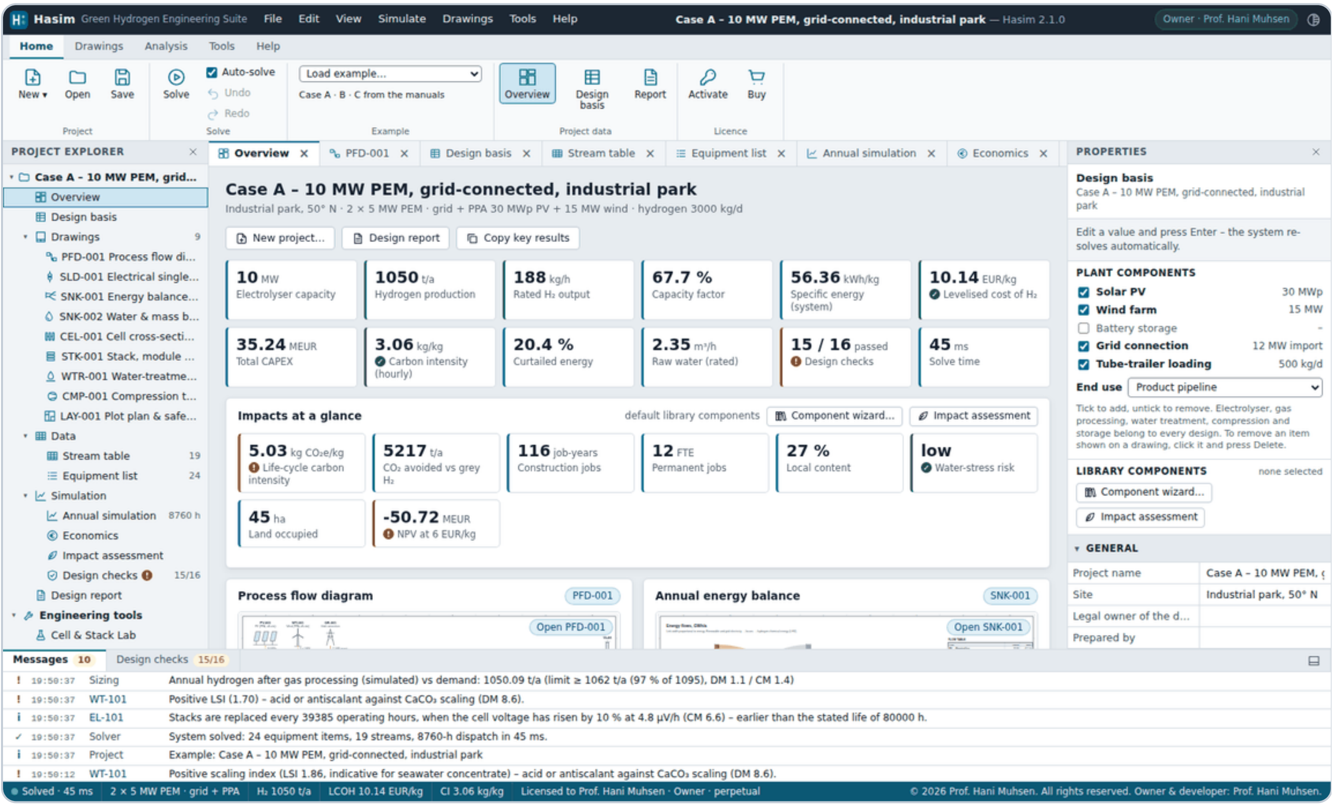


Hasim

Green Hydrogen Engineering Suite · version 2.1.0

Model-Building Examples

Building projects from scratch and from components, then thirteen step-by-step exercises: from a first grid-connected PEM plant to an islanded 100 MW ammonia project, refuelling hubs, technology and storage studies, value chains, scripted optimisation and the choice of components by their technical, economic, environmental and social impacts.



Owner and developer: Prof. Hani Muhsen

All numbers in this document were produced with Hasim 2.1.0 and can be reproduced exactly with the steps shown.

Contents

Start here – a new project from scratch: the New Project wizard, adding and removing plant components, value chains in the Model builder, and starting from the component library

How to use these examples

Each example states its goal, lists the steps in Hasim and shows the results. Steps refer to the ribbon (**Home**, **Drawings**, **Analysis**, **Tools**), the **project explorer** on the left and the **properties panel** on the right. Edit a value in the properties panel and press Enter – with auto-solve on, the whole system is re-solved. The User Manual explains every document in detail.

Start here – a new project from scratch

Hasim offers four ways to build a model. This chapter shows each of them step by step; the thirteen examples that follow then use the finished models.

Way	Use it for	Where
New Project wizard	A complete plant with drawings, stream table, equipment list, annual simulation, economics, design checks and report	File ▸ New project (wizard) · Home ▸ New ▾ · Overview ▸ New project
Plant components	Adding or removing solar PV, wind, battery, grid connection, trailer loading and the end use of an existing project	Top of the Properties panel · click an item on a drawing and press Delete
Model builder	Quick value-chain studies from blocks, from the power supply to the end use, without drawings	Tools ▸ Model builder
Component library and component wizard	Starting from the equipment: PV plants, wind turbines, batteries, water plants, stacks, compressors, vessels ... with their technical, economic, environmental and social data; the wizard shows the impacts of every choice	Tools ▸ Component library · Component wizard in the Model builder, the Design basis and the Impact assessment

A. The New Project wizard

The wizard asks for the plant in six steps and sizes it automatically with the complete system model, so that the yearly production meets the demand. We build **Aqaba Green Hydrogen**: 2 000 kg of hydrogen per day for a customer 10 km away by pipeline, with electricity from the grid and a solar and wind PPA.

1. **File ▸ New project (wizard)**. Step 1 **Product**: project name “Aqaba Green Hydrogen”, site “Aqaba, Jordan”, product **Hydrogen**, demand **2000 kg/d**, end use **Product pipeline** (10 km, 30 bar).
2. Step 2 **Power supply**: **Grid-connected** with **Solar PV** and **Wind** through a PPA; grid use **Fill to target load** with a target of 0.45, electricity price 80 EUR/MWh, grid carbon intensity 300 g/kWh.
3. Step 3 **Site & water**: climate preset **Sunny desert / Middle East** (latitude 30°, GHI 2 250 kWh/m^2, wind 7.5 m/s) and **Municipal** water. Adjust GHI and wind speed if you know the values of your site.
4. Step 4 **Electrolyser**: **PEM**. The minimum load is preset to **10 %** – the lowest load, in steps of 5 %, at which hydrogen in oxygen stays below the 2 % trip (CM 7.7) when the cathode pressure is lowered at part load; a lower value would be raised to the trip limit in the simulation. Keep **Size the plant for me**.
5. Step 5 **Storage & economics**: storage 250 bar, buffer 1 day, WACC 7 %, 25 years.
6. Step 6 **Review**: Hasim sizes the plant and shows the result. Press **Create project**.

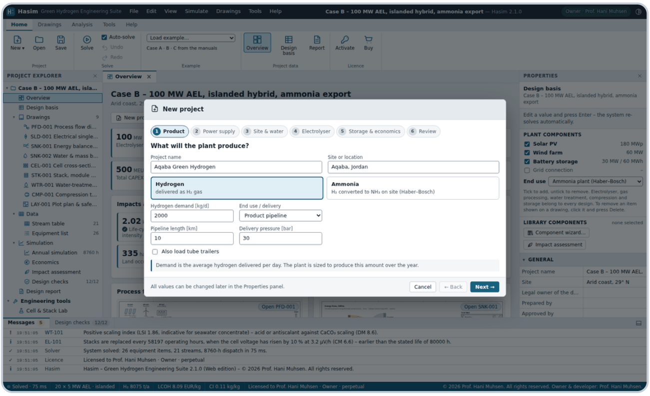


Figure S.1 – Step 1: product, demand and end use.

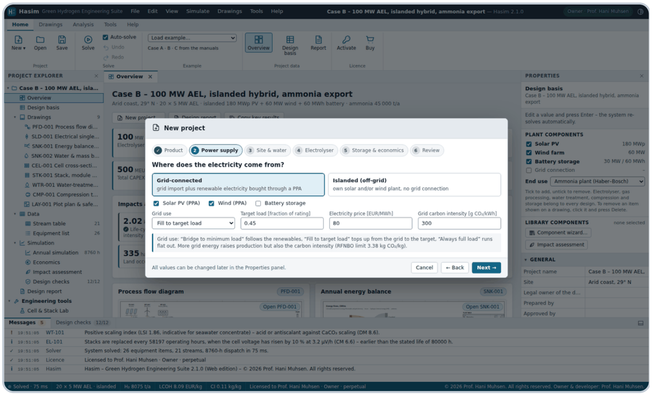


Figure S.2 – Step 2: power supply.

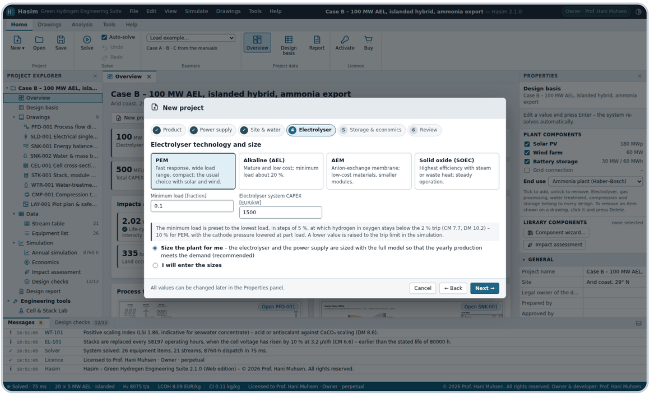


Figure S.3 – Step 4: technology, safe minimum load and sizing.

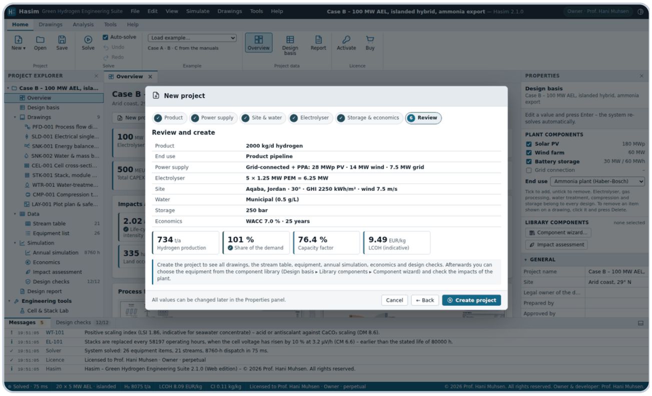


Figure S.4 – Step 6: the sized plant before it is created.

The sizing took 13 runs of the complete 8760-hour model. Hasim chose **5 × 1.25 MW PEM** (6.25 MW), **28.0 MWp** PV and **14.0 MW** wind through the PPA and a **7.5 MW** grid connection. Because the modules come in whole units, the last runs enlarge the solar and wind volumes until the production meets the demand. The plant produces 734 t/a after gas processing – 101 % of the 730 t/a demand – and passes all 16 design checks.

6.25 Electrolyser [MW]	**734** Hydrogen [t/a]	**76.4 %** Capacity factor	**9.49** LCOH [EUR/kg]
2.07 CI hourly [kg/kg]	**22.0** CAPEX [MEUR]	**23 / 18** Equipment / streams	**16 / 16** Checks passed

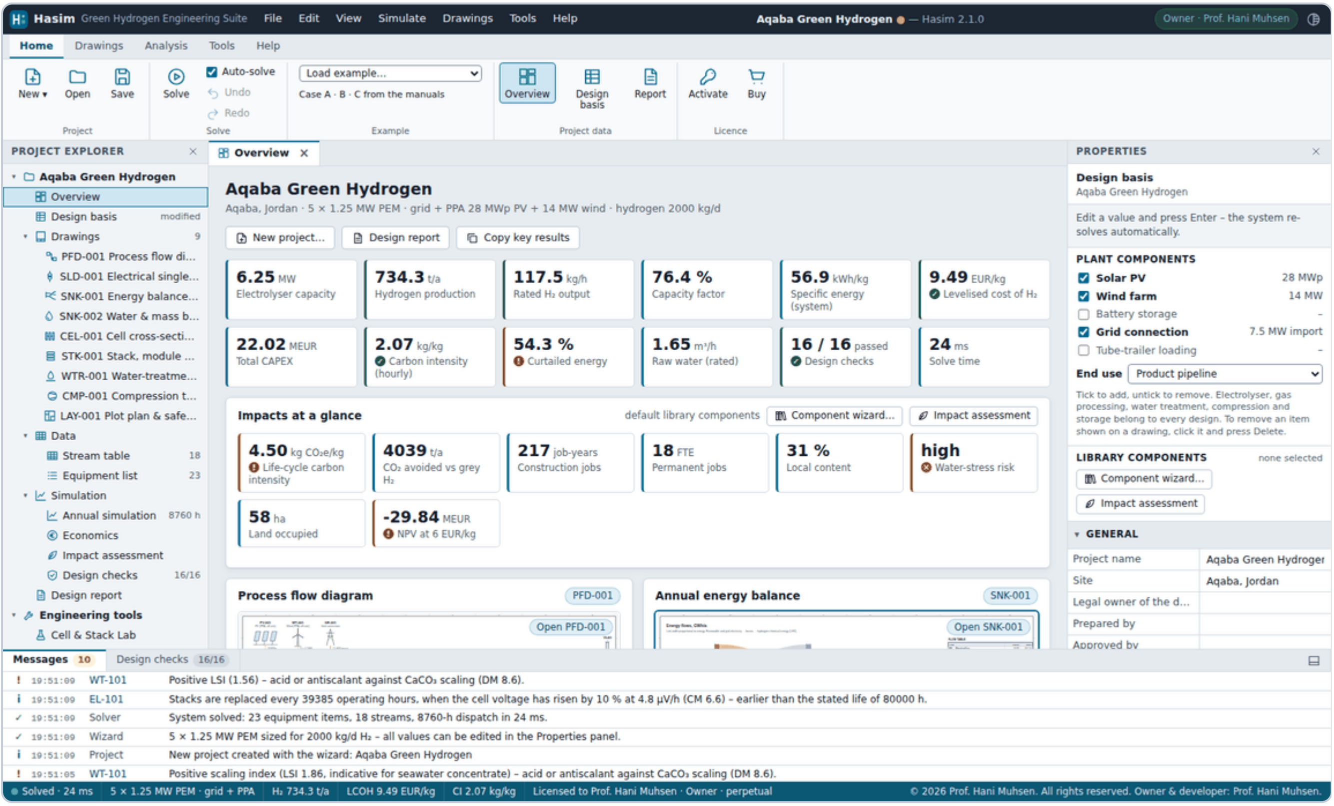


Figure S.5 – The new project: all documents are ready; every value can be changed in the Properties panel.

> **After the wizard**
>
> The project behaves like any other: edit values in the Properties panel, save it with Ctrl+S. The blue bars mark values changed from the wizard result, and **Edit ▸ Reset design basis to the wizard values** goes back to it. With an islanded plant the wizard sizes PV, wind and the optional battery for an off-grid supply; with ammonia as product it adds the Haber–Bosch plant.

B. Adding and removing plant components

The **Plant components** list at the top of the Properties panel (and of the Design basis document) shows the optional equipment. **Untick** a component to remove it – its size is remembered – and **tick** it to add it back. The **End use** list switches between delivery at the plant fence, a product pipeline, a refuelling station and an ammonia plant. Every change is one step of **Undo** (Ctrl+Z).

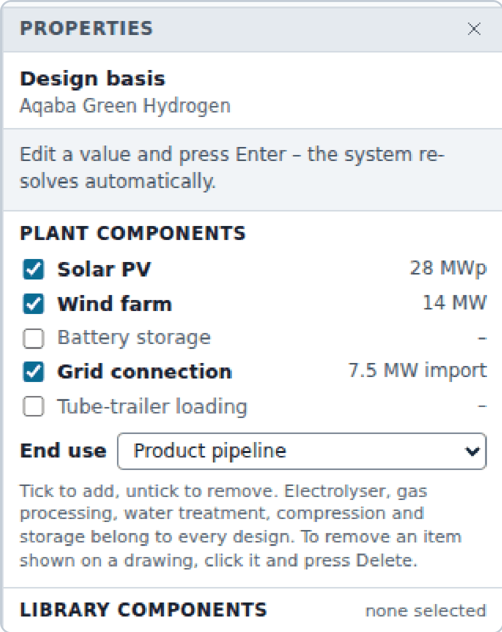


Figure S.6 – Plant components of Aqaba Green Hydrogen.

