



SETTING UP (SOLAR) ENERGY MANAGEMENT

Using Home Assistant

Abstract

This document describes the means and methods to setup (solar) energy management using home assistant.

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1 Introduction

This document describes a procedure to setup an automated (solar) energy management system with remote access capability. The document describes the required resources and provides step-by-step instructions for installation and customization of the different hard- and software components. The setup makes use of the “Home Assistant” operating system ([Home Assistant \(home-assistant.io\)](https://home-assistant.io))

2 Setting up the basic components and the environment

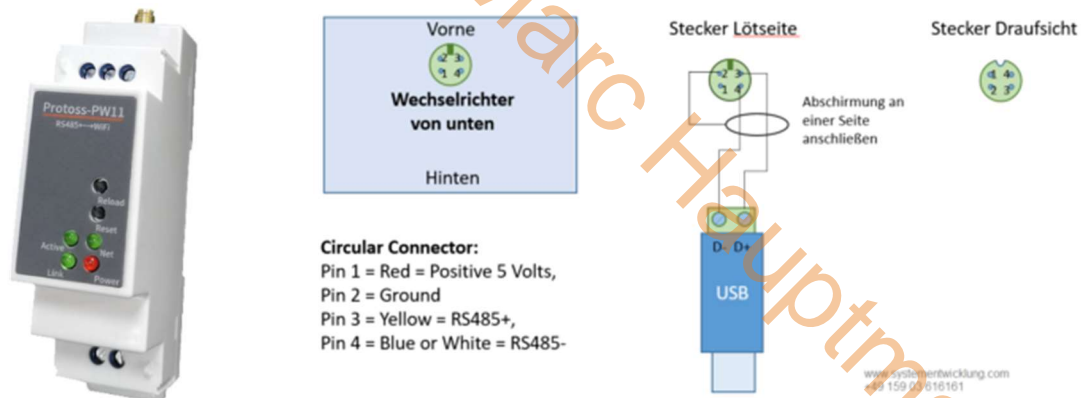
2.1 Hardware overview and sourcing

The following table summarizes the required components, where they can be obtained and their approximate pricing (based on Q3/2023 prices).

Component	Function	Sourcing	Price
Protoss PW11-H	Modbus TCP/IP bridge to connect the raspberry PI to the solar inverter. The version here is powered directly by 230V single phase via the electrical cabinet and connects to the raspberry PI via WiFi.	AliExpress	32,31 €
Sencys VOB electric cables 4mm² x3	Cables to connect the protoss interface directly to 230V AC (hence the thickness)	Brico	7,19 € per 5m
RS485 Modbus cable 1pr 24 AWG 10m	2 pole modbus cable to connect the TCP/IP bridge to the inverter.	Bol.com	29,95 €
Electric wire ferrules. (0.5 – 2.5mm)	It is highly recommended to use these for connecting the wires inside the modbus cable to the protoss TCP/IP bridge	Brico	9,99 € per set of 50pcs
RS485 connector for Solis inverter (Exceed-conn EC04681-2014-BF bundle)	Connector to connect the cable to the COM port of the Solis inverter. Note that for other inverters, other connectors maybe required.	Ebay (avarixgmbh)	13,99 €
Vemico Raspberry PI4 4GB Starter KIT	Raspberry PI is the center piece of the installation running the Home Assistant OS and communicating with all smart components. The 4 th version is recommended to run Home Wizzard properly, and the starter kit contains all basic components, such as a case, cables and an SD card storage medium.	Amazon (Vemico Webshop)	249,99 €
Optional (recommended) SSD update for RPi4	This upgrade contains an 128GB SSD, an SSD to SATA adapter to connect the SSD to the RPi4 via its USB3 connectors, and a 3D printed case that can fit both the RPi4 as well as the SSD. SSD usage is recommended to prevent “sudden death” of the SD card.	Bol.com (freva.com webshop)	49,15 €
Optional for digital meters: Home Wizard WiFi P1 Meter	WiFi Dongle that can be connected to the digital electricity meter’s P1 port, and can be used to monitor electric consumption incl. peak power as well as gas consumption.	HomeWizard Energy webshop	29,95 €
Optional (for Z-Wave connectivity): Aeotec Z-stick Gen 5+	Z-wave is an open standard for the wireless connection of devices like fire alarms. Important: only order model ZW090-C! When used in combination with an SSD, an USB extension cable might be required.	Bol.com	54,90

2.2 Installing and setting up the Modbus TCP/IP bridge

The PW11-H version of the Protoss TCP/IP modbus bridge can be installed directly into the electronic cabinet. The bottom 2 connectors are for supplying the AC voltage via the L and N wires, respectively. The top 3 connectors are the modbus +, - and ground connectors, respectively. On the inverter site, the modbus wires are soldered to the exceedconn connector as depicted below, the connector itself being attached to the inverter's COM-port.



The protoss bridge can be configured via its intranet landing page. Before the TCP/IP bridge is setup for the first time, one has to connect to the PW11 wifi network to be able to access the configuration screen. The landing page can be accessed for the first time by the default IP 10.10.100.254, using the default user name and password *admin*. The following settings are recommended/required to enable communication between both the Protoss and Raspberry PI, as well as the Raspberry PI and the inverter:

- WAN settings should be configured to DHCP ON, with a fixed WAN IP and subnet mask. To identify the right settings, let the Protoss first set up its (external) IP and mask automatically (it might be required to manually restart the protoss via the reload button in order for it to “latch on”), then fix them via DHCP ON. The latter is important to ensure home assistant’s connection to the TCP/IP-modbus bridge is stable.
- LAN settings should remain with DHCP Server OFF and standard internal IP (10.10.100.254) and mask (255.255.255.0).
- The Protoss should be configured in AP+STA mode. In this configuration, the Modbus bridge is connected both to home network via the router (meaning it is accessible within the home WiFi using its external IP) as well as accessible via the direct WiFi connection using the default IP. Use the *scan* feature in order to find the home network SSID and enter the STA KEY to connect.
- In communication settings, setup the TCP server. This is used to access modbus communication from the intranet site. Local port should be set to 8899, *buffer size* to 512 bytes, *keep alive* to 60s and *timeout* to 30s. Set *Protocol settings max accept* to 3, disable *Security* and set *Route* to Uart.
- In serial port settings, configure the serial side modbus connection (the one that goes into the inverter). Set baud rate to the baud rate of the inverter (can be checked at the inverter, but is usually 9600), and configure the data bit, stop bit and parity (usually 8, 1 and None). *Buffer size* again to 512, *gap time* to 100, *Flow control* to Half Duplex, *Cli* to always, *waiting time* to 300, and *Protocol Settings* to Modbus.

