Digitization and energy – more than the sum of its parts

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Index

1 Foreword

In 1995 we reached the milestone of 1 million households with an internet connection in the Netherlands. An unlikely feat, given that the www protocol was introduced just six years earlier. Our world would never be the same again. The world now has hundreds of millions of *digital natives.* People born after 1989, who grew up with the internet as a daily reality, people who are now starting to occupy key positions in our society: scientists, administrators, inventors, artists, engineers, entrepreneurs, teachers. People for whom digitization, artificial intelligence, cryptology, big data, blockchain, algorithms and distributed systems are part of everyday, makeable reality.

25 years later, in 2020, another milestone was reached: more than 1 million households now generate their own energy from renewable sources. And this development has a trend similar to the development of internet use in the Netherlands. It started with a few pioneers, environmentalists, scientists, enthusiasts of the latest gadgets, and now renewable energy is becoming commonplace. Homemade, local, and harvested directly from an inexhaustible source.

A few years ago we could not have imagined it, but it is now very conceivable that in 15 years' time 95% of Dutch households will generate energy from renewable sources. A world led by people who consider it quite normal to generate their own energy from inexhaustible renewable sources, to store energy themselves, to convert it, to share it with neighbours, to value it and to balance it. We are witnessing the emergence of the era of the *renewable energy natives.*

This makes the energy transition a revolution with, if possible, even more far-reaching consequences than the internet revolution.

This publication is not only intended for *digital natives* and *renewable energy natives.* Not just for colleagues, mathematicians, techies, and fellow nerds.

Now that we see that digitization in the energy domain affects everyone, and belongs to and for everyone, we are also writing this publication for non-techies. The policy maker, the involved citizen, the investor, the innovation enthusiast, the ethicist, the entrepreneur, the energy professional, for everyone who believes that digital technology and energy together are more than the sum of their parts.

2 Short summary

2.1 Digitization and energy. More than the sum of its parts

Five years ago we published the piece 'Digitization in the Energy Landscape', in which we described how digitization is fundamentally transforming our energy supply and what opportunities there were.

Fortunately, a lot has happened. There is now a Digitization Program and concrete steps are being taken towards close cooperation with the ICT Top Sector. There is still a lot to be gained, particularly at the cross-system level.

Without energy, there is no digitization and no economy. Energy is a foundation of our society. And now without a functioning digital system there is no longer an energy system. The relationship between digitization and energy has become symbiotic. We needed an energy system to develop the internet. Now we need the internet to maintain the energy system.

The internet has become the invisible digital equivalent of the micellar network that connects everything to everything in nature. Centrally managing millions of suppliers of sustainable energy is impossible.

The Netherlands now has more than 1 million providers of renewable energy. Yet we still have 97% of our energy supply to make more sustainable. This is not possible according to the rules and design principles of the current energy system. And in times of fundamental change, this creates stress. The system stress can be felt in the explosive increase in congestion zones and the physical obstacles that are now occurring in the construction and installation of solar and wind energy. A breakthrough is needed.

Digitization is roughly used in two ways: on the one hand to change existing systems, to make them superfluous, to bring about a disruption and to bring about a new order. On the other hand, we use digitization to maintain the status quo.
Digitization to pump oil more effectively, digitization to increase customer dependencies, digitization as a lock-in. We must be aware of which form of digitization we feed.

We see a fusion of our systems for digitization and energy, sometimes from the old economy, sometimes very visionary and progressive. This requires a high degree of integration and clear preconditions. A clear picture emerges of an Internet of Energy that can be viable and attractive to almost all parties. Choices for climate, for society and for a future-proof and sustainable energy system are necessary, but which choices are these? What is Wisdom? Data and algorithms are not value-free, they can disrupt balance, nature and society, but also improve. They can benefit the individual or a powerful company at the expense of others, but also improve the whole system.

Digitization is the important factor that enables a real energy transition while preserving the valuable aspects of the old. We will then see that the financial system will also change. Why? Energy is the ability to do work; when it comes within everyone's reach, value creation becomes everyone's. The modern equivalent of the gold standard then lies within society and no longer above it. Energy from renewable sources is not scarce, it is about balance: between generation and need, between supply and demand, between appliances, between local markets.

This means that the conversion and storage of energy will play an important role, but the cheapest will always be not using it at the right time. Digitization can give everyone insight into the right choices. Digitization offers enormous opportunities: everyone can map out their personal energy transition plan, and with the help of digital twins, the effects of a new solar meadow on the environment can be estimated before even a shovel goes into the ground. And with digital technology that optimizes the use of existing networks, we can save billions in infrastructure investments.

We also encounter pitfalls on the path to digitization. Problems that have no owner, for example, such as the integrity of data, or the need for grid reinforcement where flex providers determine the market. Another trap is the lock-in: being forced to use a certain technology or a certain supplier. And cybersecurity is not the responsibility of a single provider, but of the entire system.

This requires investments from all parties involved, digitization is essential for effectiveness and sustainability at system level, as is the integration and management of storage in the short and long term, and conversion to heat. Integral energy networks where the traffic of molecules, data, electricity and heat are intertwined. This requires optimization of investments. Which function and technology is most profitable in a given local network based on the integral system? The experts interviewed related the essence of the energy transition to the generations after us and the balance between man and nature. Digitization provides a connecting force where the energy sector was previously seen as separate. Digitization is not a goal but a means.

Together we can look at the costs and benefits, both financially and socially. This is already happening in the Club van Wageningen, an ongoing 'search conference' with stakeholders, because we can only shape the digitizing energy transition together, including being prepared for what can go wrong, including in our relations with other countries. There are also interdependencies there. Climate targets require a broad but also sophisticated approach; a personal, acceptable and understandable energy transition plan for every resident of all countries.

By integrating digitization and energy, not only technologically, but also economically, socially and institutionally, these two topics become more than the sum of their parts.

3 No digitization without energy

3.1 Digitization: incremental or disruptive?

Digitization is roughly used in two ways: on the one hand, we see digitization being used to challenge, disrupt the status quo, and lead to system innovation. Everything we can imagine is called into question here. Everything is allowed to change for the benefit of the intended situation: technology, market, social interweaving, laws and regulations.
This form of innovation is often potentially disruptive. If such a development is embraced by the masses, the whole system will change. Examples include the adoption of the Internet by households in the 1990s, or the increase in the number of people generating their own energy through solar panels or shares in wind turbines.

On the other hand, digitization is used to maintain the status quo, and then make it slightly bigger, better, faster, stronger. This is often aimed at improving the efficiency of the current system, but - often driven by the interests of existing players - it is not aimed at system innovation.

If we make a comparison with the development of the internet, we see different things. In the short term, there is a tendency towards bigger, better and faster, preserving the current system. Isn't large-scale hydrogen production actually another form of centralization? We still see too often a tendency towards incremental improvements of the current system. Henry Ford said that if it had been up to the consumer, he should have bred a faster horse instead of building cars. Do we therefore want to invest a lot in innovation in order to ultimately improve the status quo, without really changing anything?

It is very easy to classify all digitization under the first, disruptive category - because that responds to a popular sentiment - but let us be aware that where, for example, artificial intelligence or blockchain is used in an existing sector, this is generally is done to strengthen the existing position of that sector. That can be very good, but should not be seen as disruption or system innovation. Such incremental innovations are often very good, but they also regularly get in the way of the transition.
Because if, for example, we innovate or subsidize to sell fossil energy longer, more or better, we do little else than saddle future generations with an even bigger problem.

3.2 First there was energy

Digitization is impossible without a functioning energy system. Digitization is not self-evident. Digitization is even unthinkable for someone without access to energy.
First, an energy system was needed to be able to develop microprocessors, storage media and later also the Internet. We can thank our fossil energy system for this. All digitization relies on the existence of an energy system that functions and meets the demand the moment that energy demand is there.

That energy system was initially quite simple, local, and existed to meet the need for light and later also for heat. It was only later that the energy system became increasingly networked, cities were interconnected, and the connected capacity grew to the level where industries could be supplied with large amounts of electricity and heat.
Ultimately, we see an energy system in the Netherlands with parallel networks for electricity, heat and gas. An extremely reliable system, because in the Netherlands we only have no power for 24 minutes a year. And that reliability has proven to be extremely valuable for the creation and roll-out of the internet.

3.3 And then there was the Internet

When the internet was still a very young development, the Netherlands acquired a particularly strong position by bringing overseas cables ashore here in Europe. Data centers such as Global Crossing and SURFsara played a crucial role in the development of the Internet for the whole of Europe. This was possible thanks to the extremely reliable electricity supply system.

The development of a global electricity production and distribution system has enabled a digital revolution that is unprecedented. That development was initially independent of the sources; coal, oil or gas, it didn't really matter where the electricity was generated centrally elsewhere.

When it gets interesting is now. Decentralized generation and digitization do influence each other. Large-scale central data processing directly affects the capacity of the electricity grid, especially if it is built in places where the land is cheap but the grid is weaker. Until recently, it didn't matter where the energy for our data centers came from. There was always a coal-fired or gas-fired power station somewhere that met the fast-growing energy needs of data centers. But now, like the rest of our economy, these data centers are increasingly dependent on renewable energy, often from onshore and offshore wind, and increasingly from solar panels. Is digitization, because only recently it didn't matter where the energy came from, is it now lagging behind developments?

Because the development of microprocessors follows Moore's Law (every two years you can have twice as much computing power at the same cost, and we can perform twice as many calculations at the same cost) we see an exponential growth of computing power. The first computer processors in the 1950s had very limited computing power and contained 1 transistor per chip. In the 1980s, digital technologies began to enter our lives and work environments on a large scale. At that time, 275,000 transistors already fit on a chip.

In this decade, we are breaking the barrier of 100 billion transistors on a single computer chip.

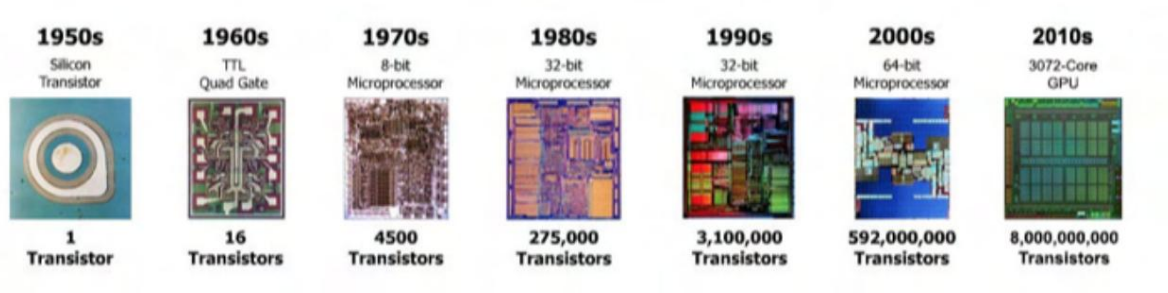

Figure 1: Exponential development of processors according to Moore's law

In 1973, the entire Arpanet (the predecessor of our internet) had 36 users worldwide. In 1989, Tim Berners Lee wrote the World Wide Web protocol and since the introduction of the WWW, the Internet became accessible to the masses.

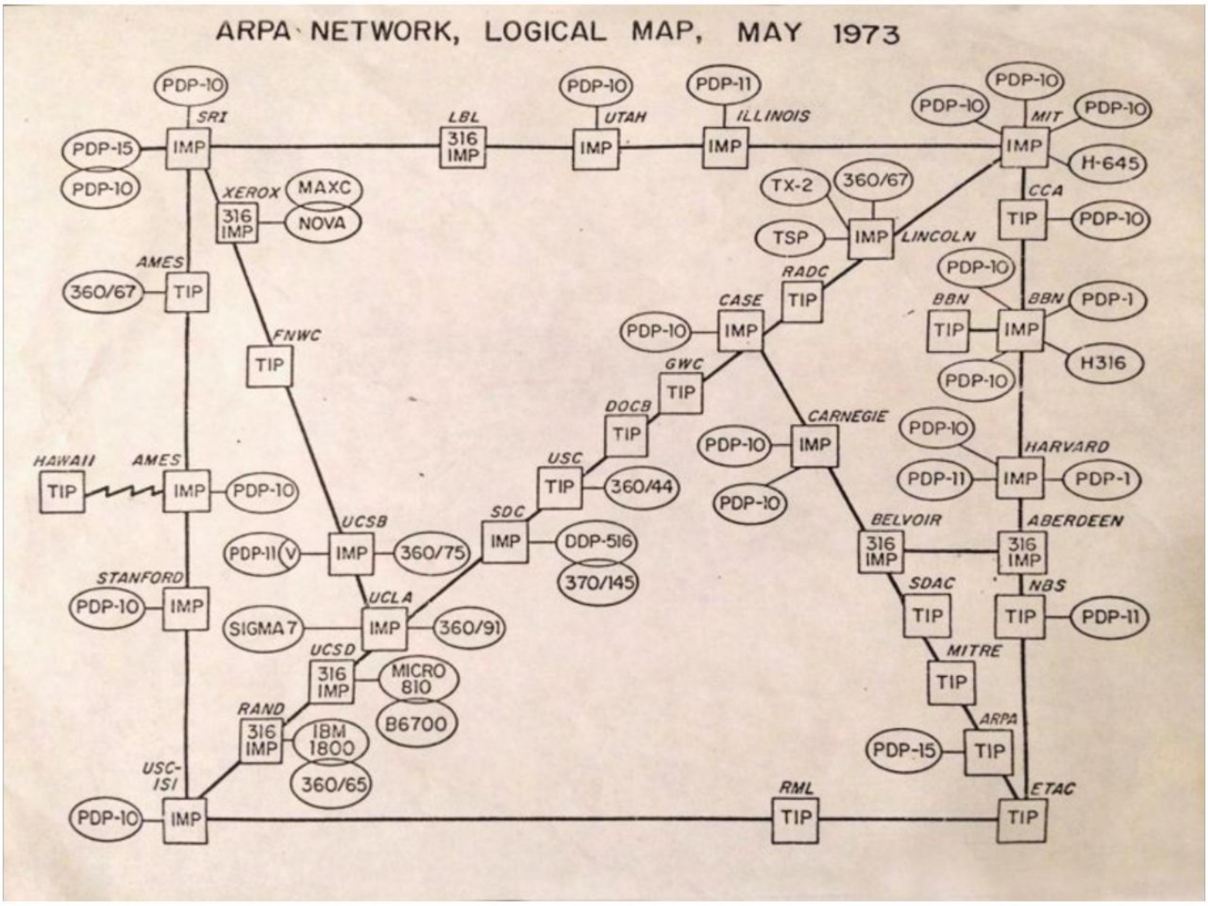

Figure 2: In 1973 Arpanet, the predecessor of our Internet, had 36 users worldwide

The emergence of the Internet in the 1990s and the adoption of decentralized renewable energy now show an interesting parallel: Around 1995, we in the Netherlands passed a historic barrier; more than a million households had access to the internet since then. In the preceding years, a growing group of enthusiasts, dreamers, investors, pioneers and innovators anticipated the moment when the level of access to the Internet would reach a point where society would be forever changed. After all: as soon as

If someone could be connected at a low cost to all the information and knowledge in the world, accessible at the touch of a button, at the time of their choice, this meant something much deeper than the adoption of a new technology. From that moment on, this person was no longer a consumer of knowledge and information, but a prosumer. Just as easily as a person could gain knowledge by looking it up through millions of bulletin boards, Internet forums, websites, and databases, that person could add their own knowledge and information to these networks, self-publish and maintain a website, and emerging online encyclopedias provide input. Slowly but surely, thanks to the internet, the world would never be the same again.

The years that followed indicate the speed of the Internet revolution. In 1998, sixteen percent of all households were connected to the Internet. In 2000 this was forty-five percent, in 2010 already ninety-three percent and now, with a few exceptions, all households in the Netherlands are connected to a worldwide network through which knowledge, data, news, sense and nonsense, joy and sorrow are shared with each other.

The internet has now been around for just over 30 years, we count 4.8 billion internet users worldwide, and this number is growing by 700,000 users per day. The average internet user is now online for almost 7 hours a day.

It seemed unimaginable in 1989, the year in which Tim Berners-Lee developed the World Wide Web protocol, but it happened anyway: we now consider it the most normal thing in the world to hear the latest news while lying in bed with a telephone . We find our life partners through the internet. We watch movies en masse that we download and watch when it suits us. 96% of the Dutch are now users of Youtube.
Last year, internet use by households increased by 35% to 22.77 million terabytes due to the increase in the number of home workers.

