HYDROGEN TO BE

GEOPOLITICAL AND SOCIAL IMPLICATIONS OF EMERGING LOW-CARBON HYDROGEN TRADE AND SUPPLY NETWORKS IN THE ARRRA SUPERCLUSTER

MANAGEMENT SUMMARY

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This management summary accompanies the report '*Hydrogen to be: Geopolitical and social implications of emerging low-carbon hydrogen trade and supply networks in the ARRRA supercluster'* (link) published with the results of the research conducted by the consortium consisting of:

- Clingendael International Energy Programme (CIEP)
- Dutch Research Institute For Transitions (DRIFT)
- Erasmus Commodity & Trade Centre (ECTC), part of Erasmus Centre for Urban, Port and Transport Economics (Erasmus UPT).
- Technology, Policy and Management Faculty of Delft University of Technology (TU Delft TPM).

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INTRODUCTION

The Russian invasion of Ukraine in February 2022 and the resulting Western sanctions against Russia have brought geopolitics and energy to the forefront of the public debate. The current global energy crisis has reiterated that geopolitical and societal dynamics have an immense influence on energy systems, and consequently, the energy transition. As is now evident, decades of European energy policy and, by implication, societal stability across Europe, was upended in a few months.

Thinking beyond current trends and near-term developments is more important than ever. This is particularly important in the energy sector, where high capital investments and long lead times necessitate robust long-term planning. Moving from the COVID-19 pandemic to the current energy crisis, the world is unevenly preparing for another crisis: a much slower unfolding, climate crisis. Transforming the energy system while minimising disruption to energy services is proving a difficult task. Hydrogen is already a part of this transformation, but its exact role in the future energy system remains unclear.

EXPLORING PATHWAYS THROUGH SCENARIOS

Formulating coherent scenarios about what future geopolitical and societal dynamics might look like, can help understand how hydrogen value chains and trade networks will emerge in uncertain and complex situations. This project therefore created scenarios **so companies, governments and business networks can develop strategies to robustly position themselves in the future low-carbon hydrogen value chains and markets**. This project addresses the implications for the Amsterdam-Rotterdam-Rhine-Ruhr-Antwerp (ARRRA) region, but derives strategic recommendations specifically for stakeholders active in the Rotterdam port-industrial cluster.

The research aims to answer the following question:

How will geopolitics shape the emergence of hydrogen trade and supply networks into the ARRRA supercluster and what effect will this have on key actors and on Dutch society in the period between 2025 and 2040?

The research used the 8-step scenario planning approach to help formulate answers to this question. It identified what is at stake, for whom, and in at what time horizon with respect to this research question. Using this analysis, it identified the most significant exogenous forces driving the development of low-carbon hydrogen supple and trade networks in the ARRRA region. This resulted in 20 key social, economic, environmental, political and technological forces (the SEEPT forces).

Social	Economic	Environmental	Political	Technological
S1: Social structure	**EC1**: CO_2 abatement policies	**ENV1**: Climate change-induced extreme weather events	**P1**: Leadership in hydrogen and hydrogen technology development	**T1**: Learning curve for non-H_2 electricity storage
S2: Public acceptance of the energy transition	**EC2**: Stability of global financial markets	**ENV2**: Scarcity of raw materials	**P2**: Degree of global cohesion	**T2**: Access to key hydrogen technologies
S3: Energy (distribution) justice	**EC3**: Extent of globalisation	**ENV3**: Land and water availability	**P3**: Rules setters in global markets	**T3**: Emergence of intercontinental energy supergrids
S4: Availability of human capital	**EC4**: Industry relocation	**ENV4**: Sustainability pathways	**P4**: Energy security in north-west Europe	**T4**: Emergence of high-energy digital appliances

