Whitepaper

DATA AND MODELLING

for transition planning in industry

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Foreword

Modelling: a profound insight towards a sustainable industry

Industry is on the verge of re-inventing itself. Big questions are ahead. What kind of industry will the Netherlands host in twenty or thirty years from now? Which companies will still be part of this? How do they assure their license-to-operate, in a sustainable, zero-emission and circular way, meeting the demand of co-workers, neighbours, nature and their direct environment?

Industrial companies have many opportunities to get prepared. But how should industry choose the right direction and invest in its future?

To get more clarity on how to approach these challenge ISPT and partners have started the Industry's Drawing Room – De Tekenkamer van de Industrie. The Tekenkamer is a thinktank where advanced transition models are developed and used together with the field of industry, grid operators and government, to get a grip on the systemic changes needed for industry and society. In this whitepaper we introduce you to our Tekenkamer.

A journey to a sustainable industry

I would like to invite you for a guided journey leading to a sustainable industry. This whitepaper is about how data and modelling tools support companies and industrial clusters in taking the right investment decisions with respect to their transition to a new system. Following the parallel of a trip by train: modelling serves as a sophisticated timetable. Starting with the initial schedule, they show you the preferred connections to arrive at your destination.

Modelling serves as a sophisticated timetable

Along the long railroad towards a circular and zero-emission industry by 2050, unexpected delays, interruptions, changed circumstances and other disruptions will occur. Modelling provides the flexibility and overview that are needed to take the right turns. The tools give confidence that you will reach the goal of your journey. It is not likely to reach the right end station in time without such an advanced and flexible journey planner.

Models and data are badly needed for creating a shared vision

This journey is not exclusive for industry, or for solitary companies. TSOs, regulators, authorities and other industrial companies are on the same track. That's why building climate-neutral and circular industry will need an integrated approach among stakeholders. Models and data are badly needed for creating a shared vision.

A profound insight as foundation for boardroom's investment decisions

This whitepaper shows how modelling works in practice, with examples and applications from the Smart Delta Resources industrial region in Zeeland. The work starts with collecting validated data, that feed into the analysis and into possible scenarios, context, and time schedules. This analysis then provides profound insight is the foundation for the boardroom's investment decisions in a complex world.

Moreover, this whitepaper is also a call for action. As the modelling is developed for and by industry itself, bottom-up, I ask you to join the development, to contribute and to benefit.

Andreas ten Cate, program manager TKI Energie en Industrie

1. Data and modelling provide a shared platform for an integrated analysis

Preparing for a net-zero emission and circular economy within twenty or thirty years is a complex and highly ambitions task for the entire industry. Short-term pathways to reach our targets in the year 2030 are challenging but reasonably well-known. Many decisions already have been taken or are imminent. But creating a clear outlook beyond the 2030 horizon will take quite an effort. Fundamental changes are needed on how we deal with alternatives for fossil feedstocks, that currently drive almost everything in society. Opportunities are numerous, but challenges and uncertainties are also large.

The industrial transition calls for innovation of the system

The development of industry within planetary boundaries requires a more comprehensive approach. The industrial transition calls for innovation of the system – the way all our production resources transform and get connected to each other and to new, renewable and emission-free energy sources. This requires that we understand the interplay and interactions between production technologies and circular raw material flows, green power production systems and the infrastructure for power, hydrogen and CO_2 that connects all these. And all this while restricted by limited availability of land.

The transition cannot afford to be dependent on stakeholders waiting for each other

One restriction that we currently experience is the limited availability and limited rate of development of infrastructure for gas and power. We experience grid congestion in many places across The Netherlands because too much new solar power is deployed and too many new grid connections are requested to match with the current grid capacity. Up to recently, grid capacity was developed upon request - the industry's demand was always matched with expansion of pipelines or cables. Decisions of companies, grid operators, regulators and authorities will be increasingly entangled. The transition cannot afford to be dependent on stakeholders waiting for each other. On the opposite: stakeholders should inspire each other and speed up their actions. Therefore, going forward, we need to improve our planning, and we need to do this planning exercise together. That is our aim.