Change	H_2 [t/a]	CI [kg/kg]	LCOH [EUR/kg]	Checks
As created	734	2.07	9.49	16/16
Untick Wind farm	626	6.68	10.26	13/15
Tick Battery storage	707	1.32	9.74	15/16

Without the wind farm the plant falls to 86 % of the demand and the carbon intensity rises to 6.68 kg/kg, above the RFNBO limit of 3.38 kg/kg – two checks fail. A battery (added with the remembered or a suggested size of 0.3 MW per MW of electrolyser) lowers the carbon intensity to 1.32 kg/kg.

To remove an item you see on a drawing, click it – its datasheet opens in the Properties panel with a **Remove from plant** button – or press **Delete**. Hasim asks for confirmation, removes the component and re-solves everything; Ctrl+Z brings it back.

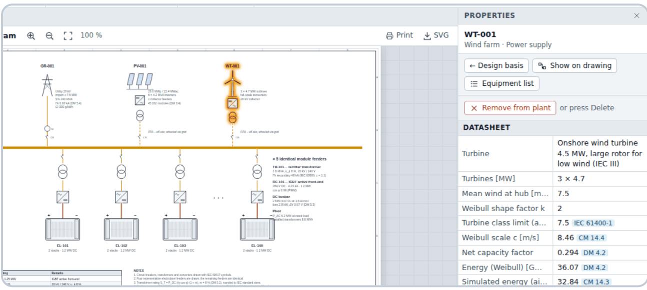


Figure S.7 – The wind farm WT-001 selected on the single-line diagram.

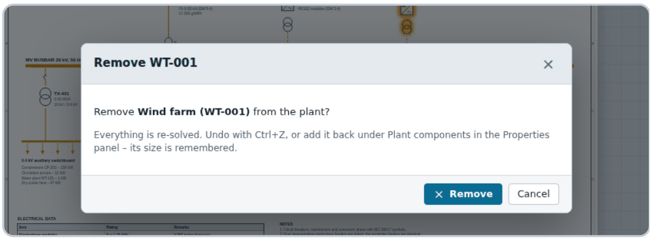


Figure S.8 – Delete asks for confirmation.

Equipment	Can it be removed?
PV-001, WT-001, BT-001, GR-001	Yes – solar PV, wind farm, battery, grid connection. At least one power source must remain. Removing the grid makes the plant islanded (PV and wind become on-site assets).
PL-301, HR-301, TL-301	Yes – pipeline, refuelling station, trailer loading (end use “At the plant fence”).
NH-301, AS-301, TK-301	Yes – the ammonia plant; the product changes to hydrogen.
EL-101, separators, coolers, deoxo, dryer	No – every electrolysis plant needs them.
WT-101, TK-101, P-101	No – they supply the demineralised water.
CP-201, ST-201	No – every design compresses and buffers the product; lower the storage pressure or the buffer instead.
TR-101, RC-101, FC-101, TX-401	No – they follow from the electrolyser rating.

C. A value chain from scratch in the Model builder

1. **Tools ▸ Model builder ▸ New empty model**. The empty chain explains how to start (Figure S.9).

2. Press **start with a standard chain** – power supply → water treatment → electrolyser → compressor → storage → economics – or add blocks from the palette. The palette is grouped by stage; each block is inserted at its place in the chain automatically.
3. Add **Refuelling station 700 bar**: it appears before Economics. Click any block to edit its parameters below the palette.
4. To delete a block, click its **×**, press **Delete block** in its editor, or select it and press the **Delete** key. **Undo** (Ctrl+Z) restores it.
5. The order checks below the chain explain every problem – for example a block before the electrolyser that receives no hydrogen. **Fix order** sorts the chain into flow order (Figure S.10).
6. Press **Run model**: the key results, the stream after each block and the calculation log appear (Figure S.11).

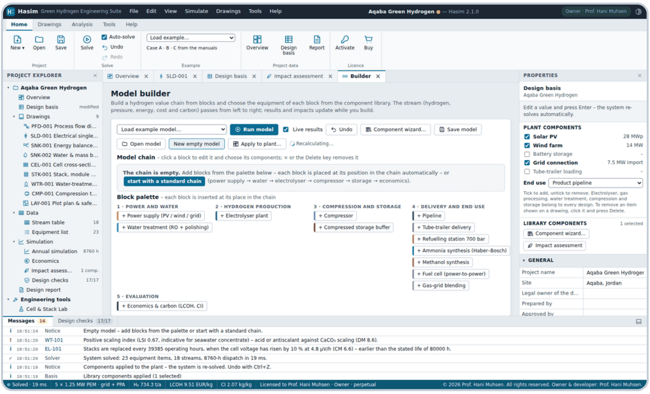


Figure S.9 – A new empty model with the start hint.

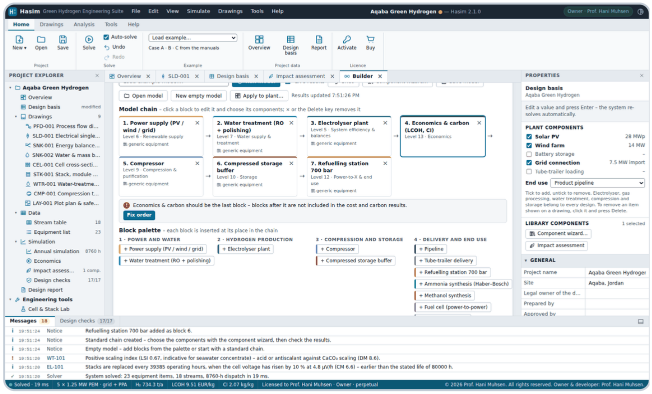


Figure S.10 – Order checks with Fix order.

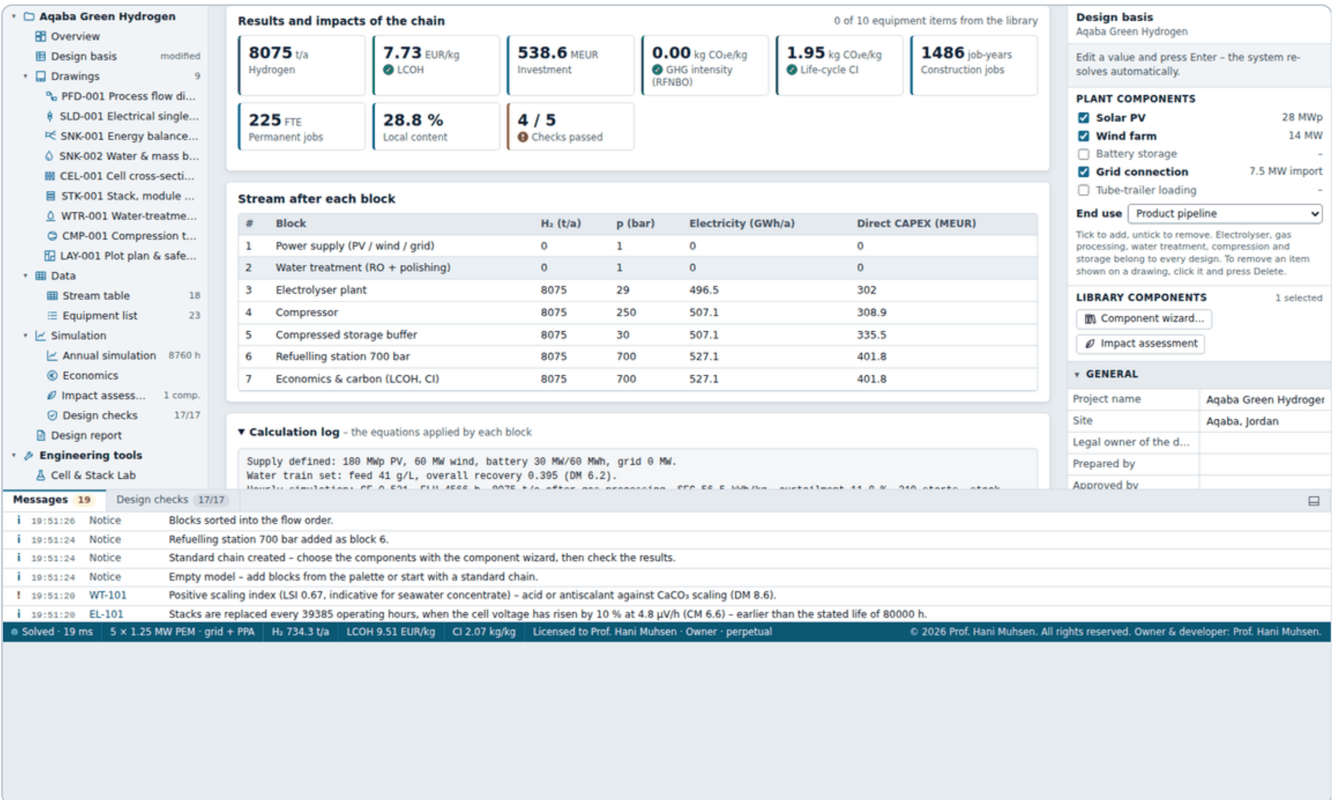


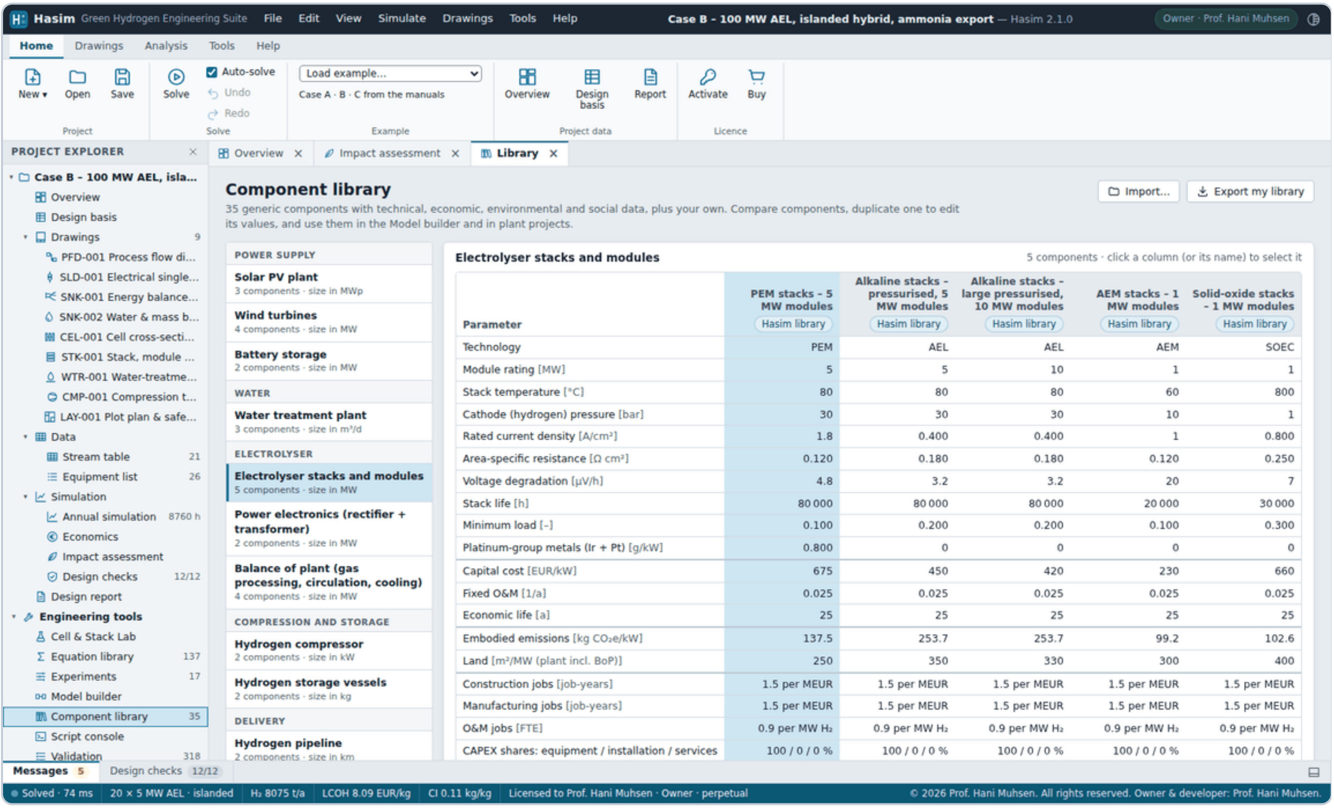
Figure S.11 – Results of the chain: key figures, stream after each block and calculation log.

D. Starting from components – library, component wizard and impacts

Instead of typing numbers into the design basis or the blocks, you can start from the equipment itself. The **component library** holds 35 generic components with their technical, economic, environmental and social data – and your own. The **component wizard** walks through the equipment of a Model-builder chain or of a plant, shows the effect of every choice on production, cost, carbon intensity, jobs, local content and checks, and applies the selection in one step.

D.1 The component library

1. **Tools ▸ Component library**. Choose a category on the left – for example **Electrolyser stacks and modules** – and compare its components column by column: the technical data used by the model, the limits of the checks, costs, embodied emissions, land and jobs (Figure S.12).
2. For your own data, select a component, press **Duplicate to edit**, name the copy and change its values – for example the price of a vendor quotation – then **Save changes**. Your components appear in every wizard, marked *my library*; **Export my library** shares them with colleagues.



Parameter	PEM stacks - 5 MW modules (Hasim library)	Alkaline stacks - pressurised, 5 MW modules (Hasim library)	Alkaline stacks - large pressurised, 10 MW modules (Hasim library)	AEM stacks - 1 MW modules (Hasim library)	Solid-oxide stacks - 1 MW modules (Hasim library)
Technology	PEM	AEL	AEL	AEM	SOEC
Module rating [MW]	5	5	10	1	1
Stack temperature [°C]	80	80	80	60	800
Cathode (hydrogen) pressure [bar]	30	30	30	10	1
Rated current density [A/cm²]	1.8	0.400	0.400	1	0.800
Area-specific resistance [Ω cm²]	0.120	0.180	0.180	0.120	0.250
Voltage degradation [µV/h]	4.8	3.2	3.2	20	7
Stack life [h]	80 000	80 000	80 000	20 000	30 000
Minimum load [-]	0.100	0.200	0.200	0.100	0.300
Platinum-group metals (Ir + Pt) [g/kW]	0.800	0	0	0	0
Capital cost [EUR/kW]	675	450	420	230	660
Fixed O&M [1/a]	0.025	0.025	0.025	0.025	0.025
Economic life [a]	25	25	25	25	25
Embodied emissions [kg CO_2e/kW]	137.5	253.7	253.7	99.2	102.6
Land [m²/MW (plant incl. BoP)]	250	350	330	300	400
Construction jobs [job-years]	1.5 per MEUR	1.5 per MEUR	1.5 per MEUR	1.5 per MEUR	1.5 per MEUR
Manufacturing jobs [job-years]	1.5 per MEUR	1.5 per MEUR	1.5 per MEUR	1.5 per MEUR	1.5 per MEUR
O&M jobs [FTE]	0.9 per MW H_2	0.9 per MW H_2	0.9 per MW H_2	0.9 per MW H_2	0.9 per MW H_2
CAPEX shares: equipment / installation / services	100 / 0 / 0 %	100 / 0 / 0 %	100 / 0 / 0 %	100 / 0 / 0 %	100 / 0 / 0 %

Figure S.12 – The component library: the five electrolyser stacks side by side.

D.2 Components in the Model builder

The Model builder opens with the chain of Case B – an islanded 100 MW alkaline plant with ammonia synthesis. We choose its stacks, PV modules and wind turbines from the library.

1. **Tools ▸ Model builder**. Click block 3 **Electrolyser plant**: **Components of this block** lists stacks, power electronics and balance of plant – all generic, so the block uses its own parameters (Figure S.13).
2. Press **Component wizard...**. It opens at the stacks and shows the equipment of all blocks of the chain as steps. Choose **Alkaline stacks – large pressurised, 10 MW modules**: with the rated power of 100 MW the block gets 10 modules.

3. Go to **Solar PV plant** and choose the bifacial modules on trackers. Go to **Wind turbines**: the site has a mean wind speed of 8.6 m/s, above the class limit of 8.5 m/s of the 5 MW IEC II turbine – choose the 4.2 MW **IEC I** turbine (Figure S.14). **Effect on the model** recalculates the chain after every choice.
4. **Apply components**. The electrolyser block lists its stack; the parameters defined by the component – technology, minimum load, temperature, pressure and CAPEX – are grey (Figure S.15). The live results show the chain with its impacts (Figure S.16).
5. The chain checks flag **unserved auxiliary energy**: at night neither PV nor the battery supplies the 6 MW of auxiliaries of the islanded chain (Figure S.17). Click block 1 **Power supply** and set **Grid import limit** to **4 MW** – all checks pass.
6. **Apply to plant...** transfers the three components to the plant project; the plant keeps its sizes, and its impact assessment opens (Example 13 continues with the plant).

