NPHyCo Final Project Conference
WP2 Technical Roadmap

Stephanie Crevon, CEA
Martin Kykal, ESG
Martin Glückler, Framatome

11.02.2025 Fondation Universitaire, Brussels

NPHyCo
Nuclear Powered Hydrogen Cogeneration

Tasks of Technical Roadmap

- NPHyCo identified **needs** of Hydrogen Production (AEL, PEM and SOEC) and compared them with the **resources available** on existing NPP sites
- The **impacts of coupling** were analyzed with two aspects:
  Safety Impacts (D2.2A) and
  Impacts on Flexible Load operation (D2.2B) ← this is the focus of todays presentation
- Conditions in favor or against coupling were listed and described (D2.3 and D2.4) and **fed into the Economic Roadmap**
- The requirements and the economic result were used **to build a decision matrix** for the comparison of different site, scenarios, technologies ← Martin Kykal will report about this aspect

Outcome of Technical Roadmap

- Integration of hydrogen production is **generally feasible** even with existing NPPs.
- Related modifications and impacts are more or less laborious and costly depending on the level of integration but **can be rationalized**.
- Conditions in favor or against are **highly site-specific** and detailed analysis needs to be carried out case by case for any specific site in question.
- Site specific as well is the **local hydrogen market** and the potential offtakers. This defines the needs for **storage and/or transportation** which has significant impact on cost.

Implementation aspects, including the decision matrix, data requirements and illustrative scenario

Martin Kykal

11.02.2025

NPHyCo
Nuclear Powered Hydrogen Cogeneration

Decision matrix

- Based on inputs from WP2,3,4
- Criterias influence the price of hydrogen
- Influence of resources – 70%
- Influence of NPP modification and HPP configuration – 10%
- Influence of transportation and storage – 20%

<table>
<tr><th colspan="2">Total share of LCOH criteria</th><th colspan="7">Structures</th></tr>
<tr><td rowspan="2">Resources</td><td rowspan="2">NB
0.7</td><td>Resource from NPP</td><td colspan="2">N el
Electricity/ steam</td><td colspan="2">N cw
Cooling water</td><td>N dw
Demi water</td><td>N oth
Other</td></tr>
<tr><td>Reliability of NPP resource supply (coefficient to resource costs)</td><td colspan="4">N5
Number of NPP units</td><td colspan="2">N6
Lifetime of NPP</td></tr>
<tr><td rowspan="2">Modification/ Configuration</td><td rowspan="2">HB
0.1</td><td>Costs of NPP modifications</td><td colspan="4">NPP systems - complexity of modification</td><td colspan="2">Licensing
NPP - location</td></tr>
<tr><td>Costs of additional equipment HPP</td><td>Cooling water</td><td colspan="3">Demi water</td><td colspan="2">Other</td></tr>
<tr><td>Logistic</td><td>LB
0.2</td><td>Logistics costs</td><td colspan="3">Intermediate storage</td><td colspan="3">Transportation from storage to consumer</td></tr>
</table>

Mapping of suitable locations

Second task has 2 parts - Collect the necessary information, and create and evaluate possible scenarios

Necessary basic information:

- Location
- Possibility of using resources - sufficient reserve
- Connection points of this resources
- Modification of NPP systems
- Impact of modification to safety
- Possible location to place the storage
- Potential consumer and their needs
- Way of transport to the consumer

In second part was created and evaluated 10 possible scenarios

Model	NB (0.7)						HB (0.1)		LB (0.2)		Total
	EL	CW	DW	Other	Reliab.	Lifetime	Modific.	HPP	Storage	Consum	
R1	0.99	0.055	0.04	0.011	1.02	1.1	1.0	1.0	0.95	1.05	1.160
R2	0.99	0.045	0.04	0.011	1.02	1.1	1.05	0.95	0.95	1.05	1.152
R3	0.99	0.055	0.04	0.011	1.02	1.1	1.0	1.0	1.0	1.05	1.171
R4	0.99	0.045	0.036	0.011	1.02	1.1	1.05	0.9	1.0	1.05	1.154
R5	0.99	0.045	0.04	0.011	1.02	1.1	1.05	0.95	1.0	1.05	1.163
K1	0.99	0.055	0.04	0.011	1.0	1.1	1.0	1.0	0.95	1.0	1.134
K2	0.99	0.045	0.04	0.011	1.0	1.1	1.05	0.95	0.95	1.0	1.126
T1	0,99	0.055	0.04	0.011	1.0	1.1	1.0	1.05	1.0	1.0	1,149
T2	0,99	0.045	0.036	0,009	1.0	1.1	1.05	0.9	1.0	1.0	1,126
Tr1	0,99	0.045	0.036	0,009	0.95	1.1	1.05	0.9	1.0	1.0	1,085
	Nel*N1	Ncw*N2	Ndw*N3	Noth*N4	N5	N6	Hm	Hc	Ls	Lc	

Description of winning scenario – Rivne NPP

- HPP with 30MW PEM electrolysers palced offsite of the NPP but in sanitary zone
- Electricity – used from NPP with special low price (home need)
- Demineralized water – used from NPP with additional treatment at HPP side to decrease conductivity
- Cooling water – used from NPP
- Waste water system and tap water – used from NPP
- Chilled water – autonomus chiller at HPP site
- Nytrogen – used bottels filled in NPP
- Instrumentation air – not used from NPP

Setup of NPP – location

Conceptual planning of pilot plant

The last step is described in detail the best scenario.

Main steps:

- Setup of NPP (modification and licensing)
- Setup of HPP (PID, description of each parts, operation, examples of producers)
- Economical setup (cost estimation, LCOH, example of bussines plan)
- Consumer (description, transportation of hydrogen)

→ This will be described in deliverable D5.3 which is currently in finalization

Flexible load impact assessment

Stéphanie Crevon, Cecilia Herrero, Martin Šilhan, Eduard Diaz

NPHyCo
Nuclear Powered Hydrogen Cogeneration

Starting Point

- There has always been a need for flexible load operation for NPP in countries to ensure the grid stability
- Due to the increase of the penetration of RE, NPPs are forced to use more and more flexible operation instead of base load operation
- In this context, the “idle capacity”- defined as the gap between available nuclear power and actual production - is expected to increase progressively
- Thus, it is interesting to investigate whether it is beneficial to use this “idle” production capacity to produce hydrogen instead

“Beneficial” meant in this context economically beneficial as well as technically beneficial = advantageous for the operation of the NPP (less fatigue etc.)

Questions raised

- What are the capabilities of NPP to perform load following?
- What are the impacts of this operation on the NPP?
- Does a NPP-HPP couple can have the same capabilities?
- Do the European NPP already use load follow operation?
- If yes, could the « idle » capacity be used to operate competitively a HPP?

NPP & Load follow operation

According to European Utility Requirements (EUR), to be connected to the grid:

Involvement in **FCR** is **mandatory** to ensure grid stability

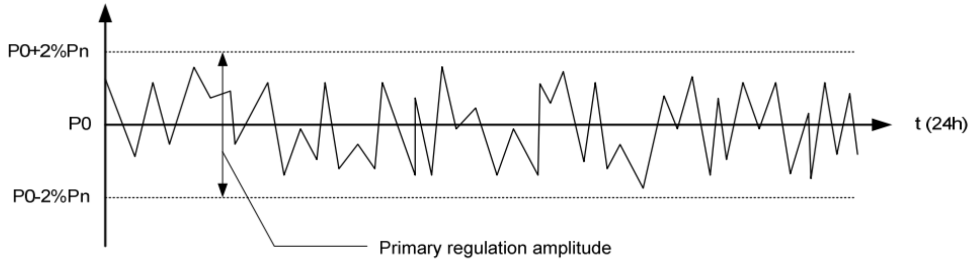
	EUR requirements
Primary frequency control range	±2% Pr
Primary frequency timescale	≤30 sec Maintain 15 min.

