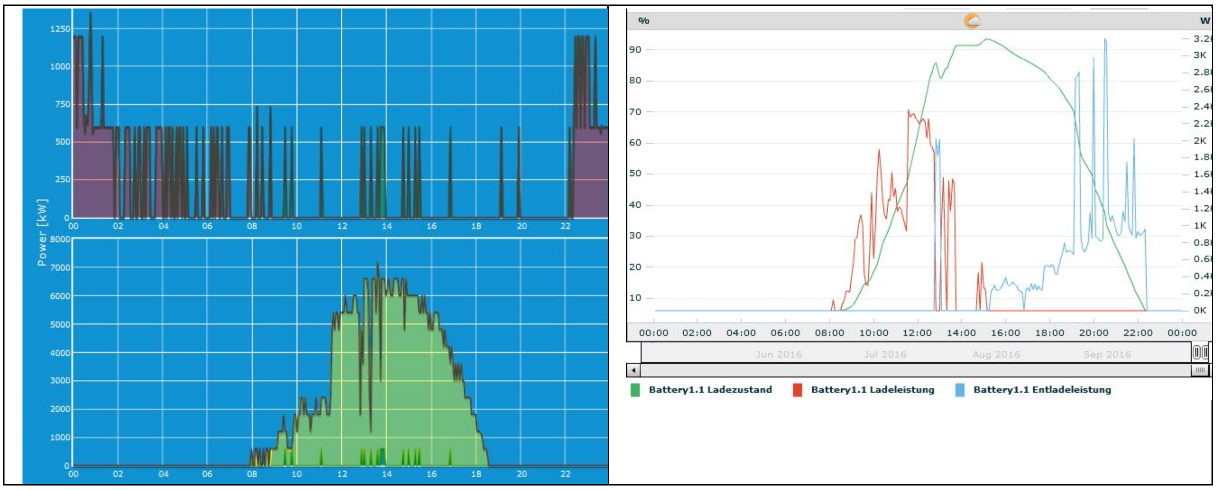


Figure 33: Left: CoSSMic GUI display of the PV generation, bottom and overall grid consumption top graph. Right: Solaredge™ power flow in and out of the battery and the battery SOC, all for the 26th Sep. 2016.

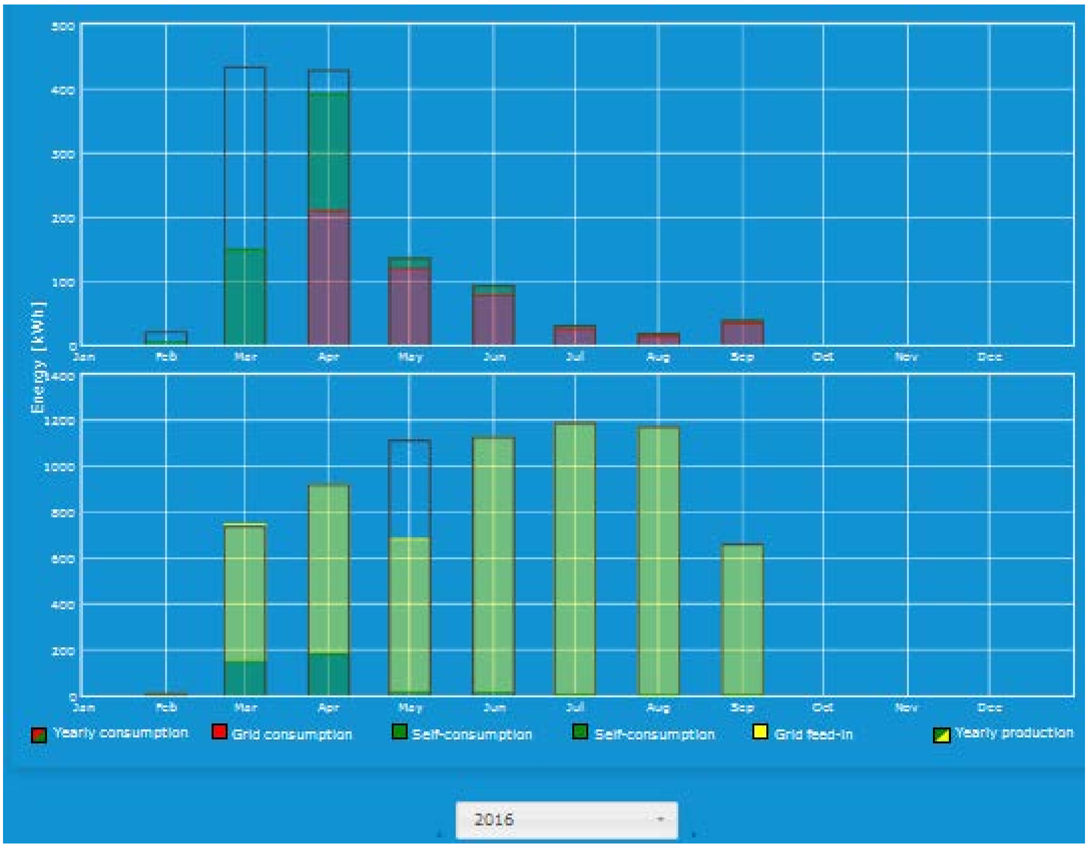


Figure 34: PV energy yield in green (light green shows the feed into public grid and the dark green the self consumption amount) and the consumption from the grid (red).

Remarks:

A check on the 20th Jul. 2016 and again in Aug. 2016 of the smart plugs connections resulted in the following observations:

The washing machine smart plug remained at the washing machine, the dishwasher smart plug is now connected to the coffee maker and the freezer smart plug was first connected to a power supply and is now connected since Aug. 2016 to the microwave oven.

There are still small transfer peaks of the order of Watts visible with irregular repetition but always longer in time separation than 3 minutes!

3.13 **Common remarks:**

- The community generation and consumption of all six KN private users shows deliberately strong scatter in the measured data.
- There are on the GUI displayed data runaways and data scatter probably due to transmission faults. Sometimes there are these data scatter also visible on the measured data by the feeds but sometimes only the scattered data without real measured data are displayed.
- There are still minor issues to optimize the CoSSMic GUI to improve the usability for the users, which are not essentially influencing the functionality of the CoSSMic system.
- At some users the units of the GUI in the History view of the day are not yet refreshed by the latest version, i. e. the power is given in W but the unit is still in kW, however, the displayed energy values over a month and a year are alright.

4 The users and the installed equipment at the Caserta trial site

In the following chapter individual details of the accomplished work at the Caserta trial site is summarized for each integrated single user with respect on the installed hardware, the gateway technology and the overall system architecture.

For the Konstanz trial site this was already done in the second project reporting period and concluded in D5.3. Since the installations in Caserta were delayed the corresponding information is included here.

The Province of Caserta developed all the planned activities described in the project plan. There has been a lack of alignment with installation and data collection activities at Konstanz mainly because of the time needed for activating the necessary bureaucratic administrative procedures required by a public body.

Moreover during the planning of installations the administration body of Province of Caserta has also required that, in order to maximize the impact of CoSSMic, that the new smart metering appliances were compliant with already existing equipment used in a different national project developed by the Province of Caserta for monitoring energy and environmental parameters.

After the approval of planned installation by the authority, for the purchase and installation of necessary equipments a public call has been opened and a contract has been awarded.

The installation of smart meters which were different from the ones used in Konstanz, on one side has implied the opportunity to extend the kind of devices used by CoSSMic and to increase the heterogeneity of trials, on the other side has required additional effort by SUN for the development new drivers, which are part of the released open source software.

This different time schedule has allowed SUN to buy, install and test an upgraded version of computer hardware (i. e. Raspberry PI 3) increasing again the heterogeneity of installations and the improvement, in terms of performance, of execution environment of CoSSMic software.

4.1 CE01: I.T.C Alfonso Gallo – Aversa

Figure 35: - I.T.C Alfonso Gallo – Aversa (CE)

The following list describes the hardware installed inside the CE01 site:

- Raspberry PI
- Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet
- 2x Energy Meter with 6 pick-up coils ZR-WMETERS-100-EM, **ZR-HMETER3P-EM** Energy Meter three-phase; 3P before and 3P past the consumer → consumption
- 2x **ZR-REP-E230M**, ZigBee ZR-REP-E230M Repeater

Below follows a sketch of the system architecture.

