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

Working Paper

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Navigating Delegated Acts 27 & 28 of RED II – Impacts on the Hydrogen & eFuels Markets

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Agenda

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eFuel Alliance e.V.

Motivation

- Green hydrogen with key role to achieve climate neutrality is a major goal of European politics
  - REPowerEU
  - European Green Deal
- Renewable hydrogen addressed in the ***Delegated Act on article 27 of the Renewable Energy Directive*** (RED II)
  - New rules formally adopted on 20.07.2023
  - The first act defines under which conditions hydrogen can be considered as renewable fuels of non-biological origin (RFNBOs)
  - The regulations should also apply to international producers who export renewable hydrogen to the EU (see next slides)

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?

The energy system model E2M2s

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

* Applications can be found in Swider and Weber (2007), Spiecker et al. (2013), Spiecker and Weber (2014), Bucksteeg et al. (2019) and Blumberg et al. (2022).

RED II restrictions in the E2M2s

- 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
- Assumption: Standards are relaxed for non-EU members
  - UK: ~97% of Electricity production Renewable or Nuclear, Gas for Peak Load coverage – also limited by CO2 Boundaries
    → No Additionality requirement & smoothed correlation requirements

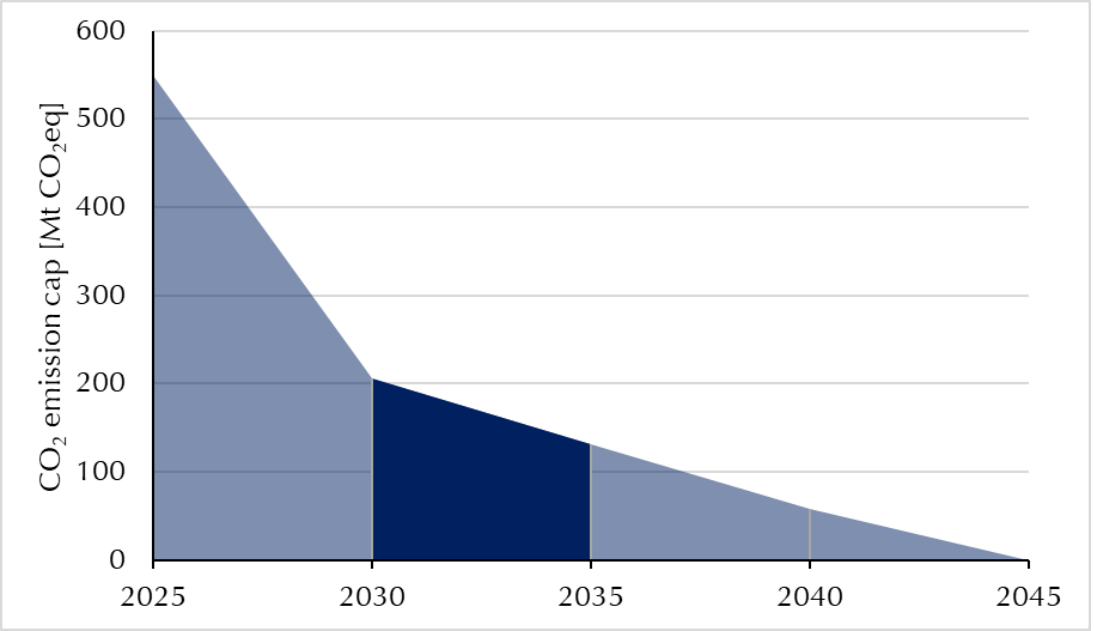
Temporal correlation:
- Elec. consumption for H2 production ≤ Infeed of coupled wind power plant in every time step

Geographical correlation:
- Coupled technologies are located in the same bidding zone

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

Data

- 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 gas turbines
  - Battery storage units
  - …



Demand [TWh]	2030	2035
Electricity	3910	4204
of which EU	3225	3455
Hydrogen	352	875
of which EU	322	791
District heat	381	396
of which EU	376	390

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* Global Ambition scenario

Case overview

Run	Scenario	Case	RED II restrictions	High import price level	Low import price level	Limited 3rd country imports
Base_HP	HP	Base		X		
RED_II_HP	HP	RED II	X	X		
Base_LP	LP	Base			X	
RED_II_LP	LP	RED II	X		X	
Base_HP_LI	HP_LI	Base		X		X
RED_II_HP_LI	HP_LI	RED II	X	X		X