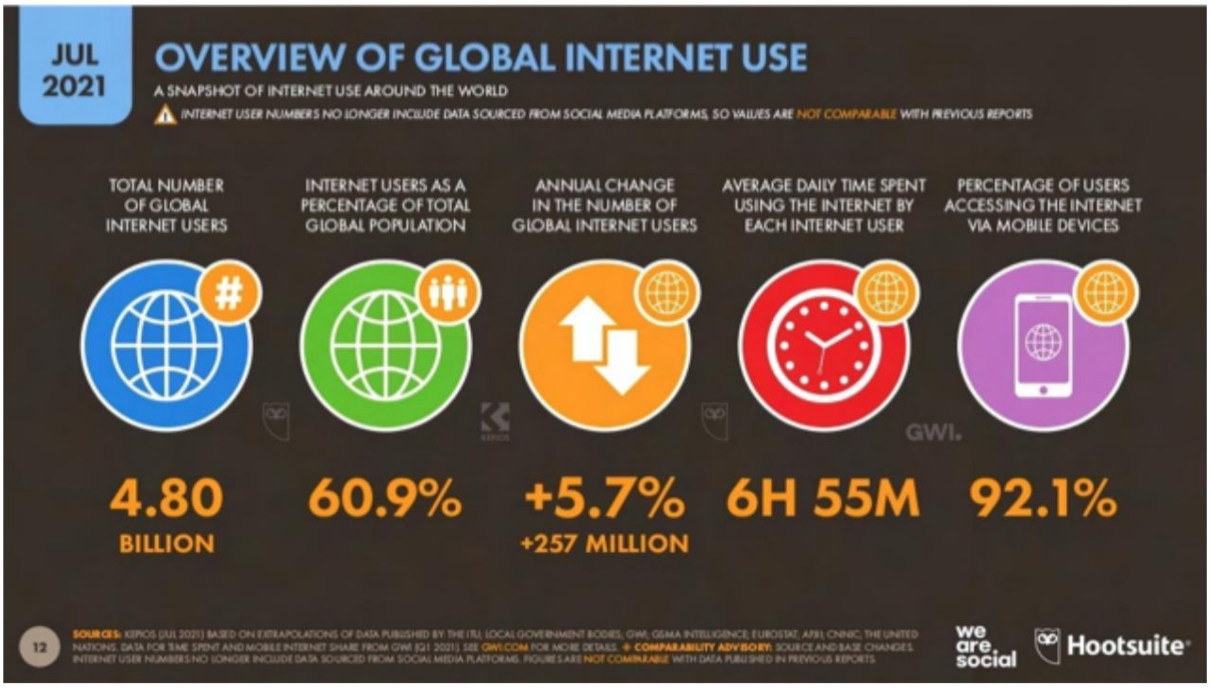

Figure 3: The Internet now has 4.8 billion users. This year, 257 million will be added. Source: Hootsuite

3.4 And now symbiosis arises

Now it is precisely the internet that makes a new energy system possible. We first designed a fairly simple system in which a few producers could control power plants according to the fluctuating demand of millions of customers. But with the planning and control systems we have for this, managing and switching millions of renewable energy providers is simply impossible. One can no longer do without the other. The systems for energy and for digital technology, communication and data are becoming intertwined.

Thanks to a distributed system for data and knowledge - our now loyal and indispensable internet - a distributed and decentralized energy system is possible for the first time.

This also means that what we have built must actually be built again. Through the eyes of an ICT specialist, the energy system will be designed very differently. We have learned to invest in digital literacy, and now we need to invest in energy literacy.
Energy professionals need to understand what digital technology is for, its context, and how it is changing the energy system. ICT professionals must learn what the role of energy is for their systems, and how they can use their knowledge to ensure that energy systems can function on the basis of renewable, non-controllable sources.

There is a great need for programmes, research and development at a supra-system level, to which individual technologies - energy technologies and digital technologies - are subordinated.

We can expect the development of the number of energy suppliers to follow roughly the same development as the number of connected users of the internet. We have now grown in 15-20 years from a few dozen power stations where energy was produced to more than a million providers of renewable energy in the Netherlands. It is a matter of (little) time before we know billions of suppliers of renewable energy worldwide, and not only in the form of electricity: also suppliers of small-scale residual heat, batteries, other forms of storage, energy converters, suppliers of molecules such as hydrogen , biogases, ammonia and so on.

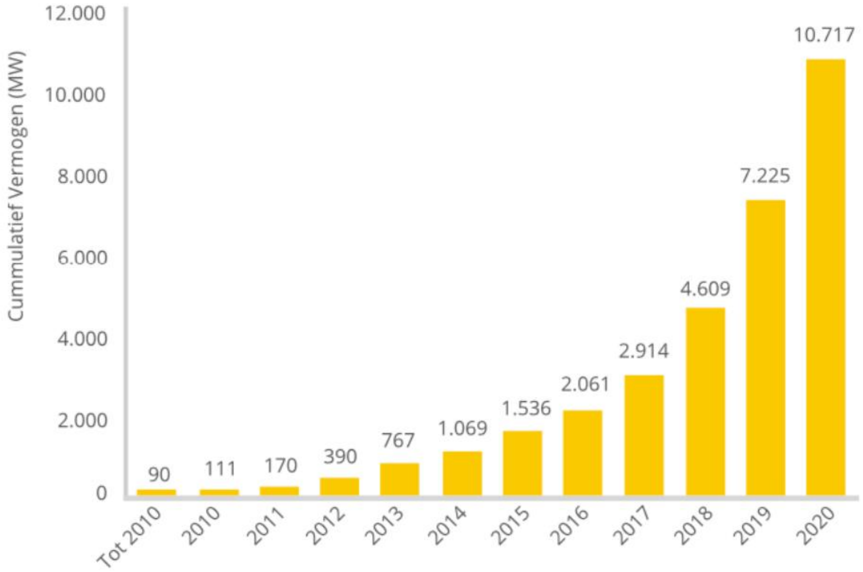

Figure 4: The number of solar installations in the Netherlands is growing exponentially. Source: National Solar Trend Report 2021 © Dutch New Energy Research

The energy system and the internet have now entered a state of symbiotic relationship. One cannot do without the other. Energy is necessary for the internet and the internet is necessary for energy.

'Energy is necessary for the internet. And the internet is necessary for energy'

The energy transition does not necessarily make everything better, cheaper, faster and more reliable. In particular, the switchover of energy carriers such as gas, oil and coal - which can be turned up or down at the push of a button on the power station according to the instantaneous demand for non-switchable sources - demands the utmost of our flexibility and management skills on the energy system. Our networks are very well designed for central control and one-way traffic, but cannot handle two-way traffic. With more than a million points at which energy is offered, traffic jams are created. And this traffic jam causes problems with frequency maintenance, balancing, the quality of power and voltage deteriorates, resulting in power outages at a local level and possibly escalating to a national and even European level.

Without digitization it is completely impossible to design, build, let alone maintain a system consisting of millions of users and billions of devices, each fulfilling multiple roles, supplying and consuming energy, across multiple energy carriers.

But when digitization and energy reinforce each other, both systems move towards a wealth of different sources, forms, and technologies that will best serve us as individual connected parties.

4 Background – how we came to one digitization agenda

In 2016, we realized that digital developments play a crucial role in the energy transition, and at the same time we noticed that there was no specific attention for this subject within the Top Sector Energy. We also foresaw that if digitization were not put on the agenda, we would watch with regret as tech giants eventually gain a dominant position in the energy domain, thereby gaining control over the provision of a basic need for every human being.

We saw that all kinds of projects were facilitated and implemented for energy innovation, but digitization had little place in the Knowledge and Innovation agendas of the Top Sector. Most projects also touched on digitization, but without a structured agenda it would remain a mess, and no serious resources would be released for it. This, while most stakeholders estimate that digitization - we don't know how, but we do know that - would be crucial for a successful transition to a decentralized, renewable energy based energy system.

Five years ago, we investigated how digitization is fundamentally transforming our energy supply and what opportunities were already there for the taking. This resulted in the report 'Digitisation in the Energy Landscape'. Fortunately, a lot has happened since then, but also a number of things that have not yet happened. Efforts have been made to stimulate technology development, but insufficient efforts are being made, particularly in the field of system transcendence. Technology is only valuable in a context, so what is the technological need when we look at social, economic or institutional developments and wishes? Which design principles must energy networks meet in order to be more than the sum of their parts? How do we ensure that local users and producers, in collaboration with providers of storage and conversion, arrive at a locally optimal system that meets the specific needs of that local community? And how do we then ensure that these locally optimized networks can in turn mutually achieve regional balance in a system that is affordable and accessible to every user, regardless of their technological preferences, specific needs and choices?

For example, we conceived the plan to write a document in which the need to focus on digitization for a successful energy transition would be explained.

With limited time and resources, a fascinating and enthusiastic kitchen table process was created. Based on our own knowledge and insights, whether or not they lack insight, we wrote the document 'Digitisation in the Energy Landscape', which we did not dare to refer to as a digitization agenda because of its arbitrary nature, but as an agenda document. The hope was that, partly thanks to this letter, digitization would be given a more prominent place in the Knowledge and Innovation Agendas, KIA, of the various TKIs of the Top Sector Energy. It worked. Every TKI now works with the subject of digitization, more and more resources are gradually becoming available for innovation/development projects at the intersection of digitization and energy, and there is now a cross-cutting program Digitization, designed by John Post, Tijs Wilbrink, and now taken to the next level by program director Harold Veldkamp.

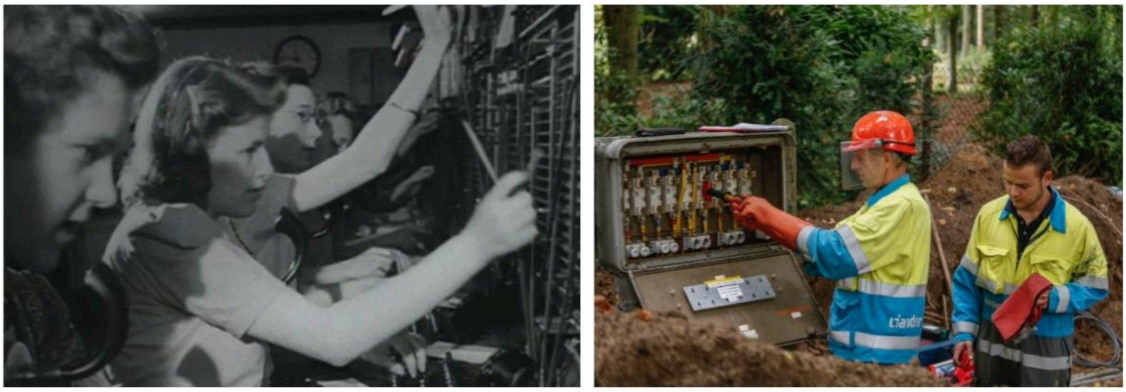

Figure 5: telecom in the 1950s vs energy today. Source: KPN & Liander

4.1 Looking back: What has happened since the publication of 'Digitisation in the Energy Landscape'?

Over the past few years, a good start has been made with the topics from the previous report, and the first results are visible. Each TKI of the Top Sector Energy has now embraced digitization as a theme, and has made resources available for this in various ways. But Brussels, science and the market are not standing still either. The aim of this new document is therefore, on the one hand, to gather new insights into the practice of digitization and, on the other hand, to reveal the greatest common denominator and trends in order to strengthen the policy that has been deployed.

Let's first look back at what we wrote then, with the starting points for the new agenda.

In 2017 we wrote 'we belong to the last generation that ever knew a world without the internet'. The world now has tens of millions of *digital natives:* entrepreneurs, professionals and academics who were born later than the internet and grew up with the daily reality of digital technology. We wondered whether ICT companies would take over the role of energy companies. That has not happened yet, but the need to integrate energy and digitization has not become less. We see the contours of companies that are no longer an ICT company, and are no longer an energy company, but are trying to build something completely new. A system is gradually emerging that shows all the characteristics of an “Internet of Energy”, but is not yet one. This requires a clear transcending vision, broad cooperation and sufficient investments. The user, who is increasingly becoming a prosumer, wants it! This means that the market is there and subsidies only have to play a role temporarily.

We wrote; 'digitisation in itself is responsible for every society-changing development of the past twenty years' and that is only partly true; look to floods, climate, polarization, radicalization and the pandemic that have dominated our society for the past year and a half.

We wrote that the digital transformation will sooner or later affect all companies, even those whose business model does not change, and that this will also hit our energy world hard. We now see that even the energy supply is being affected by the choices demanded by climate and society. Congestion, explosive price increases and threatening gas shortages are becoming visible and will come back later in this report.

We wrote that algorithms enable our systems, our environment and ourselves to become ever smarter. Data and algorithms lead to progress. The effect, if well designed, is knowledge-enhancing, democratizing and opens doors to entirely new ways of value creation. Nevertheless, in recent years we have also seen the disadvantages in the assessment of benefit applicants by the tax authorities. This indicates once again that data and systems are designed and filled by people, and are not value-free. We can now take advantage of this and include the user in our decisions.

We wrote that when an inexhaustible source such as the sun is used, the marginal production costs of energy irrevocably move towards zero. Scarcity is no longer a problem, but the balance between supply and demand is even more so. Meanwhile, the costs of generating energy from wind and solar have fallen even further, as have the costs for storage. Here are the opportunities to put the user first. If we don't, smart grids and democratic systems will remain drawing board exercises.

We wrote that the transition rests on four pillars: technology, economy, society and institutions. This requires economic, social and institutional support. Support means trust in government and science and, as we have seen in recent times, this must be proven and earned.

We wrote that the discussions about energy can only be understood from a social order; a statement about the problems of fossil energy is a statement about what reality should look like. We are now also seeing the problems of centralized sustainable energy, shortage of connection capacity in many areas, congestion, and resistance to onshore wind. Politics, science and *'energy literacy'* among users are all needed.

We wrote that the sun has provided our basic energy needs since time immemorial, but that we have not yet learned to use it properly. An organized responsibility that gives us the framework within which to develop, act and implement across borders and generations would enable all of humanity to benefit from its eternal energy source.

We wrote that energy companies and network operators cannot avoid making the step from procedure-driven decisions to data-driven decisions. Our energy bill will then increase according to the amount of imbalance we cause, or decrease if we have a balancing effect on the grid voltage. A problem in the Netherlands, however, is that the grid operator is not allowed to have a financial relationship with the customer and the retailer has less interest in it, because it makes a profit per unit of energy sold and wants to sell as much energy as possible on balance. This is an example of an 'ownerless problem', admittedly recognized and acknowledged, but for which no body feels responsible. As a result, such problems are not or hardly solved. In countries where both operate on the free market or both are in public hands, this is much less of a problem.

Nevertheless, current development leads to a two-way system, including multiple forms of storage including heat. The latter requires interoperability. Systems must be able to work together. In addition, interconnectivity is important. Neighbors sharing energy with each other is not a dream, but a logical development - highly recommended even by Brussels policy makers - especially in combination with the aforementioned interoperability. Working at district and device level is the key to solving the network operator's problems. However, this requires focused attention and support for the development of pre-competitive agreements, protocols and standards.

In 2017, we responded soberly to the blockchain hype; we called it a digital cloud-based ledger account. No more, but certainly no less because it is ideal for handling a multitude of time-bound transactions, but can also provide insight into who is doing what and where and thus detect leaks and theft. We wrote that the blockchain best suited to validate time-bound energy transactions has yet to be developed. We are now closer to that, but we still see a lock-in in various systems - in which the user of a blockchain is forced to also trade in the financial tokens belonging to that blockchain - which is crippling the overall commitment.

We wrote that small consumers, increasingly prosumers, are also becoming more flexible with their energy needs. This demanded and demands an increasingly direct connection between the network operator on the one hand, and the user and their devices on the other, but the above-mentioned compartmentalisation is also a problem here. Real-time energy pricing can only work if the instantaneous valuation of production and use across the entire chain is facilitated. We will return to this in more detail when discussing the interviews under the theme of 'transcending the system'.

We again mentioned and emphasized the importance of a new market model that facilitates direct pricing between buyer and supplier. In that atmosphere we have seen the 'experimentation scheme' come and go. Various experimental status holders complained about the limited cooperation that network operators could provide. Now that the number of producers continues to increase, a digital system must keep a multitude of suppliers and customers from different sources and across several carriers in agreement with each other, and the network operator must be able to play the desired role in this.
It is still true that design principles for the new market direction must take the above into account in order to shape the new market, and that this requires larger, cross-technology experiments and projects, as well as standards and protocols such as the Public Stack, USEF and EnergyTag.

We talked about the importance of converting surpluses into hydrogen, but also into heat in particular, but integration of the energy carrier networks is also necessary here.
Seen from the air, South Holland, for example, is a fossil fuel industry hub, but that is precisely why it is the ideal place to deploy the transition on a large scale and to use industrial residual heat in a way that serves the users who have to 'get rid of gas'. Data and automation can significantly reduce the necessary investments in infrastructure because

is not oversized. In this sense, experiments can also be conducted that are less disruptive and better integrated into reality. In this way, standards can be developed on the basis of the known protocols, with which long-term policy can also be made and lock-ins can be prevented. In this way, the necessary social support can be created and, after the 'why' of the energy transition, the 'where to' can also be understood and supported.

Digitization is now a fully-fledged subject in the TSE. There is a Digitization Program and the importance of the theme is widely recognized and supported. Ready for the next phase: Integration.

4.2 Who contributed substantively to this agenda?

This report was made possible thanks to the willingness of many experts involved to share their vision and ideas. In particular, interviews were conducted with the following people:

- Ton Backx, emeritus professor at TU/e, founder of Photon Delta
- Jaya Baloo, CISO, Avast Technologies
- Fred Boekhorst, director Team ICT
- Rob Burghard, Founder and CEO EnerGQ
- Kees Haverkamp, innovation director TJIP
- René Montenarie, ECP Platform for the Information Society
- John Post, former program director digitization Top Sector Energy
- Richard van de Sanden, director DIFFER, Dutch Institute for Fundamental Energy Research
- Rob van de Velde, director of Geonovum
- Harold Veldkamp, program director digitization Top Sector Energy
- Erik Wijnen, policy advisor EZK

In addition, many discussions were held with entrepreneurs, students, experts and scientists. In this document we attempt to honor their insights, advice and knowledge.

Each interviewee received a questionnaire in advance and was asked permission to record the interview so that these conversations can be consulted as a reference. The interviews all took place online and each lasted one hour. Each interviewee was informed that their input would be treated confidentially. No quotes are attributed to specific persons in this report.

The interviews all started with the question what they think is the essence of the energy transition. Subsequently, during the interviews, the focus was mainly on the interface between digitization and energy, for example on the influence of digitization on the development of the energy system. There was also reflection on the self-image of the energy sector; as long as the energy sector continues to see itself as an independent sector, there is no system progress. After all, energy is ubiquitous, and not the domain of a specific sector. In fact, we can already speak of more than 1 million energy producers and suppliers in the Netherlands.

The harvest of the interviews has been compiled and we were able to derive a number of conclusions from this. Later on in this document, you can read about trends that transcend systems, for example: these movements are interpreted or recognized by almost every interviewee. The same applies to other observations, and to some of the recommendations. We have also analysed, merged, enriched and tried to describe them in clear language. In this way we hope to arrive at an agenda that is widely recognised, supported, and in particular offers guidelines for policy to be formed, regulations to be developed, subsidies, financing and other forms of support for innovators in the knowledge sector, the business community and the government.

