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From Volume to Value

Action perspectives towards a sustainable, valuable and clean energy landscape in South Holland by 2050.

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Introduction

In 1964, the American philosopher Abraham Kaplan told a joke:

A policeman sees a drunkard searching for something under a streetlight. He asks the man what he had lost. "My keys", he replied. The policeman decides to help him and they both look under the streetlight together. After a few minutes, the policeman asks the drunkard if he is sure he lost his keys here. "No", the drunk replies, "my keys aren't here, I lost them in the park." The policeman asks him why on earth he was looking for them here. "Well", replies the drunk, "because this is where the light shines."

In all the discussions and fuss about making the energy transition, it sometimes feels as if we are the drunk. We face the challenge of completely restructuring our energy system, abandoning fossil fuels and embracing renewable sources. In our initial attempts to tackle this issue we are literally looking "where the light shines", by directing most of our efforts towards electricity consumption in the built environment. But household electricity consumption accounts for less than 1% of all energy flows in South Holland.[1] If we want to make structural and sustainable progress, we cannot avoid looking at the entire energy system to prevent being blinded by our search for solutions for the minute part of the problem that our light is shining on today.

<<quote box>> "**How can South Holland reduce CO_2 emissions by more than 80% by 2050 at the lowest societal cost**?"

[1] Energy transition model for South Holland. Final electricity consumption of households is 16 PJ, total energy consumption, including use in the chemical indutry that does not involve electricity production is 2221 PJ

Yes, we want a transition. But a transition whereto?

The province of South Holland and the project office *Warmte Koude Zuid-Holland* asked Kamangir to apply their hybrid approach, based on science and philosophy and –for this project- backed up by input from a broad selection of 18 experts, to search for new action perspectives based on long-term scenarios for a future in which CO_2 emissions are drastically lower than they are today.

This request needs some further explanation. The scenarios developed by Kamangir focus on the total energy system, from households to refineries, and include technical, economic and social aspects. We define cost by looking further than merely the financial costs to society: an unreliable energy supply, a damaged landscape, a less competitive industrial sector or opposition from citizens to the energy transition are also considered to be societal costs. The primary focus of this report is to drastically reduce CO_2 emissions by 2050, and does not consider the rate –however important- at which these emissions must be reduced.

On the one hand, taking a long-term look at a fundamentally uncertain change process reveals immense uncertainties. On the other hand, many matters that are now the topic of heated public debate are more or less inevitable in the long term. It is important to realise that many plausible assumptions for the long term seem extremely controversial today. The insights obtained during this project will help to guide our efforts to effect this transition and formulate an **attractive action perspective** for stakeholders. Here are a few examples:

> Discussions about solar and wind energy in the short term are often conducted from a David vs Goliath perspective, featuring small innovators versus large vested interests. In time, however, the aforementioned technologies will become so inexpensive that they will drive fossil fuels from the market. Heating and cooking with natural gas is currently the norm and the government is used to a continuous flow of substantial natural gas revenues; but by 2050 the gas reserves in Groningen will either be exhausted or much more expensive than renewable alternatives. If we assume a strong reduction in CO_2 emissions, the chance for coal-fired plants to still remain operational will become smaller the further we look into the future. The same applies to refinery capacity, whereby the oil industry will not only be put under pressure by declining oil reserves, but also by a decline in demand for fossil fuels, thanks to the rise of alternatives from renewable sources. Without wanting to downplay current issues, all this means that other questions will be more important in the long term. Therefore a question such as "What should the legacy of today's refineries be in 2050?" is more relevant than "How do we escape from the existing oil lock-in which is holding back electric mobility?'

Asking this type of question helps to elevate the current discussion and offers perspectives that allow us to take steps towards achieving far-reaching sustainability.

Consultative Scoping

In order to answer the research question in a robust and inclusive manner, we used Kamangir's methodology: *Consultative Scoping*. This method is characterised by first jointly determining what does not require discussion: the undeniabilities. For 2050, for example, it is safe to expect that the Dutch natural gas reserves will no longer be in use, buildings will be better insulated, the mobility transition will be in full swing, solar and wind energy will be much cheaper, etc. Once all this is decided upon, we develop challenging –but possible- scenarios at the outer limits of what tomorrow's energy landscape could look like. This uncovers the underlying values and effects for each scenario. Lines are constantly drawn (scoped) at each stage to create a new focus that can be supported by each participant. This produces a vision for the future that everyone is willing to support and lays the foundation for a concrete action perspective for all stakeholders. **Clarity about the direction of the transition ahead provides a context for today's action framework.**

The initial situation.

