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Hydrogen in the European power sector – A case study on the impacts of regulatory frameworks for green hydrogen

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Agenda

IAEE Milan 2023

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- Energy transition to achieve climate neutrality is a major goal of European politics
- Green hydrogen with key role in
 - REPowerEU
 - European Green Deal
- Renewable hydrogen addressed in the *Delegated Act on article 27 of the Renewable Energy Directive (RED II)*

REPowerEU (selected targets):

- 1236 GW renewable energy capacities until 2030
- 10 Mt domestic production of renewable hydrogen until 2030
- 10 Mt imports of renewable hydrogen until 2030

EU Green Deal (main targets):

- Reduction of net greenhouse gas emission by 55% compared to 1990 until 2030
- Complete climate neutrality until 2050

Delegated Act *:
When can hydrogen (or hydrogen-based fuels) be considered as renewable?

Temporal correlation:

- Hourly correlation of production and consumption
- Storage as option to shift correlation

Geographic correlation:

- Same bidding zone
- Exceptions:
 - Neighboring offshore bidding zone
 - Neighboring bidding zone with higher or equal day-ahead prices during same time period

Additionality:

- Operation started within 36 months
- Add. hydrogen capacity can be added within 36 months
- No operational or investment support received (excl. before repowering)

➤ Will the RED II criteria impede the ramp-up of electrolysis capacities in the EU?

E2M2s overview

- Model for the long-term planning and dispatch in the European electricity and heat market *
 - Endogenous capacity expansion
 - Geoscope: 34 European market areas
- Linear optimization for selected simulation years under myopic expectations
- Minimization of system costs
 - Investment and fixed costs
 - Operational costs
- Typical day approach with aggregated time segments and stochastic nodes

Integration of hydrogen sector

Hydrogen modeling

- Additional hydrogen demand restriction (per market area)

Demand

Exogenous demand (e. g. industry)
+ Endogenous demand of H₂-fired power plants
+ Exports to neighboring countries
=

Supply

Production from domestic electrolyzers
+ Imports from neighboring countries
+ Imports from third countries outside geoscope

- Third country H₂ imports regulated via
 - Fixed import price per simulation year
 - Maximum export quantities of third countries

- Implementation of restrictions into an large-scale energy system model
- Solution
 - Separate wind onshore technology for electrolysis
 - Electrolyzers can only use electricity from this technology
 - Coupled with electrolyzers of the same simulation year via assignment set

Temporal correlation:

- Elec. consumption for H2 production \leq Infeed of coupled wind power plant in every time step

