Interlinked Model

Webinar 04 June 2024

Teams Webinar – 04.06.2024

TF Interlinked Model

Agenda

	Subject	Lead	Start Time	End Time	Duration
1.	Introduction	Dante Powell	14:05	14:35	30 mins
2.	ILM Model Insights	Jean-Marc Janin	14:35	15:10	35 mins
3.	CBA Methodology	Franck Dia Wagoum Philipp Fortenbacher	15:10	15:50	40 mins
4.	PS-CBA	Franck Dia Wagoum	15:50	16:20	30 mins
5.	Recommendations & conclusions	Dante Powell	16:20	16:30	10 mins

Rules for the Q&A Session

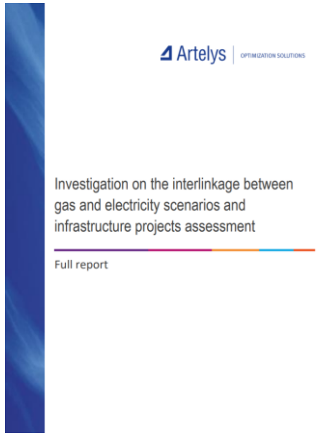
- ✓ There is a Q&A session at the end of each point of the agenda, through the Q&A
- ✓ Attendees are invited to start typing their questions in the Teams chat during the presentation including the slide #
- ✓ Give a thumbs up so we can identify the most popular comments or topics
- ✓ If some questions remain unanswered by the end of the webinar, replies will be provided via email

Introduction to the Interlinked Model

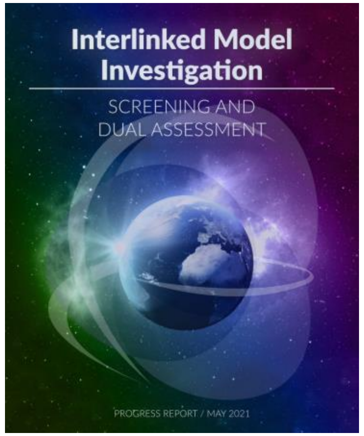
History of the interlinked Model

2016 - 2018

2018 - 2020

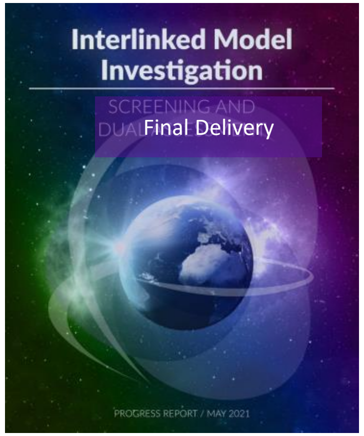


2020 – 2022



2022 - 2024

2024 - 2026



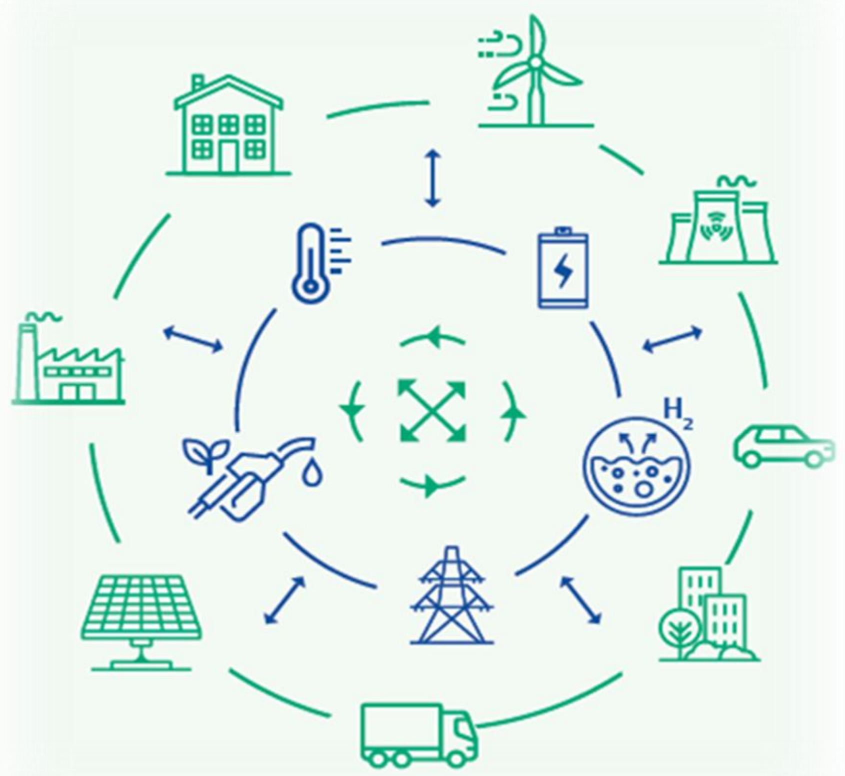
Why do we build an interlinked model?

TEN-E regulation

By 24 June 2025, […], the ENTSO-E and the ENTSOG shall jointly submit to the Commission and the ACER a consistent and progressively integrated model

Multi-sectorial planning

Offshore energy hubs



Objectives 2022/2023

Objective 2022 – 2024

- Map technical and organisational complexities identified in the ILM 2020 process
- Follow Innovation Team of WGSB in TYNDP2022 when developing the interlinked modelling
- Harmonisation of the gas and electricity grids used for dual project assessment
- Proposals for how the joint assessment of ‘hybrid projects’ should be performed

Objective 2024 – 2026

- Streamline the automation of the underlying data collection and analytical processes
- Implementation of the identified principles for harmonised assumptions in TYNDP2024
- Consider other infrastructures, inclusion of other sectors

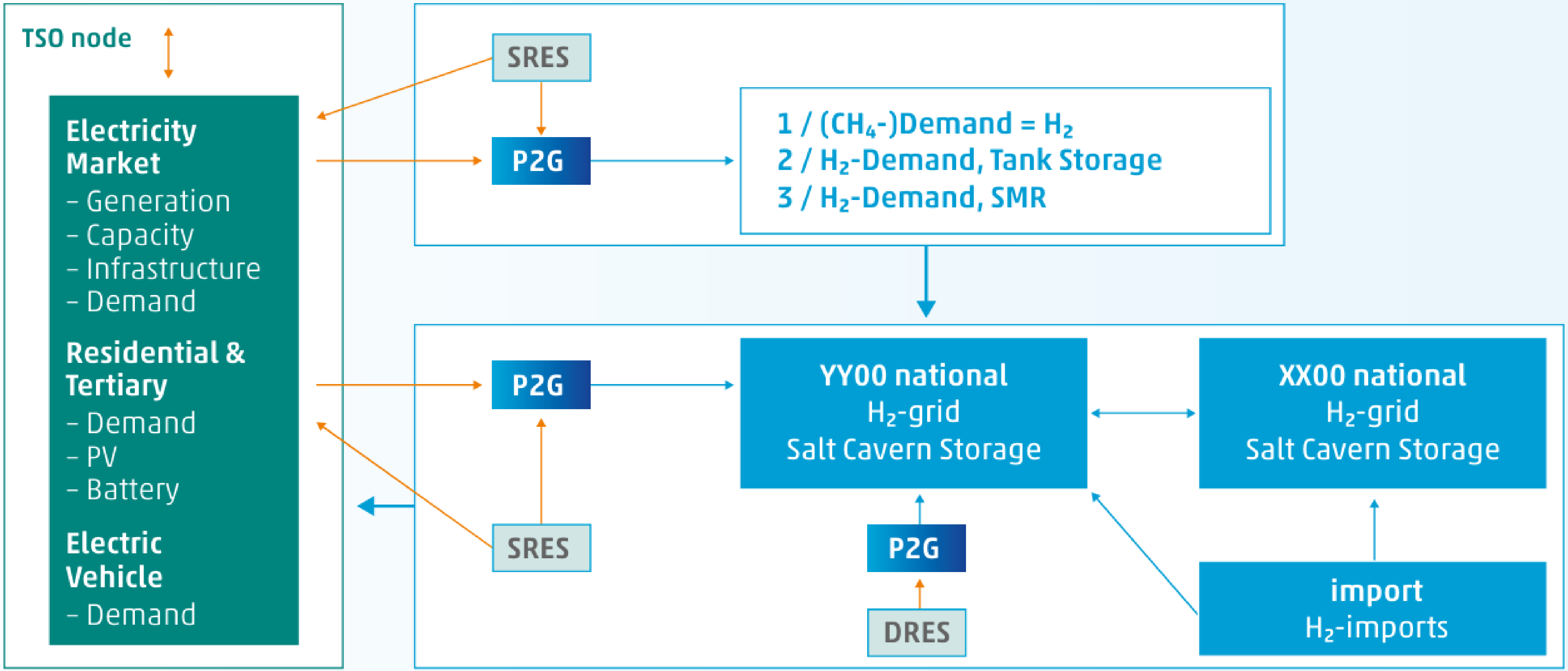
Purpose of the report

- The report is solely an update of how the development of the model is progressing.