Simulation year	High import price level	Low import price level
2025	150	150
2030	125	100
2035	100	75
2045	75	50

Values in €/MWh H2

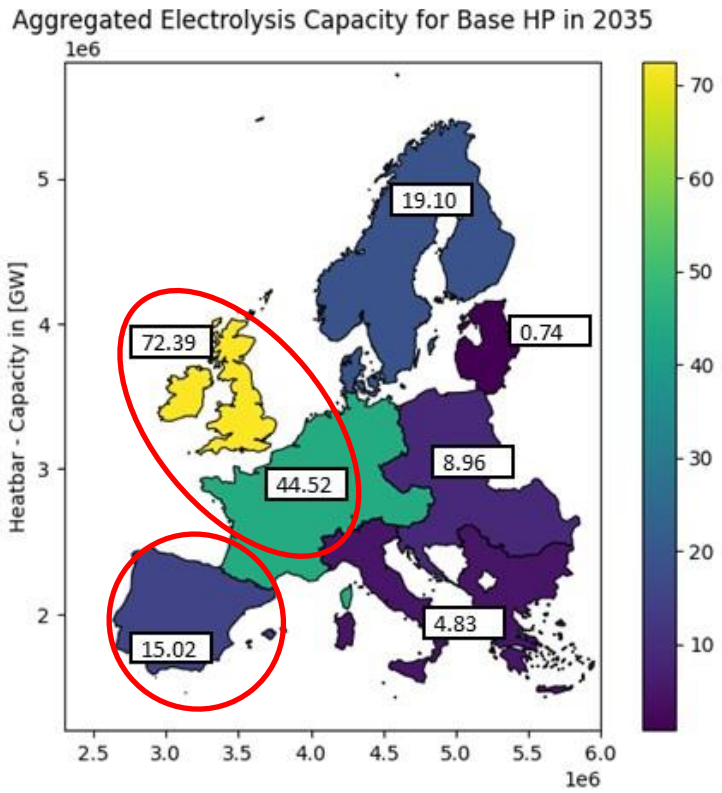
Year	2025	2030	2035	2045
Import limit	43.18	86.35	324.25	794.89

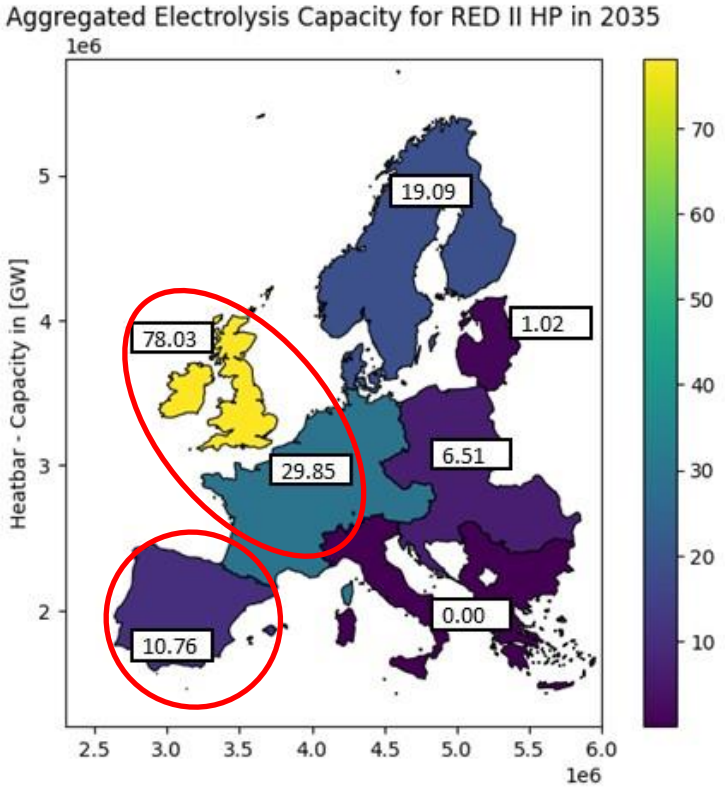
Values for 3rd Country Imports in TWh H2