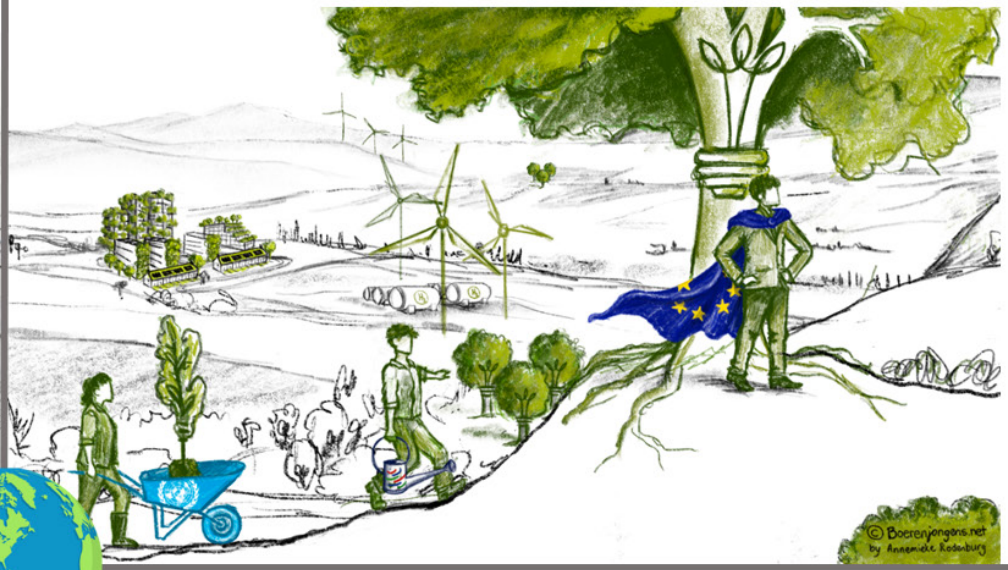
OVERVIEW OF THE SEEPT FORCES

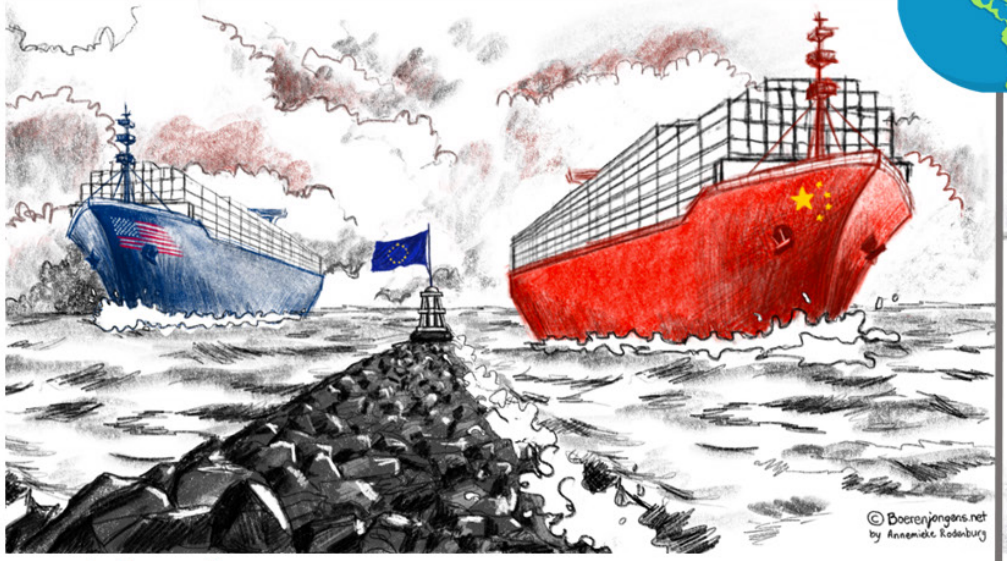
THE FOUR SCENARIOS AND HYDROGEN MARKET DEVELOPMENTS

From the SEEPT forces, six (S1, ENV4, P1, P3, P4 & T2) were prioritised as critical uncertainties to underpin four distinct scenarios of how the world might look like around 2040, described by looking back at key developments. Each scenario is summarized below, followed by the expected hydrogen market developments per scenario and their implications for low-carbon hydrogen trade and supply network development.

