1 Supplementary material to the article *How to Foster a Resilient, Efficient and Clean Hydrogen Ramp-Up? – A Comparative Assessment of the EU and US Support Systems*

1.1 Delineation of hydrogen support systems

Our aim is to compare how the hydrogen support systems of the US and the EU address the different barriers to the hydrogen market uptake. Since hydrogen strategies are usually non-binding planning documents and therefore mostly lack details regarding the exact specification of policies, it is necessary to consider also the corresponding deployment policies. To do so, we first need to describe how the national support systems are delineated, given that these systems are in general composed of multiple policy instruments with even more policies potentially influencing the hydrogen market uptake. For the delineation of a policy mix, we use a top-down approach starting from a policy strategy (cf. Ossenbrink et al. 2019), in our case the hydrogen strategies.

Hence, the set of policies to be assessed should be derived from national hydrogen strategies and cover central policy instruments that are expected to have a major impact on the development of the hydrogen market uptake. In the literature, such instruments have also been referred to as "cornerstone instruments" (UNDP 2018). In our case, cornerstone instruments are considered to explicitly address how to increase production of and demand for low-emissions hydrogen in spite of high costs as well as how to establish hydrogen infrastructures, markets and import/export routes despite low trade volumes. We identify the cornerstone instruments in an iterative way starting with instruments explicitly referring to or referred to in the hydrogen strategies and adding instruments that are directly reinforcing or limiting the impacts of the former. The list of identified cornerstone deployment instruments is provided in Table 1.

Table 1: Key instruments of EU and US hydrogen support systems and their relevance per assessment criterion

EU instrument mix	Type of instrument	Resilience of hydrogen uptake	GHG effectiveness	Economic efficiency
EU Hydrogen Strategy (EC 2020)	Strategy (production, use + transport of hydrogen)	High relevance	High relevance	Moderate relevance
Emissions Trading System (EU ETS) (European Parliament et al. 2023b)	Regulatory (production + use of hydrogen)	Low	High	High
Carbon Border Adjustment Mechanism (CBAM) (European Parliament et al. 2023c)	Regulatory (production of hydrogen)	Low	Moderate	Low
Renewable Energy Directive (RED) and its Delegated Acts (European Parliament et al. 2023a)	Regulatory (production + use of hydrogen)	High	High	Moderate
Net-Zero Industry Act (NZIA) (EC 2023e)	Regulatory (production of hydrogen + manfacturing)	High	Moderate	Low
Hydrogen and Decarbonised Gas Markets Directive and its Delegated Act (EPRS 2024)	Regulatory (production + transport of hydrogen)	High	High	Moderate
Auctions for domestic hydrogen production (Hydrogen Bank) (EC 2023d)	Grants & subsidies (production of hydrogen)	Moderate	Moderate	High
Auctions for hydrogen imports (planned) (Hydrogen Bank) (EC 2023d)	Grants & subsidies (production of hydrogen)	High	Moderate	High
Innovation Fund grants and Carbon Contracts for Differences (planned) (EC 2023b)	Grants & subsidies (production + use of hydrogen)	High	Moderate	Moderate
IPCEI Hydrogen (European Parliament et al. 2021)	Other (multiple)	Moderate	Low	Low
Trans-European Networks for Energy (TEN-E) – Projects of Common and Mutual interest (EC 2023a)	Other (transport of hydrogen)	High	Low	Moderate
Temporary Crisis and Transition Framework (EC 2023c)	Other (multiple)	Moderate	Low	Low
US instrument mix	**Type of instrument**	**Resilience of hydrogen uptake**	**GHG + env. effectiveness**	**Economic Efficiency**
US Hydrogen Strategy (Department of Energy 2023b)	Strategy (production, use + transport of hydrogen)	High	Moderate	Moderate
IRA Hydrogen Production Tax Credit (PTC) (Federal Register 2023)	Tax credit (production of hydrogen)	High	High	High
IRA Advanced Energy Project Credit (AEPC) (Department of Energy 2024c)	Tax credit (production of hydrogen)	High	Moderate	High
IRA Alternative Fuel Vehicle Refueling Property Credit (IRS 2024)	Tax credit (use of hydrogen)	Moderate	Low-Moderate	Low-Moderate
IRA Carbon Capture and Sequestration Tax Credit (CCSTC) (The White House 2023b)	Tax credit (production of hydrogen)	Moderate	High	High
IRA Grants and loans for auto manufacturing facilities to manufacture clean vehicles, including fuel cell electric vehicles (FCEVs) (Department of Energy 2024a)	Grants & subsidies (use of hydrogen)	Moderate	Low-Moderate	Low-Moderate
IRA Clean Vehicle Credit (IRS 2023a)	Tax credit (use of hydrogen)	Moderate	Low-Moderate	Low-Moderate
IRA Sustainable Aviation Fuel Credit (IRS 2023b)	Tax credit (use of hydrogen)	Moderate	Low-Moderate	Low-Moderate
BIL Industrial Demonstrations Program (Department of Energy 2023a, 2024b)	Grants & subsidies (production + use of hydrogen)	Moderate	Moderate	Low-Moderate
BIL Promotion of Regional Hydrogen Hubs (The White House 2023a)	Other (production and use of hydrogen)	High	Low	Moderate