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

Base HP (left) and RED II HP (right) in 2035 - installed electrolyzer capacities

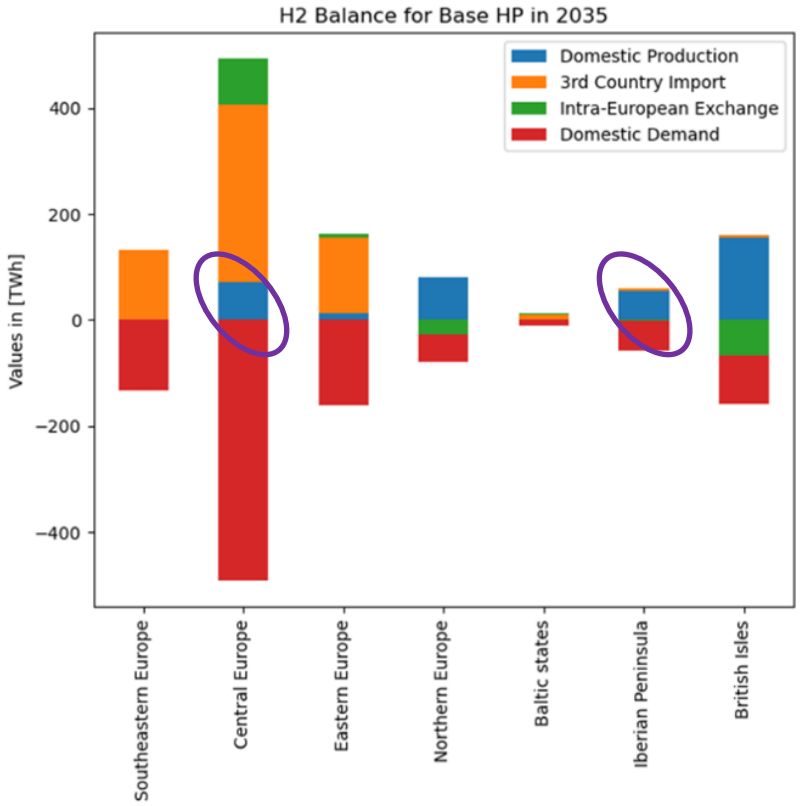
- **RED II leads to a shift in the EU from domestic production towards Net-Importer**
  - Lower investments in electrolyzers
  - Larger influence when neglecting import restrictions

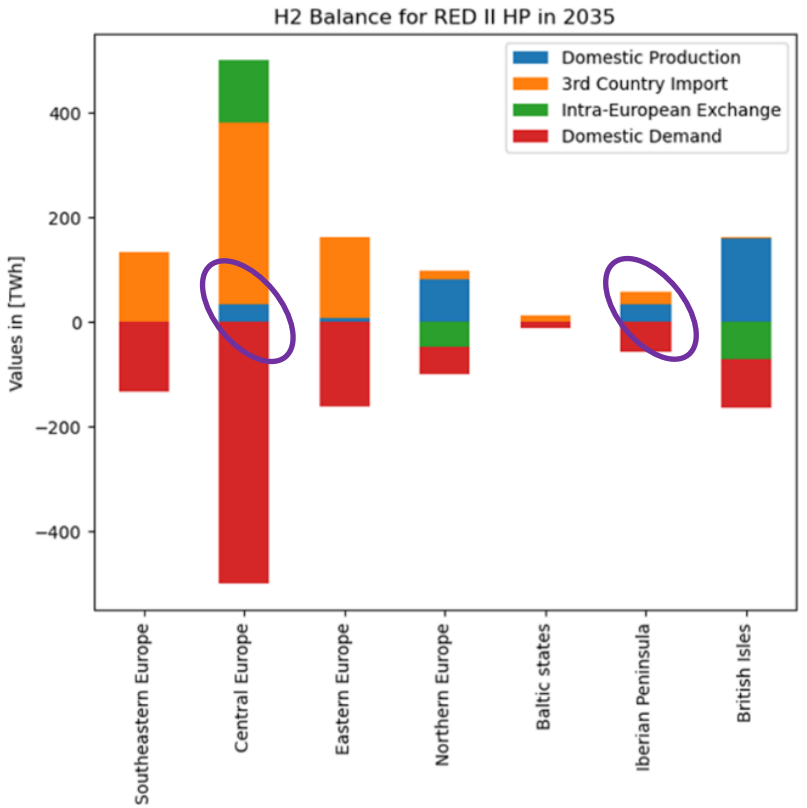




Base HP (left) and RED II HP (right) in 2035 - H2 energy balance

- **Non-EU states are taking on a role as exporters or as transit countries for third country imports**
  - Domestic production decreases by more than half in Central Europe (33.72 vs. 70.55 TWh)
  - Iberian Peninsula shows a similar strong tendency (35.16 vs. 54.99 TWh)