The transition task facing South Holland is immense <<add pie diagram>>:

- **Energy consumption in South Holland accounts for around 30% of total energy consumption in the Netherlands.**
- **Just slightly more than 1% of this comes from renewable sources.**
- The large horticulture sector in Westland and Oostland consumed 62 PJ in 2014.
- **Not electricity or natural gas, but oil is the main energy carrier in South Holland**
- South Holland is highly industrialised: the average inhabitant of Rotterdam emits 29.8 tonnes of CO_2 per year. This is the highest in the world.
- Most of all energy (around 650 PJ) is used by the large variety of industries in the region. The petrochemical industry and refineries use three quarters of this total amount, producing for European and global markets. Half of all industrial energy is used as raw material for producing plastics and chemicals.
- South Holland hosts 3.6 million people in an area of 2,818 km2. It is therefore one of the most densely populated areas on the planet.
- 1.6 million households consume 73 PJ for heating every year. **Meanwhile, 150 PetaJoules of residual heat is discharged into the Rotterdam harbour.**

The scenarios

Following a series of meetings with experts, we developed three extreme, but not impossible scenarios for 2050, each departing from a different set of values and visions. These final visions are based on two questions: which users are in the lead and what are the implications of their values? We have deliberately developed these scenarios in extreme forms, which makes them uncomfortable. This is in order to map the outer limits of possible energy landscapes and to obtain a sharper picture of possible conflicts. Each scenario was assessed using Quintel's Energy transition model.

Scenario 1: Island – what if South Holland only used its own renewable energy?

"In 2050, South Holland is an energy island. There are no net imports and all energy is obtained from local renewable sources: sun, wind, biomass, and geothermal energy. We are solving the energy problem from the bottom up. Everyone is becoming energy independent. We no longer offload the consequences of our energy requirements onto the climate or other countries. When we can't manage our energy demand inside our own homes, we first implement possibilities together with our streets, communities, or at neighbourhood, city or province levels. This means that every roof will be crammed full of solar panels, that windmills and solar power plants will be set up in every nook and cranny and that we will make maximum use of ambient heat, such as geothermal energy. We will save energy wherever possible, not just by using our cars less often and turning the heat down, but also thanks to comfortable, well-insulated houses, high-quality public transport and smart technology. Of course, this would only be possible if we all share the joys and burdens. Energy makes us dependent on each other. This may lead to conflicts, but also to sharing, solidarity and connectedness. Energy intensive industries will relocate to places where more energy is readily available, such as large agricultural areas and locations housing large power plants.

Technically, a lot is possible. The technical energy potential for renewable sources in South Holland is estimated at 400 PJ. This equals 30% of the current primary energy consumption. This amount of energy is enough to supply South Holland's inhabitants, horticulture sector and non-energy intensive companies. However, the overwhelming majority of energy intensive industries would have to leave the region. In this scenario, there will be 80 times more wind energy (on land and along the coastline) and 240 times more solar energy than we deploy today, plus 86 PJ from geothermal sources. The implication is that 90% of the available agricultural land will be filled with windmills and every roof will be covered in solar panels. Although renewable sources will provide energy at zero marginal cost, the investment required to create the infrastructure in this scenario means that energy costs per unit will still be high.

Scenario 2: Gateway – what if our industries lead the way?

"In 2050, South Holland is the industrial gateway to Europe and one of the largest energy, biomass and material hubs in the world. South Holland will have developed green gas-, material-, CO_2- and Biomass roundabouts. This goes much further than importing, processing and exporting gas, materials and such in the linear chains of the early 21st century. Its real power lies in the strong, close-knitted energy and chemical sectors, which convert electricity, heat, bio-based materials and gaseous and liquid fuels to meet international supply and demand. There is space for bio-based chemical bulk, coal and gas with CCS and the last refineries in Europe. The rest of South Holland will not only benefit from this economic activity, but also from energy production and load balancing effects of industrial clusters. For instance, this could become a heat grid. Laying down a densely interwoven heat grid is a large operation, but it would also stimulate the further development of geothermal energy. Households and companies would hardly notice the energy transition. Thanks to centralized generation and energy imports, this scenario does not require more local solar and wind energy in South Holland than we have today (which can be done better, easier and cheaper elsewhere) and in terms of landscape, South Holland will look the same as it does now. Not industries alone, but mobility also, are based on a mix of energy carriers such as bio-diesel, electricity, and hydrogen, all produced regionally."