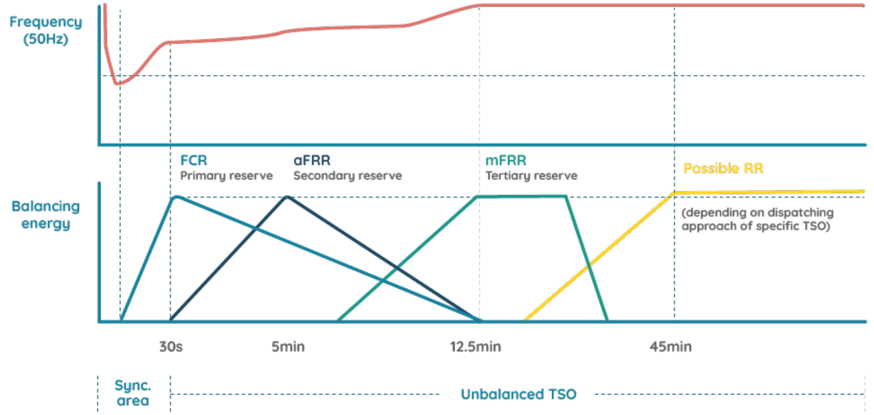
Involvement in aFRR is based on an agreement (optional):

	EUR requirements
Secondary frequency control range	±10%Pr Variation rate 1% Pr/min (maximum 5%Pr/min)
Secondary frequency timescale	≤5 min

EUR also state flexible capabilities for modern reactors:

	EUR requirements
Load following ramps	3%Pr/min
Range of operation	Between 50% and 100%Pr
Number of cycles	12 000 cycles per 60 years





sympower.net

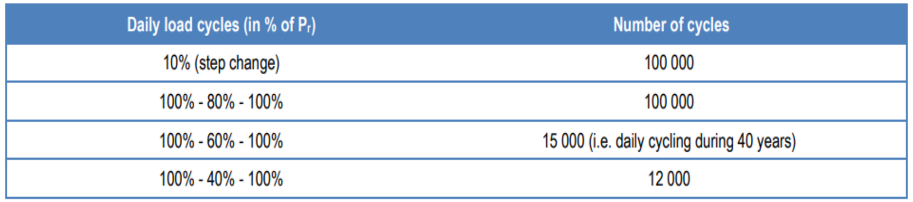
NPHyCo
Nuclear Powered Hydrogen Cogeneration

NPP & Load follow operation

Application of ancillary services constraints on an

	1000MW
Primary frequency control range	±20MW (mandatory) ±2%Pr
Primary frequency timescale	30 sec Maintain 15 min
Secondary frequency control range	Optional: ±100MW above the minimum load 10MW/min (1%Pr/min)
Load following ramps	30MW/min 3%Pr/min 12 000 cycles/60 years

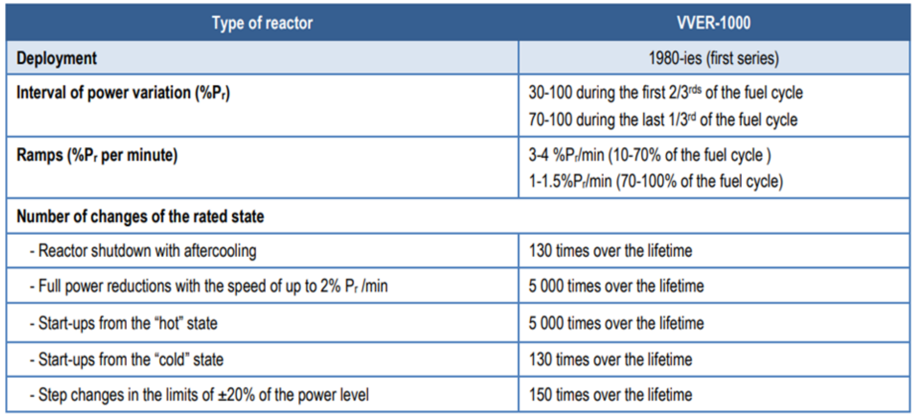
Examples of operation ranges and flexible services of existing NPPs



Daily load cycles (in % of P_r)	Number of cycles
10% (step change)	100 000
100% - 80% - 100%	100 000
100% - 60% - 100%	15 000 (i.e. daily cycling during 40 years)
100% - 40% - 100%	12 000

Source: Ludwig, *et al.*, 2010.

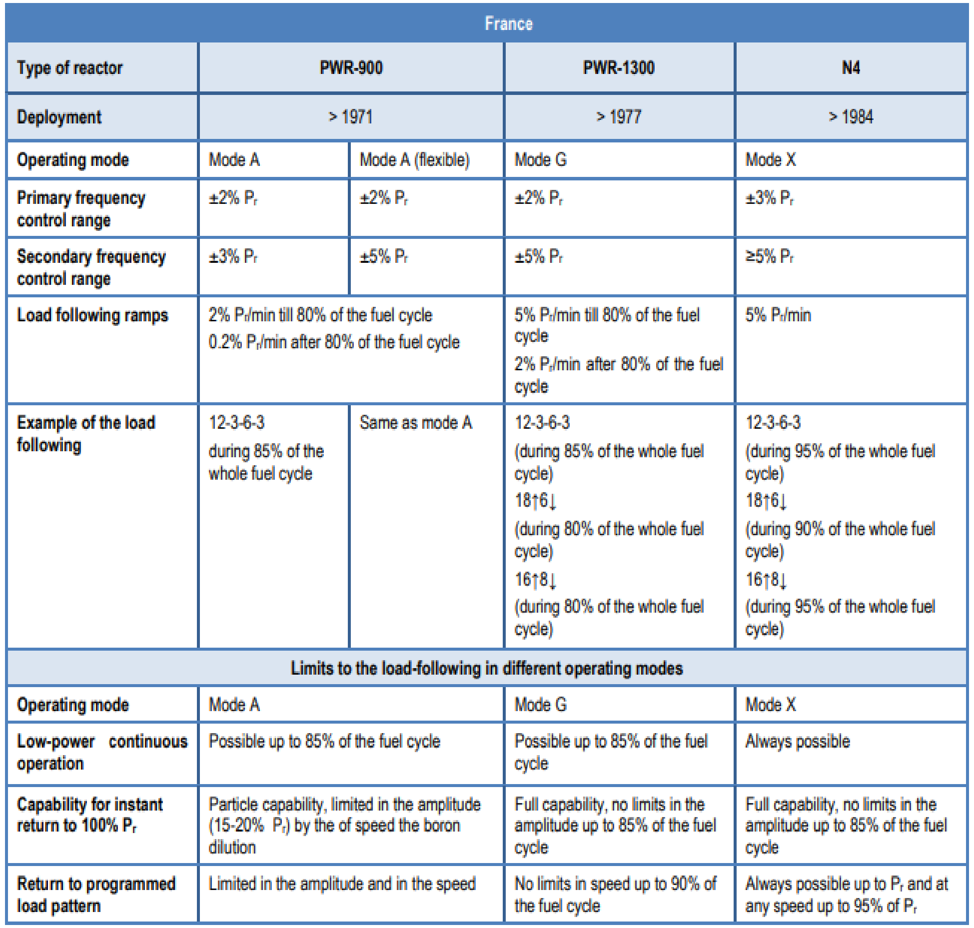
KONVOI PWR



Type of reactor	VVER-1000
Deployment	1980-ies (first series)
Interval of power variation (%P_r)	30-100 during the first 2/3^{rds} of the fuel cycle 70-100 during the last 1/3rd of the fuel cycle
Ramps (%P_r per minute)	3-4 %P_r/min (10-70% of the fuel cycle) 1-1.5%P_r/min (70-100% of the fuel cycle)
Number of changes of the rated state	
- Reactor shutdown with aftercooling	130 times over the lifetime
- Full power reductions with the speed of up to 2% P_r /min	5 000 times over the lifetime
- Start-ups from the "hot" state	5 000 times over the lifetime
- Start-ups from the "cold" state	130 times over the lifetime
- Step changes in the limits of ±20% of the power level	150 times over the lifetime

Source: Aminov, *et al.*, 1990.