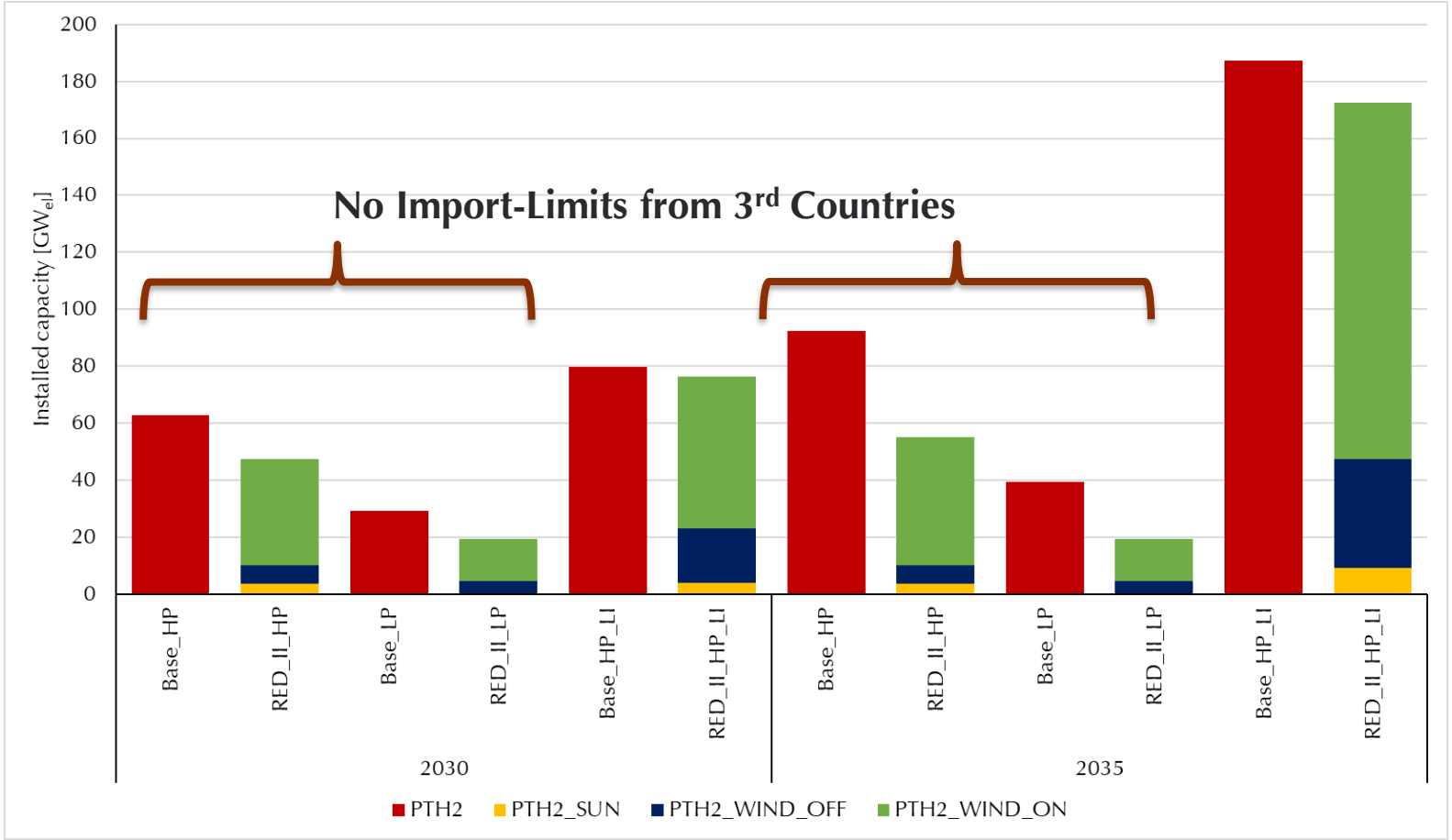


Electrolyzer capacity in the EU in 2030 and 2035 by technology combinations [GWel]

