# Welcome!

## Webinar #33:
## Hydrogen Applications in Thermoflow Software

30 June 2022

**Agenda**:

* Introduction
* Modelling Hydrogen Production Plants in THERMOFLEX / NOVO PRO
* Renewables & Hydrogen, options and examples
* Optimization of LCOH in NOVO PRO using ELINK
* Hydrogen Use in THERMOFLEX
* Q & A Session

Presenter: IGNACIO MARTIN (SPAIN)
Support: Meritt Elmasri (U.S. HQ)

# Thermoflow Training and Support

- Standard Training
- On site training course
- User's Meetings / Advanced Workshops
- Webinars when new version is released
- Help, Tutorials, PPT, Videos
- Technical Support

→ **Feature Awareness Webinars**

# Feature Awareness Webinars

1- Assemblies in TFX, June 2016
2- Scripts in Thermoflow programs, GTP-GTM-TFX
3- Multi Point Design in GTP-GTM
4- Reciprocating Engines in TFX
5- TIME in GTM
6- Matching ST Perfromance in STP
7- Modeling Solar Systems in TFX
8- Combining THERMOFLEX & Application-Specific Programs
9- Methods & Methodology in GT PRO & STEAM PRO
10- Supplementary Firing & Control Loops in GT PRO & GT MASTER
11- The Wind Turbine Feature in Thermoflex
12- Modelling GT's in Thermoflow programas-1
13- Thermoflex for on line and off line performance monitoring
14- Tflow 27, what's new
15- Modelling GT's in Thermoflow programas-2
16- Multi Point Design in GTP-GTM
17- Total Plant Cost in TFX
18- Steam Turbine Tunning
19- User Defined Components in TFX
20- Cooling System Optimization

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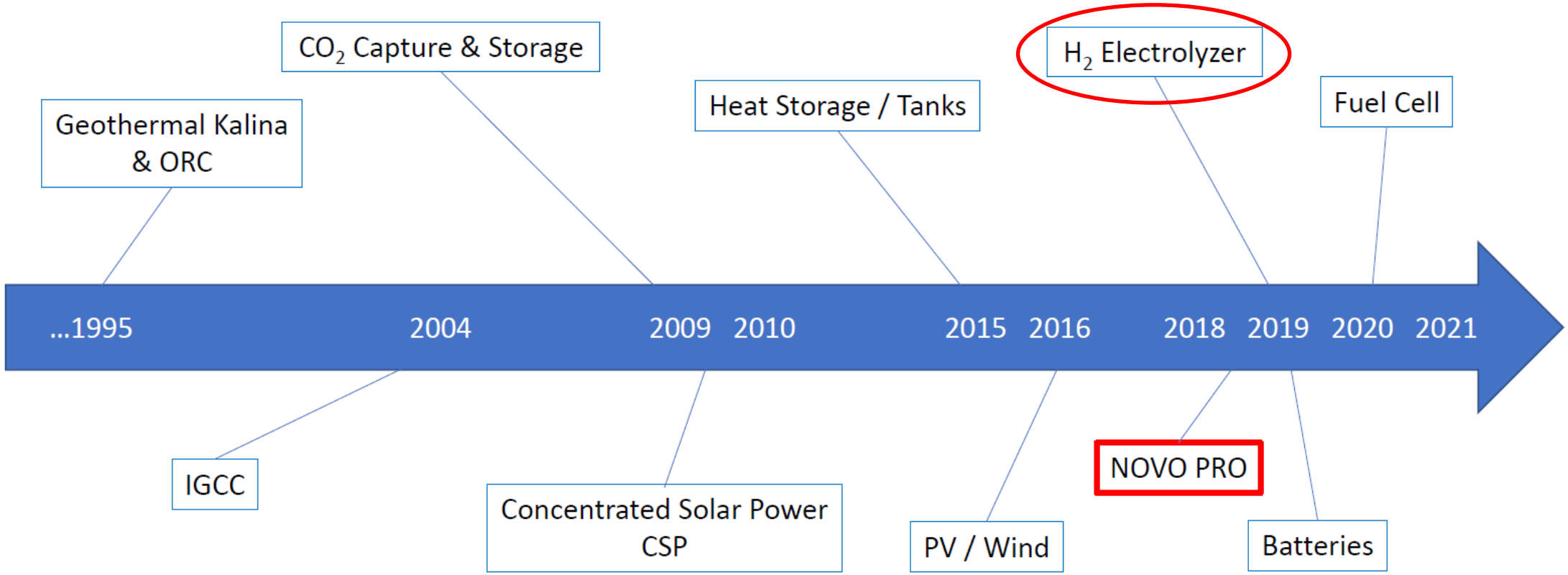
**33- Hydrogen Applications**

Thermoflow

# Thermoflow´s Products contribute to the "Green Transition"

Highlights / Milestones…



# NOVOPRO Background & Evolution

- Thermoflow main programs released between 1987 (GT PRO) and 1998 (GT MASTER, PDE, STEAM PRO, STEAM MASTER, REMASTER, PEACE, THERMOFLEX)

- NOVOPRO versión 1.1 was released with Thermoflow 28, in September 2018. Upgrades *1.2* in Mar-19, *1.3* in May-19, *1,4* in Jun-19, *1.5* in Sep-19, *1.6* in Feb-20
- Version 1.7 released with Tflow29 in Apr-20
- Version 1.9 released with Tflow30 in March-22. Current Revision (as of today) June 27, 2022

➡ Please check for new Revisions regularly, specially for NOVOPRO

# Other Sources of Information NOVOPRO / Hydrogen

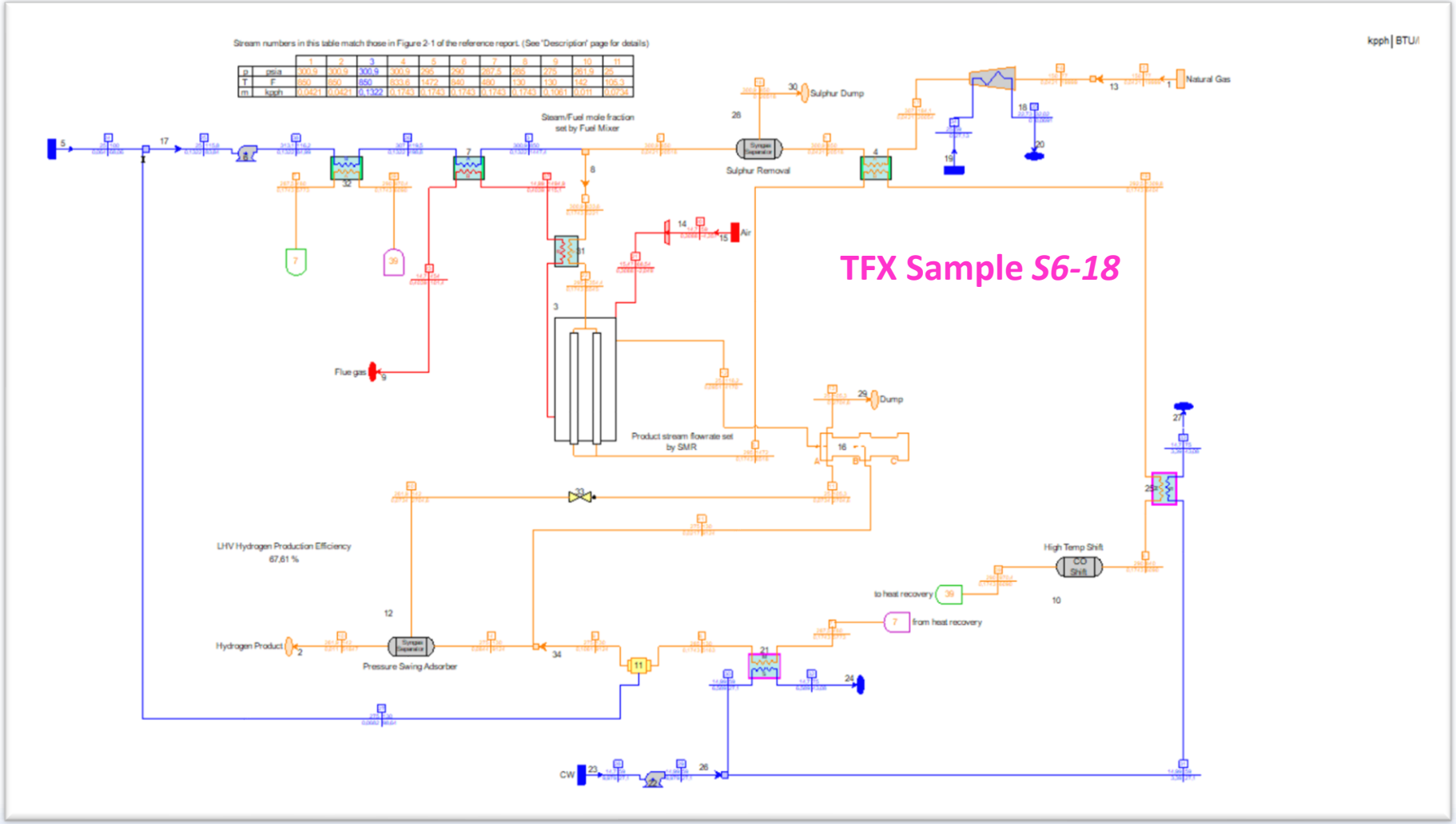
- Thermoflow Website: Description
- Thermoflow Website: Videos & Samples (specific)
- Thermoflow Service Center: Decarbonization Webinars, Asia, Europe and America Sessions, May - June 2021: Videos and Files