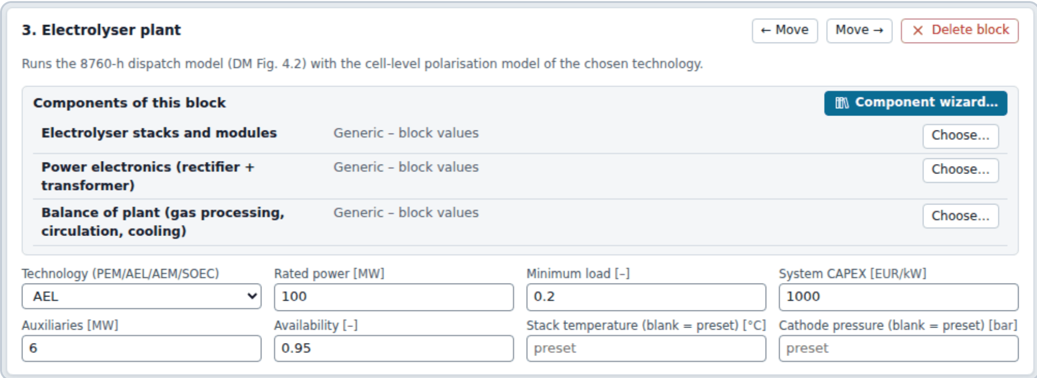


Figure S.13 – The electrolyser block with generic equipment.

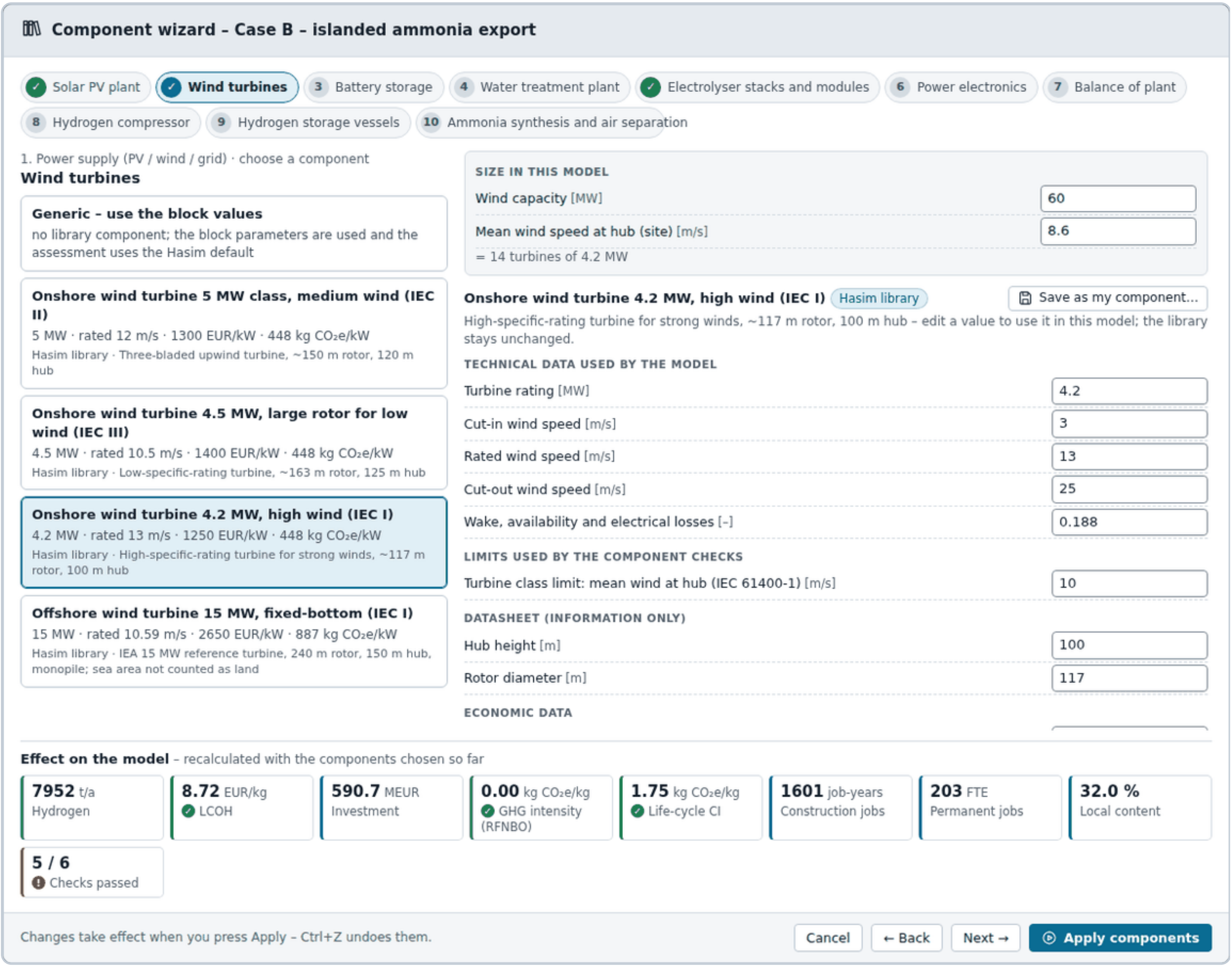


Figure S.14 – The component wizard of the chain at the wind turbines: 60 MW of IEC I turbines = 14 turbines of 4.2 MW.

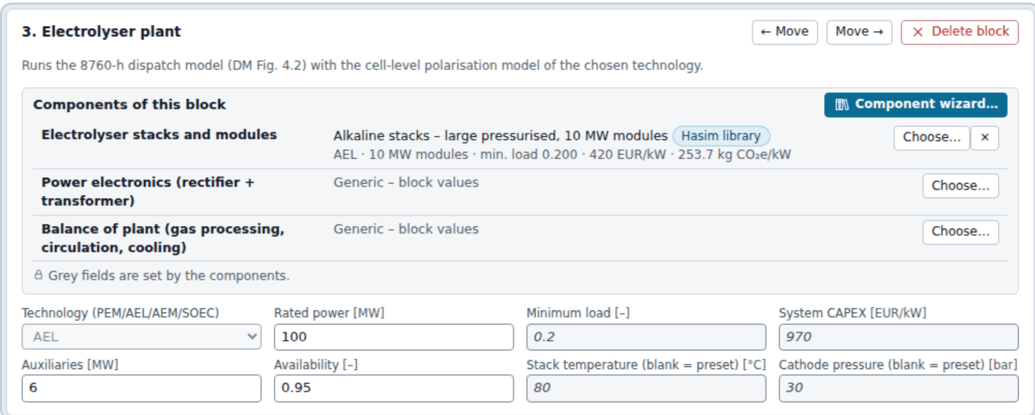


Figure S.15 – After Apply: the stack component and the parameters it defines (grey).

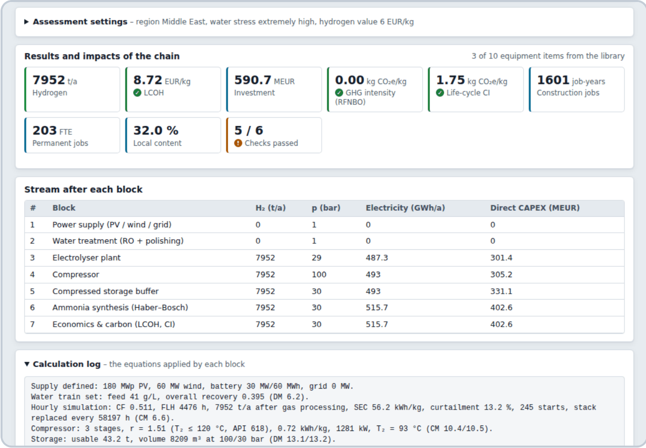


Figure S.16 – Results and impacts of the chain.

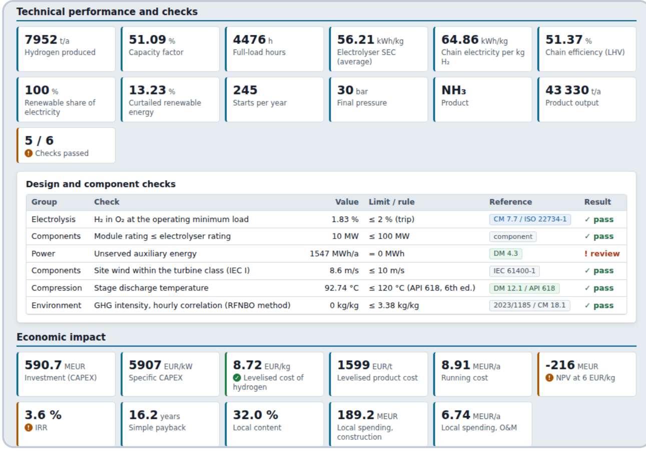


Figure S.17 – The chain checks: unserved auxiliary energy at night.

Chain of Case B	H_2 t/a	LCOH EUR/kg	CAPEX MEUR	CI life-cycle kg/kg	Construction job-years	O&M FTE	Local content	Checks
Generic equipment	8 075	8.61	593.6	1.91	1 615	203	32.2 %	3/4
Library components (AEL 10 MW, bifacial PV, IEC I wind)	7 952	8.72	590.7	1.75	1 601	203	32.0 %	5/6
… and 4 MW grid for the auxiliaries	7 984	8.71	590.5	1.84	1 601	203	32.0 %	5/6

The high-wind turbine is certified for the site but produces less energy than the medium-wind turbine – the chain loses 1.5 % of its hydrogen, and the LCOH rises from 8.61 to 8.72 EUR/kg. The small grid connection for the auxiliaries adds only 0.10 kg CO_2e/kg of electricity emissions. The chain adds the component checks – module rating, turbine class – to its own checks.

D.3 Components of a plant – water for Aqaba

The Aqaba project of section A draws municipal water in a region of extremely high water stress, so its impact assessment rates the **water-stress risk high**: its 10 280 m³ of fresh water per year would cover the domestic needs of 282 people (Figure S.19). The component wizard replaces it with seawater desalination:

1. Open the project (section A), then **Design basis ▸ Library components ▸ Choose…** in the row **Water treatment plant**.
2. Choose **Seawater RO with energy recovery + second pass + EDI** and set the **salinity of the raw water** to **40 g/L** (Red Sea). The preview shows the cost of the change (Figure S.18).
3. **Apply components**: the water source becomes seawater with the recoveries of the component and the typical composition and price of seawater (group Water of the design basis), the design checks add the salinity check, and the risk falls to *low* (Figure S.20).

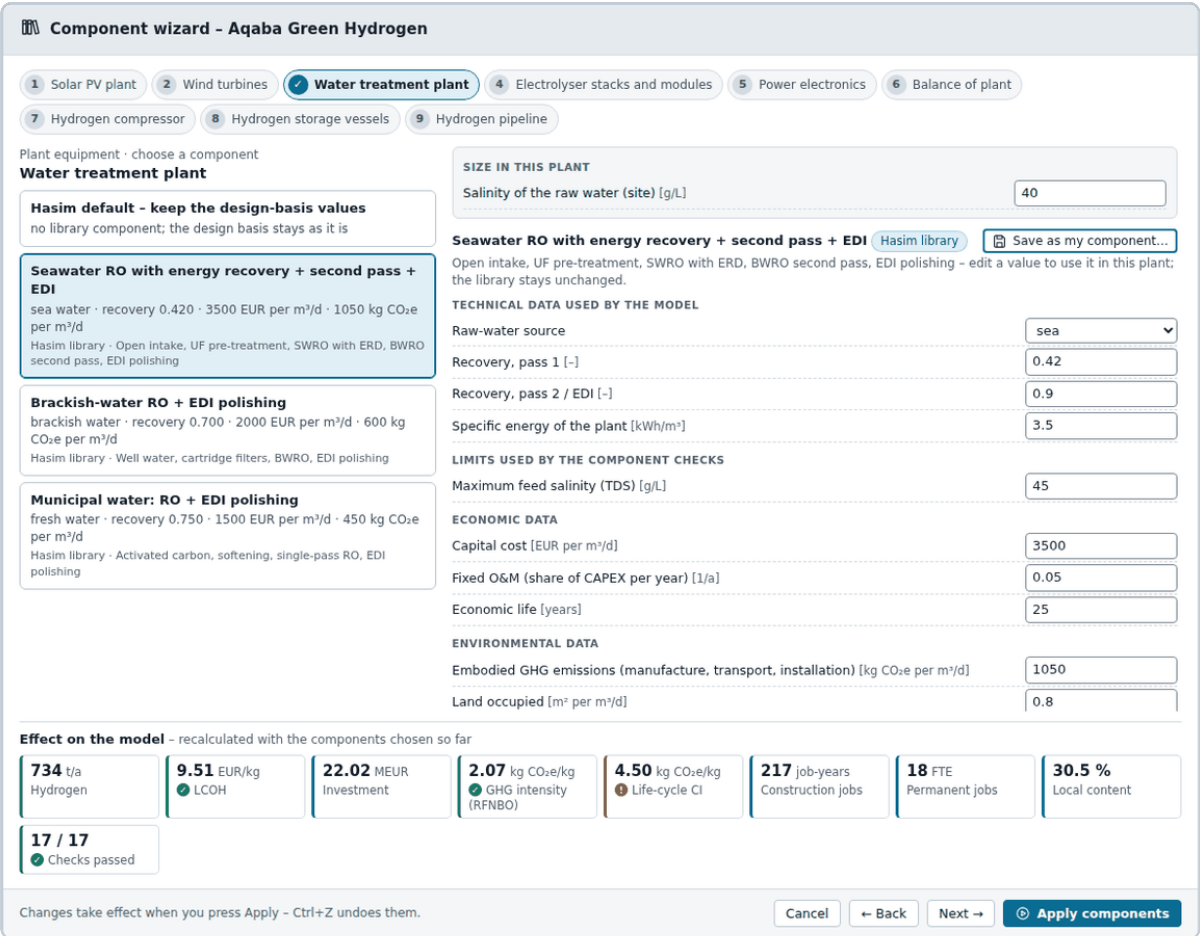


Figure S.18 – Component wizard of the Aqaba project at the water treatment plant.

Figure S.19 – Social impact of the Aqaba project with municipal water: water-stress risk high.

Figure S.20 – With seawater desalination: water-stress risk low.

Water supply of Aqaba	LCOH [EUR/kg]	Water withdrawal [m³/a]	Brine [m³/a]	Fresh water = people	Water-stress risk	Checks
Municipal water (as created)	9.49	10 280	2 570	282	high	16/16
Seawater RO + EDI, 40 g/L	9.47	19 539	11 830	0	low	17/17

Desalination hardly changes the cost of hydrogen (9.49 → 9.47 EUR/kg): the larger water plant and its energy are offset by the cheaper raw water, 0.1 instead of 1.5 EUR/m³. The plant withdraws about twice as much water – seawater instead of fresh water – and returns the brine to the sea; the design checks verify the dilution of the brine diffuser. The same wizard chooses stacks, PV, wind turbines, batteries, compressors and vessels; Example 13 compares these choices for Case B.

Example 1 – Your first project – Case A

Goal

Load the 10 MW grid-connected PEM example, find your way through its documents, and resolve the design check that is flagged.

You will learn

- to load an example and read the overview
- to navigate drawings, streams and equipment
- to use the design checks to improve a design

1. **Home ▸ Example ▸** "Case A – 10 MW PEM, grid-connected, industrial park". The system is solved immediately.
2. Open **Overview** in the project explorer: the key figures, a live thumbnail of the PFD and the energy balance, monthly production and the design checks.
3. Open **PFD-001** and click the electrolyser **EL-101**: its datasheet appears in the properties panel. Hover the stream diamonds to see flows.
4. Open **Stream table** and **Equipment list** to see all data in tabular form.
5. Open **Design checks**: one check needs review – *Annual hydrogen after gas processing (simulated) vs demand*.