At this point, it makes sense to verify whether the connection to the inverter is setup properly both hardware and software wise. For this purpose, a program like *Modbus Poll* can be utilized to send *Modbus* messages to the inverter via specific addresses. If e.g. the current date can be read out via its specific address, then the connection appears working. See here for the *Modbus addresses* for Solis' hybrid inverters: photovoltaikforum.com/core/attachment/202315-modbus-solis-rhi-5k-pdf/ (Please note that non-hybrid inverters will use different addresses!).

In case of successful connection and polling, the status page should show something similar to below screenshot, with non-zero number of sent and received bytes for the serial port, as well as the tcp server, which should also show the IP adress of the entity polling your inverter.

Serial Port State	
Received Bytes 36293452	Received Frames 4536683
Sent Bytes 36293464	Sent Frames 4536683
Failed Bytes 0	Failed Frames 0
Config 9600,8,1,NONE	
Communication State - 'netp'	
Received Bytes 54440196	Received Frames 4536683
Sent Bytes 54439699	Sent Frames 4536641
Failed Bytes 0	Failed Frames 0
Protocol TCP-SERVER	State Connected

2.3 Installing and setting up the Raspberry PI with home assistant

For the assembly of the raspberry PI, follow the latest instructions on the manufacturers website. Home assistant runs as an operating system on the raspberry PI. For engineering purposes, it can also be run on a virtual machine like *Virtual Box*; however for longterm operation, installing and running it on a raspberry PI is strongly recommended. For installing home assistant onto the raspberry PI, follow the instructions outlined here: [Raspberry Pi OS – Raspberry Pi](#).

When in the home network to which the raspberry PI is connected, home assistant can be accessed via <http://homeassistant.local:8123/>. Upon first start up, you will be asked to create an account, which later serves as the admin. It is advised to create multiple access accounts, e.g. in order to manage who

can edit and who can only view dashboards, configurations, etc. This can be done under *Settings* → *Persons*.

To ensure stability especially for remote access, it is wise to fix home assistant's IP address. This can be done via the router settings, which are typically accessible via the router's own landing page under its IP address. Additionally; it is recommended to fix the IP address inside home assistant via *Settings* → *System* → *Network* → *IPv4*. There, choose "static" and enter your IP + "/24" and leave the gateway and DNS as is.

By default home assistant will show a number of systems connected to the home network, such as the router, range extenders, but also your smart phone and other smart home devices such as Google Chromecast. These devices can also be typically monitored or even controlled via home assistant.

Make sure to setup basic settings such as time zones, country, units, etc. via *settings* → *system* → *general*, and enable advanced mode in your user profile in order to see all available tools and options.

2.4 Optional (but recommended): transferring storage to SSD

Tracking sensor values frequently in one of home assistant's databases might accelerate the wear of the SD card. It might be wise for these cases to have a backup SD card at hand. More importantly, in order to prevent the SD card from failing prematurely, one should consider upgrading the Raspberry Pi with an SSD.

The SSD should be larger than the SD card used. After build in, in home assistant go to: *Settings* → *System* → *Storage* → *transfer storage*. This will start the transfer process which may take several minutes to complete. **Keep the Raspberry Pi powered to prevent data loss** (and preferably perform a backup beforehand, see section 3.1.3 on how to setup automated cloud backup)!

In case of problems recognizing the SSD or SSD instability, disconnect other USB devices and if necessary connect an additional power supply to the USB-SATA adapter (12V).

2.5 Optional: setting up the HomeWizzard P1 meter

The home wizard P1 meter is a wifi dongle that can be connected to the P1 port of the smart electricity meter. With it, the readings of the smart electricity and connected gas meter can be read out. To connect the P1 meter to the network; follow the instructions in the companion app. (You might first have to open the P1 port on your digital electricity meter via the website [Mijn Fluvious](https://mijn.fluvious.nl).) Once the P1 meter dongle is setup, the companion app is not needed anymore; we will monitor and store everything via home assistant. Once connected, the P1 meter should also automatically show up as an integration in home assistant. This can be checked under *Settings* → *Devices and Services*. There, one can also deactivate cloud connection of the P1 meter, in order to avoid data leakage (the data will stay within the home assistant environment and is completely managed by us, the end users)

2.6 Optional: Setting up a Z-Wave smoke detector (and other devices)

Home assistant allows the integration of smart devices like smoke detectors, via protocols like Z-Wave. Z-Wave has the advantage of good range due to the usage of lower frequencies than WiFi and fairly strict governance of the standard, at the expense of higher cost.

To enable Z-Wave in home assistant, one needs a Z-Wave dongle. One such device is the Z-Stick Gen 5 from Aeotec. Beware that this stick comes in 4 versions, and only 2 versions are compatible with Raspberry Pi4 (amongst which version number *zw090*). To setup the stick, and pair a device, follow the instructions given here: [Setup Home Assistant with Z-Stick Gen5+ : Aeotec Help Desk \(freshdesk.com\)](https://www.freshdesk.com/support/solutions/articles/36000194444-setup-home-assistant-with-z-wave-gen5-aeotec). In short, one needs to first setup the Z-Wave JS UI, then add the Z-Wave JS integration.

There are various smart devices available with Z-Wave compatibility such as the Heiman HS1SA-Z smoke detector (beware that only the version ending with -Z uses Z-Wave). Pairing instructions can be found on the internet presences of the manufacturers. Once paired, they will become available as entities within the Z-Wave JS integration.

3 Configuring Home Assistant

3.1 Installing and configuring basic (recommended) add-ons

There are some add-ons that either enhance the functionality or usability of home assistant. Add-ons can be added under *Settings* → *Add-ons*. For all add-ons, make sure that after installation, automated updates and watchdog (restarts the add-on in case it is interrupted) are enabled.

3.1.1 Open Meteo

The default weather forecast in home assistant is provided by the Norwegian meteorologic institute. More accurate weather forecasts for the benelux were provided by *Buienradar*, however their API is unreliable and sometimes weather forecasts are not updated. An alternative, reliable weather forecast service is provided by *Open Meteo*. In order to add *Open Meteo* to home assistant just add the integration via *Settings* → *Appliances and services* → *add integration*.

3.1.2 File editor and advanced SSH & web terminal

The file editor is part of the official home assistant add-ons and is essential for editing files such as config.yaml. The advanced SSH & web terminal application is also part of the official add-ons, allowing the user to access the home assistant installation via the command line, e.g. in case repair is required. In both cases; follow the instructions for installation and usage. For ease of use, enable “show in home assistant sidebar” in the configuration tab. (The advanced SSH & web terminal application should be configured via the respective tab to set a userid and password. Verify the correct setup by open a powershell terminal in windows on a PC located in the same network and type “ssh” followed by “hassio@” and your home assistant IP. Enter your password and you should see home assistants command line interface.).