# Hydrogen Applications in Thermoflow Software

- **Hydrogen Production**:
  - SMR (TFX)
    - with Carbon Capture
  - Electrolysis (TFX-NOVOPRO)
    - TFX → Sizing
      - Desalination
      - Storage
      - ELINK, 24 hours simulation
    - NOVOPRO →Annual Production
      - Renewables + H2
      - ELINK, Optimization

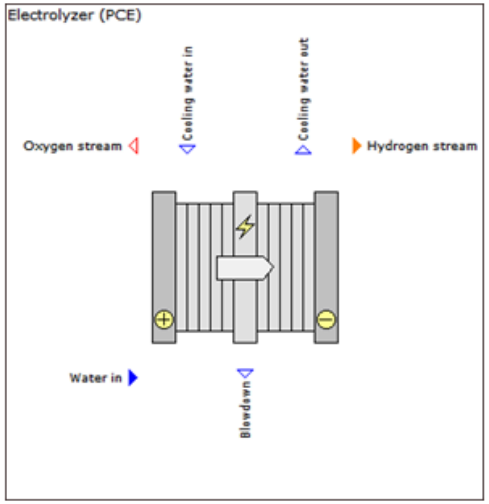
# Hydrogen Applications in Thermoflow Software

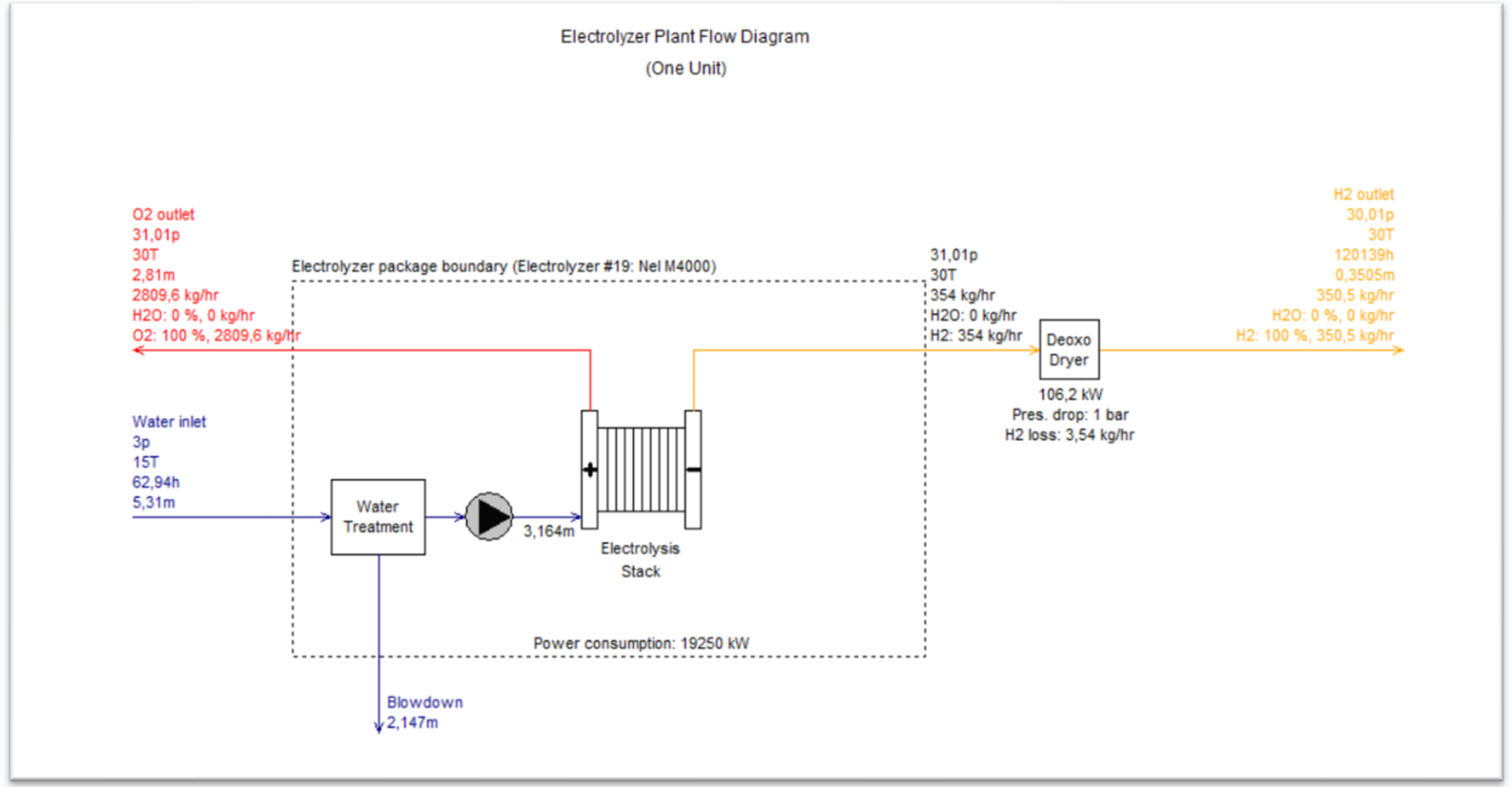
## Steam Methane Reforming in THERMOFLEX



# Hydrogen Applications in Thermoflow Software

## Electrolyzer in THERMOFLEX / NOVOPRO



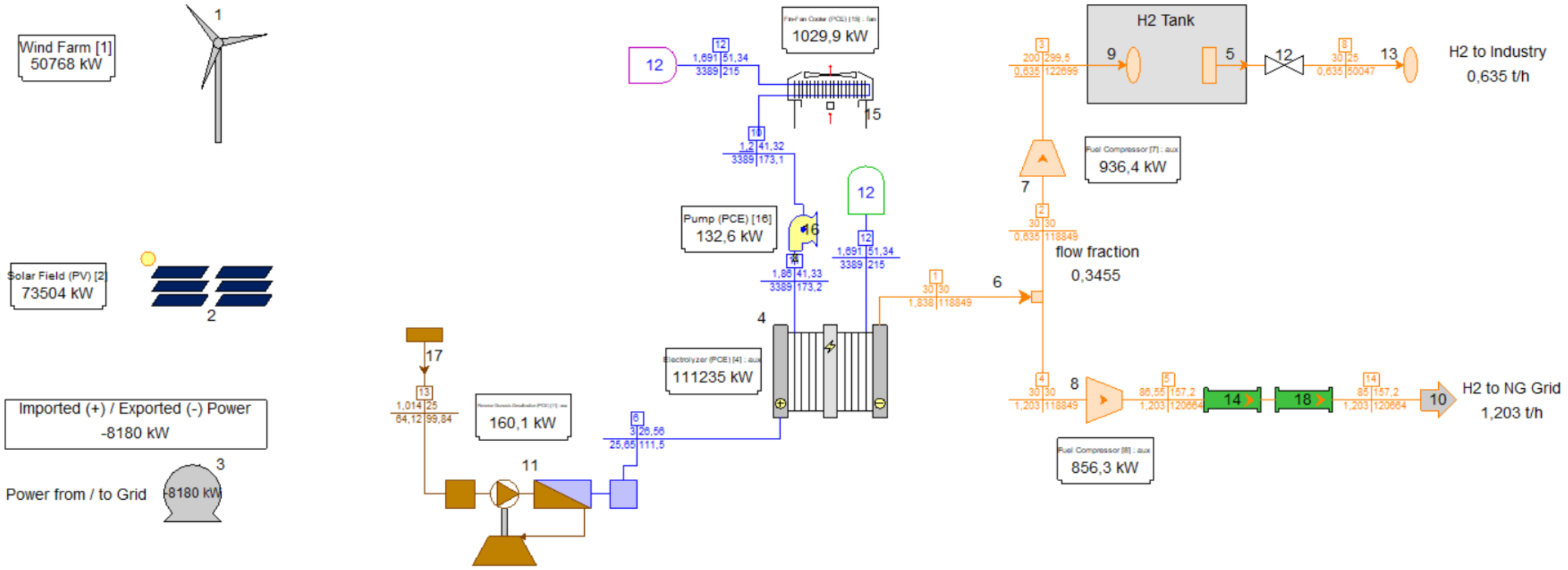



# Hydrogen Applications in Thermoflow Software

- **Hydrogen Use** (TFX):
  - Renewables to H2, H2 to Grid – Storage / Compression
  - District Heating, Heat Pumps, …
  - H2 to GT / Engine, blending with NG → 2nd Webinar with Kawasaki
  - …