Import limits drastically increase the domestic electrolyzer capacity

Over all cases: lower domestic electrolyzer capacity with RED II

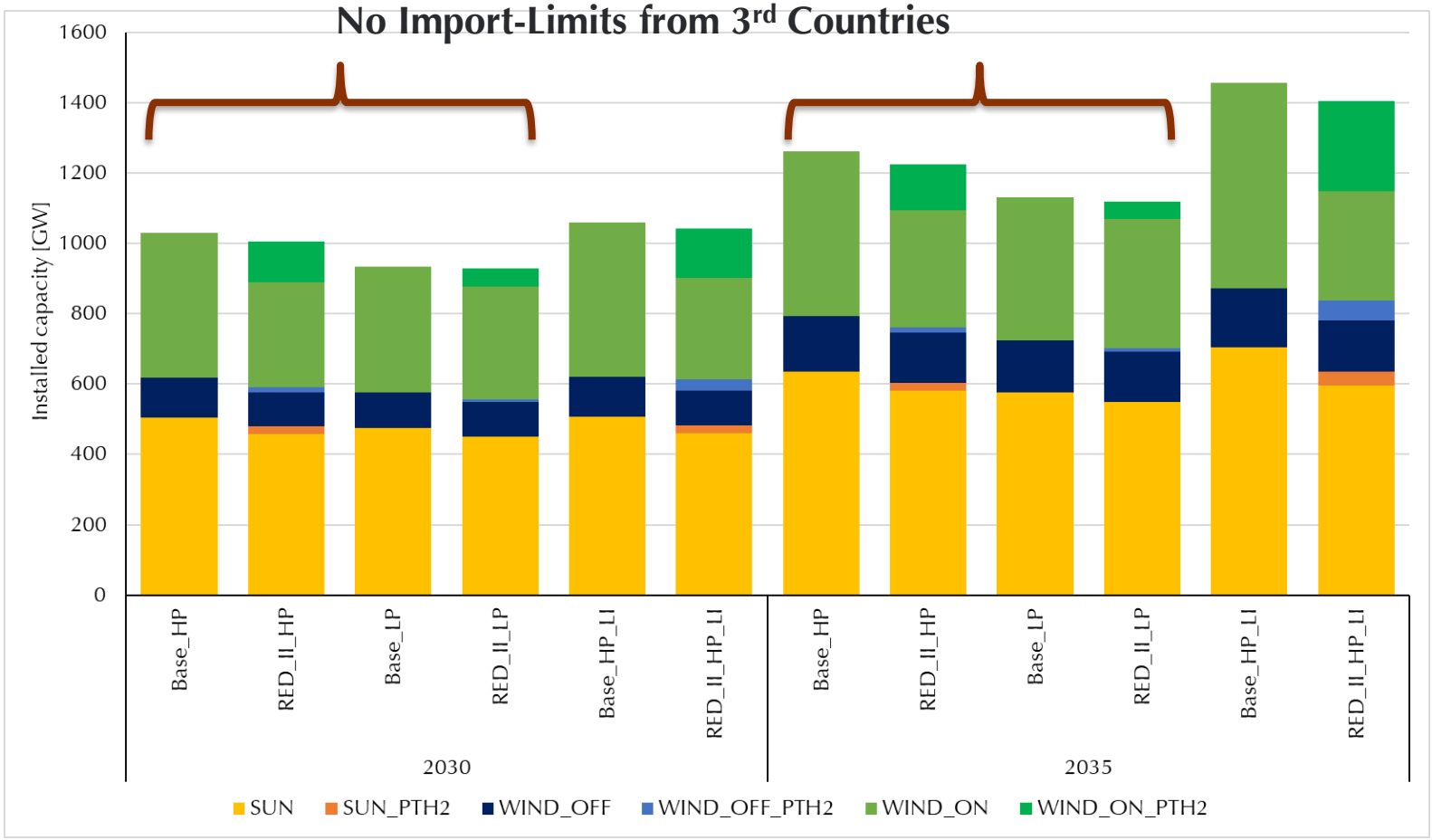
Over all RED II cases: dominance of Wind Onshore



RES capacities by technology in the EU in 2030 and 2035 [GW]

Offshore wind becomes more important as coupled technology only when import limitations are applied

