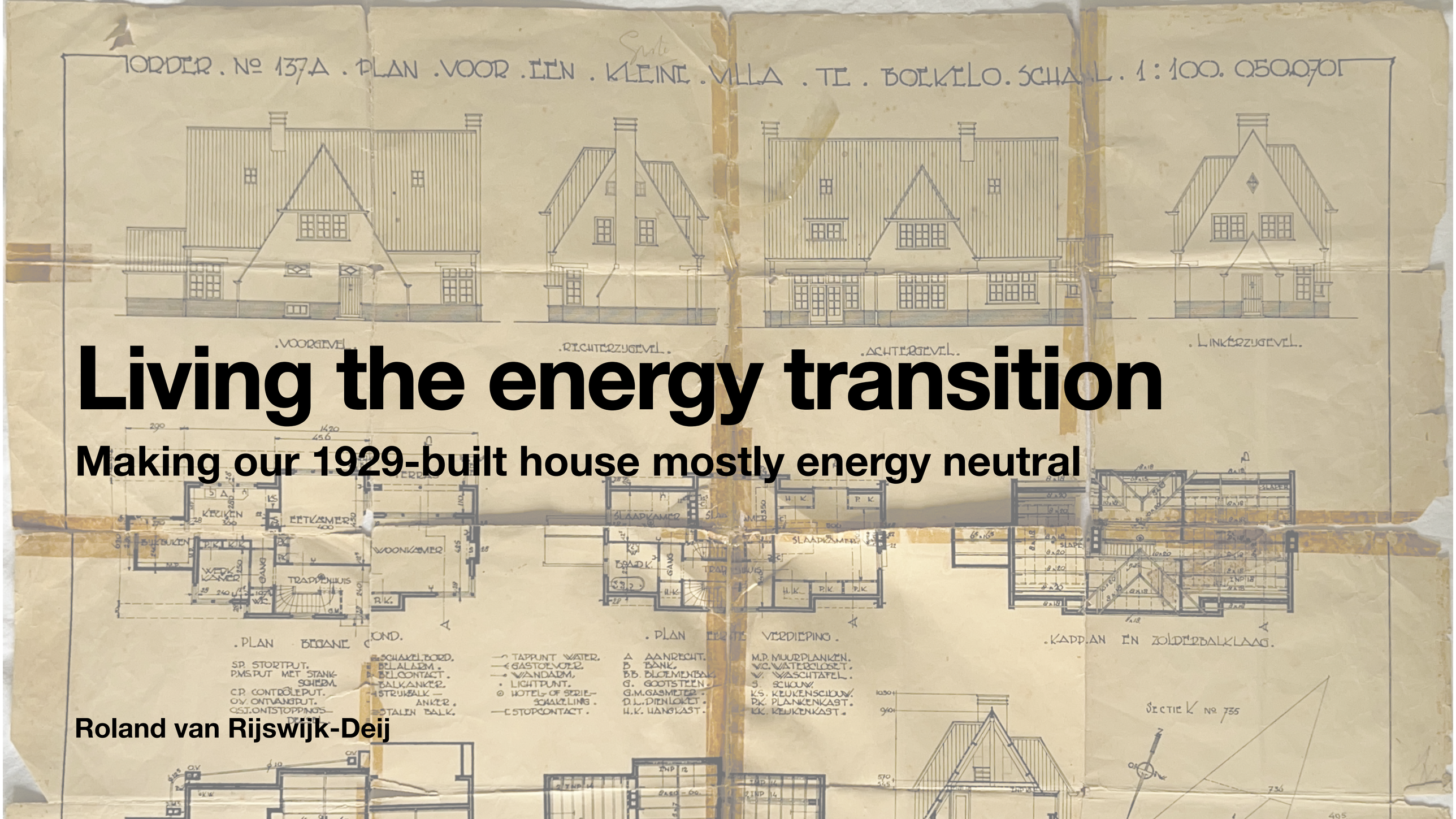


Living the energy transition

Making our 1929-built house mostly energy neutral

Roland van Rijswijk-Deij

Overview

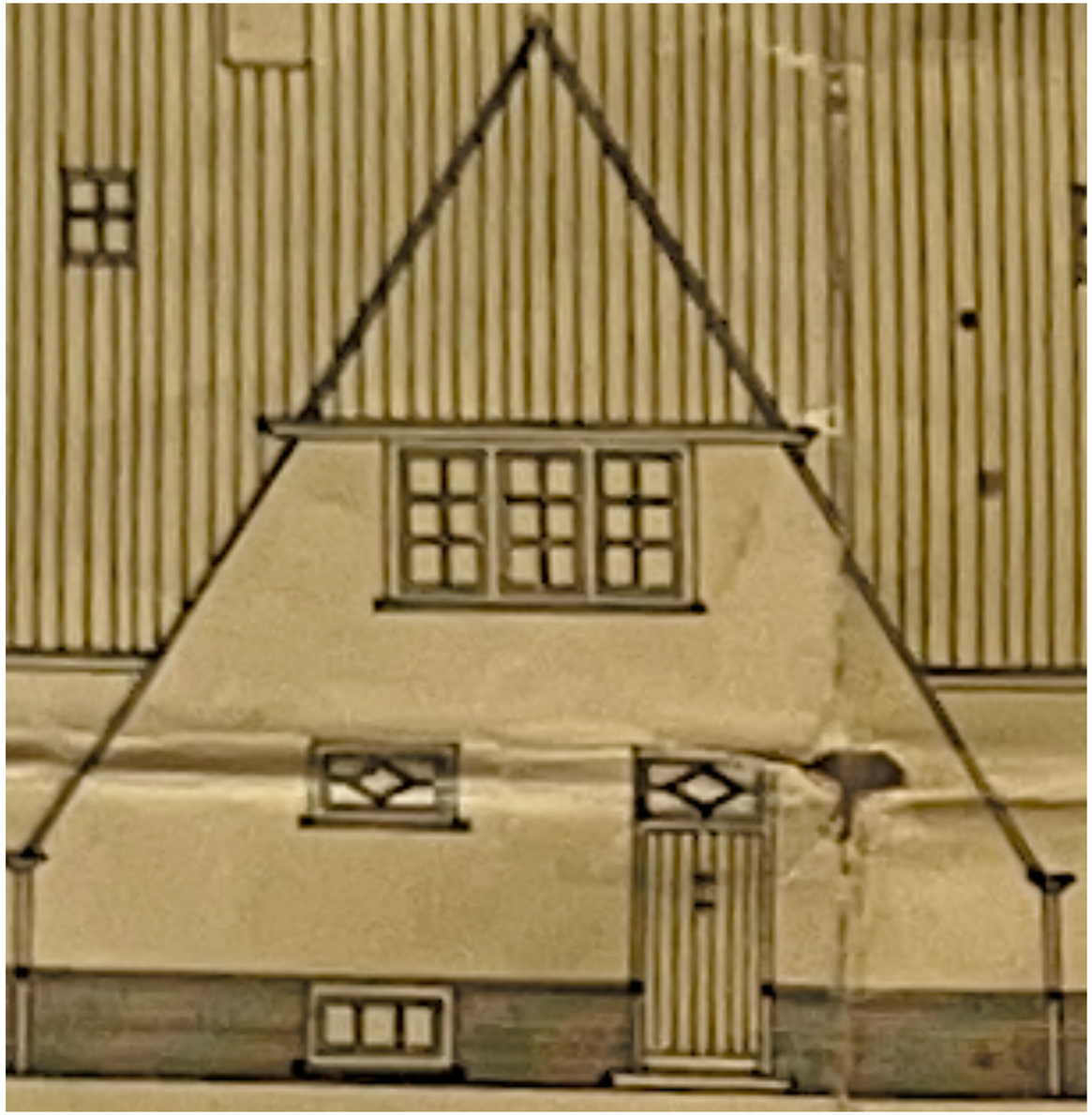
- Making a plan
- Improving insulation and heating efficiency
- Producing your own power
- Solar + electric heating
- EV charging
- Metering, monitoring and controlling
- Conclusions

Making a plan

- House built in 1929/1930
- Some insulation
  (roof, extensions from ~2010)