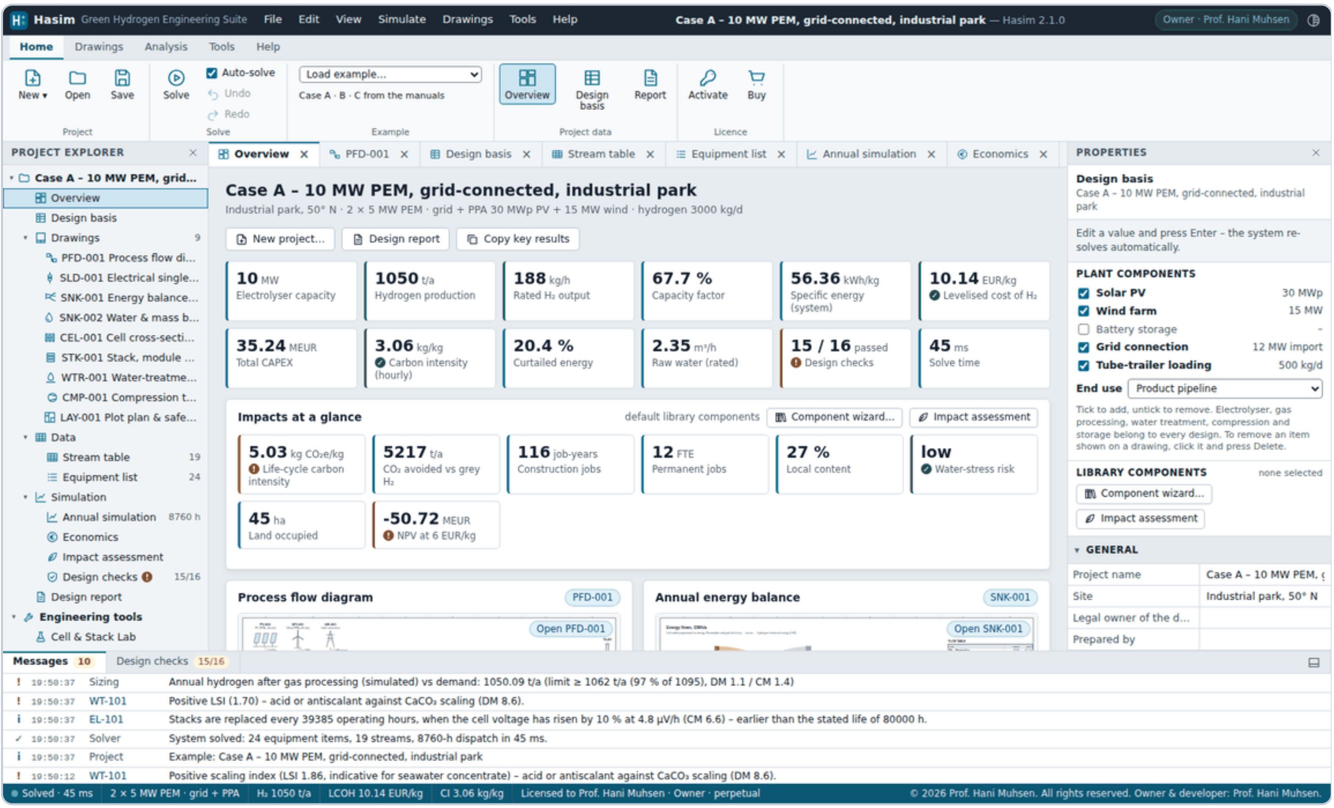


Figure 1.1 – Overview of Case A.

10 Electrolyser [MW]	**1 050** Hydrogen [t/a]	**67.7 %** Capacity factor	**10.14** LCOH [EUR/kg]
56.4 System SEC [kWh/kg]	**35.2** CAPEX [MEUR]	**3.06** CI, RFNBO hourly [kg/kg]	**15 / 16** Checks passed

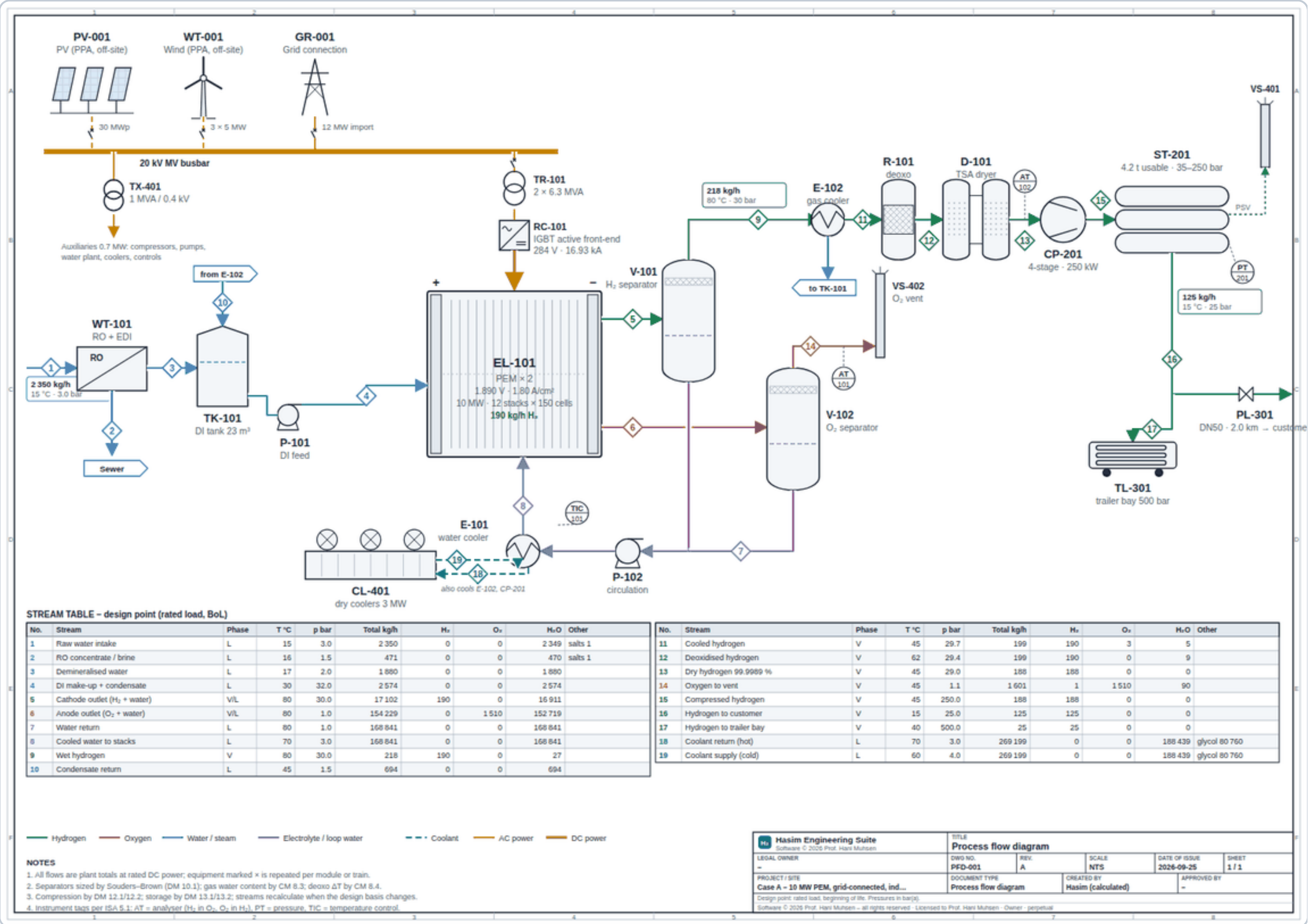


Figure 1.2 – PFD-001 of Case A with stream call-outs.

Resolving the production check

The check compares the hydrogen that leaves the plant with the demand of 3 000 kg/d (1 095 t/a) and accepts 97 % of it (1 062 t/a). Case A delivers 1 050 t/a – just short. The model accounts for every loss between the stacks and the customer: the stacks produce 1 063 t/a, the deoxo and the regeneration of the TSA dryer take 1.2 % of it (CM 8.4), the modules are out of service for maintenance 4 % of the year, one at a time (availability 0.96), and the cell voltage of the ageing stacks rises by up to 10 % before a replacement, 5 % on average (CM 6.6), which raises the specific energy. The PEM minimum load of 10 % is raised automatically to 10.6 %, the load at which hydrogen in oxygen reaches the 2 % trip (CM 7.7, ISO 22734-1) – the gas-purity check passes, but the electrolyser stops when less power is available.

Two remedies are at hand: more grid electricity or more renewable electricity. Raising **Target load** to 0.47 lifts the production to 1 062 t/a, but brings the carbon intensity close to the RFNBO limit (3.23 kg/kg; at 0.5 it exceeds it with 3.48 kg/kg, Example 3). Better: enlarge the PPA by 10 % – set **PV capacity** to **33 MWp** and **Wind capacity** to **16.5 MW** in the properties panel (group Power supply) and press Enter after each value.

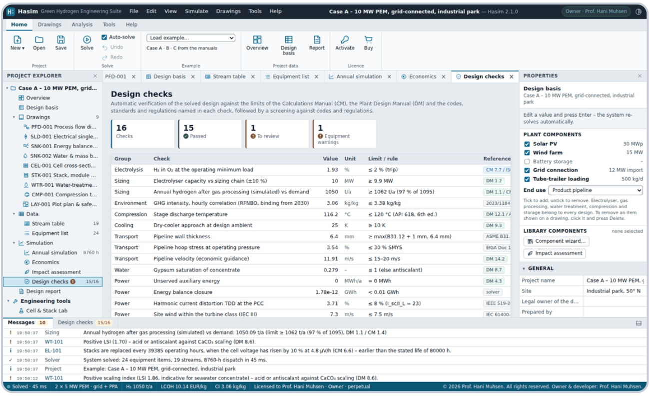


Figure 1.3 – Before: 15 of 16 checks pass.

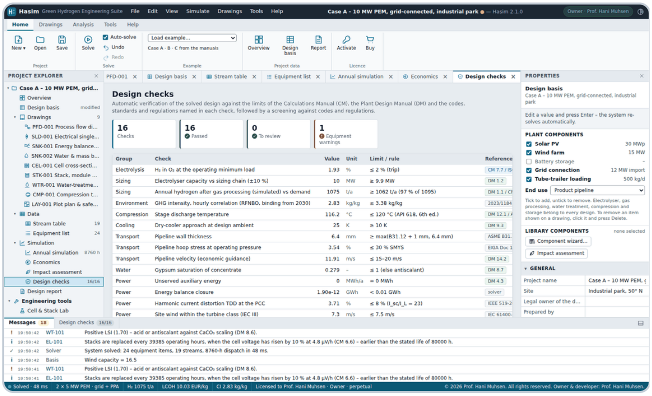


Figure 1.4 – With 10 % more PPA capacity: 16 of 16 checks pass.

The plant now delivers 1 075 t/a with a carbon intensity of 2.83 kg/kg, and the LCOH even falls from 10.14 to 10.03 EUR/kg, because the fixed costs are spread over more hydrogen – a fix confirmed by the model. Save it with **File ▸ Save project** if you want to keep it; the following examples start again from the original Case A.

Example 2 – Comparing electrolysis technologies

Goal

Evaluate PEM, alkaline, AEM and solid-oxide electrolysis for the same site and supply (Case A).

You will learn

- how the technology changes efficiency, cost and the electrical design
- to compare variants in a table

1. Load Case A. In the properties panel change **Technology** to AEL, AEM and SOEC in turn (the minimum-load preset follows the technology).
2. After each solve note the key figures from the status bar or **Edit ▸ Copy key results**.
3. Compare the single-line diagrams (**SLD-001**) of PEM and AEL.

Technology	Min. load preset / operated	SEC kWh/kg	H_2 t/a	LCOH EUR/kg	Rectifier (cos φ)	Stack replacements	Checks to review
PEM	10 % / 11 %	56.4	1 050	10.14	IGBT active front-end (0.99)	5	demand
AEL	20 % / 20 %	56.3	1 051	9.82	12-pulse thyristor (0.92)	3	demand, voltage THD at the PCC (IEEE 519)
AEM	10 % / 11 %	56.3	1 051	13.29	IGBT active front-end (0.99)	23	demand, dry-cooler approach
SOEC	30 % / 30 %	46.0	1 440	8.54	IGBT active front-end (0.99)	11	–

Alkaline electrolysis reaches practically the same specific energy as PEM here and needs a 12-pulse thyristor rectifier with harmonic filters and reactive-power compensation (power factor 0.92), whereas PEM, AEM and SOEC use IGBT active front-end rectifiers with unity power factor. On the weak grid of the industrial park (fault level 250 MVA) the voltage distortion of the thyristor rectifiers at the point of common coupling reaches 8.5 % against the limit of 5 % of IEEE 519-2022 – the harmonic filter must be designed for it. The alkaline stacks last their stated life and are replaced three times in 25 years, the PEM stacks, limited by their voltage degradation, 5 times. AEM has the lowest efficiency (56.3 kWh/kg) and misses the demand; its stacks run at 60 °C, so the coolant leaves the dry coolers only 5 K above the 35 °C design ambient (the check asks for 10 K), and the fast degradation of the AEM preset calls for 23 stack replacements. SOEC shows the lowest SEC (46.0 kWh/kg) although the steam is raised electrically here (10.9 GWh/a of its electricity). With external heat – design basis **SOEC heat for steam raising** = external, at 25 EUR/MWh – the SEC falls to 39.3 kWh/kg and the LCOH to 7.97 EUR/kg; its stacks, however, are replaced 11 times. PEM and AEM operate at the gas-purity limit of their membranes, raised automatically from the preset where necessary (Example 1).

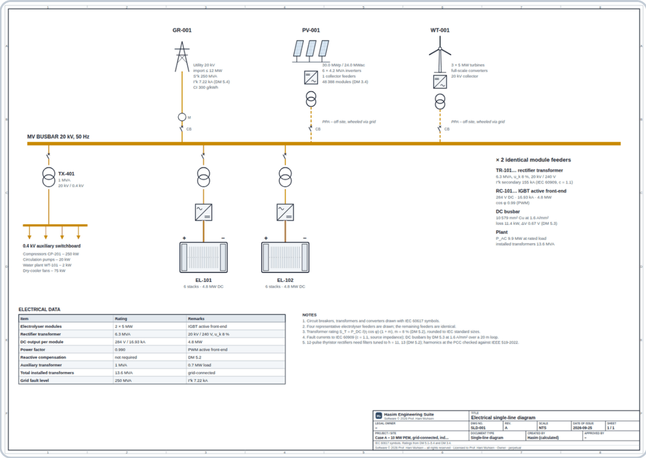


Figure 2.1 – SLD-001 with PEM: IGBT rectifiers.

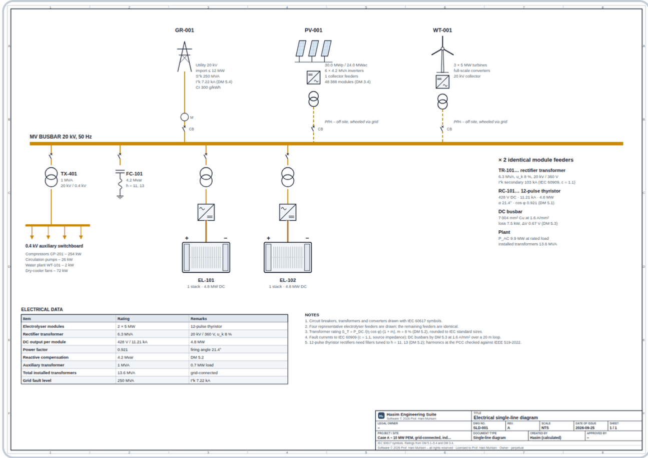


Figure 2.2 – SLD-001 with AEL: 12-pulse thyristor rectifiers and harmonic filter.

