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Green hydrogen infrastructures within the low-carbon energy transition: Emphasis on the necessity and efficiency of public Investment schemes

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Authorship declaration

"I hereby declare and confirm that this thesis is entirely the result of my own work except where otherwise indicated. I acknowledge the supervision and guidance I have received from Prof. Agime Gerbeti. This thesis is not used as part of any other examination and has not yet been published."

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Abstract

Following the draft of the European Commission's 2050 Vision "A clean planet for all" and the infamous 2020 European Green Deal, a new wave of corporate initiatives and challenges arose. Those are in line with the so-called "low-carbon energy transition" and a shift towards a greener economy. The concrete implementation thereof has been challenging due to many market failures impeding a satisfactory emergence of a market for green hydrogen. The past year, the development of the market and of the regulatory framework saw a shift in the matter as the Economic and Social Committee called for more public investment in clean energy. This has been more than ever under the spotlights. Many reports confirm this trend and underline its importance. However, some scholars seem sceptical and use L&E arguments to criticize this approach.

Therefore, considering the significance of this problematic, the aim through this EMLE thesis is to examine the efficiency of those schemes. Is public investment indeed a golden solution to the energy transition that needs to be enhanced? Or is it rather a windfall and better instruments need to be considered?

Green hydrogen infrastructures within the low-carbon energy transition: Emphasis on the necessity and efficiency of public Investment schemes

Authorship declaration 2

Abstract 3

A. Introduction 6

B. Green hydrogen as a vector of the energy transition: *Quo vadis*? 8

I. Economical assessment of the market 9

1) The technology and its value chain 10

2) Market failures 11

a) Market power 12

b) Externalities 13

c) Information asymmetry 14

II. Regulatory assessment 15

1) At the European level 15

2) At the national level 17

C. Investment in Green Hydrogen: *de lege lata and de lege ferenda*. 19

I. A fruitful environment 21

1) A shift away from conventional energy 21

a) Removing fossil-fuel subsidies 21

b) Carbon taxes 22

c) Emission trading 22

2) … And a shift towards green energy 23

a) Financial incentives 23

b) Clarity of the regulation as a signal 23

II. Public investment instruments and policies 24

1) Dedicated funds 25

2) Rules facilitating State Aids in Green Hydrogen 27

a) Non coverage by rules on State Aid 27

b) Light coverage by rules on State Aid 29

III. L&E Assessment 30

1) Picking winners 31

2) Risk considerations 32

3) Rent-seeking 34

4) Market power 35

5) Societal considerations 38

D. Conclusion 39
E. Bibliography 42

Word count: 11.499, including footnotes.

A. Introduction

Our resources on earth are scarce. Energy is scarce.

This affirmation unsettles the entirety of our planet with regards to the anxiety generated by climate change. But it also perturbs the day-to-day life of many European citizens. The most recent example only dates to the past year, 2022, and is still current. The Russian invasion of Ukraine brought to surface the problematic of the dependence of most of the European countries on Russian fossil fuels. This has escalated the electricity prices in Europe, leading to an energy crisis.

The European Union was called to react. But those are not groundbreaking news. Energy concerns have headlined all kinds of international conventions and regulations in the past years. The seventh goal of the Sustainable Development Goals (SDGs) of the United Nations is all about affordable and clean energy. Energy concerns are also treated in the groundbreaking EU Green Deal. There are even specialised international bodies for the matter such as the International Renewable Energy Agency. More specific instruments have also targeted energy like RePower EU adopted as a response to the dependence of the EU on Russian fossil fuels. And the list goes on.

When delving into these instruments, there springs up one specific yet complicated answer, that of energy transition or decarbonisation. Simply put, it means the 'removal or reduction of carbon dioxide output into the atmosphere and is achieved by switching to usage of low carbon energy sources' (Vennix et al., 2021).

Within this vague of decarbonisation, 'hydrogen' finds a revolutionary role. Already in 2002, Professor Rifkin wrote that Hydrogen is the 'forever fuel' as it is already an abundant element in the universe and extracting it only requires heat and pure water. He went as far as saying that 'a new economy powered by hydrogen will fundamentally change the nature of our market

and of our political and social institutions'. The more studies were undertaken, the more it was confirmed that without incorporating hydrogen technologies in energy transition strategies, there will not be enough potential to completely submerge in a carbon neutral future.

Due to the growing interest in the matter, the European Union decided to act. More so, it has the ambition to become its central hub in the global scene. It has set an ambitious goal to reach by 2030, that is of having 42.5% of renewables within its total energy and, to become carbon neutral by 2050. Statistics also show that since 2005, the increasing replacement of fossil fuels with renewable energy across the EU led to a 7% drop in sulphur dioxide emissions and a 1% drop in nitrogen oxide emissions (Fit for 55, 2021). Further, some of its Member States have avoided a great amount of emissions thanks to renewable energy. Such is the case of Sweden with a drop of 5.7 million tonne of CO_2 per capita. Green hydrogen is now expected to further help attain those goals, making it a big topic of conversation on the regulatory level. Also, there is a pressure on the level of the European Union to pursue this line of growth as the United States of America under the Biden Administration have adopted in 2022 the 'Inflation Reduction Act' (hereinafter, 'IRA') with similar leading goals with respect to energy and carbon neutrality by 2050 (IRA, 2022).

Even though interest in green hydrogen is reaching unprecedented levels, several barriers are still impeding its full contribution to the energy transition. Most of the obstacles arise from the fact that it is still a nascent market and an emerging industry. Its development is furthermore tinted with all sorts of market failures that only decelerate it. This is why it is crucial to gain a good overview of the recent European regulatory incentives related to its forming and its blossoming. This will be examined in the first part of the present paper – *Quo vadis*?

Then, regulating the market is coloured with financial obstacles all the way. It lacks a dedicated infrastructure, and this is hindered by the high costs of such an infrastructure compared to fossil

fuel sources (IRENA, 2021). On that regard, 'a more comprehensive understanding of the role of the state to enable innovation process for energy technologies is paramount for policy analysis' (Bettin, 2020). Therefore, public investment appears to be key in the matter and it needs to 'go beyond research and development – and support technology demonstration, manufacturing and deployment as well as energy efficiency and the build-out of electricity infrastructure at scale' (Meckling, 2019). Hence, the second part of the present paper will be dedicated to the deployment of public investments towards green hydrogen followed by the assessment of their efficiency – *de lege lata and de lege ferenda*.

Please note that green hydrogen is part of a complex value chain. This means that it would be too labyrinthine to explore those issues throughout the entirety of the value chain. When it is not possible to analyse this as a whole, we have decided to focus on its infrastructures. This is especially true when a more detailed and specific reasoning appears to be crucial. This choice is motivated by the following words of the International Renewable Energy Agency when referring to the midstream level of green hydrogen: 'many strategies were enacted in the past few years but were mostly targeted on the last level of the value chain, that of the end use of hydrogen (…). More recently, there has been a groundbreaking change that could be what might change the game for the hydrogen' (IRENA, 2020). Finally, from a geographical perspective, this paper will discuss the European market.

B. Green hydrogen as a vector of the energy transition: *Quo vadis*?

A new market for Hydrogen needs to emerge or, at least, a modification of the existing gas market. Unfortunately, many obstacles reflected in various market failures are still hindering it. When presented with market failures and when the transaction costs are too high for a

market-based instrument to solve such failures, regulation is needed (Faure, 2020). This is an application of the Coase theorem.

