VICTORIA UNIVERSITY OF WELLINGTON TE HERENGA WAKA NEW ZEALAND
Archives of Sustainable Energy Systems
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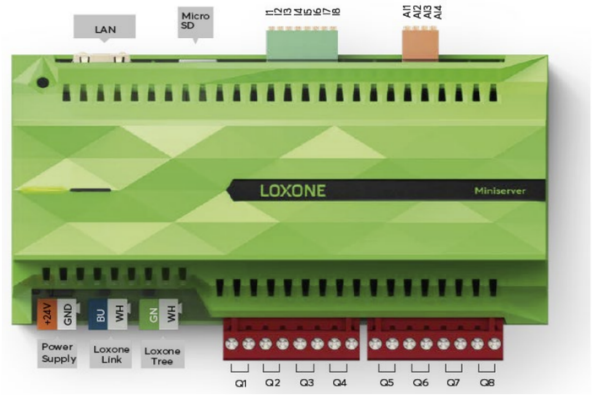
Design and implementation of a distributed energy management system for solar PV and flexible loads using a building automation platform: A residential site case study in Hamilton, Aotearoa New Zealand Supplementary Material

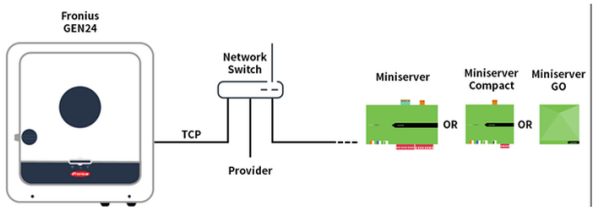
Implementation details

Supervisory controller and network integration

The local supervisory controller is a Loxone Miniserver. The Miniserver is a 19.2–30 VDC supply, eight digital inputs, four analogue inputs (0–10 V, 12-bit), and eight volt-free relay outputs rated at 250 VAC 10 A or 30 VDC 10 A. Uses Ethernet communications supporting TCP/IP, Modbus TCP and UDP. In this case it is used for local schedules, signal acquisition, relay-output supervision, and communications with the Fronius equipment.



Loxone Miniserver terminal layout and onboard I/O



Simplified Fronius GEN24 - switch - Miniserver topology

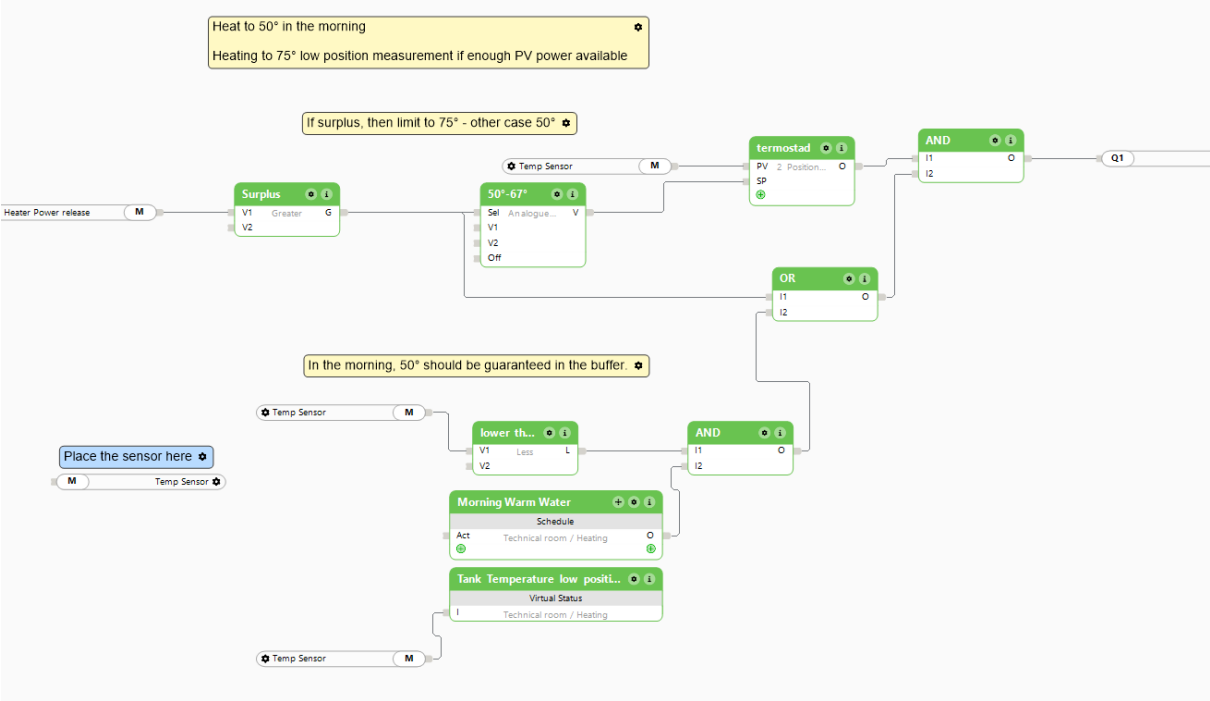
Loxone Miniserver hardware and a simplified supervisory communication pathway between the Fronius inverter, network switch, and Miniserver