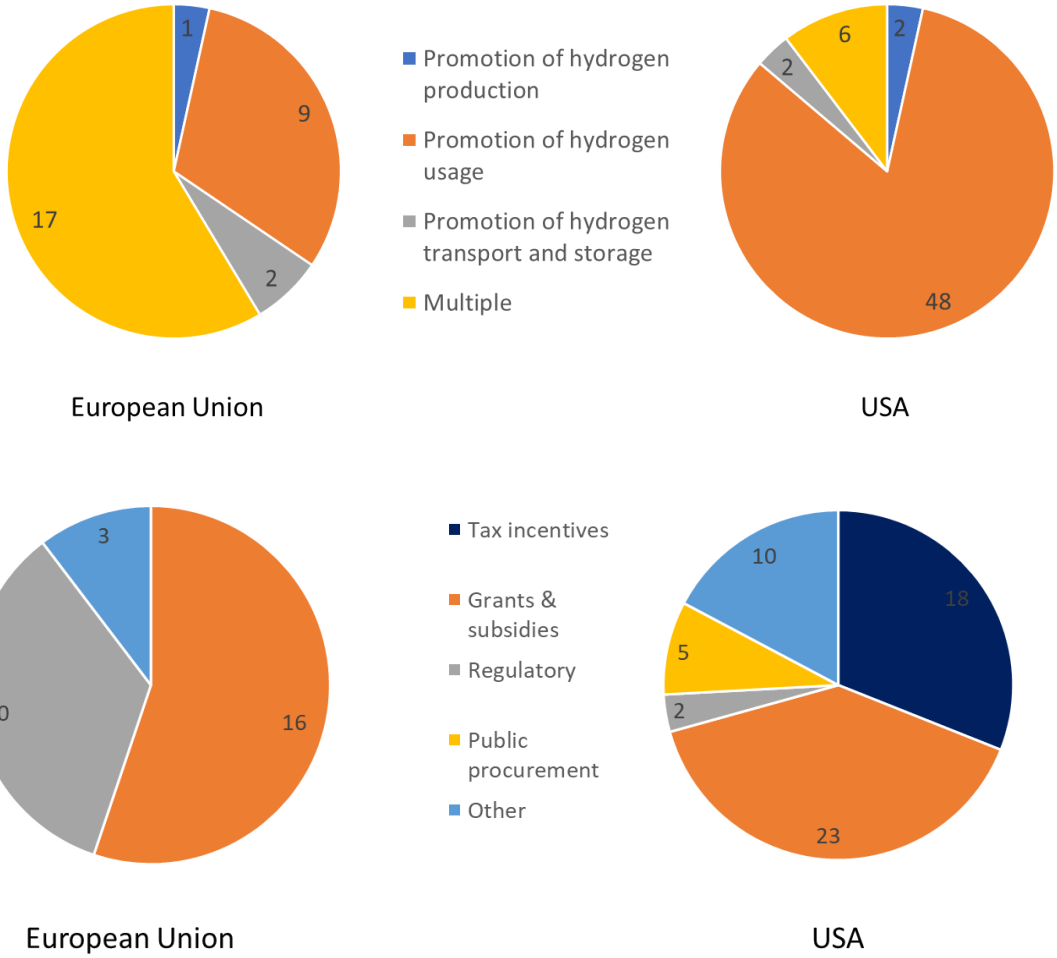
1.2 Quantitative comparison of the policy mixes