- The model will not be used for any official processes in its current state (outdated data, need for adaptations)

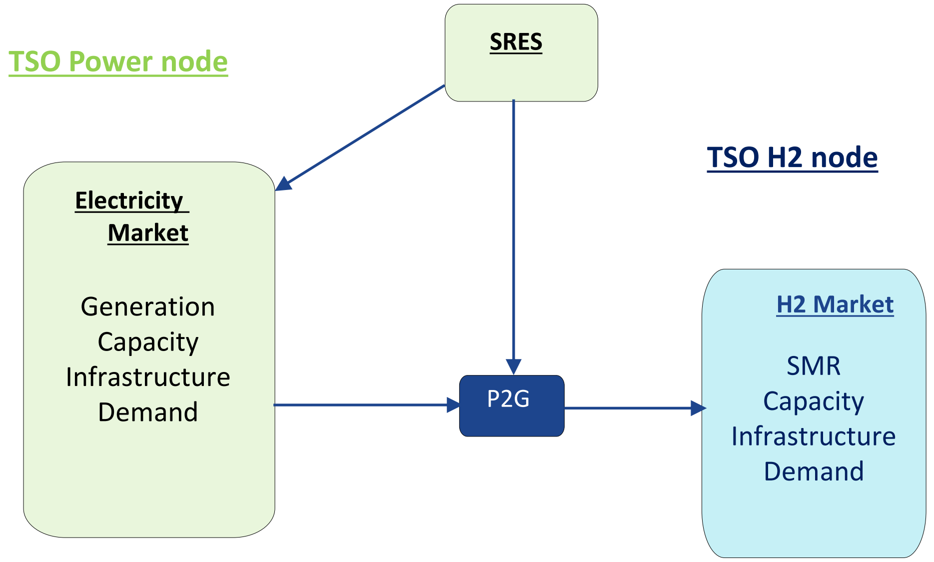
- There remains around 1.5 years to develop the final Interlinked Model for delivery to EC & ACER

ILM Modelling Approach



Interlinked Model Insights

Shared RES Management : 2 modes studied



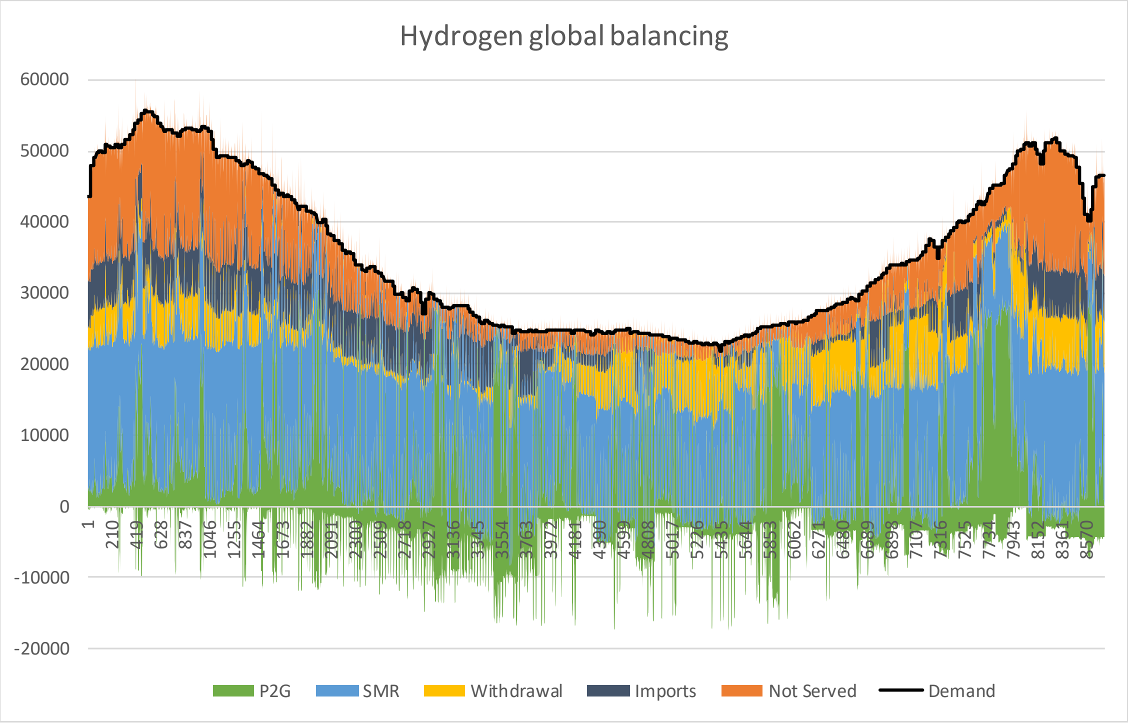
	P2G load factor	CO2 emissions	H2 not served
Mode 1	22 %	413 Mtons	55 TWh (17%)
Mode 2	45 %	473 Mtons	13 TWh (4%)

Aggregated results for DE-2030 model

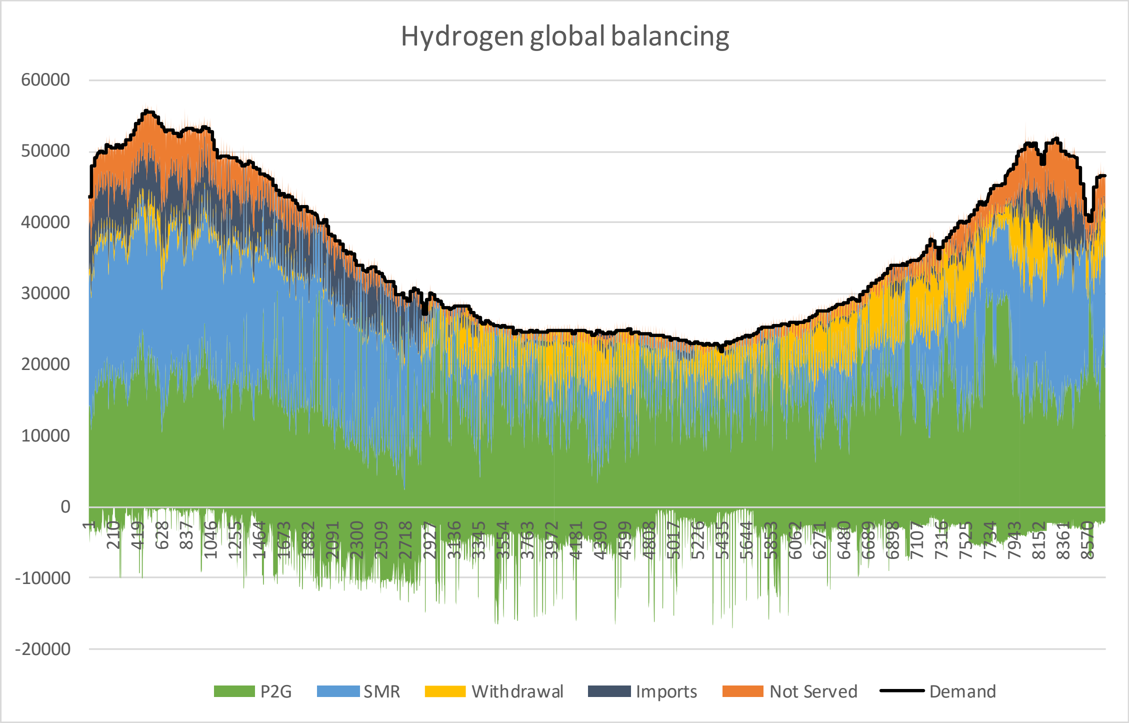
- **Mode 1 :** It consists of freely optimizing the sharing of RES between the Power Grid and P2G, on a European scale.
- **Mode 2** : It consists of favouring RES to P2G, which significantly increases the load-factor of the electrolysers and makes them profitable more quickly.
- **DE-2030** : There is a big difference in the results because many flame-fired thermal power plants are still in operation.
- **DE-2040** : There is a relative convergence of the 2 modes, with few flame-fired thermal power plants still in operation

Comparison of the 2 modes : H2 production stack for DE-2030 model

Mode 1 :



Mode 2 :



(*) Negative values correspond to volumes injected into the diffrent storages

- The low rate of 22% use of electrolyzers in **mode 1** leads to extreme volatility in P2G production.
- We note a more marked seasonality of SMR production in **mode 2**.
- In **both modes**, withdrawals from storages and imports are adjusted to ensure band production together.
- The H2 not served is almost permanent all year round, with seasonal modulation and higher intensity in **mode 1**

« Green Hydrogen » label :
« Linear » opportunities for Thermal plants to produce hydrogen

ILM-DE2030 model :	
Cheapest thermal power plant :	Gas_CCGT new
Proportional cost to generate power with this asset :	61 €/MWh
Proportional cost to generate H2 with this asset :	87 €/MWh
H2 curtail demand price selected	**80 €/MWh**

ILM-DE2040 model :	
Cheapest thermal power plant :	Gas_CCGT new
Proportional cost to generate power with this asset :	83 €/MWh
Proportional cost to generate H2 with this asset :	118 €/MWh
H2 curtail demand price selected	**115 €/MWh**

Successive steps to establish the H2 curtail demand price for models DE-2030 and DE-2040, respectively

- **Definition :** By "linear" opportunities, we consider opportunities linked to the classic "merit order" based solely on proportional generation costs in €/MWh.
- **Impact on H2 prices** : From these costs, we can deduce a profitability floor price for transforming this production into hydrogen, with a yield of this transformation of 0.7.
- **Relationship to H2 curtail demand price** : This price is a ceiling price for all H2 zones, so it should be selected below the previously set floor price to avoid any « linear » opportunities.