4.1.1 System Architecture

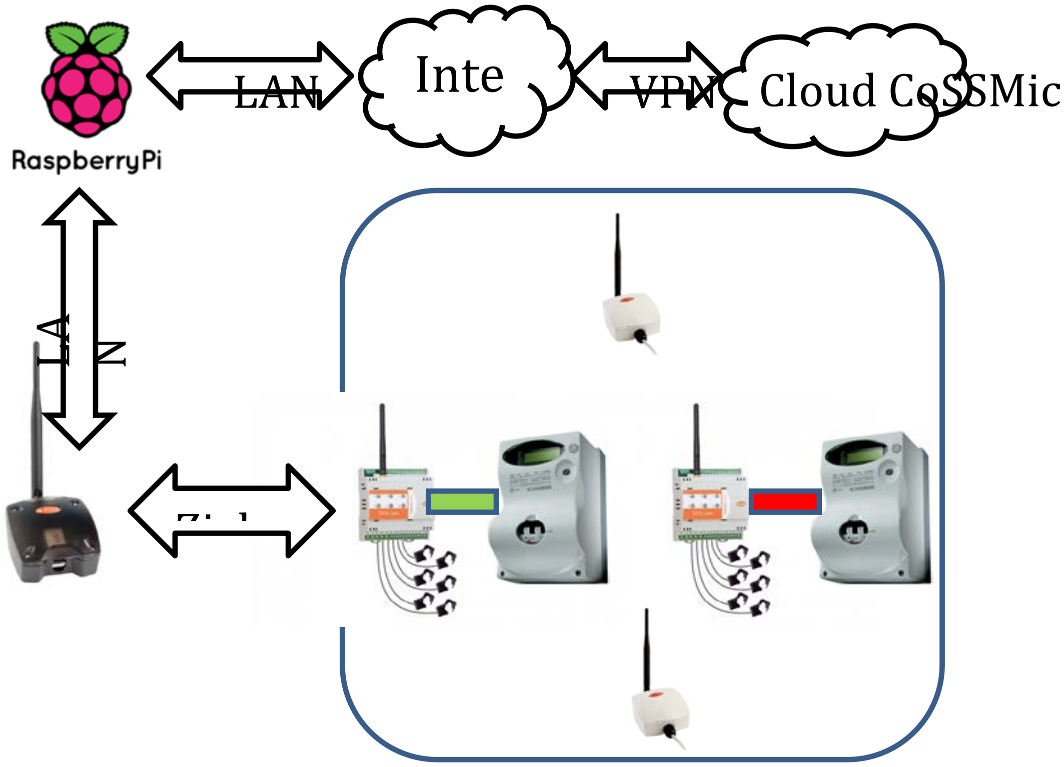


Figure 36: – System Architecture I.T.C Alfonso Gallo - Aversa (CE)

4.1.2 Installation and configuration Components

The following list describes the start of the installation process and the configuration of the hardware at the CE01site.

- Check of the internet access either by WLAN or LAN;
- Installation and configuration of a Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet within the network infrastructure;
- Installation and configuration 2 **ZR-HMETER3P-EM** Energy Meter three-phase;
- Installation and configuration 2 **ZR-REP-E230M**, ZigBee ZR-REP-E230M Repeater to extend the radio range of the devices;
- Installation and Configuration Raspberry PI, within the network infrastructure to allow the processing of data collected by the two Energy Meter ZigBee;
- Installation and Configuration of a VPN (Virtual Private Network) to allow the transmission of data collected locally from Raspberry PI to cloud CoSSMic.

Below is a table with the technical details of the configurations (Id Device and IP Address):

Raspberry PI		
Hostname	**IP Address**	**IP Address VPN**
ce01	192.168.13.253	10.8.0.101
	255.255.255.0	255.255.255.255
	192.168.13.1	10.8.0.1
Gateway ZC-GW-ETH-EM	**Energy Meter ZR-HMETER3P-EM**	
IP Address	**ID**	
192.168.13.254	125	
255.255.255.0	126	
192.168.13.1		

4.1.3 Graphic of the measures of energy meter

See for data inputs 4.2.3, 4.3.3 and 4.43, respectively.

4.2 CE02: Swimming Pool

Figure 37: – Swimming Pool

The following list describes the hardware installed inside the CE02 site:

- 2x Raspberry PI
- Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet
- 2x Energy Meter with 6 pick-up coils ZR-WMETERS-100-EM, **ZR-HMETER3P-EM** Energy Meter three-phase; 3P before and 3P past the consumer → consumption

  Below follows a sketch of the system architecture.

4.2.1 System Architecture

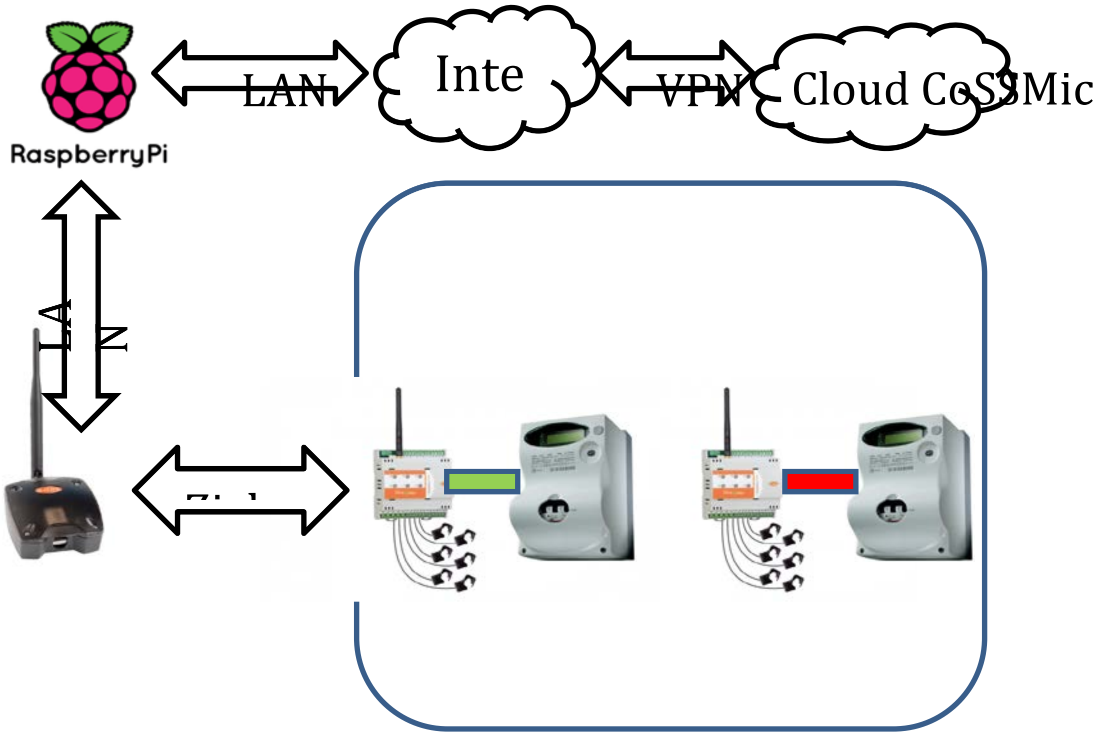


Figure 38: - System Architecture Swimming pool (CE)

4.2.2 Installation and configuration Components

The following list describes the start of the installation process and the configuration of the hardware table at the CE02 site.

- Check of the internet access either by WLAN or LAN;
- Installation and configuration of a Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet within the network infrastructure;
- Installation and configuration 2 **ZR-HMETER3P-EM** Energy Meter three-phase;
- Installation and Configuration Raspberry PI, within the network infrastructure to allow the processing of data collected by the two Energy Meter ZigBee;
- Installation and Configuration of a VPN (Virtual Private Network) to allow the transmission of data collected locally from Raspberry PI to cloud CoSSMic.

Below is a table with the technical details of the configurations (Id Device and IP Address):

Raspberry PI		
Hostname	IP Address	IP Address VPN

ce02	192.168.124.135	10.8.0.102
	255.255.255.0	255.255.255.255
	192.168.40.1	10.8.0.1
Gateway 4noks	**Energy Meter**	
IP Address	**ID**	
192.168.124.133	125	
255.255.255.0	126	
192.168.124.1		

Unfortunately it was not possible to transfer data from this Caserta site user to the cloud server because of internet access problems.