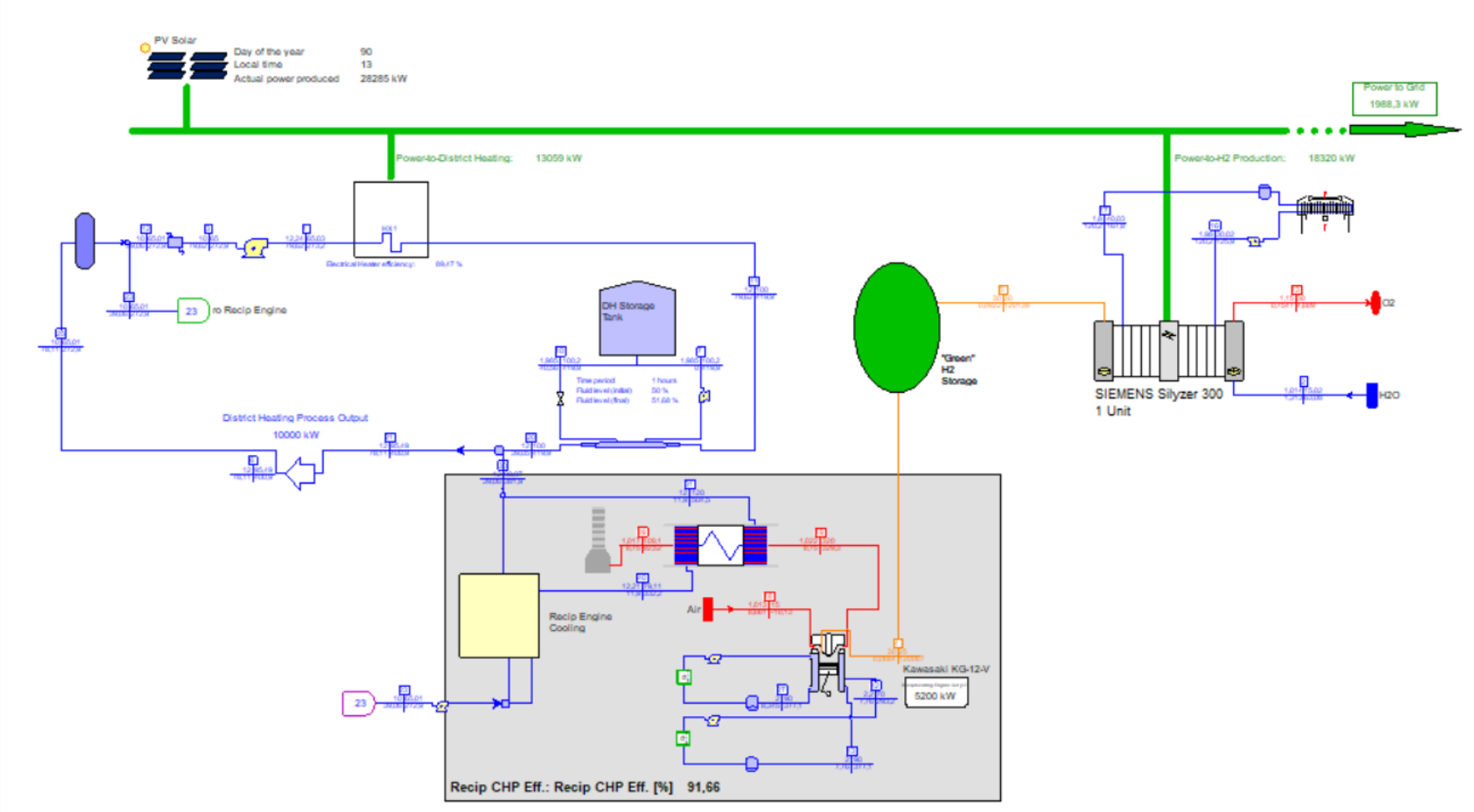
# Hydrogen Applications in Thermoflex

## PV + Wind, Desalination, Electrolyser, Cooling, Compressors, H2 Storage & Delivery, …



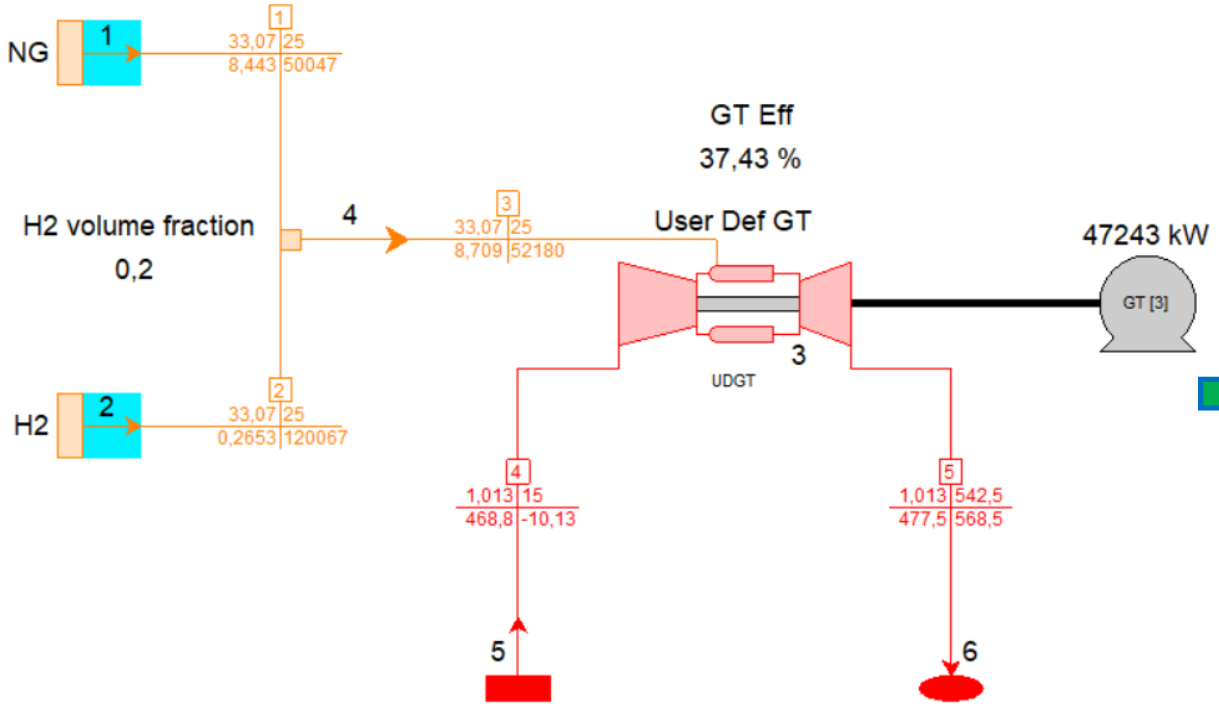
# Hydrogen Applications in Thermoflex

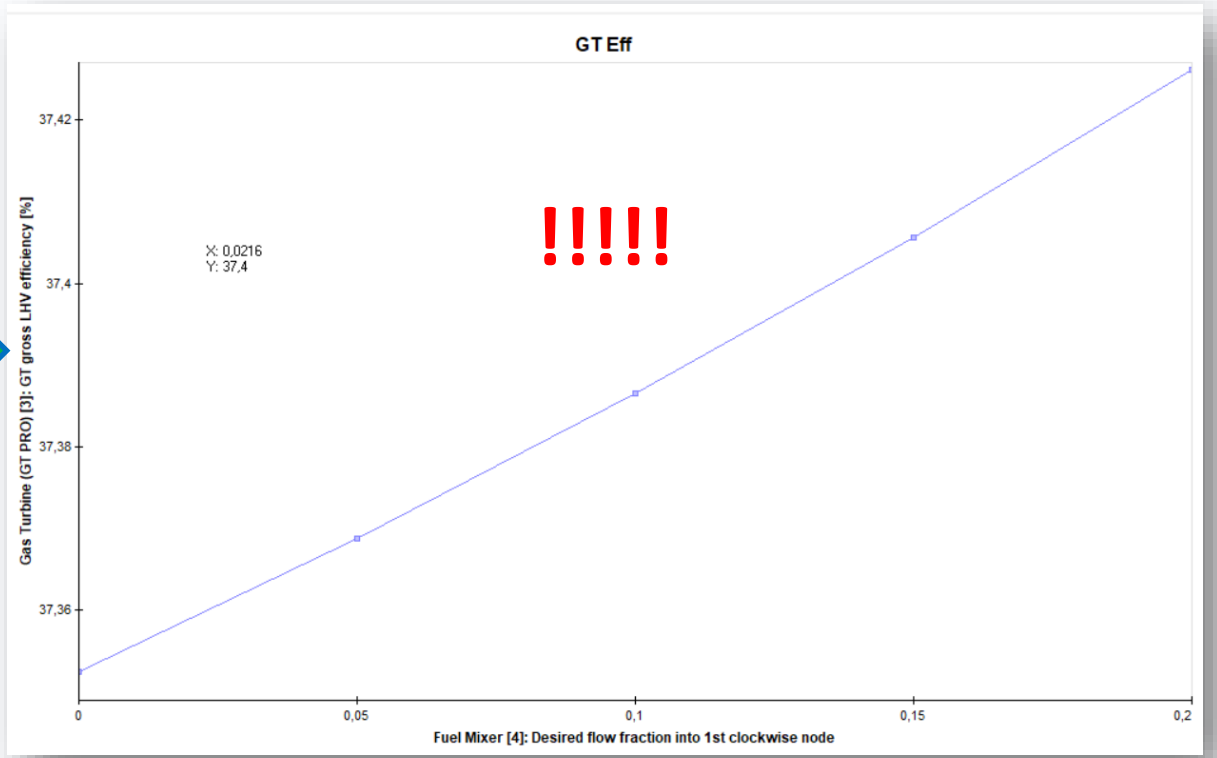
## PV, Electrolyser, District Heating, Engine, …



# Hydrogen Applications in Thermoflex

## Blending Natural Gas & Hydrogen in Gas Turbines



# 2nd Webinar on Hydrogen Announcement

- **“Modelling of Hydrogen fired Gas Turbines in GT PRO/THERMOFLEX (co-firing and pure H2 firing)**”, presented by **Kawasaki Gas Turbines Europe GmbH** and Thermoflow Inc.