5 The Top Sector Energy now: Programme Digitization

The Digitization Program has now been operational for a few years and functions as a 'linking pin between the Top Consortia for Knowledge and Innovation (TKIs) within Top Sector Energy and Top Sector ICT, aimed at concrete issues that can be tackled jointly'. In addition to conducting their own initiatives, they actively participate and contribute to programs such as the Dutch Digital Delta, the Dutch AI Coalition, the Amsterdam Economic Board with regard to LEAP, the Club van Wageningen and others.
Contributions are also made to coalitions in collaboration with other TKIs such as IRO, NWEA, NVDE, Holland Solar, Netbeheer Nederland, VEMW and VNO/NCW.

The Digitization program is also starting to develop stronger ties with knowledge institutions such as NWO, various universities, colleges and field labs.

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Empowering the new economy

Nederland is een land met een missie

Wij willen sneller innoveren om broeikasgasuitstoot zo snel mogelijk te verlagen én een CO2 neutrale maatschappij te worden. We staan voor een enorme verduurzamingsopgave: 49% CO2-emissiereductie in 2030, op weg naar 95% emissiereductie in 2050. En tegelijkertijd willen we als eerste, de beste en meest praktische innovaties voor grote maatschappelijke uitdagingen. Dat vraagt om nieuwe technologie én goedkopere, betrouwbaardere bestaande technologie. We hebben geen tijd meer te verliezen willen we de doelen uit het Klimaatakkoord halen.

De Topsector Energie is de spil in dit innovatie-ecosysteem rond Energietransitie & Duurzaamheid. Bedrijfsleven, onderzoek, onderwijs, maatschappelijke organisaties en overheden slaan hier de handen inéén. We ontdekken, onderzoeken, ontwikkelen, proberen, leren en bouwen. Aan de technieken en methodieken waarmee we onze missies gaan behalen.

Missiegerichtheid is hier het sleutelwoord. Met de missies koppelen we onze innovatiekracht aan het oplossen van die maatschappelijke uitdagingen. Met concrete oplossingen. Groot en klein. Van de nieuwste inzichten en technologieën tot praktische en leuke oplossingen in design en gebruik. De Meerjarige Missiegedreven Innovatie Programma's (MMIP's) laten zien welke innovatie-opgaven opgelost moeten worden, om onze klimaatdoelen te halen.

Digitalisering

Uitdagingen
- Kennis van ICT en digitalisering blijft een probleem
- Het kunnen denken in architecturen in plaats van p2p oplossingen
- Het denken in verbeteringen in plaats van verandering

Kansen
- De mogelijkheden van digitalisering door middel van AI, machine learning, creative platform, flex, etc.
- Privacy, inclusiviteit, autonomie of gelijke machtsverhoudingen
- Herkenning van convergentie tussen ICT en energie

Missies
- A Een volledig CO2 vrij elektriciteitssysteem in 2050
- B Een CO2-vrije gebouwde omgeving in 2050
- C Een klimaatneutrale industrie met hergebruik van grondstoffen en producten in 2050
- D Emissieloze mobiliteit voor mensen en goederen in 2020
- E In 2050 is het systeem van landbouw en natuur netto klimaatneutraal

Programma's (MMIP)
- Hernieuwbare electriciteit op zee
- Hernieuwbare electriciteitsopwekking op land
- Versnelling van energierenovaties
- Duurzame warmte en koude
- Elektrificatie van het energiesysteem
- Sluiting van industriële ketens
- Een 100% CO2-vrij industrieel warmtesysteem
- Maximale elektrificatie en radicaal vernieuwde processen
- Duurzame energiedragers voor mobiliteit
- Doelmatige vervoersbewegingen voor mensen en goederen
- Klimaatneutrale productie food en non-food
- Land en water optimaal ingericht op CO2-vastlegging en gebruik
- Robuust en maatschappelijk gedragen energiesysteem

Thema's
- Waterstof
- Groen gas
- Digitalisering

- Human capital
- Financieringsloket
- Internationale export en kennisagenda
- Maatschappelijk verantwoord innoveren

Figure 6: overview of issues and topics of the Digitization Program – Source: Top Sector Energy

5.1 Interfaces Program Digitization Top Sector Energy and Key Technologies Top Sector ICT

Below is a comparison between the substantive topics to which the Digitization Program of the Top Sector Energy focuses on the one hand, and the key technologies as supported by the Top Sector ICT on the other.

Subject	**Top Sector Energy Program Digitization**	**Key Technologies Top sector ICT**
- Energy System Architectures -	X	-
- Data in the broadest sense of the word	X	X
- Cyber security	X	X
- Digital Twins	X	-
- AI	X	X
- Blockchain	X	X
- Future Networks	-	X

The similarities are clear. However, there is no close cooperation yet. If we assume that both Top Sectors are involved in similar developments and take care of similar problems, it is advisable to reinforce each other in this. To which issues of the ICT Top Sector can the Digitization Program contribute? And for which issues of the Top Sector Energy are solutions being developed in collaboration with the Top Sector ICT and the Dutch Digital Delta?

5.2 Digitization within the TKIs and MMIPs

Within the existing TKIs and Multi-year Social Innovation Programs (MMIP), the focus is now on the following topics:

TKI Offshore Wind	• cyber security • The rest based on available budget •
TKI Urban Energy	Chain automation & optimization. • Energy System Architectures • Blockchain • Artificial Intelligence • Cyber
TKI Energy & Industry	Security, • Digital Twins with a focus on match electrification and RES process, together with New Gas, Digitization and System Integration • All the
System integration	spearheads mentioned have landing spots here, but mainly reasoned from Energy System Architectures. • Learning community HvA Amsterdam in collaboration with Human Capital Calendar
TKI New Gas	• ESA • Digital Twins with a focus on match RES
Human Capital Calendar (Together with AI Coalition, DDD and HCA)	• Impulse program for training & education in AI, applied to Energy+ putting digitization on the agenda within PPPs. • ICT labor market research with top sectors 2021. • Webinar series Green recovery/EOC2021 in collaboration with System Integration. • Blended learning for technical personnel (VR, AR) • Club van
Socially Responsible Innovate	Wageningen, • (in collaboration with Waag Society) Transposing public stack ideas on other use cases.
Program Digitization 'own subjects'	
Energy System Architectures	Design and first pilot implementation of improved OSI model for power grids (ROSIE) in the low and medium voltage field, including: • Location awareness • Nomination, allocation & reconciliation processes • Auto- identification network-linked components • Suitable communication technology • Link with application thereof to Urban Energy & Industry as minimal subset • Digital twin as first implementation (collecting evidence) • Follow-up
Societal role & use of data (architectures)	process Waag Public Stack • LEAP (energy use as a result of data demand, energy efficient infrastructure) • Development and updates
Digitization agenda	

Now the logical moment has come to move from an 'agenda document' to an 'agenda'. This also requires a different approach for this document. This is no longer completely arbitrary. Instead, interviews have been recorded with a number of digitization experts in different fields, some with a focus on the energy domain, and others not.
A qualitative research design was chosen, which means that relatively few people were interviewed, but the conversations were extensive, and certainly inspiring and broadening the picture.

6 System transcending developments

What are the major movements that, whether we choose to or not, will continue anyway? What should we take into account when trying to contribute to an energy system that is fair, inclusive, clean, sustainable, affordable, democratic and future-proof?

6.1 From A to B via the principles of B

We move from A (the current system) to B (the system we want to realize). Yet we try to reach B through the language and principles of A. And that holds us back in the transition to a new energy reality. During 2021, we searched for the principles of the 'World of B' in a parallel project in collaboration with National Program RES. Knowing these principles, being able to communicate, live and propagate them will accelerate the energy transition. This project has resulted, among other things, in the diagram below. It identifies and articulates a number of system-transcending trends.

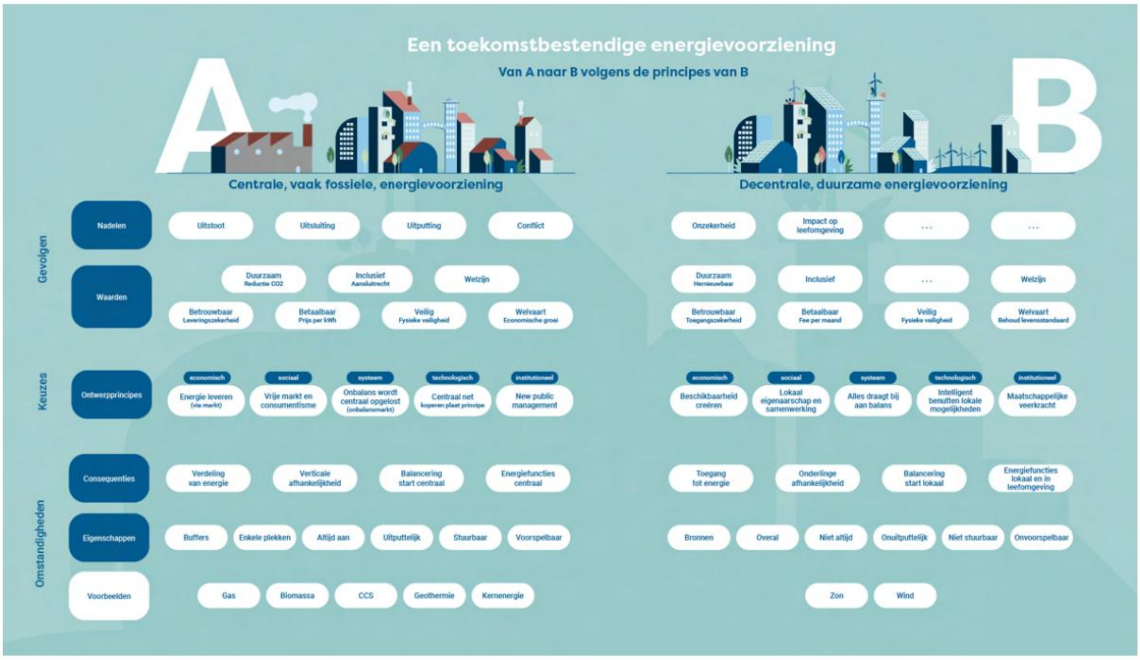


Figure 7: From A to B via the principles of B - Source: www.dewereldvanb.nl

Some cross-system developments that are also relevant at the interface of energy and digitization are explained below.

6.2 The four transitions: Technological, Economic, Social, Institutional

The essence of the energy transition was clearly related by the interviewees to the future of humanity and finding the balance between man and nature. How can we let go of our attachment to unsustainable methods and sources and move towards a system that will last us for centuries to come? How will the energy system become continuous, sustainable and also economical? After all, it is about the generations after us, for which we are now devising a solution. The challenge is not how we can make the economy grow as we used to, but how we can regain balance with nature. How we can use resources without harming or disproportionately disrupting the ecosystem. How we can move towards short cycle renewable energy resources. And this applies not only to energy, but to everything we use: how can we let the earth be the earth? People talk about the transition from smart to wise, and from success of the individual to success of the system.

The energy transition actually consists of 4 transitions simultaneously.

When we think of the energy transition, our first association is usually with solar panels and wind turbines. These are very tangible attributes. But the energy transition is more than that. The energy transition is changing us as humans. The energy transition is about restoring broken connections. The connection between us and nature. The connection between us and other people. And even about restoring the connection between us and ourselves. It is about a different view of time and place. It is about a deeper awareness of our place in the world, our place in nature. And it's about a very different notion of value.

The transition is therefore not just a technological transition. It is not as simple as turning off coal-fired power stations on the one hand and connecting solar farms on the other.

If that's the only thing we're changing, we're doing something wrong.

The energy transition is also an economic transition. Because we will value energy differently. Energy is - when it can be generated by everyone - not a product that needs to be traded with a unit price. Access to energy is then very valuable, but the volume matters much less.

The energy transition is also a social transition, because we will be connected to energy in a different way, and to each other. If we share energy with each other in our neighborhoods and on our business parks, which we generate ourselves, store locally, buffer locally to bridge seasons and locally convert it into the form we want, the moment we want this energy, energy becomes a good for what communities take care of together.

It is conceivable that parts of our energy supply are organized in this way in commons, public access and collective local ownership.

And finally, we are talking about an institutional transition, because we need new laws, new rules, and a new energy tax system.

We are already seeing that producers of solar energy no longer offer their energy on the grid, but store it in battery packs and then physically transport it on a trailer to the place where this energy is required. This is a logical consequence of an incorrectly set up energy tax system and the inability of network operators to meet the growing need for feed-in of sustainably generated energy.

We are involuntarily moving towards a world that is technologically different from today, but also economically based on different foundations, socially connected and interconnected in different ways, and in which different laws and regulations apply with regard to energy than today.

6.3 The transition will not be televised

When we welcomed television into our homes sixty years ago, we also welcomed an effective means of influencing our opinion, shaping our worldview, and steering our preferences in advance at the ballot box. We (except for a few) could not use the same television and then, based on democratic principles, shed a different light on the matter. *"The revolution will not be televised",* as Gil Scott-Heron sang in 1970.

Now, fifty years later, we are using the other screen en masse to do exactly the above. The difference is in interaction. The television was developed for one-way traffic and the internet for two-way traffic.

Figure 8: Television brought the world into your home, but it only went in one direction, just like energy did until now. Source: Wikipedia

The internet revolution has the power of central providers of knowledge and information decimated. Paper encyclopaedias no longer have any added value and increasingly find their Waterloo when they are scorched as a package of biomass in a power plant to be sold as green energy. Television has been on the decline for years. We no longer watch the news at eight o'clock in front of the tube, but whenever we want, from the channel we want, and we want to publish news ourselves, that is also possible. The internet meant *'power to the people'.*

And now it's up to us to deal with this in a responsible, mature way. We don't yet understand what it means to be in control. The Internet has become an important weapon for those who want to spread sensible and nonsensical, sometimes even dangerous ideas, build a following and make their influence felt. We have been given mature tools, and that also requires mature behavior from us.

Energy users also do not first apply for a license for the supply of electricity and gas from the Authority for Consumers and Markets. They simply order a few solar panels and an inverter and then notice that they have become much less dependent on the whims of the energy market. Also this *'transition will not be televised'.*

It may not be the first effect we think of, but democratization is one of the most fundamental movements enabled by digitization. Thanks to the internet, we are better informed, prepared, and we quickly find allies if we want to get something done. But we have also ended up in bubbles with the help of the internet.

Are we going 'deep down the rabbit hole' to become more and more permeated with alternative facts, pseudoscience, and pure charlatanism. In this way we learn again: “participation without insight leads to a statement without prospect”. Our new relationships with each other also demand new responsibilities. The Internet teaches us that 'smart' does not always mean 'wise'. It is up to us to exercise wisdom in our choices regarding the energy system.

6.4 The emergence of (semi-)autonomy

The Internet has involuntarily evolved into the invisible digital equivalent of the micellar network of fungi that connects everything to everything in nature. It transports nutrients from plant to plant, transmits information, coordinates crop growth and responds to changing conditions as a global nervous system.

The generation that will only know a world with the internet is now 32 years old.
The internet has become an integral part of our being.

We are now going through a similar development with our energy system. The central systems of large-scale generation and energy as a consumer good are rapidly making way for decentralized generation and a distributed system, in which every user can be a supplier, customer, balancer, converter or buffer.

Thanks to a distributed system for data and knowledge - our now loyal and indispensable internet - a distributed and decentralized energy system is possible for the first time.

Although local use of locally generated energy forms the basis, the link between subsystems and the management of the energy flows between these subsystems is crucial. Although the grids can be lighter because local problems are solved locally, their role in the energy system is becoming all the more important. In some places there is an average need for (much) more energy than is generated locally, or on average (much) more energy is generated than is demanded. For these cases, a coupled distributed system is necessary, which enables the exchange of energy between semi-autonomous subsystems.

Controlling the energy flows between the subsystems requires special control mechanisms: This integral energy system needs a new management system, in which each part of the energy system contributes as much as possible to the stability and balance of the entire system. Digitized information about energy flows, the Internet of Energy, is crucial to make the entire system robust and manageable in the future.

Incidentally, the distributed nature of the energy system does not mean that everything will be small-scale. In a distributed system, we see an integration of small and large-scale systems for generation, use, storage, conversion and transport.

6.5 From centralized to distributed

The decentralization of technology in the energy system also leads to the decentralization of roles and responsibilities. Functions that until recently were only conceivable on a large scale are now technically (but often not yet legally) possible on a small, local scale. Consider, for example, storage and conversion technology, but also responsibilities such as balancing local networks, dynamic and local pricing of energy, sharing energy with neighbors, or transforming a surplus of solar electricity in the summer into a neighborhood heat buffer used in winter.

Another reason for decentralizing the energy system is the difference in energy concentration between fossil carriers and, for example, solar and wind energy. A liter of oil or a cubic meter of gas contains almost 10 Kilowatt hours of energy. This makes central storage and generation very well possible. However, large amounts of electrical energy from renewable sources require much more surface area and volume. If we want to harvest the same amount of energy from renewable sources, a much larger surface area is required for generation and storage. That is why the energy transition has an enormous effect on spatial planning in our country.

Distribution in this context means that technologies, functions, roles become available on an ever smaller scale, and for more and more users.