- Roof in dire need of replacement
- AGA furnace (“always on gas!”)
- ± 60% single pane glass
- ± 4000 m^3 gas per year
  > 5000 kWh electricity per year

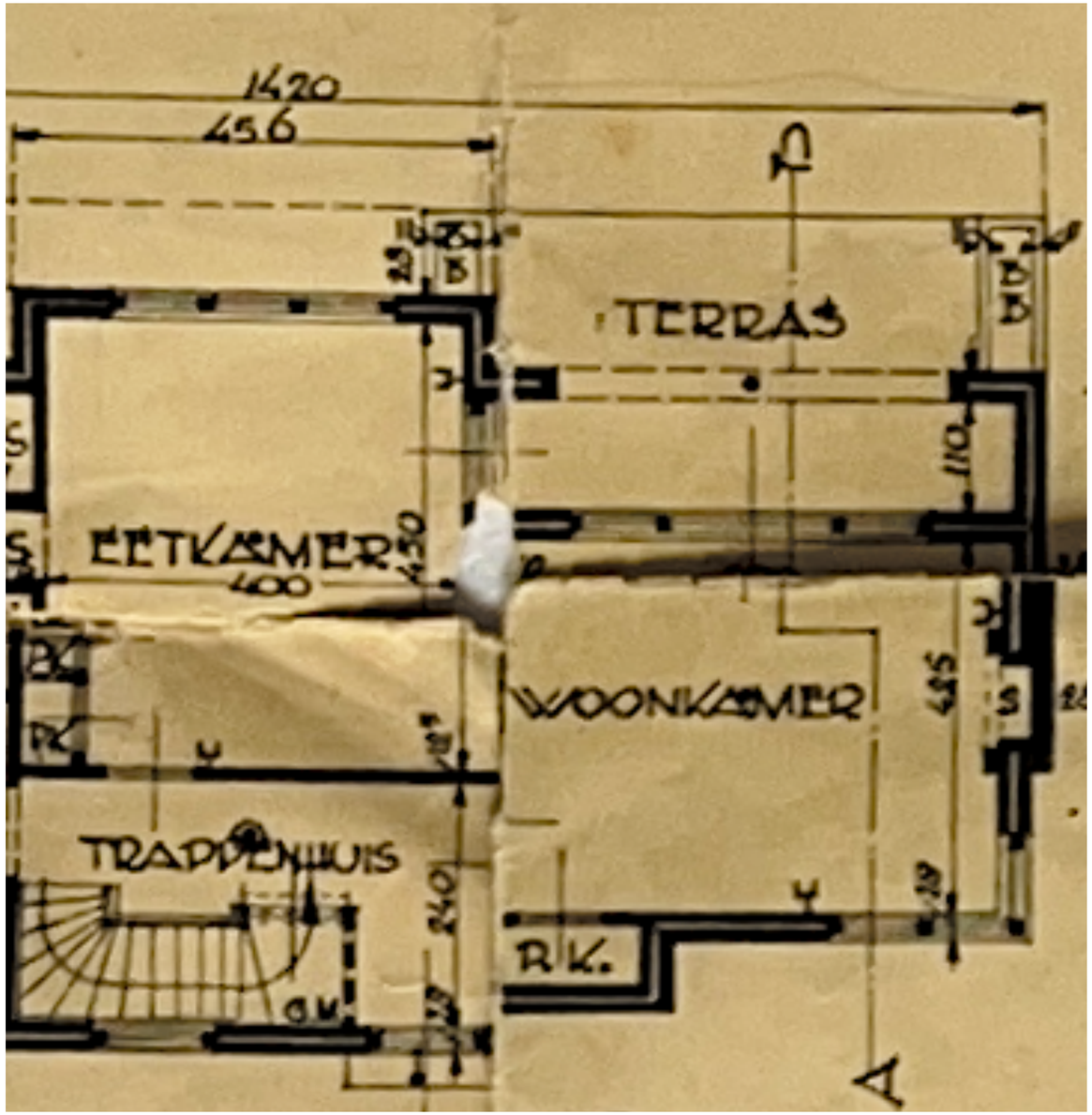
HR++ glazing

- Dozens of individual single sheet glass panes
- Replaced by HR++ with internal dividers
- Every window is unique (different sizes) — wrong sizes 4 times! 😷
- Insulation strips in doorframes to reduce draft
- Small subsidy on the glass