There will be far-reaching changes to industry. We will see smaller production volumes of 'virgin' materials and much more recycling, reuse of materials and the return of complete products to the manufacturer. In this scenario, the electrification of the chemical sector and the use of biomass will also lower emissions by more than 80%, especially due to the use of biomass and sustainable

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electricity production outside the province. 95% of our energy requirements (that may be reduced by 20%) are supplied from outside the province. **Biomass production would require 15 times more agricultural land than the province itself has available.** Carbon capture and storage will be developed further and a heat grid fed by industries will be built. Because this scenario uses many existing technologies, energy costs may be higher in the absolute sense (the highest of all the end scenarios), but the energy price per unit will be lower than in the other scenarios.

This scenario requires a large-scale transformation of the existing industrial sector, and nearly total abandonment of the petrochemical sector in its current form. This could be made possible by creating a large base load for electricity production with nuclear energy and fossil fuel plants with carbon capture and storage; by adopting a strategic position in international flows regarding sustainable electricity, hydrogen, biomass and green gas and by creating a strong regional industrial symbiosis. It would involve industries exchanging residual flows of materials and energy. The energy and chemical sectors would also have to become closely interconnected.

<<illustration: 15 times the amount of agricultural land available in the province would be required to provide energy in this final scenario, everywhere we look we see heat sinks, windmills, solar panels and biomass production >>

The largest societal costs of the Gateway scenario are the risks for the built environment, which would remain dependent on the industrial energy sector. Furthermore, with the current state of technology, 15 times the amount of agricultural land in the province would be required to meet energy demands.

Scenario 3: Next Electric – what if the focus is on electrification?

"It is not so much a question of whether we will all go electric, as when. Electric cars, heat pumps, large solar deserts and wind seas in Europe will be linked to a Super Grid. Changes in households and companies lead towards a different horticulture, industry and energy sector. The system requires much more electricity and focuess on a seasonal and instant balance between supply and demand. The gas distribution network and tank infrastructure are falling into disuse.
In the Next Electric scenario, small energy consumers are also often small producers and traders of energy: enter the prosumer. Digitization and connectivity will lead to the creation of smart grids. We will use heat pumps to heat our houses. Many roofs will have solar cells. All this will make the average house/apartment partially self-sufficient. We will drive electric cars, and use them as batteries. For households and small users, this will mean a lot of new prosumers. Not everyone will, however, be self-sufficient as not all buildings and areas will be able to supply enough cheap electricity, and not everyone will be willing or able to invest and participate actively in the energy market. They will still have to buy energyto meet their needs, and when they don't have much to spend they will be dependent upon times of overproduction when prices are low."

Many sustainable technologies, ranging from electric vehicles to PV and heat pumps use electricity. Electricity is relatively easy to transport and transform. This makes electrification look like an obvious choice.

Although electricity will become more important, it will not provide an all-encompassing solution. Full electrification means that part of the industry will disappear (oil refineries, for example) and only a part will electrify. **Industries require huge amounts of energy and need more heat than electricity.** Furthermore, although the Dutch industry is a leader in energy efficiency, industrial processes will always produce residual heat. It is difficult to say how much residual heat this may involve in 2050. This residual heat should not be regarded as waste. The integration of electricity networks and data, linked to heat, solar power and wind energy offers an enormous opportunity. If there is over-production of electricity and market prices fall under zero, excess electricity can be stored as heat and used at a later date. In the existing situation, replacing natural gas with electricity (via heat pumps, for example) may save 63 PJ of gas, but will double the demand for electricity (from 15 PJ to 36 PJ). This effect will become even more pronounced if passenger transportation is also electrified (17 PJ)

(see figure below <<add figure number in>>).