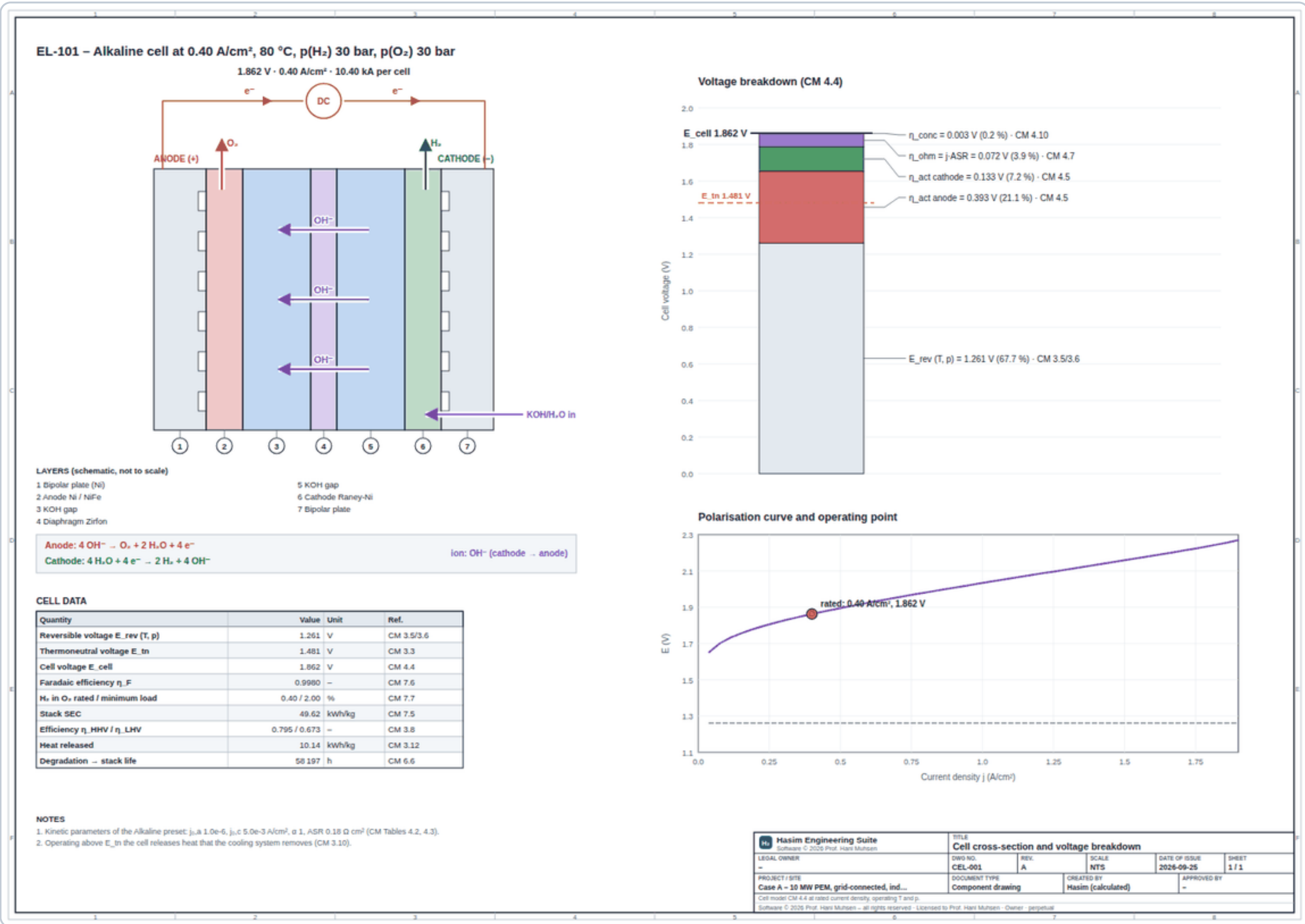


Figure 2.3 – CEL-001 for the alkaline cell of Case A.

Example 3 – Grid use and carbon intensity

Goal

Find the grid-use strategy that balances production cost and the RFNBO carbon-intensity limit of 3.38 kg CO_2e/kg H_2.

You will learn

- the grid-use modes
- hourly versus monthly temporal correlation (Delegated Regulation (EU) 2023/1184, DM 4.6)
- why the monthly correlation needs the surplus to be sold

1. Load Case A. In the group **Grid connection and electrical** set **Grid use** to “Bridge to minimum load”, “Fill to target load” (with target 0.45, 0.47 and 0.8) and “Always full load”.
2. Read hydrogen, capacity factor, LCOH and the carbon intensity in the Overview and the Design checks.
3. Set **Surplus renewable energy** (group Power supply) to “Sold to the grid” and repeat the targets 0.45 and 0.8: a second RFNBO check with monthly correlation appears.

Grid use	H_2 [t/a]	CF	Grid share	LCOH [EUR/kg]	CI hourly [kg/kg]	Checks to review
Bridge to minimum load	889	57.6 %	3.2 %	11.15	0.54	demand
Target load 0.45	1 050	67.7 %	18.1 %	10.14	3.06	demand
Target load 0.47	1 062	68.4 %	19.1 %	10.08	3.23	demand
Target load 0.80	1 292	84.1 %	34.8 %	9.17	5.95	RFNBO, hourly
Always full load	1 457	96.0 %	43.3 %	8.73	7.49	RFNBO, hourly

Surplus sold to the grid	Surplus [GWh/a]	LCOH [EUR/kg]	CI hourly [kg/kg]	CI monthly [kg/kg]	Checks to review
Target load 0.45	13.7	10.80	3.06	0.27	demand
Target load 0.80	13.7	9.70	5.95	2.77	RFNBO, hourly

More grid electricity raises production and lowers the LCOH, but it also raises the carbon intensity: the RFNBO method counts the grid electricity with the emission factor of the grid (300 g/kWh here) and the PPA electricity with zero; the emissions of manufacturing the equipment are not counted (Delegated Regulation (EU) 2023/1185). With hourly correlation, binding from 2030, only the bridging strategy and the targets up to 0.47 stay below 3.38 kg/kg, and the first two miss the demand. No strategy is the lowest-cost strategy that meets both – or the larger PPA of Example 1.

Until the end of 2029 the rules also accept monthly correlation: grid electricity counts as renewable up to the renewable electricity of the PPA that is fed into the grid in the same month. Hasim applies it only when the surplus is sold (**Surplus renewable energy** = sold): a curtailed surplus is never generated, so there is nothing to match the grid imports with. With the surplus sold, target 0.8 qualifies with a monthly carbon intensity of 2.77 kg/kg – but its LCOH rises from 9.17 to 9.70 EUR/kg, because the 13.7 GWh/a of surplus are bought at the PPA price (80 EUR/MWh) and sold at 30 EUR/MWh. From 2030 the plant would lose its RFNBO status.

Example 4 – Battery sizing for an islanded plant

Goal

Size the battery of the 100 MW islanded hybrid plant (Case B).

You will learn

- how the battery bridges to the minimum load
- to read the live power flow
- to trade battery cost against production

1. Load Case B. Set **Battery power** and **Battery energy** to the values of the table in turn.
2. Open **Annual simulation**, move the power-flow slider to 22 June 22:00 and compare the flows.

Battery [MW / MWh]	CF	Curtailed	Starts	Cycles [1/a]	H_2 [t/a]	LCOH [EUR/kg]
0 / 0	50.5 %	14.8 %	386	0	7 818	8.26
15 / 30	51.2 %	13.2 %	263	148	7 934	8.16
30 / 60	52.1 %	11.8 %	219	170	8 075	8.09
60 / 120	52.9 %	10.4 %	188	133	8 204	8.03
90 / 240	53.7 %	9.1 %	146	91	8 319	8.06

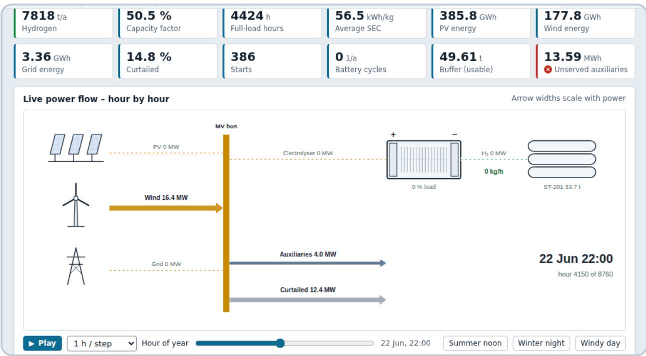


Figure 4.1 – Without battery at 22:00: 16.4 MW of wind less 4.0 MW of auxiliaries is below the 19.0 MW minimum load of the 19 modules in service; the electrolyser stops and 12.4 MW of wind power is curtailed.

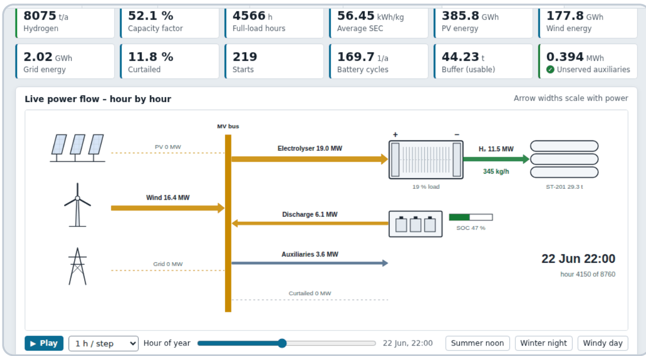


Figure 4.2 – With 30 MW / 60 MWh: the battery discharges 6.1 MW and keeps the electrolyser at its minimum load of 19.0 MW.

The battery reduces starts and curtailment and raises production. Up to 60 MW / 120 MWh each step lowers the LCOH slightly, because the battery cost is small compared to the value of the additional hydrogen; the largest battery no longer pays for itself. Without a battery the auxiliaries of the islanded plant are not always supplied at night (13.6 MWh/a unserved – the check flags it). Engineering limits – cycling, degradation, space and grid-forming capability – determine the final choice; Case B uses 30 MW / 60 MWh.

Example 5 – Sizing the electrolyser against the supply

Goal

Find the electrolyser size with the lowest LCOH for the fixed Case B supply (180 MWp PV, 60 MW wind).

You will learn

- the trade-off between utilisation and curtailment
- to run a parameter study with the script console

1. Open **Tools ▸ Script** and choose the example “Optimise the electrolyser size (8760 h)”.
2. Press **Run**: the script solves the complete system for 12 to 28 modules of 5 MW and prints a table.

Modules	MW	CF	Curtailed	H_2 [t/a]	LCOH [EUR/kg]	Checks to review
12	60	63.7 %	36.0 %	5 902	8.61	sizing chain, demand
16	80	57.1 %	23.0 %	7 074	8.18	sizing chain, demand
20	100	52.1 %	11.8 %	8 075	8.09	–
24	120	46.6 %	4.9 %	8 680	8.44	unserved auxiliaries
28	140	41.0 %	1.6 %	8 938	9.15	unserved auxiliaries

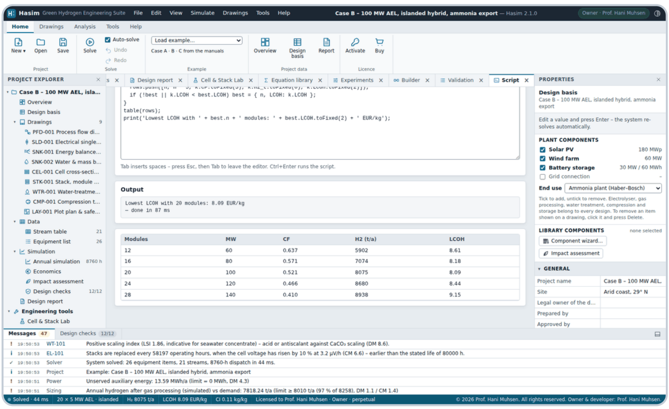


Figure 5.1 – The script console with the size-optimisation study.

The LCOH minimum lies at 100 MW. Smaller electrolysers run at higher capacity factors but curtail much more energy and cannot meet the ammonia demand – both the sizing chain and the demand check flag them. Larger ones produce more hydrogen at rising cost, and their larger auxiliaries (6 % of the rating) are no longer covered at night by the battery and the backup supply. Case B’s 100 MW meets the demand at the lowest cost.

The sizing chain and the simulation. The check *Electrolyser capacity vs sizing chain* compares the rating with the hand calculation of DM 1.2 (demand ÷ availability × life-average SEC ÷ full-load hours) – 101.0 MW for Case B with 4 900 full-load hours, rounded down from the simulation (0.521 × 8760 ÷ 0.95 = 4 804 h). With the first estimate of the Design Manual, 4 400 h, the chain would ask for 112 MW and flag the design, although the simulation meets the demand: update the full-load hours from the **Annual simulation** when the design settles.

Example 6 – Storage pressure, compression and safety distances

Goal

Choose the storage pressure of Case A considering compression and the separation distances of the storage yard.

You will learn

- how pressure changes volume, compression and consequence distances
- to read the plot plan

1. Load Case A and set **Storage pressure** to 100, 250, 350 and 500 bar.
2. After each solve open **CMP-001** and **LAY-001**.

Storage [bar]	Stages	Max. stage T °C	Compressor kW	Geometric volume m^3	Vessels (PED category)	LFL m	4.7 kW/m^2 m	NFPA 2 group 1, m
100	3	99	138	855.2	bullets D 2.4 m (IV)	11.3	4.0	7.5
250	4	116	250	281.4	cylinders D 1 m (IV)	17.1	5.9	4.2
350	5	111	292	202.4	tubes D 0.5 m (IV)	19.7	6.8	4.2
500	6	107	339	147.7	tubes D 0.5 m (IV)	22.6	7.8	4.2

Higher pressure shrinks the vessel volume (from 855.2 m^3 at 100 bar to 147.7 m^3 at 500 bar) but needs more compressor stages and power: the discharge temperature of each stage is limited to 120 °C (API 618 for hydrogen), which caps the pressure ratio per stage at about 1.7. The flammable-cloud and radiation distances of a reference 3 mm leak (CM 19.5/19.6) grow with the pressure. The separation distances of NFPA 2 depend on the pressure class and on the default pipe size of the table: above 3 000 psig (207 bar) the table assumes smaller piping, so the distance to lot lines and air intakes (exposure group 1) falls from 7.5 m to 4.2 m. The plot plan places the storage yard beyond the largest of these distances automatically.

All storage vessels fall into PED category IV (maximum pressure × volume far above 1 000 bar·L). Hasim sizes the shell with ASME VIII-1 UG-27 and switches to the thick-wall formula of Appendix 1-2 above P = 0.385·S·E – here at 500 bar; the ST-201 datasheet lists the wall thickness together with ASME VIII-2 and EN 13445 values.

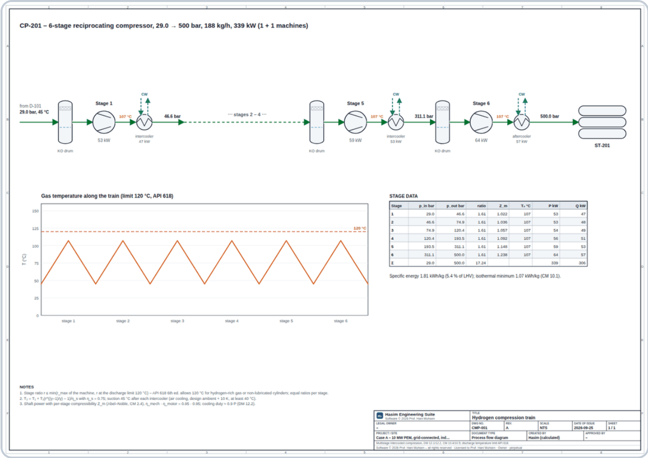


Figure 6.1 – CMP-001 at 500 bar: 6 intercooled stages, at most 107 °C.

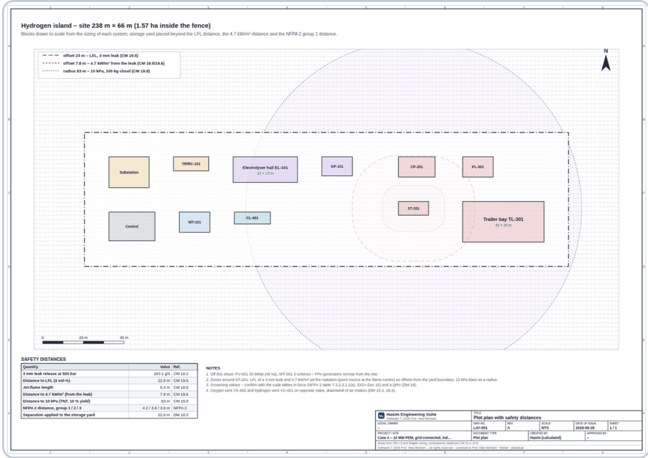


Figure 6.2 – LAY-001 at 500 bar with LFL, radiation and overpressure circles.