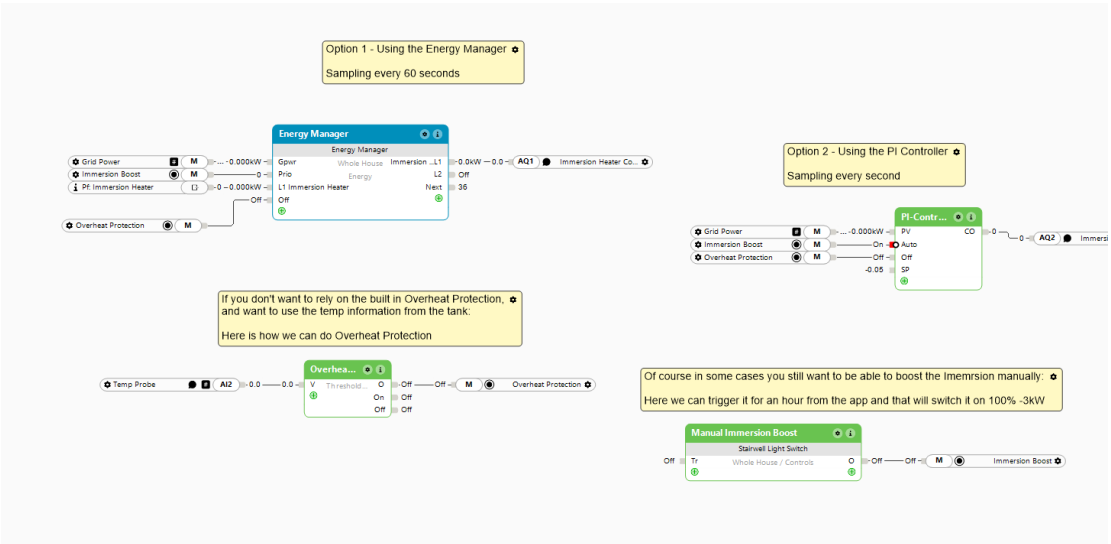
Hardware

Subsystem	Parameters	Use in the case study
Loxone Miniserver	19.2–30 VDC; 8 digital inputs; 4 analogue inputs (0–10 V, 12-bit); 8 dry-contact relay outputs; Ethernet 100 Mbps with TCP/IP, Modbus TCP and UDP.	Local supervisory EMS logic, telemetry collection, schedules, alarms, and relay-output control.
Fronius Symo GEN24 / GEN24 Plus	Open third-party interfaces documented for the GEN24 platform; GEN24 Plus is battery-ready hybrid architecture.	Primary PV inverter and the core communication point for PV-system data.
Fronius Smart Meter 63A-3	Bidirectional DIN-rail meter; 230–400 V; 3 x 63 A; accuracy class 1; Modbus RTU (RS485).	Point-of-connection import / export measurement.
300 L electric HWC	3 kW resistive element.	controllable electrical load
TS18P-CAT Pt100 probe	Pt100 Class A; 200°C; 3-wire; 316 stainless-steel sheath; cold junction rated to 105°C.	Low-position tank-temperature measurement for minimum-service and surplus-diversion logic.
PR 5114 transmitter	Input for RTD / TC / mV / R / mA / V; 3-port 3.75 kVAC galvanic isolation; programmable current or voltage output including 0–10 V.	Signal conditioning between the Pt100 probe and the Miniserver analogue input.

Logic

Surplus comparison, temperature-target selection, hysteretic relay control, and a morning service guarantee. The Greater block generates a digital surplus-permission signal, the Analogue Multiplexer selects the active temperature target (higher under surplus, lower otherwise), and the thermostat / 2-position controller applies hysteresis around the chosen set-point. A parallel morning schedule and low-position temperature check ensure that approximately 50°C is still available in the buffer after overnight use.





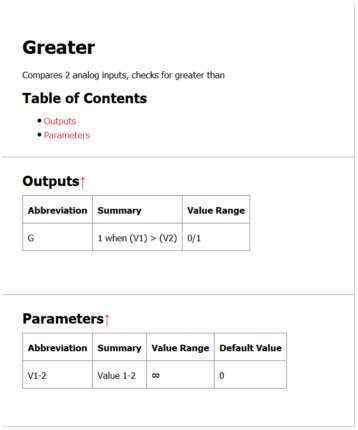
Relay logic

Functional interpretation of the Logic

Block / signal	Interpretation used in this supplement
Heater Power release	Incoming supervisory permission or release signal for HWC control.
Surplus (Greater)	Compares two analogue inputs and sets G = 1 when the release / surplus value exceeds the comparison value.
50°–67° analogue selection	Selects the active temperature target according to the surplus condition.
2Position Controller	Switches the relay output using a set-point and hysteresis around the measured tank temperature.
lower-threshold branch	Checks whether the low-position temperature is below the morning minimum requirement.
Morning Warm Water schedule	Time window that guarantees morning service.
OR / AND logic	Combines surplus-driven heating and morning minimum-service logic before final relay enable.
Q1 relay	Dry-contact supervisory relay output that enables the external hot-water switching path.