More advanced user may also want to install the *Studio Code Server add-on* by Frenck, however, for development purposes it is recommended to install Studio Code Server on an external computer and then connect to home assistant and its drives using e.g. *Samba Share*, see section 3.1.7.

3.1.3 Home assistant google drive backup

The home assistant google drive backup is a community add-on developed by Stephen Bechem ([Add-on: Home Assistant Google Drive Backup - Installation / Home Assistant OS - Home Assistant Community \(home-assistant.io\)](#)). It can not only be used to schedule local backups on a regular basis, but also to backup these backups to your personal Google Drive. For detailed instructions follow the website. For ease of use, enable “show in home assistant sidebar” in the configuration tab.

3.1.4 Maria DB

If you're working with an SD card as the primary storage medium in your raspberry PI, then it is highly recommended to switch storage of the home assistant history from the default SQLite database to Maria DB. Maria DB is available via the official home assistant add-ons collection.

Before starting Maria DB, it should be configured via the corresponding tab. Enter the credentials of the main account according to the screenshot below. Here username in the logins and rights section refers to the same username. After configuring start up Maria DB.

Logins

1	- password: [REDACTED]
2	username: [REDACTED]
3	

This section defines a create user definition in MariaDB.

Rights

1	- database: homeassistant
2	username: [REDACTED]
3	

This section grant privileges to users in MariaDB.

As a next step, go to file editor and open *secrets.yaml*. We will reference this file later in the *config.yaml* in order to enable database access and storage in MariaDB. In *secrets.yaml*, add this line: `mariadb_url: 'mysql://username:yourpassword@core-mariadb/homeassistant?charset=utf8'` Replace username with the username, and *yourpassword* with the password you configured MariaDB with. **Please note, when switching from SQLite to Maria DB, your previous history will be lost.**

3.1.5 Influx DB

Influx DB is an add on that allows to store time series data over longer periods and visualize them with e.g. Grafana. The DB runs in parallel to the home assistant DB that is used to store the short term history of the integrations and sensors.

Influx DB can be installed the easiest using the community add-on made by Franck Nijhof ([GitHub - hassio-addons/addon-influxdb: InfluxDB - Home Assistant Community Add-ons](#)). After installing the add-on, start it and open the web UI (you can pin the web UI to the left side bar in home assistant via the configuration tab). Next, in the UI, go to *Influx DB admin*, and create a new database named e.g. “home_assistent”. Here, you can also adapt the retention setting or you leave it at infinite, which is the default. In the *Users* tab, create a new user and set its password. Make sure you provide read and write rights to the home assistant DB you have just created. Lastly, add the username and password to the *secrets.yaml*, following this example:

```
influxdb_user: username
influxdb_pass: password
```

3.1.6 Jupyterlab

Jupyterlab is another add-on by Franck Nijhof ([GitHub - hassio-addons/addon-jupyterlab: JupyterLab Lite - Home Assistant Community Add-ons](#)), that allows to run python code e.g. in jupyter notebooks. It is essential if we want to perform advanced data analytics or even machine learning based on data collected in the home assistant databases.

Similar to influx DB, Jupyterlab can be installed via the add-on store community add-on collection. It is recommended to pin Jupyterlab to the left side bar via the configuration tab of the add-on for ease of access.

3.1.7 Samba Share

Samba Share is another add-on by Franck Nijhof ([addons/samba at master · home-assistant/addons · GitHub](#)), that allows to connect to home assistant’s file system on an external Windows (e.g. desktop) computer via SMB. It is essential if we want to develop add-ons or “Apps” for specific automations such as solar forecasting.

Similar to influx DB, Samba Share can be installed via the add-on store community add-on collection.

In the configuration tab, input a username and password. Name the work group "WORKGROUP". On your windows computer, enter the home assistant IP address (e.g. [\\192.168.1.48](#)), then the username and password you configured, and the home assistant filesystem becomes accessible. Check "remember my credentials" to not having to enter the username and password each time you connect, and also consider making a short cut on your desktop for easy connection.

3.1.8 App Daemon

App Daemon is yet another add-on by Franck Nijhof ([Home Assistant Community Add-on: AppDaemon 4 - Installation / Home Assistant OS - Home Assistant Community \(home-assistant.io\)](#)), that allows to run python code as "Apps" for the purpose of advanced automations and services.

Similar to influx DB, App Daemon can be installed via the add-on store community add-on collection. The general configuration of App Daemon consists of 3 steps: 1. Specifying the Alpine Linux Packages that should be installed as prerequisites. This will be installed each time App Daemon is restarted. This can be a way to install python packages such as *scikit learn* and *pandas* that require compilation and contain a lot of dependencies, which would otherwise be challenging. 2. Specifying the python packages that are required to run the code (e.g. *beautifulsoup4*, *pysolar*). 3. Set the webserver port to 5050.

The usage and python coding principles within App Daemon will be explained in more detail in section 5.3. **Fout! Verwijzingsbron niet gevonden..**

3.1.9 HACS and apexcharts-card

There is a home assistant community store, which provides many more custom made integrations, as well as front-end elements. For installation instruction, please check out this website: [Home Assistant Community Store | HACS](#).

One useful front end element is apexcharts, which implements the apexchart.js library. It can be used to make interactive graphs and add them directly into home assistant dashboards. The add-on allows a lot of flexibility in configuring the graphs, including advanced transformation functionalities for sensor data, which we can use to e.g. visualize solar forecasts.

3.2 Basic configuration via config.yaml

The basic configuration of home assistant is defined by the content of *config.yaml*. It consists of these parts:

1. The header contains mostly standard things regarding scenes; automations, voice activation.
2. In the *modbus* section, one can configure sensors that represent Modbus readouts via the specified addresses. An example is given here:

```
modbus:
  - name: "Solis_Inverter"
    type: tcp
    host: 192.168.1.9
    port: 8899
    sensors:
      - name: House load power
        data_type: uint16
        slave: 1
        address: 33147
        input_type: input
```



```

count: 1
unit_of_measurement: W
state_class: measurement
scan_interval:

```

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Here, *host* is the IP address that was configured for the Protoss TCP/IP modbus bridge, and *port* refers to the internal port of the TCP server that we set up in section 2.2. A sensor is typically configured with a name, data type; address and measurement unit according to the specification of the inverter. For Solis hybrid inverters, these specifications can be found in <https://ginlongsolis.freshdesk.com/helpdesk/attachments/36112313359>.