Consequently, the ultimate cornerstone goal becomes to create sufficient regulatory incentives so that Hydrogen can be cost-effectively transported from production to consumption. Adopting a comprehensive framework is also necessary for incentivising related investments.

As Sunita Narain, Director General of the Centre for Science and Environment in India has stated, the sphere of the 'why' a green transition should occur is outdated. Public authorities and all stakeholders should pivot towards a 'what' approach. The clock is ticking and the 'world needs real solutions that can be scaled up at speed to meet the needs of all transformational solutions' (Scoones et al., 2015).

Herewith, we would like to draw an overview of the state of developments of the state of the dynamics of the market of green hydrogen. *Quo vadis*? Part I will assess this economically and the Part II will enumerate some key legal measures.

I. Economical assessment of the market

Back in 2019, the International Energy Agency (hereinafter, 'IEA) has published some statistics showing indeed that the demand for hydrogen has increased but 99% of it is filled by fossil fuels (IEA, 2019). Due to the practical considerations and the novelty of the technology, there are various possible market failures linked to the emergence of this Hydrogen market. If those are not identified and then resolved, we could be failing this technology and not using it to its maximal potential.

This chapter therefore aims at understanding the technology at hand and its complex supply chain before delving into its potential market failures with a thorough lens directed towards the hydrogen infrastructures.

1) The technology and its value chain

Hydrogen as an atom is indeed abundantly present and makes up almost three-quarters of the mass of our universe (FSR, 2022). However, extracting it and effectively using it does not appear to be that simple. Indeed, H_2, i.e., Hydrogen in its molecular form is rather scarce. Yet, it is the form that is of interest for the energy transition at hand.

It is also worth mentioning that not only different techniques have been used and developed to extract Hydrogen, but they also contribute to what is called in jargon the different 'shades' of Hydrogen. From this point of view, Hydrogen is not that revolutionary as it has already been used for industrial purposes. In those cases, it is extracted by non-renewable means and out of unsustainable sources such as coal. This shade of hydrogen is called *grey* hydrogen. In between, we have the shade of *blue* as it presents similar characteristics to the grey hydrogen, but it also captures carbon. In that sense, it could be useful during the early stages of the energy transition (IRENA, 2021). Finally, there is the *green* hydrogen or clean hydrogen. It is hydrogen that is produced by renewable methods via green sources.

Furthermore, in order to gain a clear understanding of how the market is likely to function, regard should be made to the value chain. The overall term of 'green hydrogen' hides 4 important steps. In the first place, it needs to be *produced*. While we have mentioned that the atom H is one of the most abundant elements in our universe, it exists under various forms and not all can be used to generate energy. Only its gas variant is of relevance, but this is only found with other elements, such as with Oxygen under the molecule of H_2O (Sharma & Ghoshal, 2015). Therefore, productions processes have emerged in order to separate the Hydrogen (H_2) from the Oxygen atom (O). One eminent example is that of 'electrolysis'. This method splits water into hydrogen and oxygen via electricity. Now, if the electricity is itself generated by wind or solar energy, we can talk about 'green' hydrogen. So far, water electrolysis fuelled by renewable electricity is the most established green hydrogen production technique (IRENA,

2021). We can refer to the phase of production of Hydrogen as the *upstream* level of the supply chain.

Then, at the *midstream* level, hydrogen still needs to be *transported* and *stored*. Whilst the first stage requires a lot of research and developments and very precise techniques, this stage is all about a combination of technology and huge infrastructures. This is commonly done by containers and pipelines. The former transports and stores hydrogen either under a compressed gas form or a liquified one. The latter can only transport hydrogen through its gaseous form. This is advantageous because once transported, it needs either way to return to its gas form (Hydrogen Europe, 2023). Thus, the variable costs of pipelines are lower. However, their fixed investment costs are much higher than those of the containers.

Reaching slowly the *downstream* level of the value chain are the *end-users*. Once produced and transported, it can be concretely applied to some economic sectors. For instance, it is applied into ammonia production, steel production but also some more trendy markets such as that of cars with the fuel cell electric vehicles (IEA, 2019). It is even put into application in the construction sector to lead to a more sustainable lifestyle through the generation of electric heating (Oliveira et al., 2021).

2) Market failures

The classical rule justifying regulatory intervention by the State is when the functioning of the market fails on its own. In other words, when at least one of the 4 known market failures is of relevance: information asymmetry, market power, externalities and public goods. This analysis usually concerns already existing markets (Ogus, 2004). Yet, we have mentioned repeatedly that the particularity of the green hydrogen market is that it is tangibly non-existent. It yet needs to emerge. This makes its analysis following the traditional *ex-post* method compromised (Mulder et al., 2019). Although complicated and fairly speculatory, this blank canvas might

hold the advantage of a chance to establish *ex ante* a functioning market, rather than looking at its failures *ex-post.*

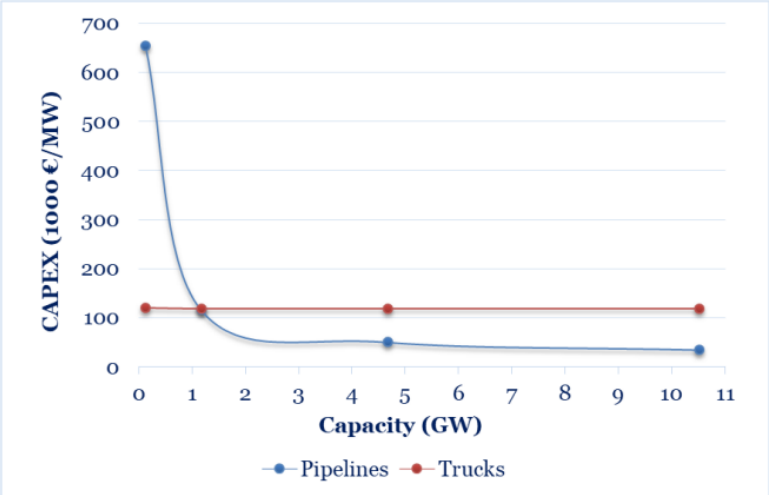
These conditions are to be determined on each part of the supply chain of Hydrogen. In fact, it would be close to impossible as well as dangerously ambitious to wholly integrate the market to start with. For the means of this thesis, we will focus on the midstream level, i.e., the storage and transport infrastructures as aforementioned.

a) Market power

According to George J. Stigler in its famous paper '*The economists and the problems of monopolies*', the ideal scenario of perfect competition on market is almost impossible to meet and many markets fall short on it. This is true for the case of green hydrogen infrastructures.

While it is correct that there are various means of transporting hydrogen, pipelines appear to be the most suitable option from a cost-benefit perspective. For a similar transport capacity, the overall costs are lower for this method on a long-term basis. Economically speaking, especially as we are talking about big quantities, a high capital cost investment will be balanced by low operation costs. Such an efficient system of transportation means lower transaction costs and, in turn, lower prices for the end consumers (World Energy Council, 2019). The figure below illustrates this difference in costs for the operation of pipelines and trucks.

Figure 4.3 Investments in pipelines and trucks in relation to total transport capacity (in 1000 €/MW)



M. Mulder et al. (2019), Outlook for a Dutch hydrogen market, p. 60.

Plus, the high initial capital costs and fixed costs make it efficient to only have one single network (Mulder et al. 2019). This amounts to a situation of a *natural monopoly*.