Control blocks and their role in the implemented logic

Block	Role	Interpretation
Greater	Surplus comparator in the commissioning relay branch	Outputs 1 when V1 exceeds V2, enabling PV-surplus permission.
Analogue Multiplexer (2-way)	Switches between the normal and surplus heating targets	Selects the active set-point passed to the relay controller.
2 Position Controller	Hysteretic relay control for the hot-water element	Uses a set-point and hysteresis band to reduce chatter and provide stable on/off behaviour.
Less	Checks whether the lower tank temperature is below the morning minimum	Provides the low-temperature condition for guaranteed morning service.
Schedule	Morning warm-water window	Activates the service-recovery window during the configured morning period.
Virtual Status	Stores/displays the lower-tank temperature status	Maintains a visible state for the logic and user interface.
AND / OR	Boolean arbitration of surplus and service conditions	Combines temperature, schedule, and surplus signals before relay output Q1.
Energy Manager	Analogue diversion option with slower recalculation	Maps measured surplus into an immersion-heater command, recalculated approximately every 60 s in the project notes.
PI Controller	Faster proportional branch for finer surplus tracking	Provides controller output based on PV / process value, with approximately 1 s sampling in the project notes.
Threshold Switch	Overheat-protection / analogue limit logic	Switches when a defined threshold is crossed and provides a simple protective edge action.
Stairwell Light Switch	Timed manual immersion boost	Used as a fixed-duration manual override / boost function.



Greater

Compares 2 analog inputs, checks for greater than

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Outputs ↑

Abbreviation	Summary	Value Range
G	1 when (V1) > (V2)	0/1

Parameters ↑

Abbreviation	Summary	Value Range	Default Value
V1-2	Value 1-2	∞	0

Greater block

Analogue Multiplexer (2-way)

This block can select between 2 analog values via a parameter input (Sel).

Online Documentation

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Inputs ↑

Abbreviation	Summary	Description	Value Range
V1	Value 1		∞
V2	Value 2		∞

Analogue Multiplexer

2 Position Controller

2 Position Controller

The 2 Position Controller manipulates a controlled variable by switching an output, using a setpoint and a hysteresis.

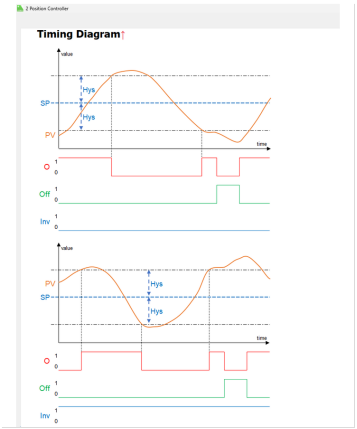
Online Documentation

Table of Contents

Inputs ↑

Abbreviation	Summary	Description	Value Range
PV	Process value	Actual value of the controlled variable.	∞
Off	Off	Pulse: Outputs are reset / switched off. On: Block is locked. Dominating input.	0/1

2 Position Controller



2 Position timing

Less

Compares 2 analog inputs, checks for less than

Table of Contents

Outputs ↑

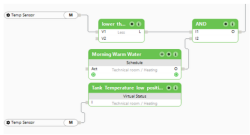
Abbreviation	Summary	Value Range
L	1 when (V1) < (V2)	0/1

Parameters ↑

Abbreviation	Summary	Value Range	Default Value
V1-2	Value 1-2	∞	0

Morning Warm Water

Less block



Schedule (Sch)

Timer switch with freely adjustable schedule and operating modes.
The timer switch can be used digitally (on/off) or analogue.
A double click on the block opens the editing window in which the schedule can be set.
By activating remanence (battery symbol), the previous state is restored after a power failure.

Online Documentation

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Schedule block

Programming example ↑

In this example, a moving average is first formed from the temperature value and then displayed in the user interface via the Virtual Status.

Activating the statistics in the Virtual Status has the advantage that the data remains saved if a sensor or the logic before the block is changed.

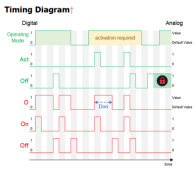
OR

This function block creates a logic OR operation. The output will be active when at least one of the inputs is active.
Multiple signals connected to the same input will also be OR-linked.

AND / OR logic

If parameter (Am) is 1, manual mode is activated. If the value of parameter (Mm) changes to 4, the timer will work with the switching time of <Operating Mode>(4).

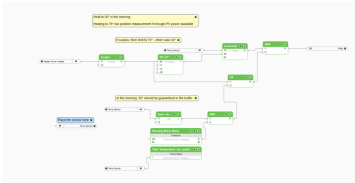
Timing Diagram ↑



Virtual Status

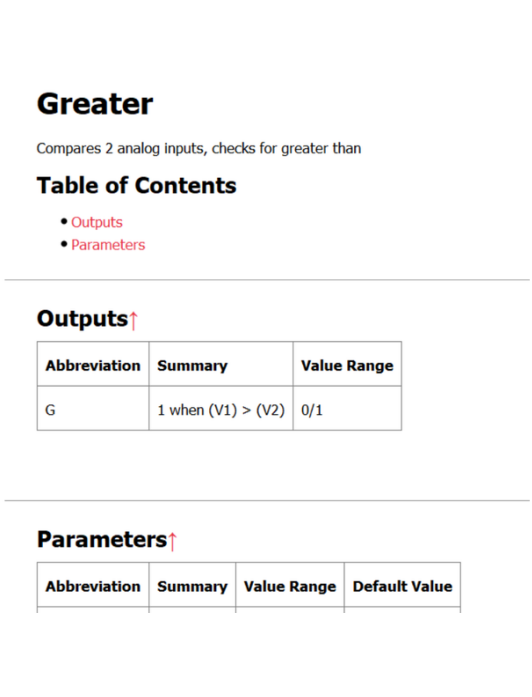
The Virtual Status is used to display values in the user interface.