Modelling helps the investment decision process

We build models that describe how each company is connected to the infrastructure, and how the need for energy changes over time due to progressive investments into carbon-neutral processes. This helps us to understand how the transformation of industries, grouped together in industrial clusters, is interconnected and how together they are dependent on the development of local infrastructure. For these models we use data, e.g. on production capacity and conversion efficiencies, use of raw materials and energy, formation of side products and waste materials and waste heat, and more. The models provide the context for each factory or site. We can explore our transition challenge by applying different scenarios, that describe our expectations on how we anticipate changes such as the demand for products, the costs of carbon emissions, the build-out of renewable power, and more. By then applying sensitivity analysis we get quantified insights in the trade-offs between different choices. And these analyses give deeper insights needed for a solid decision-making process.

Modelling builds trust, understanding and a shared vision among stakeholders

Furthermore, we do these kind of analysis in group settings, together with the relevant stakeholders. One can do modelling exercises in perfect isolation in the quietness of one's office. However, it is key that the stakeholders trust the outcome of models, and therefore have an understanding of what the models describe. And they should be able to challenge the outcomes themselves, and challenge their own understanding and believes to convince themselves of the insights coming out of this work. If we do this kind of analysis with people from industry, with grid operators, with people from various authorities, NGOs, employees or even residents, then a basis for mutual trust can be created in finding a path forward that is supported. Validated data and trusted models facilitate the exchange of visions, allow to identify synergy advantages and deliver robust transition strategies that guide the development in a region.

2. Practice what you preach: the first cases

Within the framework of the 'Tekenkamer' (Drawing Room) data and transition modelling support the stakeholders in answering questions like: how can we meet CO_2 emission targets in a cost-efficient way? What infrastructure do we need? What will happen if infrastructure is delayed?

Designing scenarios for decision making

The Tekenkamer is built on experiences with the TEACOS model form QuoMare, developed in the HyChain project. This project looks at the development of renewable hydrogen value chains in industrial clusters in the Netherlands, and in particular in the clusters of Zeeland, coordinated by Smart Delta Resources (SDR), en in the Port of Rotterdam area.
In this whitepaper will will show some illustrative cases to show how we can save costs and achieve our CO_2 emission goals in time by synchronising investments in new technologies via electrification, hydrogen production, etc. We also show the consequences of a delay in delivering new 380 kV power lines on the transition path of industry.

3. An integrated approach: context and stakeholders

By working together we can achieve substantial advantages. Cost reductions may be achieved, better investment allocations may take place and more robust timing of investments may take place when we plan to reduce our CO_2 emissions and develop hydrogen infrastructure and 380 kV grid planning, or when we consider to combine nuclear energy with offshore wind power.