Example 7 – A hydrogen refuelling hub – Case C

Goal

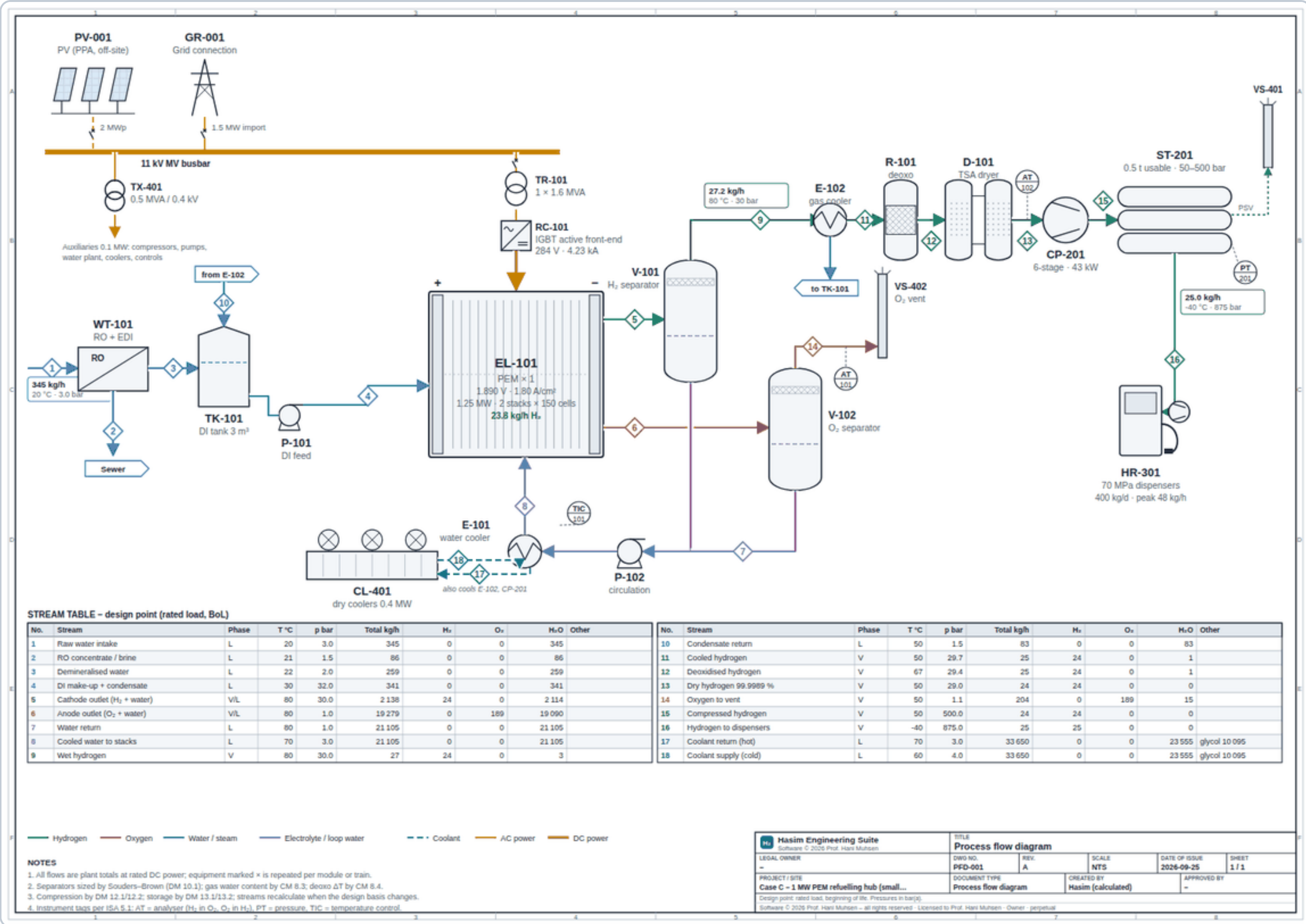
Review the 1.25 MW PEM electrolyser that supplies a 70 MPa refuelling station with 400 kg/d.

You will learn

- the refuelling-station sizing of DM 16
- why grid electricity limits the RFNBO status of small hubs

1. Load Case C. Open **Overview**, **PFD-001** and **CMP-001**.
2. Open the datasheet of **HR-301** (click it on the PFD or in the equipment list).
3. Open **Design checks**.

48 Peak hour [kg/h]	**25** Booster [kg/h]	**17.50** Cascade 900 bar [kg]	**0.22** Pre-cooling [kWh/kg]
155 Hydrogen [t/a]	**15.16** LCOH [EUR/kg]	**17.81** CI [kg/kg]	**6** Compression stages



STREAM TABLE – design point (rated load, BoL)

No.	Stream	Phase	T °C	p bar	Total kg/h	H_2	O_2	H_2O	Other
1	Raw water intake	L	20	3.0	345	0	0	345	
2	RO concentrate / brine	L	21	1.5	86	0	0	86	
3	Demineralised water	L	22	2.0	259	0	0	259	
4	DI make-up + condensate	L	30	32.0	341	0	0	341	
5	Cathode outlet (H_2 + water)	V/L	80	30.0	2 138	24	0	2 114	
6	Anode outlet (O_2 + water)	V/L	80	1.0	19 279	0	189	19 090	
7	Water return	L	80	1.0	21 105	0	0	21 105	
8	Cooled water to stacks	L	70	3.0	21 105	0	0	21 105	
9	Wet hydrogen	V	80	30.0	27	24	0	3	
10	Condensate return	L	50	1.5	83	0	0	83	
11	Cooled hydrogen	V	50	29.7	25	24	0	1	
12	Deoxidised hydrogen	V	67	29.4	25	24	0	1	
13	Dry hydrogen 99.9989 %	V	50	29.0	24	24	0	0	
14	Oxygen to vent	V	50	1.1	204	0	189	15	
15	Compressed hydrogen	V	50	500.0	24	24	0	0	
16	Hydrogen to dispensers	V	-40	875.0	25	25	0	0	
17	Coolant return (hot)	L	70	3.0	33 650	0	0	23 555	glycol 10 095
18	Coolant supply (cold)	L	60	4.0	33 650	0	0	23 555	glycol 10 095

Figure 7.1 – PFD-001 of the refuelling hub.

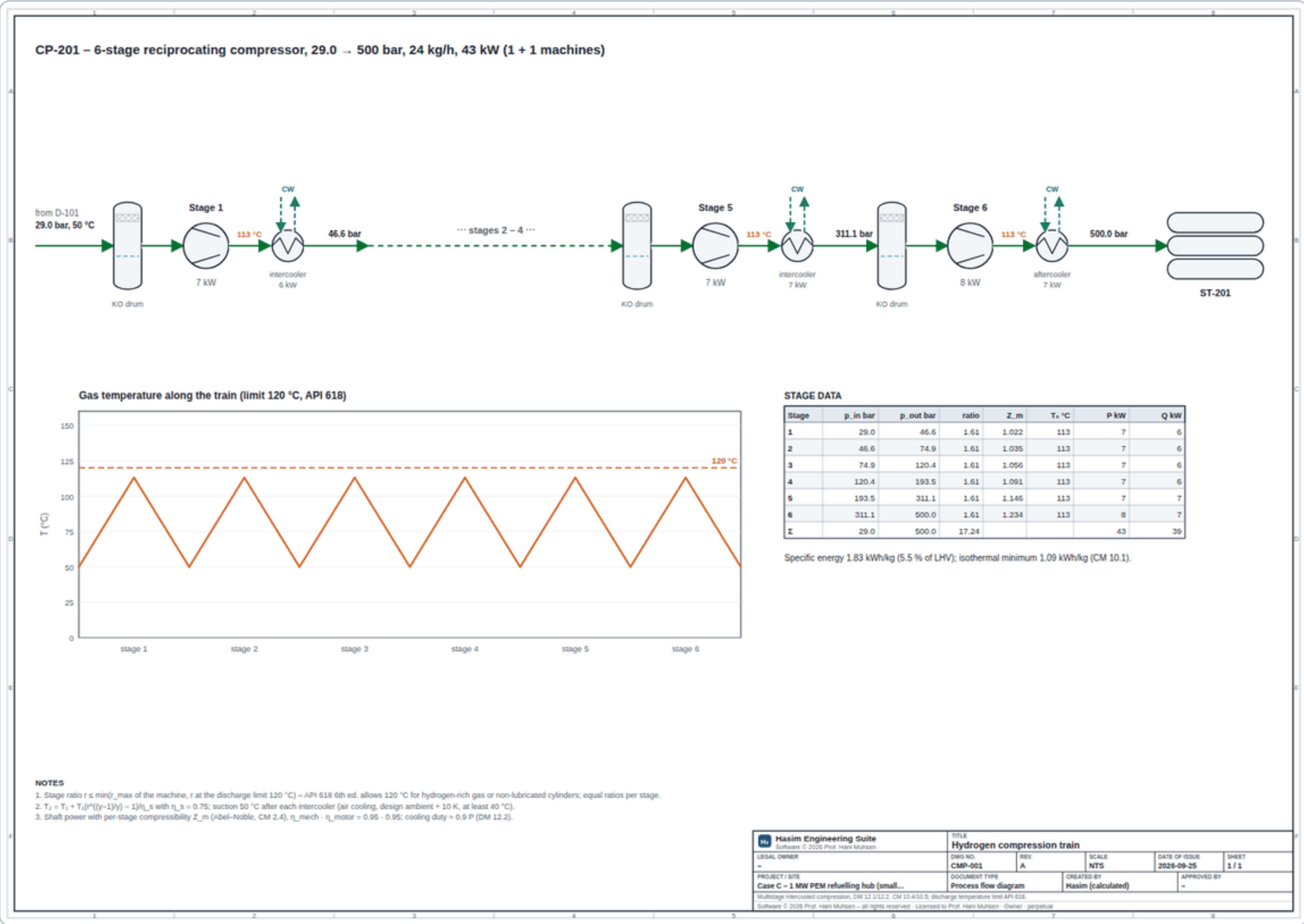


Figure 7.2 – CMP-001: compression from 29.0 to 500.0 bar in 6 stages.

With only 2 MWp of PV through the PPA, 70 % of the electricity comes from the grid at 450 g/kWh: the carbon intensity of 17.81 kg/kg is far above the RFNBO limit of 3.38 kg/kg, and the design checks flag it. More renewable electricity – a larger PPA, or on-site PV with a battery – would be the next design step. The fuel meets ISO 14687 grade D: after the deoxo and the TSA dryer the hydrogen carries 11.1 µmol/mol of impurities (limits ≤ 300 µmol/mol; H_2O ≤ 5, O_2 ≤ 5). The storage compressor respects the API 618 limit of 120 °C with 6 stages up to 500.0 bar, and, as in Case A, the PEM stacks operate at 10.6 % load at the least.

Example 8 – Seawater desalination for Case B

Goal

Examine the seawater reverse-osmosis and EDI plant that supplies 20.0 m^3/h of demineralised water to the 100 MW electrolyser.

You will learn

- the water balance of DM 6
- scaling and brine-discharge checks of DM 8

1. Load Case B and open **WTR-001**.
2. Click **WT-101** for its datasheet; check the warning in the equipment list.

Quantity	Value	Reference
Raw seawater [m^3/h]	50.8	DM 6.1
Brine / concentrate [m^3/h]	30.7	DM 6.2
Overall recovery	39.5 %	DM 6.2
Feed / concentrate TDS [g/L]	41 / 70.6	DM 8.1–8.2
HP pump energy with ERD [kWh/m^3]	2.65	DM 8.4/8.5
Water-plant power [kW]	75	
LSI of concentrate (indicative above 10 g/L)	1.86	DM 8.6
Gypsum saturation	n/a (ionic strength > 0.5 mol/L)	DM 8.7
Diffuser dilution achieved / required	69.6 / 19.7	DM 8.8
Cost of water [EUR/m^3]	5.27	DM 8.10

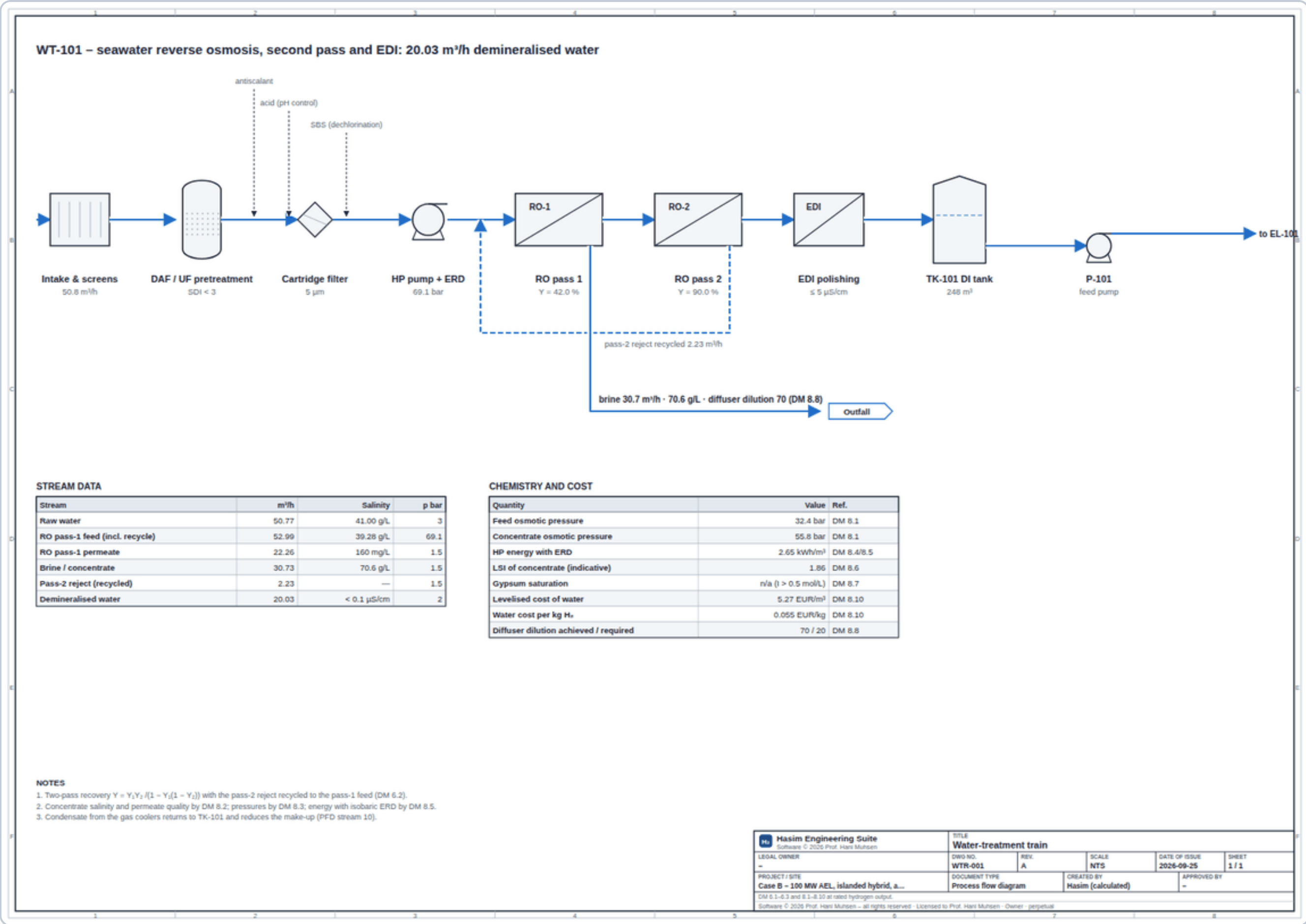


Figure 8.1 – WTR-001 water-treatment train of Case B.

The positive scaling index of the concentrate calls for antiscalant or acid dosing (the equipment list shows the warning). At seawater salinity the Langelier index is only indicative – the Stiff & Davis index applies above about 10 g/L – and the gypsum saturation is outside the validity of the activity model. The brine diffuser achieves the required dilution. Even at the stand-alone cost of water of 5.27 EUR/m³ and 26.6 litres of seawater per kg, desalination adds only about 0.14 EUR per kg of hydrogen – it is not a cost driver, but brine discharge is a permitting topic.

Example 9 – Cell and stack: polarisation and part-load purity

Goal

Understand the voltage losses of the PEM cell and why low loads are critical for gas purity.