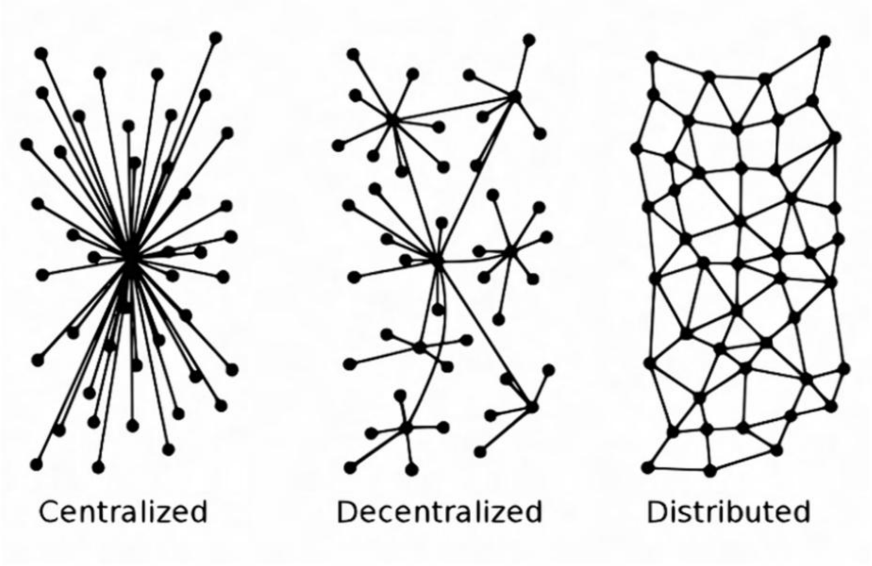


Figure 9: The development from central, via decentralized, to distributed systems. In a distributed system, there is no longer any distinction between suppliers and buyers

This does not mean that everything will be local and small-scale. Precisely by applying on a small and local scale what is possible on a small and local scale, and by applying on a large scale what large-scale needs, we are developing a resilient and robust energy system that can be used by a multitude of users - large and small, from residential to industrial. serve.

6.6 From volume to value

The market price for units of energy is less and less a reflection of the relationship between instantaneous supply and demand at a local level. With inexhaustible renewable resources, it is no longer about the unit price for energy, but the total cost of ownership of assets. Solar panels and inverters, for example, have a long technical life and in combination with storage systems at a local level, it is becoming increasingly attractive to no longer be tied to a unit price for energy, but to let it fluctuate according to the relationship between instantaneous local supply and demand.

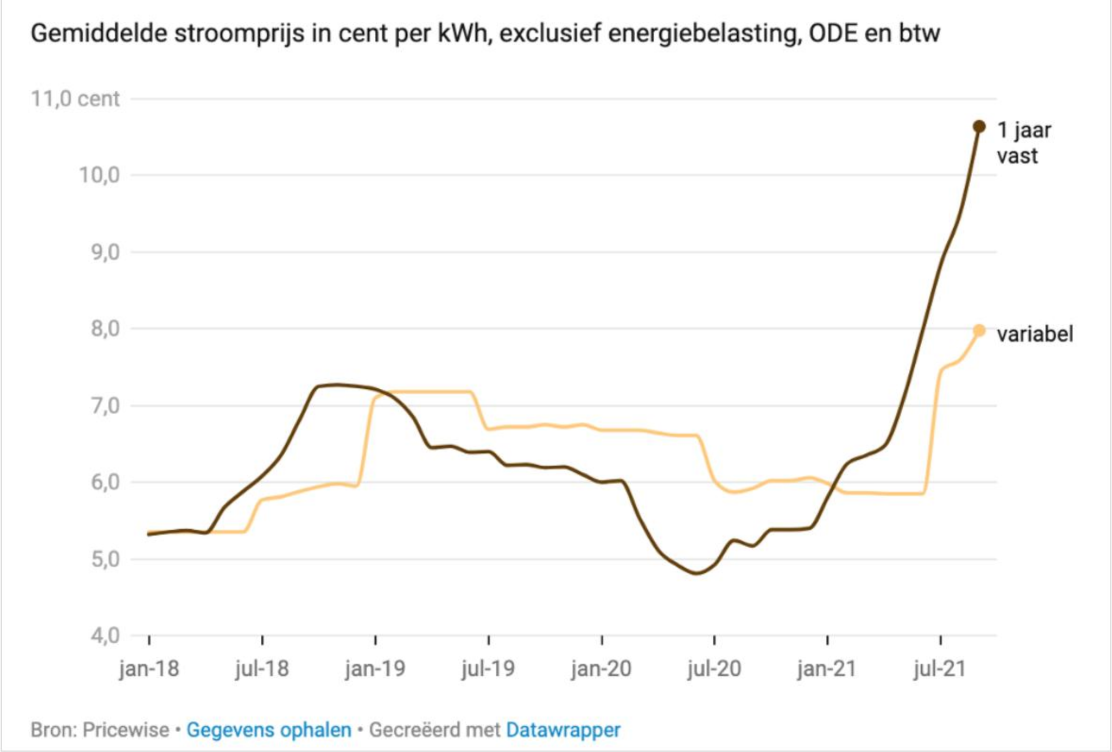


Figure 10: The average electricity price in the Netherlands has doubled in the past year as a result of rising gas prices and geopolitical dependence. This affects every energy user insofar as they are not yet self-sufficient. Source: Pricewise

Local pricing also makes it possible to work with flat-fee models for energy, in which the user pays a fixed monthly amount regardless of the amount of energy used or generated. This model has been introduced before and has become commonplace with regard to data in the form of internet subscriptions, which also consisted of unit prices per kilobyte uploaded or downloaded until the mid-1990s. A completely untenable model if we look at the abundance in which data is processed and moved nowadays. It is therefore no longer about the *volume* that is moved, but about the *value* that is created with it.

“ It is no longer about the volume that is moved, but about the value that is created.”

As soon as we generate enough energy sustainably to meet the need for energy, the focus will mainly be on the question “How can we get this energy to the right place at the right time?” Energy itself, because it is then available in abundance, is expected to have hardly any financial value (per unit of energy), just like data on the internet. The value of energy is then determined according to the use of it entire energy system. The infrastructure, which can bring the energy to the right place at the right time in the right volume, is decisive.

In that case, the current business models based on energy scarcity (prices per unit of energy) are no longer applicable. An analogy with the emergence of the internet: the first providers invoiced their customers per kilobyte uploaded and downloaded by them. After a few years, we saw the emergence of flat-fee providers, who charged their customers an amount for the throughput capacity and enabled their users to continuously upload or download if desired. The price of data faded, but the value for society did not. Generation, transport and buffer infrastructure, together with the mechanisms that ensure that the energy is in the right place at the right time and in the required volume, are essential. Important elements in the future business models are therefore the infrastructure (generation, transport, buffering and conversion) together with the complex control mechanisms that use this infrastructure in such a way that very high availability can be guaranteed for everyone at all times.

Figure 11: Solar energy is transported per battery pack to another user. A pragmatic solution for peer-to-peer energy where the system is currently inadequate. Source: Hanzenet

The analogy with the development of the Internet also applies to the decentralization of every function. At the time of the emergence of the Internet, processing power and storage capacity were scarce and extremely expensive. This logically led to the centralization of these functions: mainframes, networked storage systems, supercomputers. Your writer can still remember how he bought a 20 MegaByte external hard disk with a weight of six kilos for four hundred guilders in the early 1990s. Now, thirty years later, anyone can buy six TeraByte of external memory for this amount, or 300,000 times as much, with a total weight of a few hundred grams. The cheaper computing power and storage became, the more these functions decentralized and moved to the grid's edge. As these data processing essentials have become everyone's business, we have also become able to bring news ourselves, livestream our lives for those who want to share it, and countless people are now making a living by applying these recently decentralized technologies. fit from their living room.

The price development of energy generation and storage follows a trend comparable to that of computing power and data storage in the 1990s. It is highly conceivable that this alone will completely change the cost structure of energy. We will then no longer need an energy supplier, but we will all add balancing capacity to the grid.

7 Movements in the energy domain

As the previous chapter mentioned about system-transcending movements, this chapter focuses more on developments in and with the energy system. Some are unavoidable and dependent on much larger movements, such as the depletion of fossil fuels. Others depend on our choices, political, financial, strategic, social, economic. This is not a complete overview, but it does give a picture of a number of important developments that provide us with the certainty that everything will be different with regard to our energy supply.

7.1 From fossil buffers to renewable sources

The most important question with every investment we consider is "will this help us move towards a 100% renewable energy system?".
Too often we still see investments that, although well-intentioned, try to maintain the status quo of an energy system based on fossil carriers. This is de facto unsustainable, not even because of environmental consequences and public opinion, but because those supplies are running out. That could take quite a long time, but the fact remains that we currently use much more fossil energy than the planet can produce. Any investment that allows us to maintain or improve our level of prosperity and well-being while at the same time becoming less dependent on the availability and affordability of fossil energy carriers is therefore the *"way to go".*

Perhaps the biggest fallacy with regard to our energy supply is that oil, coal and gas are sources of *energy .* After all, oil, coal and gas are not sources, but *energy buffers,* comparable to giant batteries, which have been built up over hundreds of millions of years. The source of all this energy is the sun, which through photosynthesis, growth of plant and animal material, and the subsequent process of death, rotting, and sedimentation led to particularly large, easily extracted energy concentrations in the earth's crust. You could say that fossil energy is extracted from the most large-scale and highly concentrated energy storage system in the world. Over the past 150 years, these fossil "mega batteries" have enabled us to industrialise, to become mobile, to give us time to develop, to be educated, to live longer and healthier lives, and to have made it possible that we can now share images, sound, data and knowledge with each other worldwide in real time.

> *" In nature nothing is lost, nothing is created, everything is transformed.-Antoine Lavoisier"*

Now that we are making the transition to the real source of all this energy - sun, and partly wind and geothermal energy - you can say that we are skipping the intermediate step of millions of years of natural processes. This immediately requires us to deal with available energy in a completely different way. You can open or close a buffer whenever you want. Not a source. This means that we use small-scale, quickly switchable buffering - batteries and other types of storage - to meet our energy needs when the source is temporarily unavailable.

This also implies that our energy system needs a whole new operating system. We can no longer order power plants according to fluctuating energy demand. Instead, we will have to act much more at the place of generation and in the moment of generation. That means local control, responding to local conditions (instantaneous availability of sunlight and wind, instantaneous demand, instantaneous availability of local storage or conversion capacity, etc.). It is precisely here that a clear, logical and decentrally applicable architecture is required. And such a system is only conceivable when digital technology is applied. A good example is the tender that the Top Sector Energy recently issued as part of the System Integration Program, which is looking for holarchic (instead of hierarchical) operating systems for local energy networks.

7.2 From large-scale and 'out of sight' to intertwined with the living environment

Fossil energy is not available everywhere. In the Netherlands, we have been fortunate in the past 60 years with Groningen gas reserves, oil is extracted in the Middle East and North America, and Poland and Australia, for example, are known for their coal reserves. Location-based energy production automatically means geopolitical tension. Fossil energy is inextricably linked to the difference between the *'haves'* and the *'have nots'.*

Meanwhile, there is no place on the surface of the earth where the sun never shines and the wind never blows. There are of course places where the sun shines much more or much more intensely, and places where there is much more wind, but in principle renewable resources can be obtained everywhere. In short, you can use renewable sources everywhere, whereby the principle applies 'to row with what you have'. Only where the demand greatly exceeds the local supply is it necessary to make a connection to a place where that amount of energy is amply available. The geopolitics involved are therefore very different, and are much more about the technology, data and raw materials - for example, a 3 Megawatt wind turbine contains 4,700 kilos of copper - that are required for the technologies to extract energy from ubiquitous renewable sources . So we are seeing a shift in geopolitical relations away from politics over ownership and access to the energy supply, and more towards dependence on technology and the raw materials needed for this.

Renewable energy can therefore be harvested anywhere, but how is the question. Which technologies are available in our country? What knowledge do we have in-house? And which local raw materials can we use? One thing is certain: energy is becoming more and more intertwined with our living environment. The spatial issues of the energy transition are enormous.

There are dozens, if not hundreds of companies, whether affiliated with our universities or not, busy developing solutions - generation, storage, conversion, seasonal buffering, software, transport and more - that enable us to make increasingly effective use of locally available energy sources. to make. Let's cherish these.
Here again, a call to invest in independence is appropriate.

7.3 Decentralizes generation, so decentralizes everything

As we decentralize energy generation, it becomes necessary and inevitable that we decentralize the rest as well. Because we already generate energy in more than a million places in the Netherlands. There were only a few dozen 30 years ago. Our systems cannot deal with this. There is a traffic jam on the net. Long queues at our network operators for the much-needed installation of extra copper to handle our decentralized generation with a central, national system. But what if we decentralize storage in addition to generation? And conversion? And what if we could convert a local surplus of solar energy into a heat buffer so that we can save electricity in the summer for heating in the winter?

The functions of the energy system are all decentralized. Just as we have seen in recent decades with the internet, everything is shifting to *the grid's edge.*
But if the functions decentralize, then that also means something for our responsibilities.

Local energy generation also means local responsibility for local balance. It also means responsibility for healthy local pricing. It also means responsibility for stable local systems that meet local user demand. It also means local shared ownership.

The energy transition is about Power to the People. Literally. And with power comes responsibility.

In short, this means that as soon as we have decentralized the production of energy, we have brought upon ourselves the need to decentralize all other functions of the energy system as well. This is because this energy comes from non-switchable sources whose availability is determined by the whims of nature. Decentralized generation of energy requires decentralization of functions (conversion, storage, buffering) and of responsibilities (decentralized balancing, decentralized pricing, decentralized program responsibility, and even decentralized frequency management should be considered).

The social trend with regard to energy supply is shifting more and more towards the individual user. This certainly applies to energy cooperatives. There is an increasing movement towards independence, autonomy and care for each other. Autonomously functioning energy subsystems comply with this and are in line with these social trends. On top of that: linking the autonomous subsystems also meets the need for robustness of the total system.

These autonomous subsystems are seen as the foundation of the future energy system, whereby the link between these subsystems is felt to be essential to guarantee the need for continuous high availability of the system for everyone. However, the linking of the semi-autonomous subsystems requires a completely different form of management and different management systems than the system currently used for balancing supply and demand.

7.4 From power grids to energy grids

The current electrical energy transport to the user essentially does not take into account any limitations in the capacity of the (distribution) network. What we now refer to as an energy grid is actually not an energy grid at all, but a power grid.

The lack of storage in the current electrical power system is the reason it works as a power system and not a power system. The electricity grid is designed to meet the momentary peaks in energy demand (power peaks).
An important part of the available transport capacity of the system is therefore not used for a large part of the time.

An energy grid makes optimal use of available storage and transport capacity, and buffers energy where it will be needed. The result is therefore a much lighter transport infrastructure and much more steering and resolving power at the *grid's edge,* i.e. integrated in devices, at the lowest grid levels.

By using locally generated energy directly locally, by buffering energy at well-chosen locations in the grid, and by carefully managing the transport of energy from and to these locations, especially at the time of peaks or troughs, much larger amounts of energy can be generated. be exchanged over the available network than is currently the case.
An instantaneous local energy requirement will be met instantaneously and locally as far as possible. Only where the current need cannot be met, or where a surplus arises locally, is the step taken to the next higher grid level.

Local buffering of energy therefore contributes to solving problems associated with the asynchrony between generation of and demand for energy with exclusive use of renewable sources. The available limited transmission capacity of the current network therefore does not constitute a direct obstacle to a substantial expansion of the total quantities of energy to be transported. Intelligent flexibilization of energy demand and (local) buffering of energy are important elements that help to solve the bottlenecks in energy transport.

This bottleneck must first be mapped out by means of measurements. In fact, it must become clear what the power load is of each element in the distribution network (eg capacity of transformers and their utilisation, the transmission capacity of the medium-voltage networks and ultimately that of the low-voltage networks).

Properly dimensioned and localized storage of energy is essential for utilizing the limited transport capacity in the distribution network. The limited transport capacity can then be used to the maximum at times of low demand for energy to replenish the reserves of locally stored energy for use at a later time where demand exceeds limited transport capacity. For example, the batteries of electric vehicles can form an important part of this storage capacity. The use of the car (approximately 37km/day/car with an average energy consumption of 8kWh/day) and the battery capacity of a modern electric car (50-100kWh) show that these batteries, provided they are used intelligently, have a can play an important role in the local buffering of energy. Lightyear and Sono Motors are examples of companies that are already well advanced in bringing such developments to the market.

In a new distributed electrical energy system, storage is essential to optimally utilize the transmission capacity of the existing system. The storage or buffering of sustainable energy, which is largely lacking in the current system, is therefore crucial to transform the electrical power grid into an electrical energy grid. This means that the existing grids are used much more to their continuous capacity.

7.5 From space energy to time energy - Time of use

We are now used to shifting energy instead of simultaneously meeting energy needs. This is because of the highly concentrated fossil energy buffers that we now use, and because of the lack of storage and buffering in our energy system. For example, we can produce large amounts of energy when we need it, but shift production to places far away from us. We take the losses during generation and transport for granted. In the perception of many users, the associated greenhouse gas emissions are far enough away not to be directly annoying for our living environment. Energy is therefore a 'far from our bed show'.

> *“ Our energy supply is developing from simultaneous to 'simultaneous'”*

With the transition to renewable energy, the generation (or harvesting) of energy is becoming increasingly intertwined with our own living environment. Energy is therefore increasingly no longer out of sight and far away, but an integral part of our homes, our gardens, our companies, and our view. Because we opt for renewable, non-switchable sources, simultaneity is becoming increasingly problematic. Instead of simultaneously using energy from a highly concentrated carrier, we also harvest energy from sources available at the time when we do not need it. Using technologies for storage and conversion, we then ensure that we can use that energy again when it suits us. Here, too, we accept the energy losses of storage and conversion. We will shift more and more energy in time to meet local energy needs. Our energy supply is evolving from *simultaneous* to *parallel.*

This requires new control mechanisms. A new 'operating system' for our energy systems, which continuously determines on the basis of real-time data where, in what form and when our renewable Joule is worth the most.