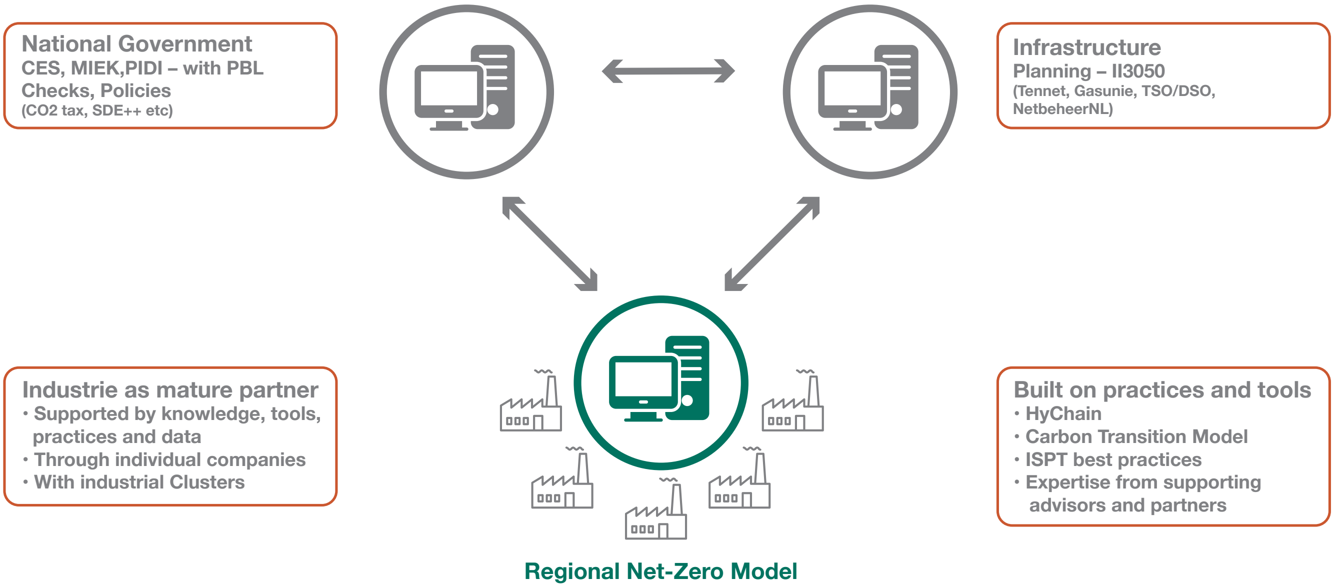

Figure 1: **The context for the industrial transition is complex: there is a strong interaction between infrastructure operators, the National government and the Industry.**

National government sets industrial boundary conditions

The national government is governing the transition planning. The government defines the environmental goals, the spatial planning, the regulatory framework, financing and subsidies for R&D and innovation, and other relevant industrial boundary conditions. For this purpose, the national government launched the National Programme Sustainable Industry (Nationaal Programma Verduurzaming Industrie) in March 2023. The government gets support for its' policies from for example PBL and TNO and they can check their policies from a top-down analysis. As industry located in a cluster of regionally, these policies not always provide you with insights needed to make decisions on your investments.

Infrastructure is the engine of the industry transition

In 2021 the infrastructure policy framework MIEK (Meerjarenprogramma Infrastructuur Energie en Klimaat—Multi-annual Programme Infrastructure Energy and Climate) was launched, leading to the Programme Infrastructure Sustainable Industry (PIDI) that is coordinated by the Ministry of Economic Affairs and Climate. In PIDI context national and regional authorities, industry, grid operators and energy producers work together towards an agenda for infrastructure investment planning that enables reaching the climate goals of the industry. Grid operators make their analysis of a future grid as preparation on their investment planning. This analysis is done in-house by the grid operators with their own modelling tools, and through making use of the Energy Transition Model of Quintel. This approach is based on a top-down analysis – taking the grid perspective as central viewpoint – and serves to determine which investments in infrastructure need to be made, and at what scale and location, to develop a robust energy grid (gas and power) for the coming decades.

Cluster Energy Strategies

To give input to the grid operators, the Dutch industry is asked periodically to provide data on their investment plans to PIDI through the Cluster Energy Strategies (CES). Each of industry cluster in the Netherlands develops such a report. It contains the development plans of the industry and indicates the integrated outlook of energy supply and demand of the industry in each cluster for the coming decades. Accumulated, the six CES's give insight into the industrial need for new infrastructure.

One element that is lacking is a consistent approach to describe and analyse the data and to use this to give direct feedback to the industry itself. In each cluster the collection of individual plans needs to be matched by available infrastructure and energy sources in the form of green power, hydrogen and other commodities. By creating a model at clusterlevel that captures the individual plans of the industry one can evaluate how the individual plans add up and identify optimizations and synergies. This leads to a much more robust insight in how the clusters can develop towards a clean future. The Tekenkamer aims to support the local cluster organizations by developing local industry models with them that allows the clusters to make their own analysis and communicate the output in various forms to the relevant parties – individual companies, grid operators and more. With this feedback to the industry, we aim to develop cluster strategies bottom-up to give actionable insights to the industry self. Doing this across clusters in a consistent manner further improves the quality and consistency of the CES-MIEK-PIDI process across the clusters and gives a much-improved outlook for the grid operators across the clusters.

Reliable exchange of plans and data for the development of the industry of the future is essential to for a solid common vision – needed to guide investments decisions, both in industry and in infrastructure.

4. TEACOS modelling for transition planning

In the Tekenkamer we develop clustermodels using the TEACOS approach of QuoMare. This modelling approach builds a network of connections between nodes and at each node changes can happen. An industry site is such an example of a node and connections between nodes are typically the needed infrastructure. The model secures that basic energy and mass balances are warranted, and a linear correlation between input and output is assumed.