VVER-1000



France				
Type of reactor	PWR-900		PWR-1300	N4
Deployment	> 1971		> 1977	> 1984
Operating mode	Mode A	Mode A (flexible)	Mode G	Mode X
Primary frequency control range	±2% P_r	±2% P_r	±2% P_r	±3% P_r
Secondary frequency control range	±3% P_r	±5% P_r	±5% P_r	≥5% P_r
Load following ramps	2% P_r/min till 80% of the fuel cycle 0.2% P_r/min after 80% of the fuel cycle		5% P_r/min till 80% of the fuel cycle 2% P_r/min after 80% of the fuel cycle	5% P_r/min
Example of the load following	12-3-6-3 during 85% of the whole fuel cycle	Same as mode A	12-3-6-3 (during 85% of the whole fuel cycle) 18↑6↓ (during 80% of the whole fuel cycle) 16↑8↓ (during 80% of the whole fuel cycle)	12-3-6-3 (during 95% of the whole fuel cycle) 18↑6↓ (during 90% of the whole fuel cycle) 16↑8↓ (during 95% of the whole fuel cycle)
Limits to the load-following in different operating modes				
Operating mode	Mode A		Mode G	Mode X
Low-power continuous operation	Possible up to 85% of the fuel cycle		Possible up to 85% of the fuel cycle	Always possible
Capability for instant return to 100% P_r	Particle capability, limited in the amplitude (15-20% P_r) by the of speed the boron dilution		Full capability, no limits in the amplitude up to 85% of the fuel cycle	Full capability, no limits in the amplitude up to 85% of the fuel cycle
Return to programmed load pattern	Limited in the amplitude and in the speed		No limits in speed up to 90% of the fuel cycle	Always possible up to P_r and at any speed up to 95% of P_r

NPPs in France

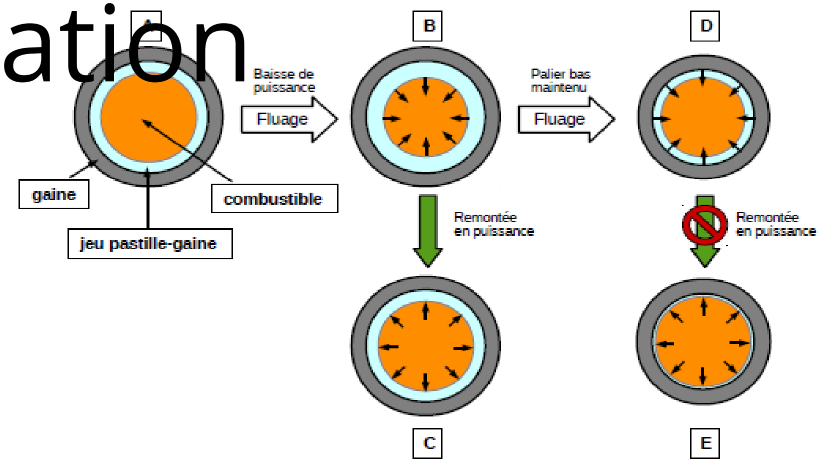
Technical impacts in NPP components when flexible operation

- The main risk of load cycling is the failure of the fuel cladding

and there are two factors to take care of:

  - The fuel cycle
  - The rate of power variation

- Nevertheless, the risk is limited as the NPP are designed for that



Mathieu Muniglia. Optimisation du pilotage d'un Réacteur à Eau Pressurisée dans le cadre de la transition énergétique à l'aide d'algorithmes évolutionnaires. Physique Nucléaire Théorique [nucl-th]. Université Paris Saclay (COmUE), 2017. Français. NNT: 2017SACLS261. tel-01678043

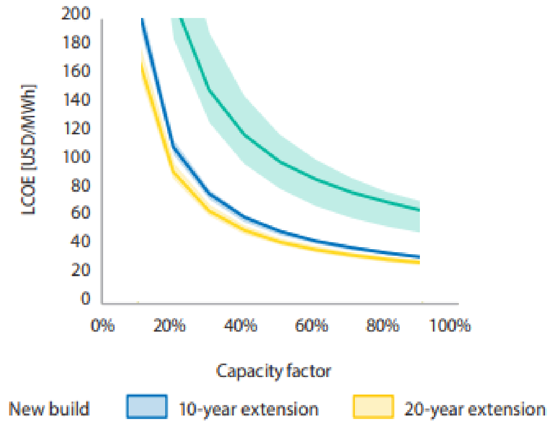
- No or very small impact (within the design margins) of the load-following on acceleration on the ageing of large equipment components
- Some influence of the load-following on the ageing of some operational components (e.g. valves) → small increase of maintenance costs
- Also, for older plants some additional investment could be needed, especially in instrumentation and control, to become eligible for operation in the load-following mode.

Economic impacts in NPP components when flexible operation

- Small increase of operation costs: In JRC report, EdF estimated in a confidential study an effect on O&M costs of 1,8% which corresponds to about 150 hours of loss of availability.
- Compensation from the ancillary services: The O&M costs due to flexible operation are not expected to play a significant role because the ancillary services markets prices compensate them.
- RE penetration erodes the capacity factors of baseload power generating plants, including nuclear plants

Year	Average capacity factor	Installed capacity
2030	84%	512 GW
2040	76%	730 GW
2050	77%	812 GW

NZE forecasts



IEA, NEA, “Projected Costs of Generating Electricity,” 2020

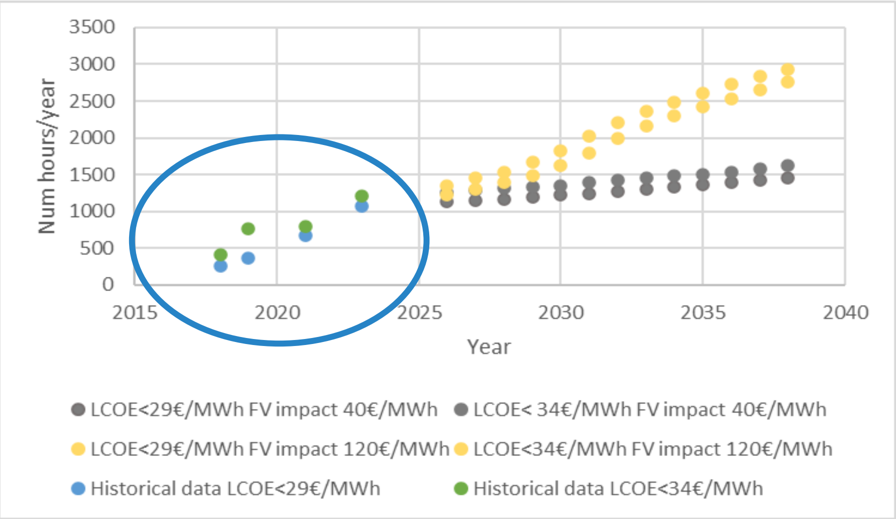
Economic impacts in NPP components when flexible operation