1. Revival of the Rhineland Model

3. Europe's Eureka





2. Right of Sun Tzu

4. Broken Bridges

The **Revival of the Rhineland Model** describes a scenario in which a post-World War II and a pre-Washington Consensus market system flourished and in which the Rhineland social market economic model prevailed in north-west Europe. This economic transition, enabled by continuing US dominance, but where the US was no longer actively lobbying to maintain open global markets. Nevertheless, the EU aligned with the US. Environmental concerns became secondary to energy security and affordability, and economic recovery from the 2020 pandemic and the energy crisis that began in 2022. European political rhetoric centred on funding wages, redistributing wealth, and social welfare which was achieved through higher corporate taxes. Energy security was strengthened at high government expense.

Low-carbon hydrogen market development was driven by pursuing pragmatic sustainability and affordability. The energy transition took many years to get going, but gradually accelerated from 2030 onwards. Industry set the pace of hydrogen adoption. Hydrogen was reserved for energy-intensive industries. Demand was mainly met from large-volume imports procured from the global market, and supplemented by low-volume regional production. There was little variety in the value chain, based mainly on a few key technology advancements for low-carbon hydrogen. This split focus achieved moderate energy security, but with continued dependence on imports, moderate affordability, and low sustainability. Climate neutrality was only reached between 2060 and 2070.

In **The Right of Sun Tzu** scenario, the world moved into a China-led situation after a power struggle between the US and China. Changes in the geopolitical balance in the Middle East reinforced a period of global bipolarism between East and West, where China increasingly took the lead. The decline of the US hegemony became evident around 2040, where China began to set the tone in international affairs and global trade. EU members split on which bloc to align with: north-west Europe leant across the Atlantic, while south and south-east Europe leant towards China. Decarbonisation was not always a priority in the bipolar world, in which regional conflicts diverted attention and resources from climate change mitigation and adaptation. Nevertheless, under Chinese leadership, the world slowly moved towards carbon neutrality after 2040.

Market development was driven by energy security logic. Throughout the 2030s, ongoing concerns for energy security encouraged regional hydrogen markets to expand. Innovation and uptake of various low-carbon hydrogen technologies contributed to a forced and continued acceleration of the energy transition. Hydrogen served energy-intensive industries and the power sector, from high regional production and modest imports. North-west European imports came from

the transatlantic market, with some value chain variety. This resulted in moderate energy security and sustainability, with climate neutrality reached between 2050 and 2060, but at the expense of low affordability.

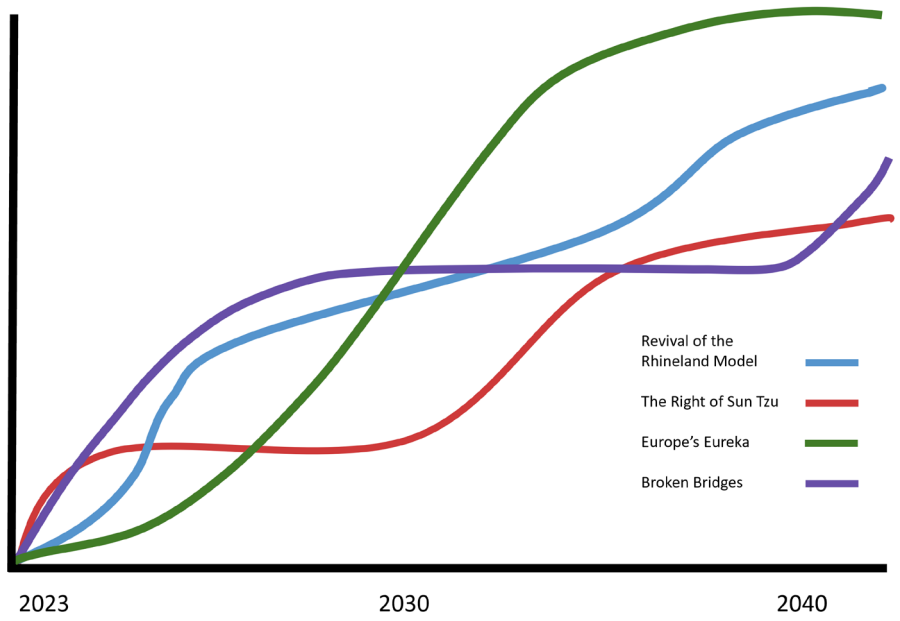
In the **Europe's Eureka** scenario, a globally permissive trade environment emerged in which diplomatic breakthroughs drove countries behind the common, EU-led goal of addressing climate change. The EU successfully bet on the transition to ride out the impact of the 2022 energy crisis. European governments, elected by collectivist societies envisioning a green future, took a more prominent role in managing their economies in pursuit of idealistic sustainability goals. The access to key energy technologies and critical raw materials at low costs enabled Europe's energy transition but meant that development slowed in countries already lagging behind.