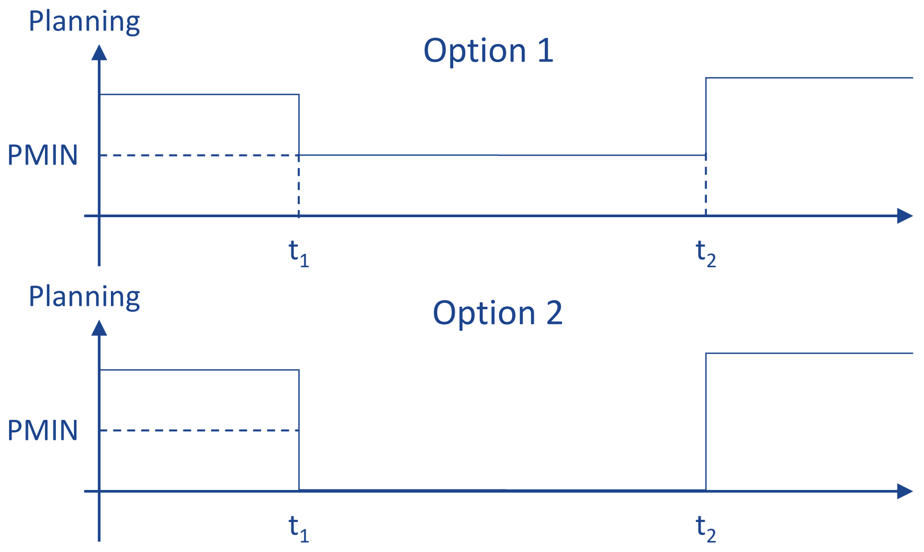
So, with such « H2 curtail demand » prices, we thwart any « linear » opportunity to generate H2 with flame-fired plants

« Green Hydrogen » label :
« Non-Linear » opportunities for Thermal plants to produce hydrogen

The modelling of thermal power plants includes 3 non-linear parameters in the adequacy model :

1. **Start-up costs (in €/start-up) :** These costs are paid when a plant is switched-on.
2. **Minimal Stable Power (PMIN in MW) :** When a plant is operating, its production must be greater than PMIN. There is therefore a range of prohibited production values:]0;PMIN[
3. **Minimal Duration (DMIN in hours) :** There must be at least DMIN hours between status “On/off” or “Off/on” state changes.

How can we counter such opportunities ?



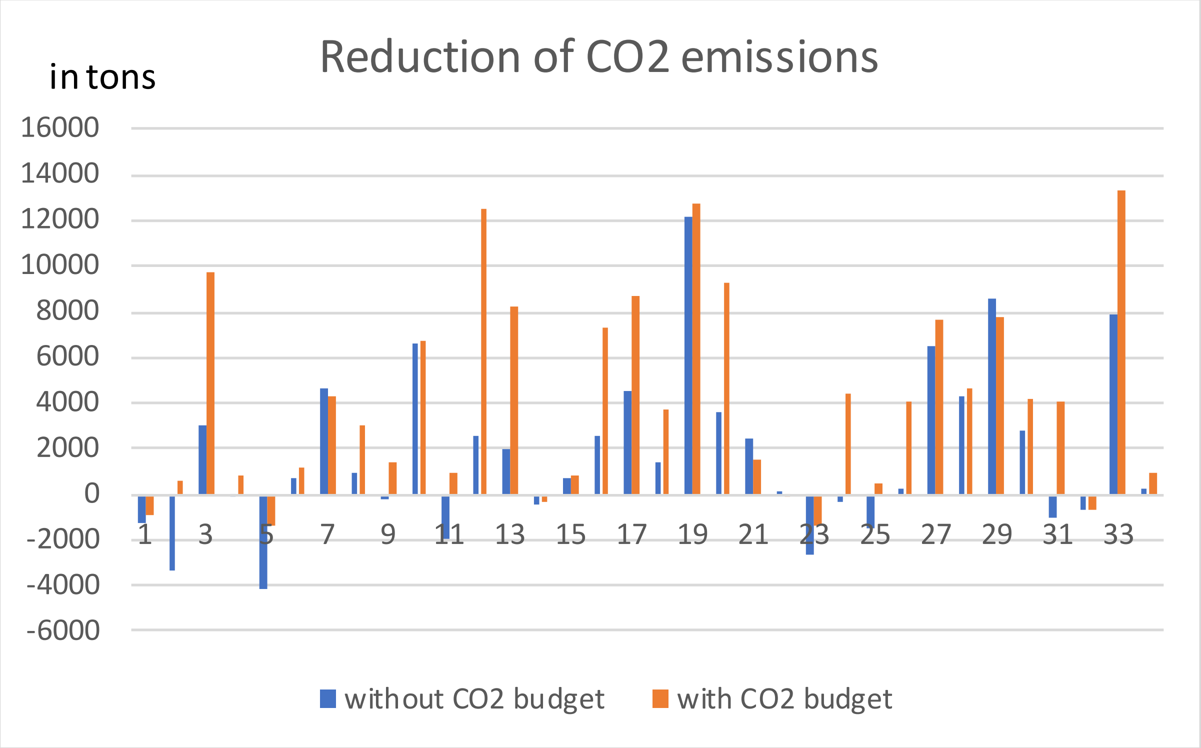
Opportunity example : 2 different options to manage the plant with similar costs

The production cost between t_1 and t_2, with Option 1, can be very similar to that of starting the plant at t_2, with Option 2

The limited incremental revenue from additional P2G generation may give Option 1 a slight advantage, but this option increases thermal plant generation and CO_2 emissions.

« Green Hydrogen » label : Introduction of a CO2 emission budget for CBA calculations using a PINT approach

- **Definition :** CBA calculations using a PINT approach are simulations for which we add P2G projects, one at a time, to assess their impacts on Power and H2 systems.
- **CO2 emission budget :** From the simulation of the reference case (without the P2G project), we can calculate an overall quantity of daily emissions on Power and H2 systems. This quantity corresponds in our daily CO2 emission budget.
- **CBA calculations with CO2 emission budget** : We carry out these simulations with an additional constraint which is not to exceed the daily budget.



Impact of the CO2 budget : reduction of CO2 emissions for each CBA assessment in the 34 « zone 1 » areas where P2G projects are located, with the DE-2030 model Globally, the C02 budget increases this reduction from 60 to 140 ktons

We can do CBA calculations that evaluate the Operational gain of various P2G projects, without including « non-linear » opportunities for flamed-fired plants to increase their generation and therefore CO2 emissions, on a global scale

Overall results for the Reference Case with the DE-2030 model

ILM-DE2030 model - Indicators on E-market :	
Operational Costs	92.7 B€
Emissions	473 Mtons
Curtailed Energy	169 TWh
Unserved Energy	0.7 TWh

ILM-DE2030 model - SRES generation split :		
E-market	387 TWh	58%
P2G	200 TWh	30%
Curtailment	82 TWh	12%

ILM-DE2030 model - Indicators on H2 market :		
Operational Costs	6.6 B€	
Production SMR	88 TWh	Load factor: 46%
Production P2G	192 TWh	Load factor: 45%
H2 curtailed demand	13 TWh	Rate : 4.1%
Imports	19 TWh	