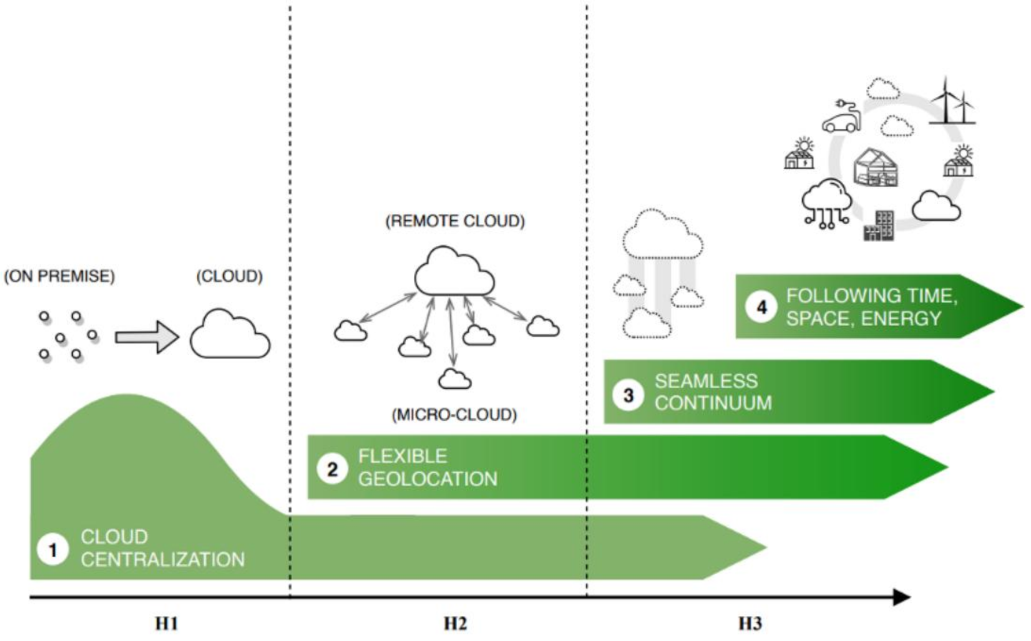


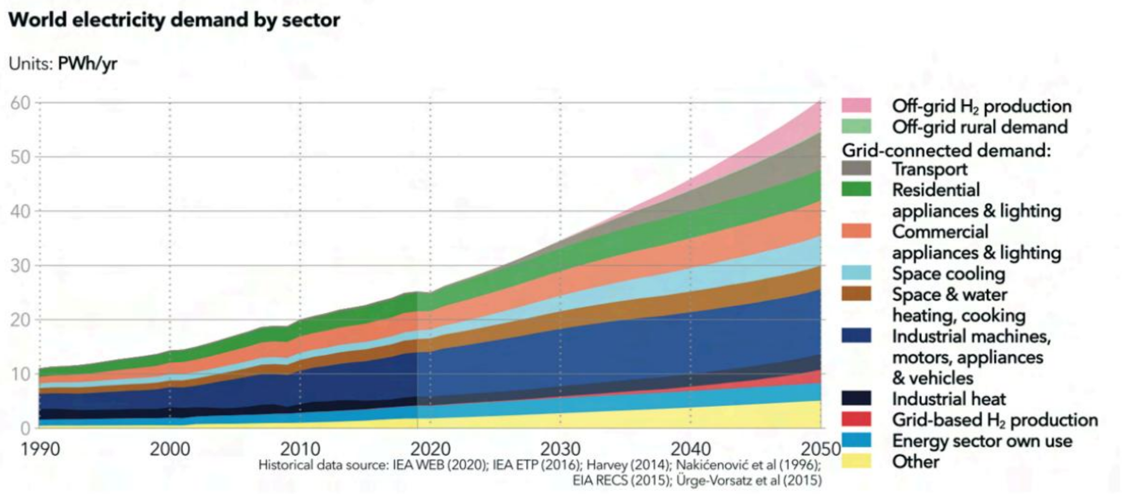
Figure 12: The development of data centers is progressing similarly to that of energy generation. Source: LEAP/Amsterdam Economic Board

7.6 From energy as a consumer good to energy as a service

Just as the internet put an end to pure consumerism for knowledge and data, we are now all prosumers. We all use and produce knowledge and data, and are free to share it. Following the same logic, an energy system based on locally produced renewable energy also puts an end to the energy consumer.

In the coming years, however, we will still be very busy phasing out our fossil energy carriers, and this will also involve major savings. At the same time, we are phasing in renewable energy, and we will be using more and more of it.

The latest predictions from DNV tell us that in the coming years we will decimate our use of oil and coal, although we will continue to use gas, but above all we will harvest a lot more energy from the sun and wind. The figure below clearly shows this development in terms of electricity. Between 2020 and 2050, our global energy use is expected to grow by 50%, with our use of electricity from solar and wind growing many times over.



Historical data source: IEA WEB (2020); IEA ETP (2016); Harvey (2014); Nakićenović et al (1996); EIA RECS (2015); Ürge-Vorsatz et al (2015)

Figure 13: DNV predicts that in 2050 38% of all energy use in the world will be electric, compared to 19% today - Source: DNV Energy Transition Outlook 2021

This is due to a number of factors, of which substitution is the most important. More and more domestic energy use is becoming electric, for which we previously used other carriers such as gas. In addition, more and more of our business processes and transport are being electrified. To illustrate: a typical Dutch household uses five times as much energy to heat the house than for all electrical applications combined. If heating is electrified, electricity consumption therefore increases by a factor of five. If this household then also starts charging an electric car at home, twice the current electricity consumption will be added to this. A positive side effect is that an electric car in absolute terms uses much less (4 to 5 times less) energy per kilometer driven than a car that runs on petrol or diesel. This is because an electric car has far fewer moving parts and suffers much less heat loss, so that a much larger part of the energy is actually converted into spinning wheels.

The other important development is the electrification of users who currently have no access at all to modern forms of energy, currently 1.2 billion people worldwide. These people will exchange biomass for cooking for electricity, for example. In rural parts of Africa, local generation of solar and wind energy is also being chosen instead of the construction of a national energy grid connected to large fossil power plants.

7.7 From *energy consumption* to *energy* consumption

'Energy consumption' is a word that we often use too easily. When it comes to fossil energy it is correct: A unit of oil, coal or gas is no longer available after use, so it is consumed, 'used up'. It will take hundreds to millions of years before the same amount of energy can be used again in the same fossil form. But with renewable energy we cannot speak of consumption. We use a unit of energy when it has been converted into electricity via a solar panel, but can reuse the same amount almost immediately. We can also state that the consumption of fossil energy should be much lower, but energy consumption from renewable sources can increase at the same time.

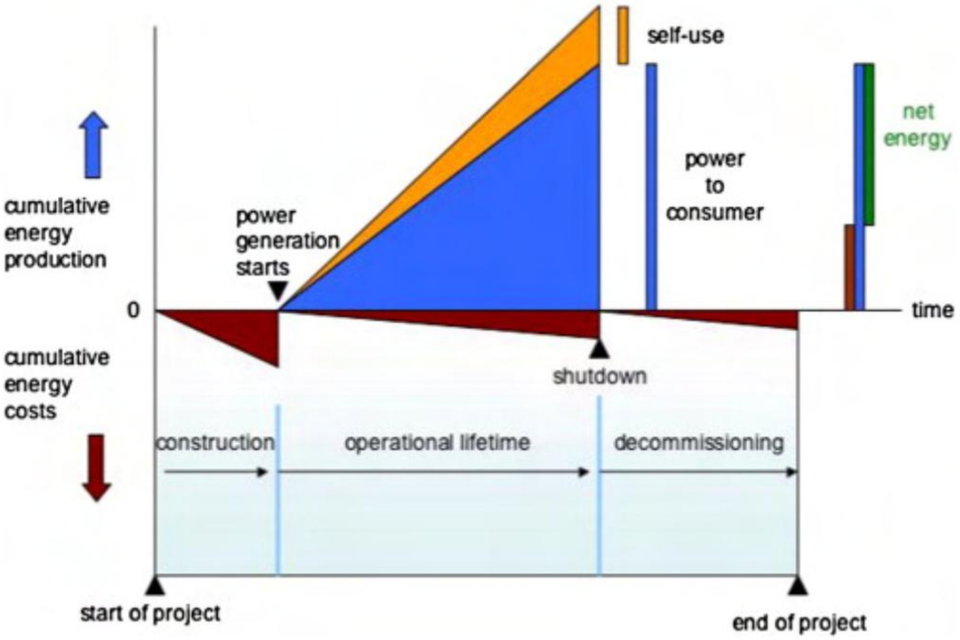
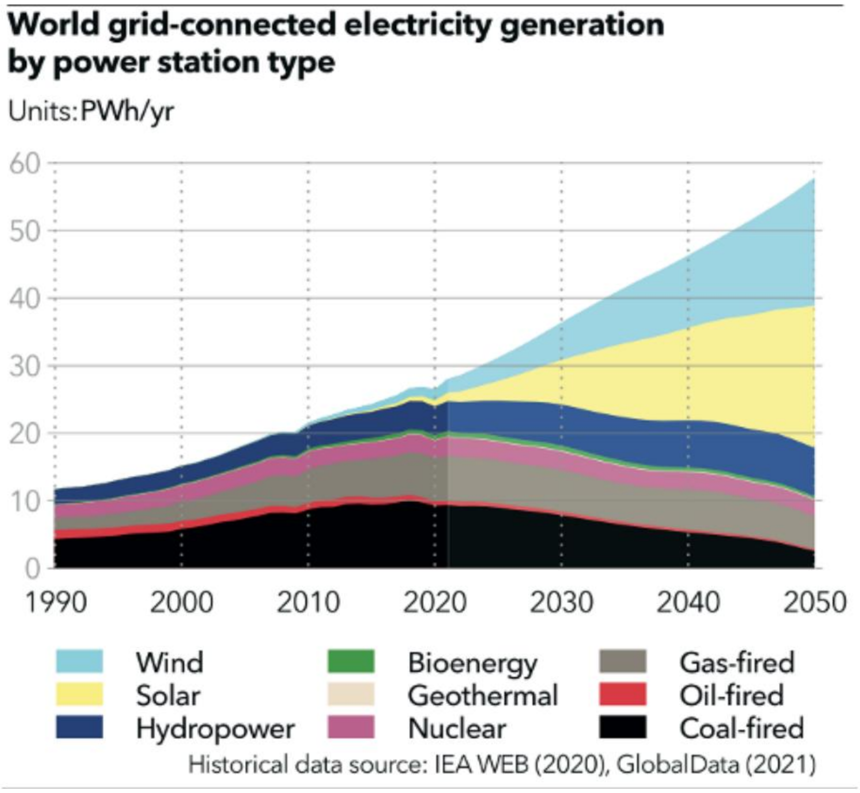


Figure 14: The principle of the Energy Return on Energy Invested explained – Source: euanmearns.com

The Energy Return on Energy Invested -EROEI- of renewable energy technology is therefore very interesting. During its lifetime, a solar panel generates more than ten times the amount of energy needed to produce that panel. At a coal-fired power station, the EROEI is by definition lower than 1. Any amount of energy that enters a coal-fired power station to be burned results in a smaller amount of energy at the exit, because of the energy losses associated with the production process.

For example, with the large-scale use of renewable energy, we can almost think in terms of *'all you can use'.* Of course, a system based on renewable energy also has its limitations - think of material use, use of space, and the need for local system integration - but the fact is that we have access to an abundance of energy from the source: more than a thousand times our energy requirement is reflected on the earth surface.


World grid-connected electricity generation by power station type

Units: PWh/yr

Historical data source: IEA WEB (2020), GlobalData (2021)

Figure 15: Global electricity use is booming, but fossil fuel consumption is declining in favor of renewables - source: DNV Energy Transition Outlook

7.8 Energy supply is increasingly dependent on the whims of the consumer nature

Fossil energy buffers are easy. You can switch them on and off at will, you can extract the energy carrier from the soil and transport it to the place where you want to convert it, and they can be meekly molded into exactly the shape we want, at the moment we want it . For example, this system of fossil mega batteries - because these are our buffers - has enabled us to design an energy system that makes energy on demand possible. A game of meticulous planning and control. As long as the supply of oil, coal or gas to the power station runs smoothly and the user pays his invoice, delivery is a practical certainty in a technical sense. In the Netherlands, we had no electricity for an average of only 24 minutes last year. That is a technical security of supply of 99.99543%, but economic security of supply may be a different story now that we have to move from own gas to import.

The instantaneous availability of energy is under high voltage. The Netherlands now has more than 250 congestion zones. In 7 of the 12 provinces it is almost impossible to connect new wind turbines or solar farms. Local power outages are becoming an increasingly real scenario. In the United States, the number of power outages has doubled every five years. The energy system simply cannot cope with millions of suppliers of uncontrollable energy.

Own renewable resources are therefore becoming increasingly important, even though they are unpredictable, ungovernable and uncontrollable. On when the sun shines or the wind blows, off when the sun doesn't shine or the wind dies down, and slightly on when a cloud floats by or leaves lie on the solar panel. There is no level to be measured. At first this was done on a very small scale, so the enormous energy system was not affected. But now, with more than 1 million small-scale providers of renewable energy in the Netherlands, we are starting to feel the problems. The power system, perfectly designed for one-way traffic, watches as it becomes infested with renewable wrong-way drivers who view the grid as a two-way street. Security of supply is at stake. The frequency management on our networks feels more and more like a juggler who gets a new ball every few seconds. It is not a question of if, but of when we will experience a power outage.

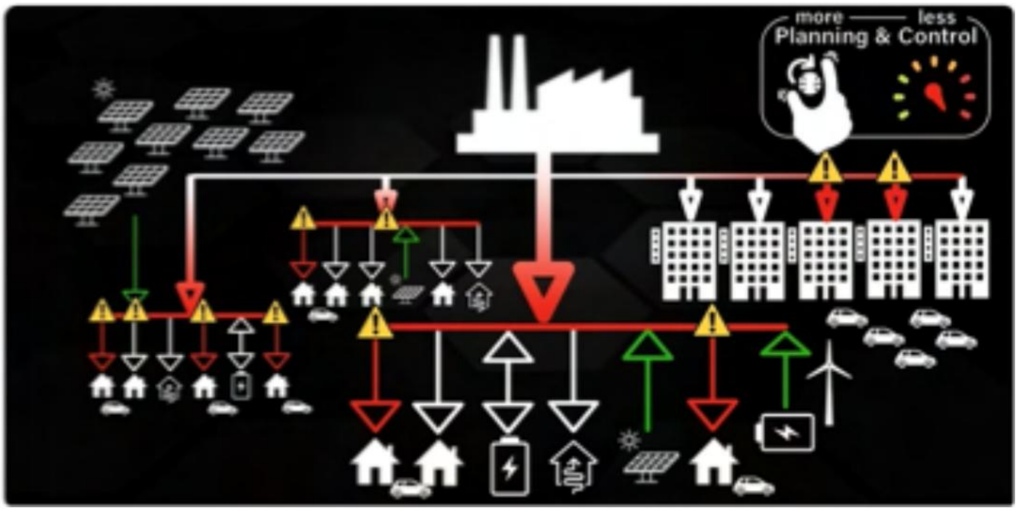


Figure 16: In the current energy system, decentralized generation from renewable non-switchable sources causes stress. Source: unify.energy

For the time being, we will maintain two energy systems: a phasing-out system that works with controllable fossil energy, and a growing system that works with ungovernable renewable sources. The sooner we become independent of the first, the more we can benefit from the second.

System integration and acting from a system-transcending vision is key. It is not only about producing energy and balancing supply and demand, but also about integrating buffering and storage as well as control models for short-term and long-term storage.

7.9 Everything to *'the grid's edge'*

Energy is increasingly moving in two directions on our networks. Peer-to-peer energy was a theory, but is now becoming more and more practice. The way we deal with energy is increasingly similar to the way we deal with data on the internet. The starting point is that every user is a prosumer, buyer and provider at the same time. Another premise is that each user can fulfill multiple roles: producer, bufferer, converter, balancer, and so on.

This is how the *Internet of Energy is born.* A global network of interconnected local energy networks. Using different energy sources, different energy carriers - molecules, electricity, heat, and different technologies for storage, conversion, demand management, balancing, pricing and system control.

In this way, it will be feasible in the long term that everyone will have access to renewable energy. This national and global societal need can be met with one fully integrated, data-driven and effective energy system.

In-depth research on a technological, economic, social and institutional level into the creation and operation of an Internet of Energy is needed. The expectation is that various underlying principles and models of the current energy system will have to be fundamentally adjusted. The development, bringing together and monitoring of concrete initiatives is crucial to realize the picture of the future outlined.

A system based entirely on short-cycle renewable energy is similar to the internet, but there is also a very important difference: In this system, instead of virtual data, enormous amounts of physical energy must be exchanged between sources, storage systems and users. Monitoring and managing these large energy flows and associated risks requires a sound system architecture.

This requires new forms of cooperation between network operators, governments, market parties and a representative representation of society. It is recommended that this be further explored and worked out in terms of requirements, roles and tasks. This is important, large and far-reaching enough to warrant a national research and development programme.