Floor insulation

- Dining room + living room have wooden floors over a crawlspace
- Lots of heat loss
- Humidity from the soil gets into the house
- Underfloor insulation with “Tonzon” (black body insulation)
- Relatively affordable, generous subsidy



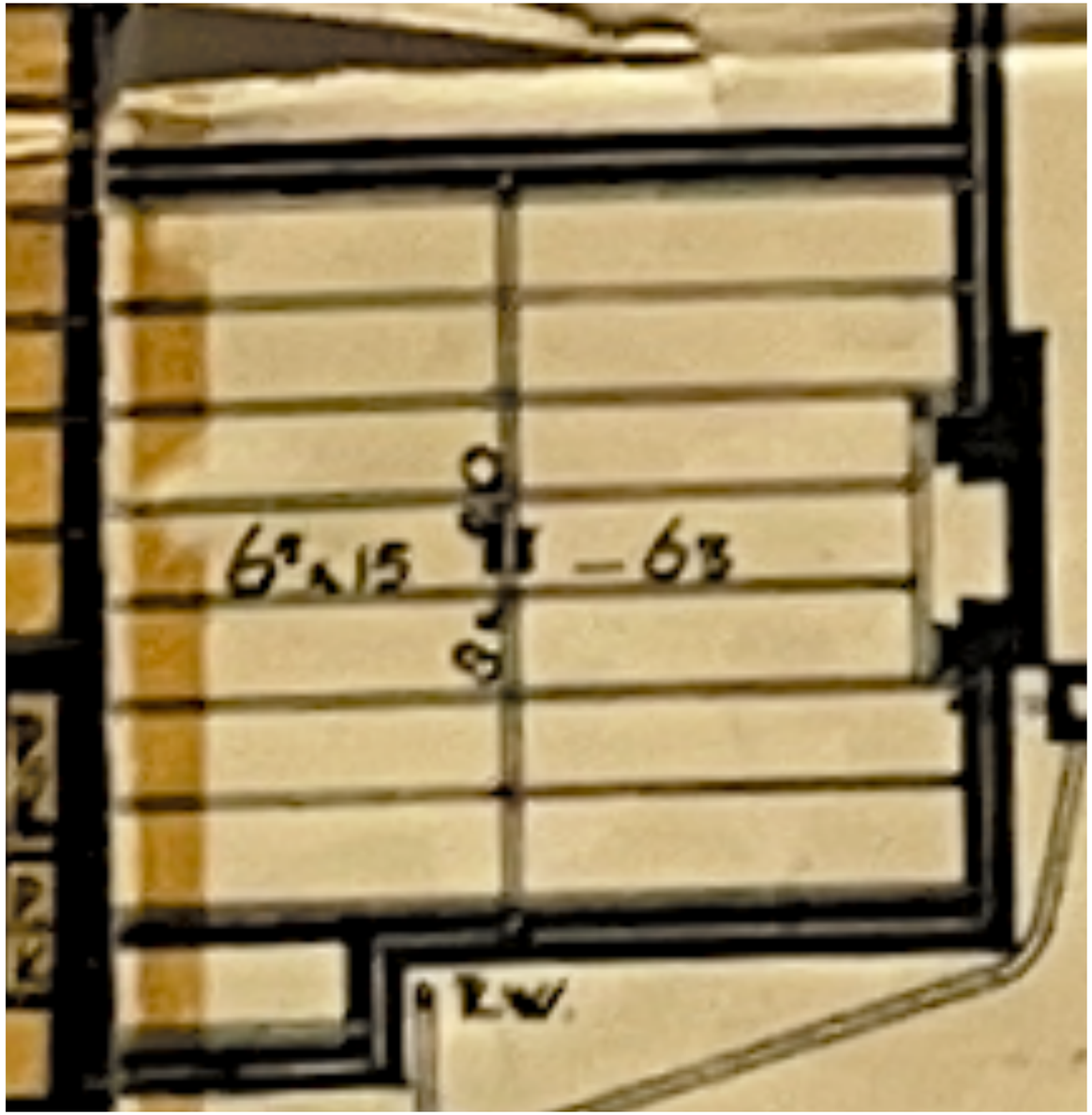

Develop
4i Privacy

After insulation; “shiny” foil is black body insulation, orange sheet stops humidity from the soil from entering the crawlspace

(work done by “isolatiedeal.nl" from Goor)

Wall insulation

- Most houses in 🇳🇱 built after ca. 1920 have a cavity wall
- Two walls with a layer of air in between
- Provides some insulation
- Filling with (recycled) rock wool significantly improves insulation
- Modest subsidy