3. In *scrape*, we can define sensors that represent information that is scraped from the web, such as energy prices. An example is given here:

```

scrape:
# Example configuration.yaml entry
- resource:
https://callmepower.be/nl/energie/leveranciers/eneco/tarieven/on-en-wind-flex
scan_interval: 3600
sensor:
- name: stroomprijs_dag
unique_id: priceday
select: "td"
index: 10
unit_of_measurement: EUR/kWh
value_template: '{{ value | replace (",", ".") | float
* 0.01 }}'

```

Resource represents the website from which the information is to be scraped. The *scrape* utility uses functionality of the *beautiful soup* package. Select and index are identical to the *select* method and indexing used by *beautiful soup* to retrieve information out of e.g. tables on website. *Value template* can be used to format the retrieved information into home assistants internal formats.

4. The *template* section lets you define template sensors, which combine and transform readings of -often multiple- existing sensor, often times using Boolean conditions. This can be used to e.g define energy tariffs for which the prices change over the course of a day. Some example is shown here:

```

template:
- sensor:
- name: stroomprijs
unit_of_measurement: EUR/kWh
state: >
{% set tariff = { "HT":
states('sensor.stroomprijs_dag'), "LT":
states('sensor.stroomprijs_nacht'), "DN":
states('sensor.p1_meter_5c2faf0f2bfc_active_tariff') | int} %}
{% if (tariff.DN<2) %}
{{ tariff.HT }}
{% else %}
{{ tariff.LT }}
{% endif %}

```

Here, we make use of the P1 smart meter's own tariff indication, distinguishing day and night tariffs automatically, but they same can be also done time based using the internal clock

feature of home assistant.

Another example are template sensor that can be used to calculate the required load and unload current for a battery to keep grid input within the “peak tariff” limit of 2.5 kW:

template:

```
- name: unload_current
  unit_of_measurement: A
  state: >
    {% set s1 = states('sensor.net_consumption') | float
%}
    {{{((min(max(0, (s1-1700)/5),1000)/50) | round(0,
default=0))*50) | round(0, default=0)}}}
- name: load_current
  unit_of_measurement: A
  state: >
    {% set s1 = states('sensor.net_consumption') | float
%}
    {{{((max(0, (1700-s1)/5)/50) | round(0, default=0))*50)
| round(0, default=0)}}}
```

Finally, we may want to setup a binary sensor, that triggers when the battery charge state is below or above a certain threshold. Compared to the binary sensor that can be configured via the helper section in home assistant (see section 3.3), the threshold can be defined via another input sensor and hence made configurable. The sensor additionally is configured via a hardcoded hysteresis to prevent rapid triggering when used in automations:

```
- binary_sensor:
  - name: batt_thresh_trigg
    #icon: mdi:thermometer-low
    availability: |
      {{ not false in
        [states('sensor.battery_charge'),

states('input_number.Battery_management_threshold')] |map('is_number')
      }}
    state: |
      {% set
entity=states('sensor.battery_charge')|float(0) %}
      {% set
limit=states('input_number.Battery_management_threshold')|float
(0) + (4 if this.state=='on' else -4) %}
      {{ entity < limit }}
```

5. Platform sensors are a useful addition, for instance to provide statistics of an sensor such as active meter power, see here for an example:

sensor:

```
- platform: statistics
  name: "Active power minute average"
  entity_id: sensor.pl_meter_5c2faf0f2bfc_active_power
  state_characteristic: mean
  max_age:
    minutes: 3
```

6. Z-Wave smoke detectors can be used to trigger alarms and notifications. It is even possible to push high priority alarms to iOS and Android devices with the companion app installed. An example of such an alarm configuration is shown here:

alert:

```
brandalarm_batterij:
  name: Rook bij batterij
  message: Er is rook bij de batterij!!
  done_message: Alarm uitgeschakeld.
  entity_id:
binary_sensor.brandalarm_batterij_smoke_detected
  state: "on"
  repeat: 1
  can_acknowledge: false
  skip_first: false
  notifiers:
    - mobile_app_iphone_van_delphine_2
    - mobile_app_sm_a505fn
  data:
    push:
      sound:
        name: default
        critical: 1
        volume: 1
        ttl: 0
      priority: high
      color: "red"
      vibrationPattern: "100, 1000, 100, 1000, 100,
1000, 100, 1000"
      importance: max
      ledColor: "red"
      channel: "alarm_ha"
```

Repeat can be used to repeat the notification according to the specified interval(s). The notifiers are the entities with the home assistant companion app installed, and data can be used to modify the notifications to e.g. always trigger a sound even the phone is in silent mode. Similarly, alarms can be set e.g. when the battery level drops or too much power is consumed. Every alarm also creates an entity, which can be used to acknowledge and subsequently toggle off the alarm. On android, above code creates a new channel the first time with above settings. Setting changes afterwards can be ignored. In order to remove a notification channel, use a service with message "remove_channel". Consequently, a service can also be used to initialize a new channel with above settings.

7. In the *recorder* section it can be specified for which sensors historical data should be stored in the *Maria DB* database for diagnostic purposes. An example of a *recorder* configuration is shown here:

```
recorder:
  db_url: !secret mariadb_url
  commit_interval: 60
  purge_keep_days: 30
  auto_purge: true
  include:
    domains:
```

```

- automation
- updater
entities:
- sensor.battery_total_power_dir
- sensor.battery_charge
- sensor.house_load_power

```

`db_url` is the url incl. credentials that was configured in section 3.1.4; When using an SD card as the storage medium, commit interval should be set to higher values (e.g. 60s) in order to avoid deteriorating the medium, while `purge_keep_days` should be kept to moderate number of days as to avoid running out of capacity. Under `include` → `entities`, the sensor for which historical data should be recorded can be defined. Alternatively, sensors can explicitly be excluded using `exclude`, though it makes more sense to keep the number of recorded sensor to a strict *need to have* base.