If we really want to influence the climate, we will need to triple the current amount of solar energy and wind power. Demand for energy will continue to decline. Thanks to electric technologies that are often more efficient, such as electric cars, heat pumps, etc., less energy will be needed.

If energy demands continue to exceed what sun, wind and biomass can offer, existing plants will maintain their profit margins and reason for existence. Despite a sharp drop in energy use in refineries and the chemical sector, South Holland will be a significant net importer of electricity.

It is certain that all-electric at every location is not the best solution. Full electrification would deny the opportunities of residual heat, synergy and buffering through diverse infrastructures and niches in which green gas and biofuels would have advantages over electricity.

The more the province becomes dependent upon electricity, the greater the importance of electricity buffers and balancing energy supply and demand. This scenario depends on a much higher buffer capacity and half of all households will have batteries, 30% will use an electric boiler and half of all cars use their batteries to store electricity temporarily if there is over-production in the province. But apart from summer, the province would still depend upon imported electricity. In this scenario, it would be **an enormous challenge to provide the required flexibility.** The increased need for electricity during winter, the two-way flow of energy and intense peaks and troughs would put more pressure on distribution networks and making them smarter would be a necessity.

The highest societal costs of Next Electric are a possible lock-in of fossil fuel electric power plants, tripled demand for sun and wind energy, the costs accompanying balancing demand and supply and the difficulty of creating an optimised local energy infrastructure.

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A summary of the scenarios

"quantitative outcomes of the different end scenarios"

	Current situation	ISLAND	GATEWAY	NEXT ELECTRIC
CO_2-emission (Mton)	44.80 Mton (40.12 Mton in 1990)	4.02 Mton	7.75 Mton	2.7 Mton
Energy consumption (EJ)	1.11 EJ	0.34 EJ	1.02 EJ	0.36 EJ
Energy import (EJ)	1.2 EJ	0.1 EJ	1.6 EJ	0.7 EJ
Energy costs (billion/year)	11.31 billion/year	9.6 billion/year	16.1 billion/year	10.7 billion/year
Bio footprint (agricultural area SH)	2.3	2	14.6	4
Sustainable energy sources (% of total)	3.2%	70.5%	59.3%	70.9%

Synthesis

The three scenarios take several hypotheses (self-sufficiency, all large-scale options, fully electric) to extremes in order to gain a better understanding of the consequences of the choices we are facing with regard to our energy landscape. The most important are:

- Each scenario implies that industry (in particular the chemical industry and refineries) must either undergo a structural change or leave altogether. It is not possible to significantly reduce CO_2 emissions without making fundamental changes to industry, unless the province decides to put blind faith in an enormous rise of carbon capture and storage. Underground storage will not actually reduce emissions, but it would make it possible to keep the environmental consequences under control. This, however, is a huge gamble.
- If industry does not make the change, the energy supply to households and other companies will be affected, as industry will not be able to deliver residual heat, respond flexibly to electricity supply, or adopt a strong economic position in, for example, international biomass flows, which could also benefit others in the region.
- Neither Island nor Gateway would have enough support from society. Many of the technologies required for Gateway (such as nuclear energy, biomass plants and CCS) are controversial and the effects of Island on the landscape, together with the high costs it would entail would probably induce friction.
- The remaining option, Next Electric, looks plausible, but would triple the already huge task of producing electricity from renewable sources, as well as having major consequences for industry.
- Despite the opportunities offered by local energy solutions and the benefits of self-sufficiency, it is important not to let autarchy become a dogma. South Holland will always

have a net dependency on energy (electricity or biomass) produced elsewhere in the Netherlands or abroad.

All three scenarios were taken to their extreme on the basis of their underlying suppositions, and have not been optimised with regard to costs. However, the total operational costs including depreciations (OPEX) in the event of Island and Next Electric are still lower than the costs of the current energy supply in a "business as usual" scenario. The OPEX in the Gateway final scenario are higher in the absolute sense, but lower per unit of energy than the other end scenarios.

Ok, what should we do then? A look into the future

Although none of the above scenarios provide the answer, each scenario contains elements that are both feasible and desirable as we move towards 2050. It comes as no surprise that a mix of energy autonomy, the development of a new bio-based industry and electrification wherever possible will take the province a long way into the right direction, without involving too many sacrifices. A few trends provide a context for the future energy landscape.