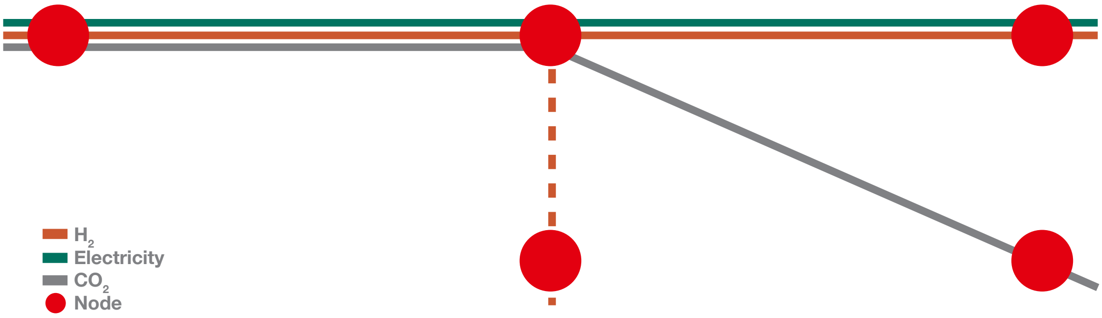

Figure 2

A simple representation is given in figure 2 which indicates factories (nodes – red dots) that are connected to infrastructure (lines) for hydrogen, power and CO2. The model can take into account existing infrastructure (lines) but also new options – possible connections one wants to make, but also possible new processes or factories that industry would like to install. For the hydrogen grid this is indicated in the figure by the dashed line. For each option we need basic data that describes input-output relationships and gives cost indications for capex and opex. In this way we basically build a network of linked business cases.