4.2.3 Graphic of the measures of energy meter

Measures of PV production have been started since September 2015. Such metering has been implemented using the web interface of available Inverters and pushing the data directly to the Cloud. Long period of service unavailability have been caused by network problems, hardware problems and disconnections.
After that other measures have been almost regularly collected since November 2016. Available data include produced energy, direct power, current and temperature of different PV strings.
Some images are provided.
Smart meters have been installed, but independently connected to a different Raspberry PI.

Figure 39: Comparison of consumed power and produced power by single strings.

Figure 40: Daily produced (bottom) and consumed (top) power of a day in Oct. 2016.

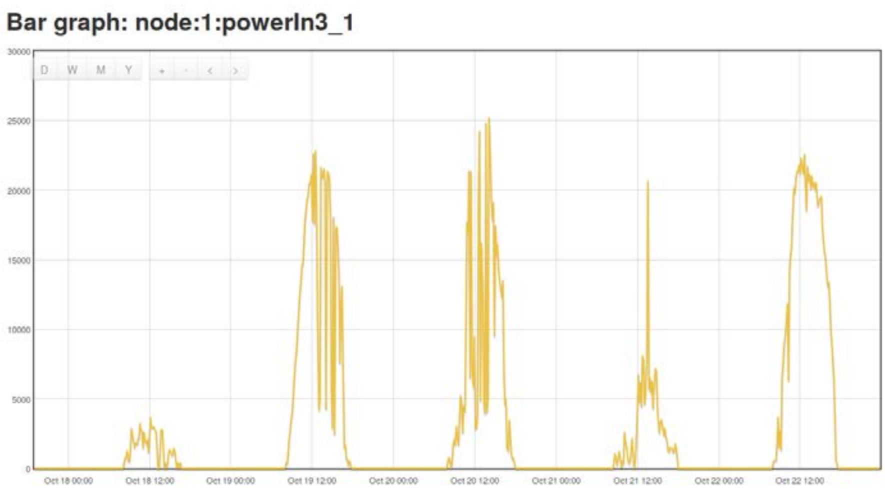


Figure 41: Comparison of PV power production over different days in Oct. 2016.

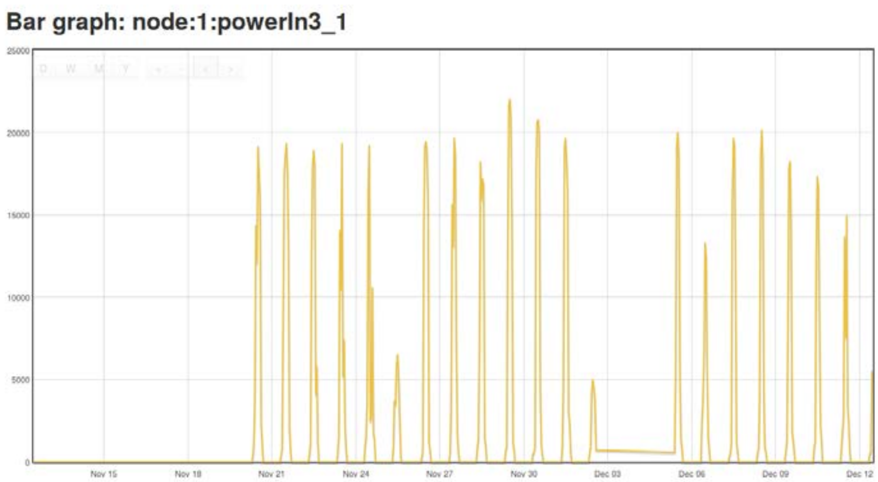


Figure 42: Comparison of PV power production over different months and downtime.

4.3 CE03: I.T.S Michelangelo Buonarroti – Caserta

Figure 43: - I.T.C Michele Buonarroti (CE)

The following list describes the hardware installed inside the CE03 site:

- Raspberry PI
- Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet
- 3x Energy Meter with 6 pick-up coils ZR-WMETERS-100-EM, **ZR-HMETER3P-EM** Energy Meter three-phase; 3P before and 3P past the consumer → consumption
- 1x **ZR-REP-E230M**, ZigBee ZR-REP-E230M Repeater

Below follows a sketch of the system architecture.

4.3.1 System Architecture

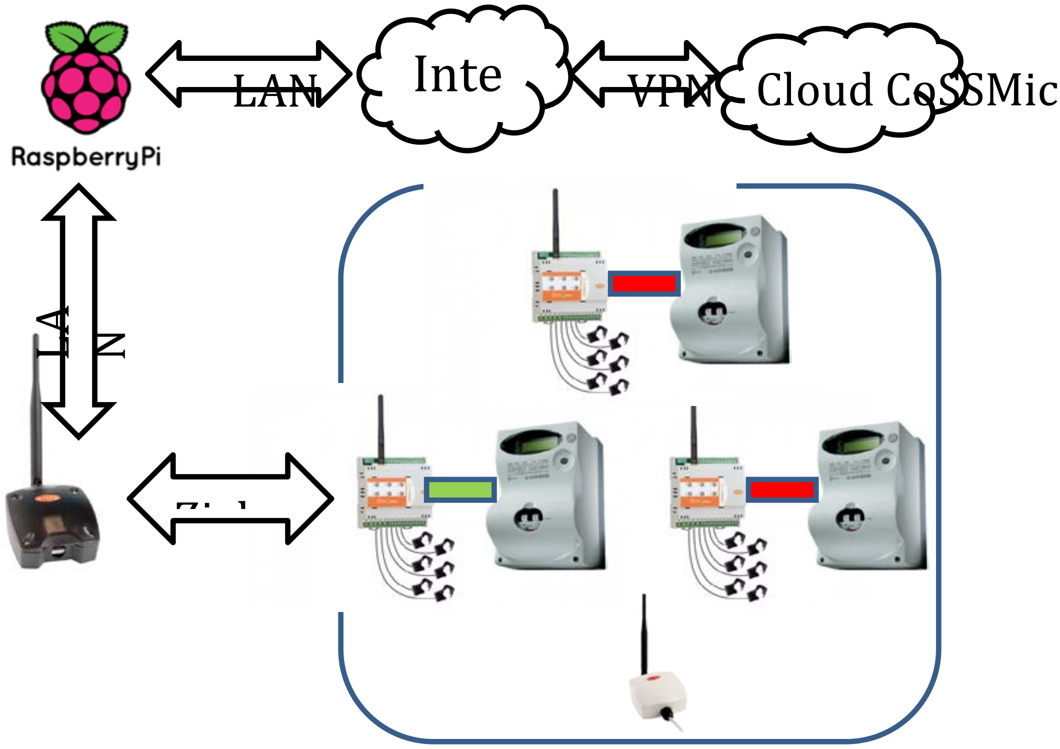


Figure 44: - System Architecture I.T.C Michelangelo Buonarroti (CE)

4.3.2 Installation and configuration Components

The following list describes the start of the installation process and the configuration of the hardware at the CE03 site.

- Check of the internet access either by WLAN or LAN;
- Installation and configuration of a Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet within the network infrastructure;
- Installation and configuration 3 **ZR-HMETER3P-EM** Energy Meter three-phase;
- Installation and configuration 1 **ZR-REP-E230M**, ZigBee ZR-REP-E230M Repeater to extend the radio range of the devices;
- Installation and Configuration Raspberry PI, within the network infrastructure to allow the processing of data collected by the three Energy Meter ZigBee;
- Installation and Configuration of a VPN (Virtual Private Network) to allow the transmission of data collected locally from Raspberry PI to cloud CoSSMic.