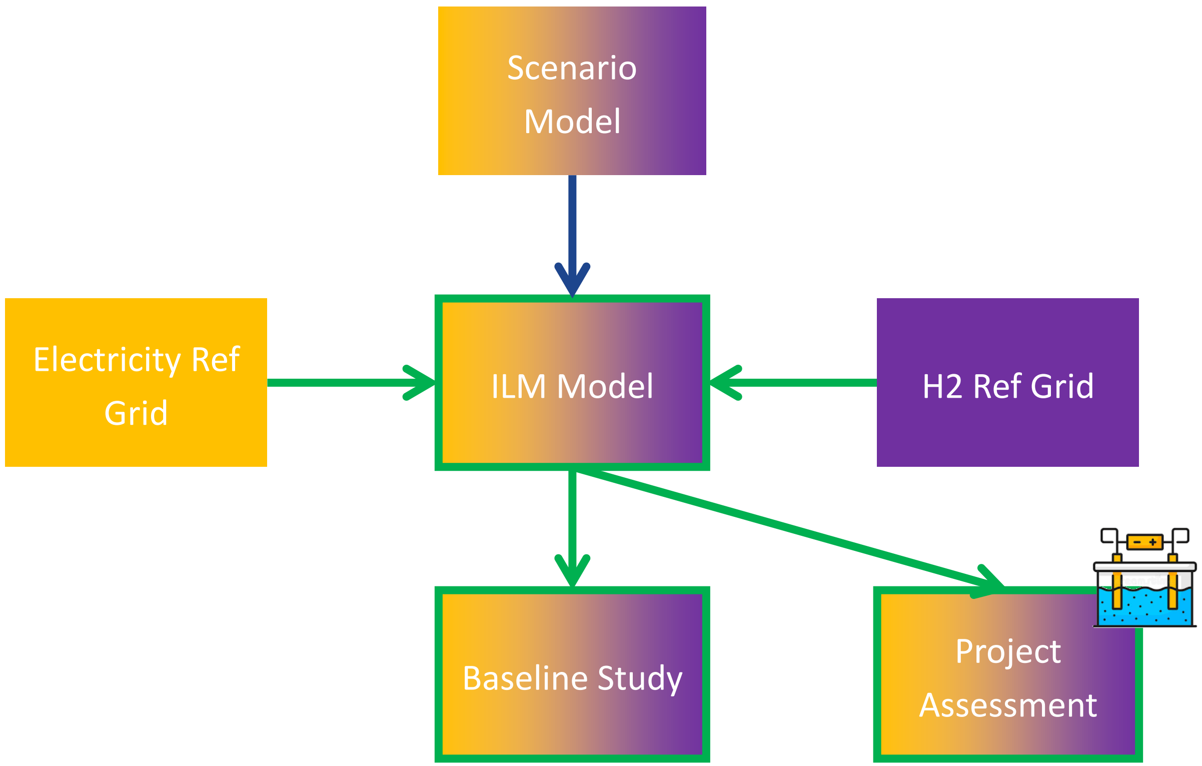
- In 2030, on the power system, we will have much more Curtailed Energy than Unserved Energy, while the development of P2G is only just beginning.
- The distribution of SRES generation is mainly towards the Power market. The SRES curtailment is limited.
- In 2030, the H2-market is still very small compared to the Power market (7%), but with this model and "mode 2", we can expect H2 generation from P2G to be twice that of Steam Methane Reforming and Imports.

These results were obtained on the “mode 2” basis for SRES management (SRES are used first for P2G)

Audience Q&A Session

Introduction to the CBA Methodology

ILM dual CBA Process Overview



TYNDP 2024 draft CBA Indicators

- The set of CBA indicators considered in ILM 2022 are inspired from the indicators used in both ENTSO-E and ENTSOG, which are also considered by JRC
- Some of these indicators are Common indicators, some others sector specific

ID ENTSOG	ID ENTSO-E	Name	Specificity
B1	B2	Societal benefit due to GHG emissions variation	Common Indicator
B2	B1	Social Economic Welfare	Common Indicator
B3	B3	Electricity RES integration	Sector-specific indicator
		Low-carbon hydrogen integration	Sector-specific indicator
		Reduction of Curtailed hydrogen demand	Sector-specific indicator

Variation of CO_2 Emissions – Common indicator

- The CO_2 emissions pattern from adding/retrieving a project is not obvious
    - Influenced by dispatch in the Electricity system and dispatch in the Hydrogen system
    - But even more influenced by the non-linear constraints of the model

- This indicators helps understanding the effect of adding a project to the overall emissions of the system and supports the Sustainability criterion from the Regulation 2022/869

- It is expressed in quantitative terms (tCO_2/year) and can be monetised (M€/year using SCC):

$$\Delta CO2\ Emissions = CO2\ Emissions_{with\ project} - CO2\ Emissions_{without\ project}$$

Electricity RES Integration – Specific indicator

- This indicators quantifies the effect of adding a project to the overall RES energy (and capacity) integrated into the system.

- This supports the Sustainability criterion from the Regulation 2022/869

- It is expressed is quantitative terms (MWh/year) and is already monetised through the SEW Indicator:

$$\Delta RES\ Energy = E_{project} - (E_{dump\ with\ project} - E_{dump\ without\ project})$$

Variation of Social Economic Welfare (SEW)

Definition

- Variation in social economic welfare from implementing a project.

Indicator Calculation

- Total Surplus (TS) Approach

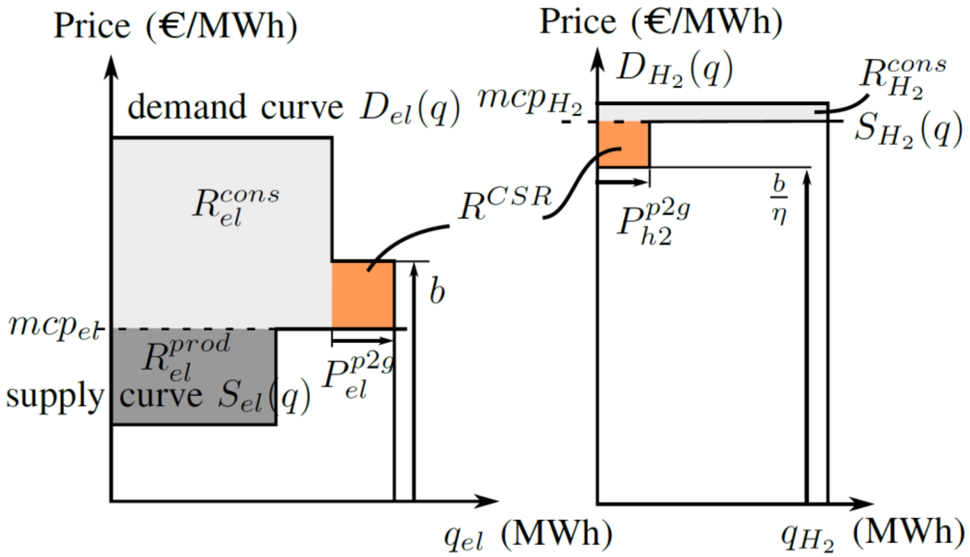
$$\Delta SEW_{\text{global}} = SEW_{\text{global}}^{withProject} - SEW_{\text{global}}^{withoutProject}$$

- Generation Cost (GC) Approach

$$\Delta SEW_{\text{global}} = GenerationCosts_{withoutProject} - GenerationCosts_{withProject}$$

SEW methodology incorporating the electricity and hydrogen sector

Illustrative example: sectorial market coupling of electricity and hydrogen with an electrolyser



- TS approach: Global SEW under sectors $S \in \{\text{electricity}, \text{hydrogen}\}$

$$SEW_{\text{global}} = \sum_{j \in S} R_{\text{cons}}^{j} + \sum_{j \in S} R_{\text{prod}}^{j} + \sum_{j \in S} R_{\text{cong}}^{j} + R_{\text{CSR}}^{\text{electricity}\leftrightarrow\text{hydrogen}},$$

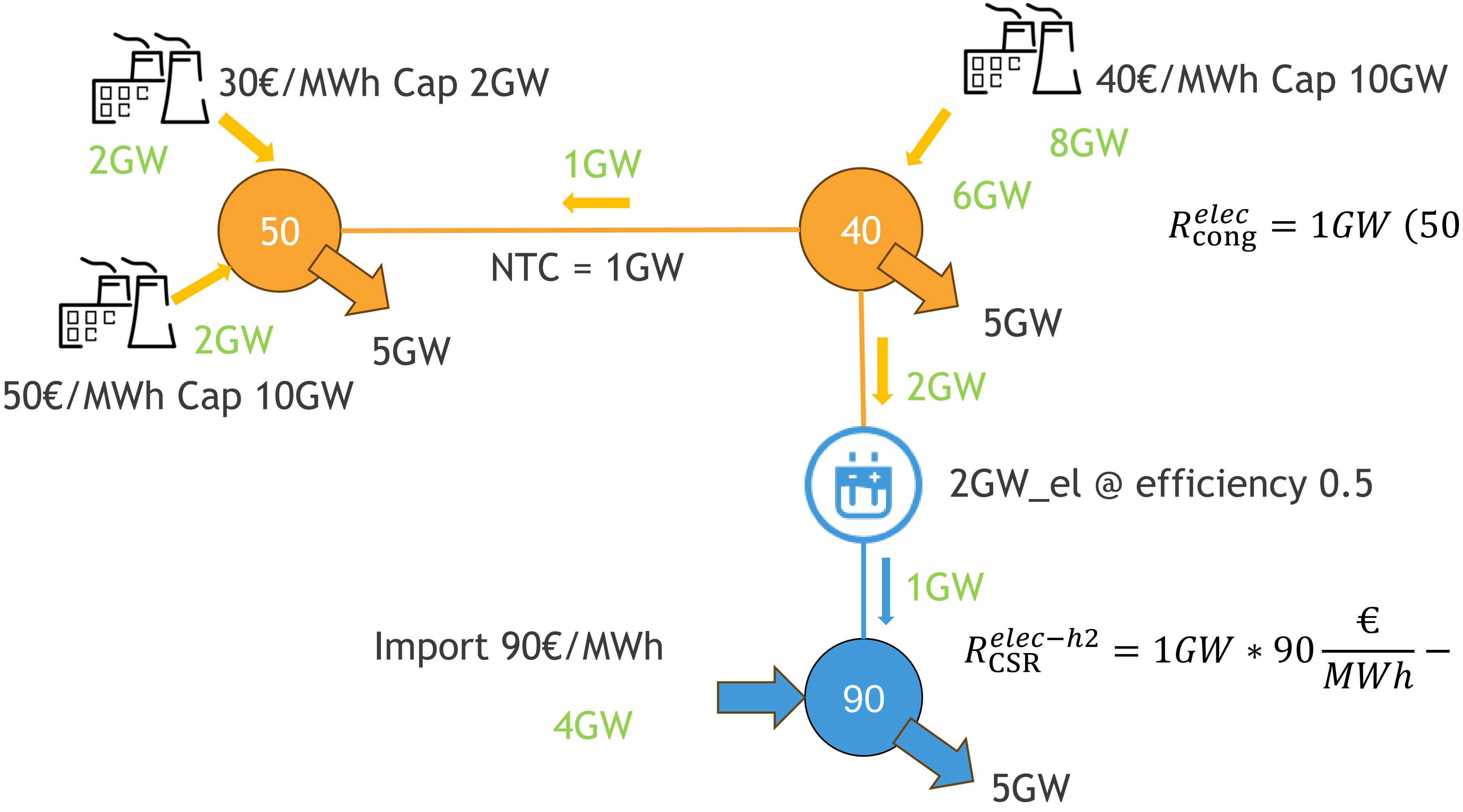
- Cross-sector rent CSR as a new welfare component