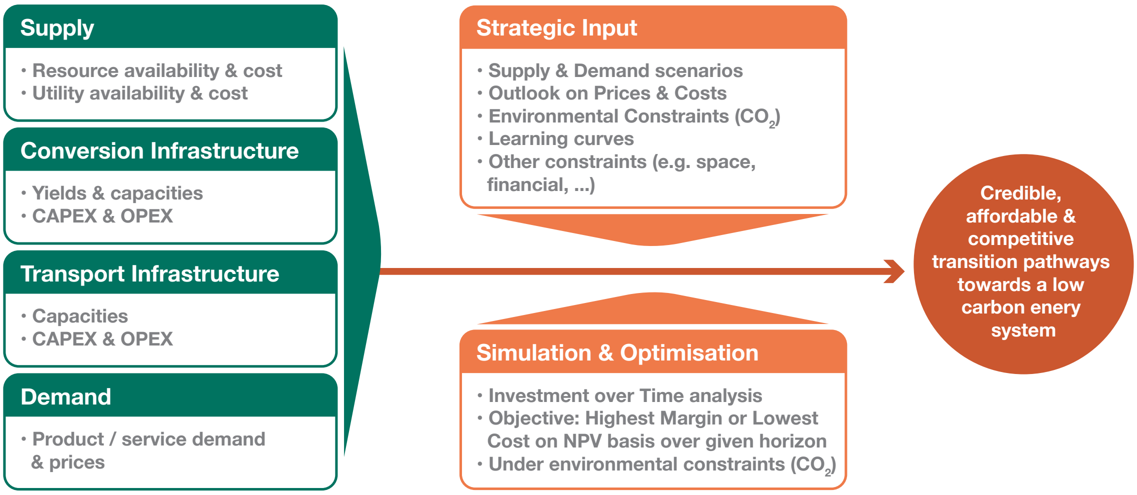

Figure 3

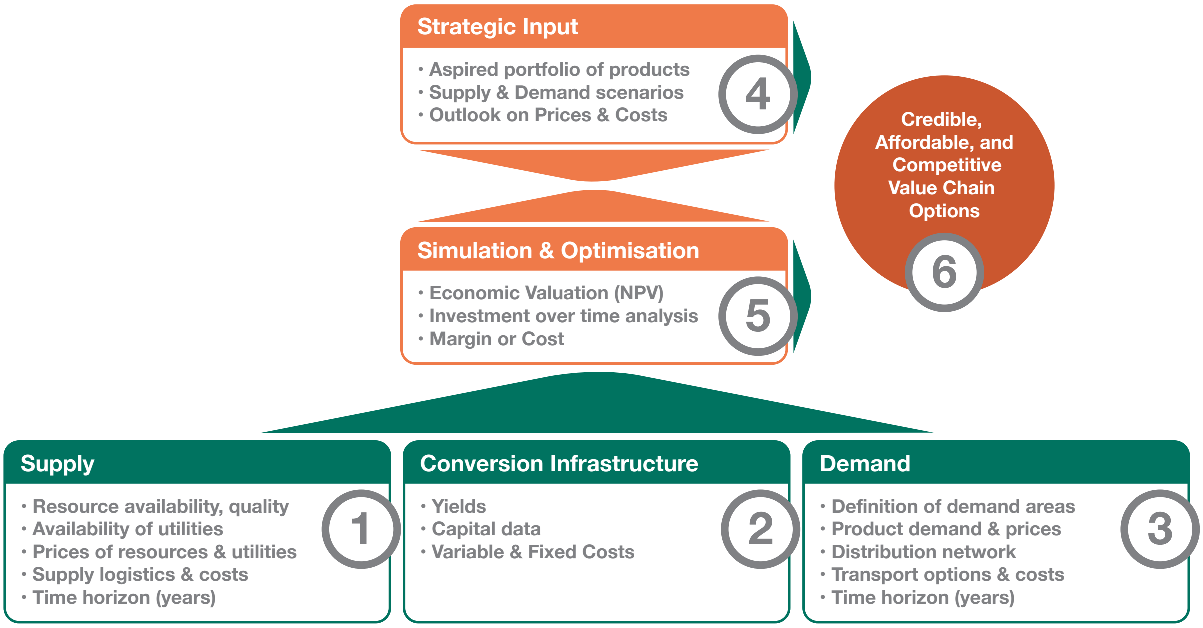

Figure 4: Modelling through TEACOS (Techno-Economic Analysis of Complex Option Spaces)

It is important to build this kind of model based on accurate data. Figure 4 (in green), shows which types of cost data are the starting point of our analysis:

- Supply of energy and other resources: quality, availability, prices, logistics and costs, time horizon;
- Conversion technologies: yields of processes, capital (Capex) and operational (Opex) costs;
- Transport infrastructure: energy carriers (power, natural gas, green gas, hydrogen) or resource gases (hydrogen, natural gas, ammonia, CO_2);
- Demand: for energy, resources, other commodities and products; prices, distribution networks, transport options and costs, time horizon.

These data come from different sources – both public and private. Initially we work with varius public sources, for example from the MIDDEN dataset of PBL and TNO, as well as from other sources such as textbooks, KEV and Netherlands Emission Authority. Together, this already gives a good picture of the transition options. As a next step we also work with restricted or confidential data from companies or other stakeholders. For example we have worked with the Energy Mix dataset, a proprietary dataset developed by Deltalinqs and other parties in Rotterdam that describe the transition options of about 35 companies in that area. As a further development we will collaborate with industries locally through the Data Safehouse, as currently operating in a first stage in the Port of Rottedam area. This further develops the interaction with local industry and improves the opportunity to jointly interact and give feedback to the local parties.

Strategic input and constraints

The model is further built upon 'strategic input'. The model aims to achieve certain targets and know where limitations and boundaries are that should be warranted. For example, the goals to reduce CO2 emissions are guided by on the one hand strict limitations (a 55% CO_2 emission reduction target in 2030 and a 95% reduction in 2050 for example), setting boundaries. On the other hand, decisions are also guided by an expected CO2 emission cost via the price increase of the Emission Trading System (ETS) of the European Commission. Other considerations are for example the limited availability of space in the region for new plants or production lines.

The model aims to select the best configuration of the industry in a region considered and looks how, over time, this is changing through investments that minimizes the overall costs while adhering to the targets and constraints. It considers limitations from individual companies, from grid availability, and can take into account for example expected learning curves of technologies. The learning curve describes the rate at which costs are expected to decline as we scale up new technologies. This has pushed down power prices from renewable offshore wind power, and is for example also expected to apply to green hydrogen production in the coming decades, and therefore is an important parameter.

Output: credible, affordable and competitive transition pathways

The TEACOS model carries out a so-called multi-period optimization – it evaluates over time which investments should be made and determines which set of consecutive investments leads to reaching the target against lowest cost or highest Net Present Value.