Hence, one of the components of market failure becomes at play: that of market power. While market power held by monopoly always raises a red flag in the sense that the single firm might abuse of its dominance, it is also true that those centralised technologies can generate a scenario of economies of scale. If so, the long-run average total cost will decrease as the output increases and the fixed costs will be counter-balanced (World Energy Council, 2019). Consequently, a public policy instrument is of essence in this case because a balance must be struck to sway more towards the positive aspect of the natural monopoly rather than its perils.

b) Externalities

Following the report of the International Renewable Energy Agency (hereinafter, 'IRENA'), the hydrogen market could generate *negative externalities*. A negative externality occurs when the economical activity at hand causes an indirect harmful impact to a third party. *In casu*, the activity is likely to generate some environmental harms. For instance, it could damage crops as land will be used to build the infrastructure. The risk is that those externalities never fully

get internalised as we might be lacking a proper monitoring system to ensure that the technology is not producing greenhouse gas emissions (World Energy Council, 2019).

One option to internalise those environmental externalities, would be to include high carbon taxes (Scita et al., 2020). This instrument usually takes the form of a predetermined price on the carbon dioxide emitted. Technically, having carbon taxes should not be a problem for the hydrogen market, even more it could be an instrument making it more competitive as its core aim is to emit less CO_2 (Wei et al., 2023). Hence, this instrument helps internalize the externalities and indirectly control if the technology indeed serves its goal. Another option would be to include a trading system (IRENA, 2021). This sets a limit on the emissions and once the limit is reached, a price must be paid. Those instruments will be detailed hereinafter.

c) Information asymmetry

As this is a new, complex and rapidly evolving technology, the information might not flow accordingly between all market players. This might occur throughout the value chain, i.e., between producers, regulators and consumers. Then, this can arise on one level of the value chain, such as the transport system between the regulators, the investors and the developers of the infrastructure. More traditionally, there is also a risk of information asymmetry from a supply-demand point of view on the market. Consumers might not be able to assess the full characteristics and advantages of green hydrogen and, in turn, might not be ready to put a high price on it (Mulder et al., 2019). Specifically on the economic sectors of end-uses, the shade of hydrogen (grey or green) might be disregarded and a fear of being cheated might arise within the consumers. Therefore, even if there is a will to go greener, there exists a risk of a legitimate confusion between green hydrogen and grey hydrogen if the price of green hydrogen remains this uncompetitive and unattractive. This may result in an *adverse selection* problem in the sense that the sustainable product gets squeezed out of the market.

As a response to this, regulation is required, on the one hand, to invest and set prices to internalise the unattractive prices on the market. On the other hand, regulation is required to send the correct signals to consumers. This can be done via a certification scheme (*see below*).

II. Regulatory assessment

The previous chapter enlightened on the complexity of the hydrogen chain and its likely market failures. This advances the fact that it is largely unlikely for its market to emerge spontaneously. Its establishment strongly relies on the availability and the efficiency of the legal standards. This is currently in development both on the level of the European Union and its Member States. Despite the level of regulation, we can expect some flexibility within the instruments as the state of the technology might require some subsequent regulatory adjustments to reflect any changes on the market (Jayanti, 2022).

1) At the European level

This year (2023), dr. Camilla Bausch, Director of the Ecologic Institute Europe, stated that 'Europe is on a journey to shift away from natural gas to renewable and low-carbon gases and we have to create the right market conditions for that to happen. In a way that promotes competitiveness, protects consumers and advances our climate-neutrality objective for 2050. This statement goes hand in hand with the past critical decade on the regulation by the European Union of general policies touching upon renewable energy and, progressively upon a specific framework for green hydrogen. Whilst many of those are soft law instruments, an increasing number is in the spectrum of hard law.

Building on that, the European climate law set a legal obligation according to which EU carbon emissions should drop by 55% by 2030. This timeline is the first stage of the European green transition. Ideally, this should be followed by a second stage aiming to make the EU carbon neutral by 2050. Hydrogen being one of the vectors, it has received broad regulatory attention

opening to the enactment of the EU Hydrogen Strategy back in 2020. It contains global provisions on the way by which hydrogen can be enabled on the market and some overall objectives to be reached.

This was followed by the 'Fit for 55' package adopted on the 14th of July 2021. This is a thorough instrument detailing how the energy framework could be aligned to reach its 2050 objectives. It contains various tools enabling this transition, one of which is a further increase of the share of renewable energy by 2030 (Fit for 55, 2021).

As a response to this, bundled with some other instruments such as REPowerEU and NextGenEU, a recent core agreement struck jointly by the European Council and the European Parliament was to review the EU renewable energy directive. The first EU Renewable Energy Directive called 'RED I' was enacted back in 2018 with a target of 32% share of renewable energy by 2030. Over the past few years, new information and studies have declared this insufficient. The target should become more ambitious. Effectively, the revised Renewable Energy Directive, RED II, was enacted in March 2023. The shares of renewable energy in the EU energy consumption now stand at 42.5% by 2030. This directive sets a broad range of goals to be reached by the Member States by 2030 with respect to renewable energies. When this document refers to 'renewable fuels of non-biological origin' (hereinafter, 'RFNBOs'), it also targets renewable hydrogen (Press Release dir. 2001/2018/EU, 2023). For example, it sets a minimum requirement on Member States to include 1% of RFNBOs in the share of renewables in the transport sector (Press Release dir. 2001/2018/EU, 2023). As for industrial purposes, the proposal insists on having 42% of the hydrogen used to be green. This targets the issue of grey hydrogen. In order to enable those requirements, the directive also softens the rules on public permits with regards to renewable energy projects considered to be of overriding public interest (Press Release dir. 2001/2018/EU, 2023). EU funds will be further deployed to those means (*see Point C.II*).

The European Commission also drafted back in mid-December 2021, the European a Hydrogen and Decarbonised Gas Market Package (hereinafter, 'Gas Package'). This package sets the direction to review the EU rules concerning the natural gas market, i.e., the Gas Directive 2009/73/EU and Gas Regulation 2009/715/EC.

The Package addresses regulating hydrogen by analogy to the regulation of natural gas markets. Instead of building new pure hydrogen networks from scratch, it suggests remodelling the existing gas infrastructure and regulation. This approach is generally referred to as 'Repurposing gas networks to pure hydrogen'.

In the long run, the goal is to create a European Network of Hydrogen Network Operators. Such networks would enable cross-border coordination and elaborate specific technical rules (Tanase, 2022). Its buildout is currently set in a bottom-up way (*see below*). On top of that, the package insists on the need to harmonise the definition of the various terms used in the jargon as they are currently quite unclear and intertwined (Marcu et al., 2022). Consumer protection rules with an aim to counter the above-mentioned informational asymmetry are also envisaged.

2) At the national level

National contributions to the EU-level target for green energy are set in the national energy and climate plans (NECPs). The regulatory cycle generally starts with the R&D programmes which aim at understanding the technology at hand (IRENA, 2021). This also helps assess the vision, goals and roadmap of the intervention to finally lead to the enactment of a concrete strategy. This of course includes direct public policies. However, a good strategy does not only create new laws but also assesses how to include already adopted policies in the overall plan. Outdated policies should ideally be reviewed or even removed as part of this programme. This is in line with the Better Regulation Toolbox as reviewed by the European Commission in July 2023. Some even go as far as suggesting that absent such a methodical process, it is all likely to fail

especially as statistics show that no EU country is currently on track to achieve its SDGs on time (Hametner and Kostechkaia, 2020). Therefore, mainstreaming sustainable developments in the regulatory environment is conditional upon an adequate use of the better regulation tools (Renda, 2017; Simonelli, 2021). Such strategies, referred to as 'National Hydrogen Strategy' have been adopted by many national governments. For example, the German government shows ambition by setting a target of gas neutrality by 2045 (Bundersministerium fur Wirtschaft und Klimaschutz, 2020). Belgium also manifested ambitious behaviour by aspiring to become a hydrogen leader (Thompson, 2023).