$$R_{\text{CSR}}^{\text{electricity}\leftrightarrow\text{hydrogen}} = \sum_{t \in T} \sum_{c \in C} \left| mcp_{\text{hydrogen}}^{c,t} p_{\text{cs,hydrogen}}^{c,t} - mcp_{\text{electricity}}^{c,t} p_{\text{cs,electricity}}^{c,t} \right|,$$

  - Needs to be calculated for every component that couples electricity with hydrogen and vice versa
  - No double counting, since contributions of P2G units or H2 gas turbines are solely attributed in the CSR (do not appear in consumer or producer surpluses)

From: T. Felling, P. Fortenbacher *Extended Social Welfare Decomposition for Multi-Energy Systems*, presented at EEM2022, **Ljubljana**

Background: Price formation in multi-sectorial markets



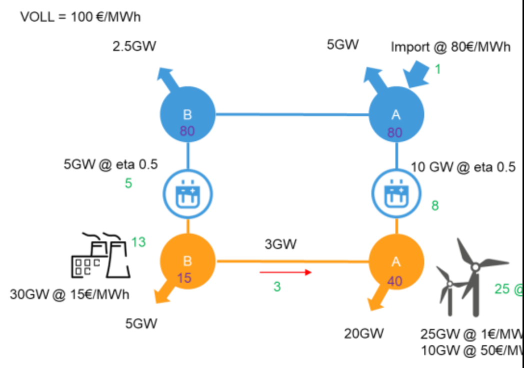
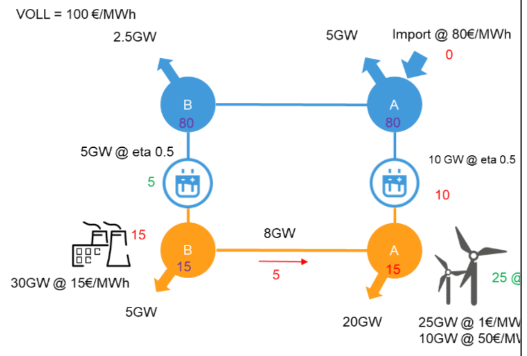
$$R_{\text{cong}}^{elec} = 1GW\ (50 - 40)\frac{€}{MWh} = 10000€$$

$$R_{\text{CSR}}^{elec-h2} = 1GW * 90\frac{€}{MWh} - 2GW * 40\frac{€}{MWh} = 10000€$$

Illustrative example under multi-sectorial coupling

Two areas A and B with an electricity and hydrogen market

- Generation cost approach and total surplus approach yield to the same benefits → approaches are equivalent

Reference Case	PINT Case Additional Transmission Capacity of 5 GW
	

Total Surplus Approach

Reference Case	PINT Case
$R_{CSR}^{elec\leftrightarrow h2} = (80*2.5-15*5)+(80*4-40*8) = 125$	$R_{CSR}^{elec\leftrightarrow h2} = (80*2.5-15*5)+(80*5-15*10) = 375$
$R_{cons}^{elec} = (100-15)*5+(100-40)*20 = 1625$	$R_{cons}^{elec} = (100-15)*5+(100-15)*20 = 2125$
$R_{cons}^{h2} = (100-80)*2.5+(100-80)*5 = 150$	$R_{cons}^{h2} = (100-80)*2.5+(100-80)*5 = 150$
$R_{prod}^{elec} = (15-15)*13+(40-1)*25 = 975$	$R_{prod}^{elec} = (15-15)*15+(15-1)*25 = 350$
$R_{prod}^{h2} = (80-80)*1 = 0$	$R_{prod}^{h2} = (80-80)*0 = 0$
$R_{cong}^{elec} = (40-15)*3 = 75$	$R_{cong}^{elec} = (15-15)*8 = 0$
$R_{cong}^{h2} = (80-80)*0 = 0$	$R_{cong}^{h2} = (80-80)*0 = 0$
$SEW = \sum R = 2950$	$SEW = \sum R = 3000$

Delta SEW = 3000-2950 = 50

Generation Cost Approach

Reference Case	PINT Case
$\text{Generation } Cost = 13*15+25*1+1*80 = 300$	$Generation\ Cost = 15*15+25*1+0*80 = 250$

Delta SEW = 300-250 = 50

From: ENTSO-E *TYNDP 2024 Implementation Guidelines* available at https://tyndp.entsoe.eu/resources/tyndp-2024-implementation-guidelines

Audience Q&A Session

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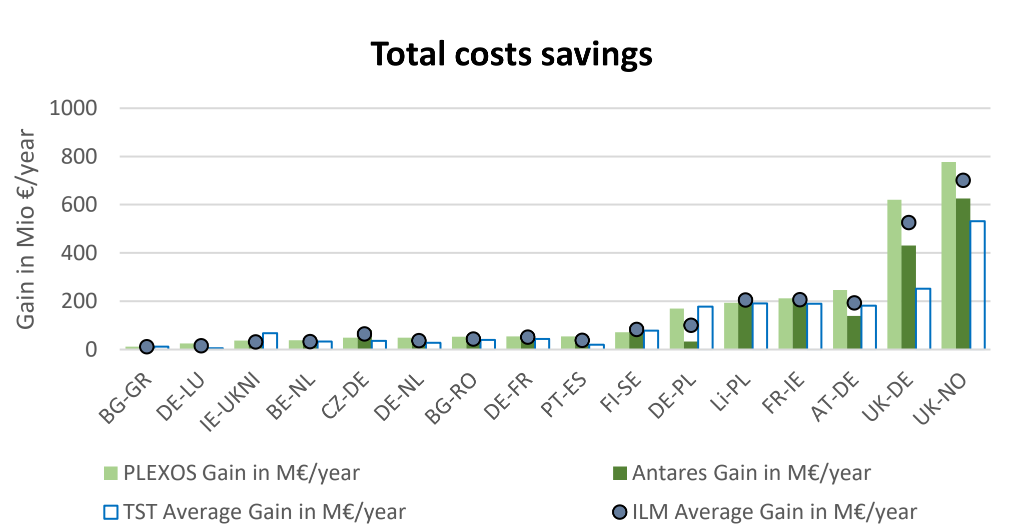
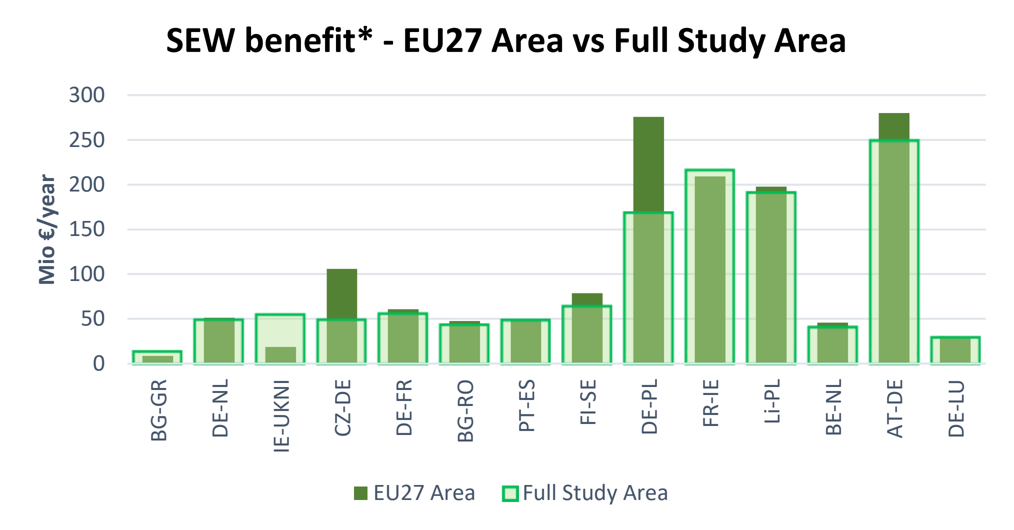
CBA Assessment Results
Power Lines, Electrolysers & Hydrogen Pipelines

Power Transmission Projects – Total Cost Savings





The results between ANTARES and PLEXOS show good alignment. Deviations in projects connecting to the UK.