Virtual Status

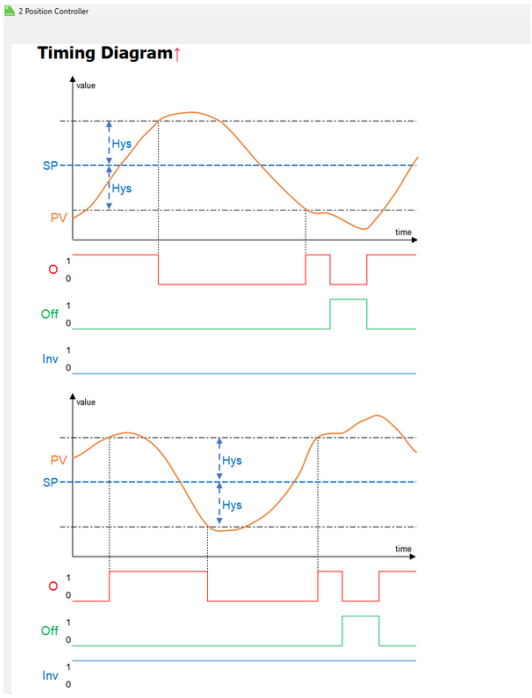


Commissioning logic screenshot

Greater block, analogue multiplexer, 2-position controller timing behaviour, Less block, Schedule block, Virtual Status, AND / OR logic

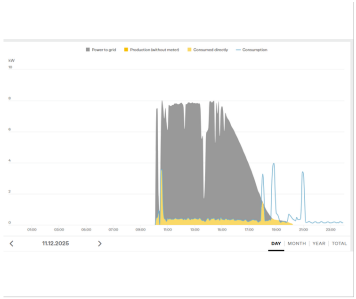


Greater block: G = 1 when V1 > V2



2-position controller: switching with hysteresis

Timing diagrams



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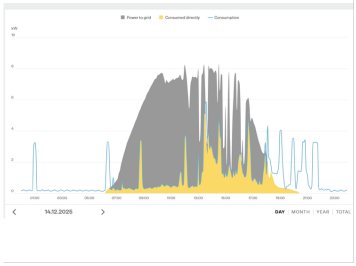

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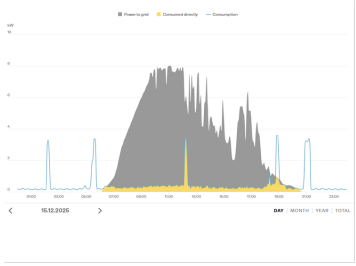

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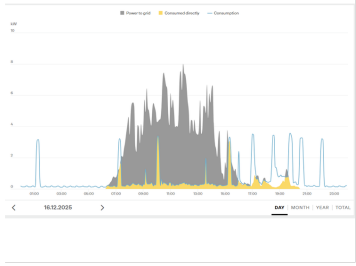

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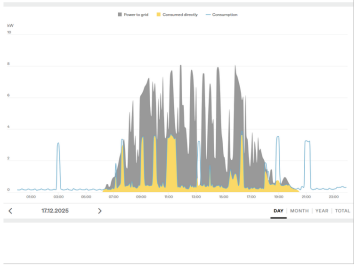

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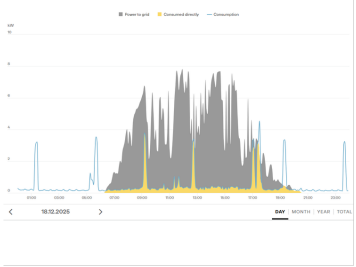
17.12.2025 (2/3)

17.12.2025 (3/3)



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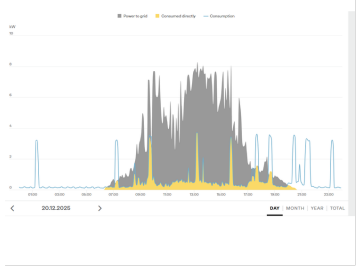

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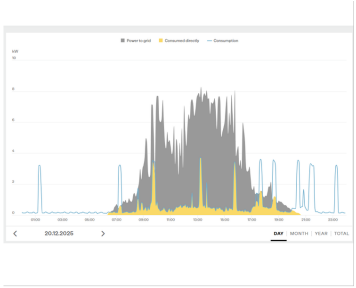
Daily energy trends



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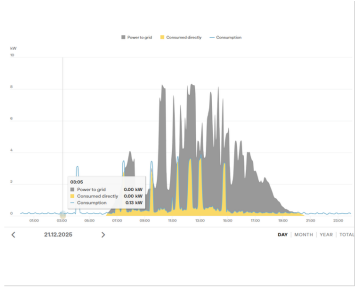