Market development was driven by a combination of energy security and idealistic sustainability values. The energy transition accelerated from incremental to exponential in the 2030s. Innovation-led cost reduction in hydrogen technologies resulted in uptake in energy-intensive steel and chemical industries, the power sector, transport and mobility, and in the built environment. This was serviced both by high regional production and large import volumes coming from a varied global market. Supply diversity led to high energy security, innovation-led cost reduction increased affordability substantially, and systemic change resulted in high sustainability with neutrality reached around 2050.

The **Broken Bridges** scenario sketches a shrinking and incohesive world, in which nations focused on domestic problems and national interests. Europe found itself on its own, which continued to fracture the EU after it was unable to overcome the energy crisis. The US presidency swung to the right once again, and the US became disinterested in climate change mitigation and in Europe. The EU reopened negotiations with Russia over its security demands. The 2030s were characterised by fragmentation and trade in distinct trade blocs. This deglobalisation process was interwoven with incoherent north-west European attempts to reduce emissions and become an international norm setter on decarbonisation. These efforts were set to fail, partly due to the surge of green colonialism sentiments in developing countries.

Market development was driven by idealistic sustainability values, with the market initially taking off quickly. However, it soon stagnated for a long period, picking up only after 2040. Hydrogen was only in demand by a downsized energy-intensive industry in the ARRRA region, and was serviced by modest regional production and low import volumes. The regional market demonstrated low value chain variety and

innovation in key (green) hydrogen technologies was not sufficient. Pursuing sustainability at all-costs resulted in just that, high costs. Consequently, energy security and affordability remained low up to 2040, despite that carbon neutrality was reached around 2050, but largely due to the demise of European industry.



S-CURVE FOR ALL FOUR HYDROGEN MARKET DEVELOPMENT SCENARIOS

STRATEGIC OPTIONS FOR STRENGTHENING THE ROTTERDAM PORT-INDUSTRIAL CLUSTER

The four scenarios point to perceived certainties and uncertainties in hydrogen market development. In the light of these, five scenario-transcending strategies can be formulated to address concerns across all or most scenarios. These are the more robust no-brainers that the actors in the port-industrial cluster can execute in any case. There are also three scenario-specific strategies that work in only two of the four scenarios, and are therefore riskier. Implementing all these strategies will require active effort from different stakeholders. Coordination, if not collaboration, will be key for the cluster's sustained survival in an increasingly uncertain world.

SCENARIO-TRANSCENDING STRATEGIES

1. **Significantly expand regional production of renewable electricity and hydrogen**: all scenarios highlight that security of supply can no longer be taken for granted. This necessitates investment in electricity and hydrogen production, even despite limited space and the risk that hydrogen use does not materialise at scale. Vertical integration of hydrogen production, with long offtake agreements, can provide some risk mitigation.