- Speakers:
  - Dr. Nurettin Tekin (Hydrogen Product Management, Kawasaki)
  - Karsten Huschka (Director Thermoflow Europe)

- Scheduled for mid of September 2022, dates to be confirmed

- More details to be announced

# Hydrogen Applications in Thermoflow Software

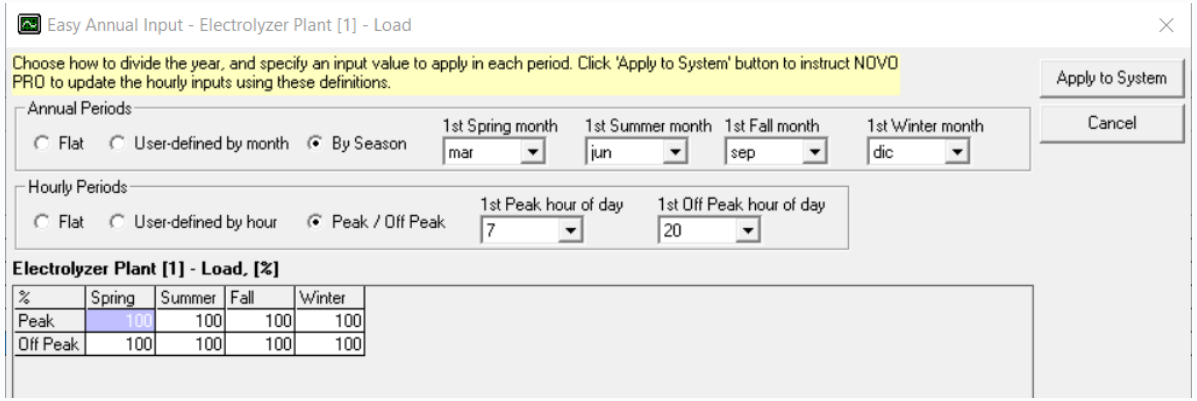
- **Hydrogen Production (NOVOPRO)**:
  - Microgrid – Plants Only
  - Renewables + H2
  - Flexible – Firm – Import from Grid
  - Hourly Hydrogen Demand definition
  - Electrolyzers Data Base / UD
  - Options: Deoxo Drier - Storage
  - PEACE Cost Definitions
  - NOVOPRO Outputs
  - LCOH Calculation
  - ELINK: Multiple Cases & Optimization

# Hydrogen Production Modes in NOVOPRO

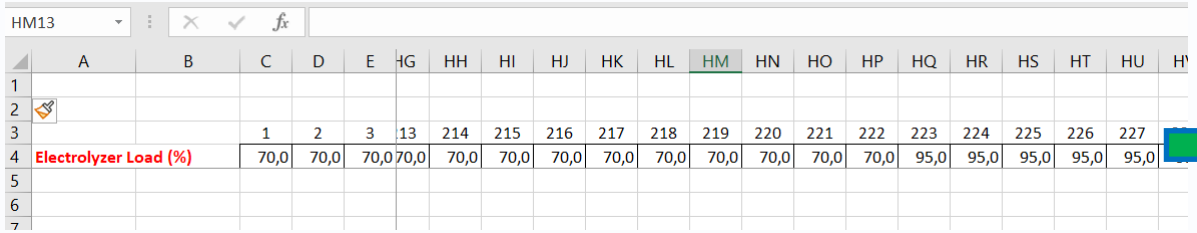
| *Mode* | *Electolyzer Options* | *Electricity Demand* | *H2 Demand* | *Notes* |
|---|---|---|---|---|
| Plants Only | | | met | Renewable Plants & Hydrogen production independent: Renewable send the power to the Grid, Electrolyzer takes de Electricity from the Grid |
| MicroGrid | Flexible | 0 | may not be met | Renewable Energy to produce Hydrogen, up to the maximum Electrolyzer capacity |
| | | >0 | may not be met | Renewable Energy to Supply the Grid electricity demand first, and surplus to produce H2 |
| | Firm, no import | 0 | may not be met | Renewable Energy to Supply the Hydrogen demand |
| | | >0 | may not be met | Renewable Energy to Supply the Hydrogen demand first, and surplus electricity to the Grid |
| | Firm, import | 0 | met | Renewable Energy to produce Hydrogen, deficit of electricity to meet the H2 demand imported from the Grid |
| | | >0 | met | Renewable Energy to produce Hydrogen, deficit of electricity to meet the H2 demand imported from the Grid, surplus electricity to supply electricity to the Grid, deficit of electricity to meet the Grid demand imported from the Grid |

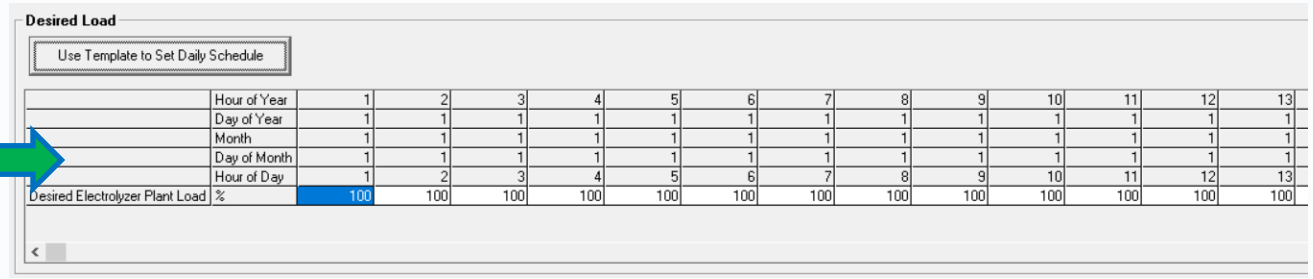
# Hydrogen Demand definition in NOVOPRO

## Use a Template




## Or Copy % Paste from Excel



# Electrolyzer Models

## Database

**Electrolyzer Package Selection**

| ID | Manufacturer & Model | H2 Production | Power Consumption | HHV Efficiency |
|---|---|---|---|---|
| | | kg/hr | kW | % |
| 0 | User-Defined Electrolyzer | | | |
| 1 | Siemens Silyzer 200 | 20,5 | 1244 | 64,95 |
| 2 | Siemens Silyzer 300 | 335,1 | 17409 | 75,87 |
| 3 | Siemens Silyzer 300C35 | 335,1 | 18123 | 72,88 |
| 4 | Siemens Silyzer 300C100 | 335,1 | 18349 | 71,98 |
| 5 | H-TEC ME450/1400 | 18,8 | 1000 | 74,1 |
| 6 | ITM HGas1SP | 10,11 | 650 | 61,32 |
| 7 | ITM HGas2SP | 19,9 | 1260 | 62,25 |
| 8 | ITM HGas3SP | 30,64 | 2000 | 60,38 |
| 9 | ITM HGasXMW | 178,7 | 10000 | 70,45 |

## User Defined

**User-defined electrolyzer**

**Electrolyzer Package Rating**

| | | |
|---|---|---|
| Pure hydrogen production rate | 354 | kg/hr |
| Package power consumption | 19250 | kW |
| Package HHV Efficiency | 72,48 | % |
| Package LHV Efficiency | 61,33 | % |

**Package Operating Data**

| | | |
|---|---|---|
| H2 outlet stream pressure | 31,01 | bar |
| H2 outlet stream temperature | 30 | C |
| H2 outlet stream relative humidity | 0 | % |
| O2 outlet stream pressure | 31,01 | bar |
| O2 outlet stream temperature | 30 | C |
| O2 outlet stream relative humidity | 0 | % |
| Water supply pressure | 3 | bar |
| Treated water consumption (kgH2O/kgH2) | 0 | |
| Cycles of concentration for water treatment blowdown | 15 | |
| Minimum load | 10 | % |

**Part Load Efficiency**

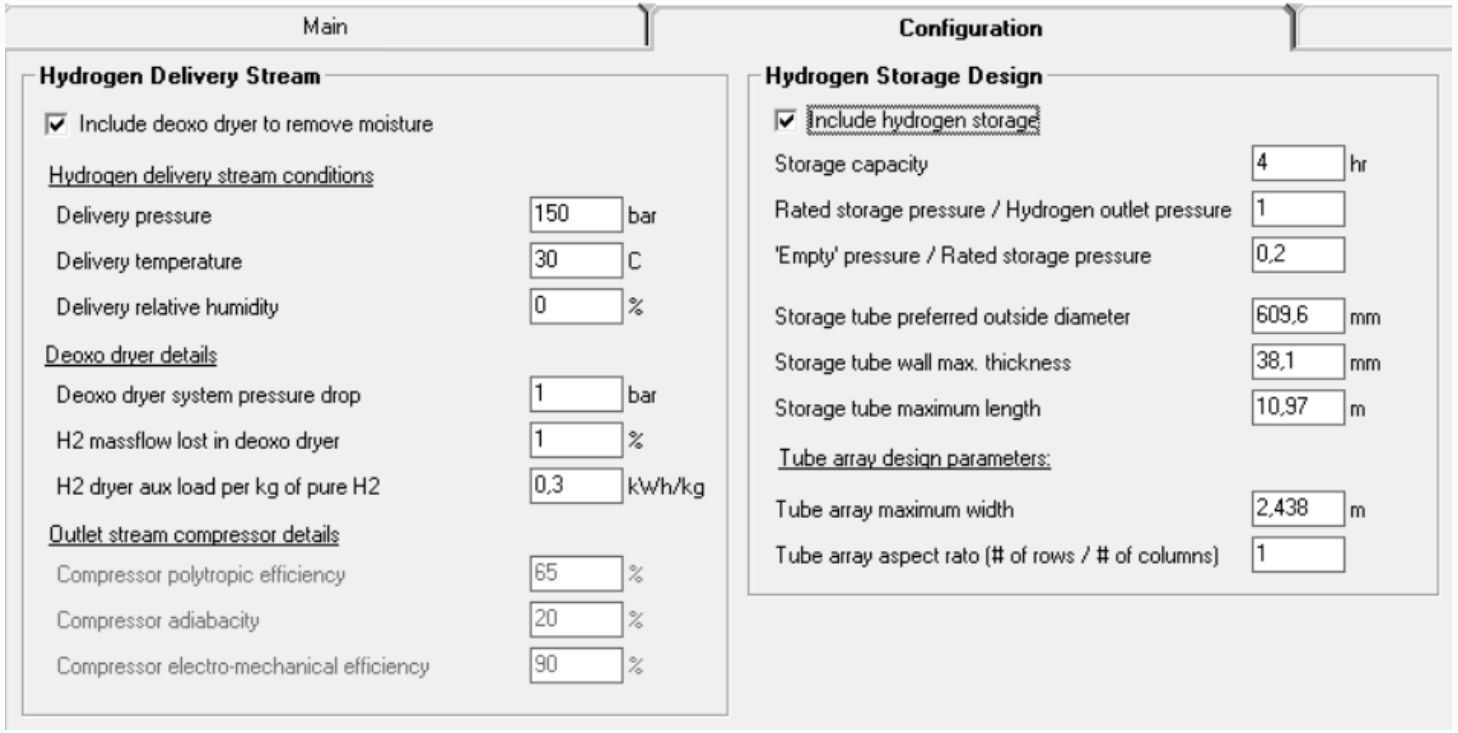
Number points on part load efficiency curve: 5