- Impact on day-ahead market prices: the number of hours where the LCOE is higher than day-ahead market price is increasing
- Example of forecasts for Spain:

Two values for LCOE:

- LCOE = 29 €/MWh
- LCOE = 34 €/MWh

From Lazard



Scenario of forecast of PV penetration through years

	2020	2030
PV	11 MW	76 MW

Two scenarios of day-ahead market price reduction:

- -40 €/MWhe (conservative)
- -120 €/MWhe

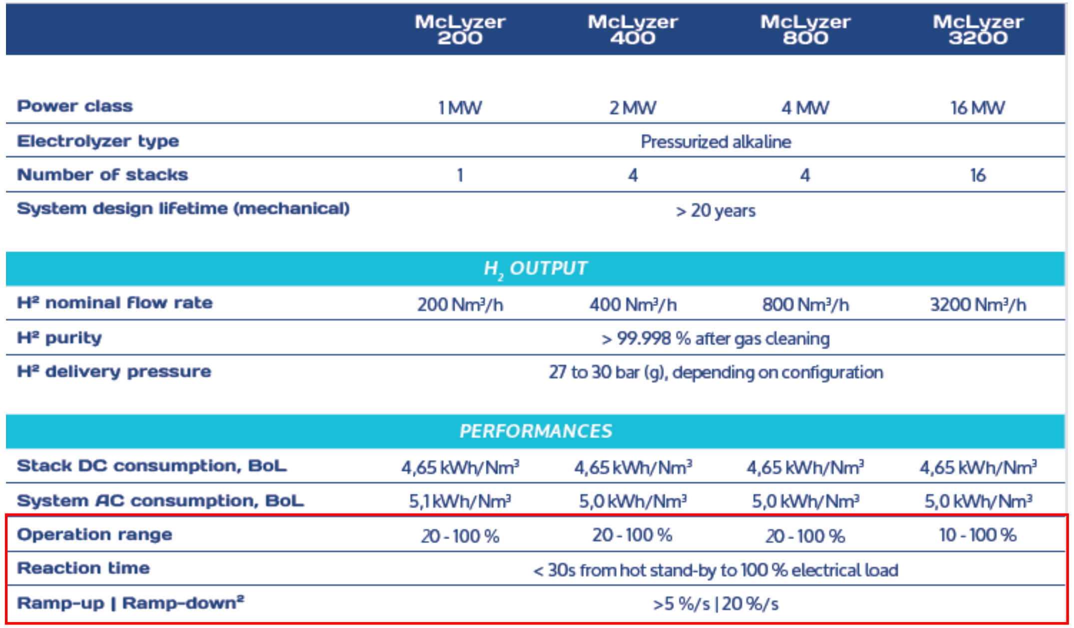
During the hours of maximum irradiance

→ Coupling a HPP to a NPP could be beneficial: load factor of NPP close to 100%, LCOE not impacted

{NPP + HPP} Flexibility capabilities

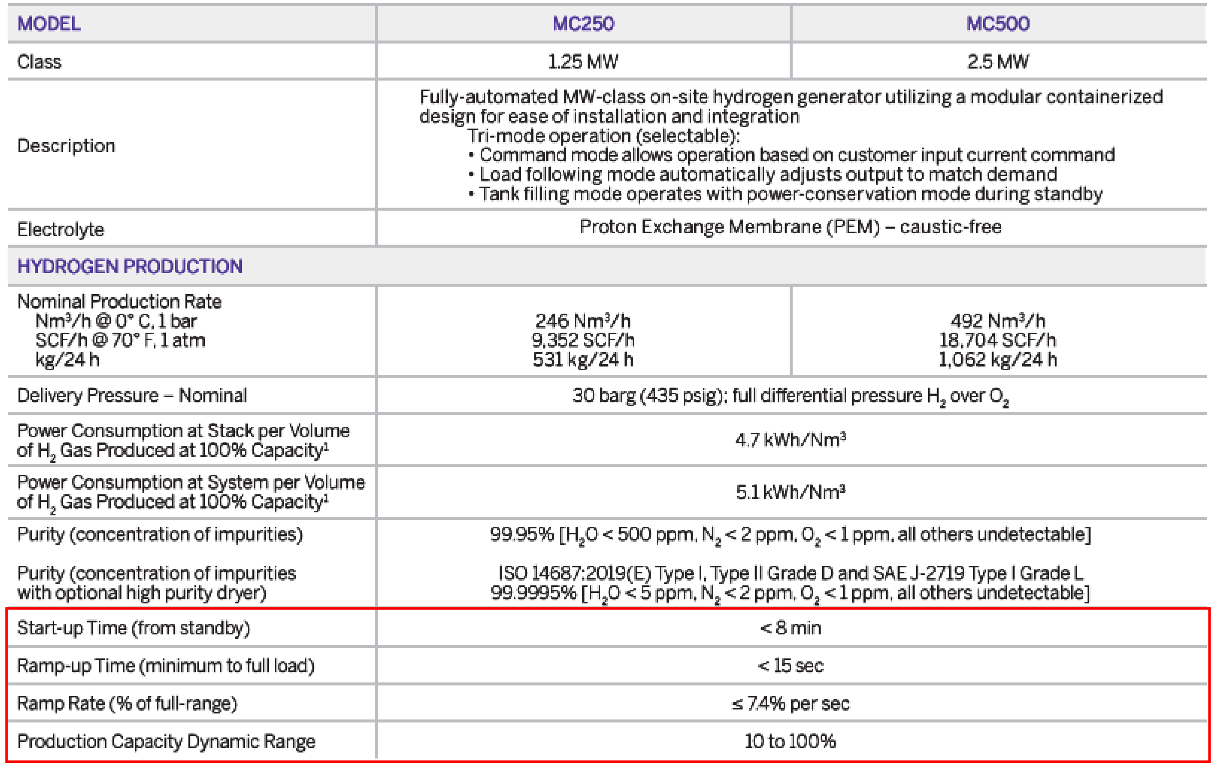
Based on:

- literature
- technical datasheets of ELZ



	McLyzer 200	McLyzer 400	McLyzer 800	McLyzer 3200
Power class	1 MW	2 MW	4 MW	16 MW
Electrolyzer type	Pressurized alkaline			
Number of stacks	1	4	4	16
System design lifetime (mechanical)	> 20 years			
H_2 OUTPUT				
H^2 nominal flow rate	200 Nm³/h	400 Nm³/h	800 Nm³/h	3200 Nm³/h
H^2 purity	> 99.998 % after gas cleaning			
H^2 delivery pressure	27 to 30 bar (g), depending on configuration			
PERFORMANCES				
Stack DC consumption, BoL	4,65 kWh/Nm³	4,65 kWh/Nm³	4,65 kWh/Nm³	4,65 kWh/Nm³
System AC consumption, BoL	5,1 kWh/Nm³	5,0 kWh/Nm³	5,0 kWh/Nm³	5,0 kWh/Nm³
Operation range	20 - 100 %	20 - 100 %	20 - 100 %	10 - 100 %
Reaction time	< 30s from hot stand-by to 100 % electrical load			
Ramp-up | Ramp-down[2]	>5 %/s | 20 %/s			

Example of AEL ELZ (MCPhy)