1. The number of prosumers will continue to grow

From individual households to the largest industrial installations, an increasing number of energy consumers will also be energy producers by 2050[2]. Enter the prosumer. Instead of a small number of large-scale producers linked to millions of buyers, the landscape will be characterised by millions of producers-consumers, whereby the degree to which supply and demand are not yet in balance will dictate the need for centralised energy generated from overwhelmingly renewable sources using a flexible infrastructure.

The new prosumers will be diverse. The first will be existing prosumers, such as the horticulture sector, switching to other sources, e.g. from gas to geothermal energy. They will be followed by households and companies producing energy using heat pumps, solar panels, etc.. The third and most important category consists of companies who have become energy producers because their waste product has value as an energy carrier[3]. Examples of this include energy flows from forestry and water purification, large industries that produce electricity, residual heat, hydrogen, ammonia or methane. These are all developments that decrease CO_2 emissions, reduce the cost of living and generate less waste. Rules and procedures that do not anticipate on this will act as a hindrance and cause higher societal costs.

2. From commodities to services

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[2] The chemical industry, refineries and horticulture already generate large quantities of energy.

[3] In the strict sense, almost no one 'produces' energy in SH. It is always a matter of converting one energy carrier into more valuable energy carriers. In this way, refineries, coal power plants, etc. create value by converting an energy carrier (oil, coal) into a different energy carrier (e.g. petrol, electricity). The concept of value or adding value is therefore crucial to becoming an energy producer.

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Changes in the way we use energy take place at the expense of traditional, centralized energy producers (gas, fuels, electricity). The latter become smaller or embrace other roles, mainly as service providers. Business models primarily based upon generating volume by selling products are giving way to value-driven business models, as we can see in the service sector. Examples include leasing solar panels, participating in ESCOs, maintaining and managing geothermal installations, etc.. They will have to face competition from new parties, many of which will come from other sectors, such as IT.

3. New ownership

Not everybody wants, or holds a position to produce their own energy. Also, some sustainable technologies – such as geothermal heat and wind energy – work best on a large scale. But even here, a form of decentralisation is taking place, albeit at the administrative level. Despite the scale of a wind park, we will increasingly see users becoming owners of the production facility. We will see that ownership relationships of energy production facilities will shift increasingly to the users of these facilities.

This development is also interesting with regard to “NIMBY” (Not in my back yard) sentiments: it is logical to assume that opposition to windmills on the horizon will become a lot less vociferous if the local residents also own these windmills. The same principle may also apply to heat grids. Shared ownership will increase acceptance of new forms of energy production.

4. Resource independence: towards multiple open energy infrastructures

Like any other economy running on renewable sources, South Holland needs multiple interconnected and open energy infrastructures to meet all of its requirements, as well as to use available resources (residual heat, biomass, geothermal energy, etc.). These infrastructures form a core value necessary for choosing the most desirable and efficient energy solutions locally.

To prevent lock-in and sub-optimisation, energy carrier networks (heat, electricity and others) must be **resource independent**. Whether energy input comes from wind, sun, gas, geothermal heat or biomass, and whether they are generated centrally or decentralized, the infrastructure must be able to transport energy to the right place through a peer-to-peer energy network. This requires:

1. minimum restrictions for energy providers to supply to the network

2. the network must not depend upon one single energy provider or resource in order to function.

These basic premises have a major influence on how we will build and manage networks.

5. Peer-to-peer energy

Every prosumer is both a provider and a user. A critical basic principle when designing a sustainable and future-focussed energy infrastructure is therefore the implementation of **two-way traffic**. The energy infrastructure will be used to enable peer-to-peer energy transactions between different types of users at any moment of the day. These energy transactions will be made 24 hours a day, 7 days a week and require their own technical and administrative solutions. There are already several initiatives to develop blockchain-based solutions for real-time validation and administration of energy transactions, without any need for intervention by third parties, such as the commodity trading energy suppliers currently operating.

6. Heat roundabout

South Holland has great potential for heat, both from geothermal sources and industries, that can be exploited using a heat roundabout integrated with the electricity grid. This heat may find its origin in residual heat from active industries (taking account of the shift of activities within the industrial sectors), geothermal heat or even from converting electricity into heat when an excess of wind or solar energy would otherwise push the grid voltage up and the energy price below zero: power to heat.