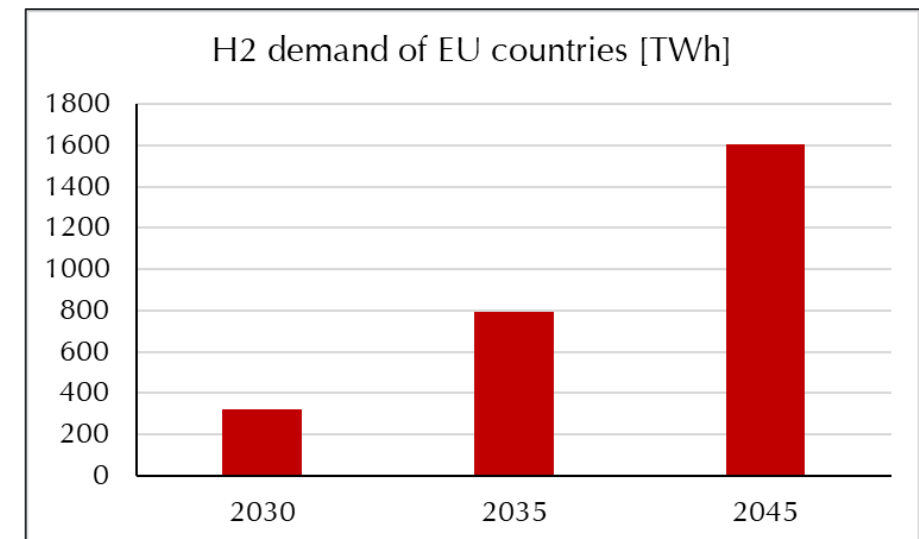
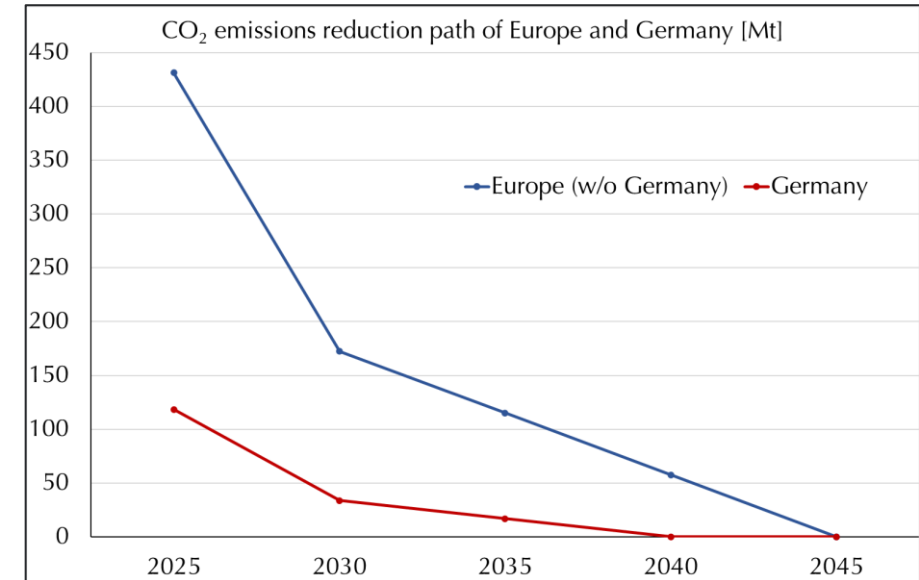
Geographical correlation:

- Coupled technologies are located in the same bidding zone

Additionality:

- Investment in wind onshore plant and electrolyzer during the same simulation year

- Main data source: TYNDP 2022 *
 - Electricity and hydrogen demand
 - Electricity and hydrogen NTCs
 - Renewable energy expansion paths
 - Hydrogen export potentials of third countries
- Power plant data
 - Commercial data
- Endogenous capacity expansion possible for:
 - Renewables (Wind Onshore / Offshore, PV)
 - Electrolyzers
 - Hydrogen and natural gas turbines / ccgts
 - Battery storage units
 - ...