Heating efficiency

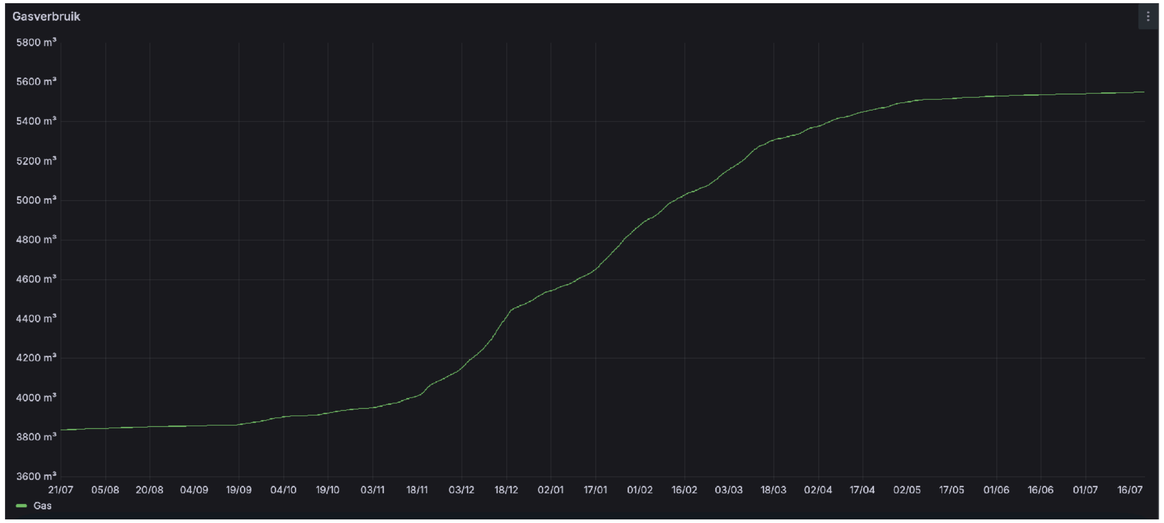
- “Classic” radiators rely on convection
- This requires relatively hot water to circulate in the heating system (> 75 ºC is not uncommon)
- Install fans underneath radiators to create forced convection
- Much lower water temperature, faster heating (more comfort)

Targeted heating

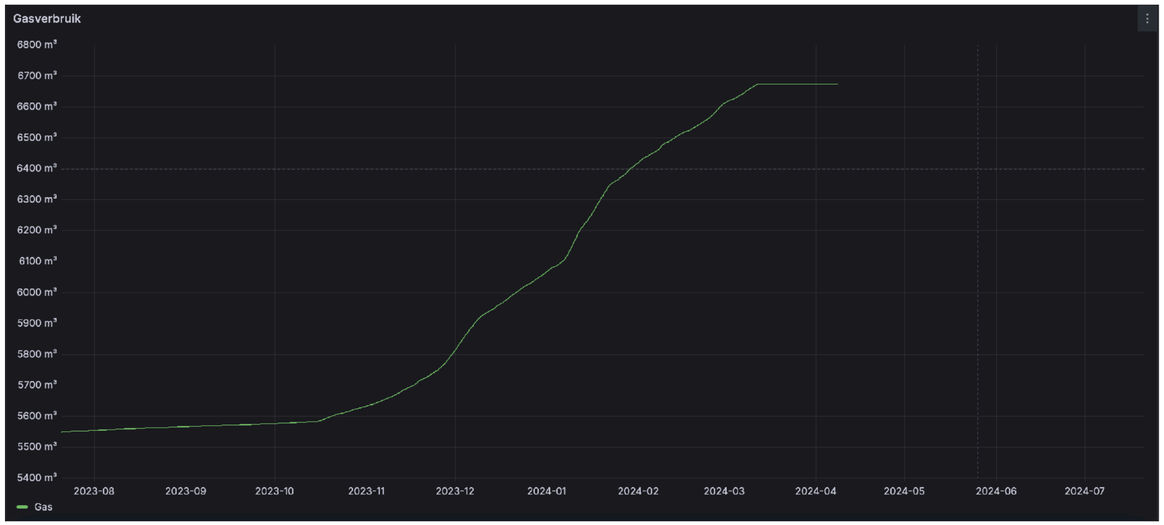
- Our house has a “classic” division into different rooms (modern: open plan designs)
- From a time before central heating, to be efficient and have comfort in living spaces
- Ideal to leverage with “smart” heating, radiator thermostats regulate temperature per room

Effects so far

- Significant reduction in use of natural gas (> 22%)
- From > 3800 m³ (previous owner) to ±1500 m³ annually
- More comfort per room (e.g., study now well-heated)
- Heater water temperature reduced from 85 °C to 55 °C (efficiency window HR heater)



Oct ’22 - Mar ’23: 1411 m³ gas



Oct ’23 - Mar ’24: 1092 m³ gas

Next step: no gas

- Insulation “as good as it gets”
- Next step: disconnect from the gas main and heat sustainably
- First up: new roof (before installing PV panels!)

PV panels

- Rear of the house has almost ideal orientation for PV
- Due south, steep roof inclination
- Advantage: peak insolation in spring and autumn
- 25x 415 Wp panels, totalling 10.25 kW installed power
- Installers “hated” our roof 😅

Home battery

- Feed-in tariffs will disappear
- Dynamic pricing will become more common
- Reduces grid congestion
- 9.2 kWh home battery
- Enough for overnight + single heating cycle for heat pump in summer

Heat battery

- Highly insulated enclosure
- EPDM “bag” contains 2000 litres of water of > 55ºC
- Acts as a battery for heat from direct solar, can also be heated by heat pump (also forced, when electricity is cheap)
- Prevents excessive heat pump modulation (reducing wear)

Heat pump

- “High” temperature heat pump (output > 60 °C)
- Rated maximum power 6 kW
- “Coefficient of Performance” (COP) of 3x to 5x

Heat pipes

- High-efficiency solar collectors
- Output temperature well over 60 ºC, even with partly cloudy skies
- On sunny days, heat output exceeds our needs for domestic hot water (buffering in the heat battery for following days)

EV charger

- Want to charge as green as possible
- Mennekes wall charger also used in “Slimpark” project @UT
- Modbus over TCP/IP (monitor + control charging current)
- 3 profiles with Python scripts: “excess PV”, “low price”, “fast”
- Different RFID tags for profiles

Putting it all together

Temperature monitoring for heat pipes

Control unit and pump for heat pipes

Heat exchanger for heat pipes (solar collectors)