Building on those strategies, core policies need to be advanced to push hydrogen from niche to mainstream (IRENA, 2021). At this phase of the regulatory cycle, public-private partnerships are important as they help understand the needs of the market and, in turn, mitigate the information asymmetry at hand. For the purposes of this paper, we will not delve into detailed considerations on that regard. It is nevertheless interesting to note that Germany, on the one hand, has adopted an approach that goes hand in hand with the 'repurposing of gas networks to hydrogen' in the sense that it has amended its Energy Industry Act by adding a new chapter on the regulation of hydrogen networks. Belgium, on the other hand, adopted in 2023 a groundbreaking proposal by establishing a dedicated regulatory framework for the market hydrogen midstream, making it the first country in the world to do so.

Finally, when hydrogen is indeed produced, national governments should think of *a posteriori* considerations. On that regard, it is strongly advised to have some certification system to ensure that the hydrogen produced won't be grey hydrogen. Indeed, the facilities can produce both shades and it might be on the long term cheaper and more advantageous cost-wise to 'falsify' the system and use the technology to produce grey hydrogen when it was initially built for green hydrogen (IRENA, 2021). Those certificates ('guarantee of origin') could eventually be

based on the number of GHG emissions. Also, these schemes could be key to creating a more global market for green H_2 as they would help clear out trading conditions (IRENA 2021).

Having regards to the elements above, it is clear that some national legislators have taken the lead. This is of course very positive as developing domestic hydrogen markets will lead to more cross-border trade and, in turn, to a mature hydrogen network. Having some Members States as pioneers in the matter follows a bottom-up approach. This means that the starting point stands at the smaller national level and then builds up to a larger regional and international scale. Having a too fragmented regulatory framework across the EU is risky and might not be very effective. This is because harmonising the rules at a later stage could present a higher administrative burden and higher regulatory costs for the Member States. It is also conceivable for such an approach to create uncertainty for the companies having benefited from a clearer policy, which could then lead to induce less cross-border trade, rather than enhancing it. In order to get the most out of the bottom-up and the top-down system, a smart mix approach can be the answer (Van den Bergh, 2016). A smart mix basically means that each regulatory canvas has its own strengths and weaknesses, and their combination could be the 'best of both worlds' (Gunningham and Sinclair, 2017). This can be done in this case by, for instance, setting an informational exchange scheme or by having a monitory assessment system.

C. Investment in Green Hydrogen: *de lege lata and de lege ferenda*.

The EU Hydrogen Strategy states that one of the key policy actions towards attaining the aforementioned objectives is to increase investment support (Economic and Social Committee and the Committee of the Regions, 2020). The Fit for 55 Package also underlined the requisite of the increase of funding for modernisation and innovation. This is applicable to all the levels of the supply chain.

Before delving into the topic of investment in green hydrogen, two prior observations are noteworthy. Let's start by mentioning that while it is true that some schemes appear to be cheap, it is often not the case. In the specific case of hydrogen infrastructures for its transport, repurposing natural gas infrastructures seems *a priori* as a cost-efficient option and as a swift one. But repurposing as such is costly because from a technical point of view, gas and hydrogen have different densities (Jayanti, 2022). Gas is transported mainly through truck and ships, which also work for transporting Hydrogen. However, as we have previously mentioned, they are not the most cost-effective option. Specific hydrogen pipelines are much more advantageous on the long run but on the short run, they first need to be recouped.

Let's continue with the observation according to which the market and government failures are also constraining investment in clean energy (OECD, 2015). As long as the market is not able to resolve such failures by appropriately internalising externalities, resolving any information asymmetry issues and by regulating the market power of such sectors, it will be utopistic to expect that the investment instruments will be directed towards green energy. If nothing changes, how can we accordingly expect to send the correct investment investments 'away from conventional energy towards clean energy' (OECD, 2015)? As a response to this, the policy guidance for Investment in Clean Energy Infrastructure as published by the OECD suggests that it is mandatory to 'provide investors with well-designed, well-timed, well targeted and time-limited incentives' and to enact policies to coordinate such incentives, whatever the form of the investment.

Regulations fostering investment in green hydrogen infrastructures are promising. We will start by analysing how a fruitful regulatory environment can lead to a shift from conventional energy towards sustainable energy. Then, we will examine the hard-core public investment funds and the leniency of the corresponding State aid rules. Finally, their efficiency will be considered from a Law and Economics angle.

I. A fruitful environment

Before analysing the *in concreto* instruments that have recently emerged, the current dynamics of the market from that perspective should be regarded. Clean energy needs an enabling environment to grow and become more and more competitive with the years (Steenkamp, 2017). Before resorting to public funds, we can start by creating a shift of investment away from conventional energy (i.e., fossil-fuels) towards clean energy (OECD, 2015).

This is what is meant by creating a 'fruitful environment' for investment. Also, from a better regulation perspective, 'when legislative proposals create new burdens – on businesses or citizens – an equivalent existing burden in the same policy area should be removed' (Dunlop et al., 2022). In other words, it is not efficient to simply regulate but also to assess which regulations are not working anymore and to do something about that.

1) A shift away from conventional energy

a) Removing fossil-fuel subsidies

The first step is to redirect the budget granted for subsidies in fossil-fuels towards green energy. It is as simple as it gets: the more public budget goes towards fossil-fuels, the more artificially attractive they will be and the more unattractive green technologies will be (OECD, 2015). While it is true that fossil-fuel subsidies can generate direct returns for politicians as they are likely to generate cheap energy to the citizens, they are environmentally disastrous and only push the problem to later (Rosers, 2021). Its disastrous effects concern our scarce resources, the climate change, energy poverty and a fall back of the country from an SDG perspective. In other words, a whole range of negative externalities. Also, let's not forget to mention that subsidies tend to stick and once granted, it will be complicated to take them away. The removal of fossil fuel subsidies should be, in consequence, done as quick as possible.

b) Carbon taxes

Carbon emissions should have a price. This should be done in a clear, credible and long-term basis (OECD, 2015). This follows a classical Pigouvian logic according to which taxes should be implemented as a mean to correct the negative externalities on the market. This is calculated based on the amount of those externalities, which is the amount of the emitted CO_2. As it is a market-based approach, it is strongly appreciated by economists because it seems to ensure the least costly compliance to society (Kettner et al., 2017). In turn, they also generate revenues that can be allocated to other funds.

Consequently, imposing carbon taxes on GHG emissions from the combustion of fossil fuels will help stabilize the market towards the most cost-effective carbon mitigation instrument. Hence, instruments emitting a lot of carbon will only become less attractive to give place to greener techniques (OECD, 2015). Its benefits are thus twofold: more resources for green funds and a signal incentivizing behavioural change.

c) Emission trading

This follows the logic of cap-and-trade. Whilst the previous measure follows a Pigouvian ideology, the present one is Coase inspired (Zaklan, 2023). When externalities are too high, he suggests setting up a 'market for pollution'. Governments would determine the optimum level of pollution and within it, firms can trade freely. This scheme also amounts to a market-based instrument.