Instead of inextricably connecting the heat roundabout with industrial residual heat (no matter what else happens, industry is bound to change) or to residual heat from coal power plants (which are certain to close down some time in the next few decades), a heat roundabout offers access to a shifting range of input resources that will continuously meet the user’s heat requirements. The heat roundabout will remain a constant factor in a changing energy landscape that can provide heat to users throughout the entire region.

The implications are: hardly any energy loss, a huge reduction in energy waste and low societal costs.

7. Flexibility and capacity markets – unity in diversity

At the moment, the energy market is a commodity market for most end users, with more or less fixed prices per unit of energy, regardless of resource or the moment at which the energy is required. In 2050, this commodity market will have given way to a variable market that is primarily driven by demand for capacity on one hand and flexibility on the other hand.

Let's start by looking at the **capacity market**. In the current situation, the capacity market is mainly in the hands of Distribution System Operators (DSO), also known as grid operators. Energy users pay according to the maximum amount of energy that they want to use simultaneously at any given moment: a thick cable is more expensive than a thin cable. In contrast to today, the capacity market will develop the facilitation of two-way traffic to an ever increasing extent. This will, among other things, imply a key role for IT technologies to validate peer-to-peer energy traffic.

And then there is the **flexibility market**. Sometimes the supply of wind and solar energy exceeds demand. At such moments, the trading price of energy falls below zero. This is pushing gas fired power plants, which until recently could cater to peak demand, out of the market. As the influence of renewable resources grows and that of fossil fuels wanes, the price of electricity will fluctuate increasingly and energy trade prices will find a new equilibrium around zero. This is because renewable resources mean that energy can be produced at zero marginal cost. You cannot make a profit on sources that cost nothing, like sunlight or wind. This means that today’s dominant volume-driven commodity market will slowly but surely give way to two new markets that have not yet remotely approached the limits of their potential to create value: capacity and flexibility.

Supply certainty makes it necessary to store energy, reduce the demand for energy or to move it to a different time. There are many options for doing so. These range from short-term energy storage (batteries, aggregators) to long-term (converting electricity into hydrogen) and from local solutions (a smart laundry machine that washes when electricity costs are low) to central solutions (large industries that temporarily switch to other resources, or even use the European capacity for hydroelectric energy - water power – as storage facilities to ensure balance between supply and demand).

The flexibility market does not yet have a clear structure. A new role is coming into play: the flexibility supplier who is paid to provide certainty and creates value through providing storage and demand management. The flexibility market is, to an important extent, a data-driven market. IT companies can anticipate energy supply (e.g. Google can estimate what time you will get home at, Uber knows your travel patterns, etc.). Connectivity through the Internet of Things will be used to develop technologies for energy production, storage and enable users to communicate with each other. The flexibility market will also integrate existing markets. Hydrogen or ammonia can be used for the chemical industry, electricity and mobility. Power-to-heat connects the heat market, electricity market and (indirectly) the gas market.

The energy dialogue takes a different turn when the flexibility market is taken into consideration. Supply certainty, affordability and added value are now generally framed from the perspective of energy resources and capacity: more plants, cheaper windmills, etc.. A new frame comes into play as the flexibility market grows in comparison to the commodity market. In this frame, supply security and affordability will be determined by the possibility to temporarily convert one energy carrier (heat, power, chemical compounds) into another one in order to attune energy demand to supply. In the flexibility market, batteries, IoT connectivity and underground storage will become new means of production, substantially adding value to the economy.

Recommendations

1. Focus on the biggest tasks ahead: industry and heating.
The industrial sector in South Holland uses almost 70% of the energy in the province. It will therefore undergo a far-reaching transformation. ***Currently, approximately 150 PJ in the form of residual heat is discharged annually: twice the amount needed to meet the heating requirements of the 3.6 million people living in South Holland.*** *The actual amount is unknown because it is not even being currently measured and this heat does not have any perceived value. In the built environment, the demand for heat is four to five times higher than the demand for electricity. In order to significantly reduce CO_2 emissions, we must turn our attention to industry and the demand for heat.*

2. Saving energy is a prerequisite.
Primary energy saving is a precondition for ensuring an energy transition that does not involve tremendously high societal costs. The province accounts for around 30% of all energy consumption in the Netherlands. Completely replacing the province's current 2000 PJ with

renewable electricity and biomass would be enormously expensive and detrimental to land use. For example, consider the local footprint of sustainable energy in ISLAND and the biomass footprint in GATEWAY. Savings in the industries require a transformation from chemical to, for example, bio-based production, a circular economy and a well-functioning emission trading system. There are also many opportunities in the built environment and transportation, for which technologies are often already available.