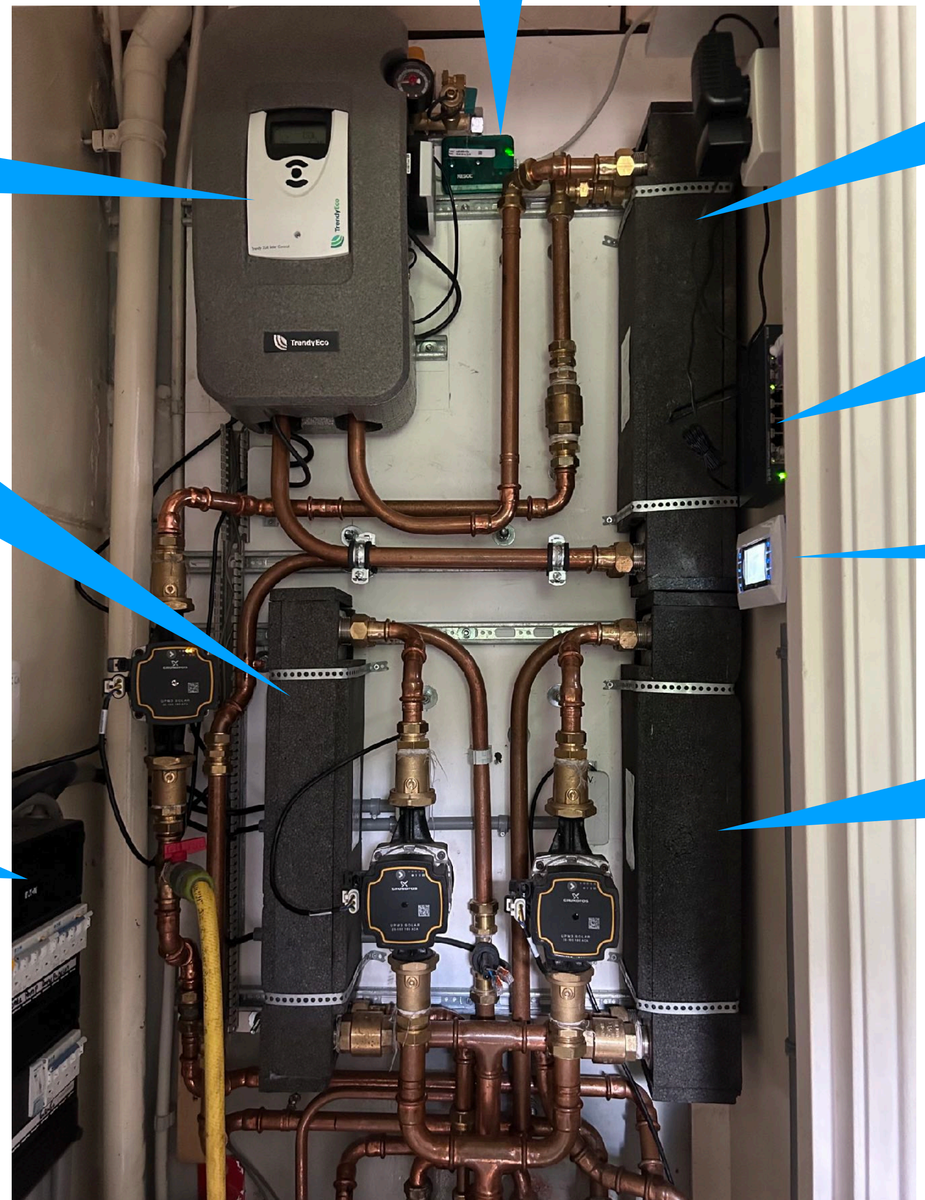
Ethernet switch for monitoring + EV charger

Heat exchanger for domestic hot water

Control unit for heat pump

Heat exchanger for domestic heating

Satellite fuse box for heat pump, EV charger and PV



Monitoring

- InfluxDB time series database
- Grafana for plotting + monitoring
- Various Python scripts to read out (among others):
  - P1 port of ESMR5 smart meter
  - Modbus for PV inverter + battery
  - Modbus for EV charger
  - Exotic serial protocol for heatpipe temperature monitoring