This is how the EU implemented a 'carbon market' under an EU emissions trading system (EU ETS). This has already been introduced in 2005. The idea is that the trading system is limited by a 'cap' (i.e., the total amount of emissions permitted on the market). Within the cap, companies receive or buy emission allowances that they can 'trade' (European Commission, 2021). Since the enactment of the Fit for 55 Package, the EU decided to get the most out of this

system by aiming higher. First, the total 'cap' will decrease per year, so less and less emissions are allowed. Second, each allowance currently gives the holder the right to emit only one tonne of CO_2.

This instrument gives more flexibility to the companies and leads to advantages akin to carbon taxes.

2) … And a shift towards green energy

Deterrence instruments are the first step to deviate from the conventional system at hand. But it is not sufficient. New instruments should be able to incentivize investment in renewables.

a) Financial incentives

First, we can mention the '*Feed-in-tariffs*'. It can be compared to a reward system. It is a 'price that is guaranteed for every kWh of renewable energy supplied to the grid' (OECD, 2015). Even though it seems at first hand like an attractive instrument, it can be tricky because setting the price higher or lower than the accurate one could lead to over or under investment. In both cases, the instrument would lose its strength and might even not lead to any result.

Second, there also exists a certification system, under the denomination of 'Tradable green certificates'. This is strongly advised on the national regulatory level (*supra*). A certification would be granted to infrastructures that comply with renewable portfolio standards. Comparably to carbon taxes and emission trading, it is a market-based instrument with an aim to increase the demand of the product. This instrument could therefore be cost-efficient, but it might generate some high administrative and monitoring costs (OECD, 2015).

b) Clarity of the regulation as a signal

The financial incentives can help signal the importance of renewables at an early stage, but they are more likely to work on an 'on- and-off' which is not the best to sustain long-term investment as different factors can impact the stability of the measure (OECD, 2015). In order

to ensure and sustain the viability of the market, there needs to be clear steps as to how the market will continue to grow at the aftermath of the first stage.

These prospects can take the form of a clear, credible and coherence policy support accompanied with efficient enforcement mechanisms. Indeed, there needs to be clear long-term prospects and policy support towards clean energy infrastructures. Absent that, investors will continue to direct towards conventional energy infrastructures despite the efforts put to promote the clean market (Blyth, 2010).

II. Public investment instruments and policies

After the USA dedicated a 5 billion dollars funds dedicated to Energy Infrastructures Reinvestment Program in its IRA, 2023 blasted off in a promising way for the European Union as it has published in February its long awaited *Green Industrial Plan*. The goal of this document is to improve the conditions for investment on the European green hydrogen market. The proposal is twofold: one the one hand, it revises the rules of the General Block Exemption Regulation towards an increase of the notification thresholds in support of green investments and, on the other hand, it facilitates the use of existing EU funds for financing clean tech innovation.

According to the recent Bloomberg report, it seems that the hard work is paying off and we are heading towards a bright future for investment in clean energy. They indicate that 'clean energy is more cost-competitive than ever as fossil fuel costs remain elevated, and renewable costs are now resuming their long-term decline' (Bloomberg, 2023).

The present section will for this purpose, first, set off an overview of the dedicated funds to promote green hydrogen infrastructure in the EU. Then, it will note the modified thresholds facilitating State Aids in the green market.

1) Dedicated funds

In 2022, global energy transition investments amounted to 1.1 trillion dollars (Bloomberg, 2023) compared to 755billion dollars in 2021 (Bloomberg, 2022). This is promising but hydrogen's part in this huge total is quite restrictive as it *only* amounts to 1.1 billion dollars, but it was the one that increased the most compared to prior years (Bloomberg, 2023). For instance, the European Green Deal alone has set a budget for clean energy amounting to 503million euros (The European Green Deal Investment Plan, 2020). The scale of public investment is simply not comparable to that of private investment. For instance, in 2021, data centres and experts demonstrated that the global cash flows stemming from public finance are of 10-15% compared to <1% of overall private finance (Climate Policy Initiative, 2021).

But where is this money coming from? The funding landscape in Europe is complicated as, on one hand, many funds overlap and, on the other, there are overlaps between the EU budget as such and that of the Member States'. To simplify the issue, we can categorize the funds into three big groups (Kneebone, 2023):

- *EU specific instruments*: they are funds following a top-bottom logic and they are generally created to enhance the green market. The logic stems from large funds and programmes that then flow into more specific secondary funds directed to decarbonisation and hydrogen specific programs.
- *Member State specific schemes*: they also follow a top-bottom approach with member states dedicating a part of their annual budget to foster such investments. It stems from specific instruments at the level of Member States direct to hydrogen specific programs.
- *Blended financing instruments*: they are more 'global' instruments in that they aim at another program but indirectly they also contribute to funding the green hydrogen projects.

In order to exemplify these affirmations, we can first mention Next Generation EU, an EU specific instrument that was put into place as a recovery plan for the EU after the sanitary crisis in 2020. We can see that in such a huge fund, hydrogen finds its place and is even considered as a 'key sector (…) due to its ability to bolster the longer-term objectives of the EU' (Hydrogen Europe, 2020). Within this project, there is a dedicated programme called InvestEU with a more concrete goal that is to focus on 'economically viable projects addressing market failures and investment gaps that hamper growth' (Hydrogen Europe, 2020). Even more so, there is a specific window of that fund called 'Strategic European Investment Facility' directed towards important value chains with an aim at 'making them stronger by supporting activities in crucial infrastructure and technologies' (Hydrogen Europe, 2020). As far as our understanding goes, it is the 'jackpot' for green hydrogen as this sentence really represents the issue that it is facing. For this programme alone, the EU will stir up a total amounting to 150 billion euros either in grants or loans. Of course, not all will be granted to green hydrogen technologies, but it allows to give an idea of the stakes.

A similar instrument originally enacted as a recovery plan but that is Member State specific is the national resilience recovery plan in Italy. As Italy plans on planning its 'Hydrogen Valley', an 'infrastructural hub' covering the whole value chain of green hydrogen, the State has attributed a fund of 14 million euros (Deiana et al., 2021).

Second, the importance of hydrogen finds its application in a recent key issue, that is the ongoing war between Russia and Ukraine. Besides the geopolitical aspects of that invasion, it has also led to a disruption of the European energy market. This is where the REPowerEU Plan enters into account with a double aim: ending the EU's dependence on Russian fossil fuels and tackling the climate crisis (REPowerEU, 2022). As renewable hydrogen is one of the solutions for decarbonisation and for replacing fossil fuels, this programme promotes its development by setting a fund of 200 million Euros specifically for such projects.

2) Rules facilitating State Aids in Green Hydrogen

Public funds give an advantage to a company over its competitors and hinders the neoclassical economic theory according to which the normal functioning of the market will select its winners. Hence, State aid is prohibited by the TFEU unless 'it is justified by reasons of general economic development'. As this is an exception, it is interpreted strictly and is strongly regulated. The relevant provisions on State aid are articles 107 and 108 of the TFEU.

Notwithstanding the principle, the practice shows that the European Union can soften those rules when out of an application of the principle of proportionality, a broader application of the derogatory system is desired as to enable a crucial State aid in specific cases. This was done in the Green Industrial Plan. Accordingly, we can still refer to the *Infrastructure Analytical Grid for Energy Infrastructure* (hereinafter, 'Energy Infrastructure Analytical Grid'). In some cases, the application of State aid rules will be simply excluded and some other cases will be lightly covered by State aid rules.