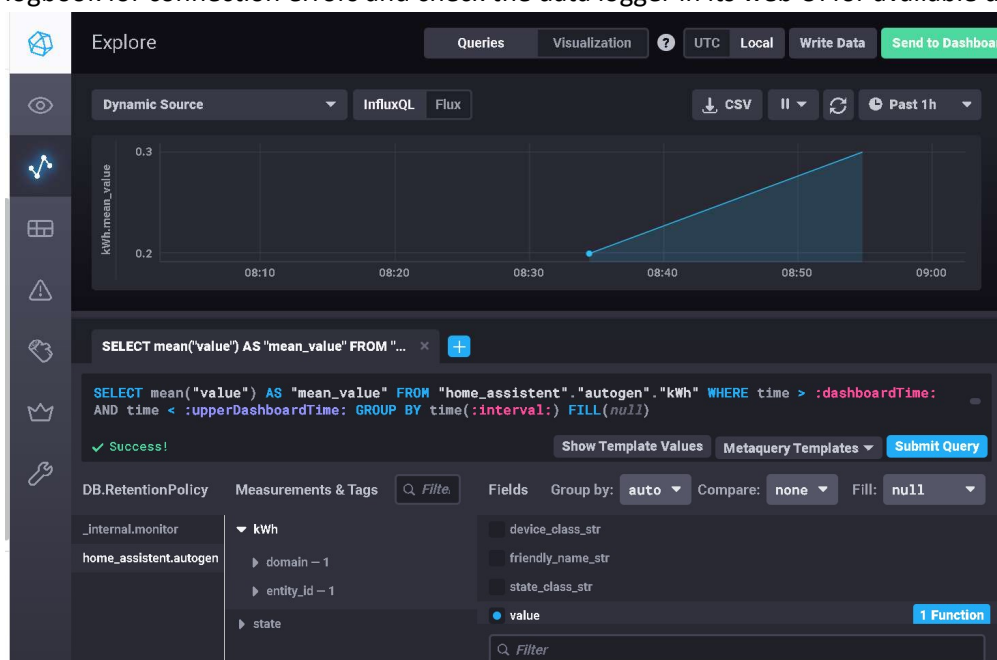
- Similarly to *MariaDB*, InfluxDB can be configured to only record certain entities and sensors. This occurs very much similar to how MariaDB is configured. We just have to provide the host (equivalent to the home assistant IP) and port (typically 8086, but check the InfluxDB web-UI), as well as the credentials as setup in section 3.1.5. Here you can find a configuration example:

```

influxdb:
  host: 192.168.1.48
  port: 8086
  database: home_assistent
  username: !secret influxdb_user
  password: !secret influxdb_pass
  max_retries: 3
  default_measurement: state
  include:
    entities:
      - sensor.daily_power_generated
      - sensor.solar_forecast_hourly

```

In order to check, whether *InfluxDB* was correctly configured, checked the home assistant logbook for connection errors and check the data logger in its web UI for available data:



3.3 Setting up and “calibrating” utility meters

Utility meters are useful in order to track e.g. energy production or consumption over fixed periods (i.e. daily). That means their value will be reset at the end of the period, and a new cycle begins with each subsequent period. Utility meter like readings are also needed to track energy production and consumption via home assistant’s energy dashboard.

While utility meters can be setup via *config.yaml* as well (e.g. `utility_meter`:

```
gas_daily:
  name: Daily gas energy consumption
  source: sensor.gas_kWh
  cycle: daily),
```

it is often more convenient to set them up via *settings* → *appliances and services* → *helpers*. There one can set the source sensor, the meter period, customize the reset point, etc. By default, a utility meter starts its first cycle after setup with a count of zero. However in some situations it might be required to set the utility meter to a starting value that e.g. reflects the reading of the underlying sensor at the time of setup. This can be done via *development tools* → *services*. In service, select *Utility meter: calibrate*, select the target sensor, set the desired target value and execute.

3.4 Setting up dashboards

Dashboards are the front end by which sensor readings can be combined, visualized and organized. They can be setup and pre-configured via *settings* → *dashboards*, here e.g it can be configured if the dashboard is visible in the side bar and if they can only be edited by the admin. Dashboards can be edited, by clicking on the 3 points in the top right corner of the respective dashboard, and selecting *configure UI*. It is recommended to use these basic 3 types of dashboards:

1. The standard home assistant “landing page” dashboard. This is the default dashboard, with a default arrangement that depends on the registered integrations and entities. It is useful to add selected utility meter readings to the top of the dashboard as “badges”. Furthermore, widgets can be added for weather and sun forecasts as well as control of smart home integrations such as Google Chromecast. Lastly, one can make cards providing overview of the states and settings of multiple entities of the same device, e.g. Z-Wave smoke detectors, as well as alarms that allow the possibility to acknowledge and toggle off.
2. The energy dashboard is a preconfigured dashboard that is very useful to track power consumption, generation and other related statistics, for selected time intervals. The dashboard readings are updated on an hourly basis, so it is less suited for real time monitoring but more for collecting long term statistics over consumption and generation. The main configuration items are the utility meters that are used to track power consumption, generation, battery charge etc. The tracking is not limit to electricity but also e.g: gas consumption can be tracked as well. There is even -albeit functionally limited- functionality to forecast solar production. Do note that when a new input is configured, it may take up to 2 hours until the readings become visible in the dashboard. It is also possible to add energy tariffs (e.g. as configured in section 3.1.6.3) to track costs and profits. In order for the costs and profits to become visible in the dashboard it is not sufficient to only add the tariffs; but the cost “sensor” that is subsequently generated by the dashboard also needs to be added to the included entities in the *recorder* configuration (see section 3.1.6.5). Usually this “sensor” carries the name of the utility meter used to track consumption/generation with an additional “_cost” added.

3. In order to complement the energy dashboard, an additional dashboard for real time monitoring of power levels and daily power generation / consumption (divided over multiple tabs) is recommended. The power readings can also be used to check for the balance of currently consumed and generated power in order to not exceed peak levels imposed by the governing entities. Needle meters are useful visualizations for real time readouts, which allow for indicating different levels of desirability, while history plots of daily utility meters allow to track the development of consumption / generation through out the day.
4. Additional, customized dashboards maybe setup in order to visualize solar predictions (see chapter **Fout! Verwijzingsbron niet gevonden.**) using the apexcharts card from HACS (see section 3.1.9), and in order to manually trigger automations. The latter should not be made available to all users, but only administrators who know what they are doing. 😊

3.5 Setting up remote access via cloudflared

A very nice feature of home assistant is the companion app. It is available for both Android and iOS, and offers the possibility to access and even configure home assistant from mobile devices such as smartphones, tablets, etc, and it even can track the location of connected mobile devices (in case location access is enabled). The companion app can easily be configured when the mobile device is connected to the same network as home assistant, and will autodetect any home assistant instance during installation and setup.