You will learn

- the loss terms of CM 4.4
- system efficiency and H_2-in-O_2 at part load (CM 7.7/7.8)

1. Open **Tools ▸ Cell & Stack Lab**, preset PEM.
2. Read the polarisation curve and loss breakdown; change temperature or ASR and watch the curves.
3. Read the part-load table and the H_2-in-O_2 chart.

j [A/cm²]	E_rev	η_anode	η_cathode	η_ohmic	E_cell [V]	SEC [kWh/kg]
0.25	1.24	0.285	0.065	0.030	1.616	44.1
0.50	1.24	0.299	0.079	0.060	1.675	45.1
1	1.24	0.313	0.093	0.120	1.766	47.3
1.50	1.24	0.321	0.102	0.180	1.845	49.3
2	1.24	0.327	0.107	0.240	1.920	51.2
2.50	1.24	0.332	0.112	0.300	1.994	53.1
3	1.24	0.335	0.116	0.360	2.067	55.1

Load	Cathode pressure [bar]	j [A/cm²]	SEC system [kWh/kg]	SEC stack [kWh/kg]	H_2 in O_2 [%]
5 %	10.0	0.110	53.4	42.0	3.70
10 %	10.0	0.214	50.0	42.7	1.93
20 %	19.4	0.412	49.7	44.3	1.94
30 %	29.1	0.602	50.3	45.5	2.00
50 %	30.0	0.967	51.4	47.1	1.29
75 %	30.0	1.395	53.0	48.9	0.90
100 %	30.0	1.800	54.5	50.4	0.70

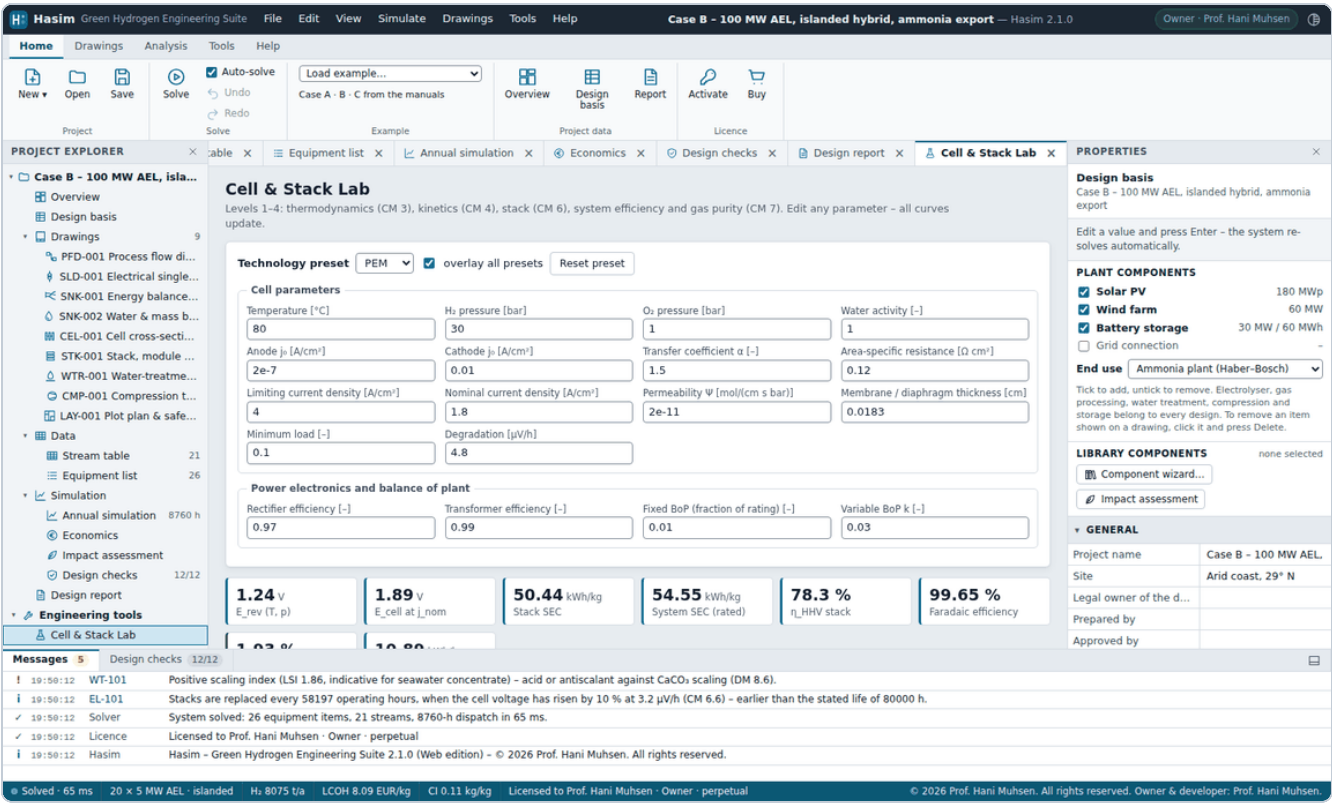


Figure 9.1 – Cell & Stack Lab with the PEM preset.

The stack is most efficient at low current density, but the balance-of-plant consumption makes the system SEC rise again below about 20 % load. At the full cathode pressure of 30 bar the crossover of hydrogen through the membrane would raise the H_2-in-O_2 content above the 2 % trip below about 31 % of the rated load. Hasim therefore lowers the cathode pressure below this load in proportion to the load, down to 10 bar – the column *Cathode pressure* – which keeps the content at the trip level down to about 10 % load, the minimum load of the PEM preset; the hydrogen produced at part load is compressed from the lower pressure. The check *H_2 in O_2 at the operating minimum load* documents it.

Example 10 – A value chain in the Model builder

Goal

Build a solar-only PEM chain that supplies a 70 MPa refuelling station, block by block.

You will learn

- to assemble and edit a block chain
- to read the stream trace from supply to product

1. Open **Tools ▸ Model builder** and choose **Load example model... ▸ Solar-only PEM to refuelling station** – or build it yourself: **New empty model**, add Power supply, Electrolyser plant, Compressor, Compressed storage buffer, Refuelling station 700 bar and Economics & carbon from the palette (each lands at its place in the chain).
2. Click a block to edit its parameters below the palette (e.g. PV size, electrolyser rating); × or the Delete key removes a block, Undo restores it.
3. Press **Run model**. The table shows the stream after each block.

#	Block	H_2 [t/a]	p [bar]	Electricity [GWh/a]	Direct CAPEX [MEUR]
1	Power supply (PV / wind / grid)	0.0	1.0	0.00	0.00
2	Electrolyser plant	177.4	29.0	10.86	9.40
3	Compressor	177.4	500.0	11.18	9.68
4	Compressed storage buffer	177.4	50.0	11.18	17.94
5	Refuelling station 700 bar	177.4	700.0	11.57	19.39
6	Economics & carbon (LCOH, CI)	177.4	700.0	11.57	19.39

177.4
Hydrogen [t/a]

700
Delivery pressure [bar]

11.57
Electricity [GWh/a]

27.3
CAPEX [MEUR]

17.42
Chain cost [EUR/kg]

0.00
Carbon intensity [kg/kg]

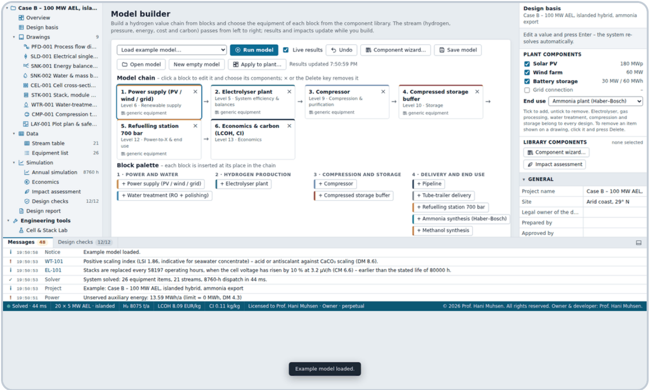


Figure 10.1 – The solar-to-refuelling chain.

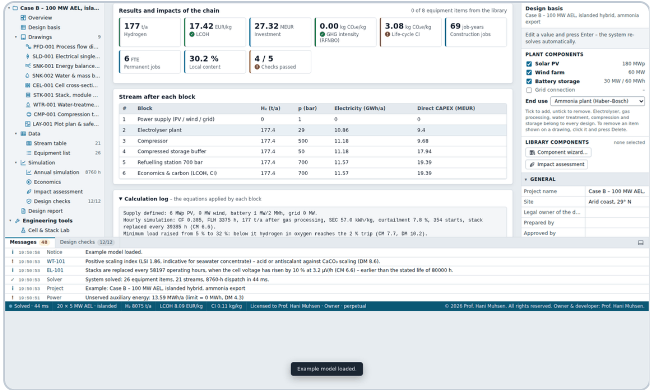


Figure 10.2 – Results after Run model.

Example 11 – An equation-level study: compression energy

Goal

Quantify how the specific compression energy and the number of stages grow with the discharge pressure (CM 10.4).

You will learn

- to use the equation library as a calculator
- to run a parametric sweep

1. Open **Tools ▸ Equations** and search “Multistage compression”.
2. Enter suction 30 bar, suction temperature 25 °C; vary **Discharge** from 100 to 300 bar with **Run sweep**.
3. The script line under the results reproduces the calculation, e.g. `H2.run('CM-10.4', {p1: 30, p2: 200})`.

Discharge [bar]	CM 10.4 stages	Max. stage T °C	Specific energy kWh/kg	T ≤ 120 °C stages	Max. stage T °C	Specific energy kWh/kg
50	1	88	0.29	1	88	0.28
100	2	100	0.69	2	100	0.69
200	3	104	1.11	3	104	1.11
350	3	131	1.52	4	102	1.47
500	4	114	1.75	4	114	1.75
700	4	126	2.04	5	104	1.98
900	5	111	2.22	5	111	2.21

Table: intercooled compression of 100 kg/h from 30 bar and 25 °C, isentropic efficiency 0.75. Left: the equation CM 10.4 with a pressure ratio of at most 2.3 per stage and a mechanical efficiency of 0.9 – the stage temperature exceeds 120 °C at 350 and 700 bar. Right: the plant compressor of Hasim (H2.compress), which limits the pressure ratio so that no stage exceeds the API 618 limit of 120 °C for hydrogen; mechanical and motor efficiency 0.95 each.

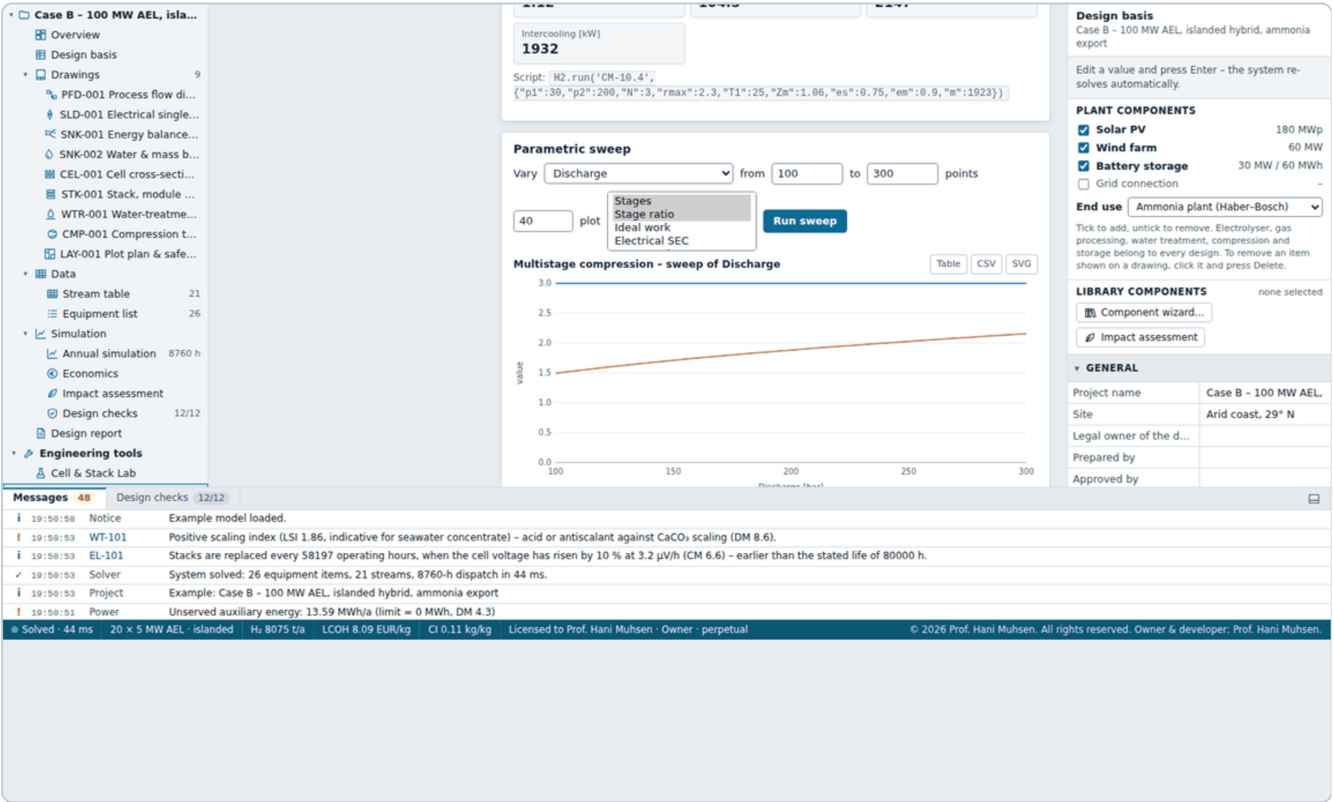


Figure 11.1 – Equation library with the sweep of the discharge pressure.

Example 12 – Automating studies with scripts

Goal

Write your own studies with the JavaScript API of the script console.

You will learn

- the main API calls
- loops over design bases, tables and plots

12.1 Solve a variant and list the equipment

```
const b = Object.assign({}, H2.CASES.A, { tech: 'AEL', capexEly: 1100 });
const sys = H2.solveSystem(b);
print('LCOH ' + sys.kpi.LCOH.toFixed(2) + ' EUR/kg, H2 ' + sys.kpi.H2_t.toFixed(0) + ' t/a');
table([['Tag', 'Equipment', 'Qty']].concat(sys.equip.map(e => [e.tag, e.name, e.count || 1])));
```

12.2 Parameter study with a chart

```
const P = [12, 16, 20, 24, 28], L = [];
for (const n of P) L.push(H2.solveSystem(Object.assign({}, H2.CASES.B, { modules: n
})).kpi.LCOH);
plot({ title: 'LCOH vs electrolyser size', xlabel: 'MW', ylabel: 'EUR/kg', x: P.map(n => 5 * n),
series: [{ name: 'LCOH', y: L }] });
```

12.3 Monte Carlo on LCOH

```
const n = 2000, L = [];
for (let i = 0; i < n; i++) {
  const u = () => 0.8 + 0.4 * Math.random();
  L.push(H2.run('CM-17.3', { Cinv: 1500 * u(), pel: 50 * u(), CF: 0.5 * u() }).LCOH);
}
L.sort((a, b) => a - b);
print('P10 ' + L[n * 0.1 | 0].toFixed(2) + '  P50 ' + L[n / 2].toFixed(2) + '  P90 ' + L[n * 0.9
| 0].toFixed(2) + ' EUR/kg');
```

12.4 From model to deliverables

When a design is final: **File ▸ Save project** keeps the design basis; **Export SVG** on each drawing and **Export CSV** in the stream table and equipment list provide the data for CAD and spreadsheets; **Design report ▸ Print / save as PDF** produces the complete report with all drawings. Licensed outputs carry your name in the title blocks.

Example 13 – Choosing components by their impacts

Goal

Choose the equipment of the islanded 100 MW ammonia plant (Case B) from the component library and weigh production, cost, emissions, jobs and the design checks.

You will learn

- to compare components with the preview of the component wizard
- how components add design checks – for example the turbine class of the site
- to read the impact assessment and change its settings

1. Load Case B and open **Impact assessment** (explorer ▸ Simulation). With its design-basis values the plant produces 8 075 t/a at 8.09 EUR/kg; the life-cycle carbon intensity is 2.02 kg CO_2e/kg, construction creates 1 618 job-years and operation 212 permanent jobs; the local content is 31.5 %.
2. Press **Component wizard…** and go to **Electrolyser stacks and modules**. Click the stack cards in turn and read **Effect on the model**. For the PEM stacks, edit **Minimum load** to 0.35 and watch the checks (Figure 13.1). Finally choose the **10 MW alkaline modules**.
3. **Solar PV plant**: compare fixed tilt with bifacial modules on trackers; choose the bifacial modules.
4. **Wind turbines**: compare the IEC II and IEC I turbines and choose the **4.2 MW IEC I** turbine (Figure 13.2).
5. **Battery storage**: choose the **4-hour** LFP containers – the battery energy becomes 30 MW × 4 h = 120 MWh.
6. **Apply components**. The design checks now contain the checks of the components – stack component matches the design-basis technology, battery cycles over its life (Figure 13.3) – and the impact assessment shows the new inventory (Figures 13.4 and 13.5). Ctrl+Z returns to the design-basis values.
7. In the design basis, group **Impact assessment**, set **Local share of equipment supply** to 0.3 – for example when PV structures, towers and vessels are made in the country.