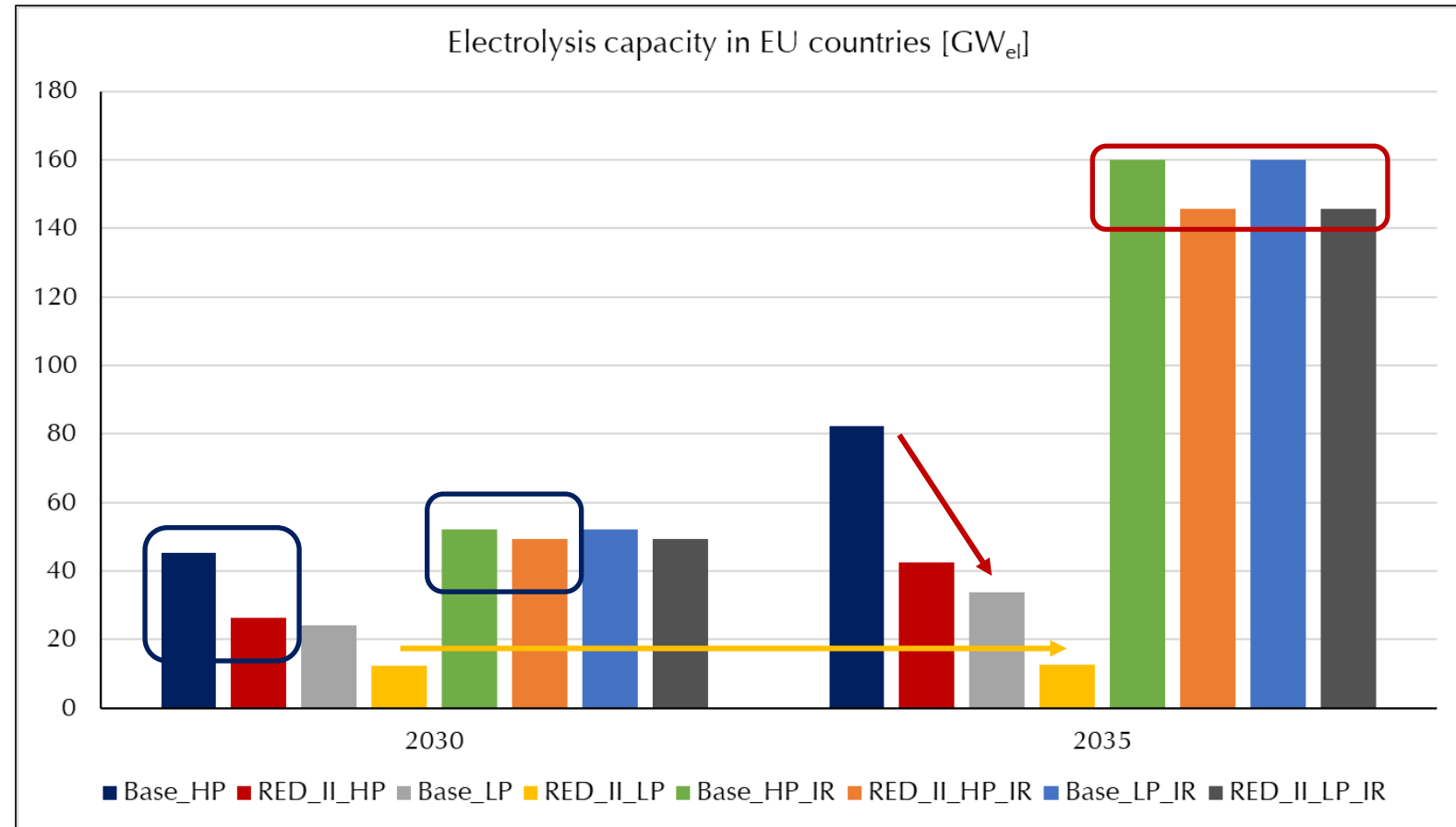


Cases	RED II restrictions	High price level (HP)	Low price level (LP)	Import restriction 3rd countries (IR)
Base_HP		X		
RED_II_HP	X	X		
Base_LP			X	
RED_II_LP	X		X	
Base_HP_IR		X		X
RED_II_HP_IR	X	X		X
Base_LP_IR			X	X
RED_II_LP_IR	X		X	X

H2 import prices [€/MWh H2]	High price level (HP)	Low price level (LP)
2025	150	150
2030	125	100
2035	100	75
2045	75	50

- Quantification of effects and interaction of
- RED II restrictions
 - Import price levels
 - Import quantity restrictions

- **RED II restrictions**
 - Lower investments in electrolyzers
 - Larger influence when neglecting import restrictions
- **Import price level**
 - Further reduction of electrolyzer investments
 - No visible influence when applying import restrictions
- **W/o import restrictions**
 - No further investment between 2030 and 2035 with RED II restrictions and low prices