The added value of the companion app is greatly enhanced when home assistant is configured for remote access, since then the companion app can be used to monitor and control home assistant “on the go”. There are several ways to make home assistant accessible remotely, one of the safest, most convenient and cheapest one is via *Cloudflare*. In order to setup remote access via *Cloudflare*, the following steps have to be taken:

1. Open a new account on <https://dash.cloudflare.com>.
2. Register an internet domain that will serve as an entry port to home assistant from remote. Unfortunately it is not possible anymore to register free domains with *Cloudflare*, instead the most convenient way is to purchase and register a domain (e.g. .uk) on *Cloudflare* itself, via *Domain Registration* → *Register Domains*. The internet domain you just registered should show up under *websites*, if not press *add a site* and follow the instructions. (Make sure to select the free plan when asked.)

The *DNS* settings of your website should show the nameservers that *Cloudflare* uses to tunnel to home assistant via your domain. *SSL* settings should be set to flexible by default.

3. Install the *Cloudflare* add-on on home assistant via *Settings* → *Add-ons* → *Add-on store*. Install the add-on via the github repository <https://github.com/brenner-tobias/ha-addons>. The add-on should be configured before start, by adding the host name that was setup in step 2 to the config page.

4. The *Config.yaml* needs some additional modification as well. Make sure the header still contains *default_config*:. Additionally, add the following lines to the *config.yaml*:

```
http:
  use_x_forwarded_for: true
  trusted_proxies:
    - IP
```

In order to configure the right *IP*, try to access home assistant by typing your domain in a browser. Most likely you will get a *400* or similar error. Now check the logbook of home assistant via the *settings* menu (under *system*). It will show some error *:/* warning related to

an external IP trying to access home assistant and being refused. The IP in question is the one to be added to the `config.yaml`.

5. In your companion app, under *settings* → *system* → *network*, configure the home assistant urls for internal and external access. To verify home assistant access works, disconnect your mobile device from the home WLAN and try to access home assistant via the 4G connection of your phone. (Alternatively, try to access home assistant via your internet browser and the domain you setup in step 2).
6. It is recommended to enable two-factor authentication for maximum security. For this, go to your user profile, and enable the option. A QR code will be displayed that you can use to register your totp authenticator app (for instance google authenticator).

If you plan to access home assistant with multiple people, then it is wise to setup multiple accounts via *settings* → *persons*. In this way you can keep admin/editing rights confined to one key user (usually yourself), and limit other users rights on a strict “need-to” base. If applicable, the companion app of other non-admin users should then be setup using their own respective home assistant user accounts, including their own two factor authentication.

4 Enabling scripts and automations

Home assistant offers the possibility to automatically trigger processes or state changes of devices upon certain events and under certain preconditions. One potential usecase is smart energy management: In Belgium, “peak consumption” is penalized by the grid owner (Fluvius), while at the same time the “electrification” of private households through electric cars and heat pumps is promoted. Home batteries may offer a way out, but may not be sufficiently charged through solar energy generation and / or have insufficient storage capacity when energy demand is high. Automations can be used to overcome these 2 issues: batteries can be charged from the grid when excess power is available (i.e. when overall energy consumption in the house is low), and battery discharge current can be limited when demand is high in order to retain battery charge as much as possible while “assisting” electrical consumption from the grid in order to stay below peak tariff thresholds. In the future, this usecase could be extended to take advantage of dynamic energy tariffs by dynamic charging (and potential later injection back into the grid as a form of “arbitrage trading”).

We will look into this example usecase in more detail in the next sections.

4.1 Preparation and precondition

To enable grid charging on the inverter side, the inverter should be pre-configured with a time interval (ideally for full flexibility from 12AM until 11.59PM) and charging of the battery from grid should be enabled. On Solis hybrid inverters, the former can be done via *Advanced Settings* → *Storage Energy Set* → *Storage Mode Select* → *Self Use* → *Time of Use*, while the latter can be done via *Advanced Settings* → *Storage Energy Set* → *Storage Mode Select* → *Self Use* → *Charge from grid* → *Allow*.

Furthermore, it is handy to monitor the applied charging settings via modbus. For this, add another modbus sensor according to section 3.2.2, with the register containing that information. On Solis inverters, the register ID is 33132. It contains 16 bits of information with the sensor readout being converted into an integer number. For instance, the setting with overnight charging disabled has bits 0 and 5 true (to generally enable battery charging) and bit 1 disabled (to disable time of use charging) resulting in output $2^0 + 2^5 = 33$. Overnight charging enabled will have bit 1 enabled, resulting in output $2^0 + 2^1 + 2^5 = 35$. We'll remember these settings for the automation. Additional modbus sensors to potentially add in order to monitor the battery's charge and discharge currents, since we are going to manipulate these settings in our automation:

- Register 33206: Maximum grid charge current of the battery
- Register 33143: Maximum battery charge current (including solar)
- Register 33144: Maximum battery discharge current

4.2 Setting up the automation flow

In our automation example, we would like to achieve 2 things:

1. Switch between battery charge and discharge mode depending on the current power consumption in the house and the solar power generation.
2. Modulate the charge / discharge current according to excess power capacity available and power assistance capacity required, respectively.

The generic flow for this situation is as follows:

1. An automation will be triggered when the (un)load current calculated in section 3.2, example 4 as the delta of energy consumption in the house, solar energy generation and peak tariff thresholds, divided by the nominal battery voltage is larger than zero.
2. The automation kicks off a script, which repeatedly executes Modbus commands to set the battery (dis)charge current according to the value as provided by aforementioned template sensor(s).

4.2.1 Setting up the scripts

Scripts can be setup via *Settings* → *Automations & scenes*. A script typically consist of a sequence of actions that can be executed one time or repeatedly, the latter as long as certain conditions are fulfilled. Although scripts come with an UI editor in home assistant, it is ultimately easier to set them up using YAML. (For this, open a script, click on the 3 dots in the upper right corner and select "Edit as YAML").

A possible action that can be executed is a service call. An example of such a service is *Modbus: Write register*. It allows selecting a register to set (e.g. 43110 for changing the time of use charging setting or 43141 for adapting the charge current), the slave (typically 1), the value to be written to the register (e.g. 33/35 for 43110 or the desired current value for 43141), and finally the hub, which should be the name of the modbus connector as configured in section 3.2.2.