Complementing the brief overview of key policy objectives and instruments, this section provides a quantitative summary of policies aimed at promoting investment in the hydrogen sector, thereby supporting the deployment of hydrogen-related technology and infrastructure in the EU and the US. For this, the paper draws on a unique data set comprising policy instruments enacted in the EU and the US up to December 2023. Policies were coded by instrument types and by targeted segment of the value chain[1]. With regard to the latter, Figure 1 reveals that the US has a stronger focus on instruments explicitly targeting hydrogen use, while the EU has a large share of instruments that target multiple segments of the hydrogen value chain.

In terms of instrument type, Figure 1 shows that both economies have deployed a similar number of investment support schemes that provide traditional grants or subsidies. Meanwhile the US has complemented this with a range of tax credits under the IRA. Generally, these function as tax incentives and have been coded as such. However, it is important to note that in certain cases they can also result in direct payments by the US tax authority to the entity claiming the tax credit, thus taking on the nature of a grant or subsidy. Unlike the EU, the US also utilizes public procurement as a vehicle for promoting the deployment of hydrogen technologies. In the EU, regulatory measures, such as the quotas for hydrogen use in the RED, play a central role.

[1] More information on the database can be found here: International Hydrogen Policy Tracker. The codebook is available upon request..

Figure 1 Policy instruments for investment promotion by target domain and type



Given the fact that the dataset does not account for the relative scope and impact of individual policy instruments, the resulting quantitative assessment should be seen against the background of the preceding qualitative review. For instance, it is important to note that the IRA tax credits are limited in number but are likely to have a large impact on investment, the relative importance of which is not captured in the quantitative data.

1.3 Guiding questions for the comparative assessment of cornerstone instruments of hydrogen support systems

Given that the impact of the instrument mix cannot be observed yet, we apply our three assessment criteria by evaluating the design of the individual instruments in the mix and synthesizing the findings across the various policies. To this end, we use a set of guiding questions based on the key indicators derived in Section 2 of the main article, see Table 2.

Table 2: Guiding questions for assessing the key indicators associated with the criteria to assess hydrogen support systems