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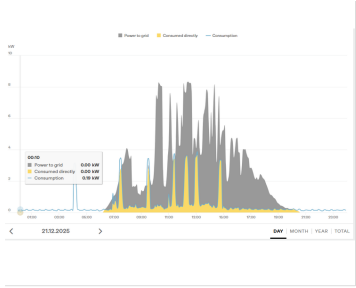

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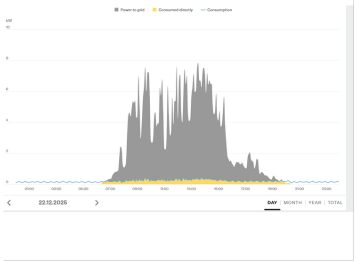

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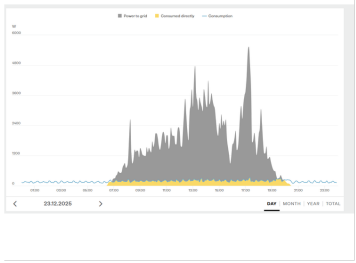

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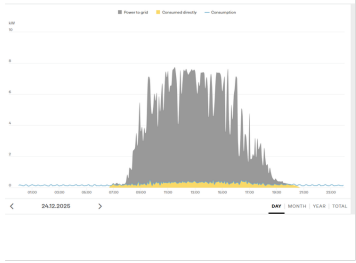

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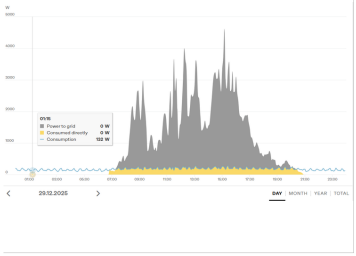

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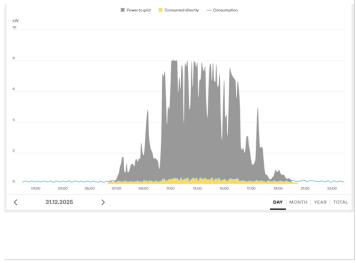

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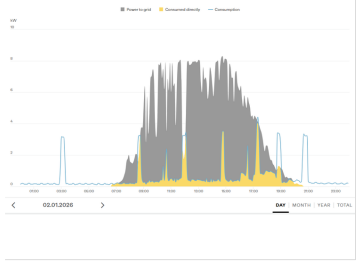

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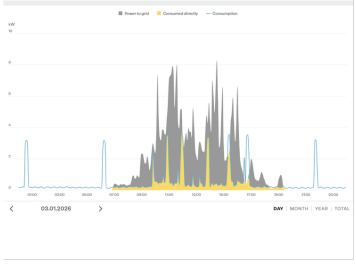

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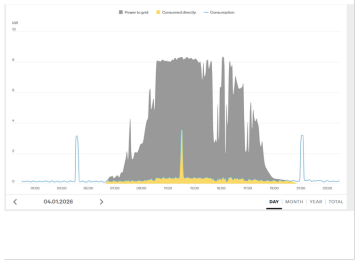

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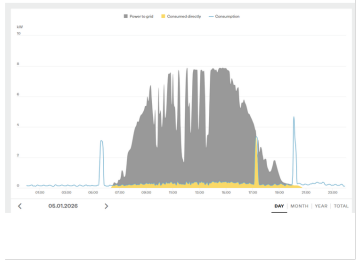

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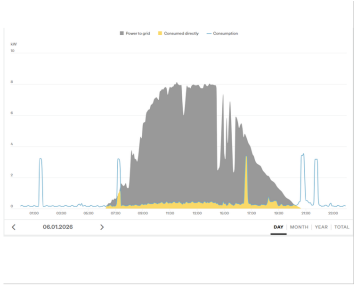
Daily energy trends



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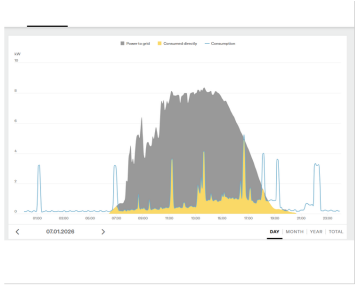

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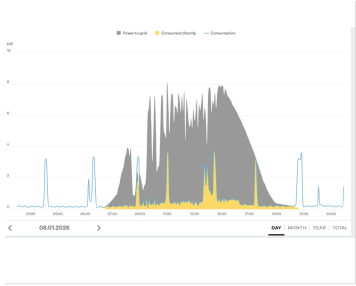

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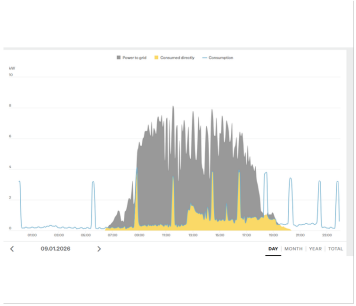