influxdata®

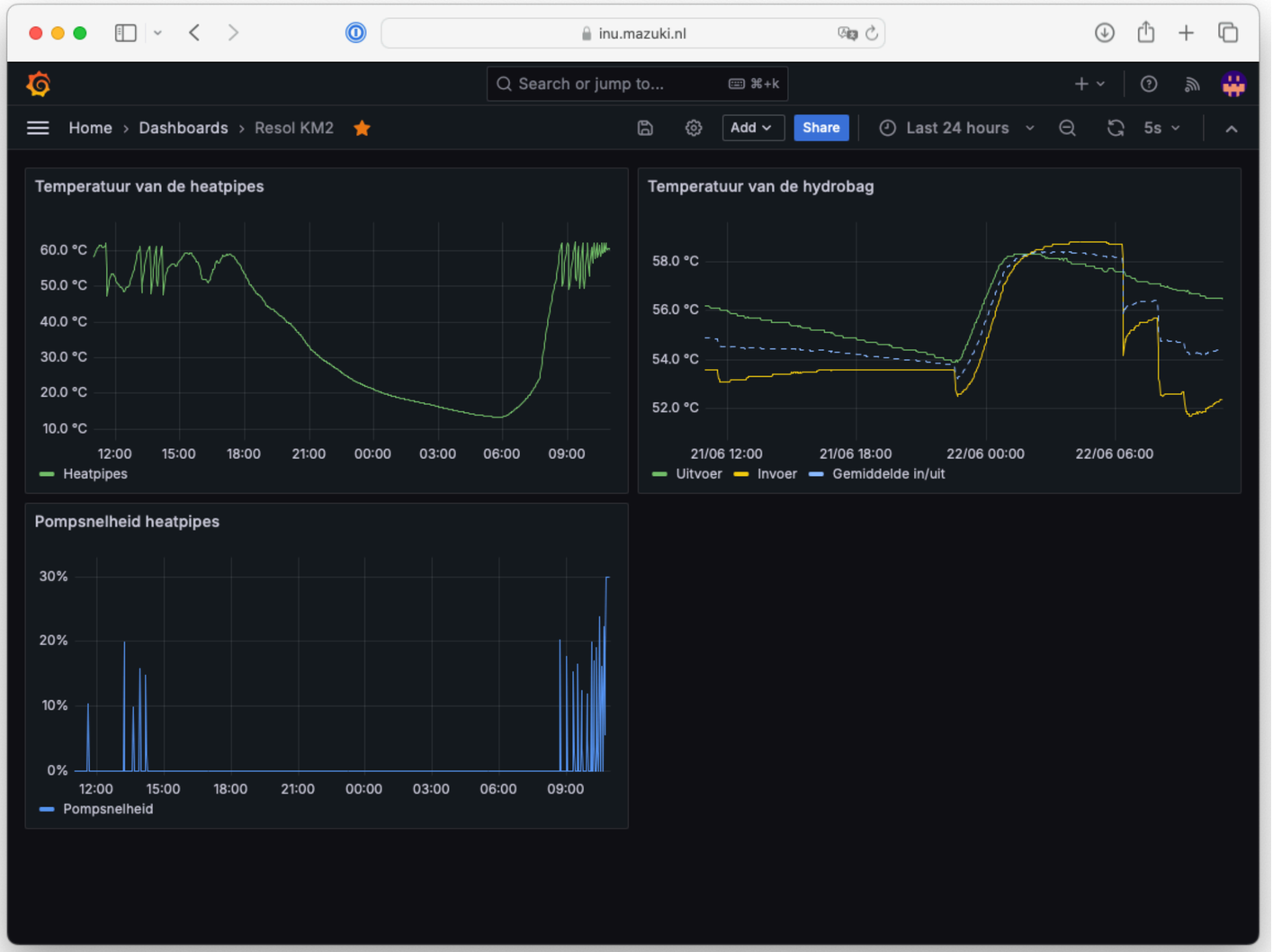
Grafana

python™

Example 1

Heatpipe monitoring

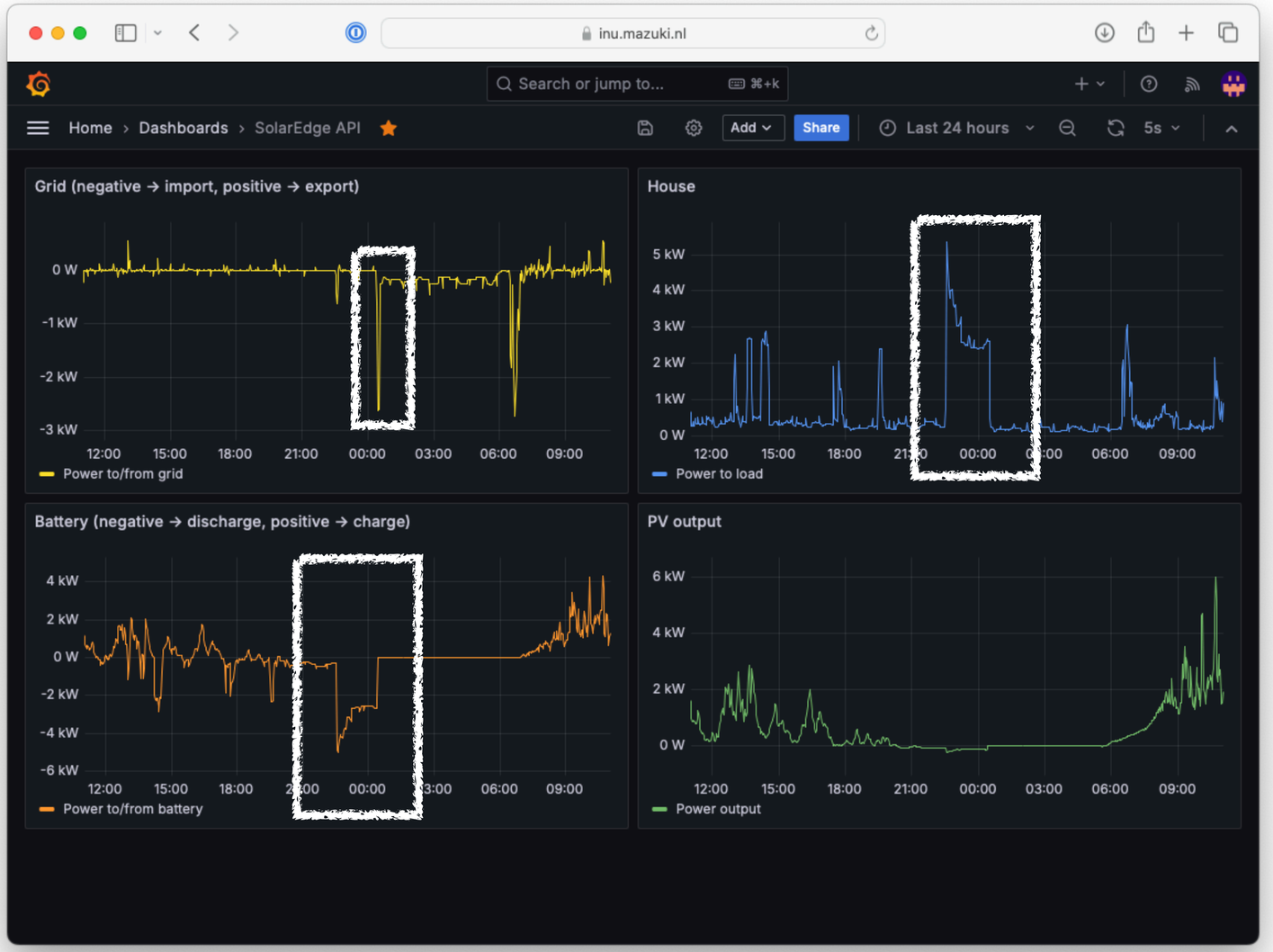
- Temperature of heat pipe array
- Temperature of sensors on the heat battery
- Pump speed of the heat pipe array
- Also serves for monitoring (excessive temperature, dry running circuit)