Below is a table with the technical details of the configurations (Id Device and IP Address):

Raspberry PI		
Hostname	IP Address	IP Address VPN

ce03	192.168.1.135	10.8.0.103
	255.255.255.0	255.255.255.255
	192.168.1.1	10.8.0.1
Gateway 4noks	**Energy Meter**	
IP Address	**ID**	
192.168.1.133	124	
255.255.255.0	125	
192.168.1.1	126	

4.3.3 Graphic of the measures of energy meter

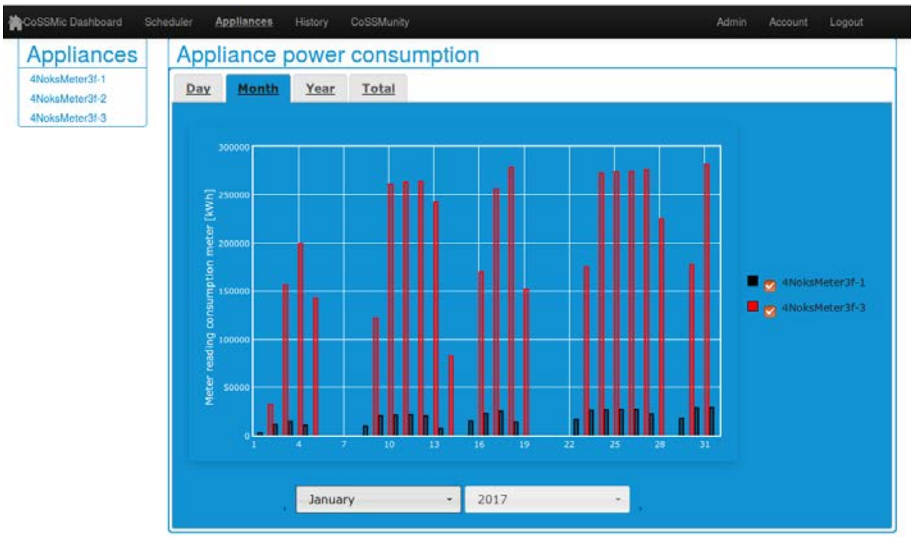


Figure 45: Monthly energy consumption measured by smart meters.

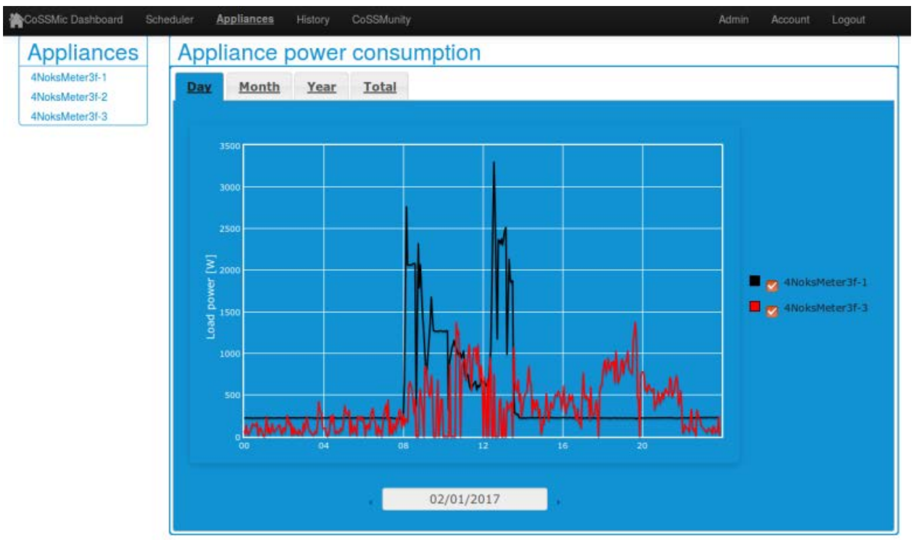


Figure 46: Example of the daily power consumption measured by smart meters.

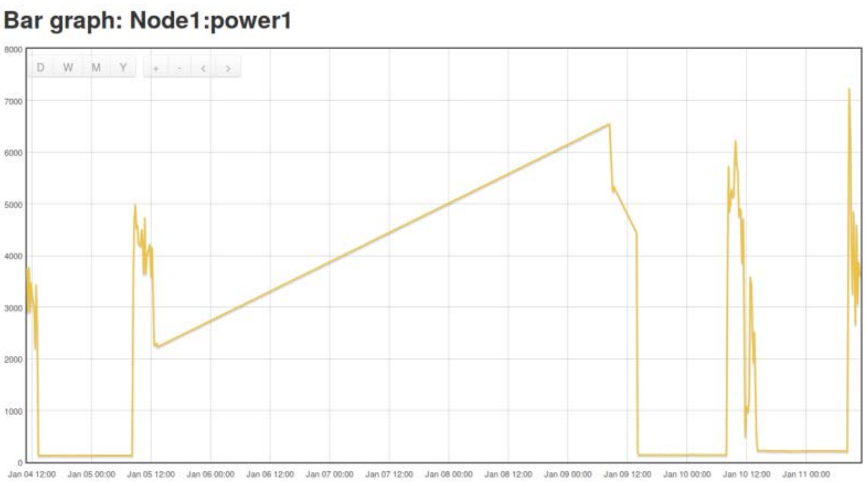


Figure 47: Example of smart meter downtime.

4.4 CE04: I.S.I.S Galileo Ferraris - Caserta

Figure 48: - I.S.I.S Galileo Ferraris (CE)

The following list describes the hardware installed inside the CE04 site:

Raspberry PI
Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet

2x Energy Meter with 6 pick-up coils ZR-WMETERS-100-EM, **ZR-HMETER3P-EM** Energy Meter three-phase; 3P before and 3P past the consumer → consumption
2x **ZR-REP-E230M**, ZigBee ZR-REP-E230M Repeater

Below follows a sketch of the system architecture.

4.4.1 System Architecture

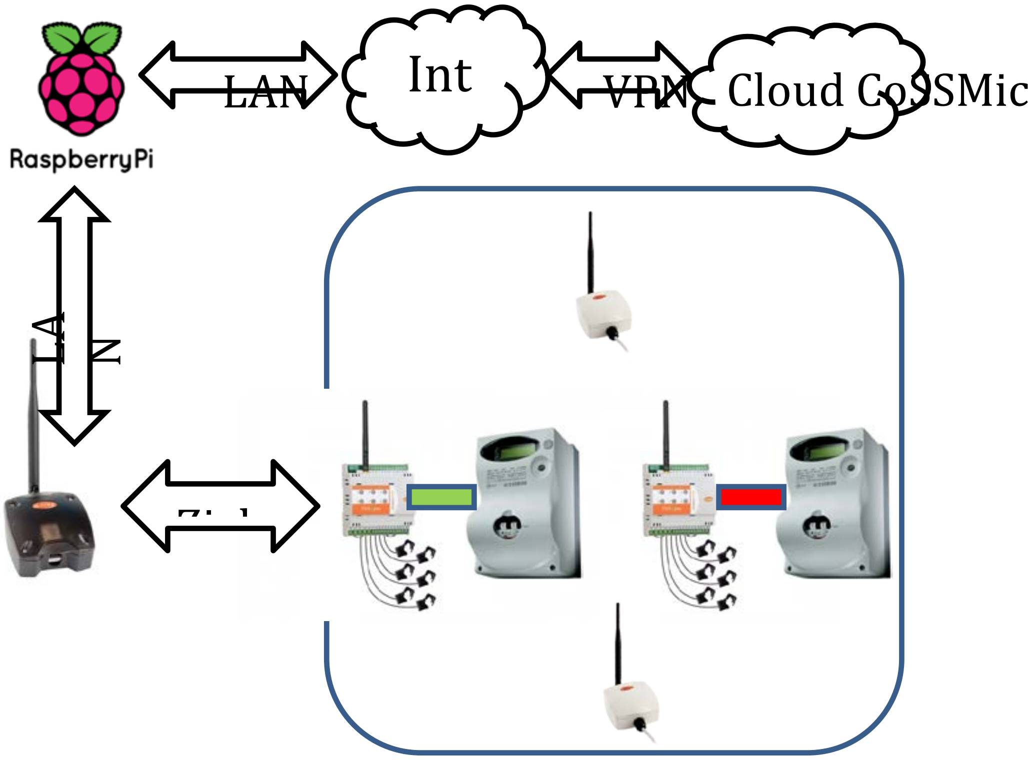


Figure 49: - System Architecture I.S.I.S Galileo Ferraris (CE)

4.4.2 Installation and configuration Components

The following list describes the start of the installation process and the configuration of the hardware at the CE04 site.