MODEL	**MC250**	**MC500**
Class	1.25 MW	2.5 MW
Description	Fully-automated MW-class on-site hydrogen generator utilizing a modular containerized design for ease of installation and integration Tri-mode operation (selectable): • Command mode allows operation based on customer input current command • Load following mode automatically adjusts output to match demand • Tank filling mode operates with power-conservation mode during standby	
Electrolyte	Proton Exchange Membrane (PEM) – caustic-free	
HYDROGEN PRODUCTION		
Nominal Production Rate Nm³/h @ 0° C, 1 bar SCF/h @ 70° F, 1 atm kg/24 h	 246 Nm³/h 9,352 SCF/h 531 kg/24 h	 492 Nm³/h 18,704 SCF/h 1,062 kg/24 h
Delivery Pressure – Nominal	30 barg (435 psig); full differential pressure H_2 over O_2	
Power Consumption at Stack per Volume of H_2 Gas Produced at 100% Capacity[1]	4.7 kWh/Nm³	
Power Consumption at System per Volume of H_2 Gas Produced at 100% Capacity[1]	5.1 kWh/Nm³	
Purity (concentration of impurities)	99.95% [H_2O < 500 ppm, N_2 < 2 ppm, O_2 < 1 ppm, all others undetectable]	
Purity (concentration of impurities with optional high purity dryer)	ISO 14687:2019(E) Type I, Type II Grade D and SAE J-2719 Type I Grade L 99.9995% [H_2O < 5 ppm, N_2 < 2 ppm, O_2 < 1 ppm, all others undetectable]	
Start-up Time (from standby)	< 8 min	
Ramp-up Time (minimum to full load)	< 15 sec	
Ramp Rate (% of full-range)	≤ 7.4% per sec	
Production Capacity Dynamic Range	10 to 100%	

Example of PEM ELZ (NEL)

{NPP + HPP} Flexibility capabilities

The flexibility of any electrolyser facility can be characterized by 3 main parameters:

- Load range (% nominal power)
- Load gradient (% nominal power/time)
- Start-up times from warm/cold condition (ti

→ So far, **PEM** is still better than AEL regarding flexibility
→ SOEC is a less flexible technology so far
→ Combine technologies allows to benefit from the advantage of each technology

Parameter	Unit	AEL	PEM	SOEC
η_{LHV}	(%)	63-71	60-68	96
Load flexibility	(%)	20-100	0-125	-100-100
Warm start-up	(-)	1-5 min	<10 s	15 min
Cold start-up	(min)	5-15	<10-15	>60
Heat-up ramp	(K/min)	0.4-1.5	0.3-1	0.5-1
Ramp-up	(%Pn/s)	10	10	0.1-0.3
Ramp-down	(%/s)	10-20	10-20	3
Current density	$(\mathrm{mA/cm^2})$	200-500	800-2500	260-1000
Voltage degradation	$(\mu\mathrm{V/h})$	<2	<14	<10
Efficiency degradation	(%/a)	0.25-1.5	0.5-2.5	3-50

{NPP + HPP} Flexibility capabilities

	440MW
Primary frequency control range (FCR)	±8,8MW (mandatory) within 30 sec. Variation rate: 17,6 MW/min
Secondary frequency control range (aFRR)	Optional: ±44MW above the minimum load (plants tend to reach ±13,2MW to ±22MW) Variation rate: 4,4MW/min (not higher than 22MW/min)
Load following ramps	EUR: 13,2MW/ min (N4 reactor: 22MW/min)

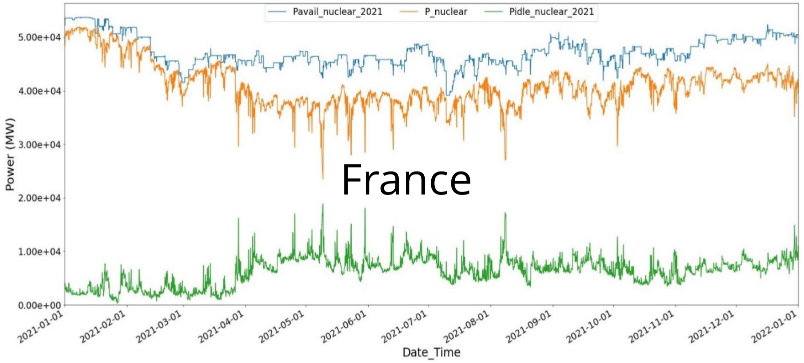
	LTE	SOEC
Primary frequency control	• **The size must be compliant with the range variation (2%Pr)** e.g. 8,8MW for a NPP of 440MW • **Warm start-up time** takes few seconds for PEM, less than 5min for AEL • **QualyGridS** project: LTE **can participate** in FCR **if they are designed to**	Less information Warm start-up time = 15min Ramp up and down are lower than LTE < 0.3 %Pn/s and 3 %Pn/s
Secondary frequency control	QualyGridS project: examples of PEM qualified for providing aFRR	
Load following	Requirements are similar to FCR and aFRR but on longer times, experimental tests and analysis are needed to conclude whether ELZ can do it	

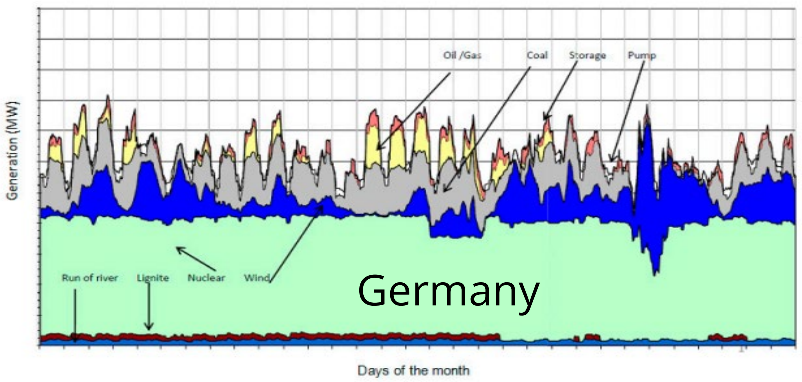
Impacts on LTE and HTSE

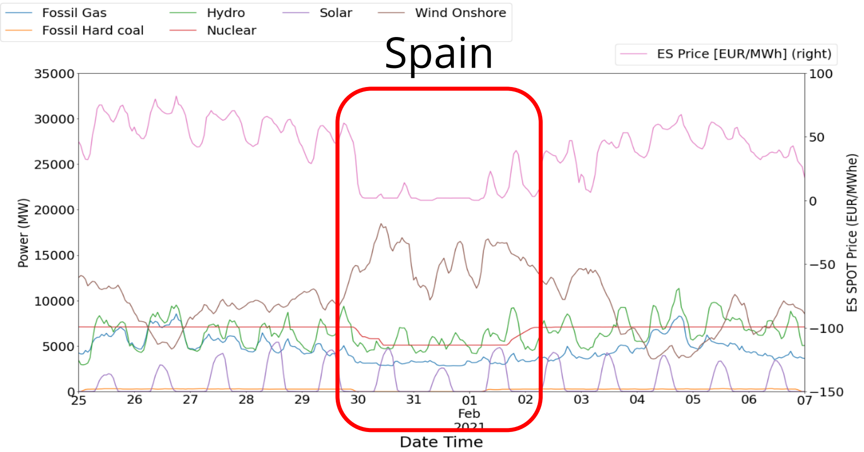
- For LTE,
  - Partial load operation may lead to dangerous levels of hydrogen in the oxygen stream (gas cross-over through the membrane or diaphragm)
  - Operation under high current densities and loads above nominal conditions leads to a higher degradation and so a reduction of the stack lifetime
  - An excessive number of start-up/shutdown cycles has proven to be more detrimental for the stack lifetime and efficiency than dynamic operation
  - No clear evidence of degradation with a variable operation
- For HTSE,
  - Lack of relevant operational data from large-scale SOEC units but there are some studies at single-cell level but it is not clear that thermal cycling due to flexible operation has a negative impact on degradation