| Load | | Efficiency Factor |
|---|---|---|
| 100 | % | 1 |
| 77,5 | % | 1,023 |
| 55 | % | 1,045 |
| 32,5 | % | 1,068 |
| 10 | % | 1,09 |

Enter 'Load' data in decending order.
First point (full load) is fixed.

# Hydrogen Production in NOVOPRO, other options

- Define delivery Pressure
- Include Deoxo Drier to remove moisture
- Include Storage



# Hydrogen Applications in NOVOPRO

- **Hydrogen Production (NOVOPRO) Case Studies**:

1. H2 Standalone
2. PV+H2
3. Wind+H2
4. PV+Battery+H2

# Hydrogen Applications in NOVOPRO

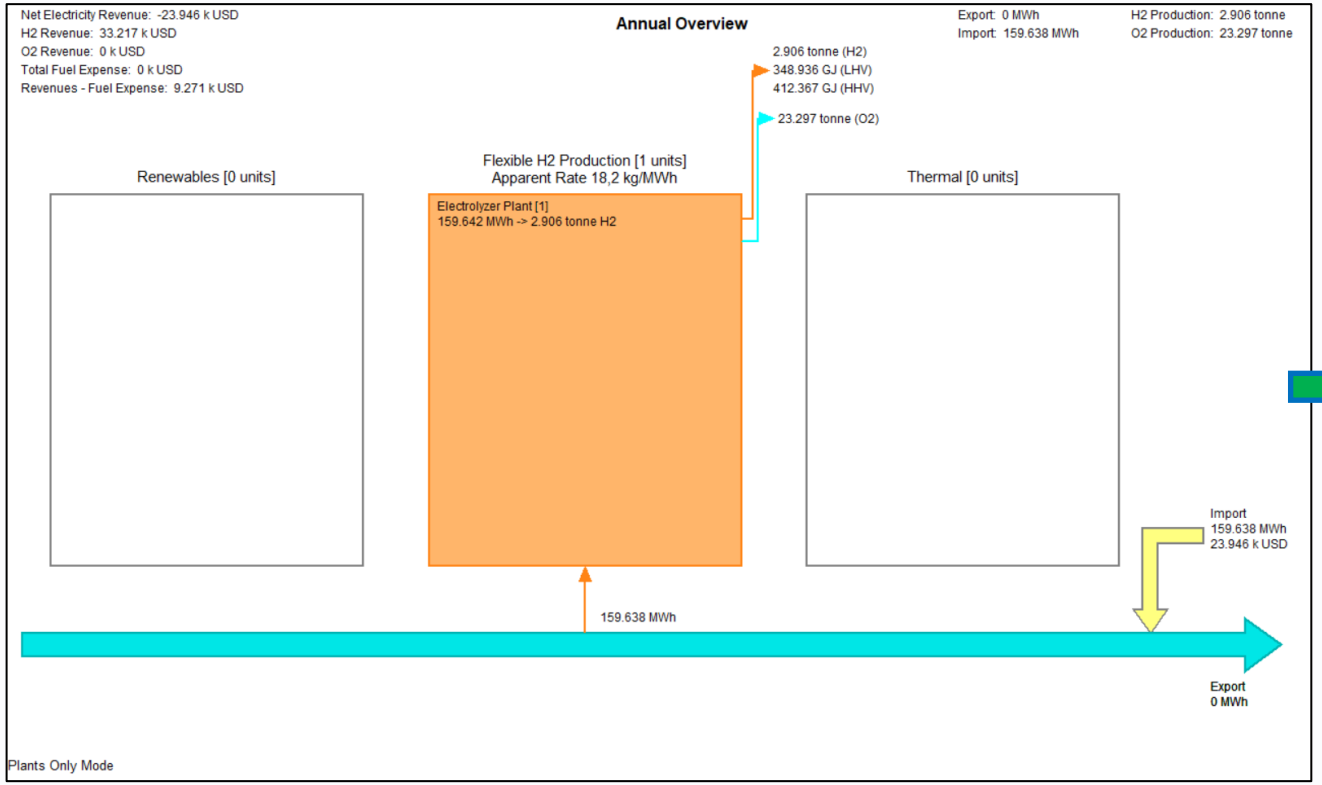
- **Case 1. Hydrogen Production only:**

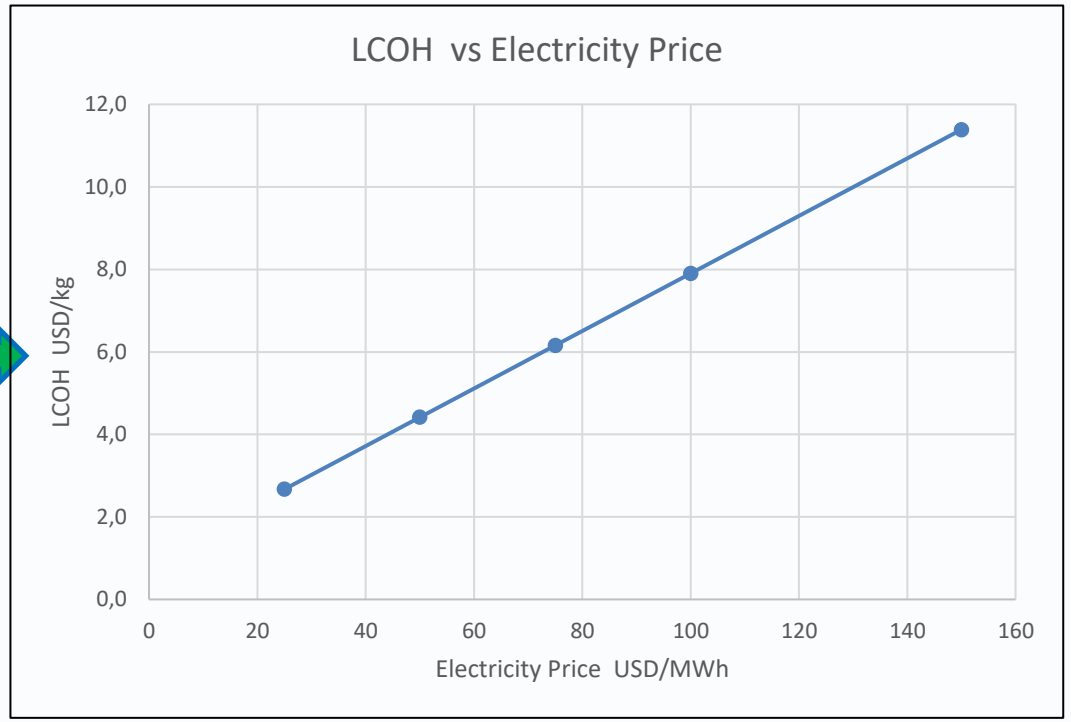
  - H2 Demand → Size of Electrolyzer
  - Electrolyzer Models
  - Electrolyzer Utilization, Capacity Factor
  - PEACE Costs, Investment and O&M Costs
  - Electricity Price

  → LCOH Calculation & Sensitivity

| *Mode* | *Electolyzer Options* | *Electricity Demand* |
|---|---|---|
| Plants Only | | |
| MicroGrid | Flexible | |
| | Firm, no import | |
| | Firm, import | |