- Check of the internet access either by WLAN or LAN;
- Installation and configuration of a Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet within the network infrastructure;
- Installation and configuration 2 **ZR-HMETER3P-EM** Energy Meter three-phase;
- Installation and configuration 2 **ZR-REP-E230M**, ZigBee ZR-REP-E230M Repeater to extend the radio range of the devices;
- Installation and Configuration Raspberry PI, within the network infrastructure to allow the processing of data collected by the two Energy Meter ZigBee;
- Installation and Configuration of a VPN (Virtual Private Network) to allow the transmission of data collected locally from Raspberry PI to cloud CoSSMic.

Below is a table with the technical details of the configurations (Id Device and IP Address):

Raspberry PI		
Hostname	**IP Address**	**IP Address VPN**
ce04	192.168.1.135	10.8.0.104
	255.255.255.0	255.255.255.255
	192.168.1.1	10.8.0.1
Gateway 4noks	**Energy Meter**	
IP Address	**ID**	
192.168.1.133	126	
255.255.255.0	125	
192.168.1.1		

4.4.3 Graphic of the measures of energy meter

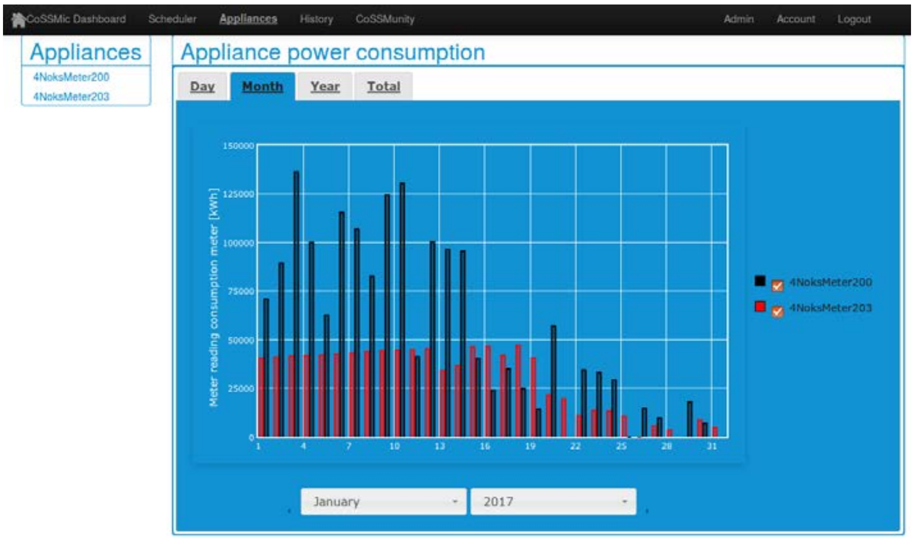


Figure 50: Example of energy consumption over different days.

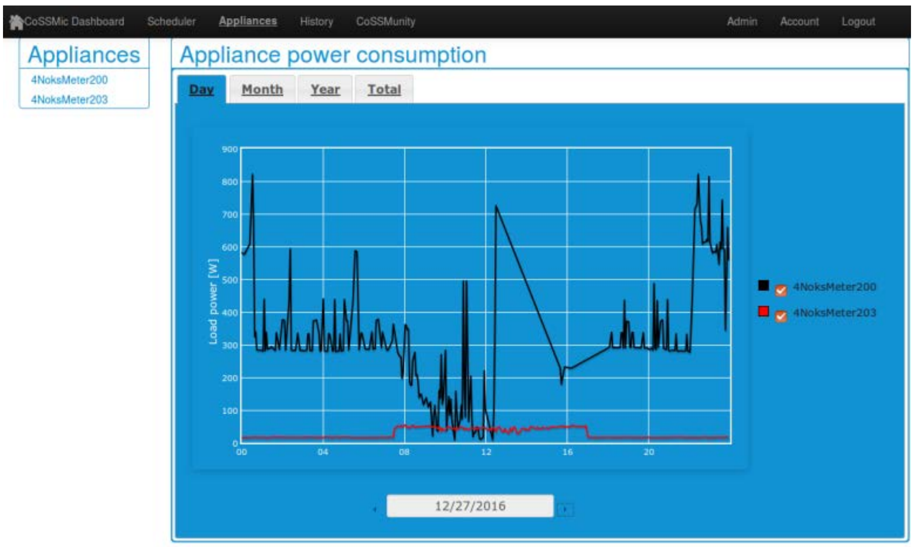


Figure 51: Comparison of daily power consumption.

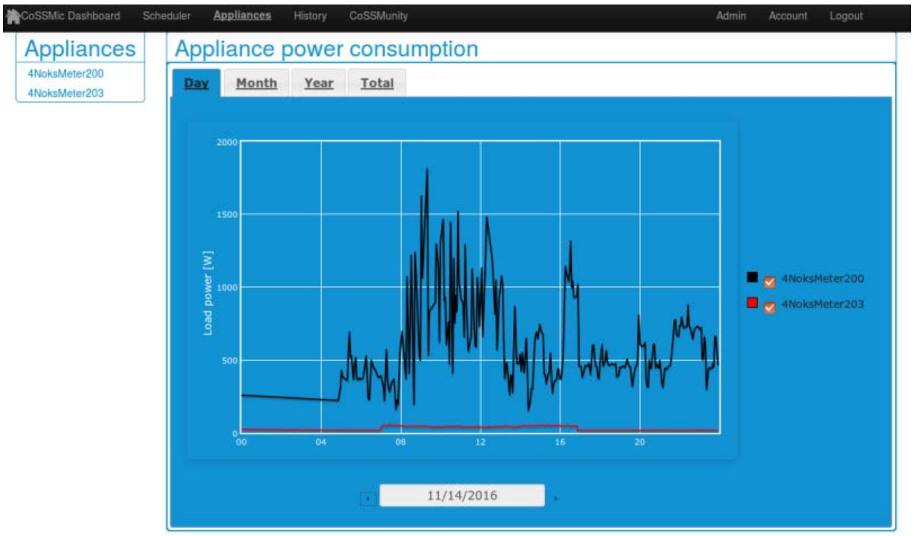


Figure 52: Example of daily power consumption.

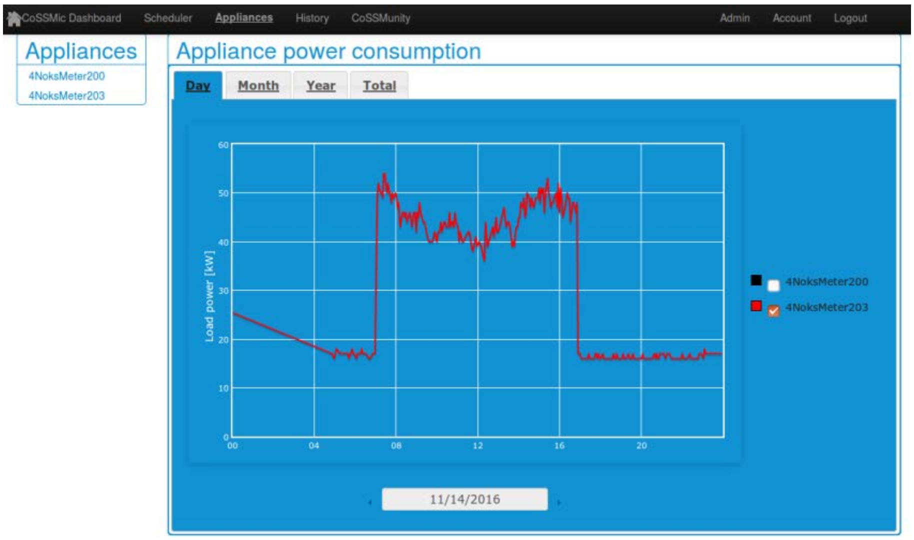


Figure 53: Detail of power consumption by a single smart meter.

4.5 CE05: Private User

The following list describes the hardware installed inside the CE05 site:

- Raspberry PI
- Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet
- 1x Energy Meter with 6 pick-up coils ZR-WMETERS-100-EM, **ZR-HMETER3P-EM** Energy Meter three-phase; 3P before and 3P past the consumer → consumption

  Below follows a sketch of the system architecture.