RED II restrictions

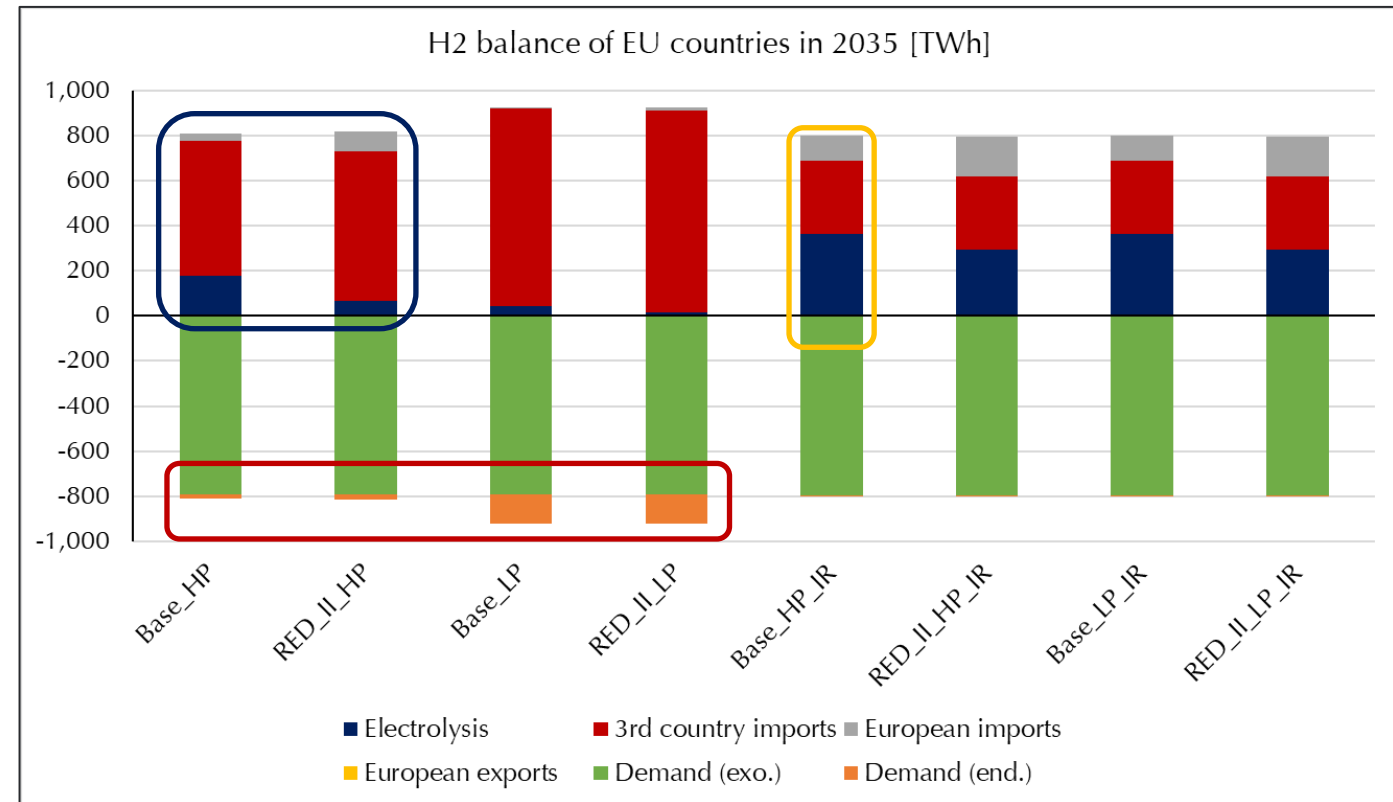
- Reduced H2 production by electrolysis
- Substituted by imports from European and third countries

Import price level

- Low price level without import restrictions leads to higher H2 usage
- No visible influence when applying import restrictions