Example 2

Inverter monitoring

- Grid import/export
- Battery charge/discharge
- PV output
- House load
- Example shows heat pump running off the battery
- Switches to grid power when battery is empty



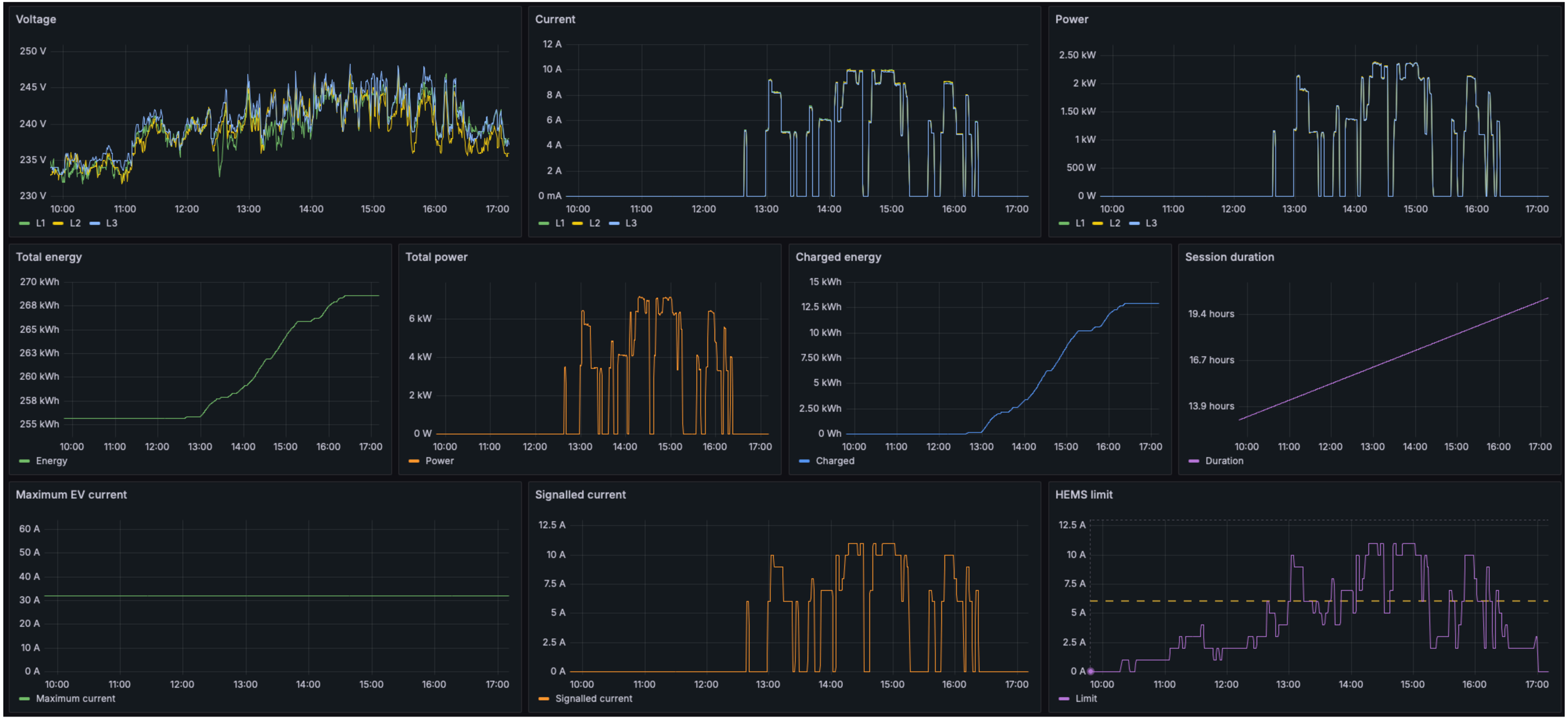
Control: EV charging from excess solar

```
if now >= next_hems_calc:
    if not hems_charging and state_of_charge > min_soc:
        # Minimum state of charge reached, turn on HEMS car charging
        hems_charging = True

        logger.info("Reached minimum state of charge ({}% >= {}%), enabling HEMS charging".format(int(state_of_charge), min_soc))

    if hems_charging and state_of_charge <= soc_floor:
        # State of charge dropped below lower bound, turn off HEMS car charging
        hems_charging = False

        logger.info("Reached lower bound for state of charge ({}% <= {}%), disabling HEMS charging".format(int(state_of_charge), soc_floor))

        hems_amp = 0

        logger.info("Setting HEMS limit to {}A per phase".format(hems_amp))

        try:
            fd = open("{}.tmp".format(hems_file), "w")

            fd.write('{}\n'.format(hems_amp))

            fd.close()

            # Atomically move HEMS file into place
            os.rename("{}.tmp".format(hems_file), hems_file)
        except Exception as e:
            logger.error("Failed to write {} ({})".format(hems_file, e))
```