The analytical grid functions on an exhaustive basis, meaning that if the scenario does not fall under the category of one of the two cases, State aid rules are deemed to be applicable. That being said, they will be generally assessed by the Energy and Environmental Guidelines[1] as well as the Service of General Economic Interest Framework[2].

a) Non coverage by rules on State Aid

Primo, This will be the case for energy infrastructures deemed as 'legal monopolies'. In some Member states, the operation of the infrastructures has been reserved to one operator (TSO – Transmission System Operator). Even if granted on national level, some cumulative conditions need to be met in order to clear any distortion of competition at EU level. First, the legal

[1] See Guidelines on State aid for climate, environmental protection and energy 2022, 2022/C 80/01, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52022XC0218%2803%29.
[2] See European Union Framework aid in the form of public service compensation, 2011, 2012/C 8/03, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2012:008:0015:0022:EN:PDF.

monopoly should be established in accordance with the treaty rules and those of the member state. Second, it should not exclude competition on and for the market. Also, it should not be in competition with other services. Finally, the exclusion of cross-subsidization and the tenure of separate accounts are requirements to be met. In short, for it to be cleared, the legal monopoly is to be established only to facilitate the transmission and storage of the produced hydrogen and not to 'pick winners' by the State.

Secundo, 'natural monopolies' are also covered. Granting a legal monopoly is not even relevant in such cases as the existing System Operator is alone on the market since any replication by other players would appear to be non-beneficial from an economic point of view. In those cases, the funding shouldn't lead to 'cross-subsidize or indirectly subsidize other economic activities' (Energy Infrastructure Analytical Grid, 2017).

Tertio, there are some infrastructures for which distortion of competition just cannot be excluded by nature. This is usually the case of some infrastructures that specifically serve their end-use and are generally built by those market actors.

Quarto, State aid provisions are excluded when they do not yield any economic advantages at such. This is also to be assessed under strict conditions. This is the case when the developer of the infrastructure does not get any direct economic advantage and that the State when funding the project acted as a 'private investor'.

The same thing applies to the operator of the infrastructure if no economic advantage can be squeezed out. This concerns, on the one hand, operators that have been selected through a system of 'tender' or 'fees'. In other words, they should not pay a more beneficial sum to exploit the infrastructure than they would've under normal and comparable market conditions. On the other hand, when the normal functioning of the market cannot duly deliver the service, the matter becomes of 'genuine service of general economic interest' (Energy Infrastructure

Grid, 2017, paragraph 18). For that, the following *Altmark* criteria[3] become of application: '(i) the infrastructure project is necessary for the provision of services that can be considered as genuine services of general economic interest for which the public service obligations have been clearly defined ; (ii) the parameters of compensation have been established in advance in an objective and transparent manner ; (iii) there is no compensation paid above the net costs of providing the public service and a reasonable profit ; and (iv) the genuine service of general economic interest has been either assigned through a public procurement procedure that ensures the provision of the service at the least cost to the community or the compensation does not exceed what an efficient company would require' (para 19, Energy Infrastructure Grid).

Finally, the Commission considers that there is no economic advantage to the user of the infrastructure when access fees and/or tariffs are set in line of the European legislation, i.e., mainly the TFEU rules in public procurement and its principles of energy law.

b) Light coverage by rules on State Aid

In some other cases, the investment will be exempted from the notification for State aid if it complies with other conditions. On that regard, art. 48 of the General Block Exemption Regulation (GBER) provides a specific framework for energy infrastructures. This mostly relates to the area in which the infrastructure is located and compliance with the overall internal market rules and the internal energy market legislation[4].

Next, if the aid for the construction of the infrastructure complies with the criteria of the decision on the operation of services of general economic interest (SGEI)[5], it also can benefit

[3] See full judgment, the Altmark Case: CJEU, Case C-280/00, Altmark Trans GmbH and Regierungsprasidium Magdeburg v Nahverkehrsgesellschaft Altmark GmH, 24 July 2003, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A62000CJ0280.
[4] See Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019 on the internal market for electricity, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019R0943.
[5] See 2012/21/EU, Commission Decision of 20 December 2011 on the application of Article 106 (2) of the TFEU to State aid in the form of public service compensation granted to certain undertakings entrusted with the operation of services of general economic interest, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32012D0021.

from an exemption of the provisions on State aid. The requirements are the following: (i) an act of entrustment, content and duration; compensation mechanism with parameters calculating, controlling and reviewing compensation; (ii) and arrangements for avoiding and recovering any overcompensation (Nicolaides, 2021).

III. L&E Assessment

The dedicated funds and the flexibility of the rules on State Aid with regards to green hydrogen set a clear tone as to how the different legislators and governments plan to finally integrate the hydrogen market.

A priori, this is the right approach. Even more so, they are the product of lengthy negotiations and are finally the long-awaited reaction from the public authorities. The goal is to adopt policy strategies that are 'framed accordingly to meet economic and societal needs while complying with contemporary global challenges' (Castrejon-Campos et al., 2022). The logic follows an endogenous growth model. Let's imagine there are two products, one containing 'dirty' technologies that emit a lot of GHG and one constituted out of 'clean' technologies. As the state of art of the dirty one is much more developed, it makes more sense economically speaking to invest in that one as it contains much more certainty and security to yield positive returns of investment. This unfortunate situation amounts to a market for lemons mechanism as introduced by Nobel Prize winner George Akerlof. When there is a high informational asymmetry between the parties on a given market, the high-quality product, i.e., the clean technologies, will be squeezed out of the market (Akerlof, 1970). The probability of this unfortunate situation on the energy market confirms the theory according to which public funds need to be solicited so that the innovation in clean technologies gets more attractive (Acemoglu et al., 2016) and its quality can be more clearly signalled.

Nonetheless, this approach received critiques by scholars. This chapter aims at raising those arguments as well as their counter arguments so that we can draw the conclusion as to whether the examined system is efficient or if its failures seem to be defenceless, driving it on the road to failure.

1) Picking winners

The first ascertainment is simple: the government is not able to effectively pick the due addressees of the public fund because it does not correctly understand the market and its conditions. Simply put, the government is not competent to 'pick winners'. A classical economic approach suggests that the role of the public policy should be limited to regulating the prices on the GHG emissions and by doing so, a normal functioning will set the financial incentives towards companies whose aim is to decarbonize.

This commentary is contested by Jonas Meckling, specialist on the topic of Environmental Science at the University of Berkley, for the following reasons. First, the amount those financial incentives will send are not substantial enough having regards to the strength and intensity at which this needs to happen. Technological change is path-dependent: private investments tend to occur in what is more profitable having regards to stocks and the available information. Therefore, it is erroneous to admit that the mere regulation of the GHG emissions will lead to the wanted market effects. A public push is necessary to support the state-of-the-art of the green technologies. Second, from a cost-benefit analysis, this amount of finance flow is much justified. The cost that the government will incur today is undoubtedly high but the benefit resulting in a few years is simply not comparable and far bigger than this cost. In fact, if the said technology indeed helps reduce the carbon emissions and reach the EU goals set for the near and far future, it might realise its goal to become the central hub for hydrogen. This will, in turn, generate a great deal of profit that just might internalise those costs. Also, from the perspective of the end-consumer, their daily costs will considerably decrease, making them less

dependent on some government aids that are currently necessary. All in all, the costs are hugely outweighed by the benefits. Third, 'picking winners' might help shift the balance of power from polluters to the economic winners. This last approach follows a 'technocentric' view of sustainable transformation. Through 'picking winners', the emphasis will be on pushing the right technologies to compete with incumbent ones (Scoones et al., 2015). Then, if they appear to indeed level up to the sustainable requirements, a desired shift of power will naturally occur.