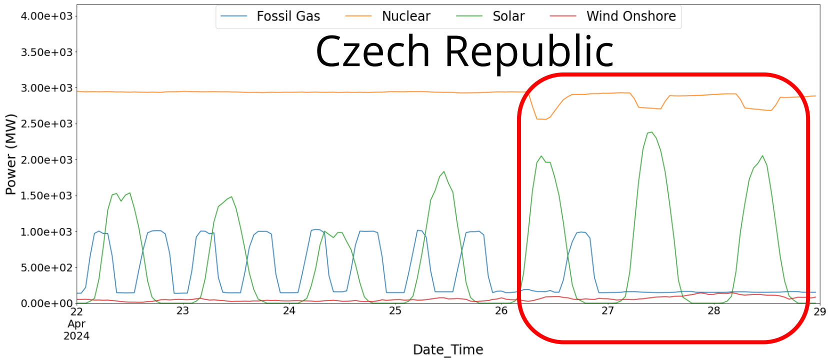
Current use of load follow operation in European NPP

- The majority of the EU countries does not use load following, resulting in limited idle capacity potential

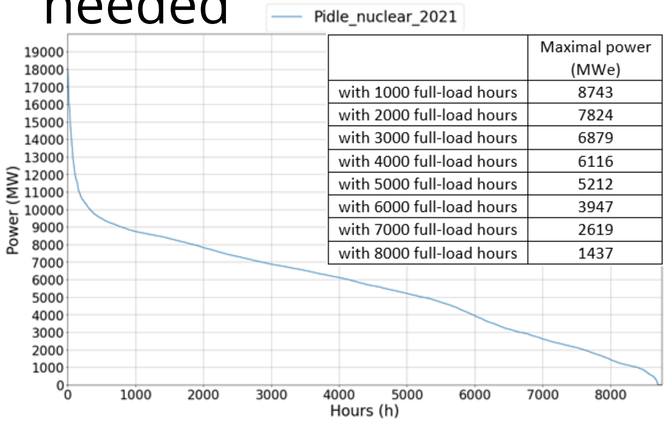








- There is an ongoing trend
- To conclude whether it is interesting to connect a HPP directly to a NPP, a study on a specific site is needed



	Maximal power (MWe)
with 1000 full-load hours	8743
with 2000 full-load hours	7824
with 3000 full-load hours	6879
with 4000 full-load hours	6116
with 5000 full-load hours	5212
with 6000 full-load hours	3947
with 7000 full-load hours	2619
with 8000 full-load hours	1437

German case

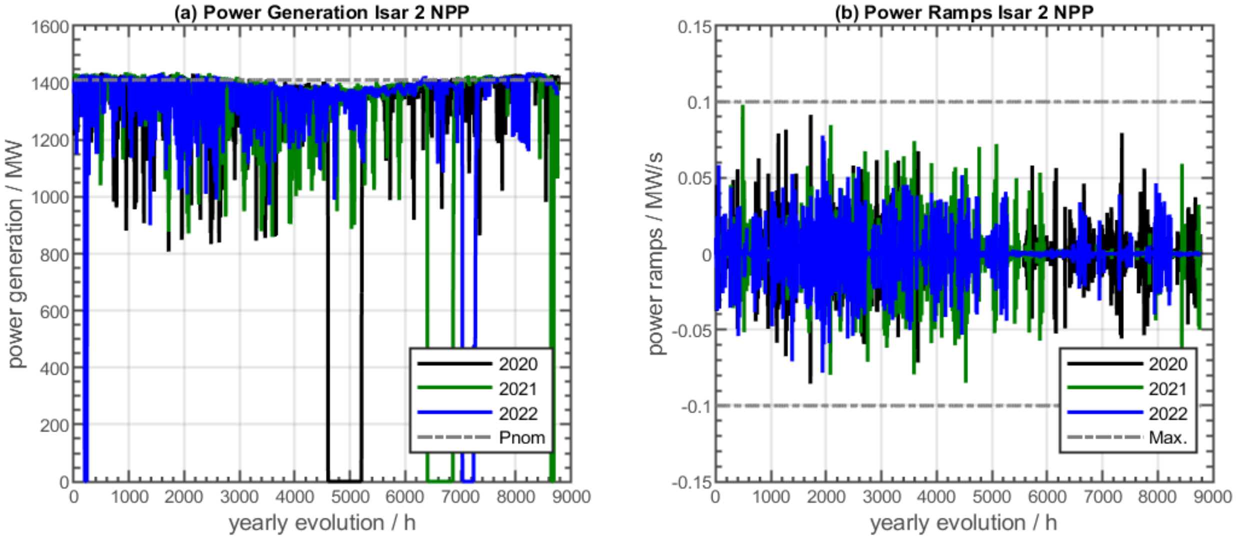
- NPP Isar 2:
  - ISAR 1 (BWR)
  - ISAR 2 (PWR)

1410 MWe

- Study the feasibility of connecting a HPP of 45 MW:
  - Technical (ramps)
  - Economic (nb of operating hours)

	Capacity (MW)	P_{FCR} (MW)	Power ramps (Pr/min)	Power ramps (MW/s)
Isar2 NPP	1410	28,2	5	1,175

Electrolyser Model	**Type**	**Capacity**	**Turndown ratio**	**Start-up time**	**Reaction rate**	**Ramp-up/ Ramp-down**	**Ramp-up/ Ramp-down**
		(MW)	(%)	(min)	(s)	(%Pn/s)	(MW/s)
Silyzer-300	PEM	17,5	> 5	< 1	?	10	1,75
NEL-4000	PEM	20,0	10 - 100	< 5	< 14	10	2,0
Verde-3000	AEL	15,0	20 - 100	5 - 10	?	10	1,5
McLyzer-3200	AEL	16,0	10 - 100	?	< 30	5	0,8



→ a power ramp amplitude of 12 MW/min (below 1%Pr)

Year	P > 15 MW	P > 30 MW	P > 45 MW
2020	5065 h	4056 h	3192 h
2021	3635 h	2546 h	1533 h
2022	5028 h	3761 h	2453 h

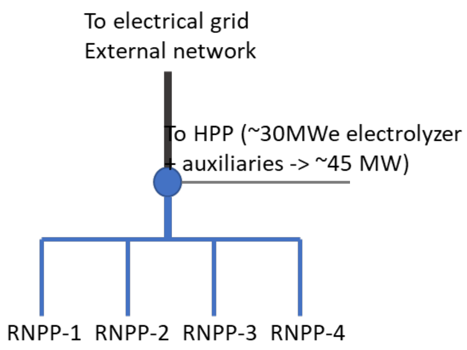
→ AEL/PEM are suitable, PEM would be preferred

→ With a 45 MW HPP, the load factor would be 27,3 %, if the BOP was shared, it can jump to 39,4%