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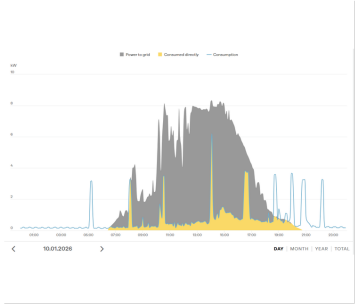

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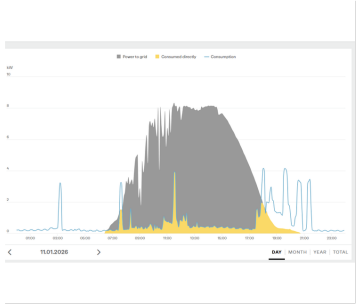

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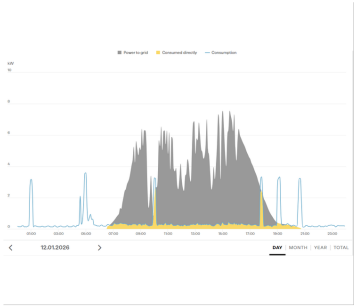

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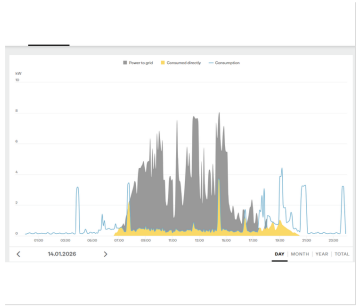

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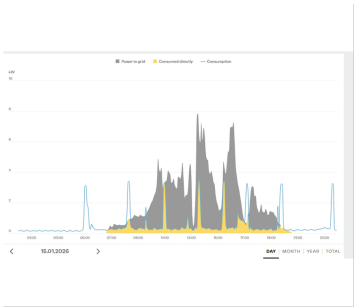

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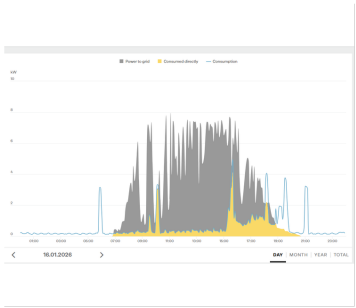

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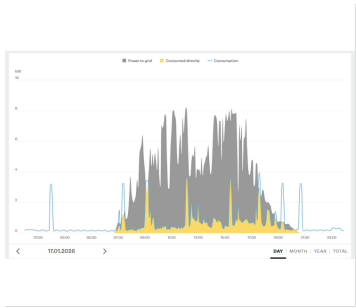

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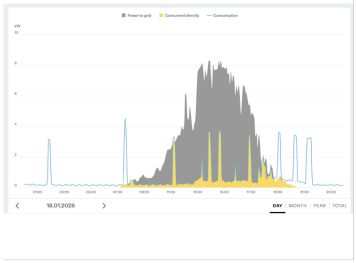
Daily energy trends.



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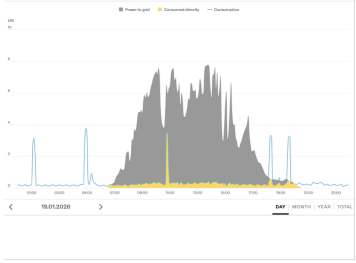

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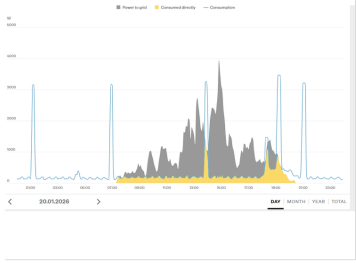

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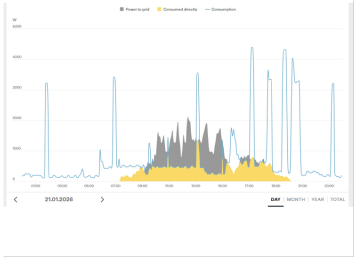

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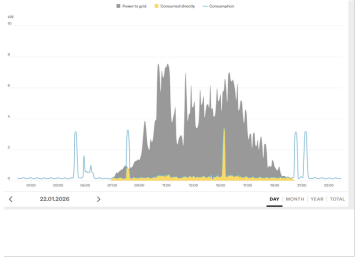

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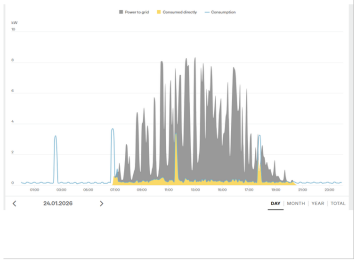

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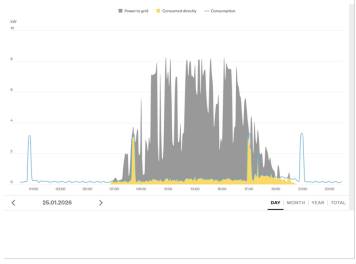

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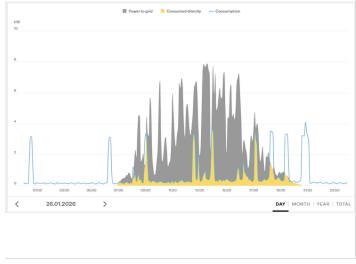