In our case, 2 scripts are to be prepared:

1. A script that activates battery charging from grid and continuously adapts the grid charge current according to the template sensor setup earlier. The latter is done as long as the battery charge is below a (user configurable) threshold (e.g. using the binary sensor configured in section 3.2, example 4), and the charge current is above 0. Once the condition is violated, the loop is stopped and the inverter is set back to discharge mode. In YAML, the script looks like this:

```
alias: Battery load management
sequence:
  - repeat:
    while:
      - condition: numeric_state
        entity_id: sensor.load_current
        above: 0
      - condition: state
        entity_id: binary_sensor.batt_thresh_trigg
        state: "on"
    sequence:
```

```

- service: modbus.write_register
  data:
    address: 43110
    slave: 1
    value: 35
    hub: Solis_Inverter
- service: modbus.write_register
  data:
    address: 43141
    slave: 1
    value: |
      {{states('sensor.load_current')}}
    hub: Solis_Inverter
- delay:
  seconds: 20
- service: modbus.write_register
  data:
    hub: Solis_Inverter
    address: 43110
    value: 33
    slave: 1
mode: single
icon: mdi:home-battery

```

2. Similarly, a script that activates battery discharging and continuously adapts the discharge current according to the template sensor setup earlier. The latter is done as long as the battery charge is below a (user configurable) threshold (e.g. using the binary sensor configured in section 3.2, example 4), and the discharge current is above 0. Once the condition is violated, the loop is stopped and the inverter is set back to discharge mode. In YAML, the script looks like this:

```

alias: Battery unload management
sequence:
  - repeat:
    while:
      - condition: numeric_state
        entity_id: sensor.unload_current
        above: 0
      - condition: state
        entity_id: binary_sensor.batt_thresh_trigg
        state: "on"
    sequence:
      - service: modbus.write_register
        data:
          hub: Solis_Inverter
          slave: 1
          value: 33
          address: 43110
      - service: modbus.write_register
        data:
          address: 43118
          slave: 1
          value: |

```

```

        {{states('sensor.unload_current')}}
        hub: Solis_Inverter
        - delay:
            seconds: 20
    - service: modbus.write_register
      data:
        hub: Solis_Inverter
        address: 43118
        slave: 1
        value: 1000
mode: single
icon: mdi:home-battery-outline

```

An additional script maybe prepared in order to reliably reset the inverter to default conditions (discharge mode and default discharge current). This script repeatedly executes the corresponding modbus commands until the values of the state sensors set up in section 4.1 matches the expected values:

```

alias: Reset load / unload
sequence:
  - repeat:
      sequence:
        - service: modbus.write_register
          data:
            hub: Solis_Inverter
            address: 43110
            value: 33
            slave: 1
      until:
        - condition: numeric_state
          entity_id: sensor.gridchgstate
          above: 32
          below: 34
  - repeat:
      sequence:
        - service: modbus.write_register
          data:
            hub: Solis_Inverter
            address: 43118
            slave: 1
            value: 1000
      until:
        - condition: numeric_state
          entity_id: sensor.max_ontlaadstroom_batt
          above: 99
          below: 101
mode: single
icon: mdi:lock-reset

```

4.2.2 Setting up the automations

Automations can be setup via *Settings* → *Automations & scenes*. An automation typically consists of a trigger, conditions as well as an action. In order to execute the scripts set up in section 4.2.1, we prepare 2 (3) automations:

1. The first automation executes the script controlling the charging behavior of the battery. It is triggered when the template sensor of the calculated load current is larger than 0 and/or the battery charge drops below a certain threshold. Both situations serve as both triggers and conditions:

```
alias: Load management
description: triggers script to adapt battery load
trigger:
  - platform: numeric_state
    entity_id:
      - sensor.load_current
    above: 0
  - platform: state
    entity_id:
      - binary_sensor.batt_thresh_trigg
    from: "off"
    to: "on"
condition:
  - condition: numeric_state
    entity_id: sensor.load_current
    above: 0
  - condition: state
    entity_id: binary_sensor.batt_thresh_trigg
    state: "on"
action:
  - service: script.turn_on
    data: {}
    target:
      entity_id: script.battery_load_management_dupliceren
mode: single
```

2. The second automation executes the script controlling the discharging behavior of the battery. It is triggered when the template sensor of the calculated unload current is larger than 0 and/or the battery charge drops below a certain threshold. Both situations serve as both triggers and conditions:

```
alias: Unload management
description: triggers script to adapt battery unload
trigger:
  - platform: numeric_state
    entity_id:
      - sensor.unload_current
    above: 0
  - platform: state
    entity_id:
      - binary_sensor.batt_thresh_trigg
    from: "off"
    to: "on"
condition:
```

```

- condition: numeric_state
  entity_id: sensor.unload_current
  above: 0
- condition: state
  entity_id: binary_sensor.batt_thresh_trigg
  state: "on"
action:
- service: script.turn_on
  data: {}
  target:
    entity_id: script.battery_management
mode: single

```

3. Optionally, a third automation triggers the reset of the inverter in case minute average power consumption from the grid (according to the sensor setup in section 3.2, example 5) is larger than 2.5kW and the battery charge is above the threshold for the previous automations. This can be used as a safety net when reset of the inverter previously failed e.g. due to connection issues:

```

alias: Reset load/unload
description: Resets load - unload state of the inverter to default
trigger:
- platform: numeric_state
  entity_id:
    - sensor.active_power_minute_average
  above: 2500
condition:
- condition: state
  entity_id: binary_sensor.batt_thres_trig
  state: "off"
action:
- service: modbus.write_register
  data:
    hub: Solis_Inverter
    address: 43110
    value: 33
    slave: 1
- service: modbus.write_register
  data:
    hub: Solis_Inverter
    address: 43118
    value: 1000
    slave: 1
- service: script.turn_on
  data: {}
  target:
    entity_id: script.reset_load_unload
mode: single

```

All automations can also be triggered via action buttons in dashboard, e.g. in rare cases when automations were not kicked off due to conditions failing. Additionally, services could be utilized as

part of the automation in order to send notifications that automations were triggered to users' cellphones similar to the alerts we've set up in sections 3.2.5.

The variable battery charge threshold used in these automations (and the scripts they trigger), can be used to ensure enough capacity is left in the battery for solar charging. As such, the threshold can be automatically set based on predictions of solar production. The next chapter will explain in more detailed how such solar forecasts can be setup in a customized fashion.

5 Building a solar predictor using Python and AppDaemon

In order to determine the variable battery charge threshold used in the previous chapter and in general developing an idea of near future solar production, we can use the solar yield data stored in InfluxDB, and combine it with weather forecast data from OpenMeteo before offering it to a machine learning model for training purposes.

Setting up the solar prediction engine involves three main steps:

1. Exporting solar production data from influxDB.
2. Offline model training.
3. Model deployment and forecast visualization.

Each of this steps will be described further in the next sections

5.1 Exporting solar production data from influxDB

Home assistant's databases like influx DB can be accessed and queried within home assistant using the jupyterlab add-on (see section 3.1.6).