3. Take responsibility for the legacy of the fossil fuel industry and the transformation towards a renewables-driven industrial sector.

The fossil fuel industry has brought us many benefits, but is condemned to obsolescence. Fire-based resources, like oil, coal, natural gas and waste generate too much pollution and dependency, while fire-free alternatives are quickly becoming cheaper, more effective, and increasingly attractive. Ideally, the old order will receive appropriate palliative care, leave behind an infrastructure, a heat grid, a circular model, a green chemical sector, and either be part of the new world, or cease to exist.

4. Flexibility and interconnectedness may become more interesting than production.

In 2050, the province will be less substantial in terms of energy production than it is today. Compared to today, South Holland will produce less fuel and electricity in any of the three scenarios we developed. The volume, diversity and density of energy consumption and production in South Holland does, however, open up new opportunities for the flexibility market. A competitive industrial sector in South Holland will probably have to rely more on smart use and exchange of power flows: industrial symbiosis. The aforementioned peer-to-peer transactions in the built environment and an open heat grid are inextricably linked to interconnectedness and the flexibility market: the energy internet. Organising flexibility effectively is probably more complex economically, socially and technically, than making the shift from fossil fuel to sustainable resources and technologies. When South Holland manages to become a frontrunner, this will open up enormous national and international opportunities for its economy and society.

5. Energy is also a data issue.

Trade between a large variety of prosumers, from the industrial scale right down to the household level, as well as functioning capacity and flexibility markets will only be feasible if they can be vouchsafed by a strong IT infrastructure. This cannot be seen separately from all the developments that are currently labeled 'smart': smart grids, smart industry, smart cities and smart citizens. Energy is no longer just a matter of Joules, but also of bits and bytes.

6. Do not postpone the heat roundabout.

A strong heat grid offers great opportunities. Water and electricity are ultimate energy carriers in a resource-independent energy infrastructure. A heat grid is not merely a means to use fossil fuels more efficiently, for as long as they are still valuable, but it also increases opportunities for using residual heat and geothermal energy. This infrastructure must be developed early and steadily. Energy saving, insulation, heat pumps and other partial solutions are also needed. A great variety of users must be able to choose both individually and collectively which combination fits them best.

7. Always give room to local solutions.

Bottom-up, local solutions empower citizens to become owners of the energy transition and contribute towards a sustainable energy economy. If citizens do not get a chance to contribute to co-financing, work in clean tech, become energy producers, exchange energy or set up social initiatives, only two roles remain open to them: passive consumer or active opponent. Every

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attempt at an energy transition without a central role for the user will lose legitimacy and will – justifiably – be opposed.

8. Organise local consultation processes.
All recommendations mentioned above provide preconditions, mechanisms and options for a clean, sustainable, and unifying energy economy. These conditions are necessary, but do not suffice by themselves. The success of these plans to achieve a prosperous society will depend on the ability to make choices together with all parties involved, in dialogue at neighbourhood level, on business premises, and in the industrial areas. All actors carry a responsibility to work towards this higher goal, despite the fact that the energy transition will not always be in everyone's short-term interest. Jointly developing the skills to engage into dialogue with each other, transcending personal, political or commercial interests regardless of our role, position or influence, will help us to serve a goal higher than ourselves. As stakeholders, we can unite to find solutions that serve the common good. Finally, in addition to the focus on the technical aspects of a new energy service, it is necessary to pay attention to the social and economic pillars that will lead this necessary and inevitable transition to a democrastic and sustainable energy system that will serve the public interest. An energy system borne up by its technological value, economic value, and social value.

Acknowledgements

The following quote by Buckminster Fuller became the motto that guided this process: "*You can never change things by fighting the existing reality. To change something, build a new model that makes the existing model obsolete.*" Building this new model is not the achievement of a few individuals, but the result of an active and ongoing dialogue that transcends individual interests between people with diverse approaches, knowledge and ideas.

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