# Case 1. Hydrogen Production only



# Hydrogen Applications in NOVOPRO

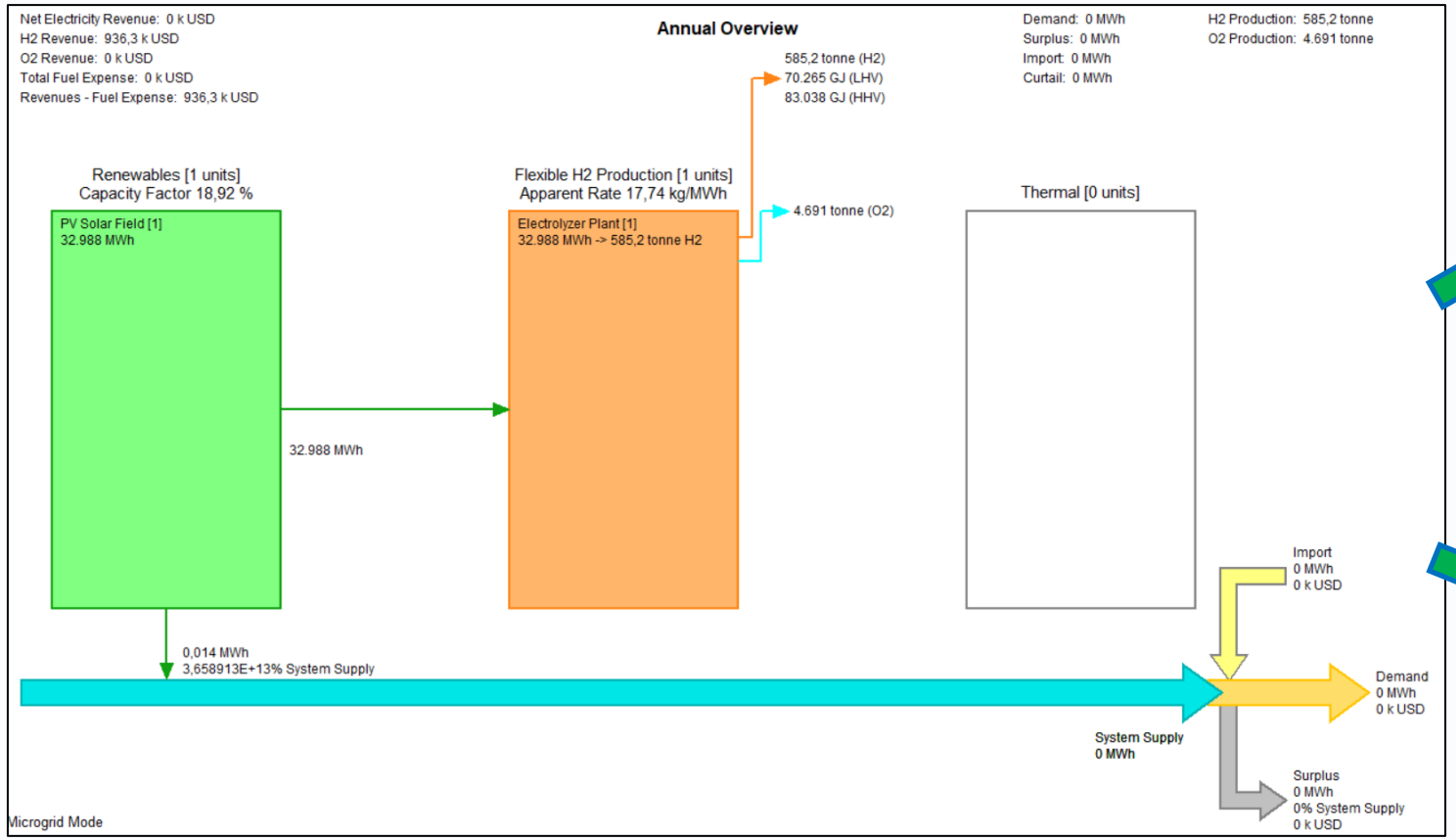
- **Case 2. Hydrogen Production from PV, no Grid export – no Grid Import:**

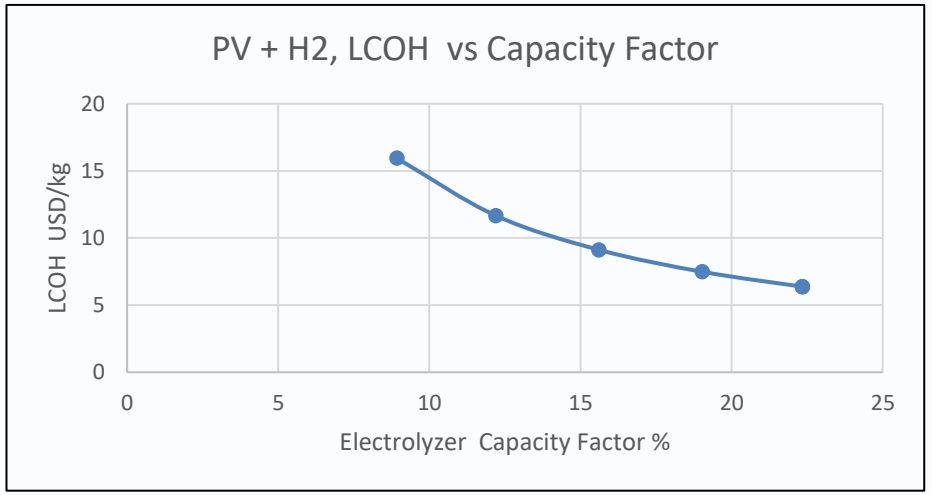
  - PV Field Size and Configuration
  - PV annual yield → H2 Production
  - PV & Electrolyzer Utilization, Capacity Factor
  - PV Investment, O&M Cost, Land Cost
  - Electrolyzer, Investment and O&M Costs

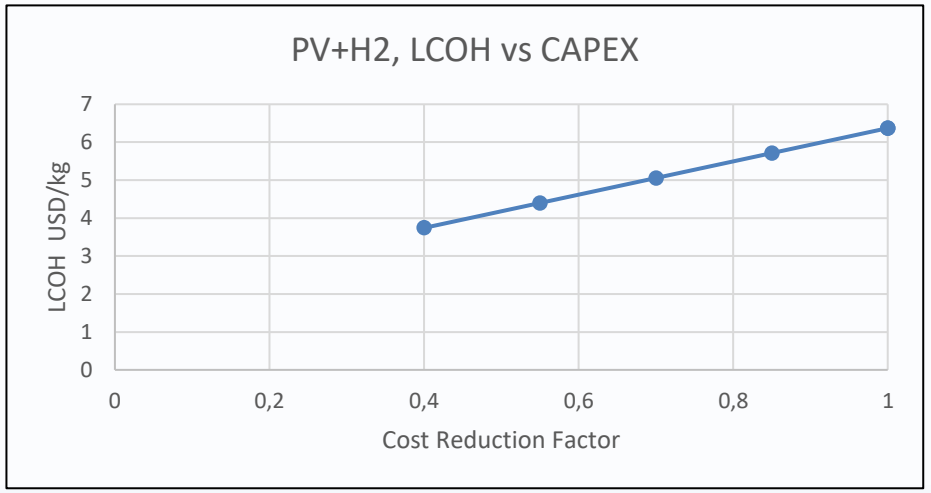
  → LCOH Calculation & Sensitivity

| *Mode* | *Electolyzer Options* | *Electricity Demand* |
|---|---|---|
| Plants Only | | |
| MicroGrid | Flexible | = 0 |
| | Firm, no import | |
| | Firm, import | |

# Case 2. Hydrogen Production from PV, no Grid export – no Grid Import



# Hydrogen Applications in NOVOPRO

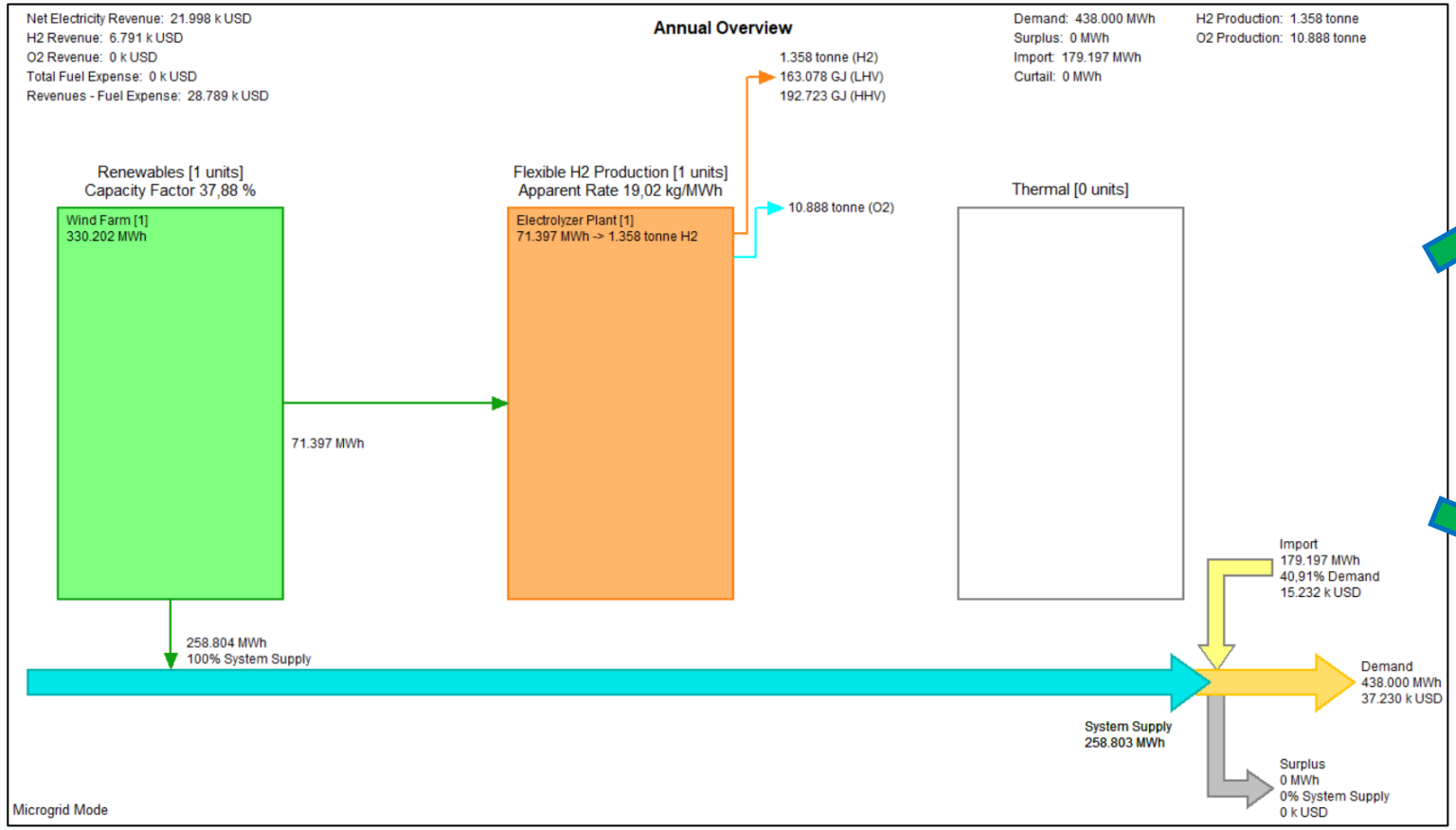
- **Case 3. Wind Farm supplying a demand, Wind Farm oversized and surplus to Hydrogen:**