4.5.1 *System Architecture*

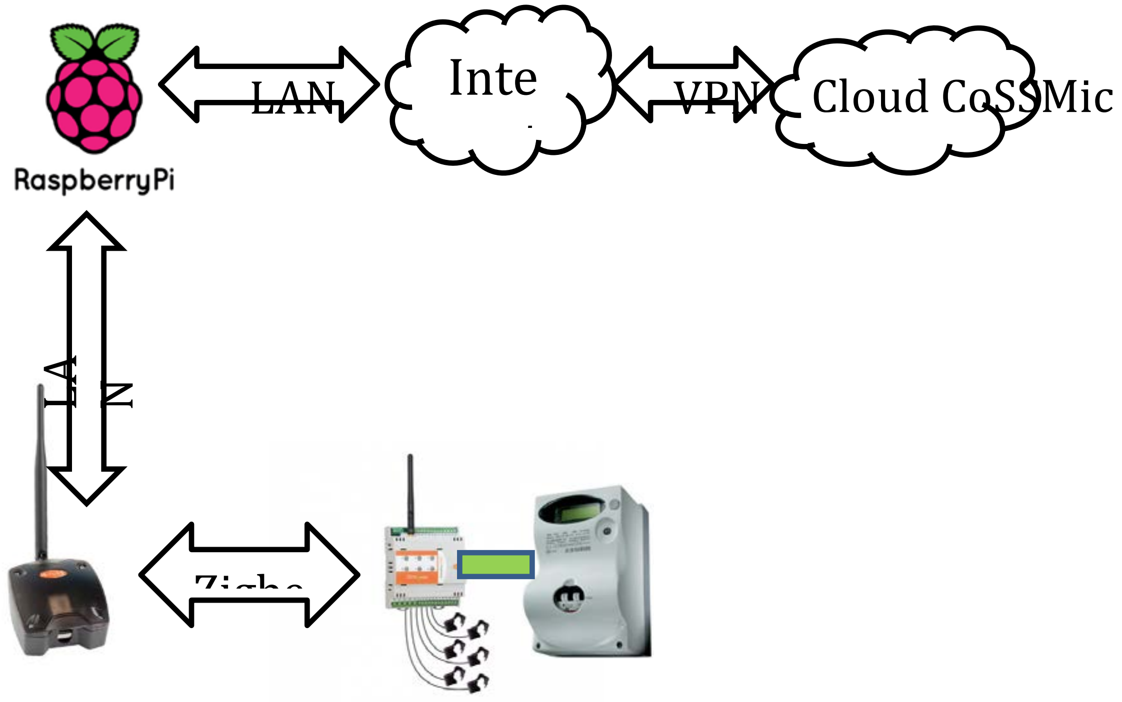


Figure 54: - System Architecture of the private house

4.5.2 *Installation and configuration Components*

The following list describes the start of the installation process and the configuration of the hardware at the CE05 site.

- Check of the internet access either by WLAN or LAN;
- Installation and configuration of a Gateway **ZC-GW-ETH-EM**, Gateway Modbus Ethernet within the network infrastructure;
- Installation and configuration 1 **ZR-HMETER3P-EM** Energy Meter three-phase;
- Installation and Configuration Raspberry PI, within the network infrastructure to allow the processing of data collected by the two Energy Meter ZigBee;
- Installation and Configuration of a VPN (Virtual Private Network) to allow the transmission of data collected locally from Raspberry PI to cloud CoSSMic.

Below is a table with the technical details of the configurations (Id Device and IP Address):

Raspberry PI		
Hostname	**IP Address**	**IP Address VPN**
ce05	192.168.1.117	10.8.0.105
	255.255.255.0	255.255.255.255
	192.168.1.1	10.8.0.1
Gateway 4noks	**Energy Meter**	

IP Address	ID
192.168.1.133	126
255.255.255.0	
192.168.1.1	

4.5.3 Graphic of the measures of energy meter

There are no data of private users available because of connection problems between the smart meters and the Raspberry PI.

4.6 **Stability of the monitoring system**

To ensure proper operation of 'whole system there has been installed and configured a monitoring software, which verifies in real time the availability of the devices (i. e. Raspberry PI) connected to the VPN, so as to ensure greater efficiency in maintenance activities of the various sites geographically dispersed in different areas.

The selected system was the Network Management System “Zabbix”.

Zabbix is a software which monitors numerous parameters of a network and thus among others the health and integrity of servers. Zabbix uses a flexible notification mechanism that allows users to configure e-mail based alerts for any event. This allows a fast reaction to server problems. Zabbix offers excellent reporting and data visualisation features based on the stored data. This makes Zabbix ideal for capacity planning.
Zabbix supports both polling and trapping. All Zabbix reports and statistics, as well as configuration parameters, are accessed through a web-based front-end. A web-based front-end ensures that the status of your network and the health of your servers can be checked and assessed from any location. Properly configured, Zabbix can play an important role in monitoring of IT infrastructures. This is equally true for small organizations with only a few servers and for large companies with a multitude of servers.
Zabbix is free of charge. Zabbix is written and distributed under the GPL General Public License version 2. It means that its source code is freely distributed and available for the general public.

Figure 55 shows an illustration of the Zabbix monitoring software, which is graphically on a map of the province of Caserta, in green installations of software components described above without problems, while red installations with problems (Swimming Pool, problem internet connection).

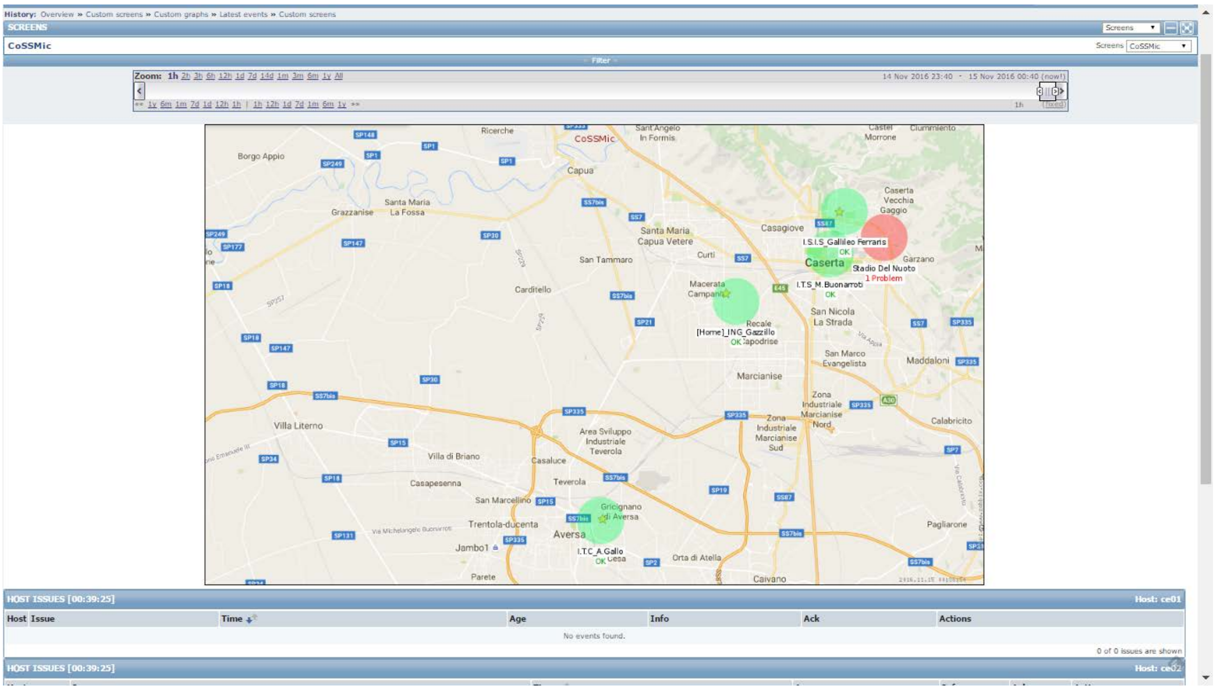


Figure 55: - Network Management System – Zabbix.

5 Data acquisition and data traffic

Efficiency gains from renewable for power supply have a time-dependent component. With increasing intermittent energy sources also the electricity prices fluctuate and may increase in volatility in intra-day trading. The idea is that a dependency between flexibility and energy efficiency on the consumer side influences the energy costs and thus it is also considered to apply appropriate regulatory interventions to adjust the demand and supply to fluctuating energy offers.
Therefore it is of vital interest of the energy consumers but also for the energy utility suppliers to know as good as necessary in time and amount the consumption and generation of electrical power and its time integral the energy.
This chapter mentions and describes in short the concepts for the different data acquisition methods. For the data evaluation design of the collected data refer to D6.1, for the Data evaluation to D6.2 and for details of the integrated hardware D5.3.