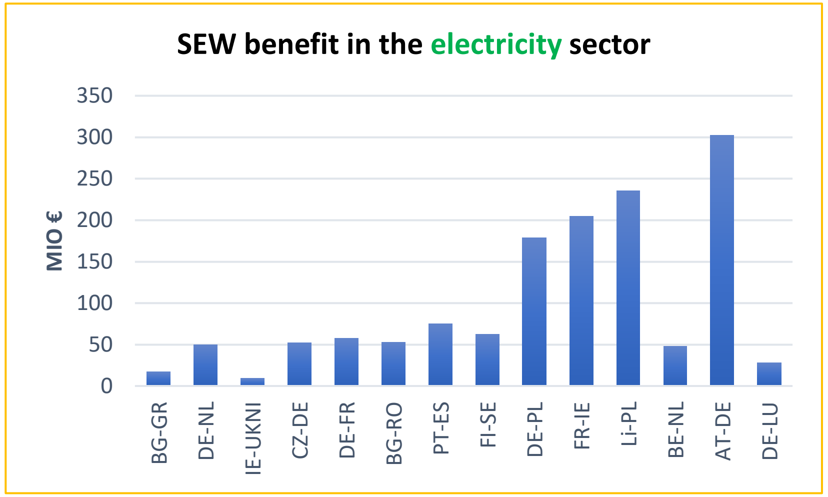
Comparison of TST model and ILM model shows good alignment

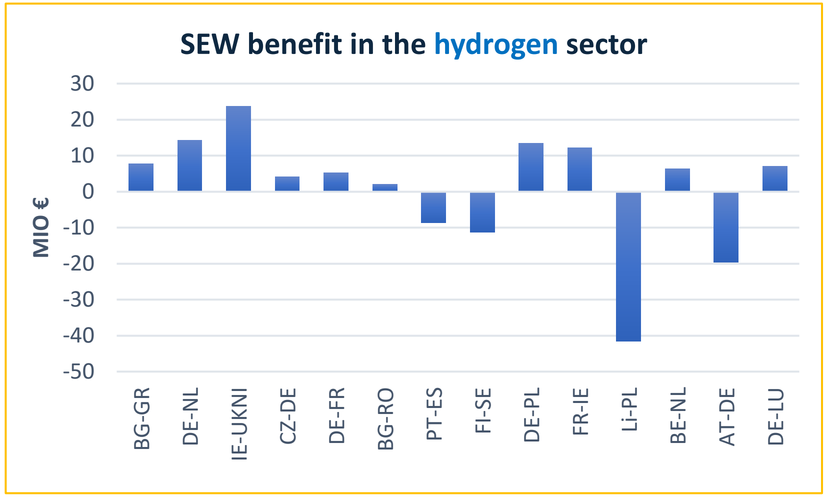
The EC will require the TYNDP to show how projects bring benefits to the European Union

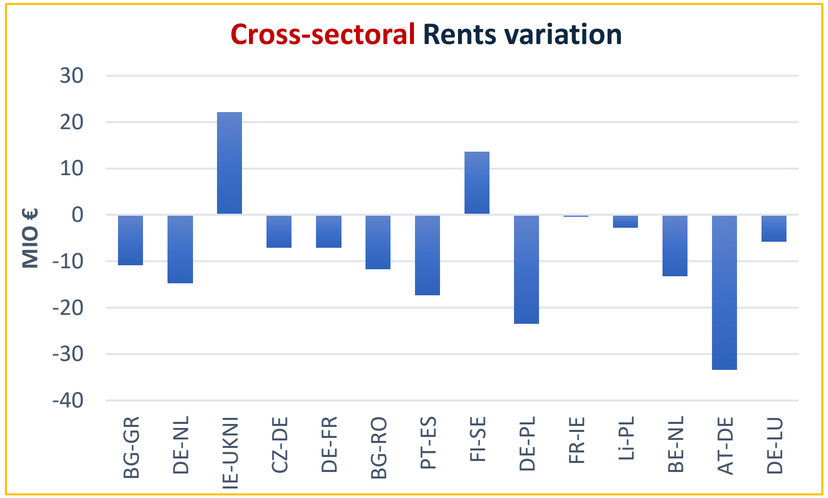
For most electricity projects, the benefits are concentrated within the union. For the projects where there is a difference the EU27 countries higher benefits (with some except e.g. UK – Europe)

** Reminder: from our assumptions of inelastic demand and no change in the grid when the project is added besides the project's infrastructure itself, total costs savings equals the social economic welfare (for full study area)*

Power Transmission Projects – Social Economic Welfare Split





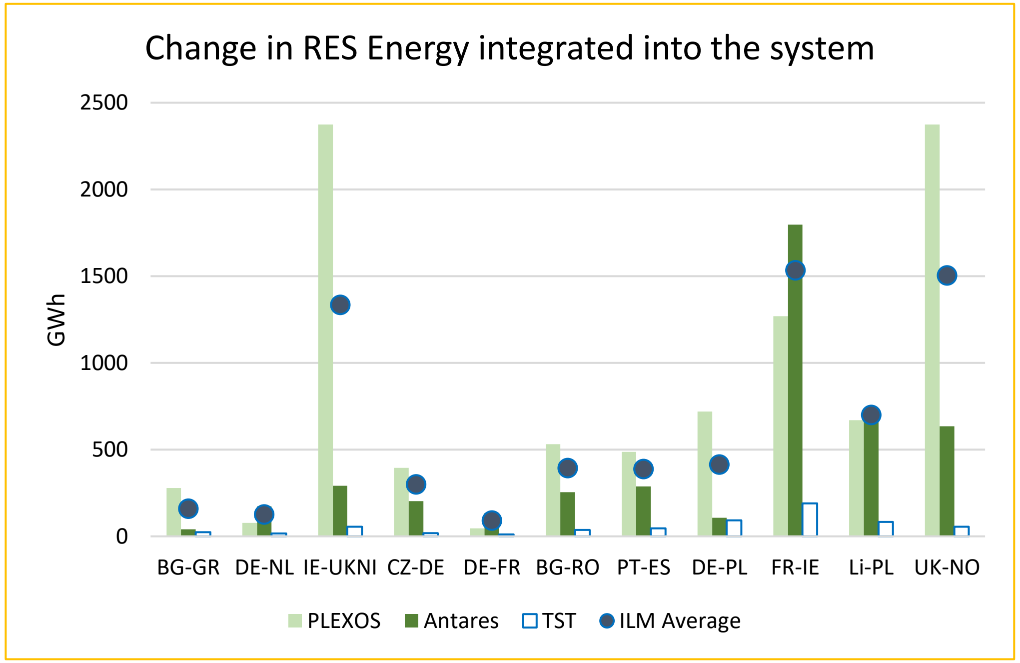


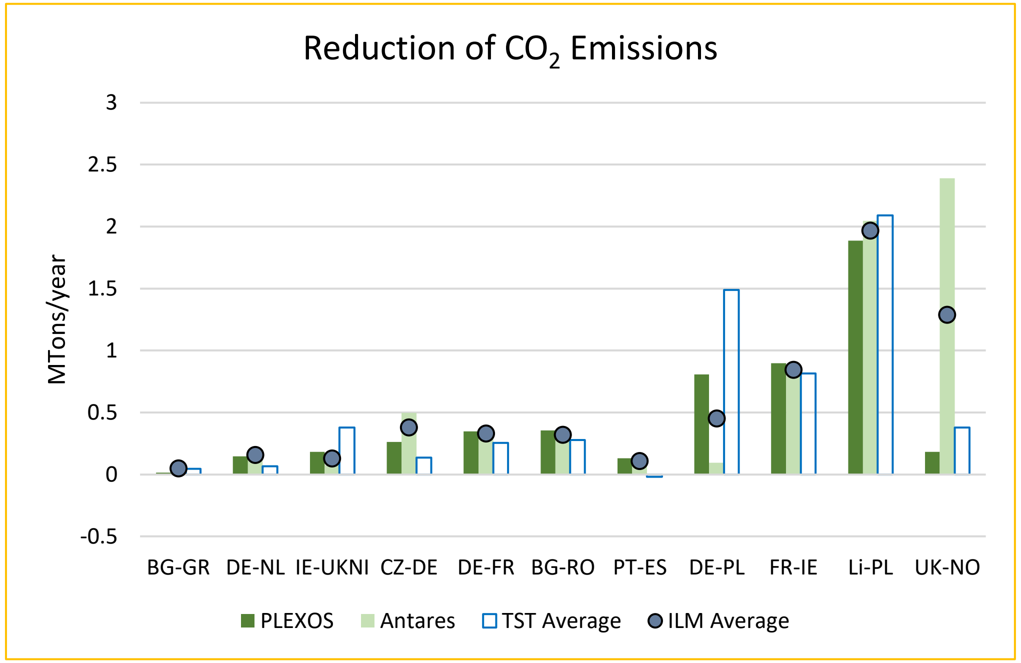
Most of the projects' benefits are obtained in the electricity sector.