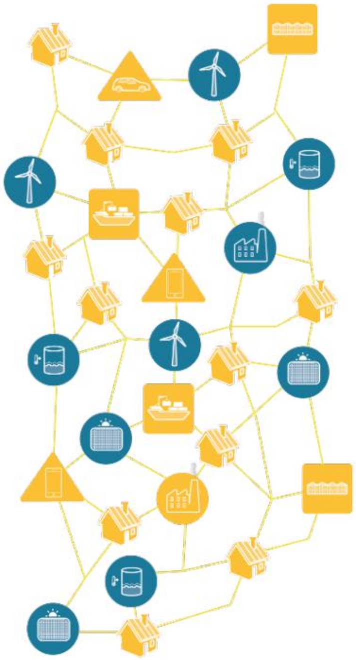


Figure 17: In the distributed energy system it is no longer possible to distinguish who produces and who uses. Each connected user can fulfill multiple roles - Source: Kamangir

7.10 Everyone becomes a system participant: the set-up of the distributed system.

At the system level, the greatest effectiveness is achieved by using energy where it is generated, with as few intermediate steps as possible. The ideal system is a system where - including the buffering - locally generated energy is in balance with locally used energy. In this case, due to the small number of directly involved local parties, the balancing between supply and demand can be handled relatively easily locally and autonomously. This is even possible within a machine: an electric car fitted with solar panels is simultaneously a producer, user and storage medium. Only where this car generates more than necessary (when stationary) or needs more than it generates (at speed) is the balance broken and a connection with other users is required, as is possible via a charging station. If demand exceeds supply, the extra energy demanded is preferably drawn from local buffers and if supply exceeds demand, the excess energy is preferably stored in these locally installed buffers.

This means that every user becomes a producer, transporter, converter, supplier, aggregator, program responsible party, etc.

7.11 Internet of Energy: major impact on system management; much less investment in infrastructure

The highly distributed structure for energy generation in the future will require a completely different way of dealing with energy flows. A system consisting of linked semi-autonomous subsystems will also require completely new strategies for managing these energy flows. Digital information about energy flows, the Internet of Energy, is the key here. The changes in the way in which energy is generated and the fact that this happens in a highly distributed manner have an enormous impact on the way in which energy flows must be managed and balanced.

Sustainable energy is generated by a very broad mix of parties, ranging from the individual user, who mainly generates for himself, to large-scale generators (wind farms, solar parks, hydroelectric power stations, etc.). Regardless of the scale on which it takes place: too much locally generated energy is shared with others, and instantaneous shortages are made up with the surpluses of others.

Essential in the future energy system is the maximum use of distribution and transport infrastructure and well-located and dimensioned capacity for energy buffering. To make maximum use of the fully integrated system, precise monitoring of the transported energy over each route is necessary to ensure effective and robust use of the costly infrastructure.

A self-organizing system for balancing generation, use and storage of energy requires precise monitoring. At the moment, this data is only available to a limited extent, especially in the distribution network. This results in a non-optimal use of the potentially available transmission capacity in the existing distribution networks. Precise monitoring and analysis of the said data means that the available capacity of the current distribution network for the transport of energy can be increased significantly.

The creation of an Internet of Energy also requires well-chosen (in terms of location), well-dimensioned buffering of energy (storage capacity with, if desired, linked energy conversion) and controlled demand for energy from devices that demand a lot of energy (electric cars, heat pumps, washing machines, industrial process units, etc.). A properly - distributed - set up and managed Internet of Energy may result in much lower investments in the expansion of the distribution network in particular than is currently thought.

8 Movements in the digitization domain

Solutions are also being developed from the ICT domain that take the energy system to the next level. The overview below is by no means complete, but gives a brief overview of the possibilities of a few developments. This overview deserves to be elaborated in later publications.

8.1 Opportunity and pitfall: Hyperpersonalization

One of the things that the current state of digitization makes possible is far-reaching individualization. This applies to products we order that exactly meet all the details we want, but also to the gaming experience if we dress our avatar in a simulation game exactly as we want and attribute all kinds of properties to it that give us the experience of living in a parallel world.

With regard to energy, we are not there yet. There are international climate agreements, there is a Dutch energy agreement and a climate agreement (2019), there are Regional Energy Strategies. These are seen by the energy user in the media, but what is expected of the user himself? What can it do itself? A huge amount is invested in awareness campaigns, in participation plans, in subsidies for large-scale energy generation, but there is not one single plan that shows what choices someone can make as an individual user of the energy system to help complete the energy transition.

And that is exactly what the user needs, and what is now possible when we use the right digital technologies and provide a clear and pleasant UX -user experience-.

With a relatively simple set of algorithms, calculating with the right data and linked to the right APIs, for example, an interface can be developed that shows each individual user exactly which investment in energy saving pays off the most, when it should be done and how quickly. it pays for itself. For example, the user knows exactly whether in his individual case investments should be made in generation, savings, storage or conversion. And whether this investment pays off better on an individual level or on a neighborhood level.

On the same basis, an interface can be offered that helps the user to become more independent from energy suppliers and volatile markets as effectively and quickly as possible.

The granularity with which data can now be generated and processed has greatly improved compared to a few years ago. We are now no longer afraid to work on a local network with minute values, where not long ago we were left completely in the dark, or could only provide a meter reading once a year at the most.

A warning is in order: if we stimulate hyper-personalization without considering who will own or control the data in question, we create the possibility of creating a tech giant that can wield a disproportionate degree of power.

exercise over millions of energy users. Let us be aware that AirBnB, Uber and Facebook are not so much examples of the new economy as examples of the old economic, centralized model in which a few can acquire wealth and power at the expense of millions of users. This is possible because the technology decentralizes, but the business model does not. That such a party causes a disruption on the market for taxis or hotel rooms is one thing, but this must be prevented at all costs when it comes to the fulfillment of a basic need such as energy.

This also requires an open and honest data architecture. A system design that brings and leaves the user in his value. A framework that allows freedom and autonomy.
Within which individual choices can be made, just as with regard to our internet use.
An equivalent of the www protocol for energy will allow us to be free to choose any technology or provider, just like on the internet, and still be connected.

Hyper-personalization is valuable and perfectly possible through digitization and behavioral science, but not without a framework that protects the user. Citizens themselves can make a major contribution to this, as we learn in the Club van Wageningen. The better you know and trust your community the further you can go together. The starting point must therefore be: bi-directional. We must learn not to address the energy user as a consumer, but as a prosumer.

8.2 AI

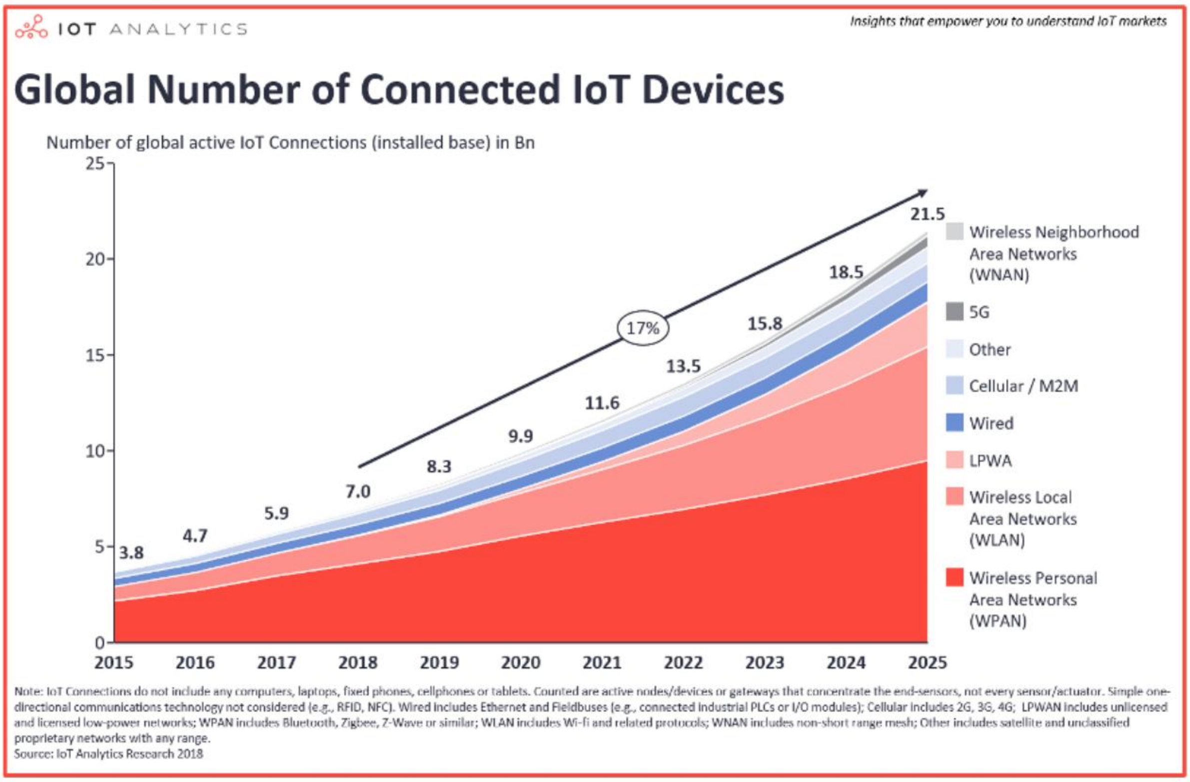
Artificial Intelligence is regarded as one of the key technologies of the ICT Top Sector. And that is not without reason. Within a few years, the Dutch AI Coalition (NL AIC) has grown into one of the largest cross-sector public-private partnerships in the Netherlands, with hundreds of participants. AI has not yet been fully embraced in the energy domain. We are still looking for relevant use cases, which in turn are often dependent on the availability of sound data. And yet the global market for AI in the field of energy is growing at tens of percent per year.

AI comes in different forms. Essentially, it involves performing calculations over large data sets. But with developments such as machine learning and artificial narrow intelligence, AI increasingly includes self-learning capabilities. It is to be expected that many tasks currently performed by energy analysts, traders and planners will be taken over by artificially intelligent systems.

8.3 Internet of Things

In addition to the 4.8 billion human users that the internet now has, there are also 12 billion devices connected to the Internet of Things, the IoT. These devices control and are controlled remotely, without human intervention. This number does not include our laptops and mobile phones. Nowadays, almost every modern car is connected to the IoT. More and more refrigerators, televisions, industrial ovens and inverters too. Each of these devices has energy needed. A large number of these devices are primarily used to generate energy, such as solar panels and wind turbines. And a large proportion of these devices have energy as a (possible) residual current, such as the residual heat from an oven, but also the storage capacity of an electric car.

This machine-to-machine interaction offers enormous opportunities to achieve automated system balance. Especially if we recognize that many of these IoT devices collectively fulfill all the functions of the energy system, but then on a small scale, behind the medium-voltage substation, simply at district level.



Note: IoT Connections do not include any computers, laptops, fixed phones, cellphones or tablets. Counted are active nodes/devices or gateways that concentrate the end-sensors, not every sensor/actuator. Simple one-directional communications technology not considered (e.g., RFID, NFC). Wired includes Ethernet and Fieldbuses (e.g., connected industrial PLCs or I/O modules); Cellular includes 2G, 3G, 4G; LPWAN includes unlicensed and licensed low-power networks; WPAN includes Bluetooth, Zigbee, Z-Wave or similar; WLAN includes Wi-fi and related protocols; WNAN includes non-short range mesh; Other includes satellite and unclassified proprietary networks with any range.
Source: IoT Analytics Research 2018

Figure 18: The number of IoT-connected devices has doubled in 5 years to approximately 12 billion worldwide, currently growing at 17% per year. Source: IoT Analytics

8.4 Digital Twins

Digital twins - digital copies of physical assets - play an increasingly important role in managing, controlling and shaping energy systems. But digital twins, if parameterized correctly and fed with honest data, also provide all the necessary information to make investment decisions much more accurately. This means that with the correct use of digital twins we can determine much more accurately whether a region or user would benefit more from investing in production, storage, conversion, transport infrastructure or demand-side management.

For example, using a digital twin of the energy system, the soil and the buildings in a district, it is possible to accurately estimate the effect of installing a new wind turbine, neighborhood battery or charging stations for electric cars before they are physically be installed. Digital twins - together with user interfaces and software that are understandable and usable - enable civil servants, project developers, citizens, network operators and other stakeholders to gain much better insight into necessary changes in local energy systems. With a synthetic population - a digital version of a community, including personal characteristics such as preferences, life patterns and needs - even the social impacts of changes can be estimated in advance, such as the resistance or support for a new solar farm.

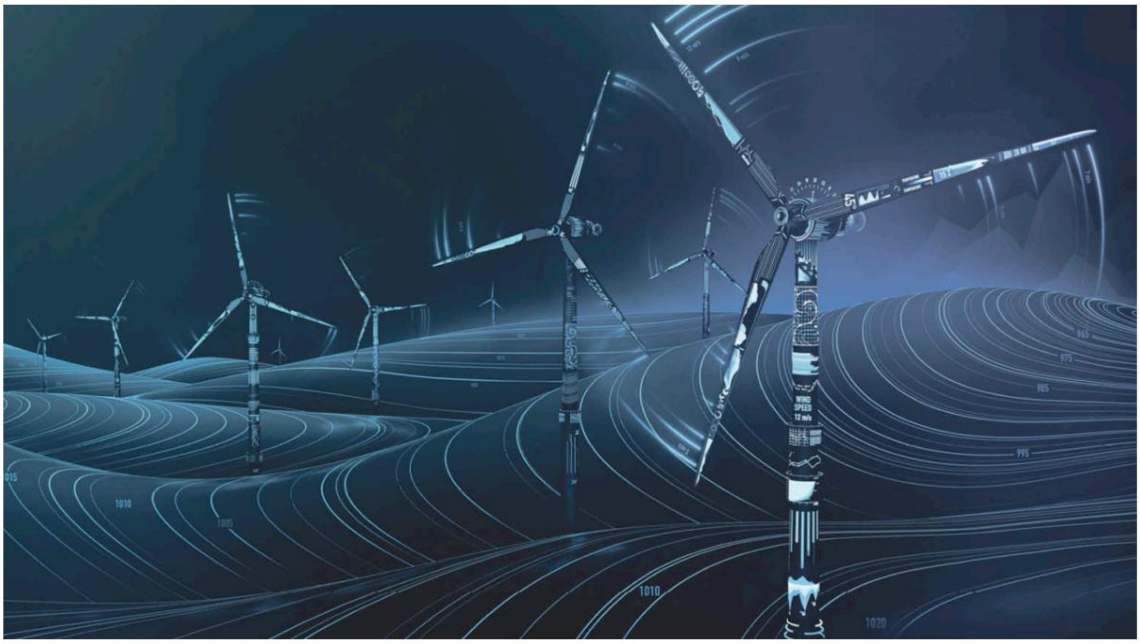


Figure 19: Digital twins, for example, allow energy system impacts to be accurately estimated before they are physically implemented. Source: Raconteur.net

9 Pitfalls and reminders

What pitfalls can we best avoid? How do we avoid having to conclude afterwards that we have invested a great deal, but above all in a sinking ship? Or in a development that turns out to be outdated within a few years? Or that our choices may have even unintentionally delayed the energy transition?

The overview below is intended to give an idea of a number of important pitfalls that can determine the future of our energy system. Not stepping in probably means a smoother transition, better public support, less geopolitical tension and lower costs.

9.1 Ownerless Issues

It is not possible to designate a clear owner or responsible person for many problems that are currently occurring in the energy system.

For example, there are no standards or protocols for interoperability between different energy networks, such as those for electricity and heat, or between two nearby local energy networks. But isn't there a party that is responsible for the realization of this interoperability? This means that important opportunities for achieving an effective and affordable energy system for all users are lost.

It is also impossible to designate an owner who is responsible for a holarchic or non-holarchic operating system for local networks, while the regional and national network operators do not have the possibilities to control and optimize at a local level, while more and more energy is generated locally and is used.

It is evident that the grid managers cannot meet the demand for connection and grid reinforcement. But much of this demand is caused by developers who want to install generation capacity, but do not connect storage and balancing power. By continuing to think and act in silos, we delay the transition to an inevitably integrated energy system.

Another example: the cyber security of our energy systems also has no clear owner. There are, of course, laws and regulations that market parties must comply with with regard to personal data, but there is no regulator who cares about the security of the entire system.

Within the Ministry of Economic Affairs and Climate there is not yet sufficient cooperation between, for example, the ICT directorate and the Energy directorate. For example, important opportunities are missed because, for example, the ICT Top Sector is indeed affected by energy-related problems (such as the energy supply of data centers) and the Energy Top Sector would also greatly benefit from a firm approach to digitization opportunities and problems that affect the energy system.

9.2 Who owns the data?

Even though we have embraced a General Data Protection Regulation (GDPR) in Europe, it is now a common phenomenon that data generated by our devices is appropriated by the manufacturer. Manufacturers of inverters for solar installations, for example, can use their customers' data to gain a foothold in the flexibility market. The owner of that inverter is then rewarded with a tip. This is not in proportion to the value that the manufacturer assigns itself. It is highly questionable whether such practices are desirable, or even continue to be allowed by the European Commission. For example, the Digital Services Act Package was recently presented, which aims to protect the fundamental rights of users.

It is recommended in the Netherlands to prevent and where necessary combat personal data generated by users from being appropriated by manufacturers and suppliers for their own gain.

9.3 Investing in Lock-In

Lock-ins exist on many levels, and all deserve to be avoided. The choice of a supplier can lead to a technological lock-in. For example, if the customer of an electric car is then only dependent on compatible equipment, software or parts. KPN's decision in the 1990s to roll out an ISDN network for internet and telephony nationwide cost 11.3 billion euros. During its roll-out it became clear that new, better technologies would gain the upper hand, but wells were dug and cables laid for years.

A commercial lock-in occurs when, for example, an infrared panel can only be operated by means of a mobile app, which can be downloaded for a fee.

Data lock-ins play an increasingly important role. Just as it is almost impossible for an internet user to be independent of Google or Facebook, the buyer of a solar installation usually cannot choose what happens to his data. Via handy constructions, this is then owned by the manufacturer of the inverter, and money is then earned on the flex market with that data.

Then there is geopolitical lock-in, as we have in Europe with exporting countries of natural gas, oil or coal, but also of raw materials for electronic equipment such as copper, lithium, nickel and cobalt. When we decided to become an electricity exporting country in the 1990s, we forced ourselves to become a raw material importing country, with years of problems as a result.

It is recommended to always invest in minimal lock-in. What investments can we make to be as independent as possible? Both on an individual level for the user and on a national level.