5.1 Internal data traffic

Data are measured by smart meters, smart plugs and sensors transferred to and stored at the local Raspberry PIs. In order to calculate community figures of merit as for example the overall community consumption and PV generation, self consumption, etc. the data are also transferred to a central cloud server for processing and to be proliferated again to the single households to be displayed on the GUI. Due to too high data traffic it may come to longer setup times for the displayed data and graphics by the GUI. Thus it might be possible to have certain community data available on each user´s Raspberry PI to run the entire communication peer to peer like.

5.1.1 Radio frequency assisted

The HomeMatic system transmits / receives under a radio frequency of about 868.3 MHz and the smart plug socket measures best with a time resolution of 1s the power flow for our purpose, but also frequency, current and voltage measurement and transmission are possible. The resulting energy is then built within the receiver by a plain integration of the power values, respectively.
The transmission is realized within specific defaults setups, as time defaults, measured value threshold, average value, etc..[2]
By taking into account the maximum Duty activation time period (legal national time-out timer) to 1%, then there is a time window of data transmission time of 36s within one hour. The default transmission of data is set for every 3 minutes.

[2] http://www.elv.de/Schalten-und-Messen-%E2%80%93-HomeMatic%C2%AE-Funk-Schaltaktor-mit-Leistungsmessung-Teil-1/x.aspx/cid_726/detail_47531

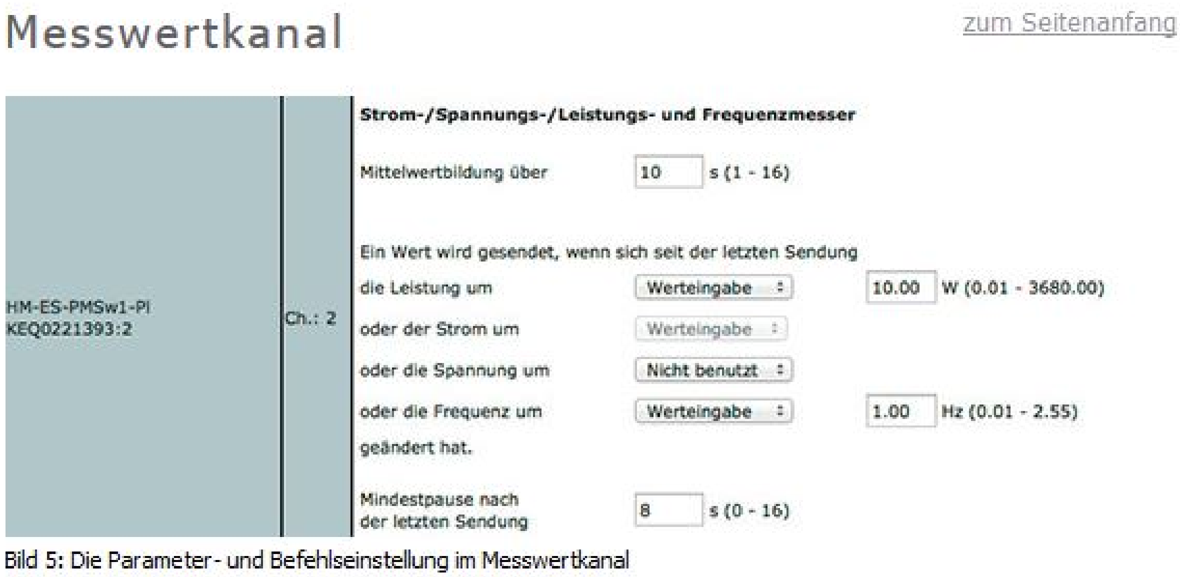


Figure 56: Displayed configurations for the HomeMatic data transmission and reception.

5.1.2 Smart meters UMTS connected

As a special way to get the measured data transmitted from the smart meter when no WLAN and also LAN access is available. In schools in Germany it is forbidden by legal regulations to run WLAN and the way to the next LAN access socket could be rather long or also restricted because of its location inside the teacher´s preparation office.

5.1.3 Smart meters to Raspberry PI cable connection

This direct connecting method is easy, save and durable when the location is suited for this connection type via RS 485 interface and should always be preferred.

5.1.4 From Raspberry PI to the internet

Whenever it was feasible at the user site location the connection between the Raspberry PI and the internet was realized by local area network with a cable connection (LAN). As an alternative the Raspberry PI could also be connected to internet by wireless local area network (WLAN).

5.2 **External data traffic**

The weather forecast data are generated and send out every six hours by Deutscher Wetterdienst (DWD) on a FTP-server. However, the processing time of the raw data to be available to customers is up to six hours! This fact leads to a mismatch between the generation and the proliferation of the forecast data of up to six hours. This can be seen in the following cutout list of the data as sent to the FTP-server.
The data name consists of the location (KN stands for Konstanz) and the date and time in UTC and the local time when the data are available on the FTP-server is given as local CEST.

KN_2016101012.csv	2016-Oct-10 20:02:05	2.2K	text/csv
KN_2016101018.csv	2016-Oct-11 02:01:58	2.0K	text/csv
KN_2016101100.csv	2016-Oct-11 08:02:05	2.0K	text/csv
KN_2016101106.csv	2016-Oct-11 14:02:01	2.2K	text/csv
KN_2016101112.csv	2016-Oct-11 20:02:05	2.2K	text/csv
KN_2016101118.csv	2016-Oct-12 02:02:00	2.0K	text/csv
KN_2016101200.csv	2016-Oct-12 08:02:00	2.0K	text/csv
KN_2016101206.csv	2016-Oct-12 14:02:00	2.2K	text/csv
KN_2016101212.csv	2016-Oct-12 20:02:07	2.2K	text/csv

Figure 57: Cut-out of the data list displayed for the 11th Oct. 2016 (grey highlighted) with the time stamp of generation in the left column in UTC and the time stamp of reception of the data at the FTP-server in the second column from left in CEST.

6 Cooperation with the users

6.1 Workshops and common meetings with the users

The introduction of the trial users into the project target and into the "Spirit of CoSSMic" was started already in the very early stage of the project start during the workshops carried out within WP2 in the first six months of the project period and was followed up by face to face meetings and interviews and finally in the two days lasting Smart Energy Workshop in Konstanz on the 13th and 14th Jul. 2015 followed by the one day Smart Energy Workshop II in Konstanz on the 29th Nov. 2016.

Also in Caserta took place a first workshop together with the kick-off meeting of the project in Oct. 2013, and a first and a second Smart Energy Workshop on the 4th Feb. 2015 and 27th Oct. 2016.

Further face to face meetings with the users are ongoing and are planned until project´s end and will be arranged whenever necessary, also immediately before the official trial start in order to:

- Introduce the trial users practically into the used equipment.
- Introduce the trial users into the software especially how to handle the graphical user interface, i. e. GUI, on a common communication and activation base.
- Introduce the trial users into the GUI in details about how to
    - Get an overview of the own household with all connected devices
    - Control the own household, schedule, reschedule and skip tasks, etc.
    - Get an overview about the entire neighbourhood behaviour
    - Set preferences and constraints for the energy management with respect to the own PV generation, the supply by the neighbourhood or the external power net, the own and overall demand and use and the storage of the electrical energy via GUI

6.2 Direct contacts with the trial users

The operation of a help-desk or help line was not realized but the users could get support and problem solving help during the trial with trial related problems on a very short time base by face to face meetings, telephone contacts and email exchange.

There have been two emails to inform all Konstanz trial users together about the development and status of the software development and the implementation.