The SEW movements in the hydrogen sector are comparatively very small.

The CSR SEW movements are comparatively very small

Power Transmission Projects – GHG Emissions & RES Curtailment

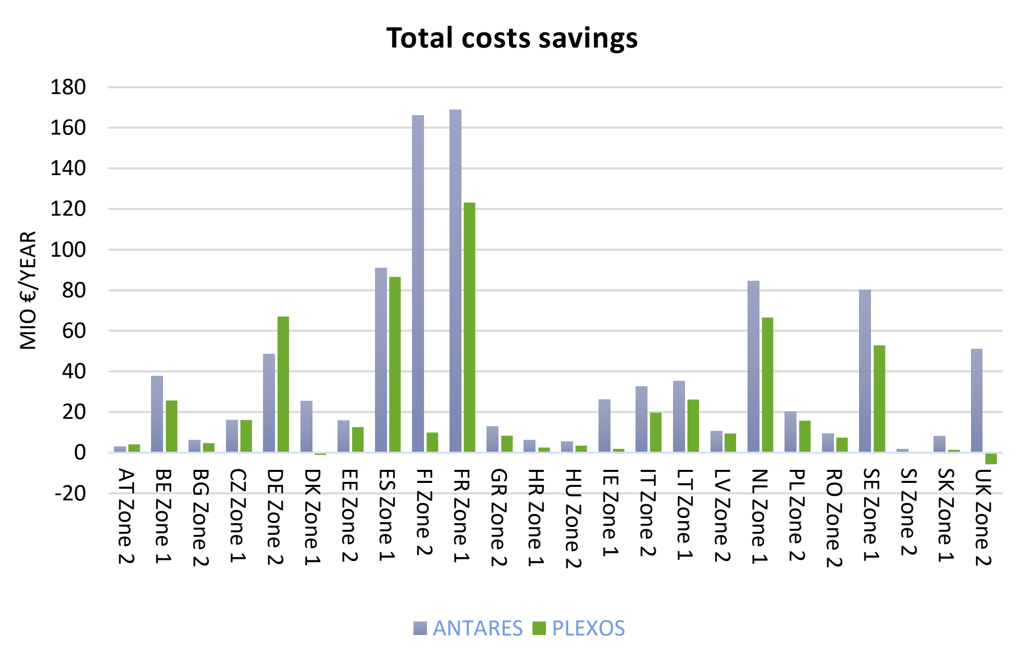


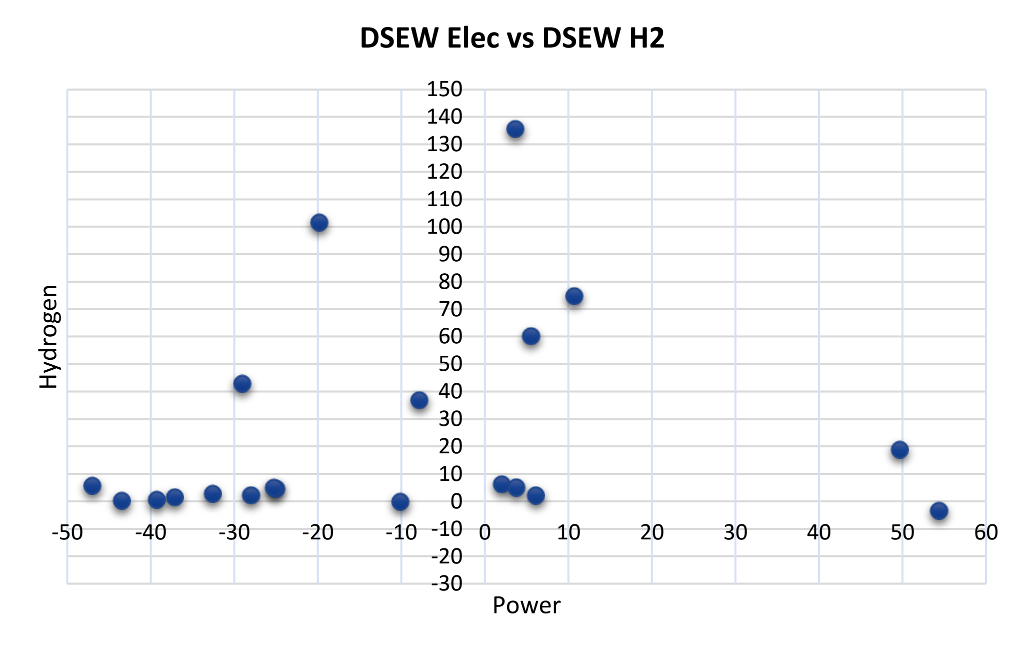


RES integration results are not as aligned as the SEW results, across tools and models. ILM Model shows higher RES integration benefits across the board.

Similar alignment as with the SEW indicator, both across tools and models. The model which show higher results are fluctuate between the ILM and TST model.

Electrolyser Projects – Total Cost Savings

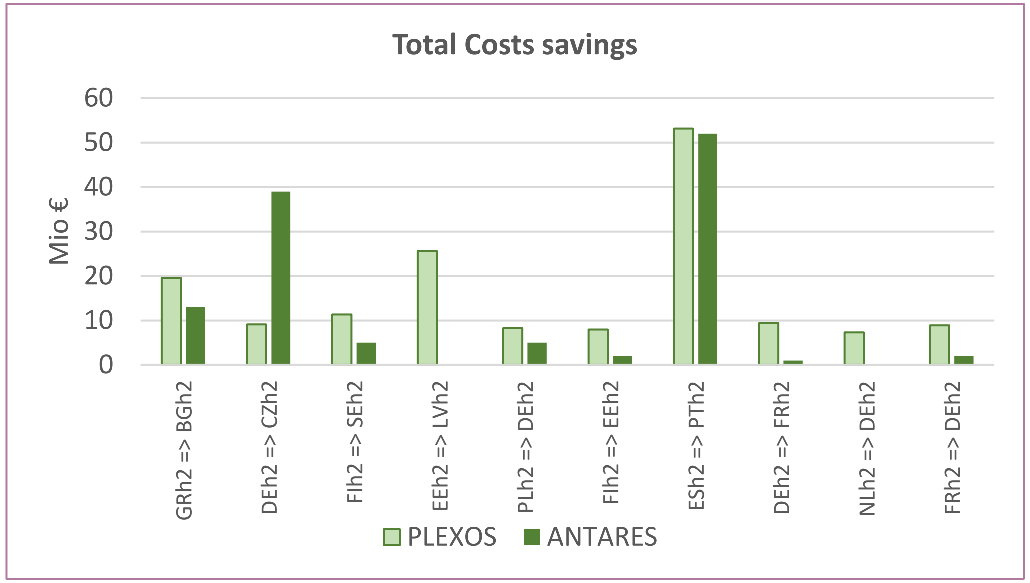


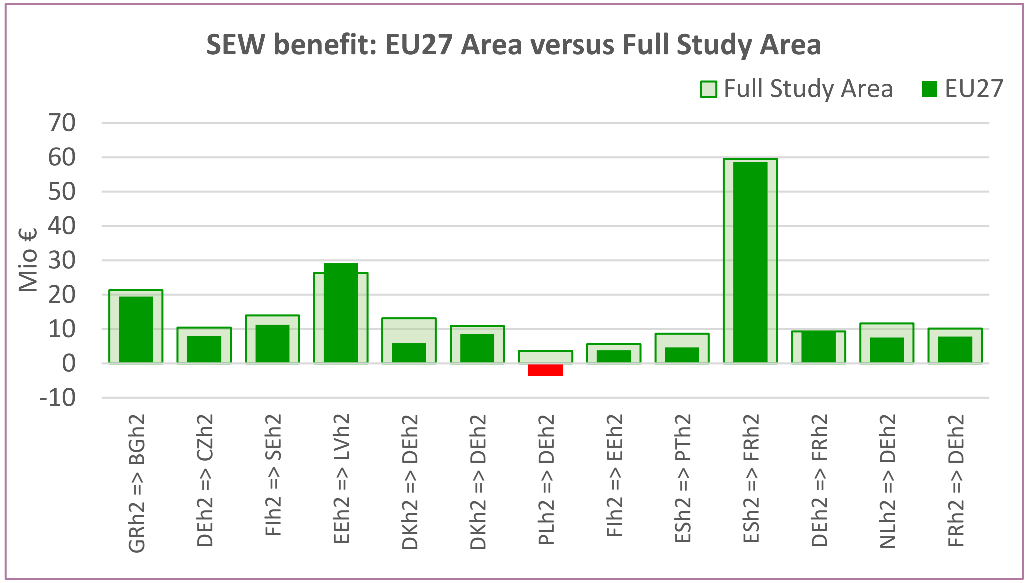


The SEW results for electrolysers show a relatively good alignment with the exception of Finland and UK. These deviations will be further Investigated

When looking at the split between benefits in the h2 and electricity sector, the h2 (y-axis) always shows a positive benefits where the electricity sector sees a cost.