9.4 Perverse incentives

An essential point of attention is the impeding influence of a number of existing mechanisms with regard to the future energy system: the perverse incentives. Encouraging an accelerated transition means an accelerated phasing out (and divestment) of undesirable aspects in the current system and the creation of incentives in favor of the future system. If it can be established geologically that the use of fossil fuel will be 1 million times less by the coming generations, it therefore does not pay to invest in incremental improvements of the current system, but only to invest in a new system based 100% on renewable energy sources. system.

In our current system of taxes, laws and regulations, investing in large-scale generation of sustainable energy leads to price erosion of energy: the more renewable energy is produced, the lower the market price of all energy will be. This mechanism thus undermines precisely the investments that make this transition possible. Taxes, laws and regulations must therefore be redesigned in such a way that economic models become feasible that create lasting value from these investments. An energy transition can take place here, whereby, based on price erosion of energy, growing economic value is simultaneously created on the basis of sustainable investments in required infrastructure and in its use and maintenance.

9.5 The World Wide Wait of Energy

In the same light, we used to call the WWW the World Wide Wait. Due to the limited availability of bandwidth, it could take a very long time to download a photo. This World Wide Wait is also coming in the field of energy. When the demand exceeds the current supply, you will simply have to wait (as long as we cannot buffer and convert easily and cheaply) until the capacity you have requested is made available to you. It is highly questionable whether such situations can be treated fairly, inclusively and democratically.

Explore the costs of producing energy from renewable sources, buffering energy in short-term batteries or seasonal storage in other forms of energy, converting energy from one form to another, and the operating systems required to approach instantaneous balance all a logarithmic decrease in price.

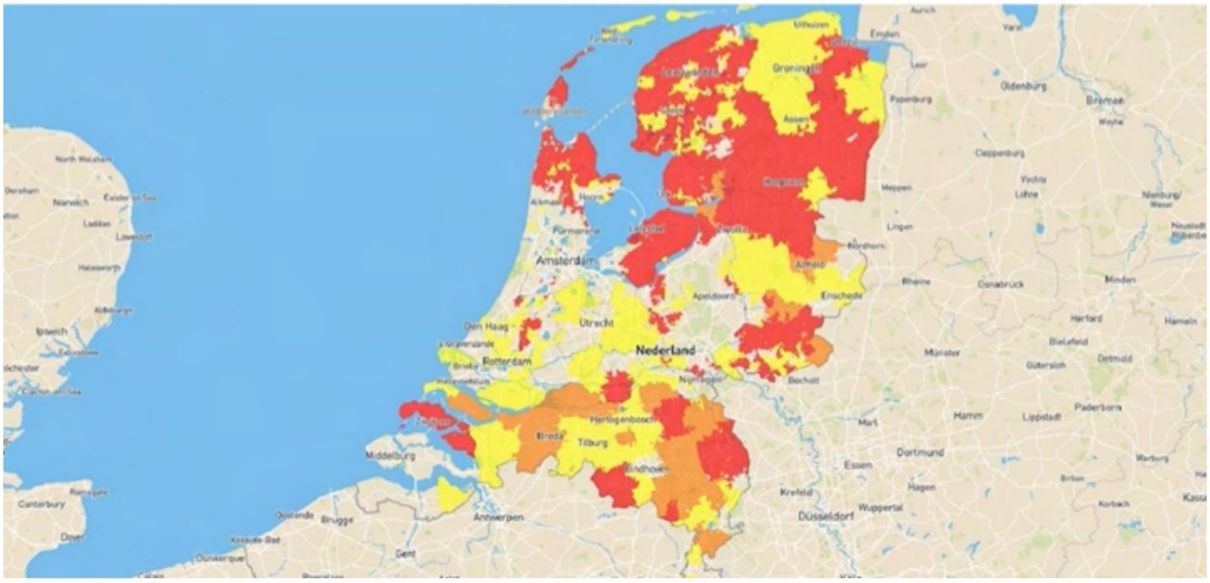


Figure 20: The congestion map of the Netherlands. It is not possible to place new capital on about ÿ of the country, and it is becoming increasingly difficult to expand companies. Source: Netbeheer Nederland

This also opens up the market for new types of market parties: the buffer, converter, producer and balancer of an energy system will manifest themselves on an increasingly smaller scale, right down to the capillaries of our networks. Yet we do not want to go to a situation such as with trading in shares and crypto currencies. There the competition has led to a fierce digital battle where the strongest systems, the fastest connection and the smartest bots always win, and the normal user no longer has a chance.

The stress on the energy system is now enormous. More than 250 locations in the Netherlands are already experiencing congestion. And in the coming years, the number of cases of congestion will increase exponentially. In the meantime, it is no longer possible to install decentralized generation on almost a third of the Dutch land area - Noord-Holland-Noord, Friesland, Groningen and Drenthe, for example - and in cities such as Amsterdam, Leeuwarden and parts of Zeeland the available grid capacity does allow it. to install sunbathing areas, but not to expand businesses. Our energy system and the way in which we have set up our grids can now be regarded as one of the most important bottlenecks for a successful energy transition.

To illustrate the unsuitability of centrally controlled grids and balancing with an example: in a residential area with about 60 houses, about 1,000 devices will demand or supply electricity. If every 15 seconds it is verified whether the system is still in balance by sending a signal to all these devices, this amounts to 2.1 billion verifications per year. With these huge numbers, it is hard to imagine that central control of the energy system remains possible.

9.6 The market wants it, but is not going to solve it

If we continue to follow the credo 'the market must solve it', we can state with certainty that this will not be the case. Then the law of the richest applies. The market is not designed to be ethical or cross-system. The market is ordered based on differences between supply and demand. Where scarcity occurs, prices rise. Where there is more need for electricity than the current supply, imbalance occurs, and then every kilowatt hour is worth the most. Keeping the market as it is is not going to work. This would mean that all grids would have to be set up to handle a maximum peak load, so grid reinforcement with all the associated costs, which will be passed on to the user. At the same time, aggregators and flex providers will only start offering their product if its price rises above a certain level. Gaming of the market then becomes a given. The ordinary user such as households, small entrepreneurs and minimum wage earners will be left behind.

At present, 550,000 households in the Netherlands already live in energy poverty. These are households that spend more than 10% of their income on energy. With current developments, that will be 1,500,000 in 2030. Our factories will be running, but for many people it will be cold at home, or the energy supplier will have a stranglehold on the weak customer. Is it conceivable that part of the energy supply can be socialized again, so that at least no one has to suffer from the cold? Is it conceivable to use, for example, a combination of decentralized generation, storage, heat buffers and platform technology? What if we could reorder the market so that energy from renewable sources can be used directly and tax-free, and that disruption of the system balance by asking for energy where or when it is not available is actually taxed? Then we are back to the original credo of the regulatory energy tax introduced in 1996: “the polluter pays”.

10 Preconditions and solutions

The energy system we know and cherish is shaking to its foundations. We will not get there by improving the current situation step by step. That is simply impossible if we realize the extent to which we have to organize our systems differently. If we want to - and we want to - meet the standards set during the climate summits in Paris, Katowice and Glasgow, we will radically say goodbye to fossil energy within a generation. We have to, because we currently burn 1 million times more fossil energy than the earth can produce by converting plant and animal material into oil, coal and gas. And we simply cannot further develop a diesel car that currently drives 1 liter per 15 kilometers until it can drive no less than 15 million kilometers on a liter of diesel. We therefore need completely different systems, designed on a completely new basis: namely based on 100% renewable energy.

For this reason, we cannot view energy as a separate sector, or as an isolated problem that needs to be solved with energy goggles on. Our decisions affect the whole of society, the whole economy, the whole ecology, and many generations after us.

10.1 A cross-system approach

The emerging influence of data and digitization makes a system-transcending approach more possible. We can oversee and plan better. What is too much here is needed there and what is too much now will be needed later. At its best, digitization provides a connecting force with regard to previously separate sectors. This also affects the top sector policy; as long as the energy sector continues to see itself as a separate sector, there is no system progress.
Energy is needed always, by everyone and everywhere. With more than a million prosumers, one can no longer speak of an energy sector, but energy involuntarily becomes more and more a cross-cutting theme, just like digitization. Another important influence on the development of the energy system is the correlation between the strongly falling costs of data processing and storage on the one hand, and those of energy production and storage on the other.

Insight into interdependencies of energy in the chain is vital. It is then important to look at costs and benefits, both economically and socially. Only in this way can future-proof government policy be formed. You can integrate much better and solve several problems at the same time; we are already seeing solar parks where algae and raspberries are grown under solar panels instead of under foil that decays and blows away. Investments and subsidies should also make this possible. The system lives and must live as it changes. With a system-transcending view, we can transform on a level deeper than we currently control. This is how our system can undergo a metamorphosis, change into something completely different while living on.

People are aware that everything will become digital, and soon more and more autonomous, self-managing. Nevertheless, we saw that the design principles were used by exponents of the old economy with new technology. Large parties use the internet to collect and sell data. It is regularly indicated that we do not want to repeat that with energy. Energy is a basic supply. Innovation takes place and policy follows, but the consequences must be taken into account. Conversely, policy can also actively create the conditions under which innovation takes place, and these innovations can grow. In any case, a framework of ethics, values and design principles is needed. Actually, we now have to take into account the worst case scenario such as a series of blackouts. So what's our plan? How much can the current system handle?

It is important to set a goal and to paint a picture of the future and work towards it, instead of moving at random now and in any direction. If we limit our view to that of the energy world, we will never be able to understand, let alone control, the changes in the system. We can move from A to B if we understand, experience and incorporate the principles of B.

It is also important to learn from all the political, social, commercial and even dark sides of previous developments, both in the field of energy and digitalisation.

Digitization is not a goal but a means. The advice is regularly to look at the question of how we develop fully renewable-based, resilient, stable and affordable energy systems from a digital perspective. That is seen as an important goal of this new research, also because we see increasingly large gaps between electricity supply and demand.

10.2 The inevitability of a new market model

If energy can be generated by anyone from inexhaustible sources, this will have a profound effect, not only economically but also socially. Energy, being the ability to perform work, and thus the foundation of our economy, is no longer dependent on the supply and pricing of a few parties, but is within everyone's reach. This also means that anyone can 'bring' energy to the system.
This increases the value creation capacity of everyone. Gradually, the concept of 'energy consumer' will fade away and become a thing of the past. With an increasing share of renewable, decentrally produced energy in the total energy mix, the existing parties of energy suppliers, producers, will lose power. They will change to providers of platform technology, services and balancing.

The economic model of TO = pq (total yield is price times quantity), which has been dominant in our energy reality for years, no longer holds true. Just as twenty-five years ago we were used to paying per kilobyte of uploaded and downloaded data to our internet provider, but soon made the switch to flat-fee providers who offered unlimited internet access for a fixed monthly fee, we will also be following this development. see in the energy domain. After all, it is no longer about volume, because energy from renewable sources is not scarce. Much more important is balance. The better the energy system is continuously balanced, the more useful, stable, reliable and cheaper it is for the user. A user can thus pay to purchase energy at one moment and have to pay to supply energy at another moment. Or vice versa: one the user can be paid one moment to supply energy, and the next moment to be paid to purchase energy.

Research into and development of new pricing, valuation and market models based on 100% renewable, decentralized, and with distributed storage and conversion is needed. Consider, for example, flat-fee models for energy, and market models that no longer price and charge per unit of energy, but take the degree of balance in an energy network as a starting point, for example. Then private and local grids can be helpful, as well as self-government and self-management of energy systems, digital twinning and parameterization of assets.

In time we will hopefully no longer be connected to the energy system because we are dependent, but precisely because the user is valuable in contributing to the balance of the entire system.

10.3 From planning & control to sense & respond

Although the first reaction to the system stress on our grids is “so we need more planning and control”, digitization enables a completely different kind of solution, one that has been successfully applied in nature for hundreds of millions of years: sense & respond.

Our energy system is being tightly orchestrated right now, like a professional orchestra. The players -power plants, network operators, energy traders- are particularly adept at their game and master their instrument down to the last detail. The smallest fluctuations in pitch, the frequency of our electricity grid for example, already lead to false tones and our professionals do everything they can to prevent this. And the audience loves it. Every day. As if energy is as self-evident as the soft tones of Radio 4 in the background during breakfast.

But the energy transition requires a new dynamic. Because now the users are no longer just listeners. More and more are playing with it. They do this on self-made instruments, which are not always tuned exactly. A cacophony gradually arises in the ether and the conductor and his professional musicians slowly don't know what to do with this new reality.

“Not everything that can be counted counts, and not everything that counts can be counted,” said William Bruce Cameron. The biggest bottleneck in the energy transition is not the infrastructure; not the people, not the economy, but the tendency to plan and control.

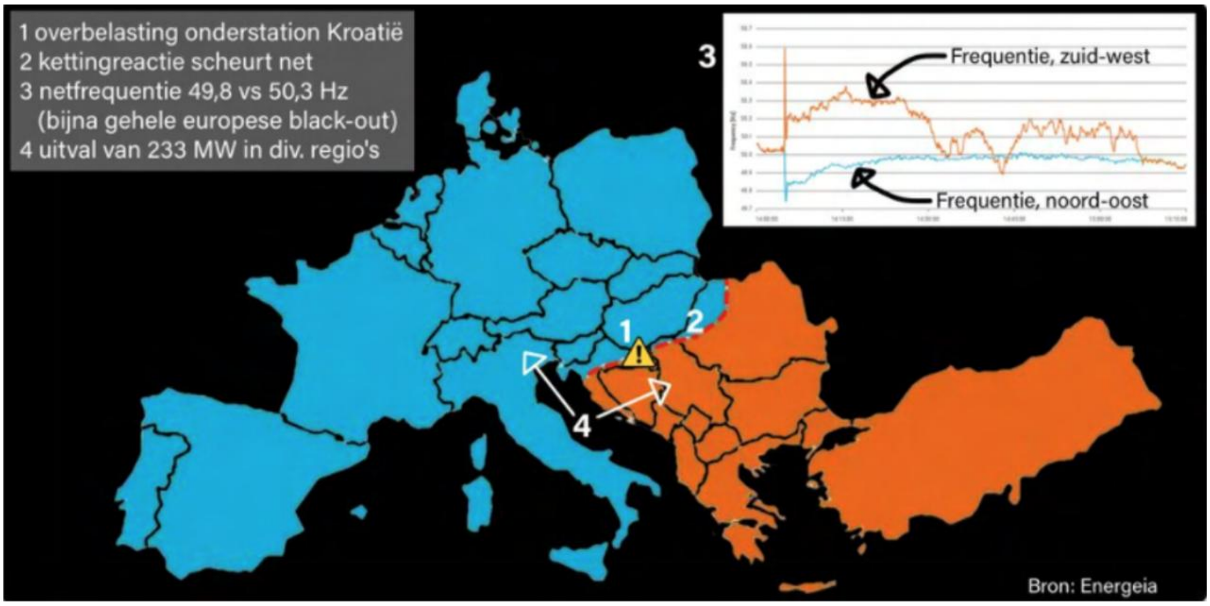


Figure 21: Discord - on January 8, 2021, a medium-voltage substation in Croatia failed, with the result that a few minutes later half of Europe was almost without power - source: Energeia

The energy transition requires the dynamics of a jam session. It contains elements of the existing repertoire, but it is no longer certain who plays which part. It's time to improvise. Because the interplay is constantly changing, the harmony is disturbed and everyone has to constantly search for the right key. It requires control, craftsmanship and creativity. And it takes tools; handy tools to always play automatically in the right key, for example. Filters to ensure that one instrument does not drown out the other. Jamming is hard work, listening carefully and responding to a continuously changing situation. Only when the rules are clear, everyone knows when they can take the space to play their solo, rhythm, key and mood are clear can it start to sound like music. And then it is no longer the soft background music of the radio, but we are all connected through our home studios, and we come together in harmony in continuous movement.

For the first time, digital technology enables a new energy system that works on the basis of *sense & respond* . We first designed a fairly simple system in which a few producers could control power plants according to the fluctuating demand of millions of customers. But with the planning and control systems we have for this, managing and switching millions of renewable energy providers is simply impossible.

Our networks are very well designed for central control and one-way traffic, but cannot handle two-way traffic. With more than a million points at which energy is offered, traffic jams are created. If we continue to act according to the current credo of operational excellence through planning & control, we will end up with the conclusion 'surgery successful, patient deceased'.

In essence, we are moving from a complex system, which by definition depends on complex rules and authorities enforcing them, to an autonomous and

self-organizing system. For this, the complex rules and the authorities that monitor compliance are not necessary.
A wonderful example from nature is the flock of birds. Every year we witness the wonderful movements that such a swarm of dozens, hundreds and often even thousands of birds make. And when we think about it, we realize that that swarm is not complying with any controlling authority. There is no boss bird, no navigation bird, and no traffic rules bird. Yet the swarm rises, the swarm remains a beautiful swarm, and the same swarm arrives at its destination.

In 1986, computer programmer Craig Reynolds developed *Boids.* A simple program to simulate the behavior of a flock of birds, based on only three lines of code: a.) Spacing: steer not to hit other birds in the flock b.) Direction: follow the direction of the birds next to and around you c.) Cohesion: move to the center of the swarm respecting the first two rules

With nothing more than the above rules - embedded in each participant in the swarm - you see a swarm emerge on the screen that behaves almost the same as the natural phenomenon on which this program is based.