Due to its lower FLHs, PV is generally used for general electricity production and is not that attractive for coupling with a capital-intensive technology like electrolyzers



Hydrogen balances (supply & demand) of the EU in 2030 and 2035 [TWh]

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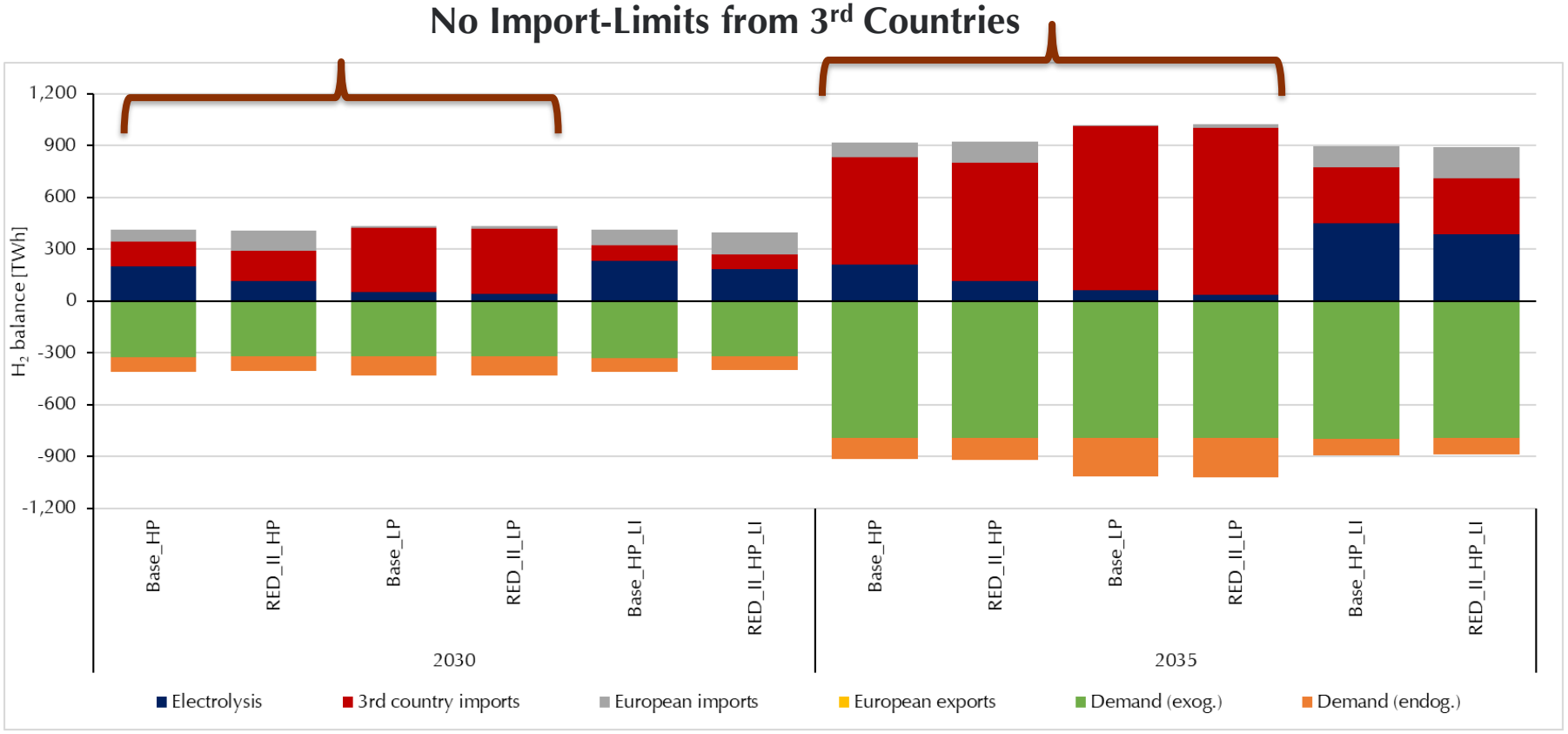
Distribution of H2-supply sources differs substantially between the three scenarios

Domestic electrolysis contributes less to overall supply when the RED II constraints are active

Reconversion depends on Import prices rather than domestic conditions



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Conclusion

- 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 major 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 continously
  - 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

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