2. **Diversify imports in terms of suppliers, energy sources and carriers**: with growing geopolitical and trade barriers, energy flows may be disrupted and assets abroad may be stranded. For future hydrogen users and importers, such as the chemical, steel, refining and transport sectors, supply diversification is critical. The scenarios highlight that from a security of supply perspective, investments in the transatlantic basin and southern Europe are most robust. The Middle East and northern Africa may be riskier. But if deglobalisation intensifies, this region may become an important export hub for Europe, and should therefore also be a focus of European energy and climate diplomacy.

3. **Invest in optionality and multi-functionality of terminals, conversion, storage, infrastructure and machinery**: in the energy transition, there is no silver bullet, and actors in the Rotterdam port-industrial cluster should not put 'all their eggs in one basket'. For users of hydrogen, this optionality means flexible offtake agreements, or offtakes with flexibility clauses. For grid operators, this means multi-functional and multi-directional infrastructure. This includes adapting gas pipelines, new or refurbished, for hydrogen and to service other mixtures, such as methane, hydrogen sulphide and ammonia. Existing fossil fuel infrastructure, such as LNG terminals, should be adapted to handle ammonia and other hydrogen derivatives, but without unnecessarily prolonging fossil fuel use.

4. **Invest in backup and redundant hydrogen production, conversion, storage and infrastructure capacity**: increased optionality should be complemented with building in redundancies, such as backup power generation, strategic energy reserves or pipelines not operating at full capacity. Redundancy is seen as costly, but costs are not the same as value. The value provided by redundancy should be built into investment decisions.

5. **Double down on circularity**: while already in progress, doubling down circularity can eliminate some external (energy) dependencies. This can be done by attracting new business and service providers, and co-investment in port infrastructure required for transporting materials, molecules and energy across

the cluster. The Rotterdam Port Authority can support knowledge sharing, for example, on improving collecting, sorting and processing for sparce materials such as platinum, and scaling up innovations beyond pilot projects. However, circularity will also create new physical and relational interdependencies.

SCENARIO-SPECIFIC STRATEGIES

6. **Replace current grey hydrogen use with low-carbon hydrogen and fully embrace the transition in other industrial segments**: replacing current grey hydrogen demand in the chemical industry is a low-regret strategy. It can serve as an important signal for low-carbon hydrogen adoption in other sectors. It also makes a meaningful statement to governments and society that the sector is embracing the energy transition as a proactive rather than compliant partner. This is important, as none of the scenarios guarantee a social and political licence to operate for large (chemical) industries in the ARRRA region.

7. **Increase investments in and control over strategic transition resources**: a successful hydrogen transition requires strategic transition materials, technologies and skilled labour to be available and affordable. Under the Right of Sun Tzu and Broken Bridges, north-west European governments need to increase diplomatic and trade efforts with critical raw material producing countries, and start monitoring the ARRRA region's material and technology needs as well as import dependencies. This includes playing to north-west Europe's strengths, by prioritising innovation policies and programmes around next generation materials and clean technologies. Protectionism rules, particularly to prevent (early) foreign take-over of strategic companies, may be needed. This includes prioritising security and stability in industrial policy, by maintaining, starting or reshoring critical processes. However, this strategy has its risks, and does not apply in all scenarios. Protectionism is expensive, especially when costs are socialised and returns privatised, moreover, the desirability of protecting inefficient industries is also questionable.

8. **Collaborate with other ports in the ARRRA region for import and trade of hydrogen and hydrogen derivatives**: the energy transition is a challenge too large to be tackled by a single port-industrial cluster alone. Under the Right of Sun Tzu and Europe's Eureka, and in the context of frequent global supply chain disruptions and changes, close collaboration can build resilience in the ARRRA region. This would involve data sharing and simultaneous adoption of new technology to improve coordination. It would also require some degree of intra-regional port specialisation, for example, with the Port of Rotterdam using its proximity to offshore underground storage for hydrogen or carbon capture and storage.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