→ Need specific operation strategies

Rivne & Khmelnytskyi cases

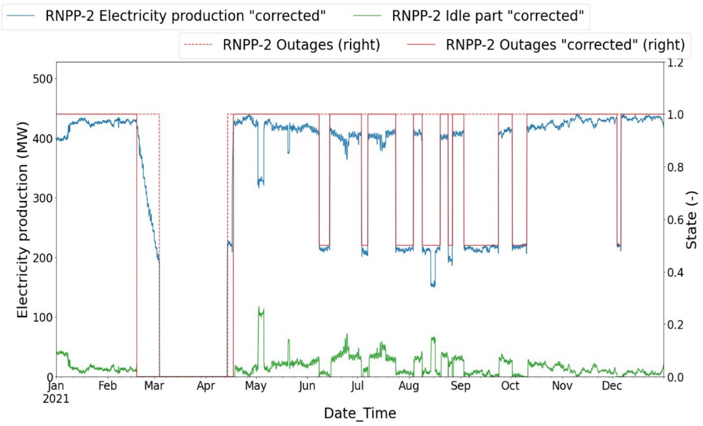
- **Rivne**

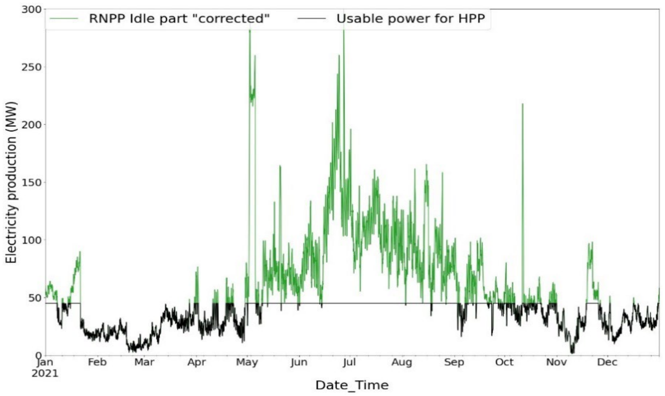


To electrical grid
External network

To HPP (~30MWe electrolyzer + auxiliaries -> ~45 MW)

RNPP-1 RNPP-2 RNPP-3 RNPP-4





Min Power (MW) / (%Pn)	4,5 / 10
Max Power (MW) / (%Pn)	45 / 100
Mean Power (MW) / (%Pn)	35,76 / 79,5
Number of hours in [10%,100%] of Pn	8716
Number of hours at 100%Pn	4358
Maximal ramp down (%Pn/min)	-0,89
Maximal ramp up (%Pn/min)	1,03

NPP	P available > 15 MWe	P available > 30 MWe	P available > 45 MWe
Rivne	8173 hours	6043 hours	4358 hours

→ Ramps are suitable for an ELZ and number of operating hours is interesting

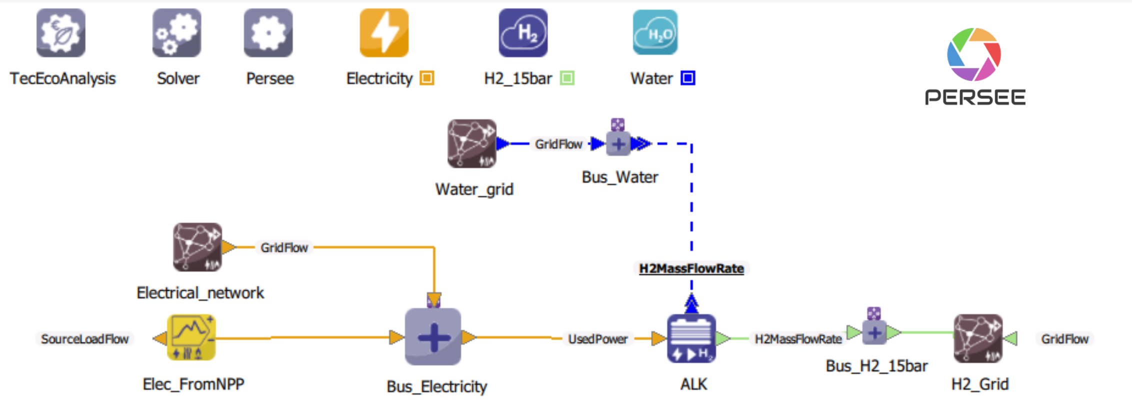
- **Khmelnytsky**

NPP	Pavailable > 15MWe	Pavailable > 30MWe	Pavailable > 45MWe
KhNPP	6590 hours	2929 hours	823 hours

→ Nb of operating hours is not enough

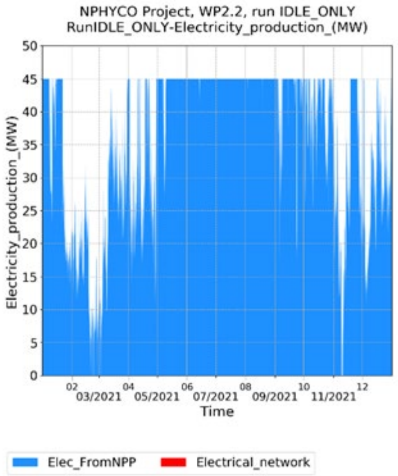
Rivne case

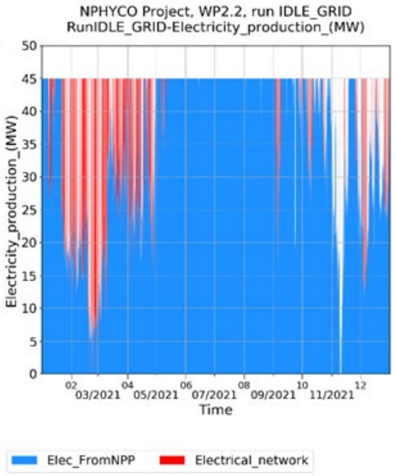
- Several operation strategies

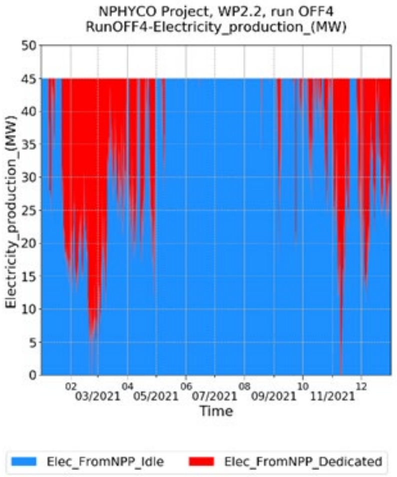


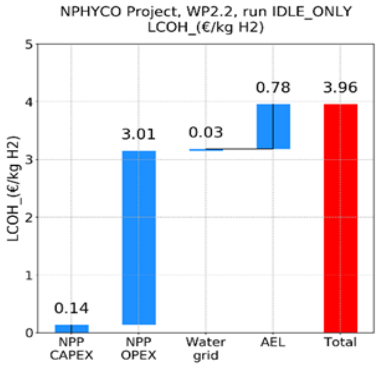
Case	"Idle" only	OFF4
CO_2 intensity (kg CO_2 eq/kg H2)	0,81	0,8
Running time availability (%)	96,5	
Rate of use (%)	76,5	96,5
Number of operating hours (h)	8452	8496
Number of full-load operating hours (h)	4099	8496
H2 production over 16 years (ktons H2)	74,2	94,06

Technical KPIs









OFF4 scenario

Defined in WP3

NPP sells electricity to HPP at a reduced cost (40,12 €/MWhe)

$$\Delta TC = loss\ for\ the\ NPP$$

$$(depends\ on\ day\text{-}ahead\ market\ price)$$

Case	"Idle" only	"Idle" + Grid	OFF4	OFF4 w/o"Idle"
LCOH (€/kg H2)	3,96	4,00	4,05	4,98

Economic KPI

→ Using the idle capacity is always profitable, the additional connection to the grid is not, in this case

Conclusion

- The majority of the NPP are able to perform load following but nowadays, the majority operates in baseload mode but there is a trend to flexible operation due to RE penetration
- Overall, a combined use of NPP with a HPP in load follow mode is technically feasible, the couple is able to answer at least the same constraints as the NPP alone, and it can bring advantages with regard to increased power production of RE
- Operation strategies need to be refined to study the profitability of such a coupling and more detailed studies were conducted in WP3

Thank you!