Import restrictions

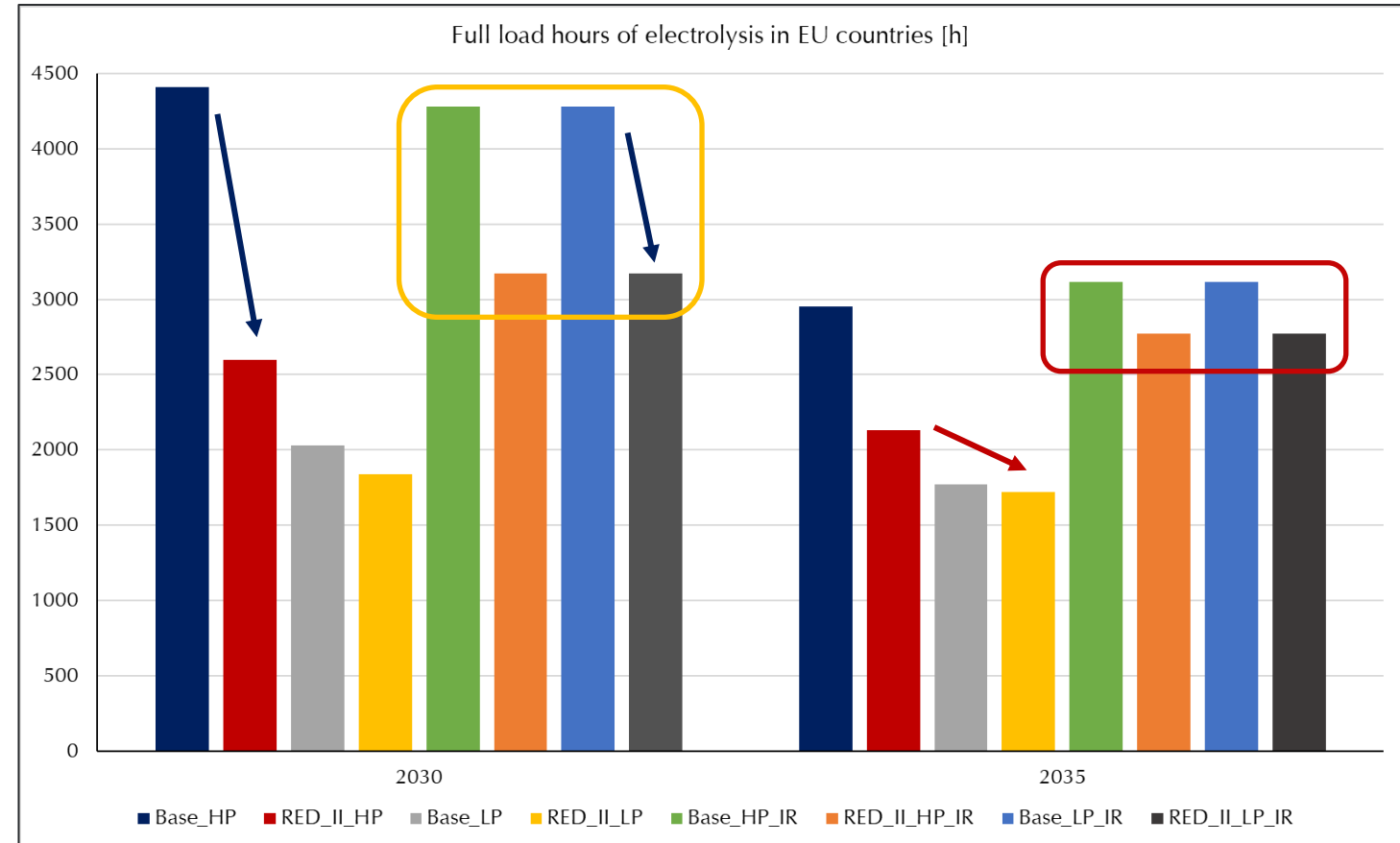
- Increased domestic electrolysis and imports from European countries



- **RED II restrictions**
 - Reduction of FLHs in all cases

- **Import price level**
 - Low price level without import restrictions leads to lower FLHs
 - No visible influence when applying import restrictions

- **Import restrictions**
 - Higher FLHs in almost all cases



- Modelling
 - RED II restrictions lead to lower investments in electrolyzers
 - High sensitivity to import price levels
 - Import quantity restrictions reduce these effects
 - Hydrogen-fired power plants have no mayor role in the medium-term
- Model parameters like import prices and import restrictions have to be selected carefully
- Regulatory frameworks should be evaluated under different assumptions about input parameters
- Policy implications
 - EU should monitor ramp-up closely and reflect restrictions continuously
 - Domestic electrolysis necessary to meet demand and secure certain level of autarchy → especially after energy crisis
- Trade-off between strict criteria to ensure decarbonization goals and impeding ramp-up

■ Politics

- RED II: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32018L2001>
- Delegated act for article 27 of the renewable energy directive (RED II): https://energy.ec.europa.eu/system/files/2023-02/C_2023_1087_1_EN_ACT_part1_v8.pdf
- REPowerEU: https://commission.europa.eu/publications/key-documents-repowereu_en
- European Green Deal: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

■ Model

- Swider and Weber (2007). The costs of wind's intermittency in Germany: application of a stochastic electricity market model
- Spiecker et al. (2013). Evaluating interconnector investments in the north European electricity system considering fluctuating wind power penetration
- Spiecker and Weber (2014). The future of the European electricity system and the impact of fluctuating renewable energy – A scenario analysis
- Bucksteeg et al. (2019). Impact of Coordinated Capacity Mechanisms on the European Power Market
- Blumberg et al. (2022). The impact of electric vehicles on the future European electricity system – A scenario analysis

■ Data

- TYNDP 2022 datasets: <https://2022.entsos-tyndp-scenarios.eu/download/>



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Thank you for your attention

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