2) Risk considerations

Green hydrogen technologies are still on early stage which naturally increases the risks of such investments. It is called by some 'the genuinely unknown' (Mazzucato, 2015). Therefore, some authors seem sceptic as to the necessity to invest public money into a technology that might not yield the expected positive returns. Yet, as far as neoclassical economics goes, state intervention should occur to fix problems of efficient allocation of resources when there is a far amount of market failures. They make it clear that it is not the role of the State to 'create' wealth as this should happen spontaneously on the market (Mazzucato, 2015). It could be even more harmful because it might 'crowd-out' the willingness of private firms to invest (Mazzucato, 2015). Furthermore, another consequence of this technological innovation is that it leads to a fair amount of information asymmetry between firms and the government. In fact, it might be hard for politicians to really have a proper understanding of the state of the art. Selecting the wrong companies might have dramatic consequences in the sense that if the companies were to fail, it would mean that the whole public policy has failed (Meckling et al., 2022).

These issues can be resolved first by a plain economic concept, that of spreading the investment portfolio, and thus spreading risks. Second, one can question the vision of the State as such. Concretely, should the role of the State be limited to only risk-averse investments and to fix issues? Philosophically speaking, some argue that the State's role should not be confined to

that and on the contrary, boldly lead the way. Indeed, by doing so, they actually 'crowd-in' further opportunities' for private investment seeing that it helps emerge a completely new market and, hence, new portfolios of investment (Mazzucato, 2015). Third, and this might be the most convincing solution, by including policy evaluations. By doing so, this first helps the government to look at what is really working, what isn't and adjust their investment trends. Plus, this helps diminish the information asymmetry as this will push the authorities to gain a better understanding of the market.

An example of this programme is observed in the United States of America, called 'Evidence-Based' by its Office of Management and Budget. That type of program is data based and aims to answer the academical scepticism with respect to the relationship between the supposed necessary investment in green technologies and a *de facto* decarbonisation. As a response, those type of programmes also embrace empirical approaches, following namely the concept of a *learning curve*. This can be broadly defined as a 'mathematical concept that graphically depicts how a process is improved over time due to learning and increased proficiency' (Kagan, 2023). A learning curve computation is based on the law of learning by doing. *In casu*, its purpose is to ascertain how the experience gained by deploying more and more hydrogen technologies leads to a cost saving over time (Castrejon-Campos et al., 2022). A study was undertaken last May with a focus on the production of Hydrogen. An analogy can be made, with some necessary scientific reservations, with the rest of the value chain of green hydrogen. On that market, the authors show that early technologies with a *de facto* more experience, can produce very low to no-carbon hydrogen (Revinova et al., 2023). This overturns the scepticism. Unfortunately, however, this finding cannot be extended to every single technology that is being developed. We can still wonder if this is actually not just another way of underlining the success of learning curves. The issue is even more circular as the authors conclude their study

by insisting on the role of State support to improve the technologies so that more experience can be attained (Revinova et al., 2023). Only then will the study be thoroughgoing.

This being so, public investment appears to be a *sine qua non* requirement for an effective green transition that green hydrogen can help reach. It would be erroneous to let the academic scepticism take over as it can be moderated by including solutions derived, on the one hand, from the abovementioned economical concepts and, on the other, from recent empirical methods.

3) Rent-seeking

By having strong public support, there could be a risk of 'rent-seeking by green industries' (Helm, 2020). This term refers to the risk of some politicians supporting green industries so that they gain political support in return. Rents *per se* are not harmful. They are advantages that some groups gain due to a measure of the government. In such cases, this happens naturally and is, therefore, legal (Espinosa, 2020). In those cases, they are even considered as a 'common feature of economic life and are crucial to driving the entrepreneurial process of efficient resource allocation' (Espinosa et al., 2021). However, they become harmful when they are artificially created by the parties and can thus manifest in cases of corruption and undue gains strange to the normal and efficient dynamism of the market. It rather weakens it by superfluously concentrating the market or distorting its price system (Espinosa et al., 2021). Those distortions of the market are subsequently captured by the parties participating in this behaviour as they get abnormal gains. This behaviour paralyzes the market (Baumol, 1990). Green industries are not shielded from rent-seeking behaviours. They might capture rents by resorting to too high prices on the downstream market or, even, by further concentrating the market when refusing access to their infrastructures. This, surely, is not desirable and even noxious. It is to be avoided at all costs, or else the enthusiasm towards these groundbreaking initiatives might ricochet.

Other scholars argue that rent-seeking is inevitable to a certain extent. At the end of the day, every project and every investment arising from the State can create those risks. However, we should balance the extra profit of the investment with its opportunity cost. Moreover, this could be justified by the Pigouvian approach of the necessity of public intervention via taxes or subsidies to internalize externalities (Furton, 2019). And there is a good deal of those on this market. Following this approach, the private and social costs are to be balanced to attain a non-divergent social optimum (Boettke et al., 2020), that is with the hypothesis that the government can locate this social optimum for the energy market. By drawing those lines, we can hope to avoid the unpleasant situation where 'desirable rents turn into excessive rents and transient rent become permanent ones' (Meckling, 2022).

Besides those considerations, we can quarter the risk of rent-seeking by imagining a sort of safety net mechanism including some disciplinary mechanisms. For example, something as simple as a sunset clause could be of assistance. This means that the policy granting the investment will automatically be terminated and cease to produce any effects at a fixed time period. This reduces the freedom of the authority granting the investment to what is strictly necessary to allow an effective transition. Put simply, there shouldn't be a too broad discretionary power attributed to the government and its administration as per necessity of the swiftness of the transition but instead an upstanding level of legislative rigor and checks and balances (Espinosa et al., 2021). On that regard, throughout the whole procedure, an obligation of transparency and monitoring set at the administrative agencies is key (Meckling, 2022).

4) Market power

It goes without saying that the way the public investment in green hydrogen is to occur raises substantive questions about the competitive character of the market. As we have already stated when analysing the potential market failures, the dynamics of the market itself present *a priori* prospects of some key players having market power. Building on that, the public investment

can escalate this element further, rather than combating it. In fact, by granting subsidies and easing up the rules on State aid, non-subsidised competitors feel a financial weight pushing them to exit the market or not entering it in the first place (OECD, 2022). Barriers to entry are specifically true in the case of the midstream market as it is a capital-intensive industry with high sunk costs (OECD, 2022).

So far, we have identified two types of monopolies on the market of hydrogen infrastructures: natural monopolies and legal monopolies. Natural monopolies occur when there are no other substitutes on the market. This is quite common in the hydrogen market as the cost of the infrastructure alone is massive, which creates a substantive entry barrier to other competitors. We can cite on that regard the German example. Legal monopolies, on the other hand, are the product of the government. Rather than merely observing it, the government actively grants the dominance of the market to a market player in order to respond to a big and hard to naturally attain demand on that market (Choi et al., 2019). This is for instance the case in Belgium (Belga, 2023). The first scenario might not be ideal, but it still somehow pushes the market to develop as this dominant player will need to continue to innovate to maintain its position. It becomes trickier when the government opts for the second scenario since ulterior developments of the market might not push the legal dominant player to innovate to maintain its position. Hence, other companies face the risk of being squeezed out of the market. In such cases, the regulation introducing legal monopolies should be followed-up with a thorough justification.