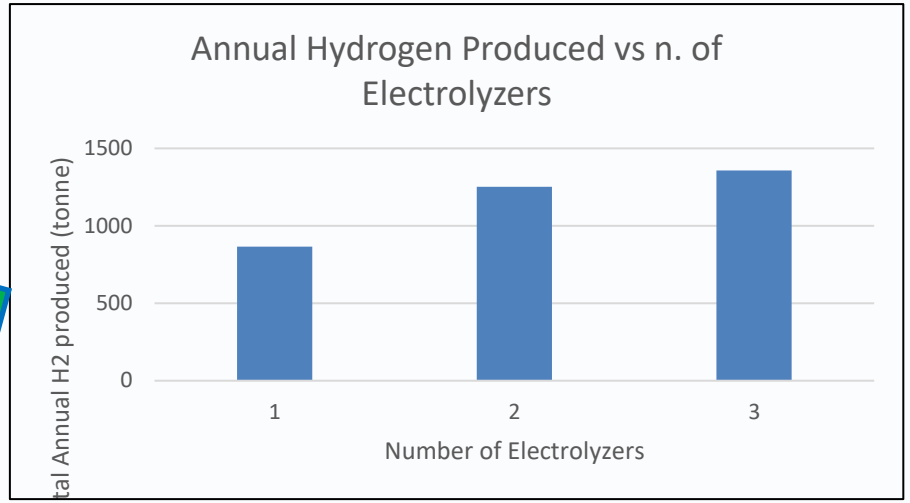
  - Wind Farm Size and Configuration
  - Wind Farm annual yield → Demand supplied and Surplus
  - Electrolyzer Size, Hydrogen produced, Capacity Factor
  - LCOE / LCOH calculation
  - Electrolyzer+Wind, Investment and O&M Costs

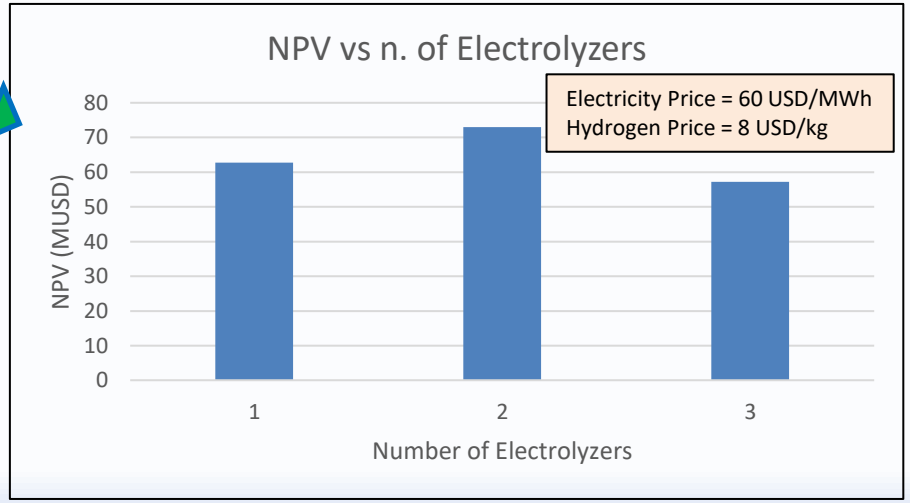
  → LCOH Calculation & Sensitivity

| *Mode* | *Electolyzer Options* | *Electricity Demand* |
|---|---|---|
| Plants Only | | |
| MicroGrid | Flexible | > 0 |
| | Firm, no import | |
| | Firm, import | |

# Case 3. Wind Farm supplying a demand, Wind Farm oversized and surplus to Hydrogen



# Hydrogen Applications in Thermoflow Software

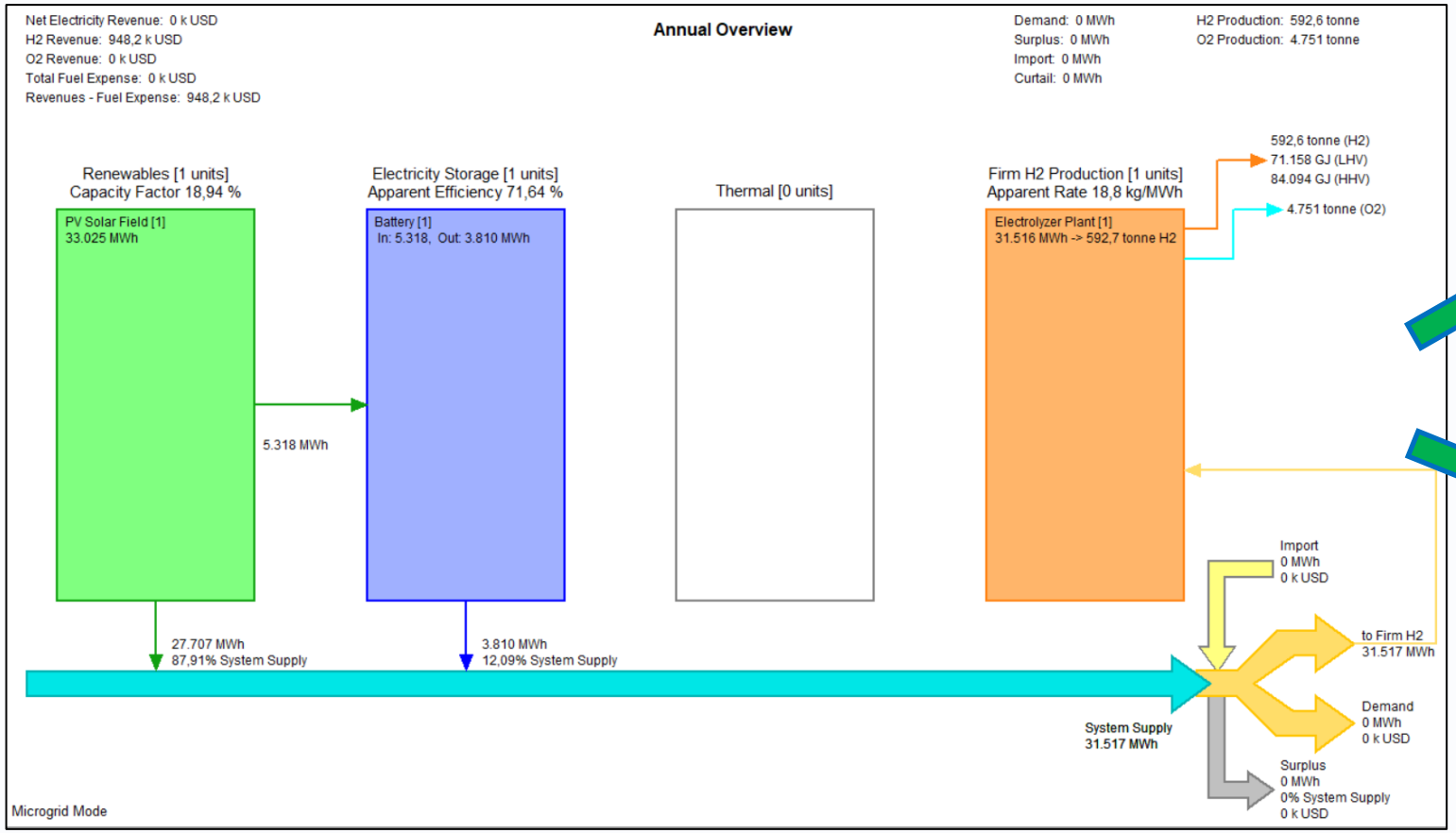
- **Case 4. PV + Hydrogen + Battery: Electrolyzer undersized with respect the PV Field**