The evaluation is then done by analyzing different scenarios and sensitivity analysis. In this way the robustness of the identified pathways is determined. This means that we look at which investment in the next decade keeps coming back under various possible future outcomes. When we see that over a range of power and energy prices, over a range of ETS prices and over ranges of other varies parameters the same or similar need for infrastructure keeps being prognosed, then this indicates that the investment in infrastructure is a no-regret investment. It is well possible that not in every outcome the infrastructure is used by the same industry to the same extent, but overall, it then indicates that this infrastructure investment is needed for the cluster as a whole. When these results are then evaluated and validated with the individual industries we come to supported investment plans, which are then deemed to result in credible, affordable and competitive transition pathways towards for industrial transition planning.

5. Two examples of transition pathway planning

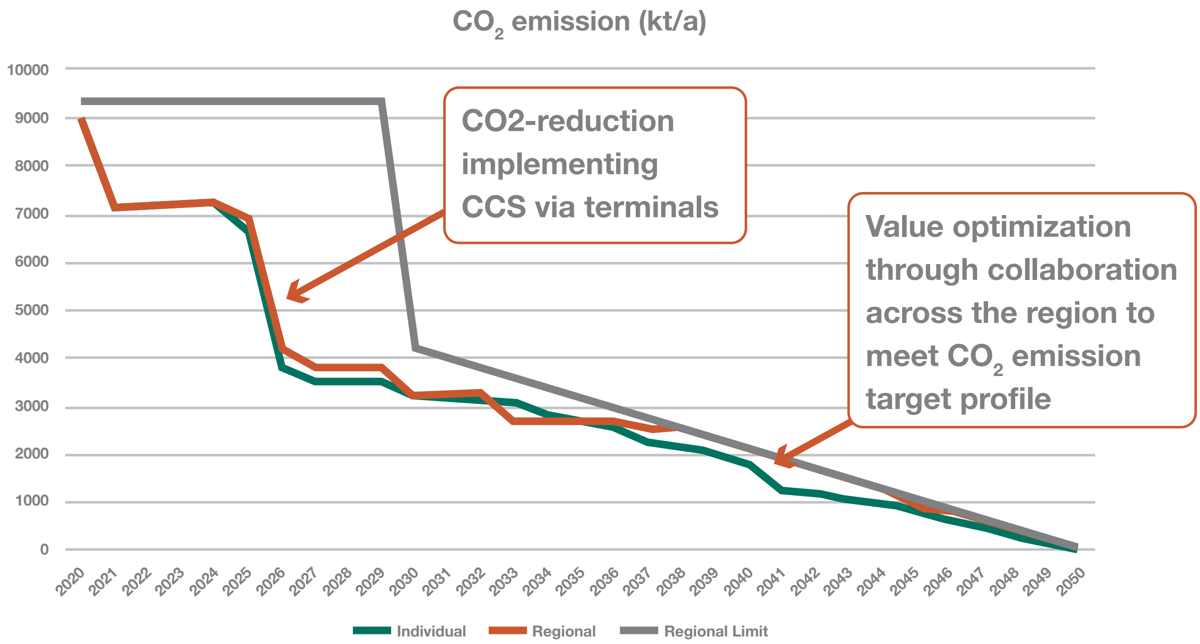

Figure 5: Balance impact of regional collaboration in transition strategies

Case I: The cluster collaboration scenario

In short:

- Collaboration can save up to billions in investments, creating room for better allocation of funds
- By collaborating and coordinating investments less primary energy and resources like green hydrogen are needed compared to planning based on individual investments
- Individual agreements (Maatwerk afspraken) by the government focus on individual transition planning. This approach disregards the opportunities from clustering companies, risking higher costs, both public and private. Supporting alignment with combined cluster transition strategies is important.
- Collaboration scenarios can also have downsides or risks. Creating investment space may require the need to temporarily by more EU carbon allowances, which poses a financial risk. This means making a trade-off between taking costs earlier or accepting risks at later stages. Allocating liberated funds again may serve to further reduce this risk and avoid emissions.

In case I, the TEACOS model is used for the developing transition pathway for a cluster, comparing the effect of consecutive investments by individual decision making (blue line) with the effect when investments are coordinated across the entities in the cluster. When applying regional optimization to tune investments, a joint optimized pathway is identified (orange line). The CO_2 emission reduction goal up to 2050 (the grey line) is achieved in both cases.