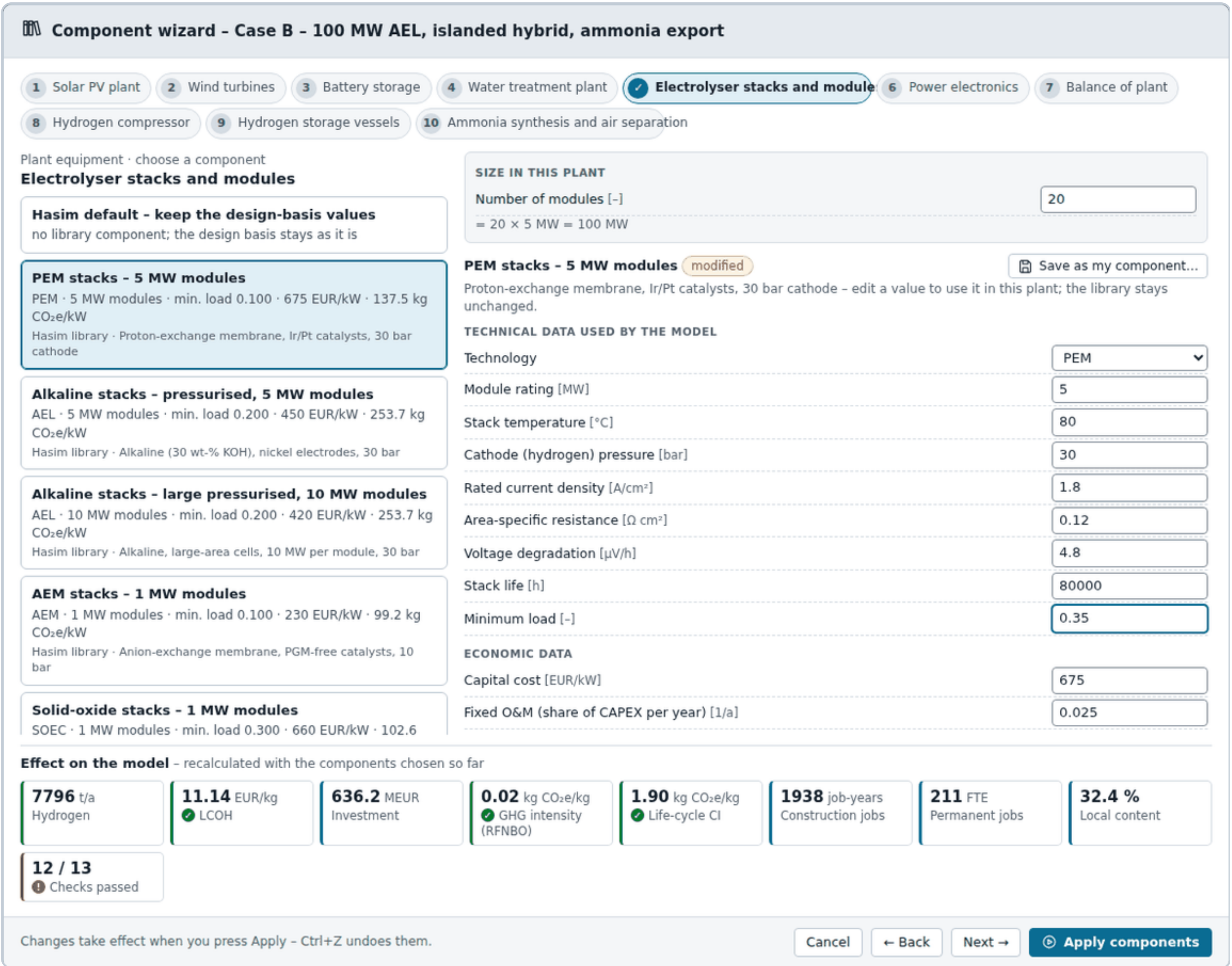


Figure 13.1 – PEM stacks with the minimum load edited to 0.35: all checks pass, but production falls and the LCOH rises.

Variant of Case B	H_2 t/a	LCOH EUR/kg	CAPEX MEUR	CI life-cycle kg/kg	Embodied kt CO_2e	Land ha	Construction job-years	O&M FTE	Local content	Checks
Case B – design-basis values no component selected; impact data from the Hasim defaults	8 075	8.09	500.0	2.02	385.7	335	1 618	212	31.5 %	12/12
Stacks: alkaline, 10 MW modules 10 × 10 MW instead of 20 × 5 MW	8 059	8.04	492.2	1.88	359.4	335	1 600	212	31.2 %	13/13
Stacks: PEM, 5 MW modules minimum load 0.10 of the component	8 081	11.01	629.5	1.97	377.5	334	1 922	211	32.5 %	13/13
Stacks: PEM, minimum load 0.35 edited in the wizard (modified)	7 796	11.14	636.2	1.90	365.4	335	1 938	211	32.4 %	12/13 !
PV: fixed tilt mono-Si modules on fixed racks	7 380	8.67	494.0	2.07	361.7	238	1 631	212	31.5 %	11/12 !
PV: bifacial on trackers glass-glass modules, single-axis trackers	8 148	8.11	505.1	1.95	374.5	335	1 614	212	31.6 %	12/12
Wind: 5 MW, IEC class II class limit 8.5 m/s	8 075	8.09	500.0	2.02	385.7	335	1 618	212	31.5 %	11/12 !

Variant of Case B	H_2 t/a	LCOH EUR/kg	CAPEX MEUR	CI life-cycle kg/kg	Embodied kt CO_2e	Land ha	Construction job-years	O&M FTE	Local content	Checks
Wind: 4.2 MW, IEC class I class limit 10 m/s	7 837	8.23	497.2	1.97	360.6	335	1 620	212	31.6 %	11/12 !
Battery: LFP, 4-hour 30 MW / 120 MWh instead of 60 MWh	8 202	8.01	498.0	2.00	391.6	335	1 568	212	30.5 %	13/13
Selected set AEL 10 MW + bifacial PV + IEC I wind + 4-h battery	8 061	8.18	491.5	1.97	379.4	335	1 546	212	30.1 %	14/14
Selected set, 30 % local equipment settings: local share of equipment supply 0.3	8 061	8.18	491.5	1.97	379.4	335	1 546	212	46.7 %	14/14

! = a check needs review: Stacks: PEM, minimum load 0.35 – demand; PV: fixed tilt – demand; Wind: 5 MW, IEC class II – site wind within the turbine class (IEC II); Wind: 4.2 MW, IEC class I – demand. Region Middle East (jobs × 2), baseline water stress extremely high, hydrogen value 6 EUR/kg.

Stacks decide the investment. The 10 MW alkaline modules cost 970 instead of 1 000 EUR/kW for stack, power electronics and balance of plant, and the LCOH falls to 8.04 EUR/kg. PEM stacks cost 1 500 EUR/kW in the library – the technology cost of the Calculations Manual – so the LCOH rises to 11.01 EUR/kg; the stacks contain 80 kg of iridium and platinum and, limited by their voltage degradation, are replaced 4 times in 25 years (alkaline: three times). Their minimum load of 10 % would let hydrogen in oxygen exceed the 2 % trip, so Hasim operates them at 10.6 % at the least; editing the minimum load to 0.35 adds a margin but costs 3.5 % of the production, because the electrolyser stops more often.

PV: bifacial modules on trackers yield more energy per MWp – 0.9 % more hydrogen – and the lowest carbon intensity of all variants (1.95 kg/kg), because their lower embodied emissions per kWp are spread over more hydrogen. Fixed racks need 97 ha less land but lose 8.6 % of the hydrogen and miss the ammonia demand.

Wind is a question of the site: its mean wind of 8.6 m/s exceeds the limit of the IEC II class (8.5 m/s) and the design check of the turbine class asks for a review. The IEC I turbine is designed for such sites but, rated at 13 m/s, yields less: 2.9 % less hydrogen and 8.23 EUR/kg. A site-suitability assessment of the turbine supplier (IEC 61400-1) may still allow the larger rotor – the check makes the question visible.

Battery: the 4-hour containers double the stored energy to 120 MWh. The electrolyser runs more hours at night – 1.6 % more hydrogen and 8.01 EUR/kg – but the extra running hours wear the stacks: they are replaced three times instead of three times in 25 years. With the larger battery this adds 5.9 kt of embodied emissions, and the life-cycle carbon intensity rises to 2.00 kg/kg. In Case B the battery is paid from the other direct costs of the design basis ("Other direct costs (× electrolyser)" covers battery and storage) – check this budget when the battery grows.

The **selected set** passes all 14 checks at practically the cost of the design-basis plant (8.18 vs 8.09 EUR/kg) with 1 546 construction job-years and 212 permanent jobs. Manufacturing 30 % of the equipment in the country raises the local content from 30.1 % to 46.7 % and creates 520 job-years of local manufacturing. Jobs scale with the labour productivity of the region:

Region	OECD	Middle East	Latin America	China	India	Developing Asia	Africa	Transition economies
Multiplier	1	2	2.3	1.3	1.4	1.5	6.8	1.7
Construction [job-years]	809	1 618	1 860	1 052	1 132	1 213	5 500	1 375
O&M [FTE]	106	212	244	138	149	159	722	180

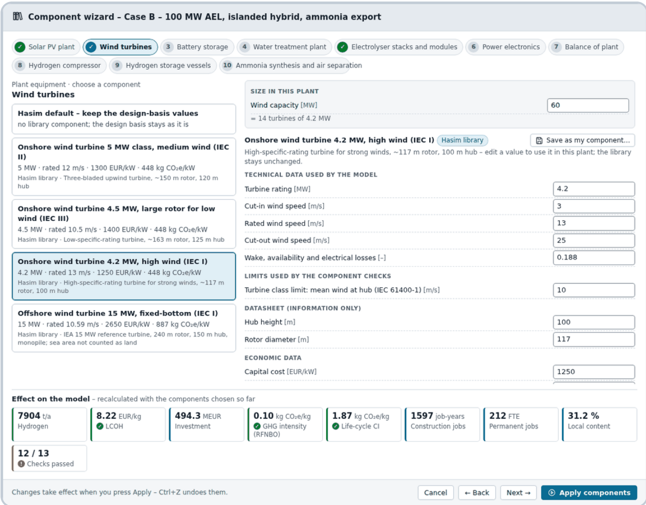


Figure 13.2 – The wind-turbine step: the IEC I turbine for the 8.6 m/s site.

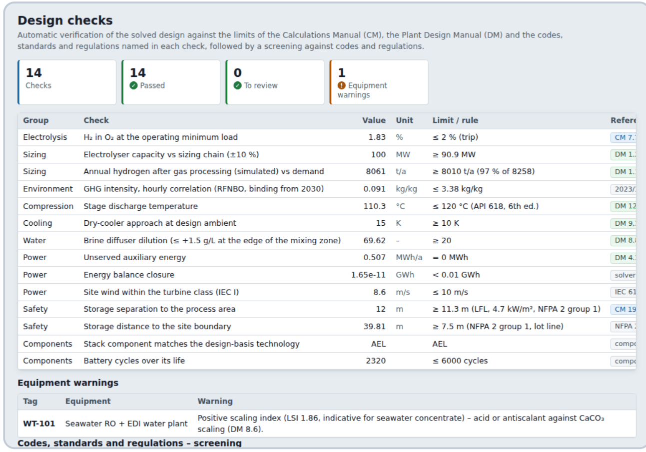


Figure 13.3 – Design checks with the checks of the selected components.

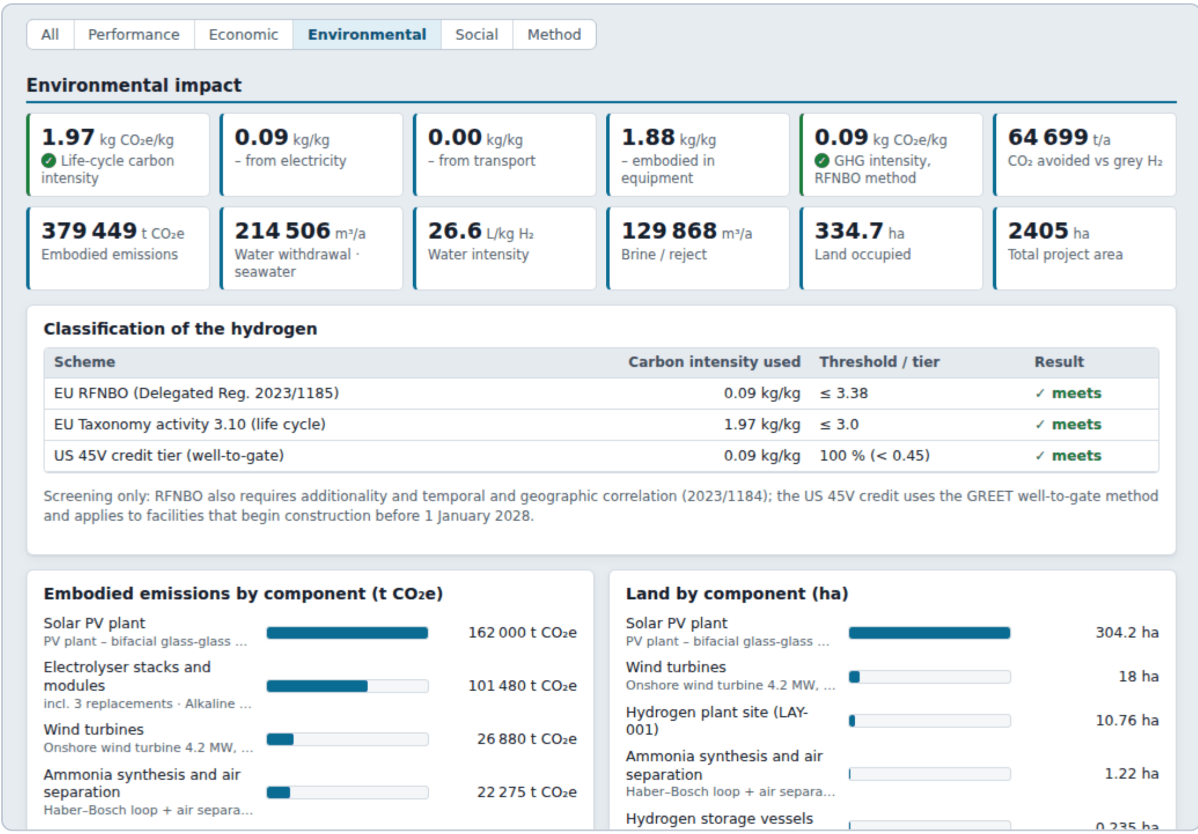


Figure 13.4 – Environmental impact with the selected components: embodied emissions and land by component.

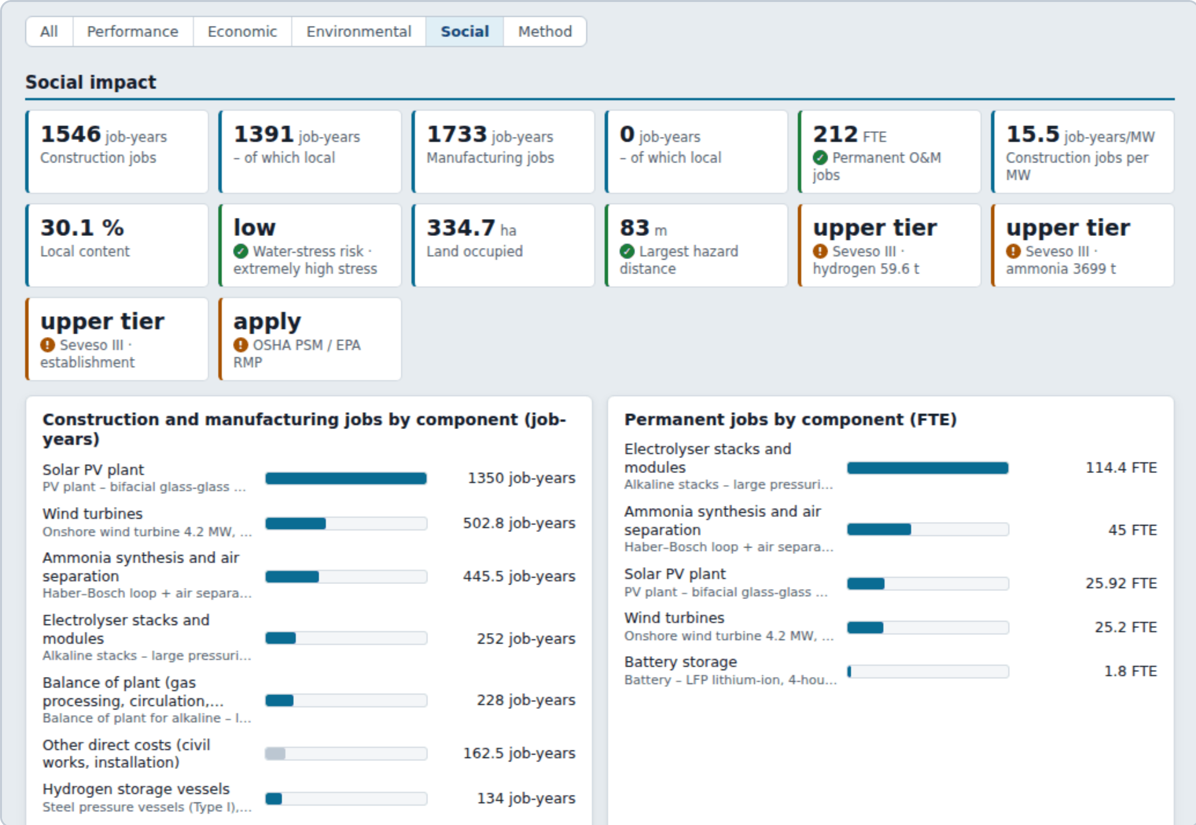


Figure 13.5 – Social impact with the selected components: jobs by component, water-stress risk and safety.

Your own data

The library values are screening values. For a real project, duplicate the components to your library and enter the quotations and datasheets of your suppliers – efficiency, costs, environmental product declarations – and the employment factors of a local study (User Manual, sections 9.4 and 11.4). The wizard then compares your candidates in the same way.

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