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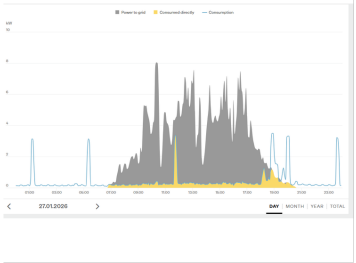

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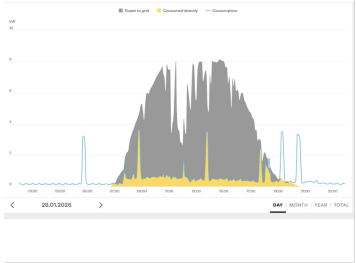

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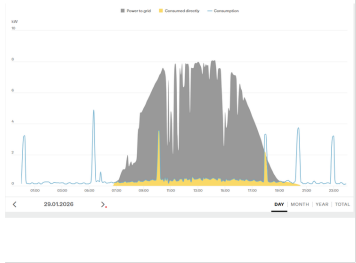
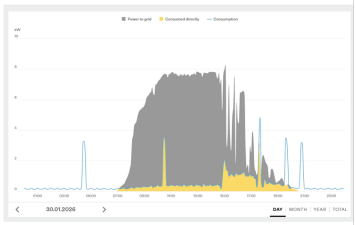


29.01.2026

Daily energy trends



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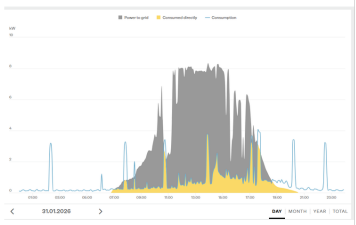

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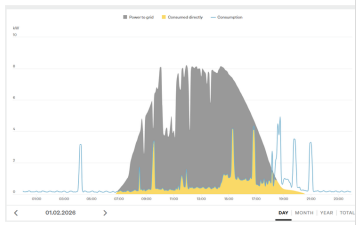

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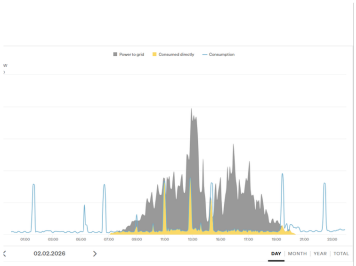

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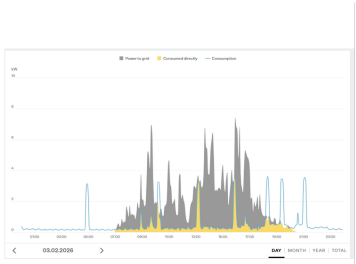

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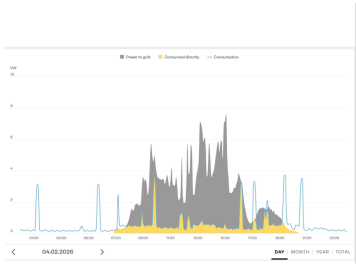
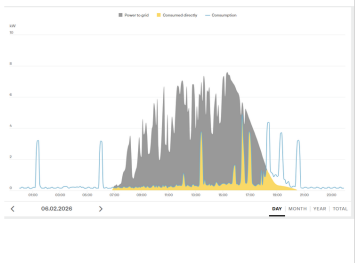


04.02.2026

05.02.2026



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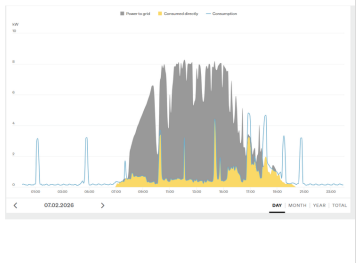

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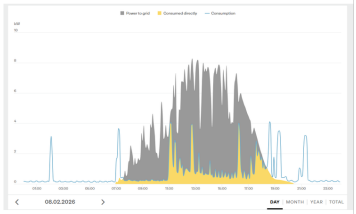

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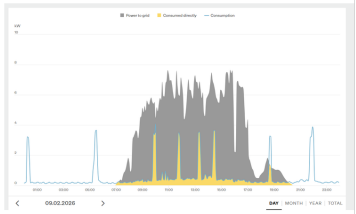

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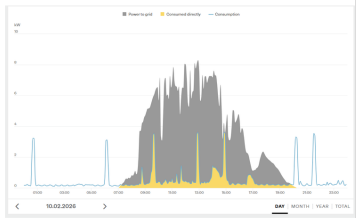
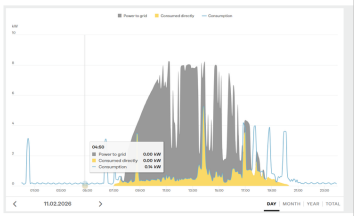


10.02.2026

Daily energy trends



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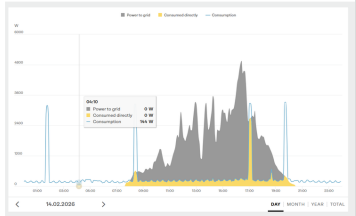
12.02.2026



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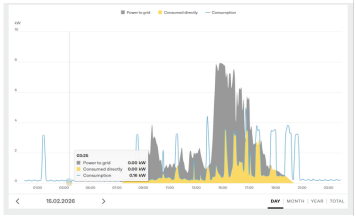