Instead of each company making individual investments to comply with the emission targets, investments are coordinated across the cluster in such a way that the cluster as a whole complies with the CO_2 goals. The scenario comparison shows that coordinating across companies may lead to some more CO2 emission, but also saves more than € 1.5 bn in investments. The EU Emissions Trading Scheme (EU-ETS) allows individual companies to be flexible in planning investments in CO2 emission reduction measures and would allow the cluster to act as one entity to reach CO2 emission goals.

The increased emission in this pathway would mean on the one hand using less green H2 than the individual scenario, but on the other hand taking a risk in having to buy additional CO2 emissions rights compared to the individual pathway. However, by creating an investment headroom, additional investments can be made or identified that allow the cluster to further decrease its cumulative CO_2 emissions. With this investment room in mind, one can engage with the industries to look for further reduction measures that can be incorporated in the model to look for additional emission reduction opportunities.

Presently, the Dutch government is developing individual agreements (*maatwerkafspraken*) with the twenty largest industrial CO2 emitters in the country. This modelling exercise shows that one should keep an open eye to the opportunities to work together in the clusters. Individual agreements could drive up costs if they would not allow combined cluster transition strategies.

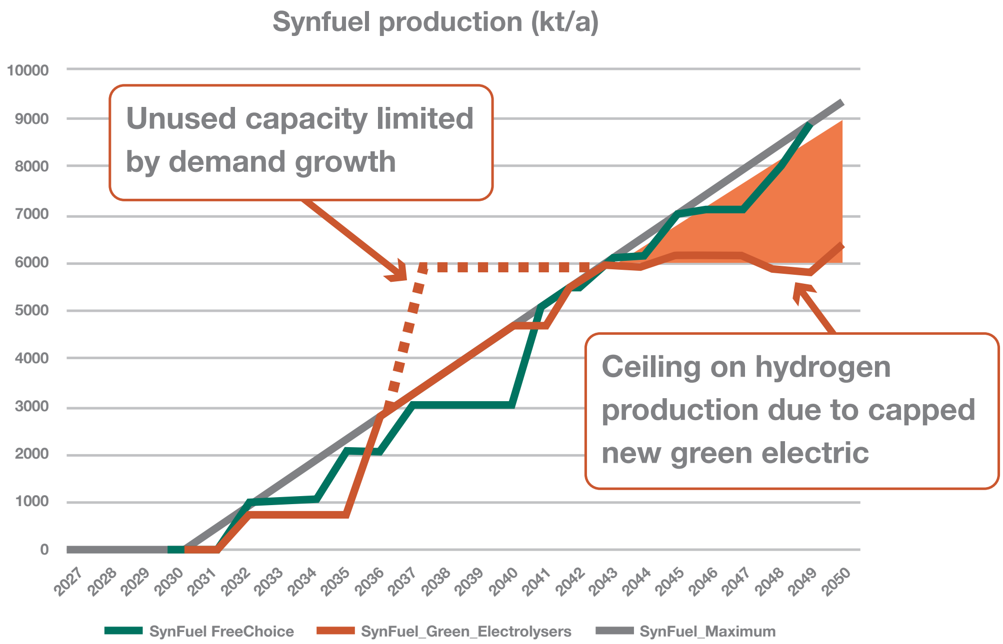

Figure 6

Case II: Impact of 380 kV high-voltage grid expansion timing on industrial transition

In short:

- The model shows the impact of a 5 year delay in building a 380 kV grid expansion on industrial CO_2 emissions
- Delayed power supply delays the start-up of electric furnaces
- In the specific case it was found that this delay results in a cumulative extra CO_2 emission of 10 million tonnes in the 2032-2047 period.

In case II an analysis is made to evaluate the impact of delays in the planned expansion of 380kV high voltage grids in an industry cluster.