To access the data stored in influx DB, we need to install a couple of packages via *pip install packagename*. The packages we require are pandas (should already be installed), influxdb (not influxdbclient) and datetime (should already be installed).

We load the packages and relevant classes via:

```
from datetime import timedelta
import pandas as pd
from influxdb import InfluxDBClient
```

We establish a connection to our influx database via:

```
client = InfluxDBClient(host='...', port=8086, username='...', password='...', database='...')
```

The host, username, password and database name correspond to what we have setup previously as described in sections 3.1.5 and 3.2.8.

We can query the influx db following below example:

```
result=client.query('SELECT value AS "value" FROM "home_assistent"."autogen"."kWh"')
```

A good tip is to use the influx DB UI's data explorer in order to construct the right queries.

Finally, the result is a JSON dictionary that can be converted to a pandas dataframe using:

```
df = pd.DataFrame.from_dict(result.get_points(), orient='columns')
```

and exported using:

```
df.to_csv(r'vermogen_n.csv', sep=';')
```

The resulting csv file can be downloaded from the Raspberry Pi via the home assistant web interface and used for offline machine learning model training.

5.2 Offline model training

The training of the prediction model is based handled offline, in order to not deplete the limited resources of the Raspberry Pi. For that purpose, a distribution like *Anaconda* can be used.

The generic model training approach involves the following steps:

1. Preprocessing the solar production data, in order to convert it into kWh dataset per hourly interval as input for the model to train towards.
2. Querying solar positioning and historical weather data for the same time period, using the PySolar package and OpenMeteo API, respectively.
3. Training a Random Forest Regression model and tuning its hyperparameters, and exporting the final model for deployment to the RPi.

The core idea of the solar prediction approach involves calculating “features” that represent the energy irradiated on the solar panels. These features are:

1. The global direct irradiance, which is a function of the direct normal irradiance (as provided by OpenMeteo) and the angle of incidence, which itself is a function of the tilt and azimuth of the solar panels, and the altitude and azimuth of the sun (as provided by PySolar).
2. The global diffuse irradiance, which is a function of the diffuse horizontal irradiance (as provided by OpenMeteo) and the tilt of the solar panels.

The general concept behind these calculations is very well explained in this video: [PV3x 2017 2 3 1 Calculating Irradiance based on Tilt Angle video 720 \(youtube.com\)](https://www.youtube.com/watch?v=PV3x2017231)

Above features are augmented with additional features such as snow depth and cloud coverage, as these may impact the working of the solar panels further and/or may subtly influence the diffuse radiation levels.

An example Jupyter notebook for the model training can be found on Github at [Solar_Forecast_ML/Offline_training at main · marchauptmann1984/Solar_Forecast_ML · GitHub](https://github.com/marchauptmann1984/Solar_Forecast_ML).

5.3 Model deployment and forecast visualization

In order to run the model and periodically provide forecasts, we can use *AppDaemon* (see 3.1.8). AppDaemon allows to run python code that interfaces with home assistants integrations, sensors, etc.

First, AppDaemon needs to be setup with the right packages that are needed to run the python code. 2 types of packages are required: 1. System packages, which are Alpine Linux packages. Many compiled Python packages with dependencies in other Python packages are available as system packages, which provides a good workaround to get them installed without too much hassle. Packages that are required for our solar forecasting code are *py3-scikit-learn* and *py3-pandas*. 2. Python packages. Here, non-compiled packages can be installed. Packages that are required for our solar forecasting code are *pysolar* and *beautifulsoup4*. When specifying packages to be installed, keep in mind that these packages are downloaded, unzipped and installed each time AppDaemon is restarted. So keeping it lean will help to minimize startup time.

Secondly, we need to prepare and configure the “App” to run. This step consists of 3 parts: 1. The config.yaml for the AppDaemon apps, defining the main class according to the python script per app.

2. The model zip files, containing the trained machine learning model. 3. The actual Python script. There is extensive AppDaemon documentation available on the net, so we won't go into software engineering details here. From a functional point of view, the script does the following things: 1. Retrieving weather forecast and solar position information. 2. Calculating the features as used during model training. 3. Running the model for these features and retrieve its predictions of the solar generated power. 4. Exporting the model forecast into a home assistant sensor (as a timeseries attribute) for further visualization. An additional sensor contains the forecast for solar production in the next 12 hours, which can be used to determine the battery management threshold as utilized in section 4.2. The code and corresponding configuration can be found here: [Solar Forecast ML/AppDaemon deploy at main · marchauptmann1984/Solar_Forecast_ML](https://github.com/marchauptmann1984/Solar_Forecast_ML) · [GitHub](https://github.com/marchauptmann1984/Solar_Forecast_ML)

It is best to perform the coding offline, via an IDE like VisualStudio, then copy the code and corresponding files to the RPi using *SambaShare* (see 3.1.7). The target directory for the AppDaemon apps is `\addon_configs\appdaemon\apps`.

The forecast can be visualized using ApexCharts (see 3.1.9), together with the actual solar production. See below an example for configuration:

```
type: custom:apexcharts-card
graph_span: 30h
span:
  start: day
  offset: +9h
header:
  show: true
  title: Hourly solar yield measured vs. predicted
  show_states: false
  colorize_states: false
series:
- entity: sensor.daily_power_generated
  type: column
  group_by:
    func: diff
    fill: last
    start_with_last: true
    duration: 1h
  opacity: 0.5
  show:
    in_header: before_now
    time_delta: +0.5h
- entity: sensor.solar_forecast_hourly
  name: Solar forecast
  type: line
  color: grey
  data_generator: |
    return entity.attributes.PeakTimes.map((peak, index) => {
      return [new Date(peak).getTime(),
entity.attributes.PeakHeights[index]];
    });
  unit: kWh
  show:
    legend_value: true
```

```
    in_header: before_now
    time_delta: +0.5h
now:
  show: true
  label: now
yaxis:
  - min: 0
    max: ~2
    apex_config:
      tickAmount: 10
      title:
        text: Solar yield [kWh]
apex_config:
  dataLabels:
    enabled: true
  dropShadow:
    enabled: true
```

In this example, the power generated hourly is plotted against the forecast extracted from the sensor attribute time series. Axis and timeseries labels are added as well as an indicator for the current timing. The chart can be added natively to a dedicated dashboard for energy forecasting.

6 Next steps

This is a living document describing the key steps in order to setup home assistant for energy automation and monitoring purposes. It is aimed to continuously expand this document with new insights and ideas. Some items on the “backlog” include:

1. Automation of a heat pump installation and synchronization with the solar installation.
2. Adding zones, areas, rooms (incl. automated notifications), and other smart devices such as switches.