Hydrogen Pipeline Projects – Total Cost Savings





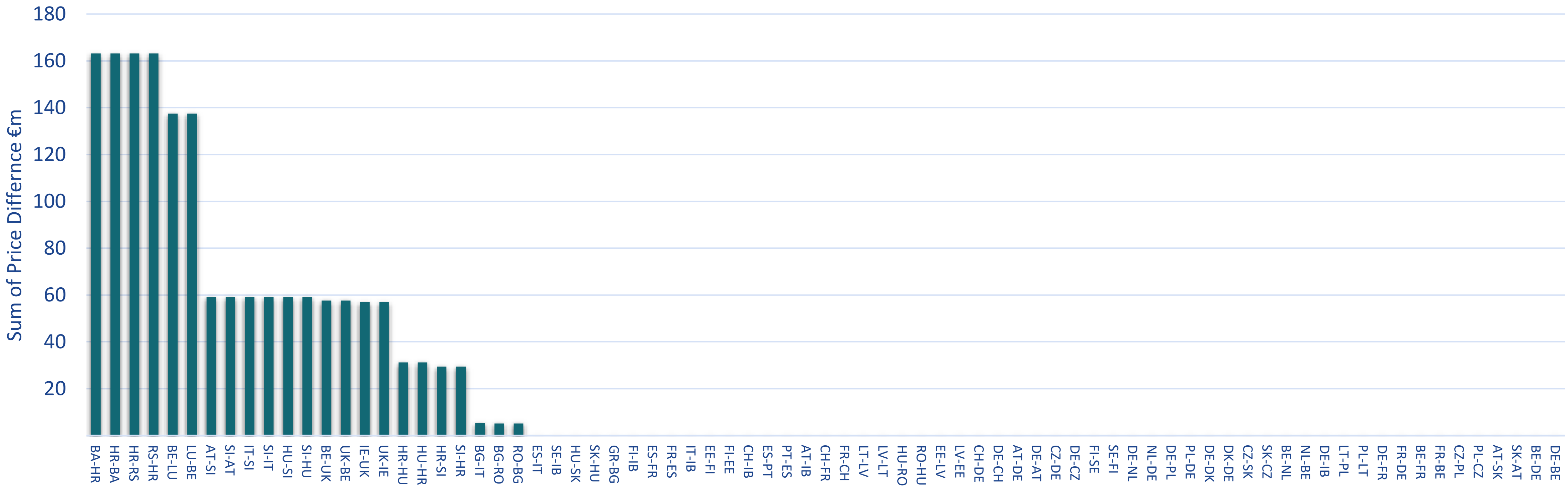
There is a fundamental issue with hydrogen projects in the magnitude of project benefits, which has been limited to the pricing structure of supply sources.

Alignment has somewhat been reached but a full alignment cannot be claimed

H2 projects typically produce similar benefits for the EU and for the Pan-EU area.

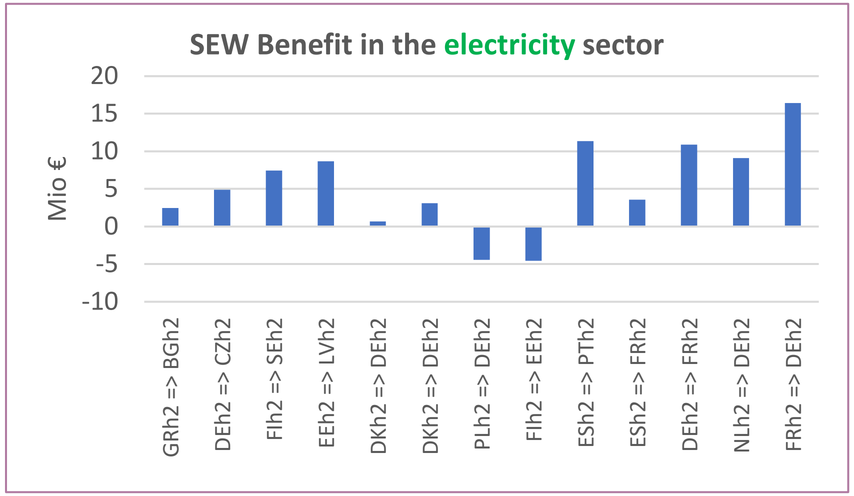
Project 21 connecting DK-DE show negative benefits in the EU area PLEXOS and low benefits overall when compared to ANTARES. This will be further explored

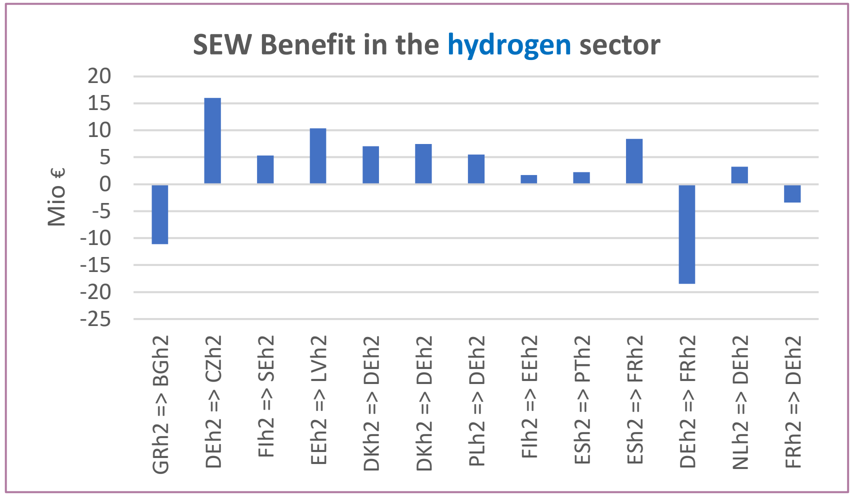
Cross Border Price Differences

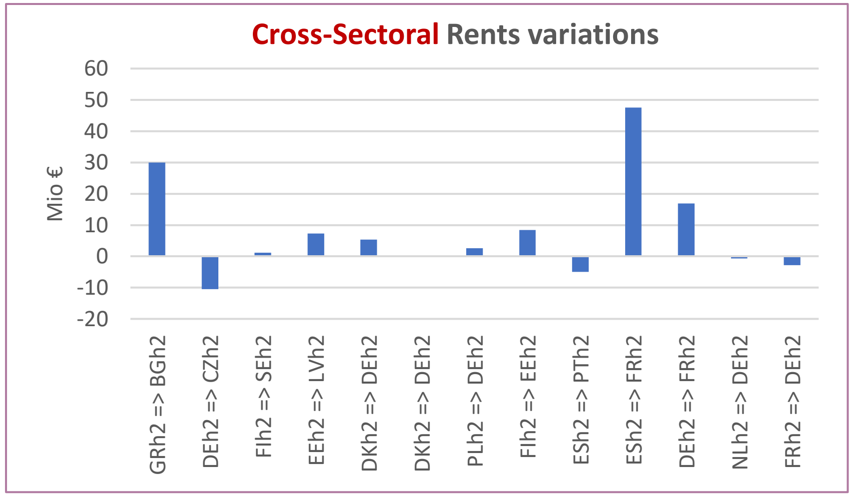


Low benefits for hydrogen project have been observed. This will be mainly due to the flat pricing structure in the model (Green, Pink or Blue h_2) this means there is less need for cross border flows as there are less price difference.

Hydrogen Pipeline Projects – Social Economic Welfare Split







Hydrogen projects bring benefits to both the electricity and hydrogen sector

These benefits are however rather low

The projects which bring negative benefits change depending on the sector being observed

Audience Q&A Session

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Recommendations

Recommendation 1: SEW Approach - global SEW decomposition methodology should be used for any interlinked assessment. The SEW benefit be always communicated for the whole system.

Recommendation 2: Use of Model - The TF ILM recommends that the final ILM is used for CBA project assessments for the TYNDPs, when cross sectoral impacts are expected.

Recommendation 3: Consistency of modelling - ILM is based on the TYNDP scenario model, keeping the key concepts as consistent as possible. Single sector modifications should be implemented in the ILM

Recommendation 4: Price structure for hydrogen market - It is recommended that a varied supply source price structure is used for the hydrogen market.

Conclusions

Conclusions

- Significant progress has been made in the interlinked model, some of which were already considered in the TYNDP 2024 Scenario development process.
- The effect of electrolysers dispatch on projects must be further explored.
- All recommendations should be carried forward into the next stage of the ILM development process
- One of the main developments of the Final interlinked model will be the inclusion of the methane system

Thank you for your attention

Location: Teams Webinar

Date: 04/06/2024