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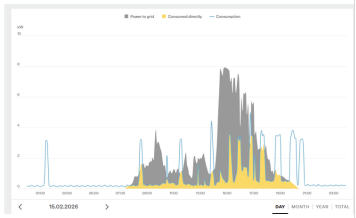

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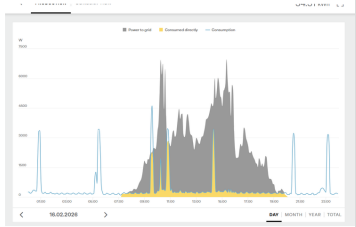

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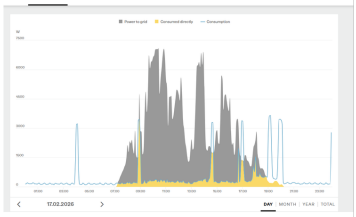

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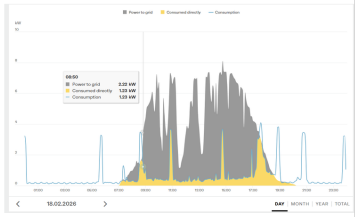

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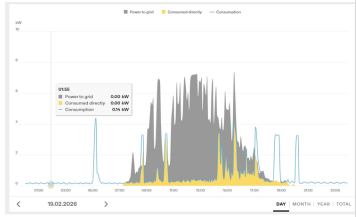

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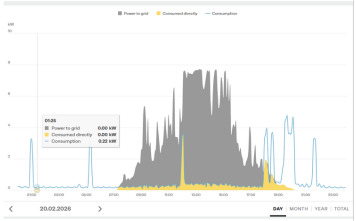

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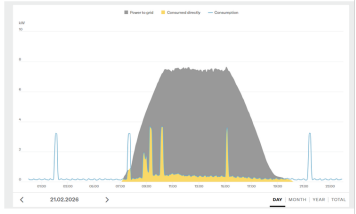

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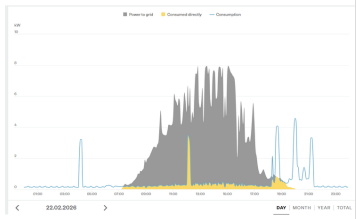
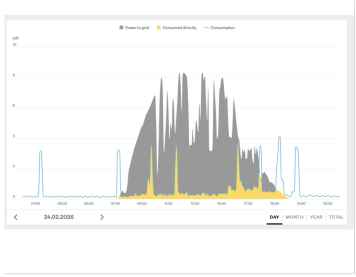


22.02.2026

Daily energy trends

23.02.2026



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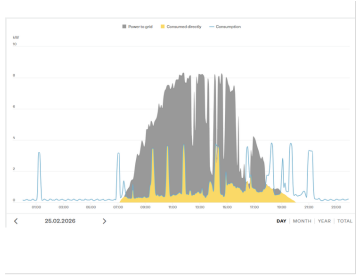

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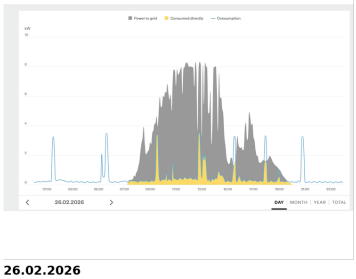

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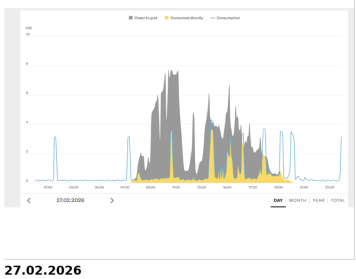

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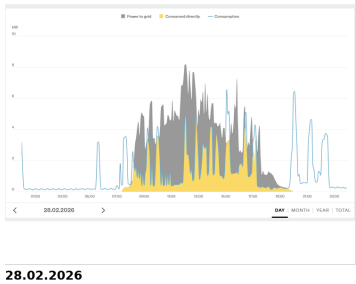

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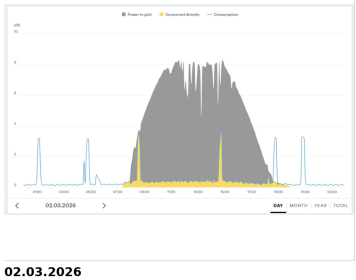
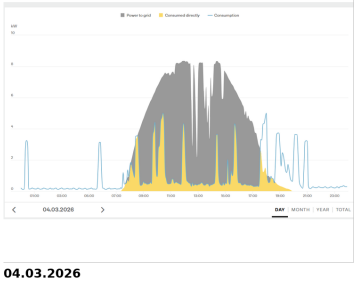
01.03.2026



02.03.2026

03.03.2026



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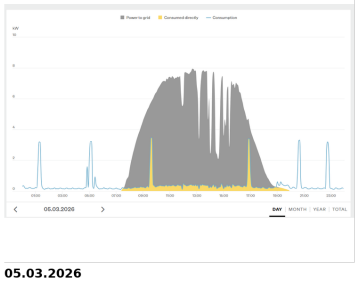

05.03.2026

Daily energy trends