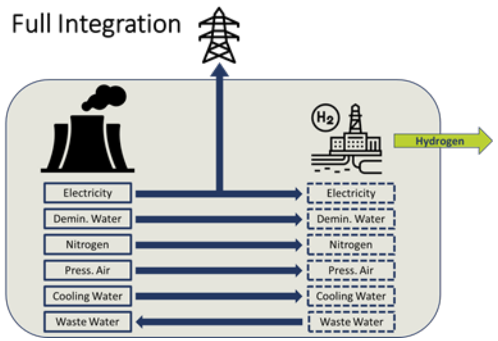
www.nphyco.org

NPHyCo
Nuclear Powered Hydrogen Cogeneration

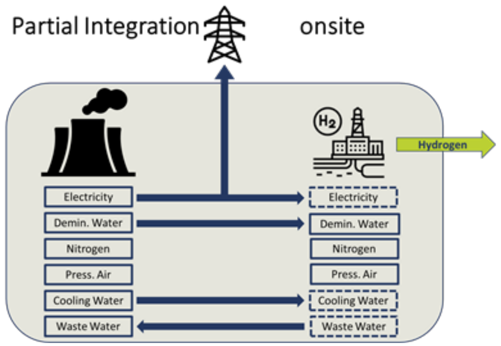
BackUp

Possibilities of Integration

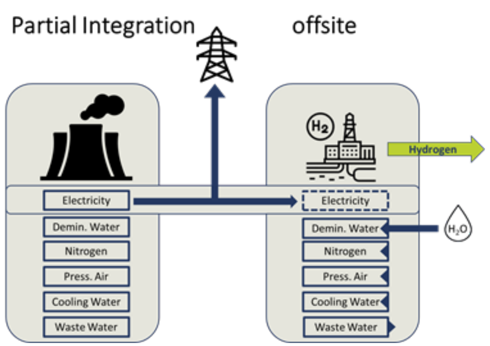
With respect to the needs of hydrogen production via electrolysis of water (AEL, PEM, SOEC) coupling to a NPP may be performed at different levels of Integration



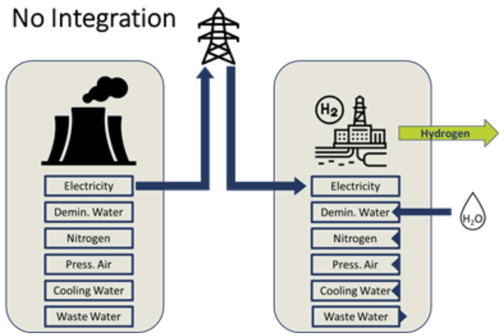
All Inputs to HPP
provided by facilities of NPP



Some Inputs to HPP
provided by facilities of NPP
e.g. electricity, water or cooling
Other Input is produced within the HPP
HPP located onsite of NPP



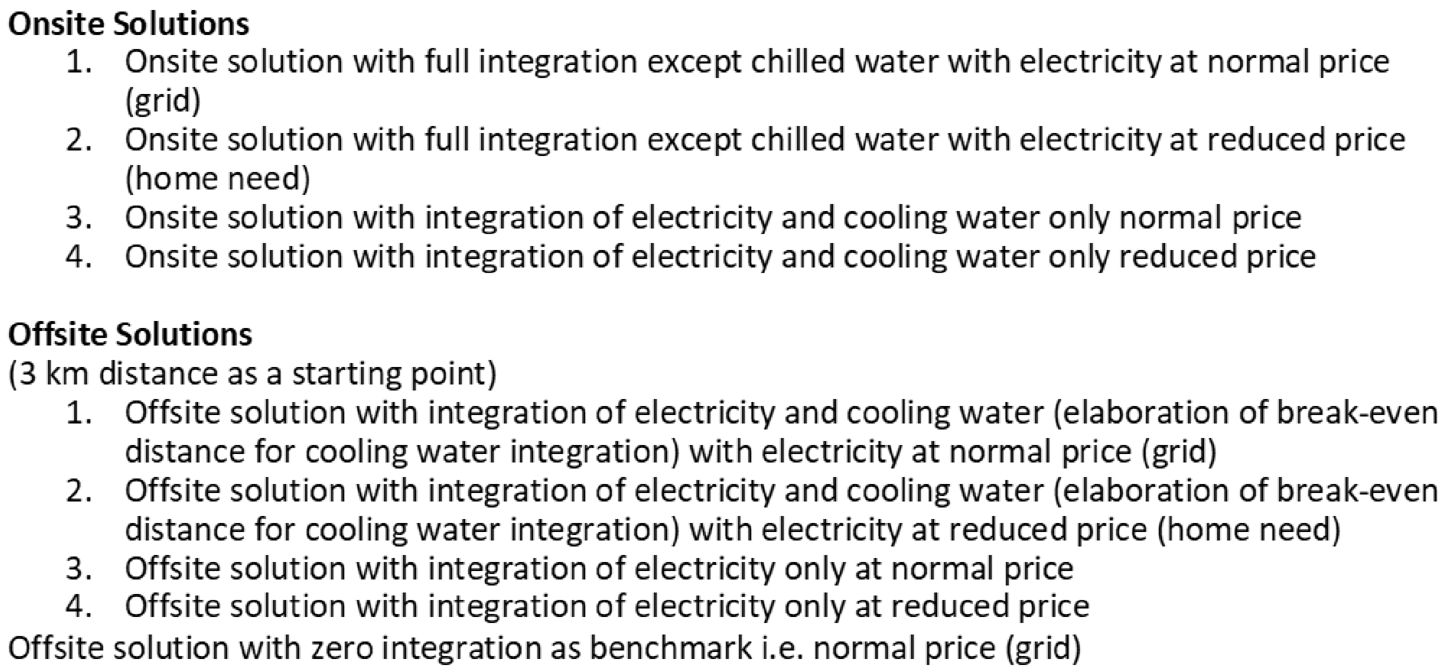
Some Inputs to HPP
provided by facilities of NPP
e.g. direct line for supply of electricity
Other Input is produced within the HPP
HPP located offsite of NPP



No Inputs to HPP are provided by facilities of NPP
HPP within the same location and framework as NPP to be used as a benchmark for uncoupled H2 production

Preset of Integration Scenarios

The following 7 pre-sets of Integration Scenarios have been investigated in NPHyCo for sites where sufficient information was available



Onsite Solutions

1. Onsite solution with full integration except chilled water with electricity at normal price (grid)
2. Onsite solution with full integration except chilled water with electricity at reduced price (home need)
3. Onsite solution with integration of electricity and cooling water only normal price
4. Onsite solution with integration of electricity and cooling water only reduced price

Offsite Solutions

(3 km distance as a starting point)

1. Offsite solution with integration of electricity and cooling water (elaboration of break-even distance for cooling water integration) with electricity at normal price (grid)
2. Offsite solution with integration of electricity and cooling water (elaboration of break-even distance for cooling water integration) with electricity at reduced price (home need)
3. Offsite solution with integration of electricity only at normal price
4. Offsite solution with integration of electricity only at reduced price

Offsite solution with zero integration as benchmark i.e. normal price (grid)

Steps to find the possible integration scenario

- Key step is to find the location on the NPP site
- Find the possible consumer and the way of transport of hydrogen to him
- Identify the resources which is possible to use from NPP
- Identify the connection points for selected resources
- Create the possible modifications of the affected systems
- Identify the safety impact of the modifications