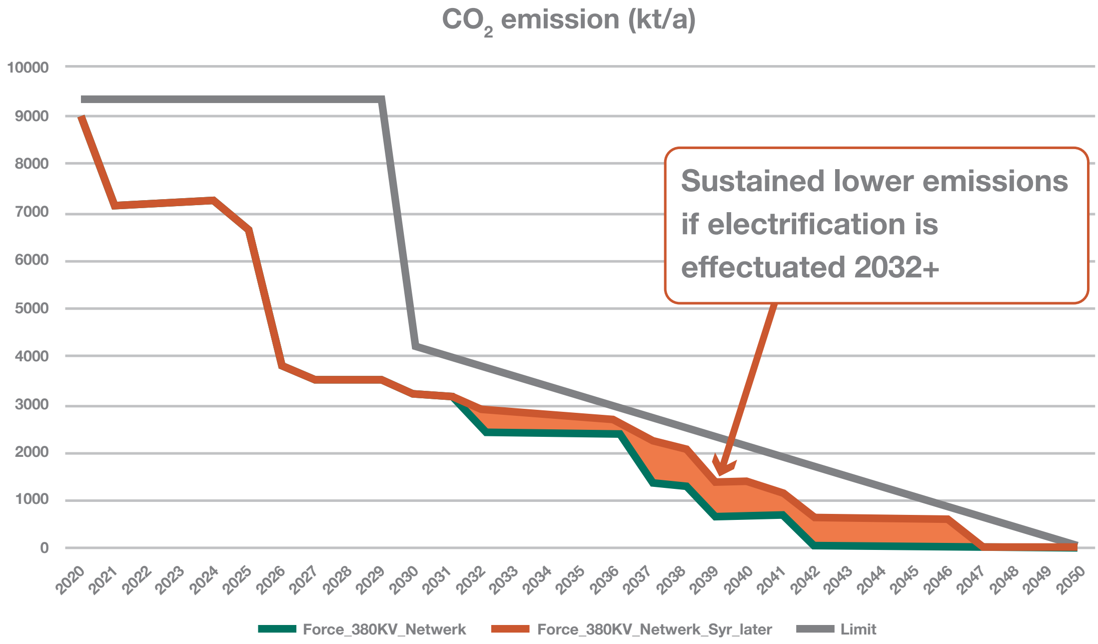

Figure 7

Electrification of processes replacing gas-fired boilers with electric furnaces, is an important means to achieve climate-neutrality. Electrification has an immediate impact in emission reduction. With the model we can quantify the effect of delays in delivery of infrastructure. Figure zzz shows the impact of a 5-year delay in delivery of a 380 kV grid expasion in terms of CO_2 emissions in industry. If the 380 kV enforcement will occur in 2037 (orange line) instead of 2032 (blue line), the restricted supply of power will restrict the use of electric furnaces in industry. In this example, the delay results in a total of additional emission of 10 million tonnes of CO_2 during the period 2032-2047 (the green area).

The need for quantified information for solid decision-making

These cases show the three main pillars for informed decision-making in the energy transition:

1. Transition modelling has an added value in providing the right numbers and margins. Anyone can imagine that collaboration between companies can lead to smart solutions and bring cost-benefits. It is also clear that timely upgrading of 380 kV networks is important to industry. For decisions about investments or for communications with partners or authorities, quantified results are a prerequisite.
2. Collaboration makes it more effective and cost-efficient to decarbonize the industry. Transition modelling provides the language for this collaboration. The quantified basis forces to describe each technology or solution in the same basic data and information which allows to compare apples with apples. In this way, it translates mutual interest of industries into actual solutions and actionable insights. Furthermore, it allows to jointly challenge solutions, leading to better solutions and a deeper understanding of the challenges shared amongst the stakeholders.
3. External factors and regulations are of the utmost importance for the design of climate-neutral pathways. As the cases show, industries are dependent on these factors, and therefore should communicate closely with the grid operators to approach the transition together — based on reliable modelling.

Transition modelling provides the language for collaboration in decarbonizing industry

6. Join us!

This whitepaper shows that transition modelling, data analysis and collaboration are instrumental to support the big investments that lie ahead for the entire Dutch industry. They give guidance, and therefore are a prerequisite for designing robust pathways towards climate neutrality in the short time we have – less than thirty years. Together with a well-organized collaboration and exchange of data and visions within clusters and beyond, this will support timely execution, lead to cost-efficiency and increase quality in the process to come to investment decisions.
By painting a clearer picture of the transition pathways, modelling already supports industries in the industry clusters in Zeeland and Rotterdam, enabling to dive deeper into transition pathways. Knowing which elements are important, how synergies work and how changing conditions alter the outcomes allows the industries to take the lead in sustainability. We work hard to improve insights towards actual investment decisions, to be applied by any industry cluster. Will you join us on our journey?

Are you interested in learning more?

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