Market power, specially on the midstream market of green hydrogen, is inevitable. Even more so, to a certain extent, it is a precondition to its existence. While it is true that subsidies contribute to spiralling said dominance (and even in some case, we can argue that the dominance becomes government made), they fall out of the scope of competition specific instruments. Although we do not want to adopt a pure legalistic approach, one cannot ignore that they do answer to legitimate objectives. In order to strike a balance however between the

different considerations, their anti-competitive effects should be moderated and observed. Some state that they could be regarded as an element to consider in competition enforcement cases (OECD, 2022). Forthwith this isn't the majoritarian approach.

The regulatory trend on that regard emanates from a rationale according to which governments are well aware of the non-competitive market structures that natural and legal monopolies are likely to produce. Nonetheless, they moderate it by including some additional regulatory provisions. The Gas Package developed in late 2021 also seeks to develop hydrogen markets in a competitive way.

In fact, Hydrogen proposals both on the EU and the national level introduce unbundling requirements. Unbundling means separating with the intention of avoiding cross-subsidization. It contains two dimensions: vertical and horizontal. The former works on separating the levels of the activity on the value chain. As for the latter, it obliges to separate the hydrogen network operations from companies active in natural gases. Both are likely to produce similar effects in the sense that vertically or horizontally integrated companies should not be incentivised to discriminate against other competitors (Tanase, 2022). On top of it being horizontal or vertical, it is both legal and financial. Legal refers to an independence in terms of the legal form of the undertaking. Financial unbundling or accounting unbundling is the separation of accounts in order to ensure that there isn't any joint financing horizontally nor any risk of cross-subsidization.

Generally speaking, regulatory flexibility is granted in the first stage, i.e., up until 2030. While horizontal bundles are deemed to be interpreted in a very restrictive way by the legal practitioners, article 31 of the Gas Package admits vertical bundles in some cases in the first stage of the transition (Tanase, 2022). Besides that, some entities fall under the exceptions applicable in the transitory period until 2030. These are, first, privately owned infrastructures,

which are already existing private hydrogen networks. Second, article 48 of the Gas Package extends this exemption to geographically confined networks, in other words, networks containing clear and limited exit points through one single entry point (Tanase, 2022).

Nationally, Member States can build on those standard rules. In the German example of natural monopolies, there is solid obligation on the network to grant some mutually beneficial access conditions (von Burchard, 2021). In the Belgian proposal, a clear and unambiguous transitory period is provided. It means that although a legal monopoly is conceded, it is not deemed to be so forever. This is right-minded as additional precaution is crucial for legal monopolies.

All in all, it's all a question of balance. The anti-competitive risk is undoubtedly under the radar but so is the need for public investment. That's the balance that regulators have been striving for: how to combine core rules to battle the growing market power whilst promoting investment and sending the correct economic incentives for the market to emerge?

5) Societal considerations

Those are public funds and when public funds are in interplay, the cost-benefit aspect of the measure becomes trickier as it also means public property to the society. As a result, the society's willingness to pay for these projects should be envisaged (Kovac et al., 2021). Thus, the implementation of hydrogen technology and shifting towards an energy market based on it could have some interesting societal considerations. It is indeed a matter that affects the daily life of citizens and will be indirectly financed by taxes.

Hydrogen policies cannot ignore energy equity practices and should maybe also explore the different approaches and point of views of the community (Scott et al., 2020). An example of that is the non-unanimity concerning the safety of hydrogen. Because of its technicity, many citizens might be sceptic as to the incorporation of this new way of doing into their daily routine. They might think that a new chemical compound could present flammable

characteristics and be thus harmful for their health (Kovac et al., 2021). The literature also goes as far as saying that the likely negative externalities will be disproportionately distributed on the citizens and less favourable communities will suffer more from such a burden (Carley, 2020). Accordingly, it cannot be explored merely from a legal and economical perspective but also from a social one due to the big shift it is likely to incur.

On that regard, as long as the problem does not get overshadowed, we can expect this obstacle to be resolved by a sufficient degree of transparency from the government. The policy 'must be clear about the ultimate motive that is carbon-neutral society, direct about the possibility of reaching it, and convincing enough to receive support' (Kovac et al., 2021).

D. Conclusion

Achim Steiner, Under-Secretary General at the United Nations, declared that 'in the twenty-first century environmental imperatives will increasingly define economic policy and societal choices. Key questions such as who will make these choices, who could be the winners and losers and how will our political and governance systems mediate this process of transition are key to understanding the political economy of green transformation'. This statement finds a big relevance as we are drawing the final conclusions of this paper.

The urgency of the global transition and the EU objectives with respect to carbon neutrality have elevated the H_2 atom to an immense potential. A green hydrogen market must emerge as soon as possible, and it is time-bound. The numbers we have mentioned are promising but it is not enough. According to the specialists on the matter, like Jonas Meckling, these numbers need to increase by a factor of 6 in order to effectively limit global warming by 2030. The complexity, the technicity, the novelty and the urgency of the matter have put forward questions about the financial considerations intertwined with this transition. Those question are important because it is only by resolving them that the market can work and, in turn, reach

more sustainability (Haas et al., 2019). This paper focused on the public investment stream of those financial considerations.

The European Union and its Member States opened a wide door towards a new era of public investment in green hydrogen and more specifically, in green hydrogen infrastructures. This is all and well but the regulatory framework still lacks a harmonious and easy to access information. In fact, it is only by overlaying all sorts of European and national instruments that one can gain a slight understanding of the action and strategy of the investment schemes *in concreto*. This observation is unfortunate because it contributes to critics about rent-seeking and picking winners. This is in the sense that only a small number of companies have a chance to receive those funds since they are the only ones with enough resources (i.e., namely time and money) to know of the existence of such instruments to start with and then to apply to them. Smaller companies might be too constrained as their focus is towards the R&D of their technologies and have less resources to spend on researching and understanding the public investment schemes. This observation can be phrased from a behavioural point of view as an information overload bias. Such a bias is likely to reduce the effectiveness of some promising funds and rules. Hence, there should be a simplification and salience of the rules. By doing so, cognitive empowerment will be fostered, and this can be truly de-biasing.

Another noteworthy concluding observation is that the rules on investment in renewable energy are still tinged by various market and government failures. This includes a weak environmental policy backdrop that fails to sufficiently price fossil-fuel externalities such as greenhouse gas emissions and local air pollution and some loopholes that can favour investment in carbon-intensive energy infrastructure projects, instead of clean energy ones. As we have mentioned, the focus cannot be only targeted towards creating more funds but also towards creating a fruitful regulatory environment to clean out outdated legislations. It’s all about having a good overview of the entire situation. Conversely, we have also noticed that some regulatory efforts

to take those market failures into account whilst promoting public investment were gravely criticised. The balance is complicated to strike but the road ahead seems quite opportunistic.

We can expect the regulatory scene to grow further, and those later developments might hold some even more satisfactory answers. The success of the transition will depend on the rigour of the balance drawn between the urgency of the matter and the importance of its piecemeal buildout. If successful, the public help would have been a mere first ‘push’ towards a mature and standalone functioning market for green hydrogen infrastructures.

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