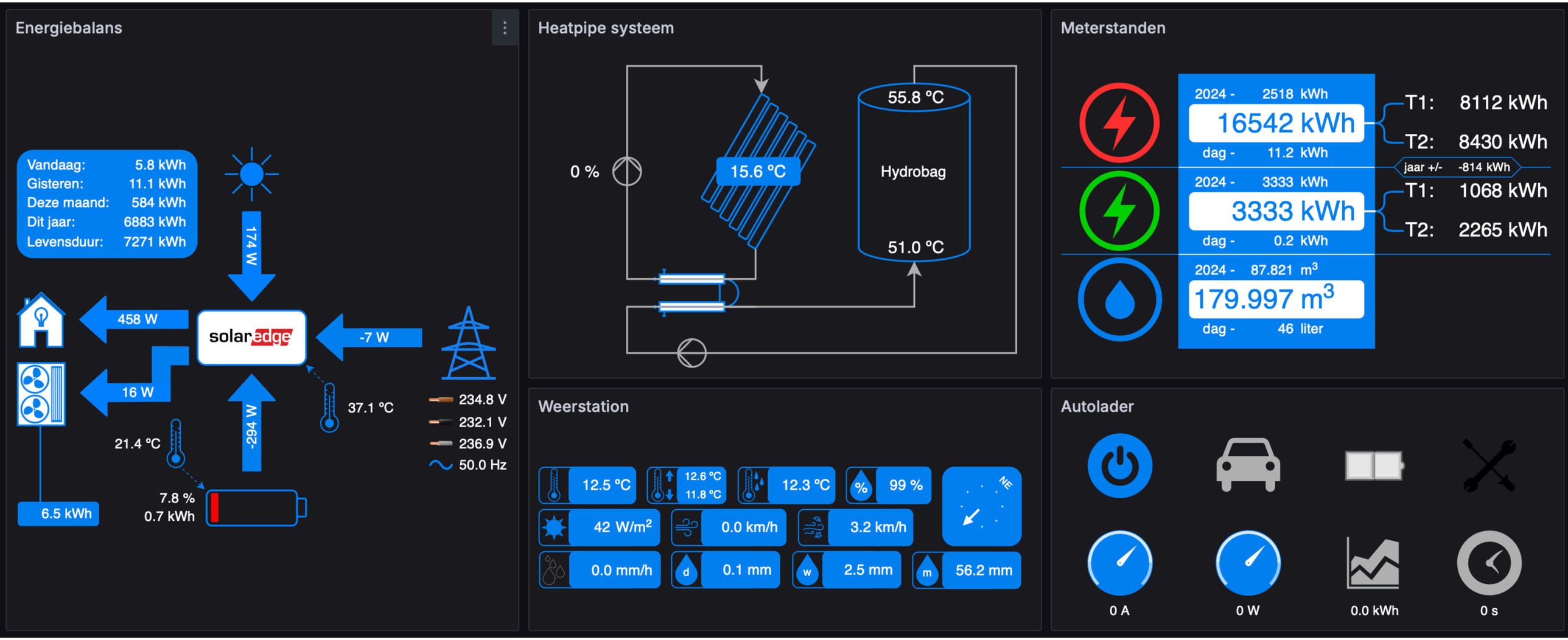
```
if hems_charging and len(acc_prod_values) > 0:
    # HEMS charging is enabled, calculate new HEMS value based on PV production
    # over the last 5 minutes
    logger.info("Computing new HEMS output value")

    pv_avg = np.average(acc_prod_values)

    logger.info("Average PV output over {} values is {}W".format(len(acc_prod_values), int(pv_avg)))

    hems_amp = pv_avg / hems_volt / 3

    logger.info("Raw current per phase for HEMS is {:0.2f}A".format(hems_amp))

    if hems_amp > max_hems:
        hems_amp = max_hems
    elif hems_amp < 0:
        hems_amp = 0

    hems_amp = int(math.floor(hems_amp))

    logger.info("Setting HEMS limit to {}A per phase".format(hems_amp))

    try:
        fd = open("{}.tmp".format(hems_file), "w")

        fd.write('{}\n'.format(hems_amp))

        fd.close()

        # Atomically move HEMS file into place
        os.rename("{}.tmp".format(hems_file), hems_file)
    except Exception as e:
        logger.error("Failed to write {} ({})".format(hems_file, e))
```

```
Jun 17 12:49:28 inu solaredge_influx.sh[3434683]: - [INFO] Computing new HEMS output value
Jun 17 12:49:28 inu solaredge_influx.sh[3434683]: - [INFO] Average PV output over 32 values is 7737W
Jun 17 12:49:28 inu solaredge_influx.sh[3434683]: - [INFO] Raw current per phase for HEMS is 11.21A
Jun 17 12:49:28 inu solaredge_influx.sh[3434683]: - [INFO] Setting HEMS limit to 11A per phase
Jun 17 12:49:28 inu solaredge_influx.sh[3434683]: - [INFO] Next HEMS calculation at 2024-06-17 12:52:27.117345
Jun 17 12:52:27 inu solaredge_influx.sh[3434683]: - [INFO] Computing new HEMS output value
Jun 17 12:52:27 inu solaredge_influx.sh[3434683]: - [INFO] Average PV output over 32 values is 7770W
Jun 17 12:52:27 inu solaredge_influx.sh[3434683]: - [INFO] Raw current per phase for HEMS is 11.26A
Jun 17 12:52:27 inu solaredge_influx.sh[3434683]: - [INFO] Setting HEMS limit to 11A per phase
Jun 17 12:52:27 inu solaredge_influx.sh[3434683]: - [INFO] Next HEMS calculation at 2024-06-17 12:55:27.117345
Jun 17 12:55:32 inu solaredge_influx.sh[3434683]: - [INFO] Computing new HEMS output value
Jun 17 12:55:32 inu solaredge_influx.sh[3434683]: - [INFO] Average PV output over 33 values is 7959W
Jun 17 12:55:32 inu solaredge_influx.sh[3434683]: - [INFO] Raw current per phase for HEMS is 11.54A
Jun 17 12:55:32 inu solaredge_influx.sh[3434683]: - [INFO] Setting HEMS limit to 11A per phase
Jun 17 12:55:32 inu solaredge_influx.sh[3434683]: - [INFO] Next HEMS calculation at 2024-06-17 12:58:27.117345
```

Control: EV charging from excess solar



Recent addition: “whole house overview”



Next project

“Smart grid ready”

- Our heat pump can be controlled
- Simple 2-contact protocol:
  00 = Normal operation
  10 = Blocked operation
  01 = Encourage operation
  11 = Ordered operation
- Someone decided using a 230V relay-controlled signal was the right communication bus 🙄🙄🙄

Conclusions & future work

- The system is fairly complex; lots of things to tweak and control
- It is possible to comfortably heat and get domestic hot water without gas
- Future work:
  - Understand heat pump efficiency better; there is room for improvement
  - Expand battery system
- **On offer: use my data for student projects! (everything is in InfluxDB)**