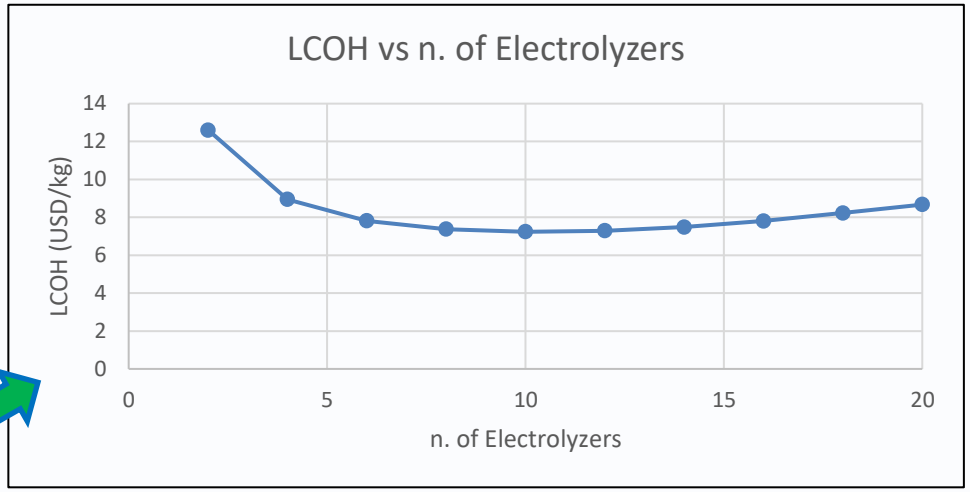
  - PV Field Size and Configuration
  - Number of Electrolyzers
  - LCOH optimization
  - Battery definition and sizing, Usable capacity
  - PV, Electrolyzer & Battery Investment and O&M Costs
  - H2 hourly production profile

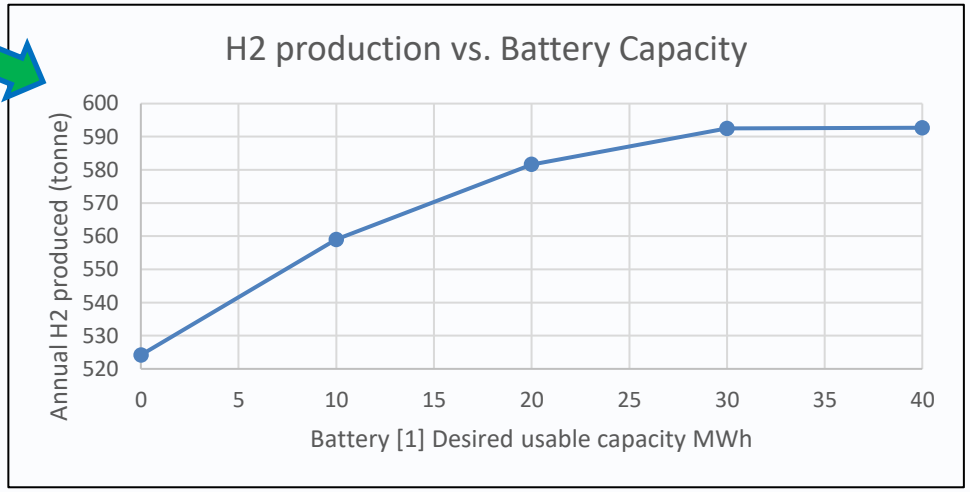
  → LCOH Calculation & Sensitivity

| *Mode* | *Electolyzer Options* | *Electricity Demand* |
|---|---|---|
| Plants Only | | |
| MicroGrid | Flexible | |
| | Firm, no import | = 0 |
| | Firm, import | |

# Case 4. PV + Hydrogen + Battery: Electrolyzer undersized with respect the PV Field

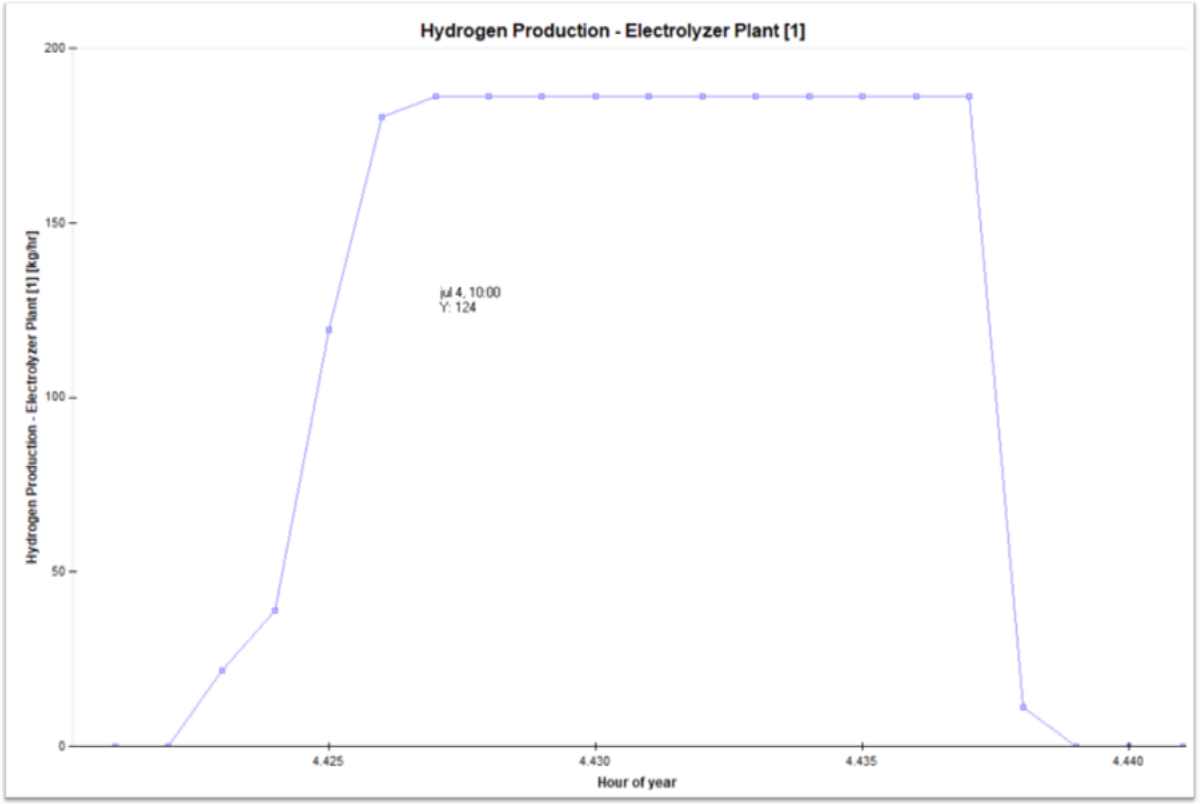


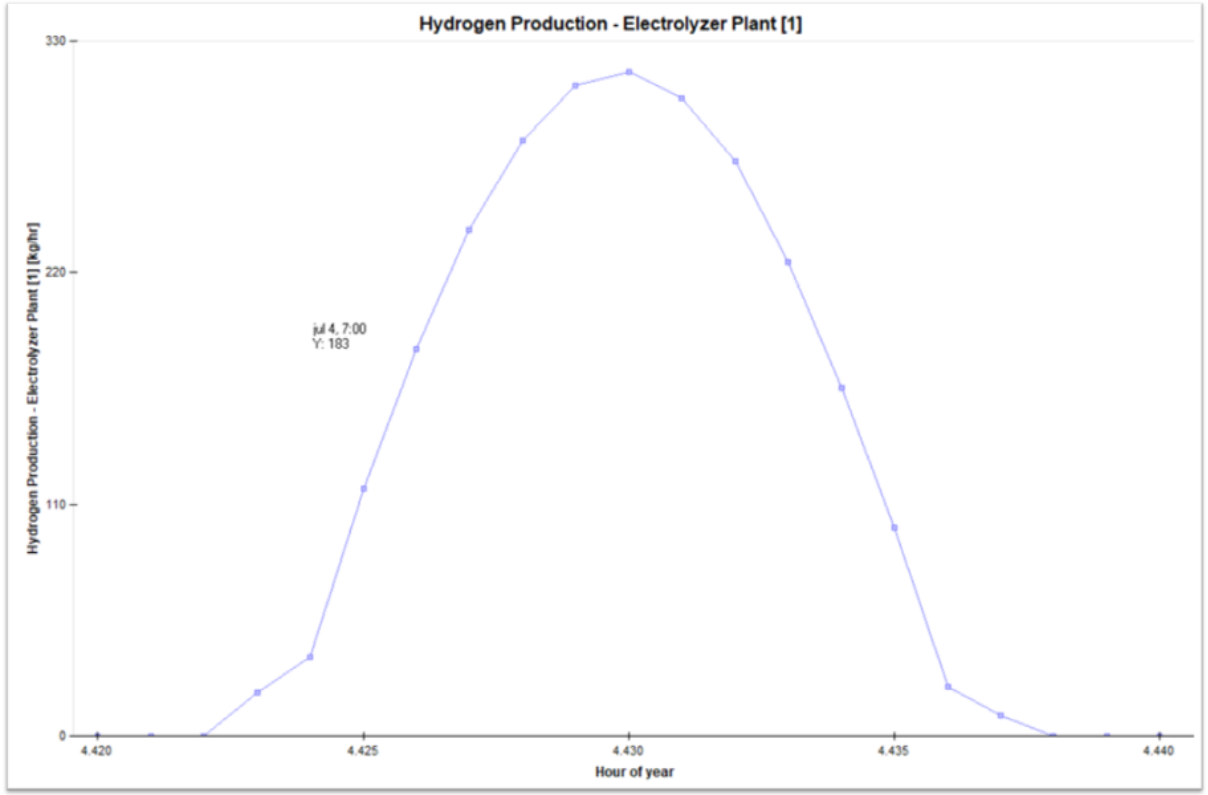



# Case 4. PV + Hydrogen + Battery: Electrolyzer undersized with respect the PV Field

20 MW PV + 10 MW Electrolyzer + (10 MW / 30 MWh) Batteries




20 MW PV +20 MW Electrolyzer, no Batteries



# Q & A Session

→ **Please help us by filling the survey**

- Please forward your questions on the WebEx Chat
- Further questions by email to: **info@thermoflow.com**
- PP Presentation will be available on the Website / Tutorials
- Video will be available on the Service Center

# Thank you!

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