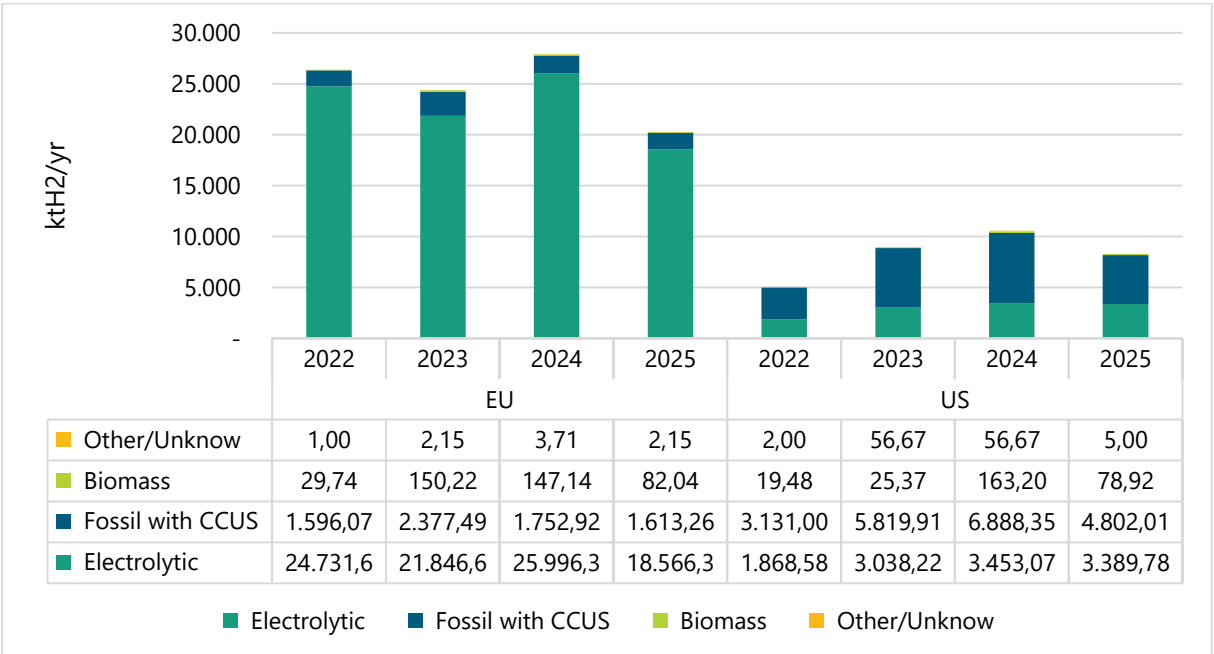
Resilience of hydrogen uptake	GHG effectiveness	Economic efficiency
A1. How does the instrument mix align the uptake of hydrogen demand with the uptake of supply, including provision of transport and storage infrastructure development?	B1. How is production and/or use of hydrogen with substantial GHG emissions reductions ensured or incentivized?	C1. How is allocation of support to the most cost-efficient H_2 producers and users incentivized?
A2. Is the creation of export/import infrastructures for hydrogen and/or certain derivatives incentivized?	B2. Which types of H_2 production are eligible? Is it consistent across policies?	C2. How is the level of financial support determined and ensured that excess financial support to private actors is avoided?
A3. How is local manufacturing addressed by the instrument mix?	B3. How is use of H_2 in applications without more effective options incentivized? Which end-use sectors are prioritized?	C3. Do the support systems hedge against any economic risks and uncertainties and how?
A4. Do the instruments address diversity of suppliers, producers & manufacturers?	B4. How does the instrument mix address a potential fossil lock-in?	C4. What is the administrative burden and costs for legislative authorities and other actors?

1.4 Additional analysis to validate the ex-ante assessment

To assess the effects of policy measures on the actual ramp-up of hydrogen supply and infrastructure, hydrogen supply developments in the IEA databases are assessed over the period 2022–2025. **Figure** 2 shows the development of project announcments for hydrogen production capacity operational by 2030, both electrolytic and fossil with CCUS from 2022 to 2025. Over the assessment

period, the announcement of hydrogen capacity exhibits strong volatility across both the EU and the US, particularly when comparing electrolytic and fossil-based production with CCUS. In terms of total announced capacity, the US exhibits significantly higher short-term growth rates than the EU, particularly in 2023. Announced electrolytic capacity in the US grew by 62.6% in 2023, while there was a decline in the EU (-11.7%). Fossil-based capacity with CCUS expanded by almost 90% in the US, compared to around 50% in the EU from 2022 to 2023. However, clear signs of a slow-down and partial contraction emerge by 2025 in both regions, particularly for fossil-based projects with CCUS. The reductions in announced capacity observed in the US and the EU between 2024 and 2025 are consistent with global developments, as total announced hydrogen project capacity for 2030 declined for the first time since the IEA's Global Hydrogen Review 2021 (IEA 2025).

Figure 2 Development of projects announced to be operational by 2030 per production technology in the EU and the US



	EU 2022	EU 2023	EU 2024	EU 2025	US 2022	US 2023	US 2024	US 2025
Other/Unknow	1,00	2,15	3,71	2,15	2,00	56,67	56,67	5,00
Biomass	29,74	150,22	147,14	82,04	19,48	25,37	163,20	78,92
Fossil with CCUS	1.596,07	2.377,49	1.752,92	1.613,26	3.131,00	5.819,91	6.888,35	4.802,01
Electrolytic	24.731,6	21.846,6	25.996,3	18.566,3	1.868,58	3.038,22	3.453,07	3.389,78

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