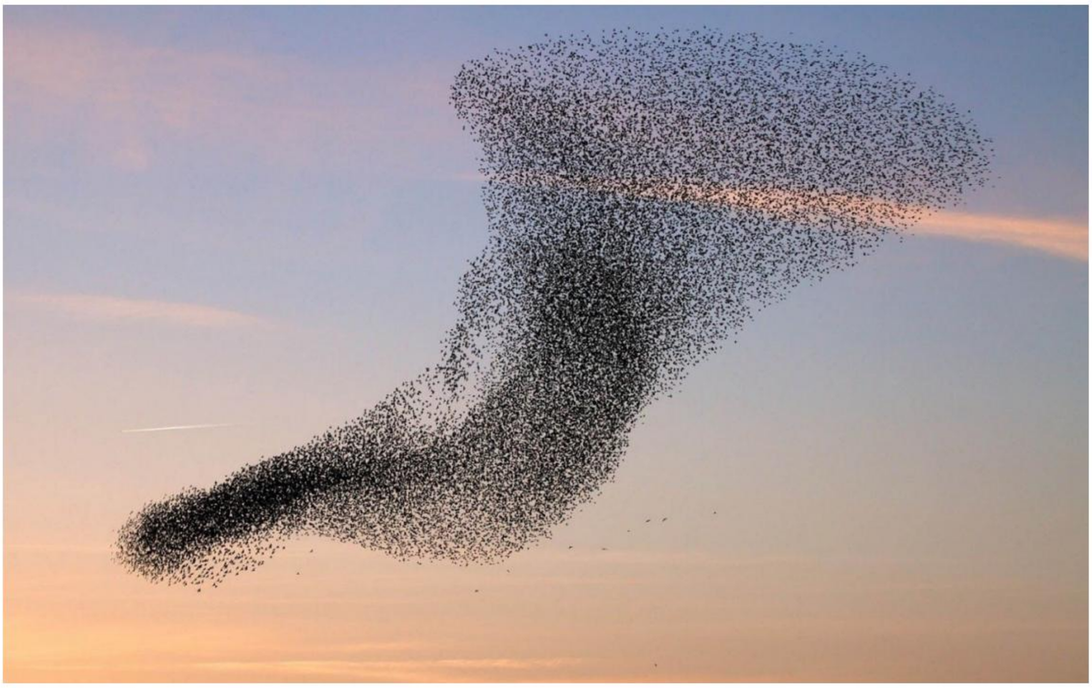


Figure 22: A flock of birds can essentially be captured in three lines of code. Source: howitworks.com

Is it possible to organize our energy system like a flock of birds? A system with self-organizing capacity, able to look for balance itself by making connections with other parts of that system where necessary?

It is certainly recommended to do research on this. It is precisely nature, our greatest and best example of unsteerability, diversity and resilience, that most likely holds the keys to the answers when it comes to developing and maintain a diverse and distributed energy system. There is a clear link with system integration research on holons and holarchic operating systems: https://tse.kpserver.io/holarchisch-energiesysteem/een-energie-holarchie

10.4 Standards and Protocols

There is a great need for standardization with matching protocols, with an unclear picture to what level of detail standardization should take place. We can see this as an opportunity and not as a handicap.

The more powerful the technology, the less stringent the standards.
The level of detail at which the standards must be formulated is partly determined by the available technology. For example, Artificial Intelligence can be used to interconnect different systems that meet accepted standards. The more powerful the technology, the less stringent the agreed standards may be.

Good pre-competitive protocols are necessary for maximum use of the functions and capacities of the various systems that we want to operate with each other.
Ultimately, the new energy systems must evolve towards a system in which all connected devices have sufficient intelligence to support the autonomous exchange of energy. A condition for achieving an effective peer-to-peer exchange of energy is a policy on protocols and standards that offers a lot of scope in technology development. The architecture of the future system and the communication structures used must meet minimum requirements to ensure reliable communication and
interoperability between subsystems from different suppliers.

10.1 Choose fair, inclusive, democratically controlled

Only if we choose to do so together. One of the reasons for writing 'Digitization in the Energy Landscape' in 2017 was the real-world scenario that an equivalent of Uber or Facebook or Amazon would emerge for energy. The fact that a company can turn the taxi market upside down thanks to the smart use of platform technology and algorithms is annoying for the existing industry, but as a society we will survive that. But when a basic need is controlled and regulated by powers over which we as users have no influence, it has far-reaching consequences. It is already the case that geopolitics determine whether we have a high or a low energy bill. Tech giants are increasingly determining what happens to our energy data. The inverters of our solar installations are ours, but the data they generate is not, which in turn is used by the manufacturer to build a strong position in the flex market.

Since 2018, the Club van Wageningen has been working on the rules for fairness, inclusiveness and democracy in a largely digitized energy system. Their insights and discoveries are of value to policymakers, entrepreneurs and system parties. The club van Wageningen is a change network of influential pioneers from energy companies, network operators, science, prosumers, the government and start-ups. Their common belief is that we can only solve the immensely complex issue of the digitizing energy transition with all actors.

The Rathenau Institute has also been conducting research at the intersection of ethics and technology for many years. It is recommended to support such initiatives. After all, the energy transition is not purely technological, but also economic, social and institutional.

The energy transition is also about together. Search together, learn together, solve together and build together.

10.2 Functioning data system is crucial

In the beginning there was no energy system, and then there was, and thanks to that energy system a data system has become possible. But now an energy system - distributed, using a multitude of sources and carriers, widespread and deeply intertwined in society - in turn can no longer exist without a functioning data system. So a symbiotic relationship has developed between the systems for energy and data. This means that we can only reason in terms of one integral energy data system. This has major consequences, because KPN and Ziggo can be regarded as network managers just as much as Enexis, Gasunie and TenneT.

But a data system is nothing without being focused on the purpose and the user. There is a trend towards localization, and rightly so because it is more familiar, more manageable, and in many cases cheaper. Combining functions helps the user and effectiveness. Look at all the functions in a smartphone, but also at a Tesla or Renault Zoe that fulfill almost all functions of the energy system, except generation. Or even: Sono Motors and Lightyear are already mounting solar panels on the roof.

10.3 Open and honest data architecture

There is a growing need for a cross-system open data architecture. An environment in which data from the various parties involved - users, network operators, developers, producers, etc. - can be united in order to make better decisions and to invest more specifically in the quality of the local energy system.

The internet has brought us many beautiful things, but also some monsters. Tech giants that have a power that transcends countries, and a business model that encourages putting ethics aside. A comparison with financial institutions is in order. But we are also working on solving these disadvantages. In that context, it is important to mention what www inventor Tim Berners Lee is developing with his initiative 'Solid' because it radically changes the way web applications can work, resulting in better privacy and ownership of data. Applications can be easily managed by the user and decentralized, rather than controlled by central parties. Following a similar philosophy, Waag Society has been working on a Public Stack as design template for the digital society, in which socio-economic considerations, user sovereignty and fundamental rights and values are safeguarded.

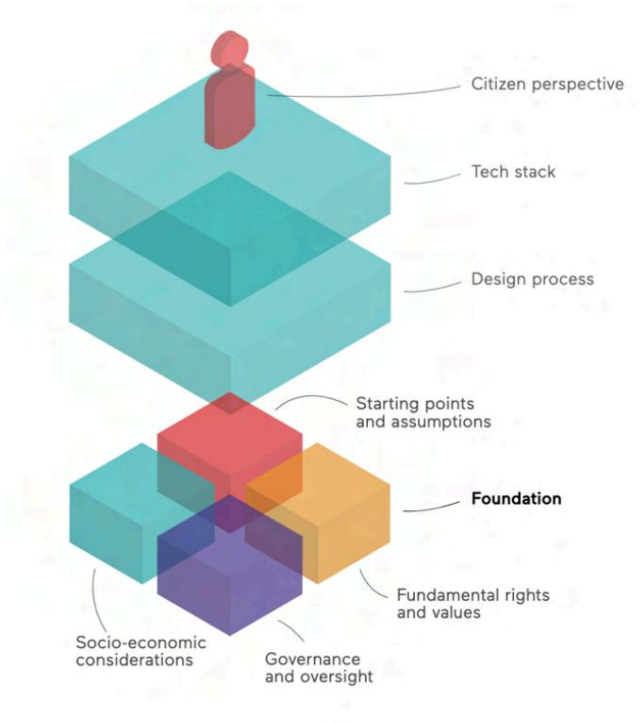


Figure 23: the Public Stack safeguards fundamental rights and values, governance, and socio-economic considerations. Source: Waag Society

In such a data environment, various data providers must have the certainty that their data will not be used for improper commercial gain by another party, but above all, users and asset owners must have the certainty that their data really belongs to and for them. . An environment in which we can unite geodata, building data, infrastructure data, weather data, energy data, measurement data and other data in order to make well-considered choices. Choices with regard to investments in infrastructure, but also, for example, which partial solutions are most effective in their situation and at that location: not only investments in generation, but also in transport capacity, storage and conversion technology, for example. Also think of such an architecture that helps answer the question "where, in what form and at what time is a renewably generated Joule worth the most?".

10.4 Cyber security at all levels

Cyber security is an issue that applies to all sectors in society, including the top sectors. Unfortunately, it is a condition and too often not yet understood or applied. "Everything you digitize also makes you vulnerable." *Cybersecurity by design* would be an appropriate part of any innovation process in which digitization plays an important role. Designing systems in such a way that they cannot be hacked, or designing them in such a decentralized way that hacking of each component is not attractive enough on its own, is a very important threat to a digitized energy system. Here, too, we find an important answer in decentralization.

A few TKIs have embraced cybersecurity as an important topic in recent years, but not everyone is aware of the risks of a weakly secured but largely digitized energy system. Energy is a basic need and its distribution takes place over a critical infrastructure. With regard to energy, we actually have no idea of the state and risks with regard to security.

It is essential that all existing infrastructures that are subject to digitization are adequately secured. At the same time, every innovation must also meet security standards to be determined, but these standards do not exist yet and few are concerned with this.

A loud call for *'security by design'* is appropriate here.

10.5 A future-proof reference architecture

In an optimal energy system it is determined per generated joule 'where is this joule most needed, in what form, and at what time?'. We work more and more with uncontrollable sources and we know one thing for sure: energy never arises out of nothing. At most you can use as much of it effectively as possible. Sometimes an electrical joule is worth the most by using it right away in the form of light. Sometimes it pays to convert that same joule into heat and store it for the winter. And in another case, that joule may prove most valuable when it is sent to a neighboring company that has a large, important energy need at the time. Perhaps an energy meter will no longer be simply a 'remote cash register', but will function much more as a router, which, using smart algorithms, continuously searches for the maximum value of every joule of energy that passes through it, be it a unit of electricity. , heat, or a molecular carrier.

There is a need for a journey of discovery into models for integrated energy networks, where the movement of molecules, electricity and heat are intertwined. It concerns calculation and control models to optimize conversions, flow direction, and automatic local *merit ordering* of energy functions, prioritizing different forms of energy and uses. The question is whether the market can realize this and whether a competition model is the most ideal to achieve optimization. The system may require flexibility in consumption, while the use of the battery on the frequency market is more lucrative at that time. So in policy and development together with the stakeholders, it is now about investment optimization models: which function and technology yields the most in a specific local network based on an integrated system? So don't invest haphazardly in renewable generation, but make a well-considered choice for local generation, storage, both in the short and long term, conversion, and control of use.

What is necessary is a system-transcending architecture that optimally allows individual freedom. By developing pre-competitive protocols instead of letting the market determine a standard with power - with all the resulting lock-ins - a framework can be created within which the values - fair, inclusive, sustainable, democratic - remain intact doing. The freedom paradox also applies here: freedom is only preserved with a clear framework and clear rules.

10.6 Do not make technology, but user experience leading for development

Too often we innovate according to the creed 'solution seeks problem'. Technology is looking for better, faster, larger, other applications of that technology.
We live in a culture of *'technology first',* and lose the customer, the user, the citizen. And not just the citizen, because the policymaker too often can no longer see the wood for the trees. Often the best solution does not have more, but fewer buttons, options and visible complexity. What happens under the hood can be very complex, but if we want to offer solutions that are really embraced, we have to invest in a user experience that is more logical, simpler, clearer. What problem do we really want to solve? Developing technology is a profession that many people understand, but developing technology that addresses a real problem in a way that those involved actually understand, very few can.

Technology ideally follows a clear picture of an optimal user experience. And from that user experience, an image of usable partial solutions is created. Then follows integration into an integral solution for the user, in a language and form that the user understands.

Here it also pays to include ICT professionals in energy literacy, and energy professionals in ICT literacy. But above all it pays to invest in knowledge and skills in the field of design, user experience, graphic and industrial design, ergonomics and service design.

11 Conclusions, recommendations

Now that we have come to the end of this publication, we provide a brief overview of the recommendations and conclusions resulting from the research on which this digitization agenda is based.

Cross-system

1. Digitization is developing very fast. This agenda preferably deserves an annual update and enrichment.
2. Move from A to B through the principles of B. We cannot reach the future through the principles and laws of today. Explore, recognize, embrace and embody the principles of the energy system we want. Do not innovate incrementally from the sub-optimal reality of today, but from the desired future.
3. Invest not only in technology, but also in economic, social and institutional innovation.
4. Be aware of the dual nature of digitization. Not all digitization is system innovation. Not all innovation leads to a sustainable, inclusive, reliable and affordable energy system. Invest in digitization that matters.
5. Energy is the foundation of the economy. Without a working energy system, the economics - let alone digitization - non-existent.
6. Develop scenarios and action perspectives for situations in which things go wrong such as large-scale power failure, unaffordable energy, failure of market parties. Perform stress tests regularly.
7. Take ownership of 'ownerless problems' such as the situations where split incentives arise between owners and users of assets and infrastructure.
8. Digitization and energy are both cross-cutting themes by definition. This also affects the top sector policy; as long as the energy sector continues to see itself as a separate sector, system progress and integration is extremely difficult.
9. Stimulate long-term projects and programs in which new systems are developed, independent of the technology ultimately to be used.
10. Develop a substantial organization around the theme of digitization, and make the necessary budgets for directing, increasing and deepening knowledge and insight at the intersection of energy and digitization. This organization should be involved in every TKI, every MMIP and act as a valuable sounding board in the programs and projects to be developed on this interface.

Technological

11. Develop a national program for research and development at the intersection of digitization and energy. Do this in collaboration between the Top Sector Energy and the Top Sector ICT, with the support of the relevant departments of the Ministry of Economic Affairs and Climate and the relevant top consortia 12. Connect the initiatives from the Top Sector Energy to the 5 key technologies used by the Top sector ICT: AI, blockchain, big data analytics, cyber security, future networks.

13. Invest in research and development of (semi-)autonomous energy systems. Think this includes hardware integrations, but also protocols and standards, algorithms, operating systems, applications of artificial intelligence, applications of blockchain and digital currencies.

14. Invest in distributed energy systems and interconnected networks for electricity, molecules, heat and data.
15. Take into account an increasing demand for - especially electrical - energy, and encourage developments that ensure that users can produce and use this locally and at the time they want.
16. Invest in decentralization of not only generation, but of short-term storage, seasonal storage and conversion, and of responsibilities such as balancing, guaranteeing the quality of power and voltage, and facilitating decentralized markets on local networks.

17. Invest in the development of Energy Service Providers. In the development of new service providers that do not supply energy, but make the supply of energy superfluous by promoting system balance and enabling peer-to-peer energy traffic.

18. Invest in the development of power grids into energy grids, through two-way traffic and integration with storage, buffering and conversion. This reduces the pressure on the grid managers to meet all the needs of the energy system with grid reinforcement.
19. Invest in the development of artificial intelligence, digital twins, blockchain technology, and IoT applications. Assess use cases for their cross-system approach.
20. Develop a national Internet of Energy program: the interweaving of systems for data and energy, and peer-to-peer energy traffic.

Economic

21. From volume to value: research and develop ways to make the valuation of energy no longer dependent on volumes moved, but on the value these movements add to the system.
22. Subsidies are still provided to unsustainable technologies and models. This should be phased out in favor of future-proof solutions.

Social

23. *It's all about the people.* Involve society. Apply for a strategic breakthrough the entire system at the table. Investigate the underlying motivation of the energy user. Investigate the 'question behind the question'.
24. Stimulate development primarily based on the user and his needs, and not primarily based on technology. Let technology follow the required solutions of users and user groups. Use what already exists and develop the rest. Provide an overview and a higher level insight into the system.
25. Give room for experimentation. Experimentation - also outside the current legal and regulatory framework - is necessary for the development of future-proof energy systems, markets, operating models and technologies.

26. Take advantage of the possibilities for hyper-personalization. Each individual can have his own personal energy transition plan. And be aware of the pitfalls of that same hyper-personalization, make sure that the user does not become a toy of tech giants.
27. Take into account the emergence of digitally-driven companies that have a very large can influence the energy system and, because of their international character, can partly evade Dutch legislation and tax liability.

28. Make every initiative related to digitization also pay attention to privacy, cybersecurity and data ownership 29. Take responsibility for stimulating inclusiveness, fairness and

democracy in the energy system at the various TKIs, but also at each recipient of a subsidy or other support

Institutional

30. Invest in independence: from geopolitics, from technology, in energy independence at the individual level. Avoid lock-ins.
31. Facilitate the development of pre-competitive conditions as protocols and standards for the exchange of energy, integration of carrier networks for heat and electricity and for the integration of networks for data and energy.
32. Direct the development of a clear, sound and future-proof reference architecture that offers users freedom with regard to their individual technological choices on the one hand, and enables interoperability with other users who opt for different technology.

33. Do not be afraid to fundamentally review existing system features, such as the energy tax system, the market model and the privatization of certain parts of the energy system.

Spatial 34.

Invest in ways to intertwine the energy supply with the living environment in a non-intrusive way. Take advantage of available solutions for data visualization, modeling, simulations and dynamic user interfaces to promote multiple land uses and make the most of local opportunities and meet local needs.

12 Acknowledgments

This publication was only possible thanks to the support of the Top Sector Energy and RVO, and is especially enriched thanks to the insights of the many experts, interviewees, and the ever-growing network of people who devote themselves to building a beautiful energy future, and see the value of digitization in this.

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Thanks to the support of these experts, and looking ahead to the development of cross-system programs and projects for digitization in the energy domain, we can conclude: together, energy and digitization are indeed more than the sum of their parts.