Email from 7th March 2016 to the trial users

Am 07.03.2016 um 12:00 schrieb Joachim Glatz-Reichenbach:

Liebe CoSSMic-Teilnehmer

In Ihren Heimen wurden nun schon seit Beginn 2015 einige elektronische Geräte zur Einbindung und Teilnahme Ihres Haushalts in einem Feldversuch im Projekt CoSSMic, zur intelligenten Nutzung von elektrischer Energie, installiert. Die elektrischen Verbrauchs- und Erzeugungsdaten wurden bereits für einige Haushalte, jedoch zeitlich begrenzt, in Testläufen lokal aufgezeichnet und gespeichert. Dabei konnten wir schon jetzt das Potential für eine verbesserte Energienutzung erkennen und der Vermeidung von Lastspitzen aufgezeigt.
Ziel des Projekts CoSSMic ist es ja die vorhandene erzeugte und vom externen Netz bezogene elektrische Energie, insbesondere die von den in CoSSMic integrierten PV-Anlagen in der CoSSMic-

Gemeinschaft so gut wie möglich selbst zu nutzen, weshalb wir eine steuernde Software dazu entwickelt haben.
Mit einer Verzögerung, wie es bei grundsätzlichen Neuentwicklung nicht unüblich ist, was sich durch unvorhergesehene Aspekte und auch Probleme ergeben kann, sind nun die Graphische Benutzeroberfläche (kurz als GUI bezeichnet) und die Steuer-Software, beides läuft auf jedem im Haushalt installierten Raspberry PI Computer autonom, einsatzbereit.
Insbesondere haben wir versucht auch nach Ihren Vorgaben aus den mit Ihnen geführten Gesprächen Anregungen und Vorschläge zu berücksichtigen.
Die CoSSMic-Software soll nur über Ihre Vorgaben und Zielsetzungen, die Sie über die GUI ins System eingeben und dem Ziel den Eigenverbrauch der Gemeinschaft zu optimieren in Zukunft den Energiefluss der angeschlossenen Haushaltsgeräte aufzeichnen und gegebenenfalls diese auch schalten.
Ich werde ab Mitte März auf Sie persönlich zukommen, um mit Ihnen die weitere Vorgehensweise zu besprechen. Insbesondere möchte ich alle ihre Fragen aufnehmen und sofort oder nach Rücksprache mit dem CoSSMic-Team beantworten und Ihnen die Nutzung von GUI und CoSSMic-Software näherbringen und erklären.

Mit freundlichen Grüßen im Namen des gesamten CoSSMic-Teams
Joachim Glatz-Reichenbach
PS: Der email-Text ist auch als word-Datei angehängt.

Email from 17th August 2016 to the trial users

Am 14.07.2016 um 17:18 schrieb Joachim Glatz-Reichenbach:
Liebe CoSSMic-Teilnehmer,
leider ist schon wieder eine geraume Zeit vergangen, seit ich mich im März dieses Jahres per email an Sie gewendet habe, um über den Fortgang des Projekts zu berichten. Sicherlich habe ich jeden von Ihnen in der Zwischenzeit auch persönlich zu CoSSMic konsultiert, kurzfristig informiert und gegebenenfalls an den Installationen Veränderungen durchführen können.
Unser CoSSMic Herzstück ist, neben der installierten Hardware in Ihren Haushalten und der Graphischen Benutzeroberfläche (GUI), die entwickelte Software, die wir kurz "Distributed Scheduler" nennen. Diese wird verantwortlich sein für den Informationsaustausch zwischen Ihnen und Ihrem "Smart" Haushalt und wird nach Ihren Vorgaben den Energieverbrauch, bereitgestellt aus PV-Anlage und Stadtwerkenetz, in Ihrem Haushalt steuern und auch Informationen der anderen Teilnehmerhaushalte über Verbrauch und Erzeugung nutzen.
Leider sind wir immer noch in der Testphase der neuentwickelten Software (Distributed Scheduler) um sicher zu gehen, dass im Feldeinsatz, wenn diese Software auf jedem installierten Raspberry PI lokal laufen wird, keine unvorhergesehenen Ereignisse auftreten können.
Bitte wenden Sie sich bei weiteren Fragen direkt an mich, Tel.: 07531-3618351, joachim.glatz-reichenbach@isc-konstanz.de)
Außerdem erbitte ich noch etwas Geduld und Verständnis für unser Vorhaben
Dafür haben Sie schon jetzt an dieser Stelle meinen herzlichen Dank.
Mit freundlichen Grüßen
Joachim Glatz-Reichenbach und das gesamte CoSSMic-Team
PS:
Am 29. November 2016 werden wir einen Smart Energy Workshop II in Konstanz im Konzil im Rahmen von CoSSMic veranstalten. Dazu sind Sie schon jetzt recht herzlich eingeladen. Weitere Informationen dazu werden noch folgen. Anbei schon einmal das vorläufige grobe Programm

Dienstag, 29.11.2016

sind Vorträge zu folgenden Themenkreisen geplant:

09:30-09:40	***Start mit Begrüßung***
09:40-12:30	***Technologie/Wissenschaft/CoSSMic***
14:00-16:00	***Anwendungen zur Speichertechnologie***
16.30-18:00	***Regularien/Förderung/Pilotprojekte***
19:00 -21:30	***Tageszusammenfassung und Abendveranstaltung zum Thema Smart Grids und Energiespeicher***

Auf Grund einer internationalen Beteiligung von Vortragenden und Gästen sind die Vorträge bis Mittag in Englischer Sprache.

The two emails in German were included to the document, to illustrate the information flow to the trial participants about the current state of the technical development.

In Addition the cooperation and exchange with the users was extensively carried out during the user centred workshops and continued further on during the trials, but was not documented in detail. The communication with users continued during the maintenance work and is documented as evaluation result in D6.2. The reported feedback from two different users, with and without an installed PV system, in D6.3 can also be regarded as one example for capturing the trial user feedback.

7 Lessons Learned

Regarding performance and reliability of the devices we elaborated the following lessons learned from our experiments and trials:

1. Highly reliable data acquisition with Raspberry Pi 2 in combination with wire connected IEC62056 Mode 21 interface to smart meters can be achieved. The transfer of measured data from smart plugs as the measuring system to the gateway (Raspberry Pi) via radio frequency is recommended only as the second choice.

2. It is necessary to implement an automatic check and control mechanism regarding the plausibility of transferred, energy measurements, before they are stored and further processed.

3. For the evaluation of new IT elements, it is highly recommended to introduce a prototype test facility or even better a laboratory with identical hardware and software setups as foreseen for the installation during the field tests at the trail households. This approach is suggested in the new H2020 project proposal “Dominoes”

4. In order to collect as much data as possible and to have enough time for troubleshooting and improvements, scientists should start already at the early stage of the project with hardware installation for data collection (as partially done at the CoSSMic trial sites). The software for evaluation and visualisation of the collected data can be up-dated from time to time.

5. The interaction between the households (the CoSSMic users) and the CoSSMic team must enable individual support. Even if the technology should work automatically, special questions and preferences of different households have to be considered.

6. Mostly the low-cost smart-plugs used to measure and control individual devices worked reliably, although we also observed irregularities in the measurements that could be explained by failures of the plugs. However the limited control an access to the status of devices offered by the plugs clearly limited the sophistication of the system. For example, not all dishwasher and washing machine models could be controlled because they do not remember their state when switched off and switched on again, and the inherent flexibility of heat pumps, air conditioners and immersed water heaters could be exploited much more effectively with more direct control of the built-in thermostat. Therefore we conclude that appliances with adequate control interfaces, as are now appearing on the market, are needed to fully exploit the benefits of coordinated automatic load shifting.

8 Summary

During the time period of the last CoSSMic project year the trials have been running actively, covering the entire calendar year 2016. All Konstanz trial sit users and at the end of the year also some Caserta trial site users could be integrated to measure, monitor, display and store their consumption and PV generation data. The users could already decide on an early stage software version to schedule manually their devices with support of the displayed weather forecast data for the following four days and the parallel displayed consumption and PV generation data of the actual day of the Konstanz private trial user's neighbourhood on the GUI (graphical user interface) on their computers and handhelds.

Maintenance of the installed hardware technology was restricted mainly on resetting and restarting of single smart plugs and their integrated emitter and receiver radio frequency systems for data transmission to the gateway (i. e. Raspberry PI), and on the restarting of Raspberry PIs. Most of these resets could be done remotely, except of some local visits at the users sites. Only few items as for example some overloaded power supplies for the Raspberry PIs had to be exchanged. There was not a permanently occupied help-desk or help-line for assistance introduced to the users service. But all of the users had direct contact with and to the local CoSSMic installation and maintenance team by telephone contact, email access and if necessary also personal visits at the users homes. In this way the users could get direct support to find solutions for rising up misunderstandings and problems involved and related during or due to the trials.