Rethinking Infrastructure as the Fabric of a Changing Society

With a Focus on the Energy System

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Abstract In this chapter, we explore the nature of infrastructure, how it is appreciated by society, how this appreciation has changed over the lifetime of the infrastructure, and how infrastructure development and performance are influenced by the governance structures in place. While the focus in this chapter is on energy infrastructure, ample illustrative material is also provided from other infrastructure sectors. We examine the trends towards technological and administrative decentralisation and towards digitalisation of infrastructure (service) provision. These trends enable formerly passive consumers to adopt new roles as providers of energy, data and transport services, and result in strongly increasing cross-sector interdependencies, especially between energy, transport and digital infrastructure. These interdependencies, however, are not reflected in the siloed governance structure of these domains, which hinders the energy transition. Furthermore, we diagnose a mismatch between, on the one hand, the focus of energy infrastructure governance on cost-effectiveness—with a view to low-cost service provision—and, on the other hand, the role of infrastructure in upholding and creating social value in terms of equity, fairness and social justice. Since the energy market liberalisation, the fundamental role of infrastructure as the *fabric of society* appears to be a blind spot in reflections on infrastructure and largely unexplored territory in current infrastructure policy and governance. If not remedied, this blind spot may exacerbate existing inequalities between energy consumers and create new divides in society, as is illustrated by current developments in the Netherlands with respect to sustainable heat provision. We advocate a richer value orientation in energy infrastructure governance and infrastructure governance at large, which goes beyond the current focus on efficiency and economic value, in recognition of changing societal values and priorities and, most of all, to fulfil the potential of infrastructure in creating an inclusive society.

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Introduction

On 11 December 2019, EU President Ursula von der Leyen presented the European Green Deal to the European Parliament. The European Green Deal embodies the ambition for Europe to become the world's first climate neutral continent by 2050. Quoting Von der Leyen in her address to the European Parliament: "*The European Green Deal is our new growth strategy—for a growth that gives back more than it takes away. It shows how to transform our way of living and working, of producing and consuming so that we live healthier and make our businesses innovative. We can all be involved in the transition and we can all benefit from the opportunities.*" (EC, 2019a). Von der Leyen refers to the adoption of the European Green Deal by the EU College of Commissioners as: "*Today is the start of a journey. But this is Europe's 'man on the moon' moment*." (EC, 2019b). At the conference on the first European Climate Law, 28 January 2020, in Brussels, EU Executive Vice-President Frans Timmermans described the challenge of transforming a society entirely based on carbon to a climate neutral society that can function without carbon as a change of '*tectonic nature*'.

The big words used in the presentation of the European Green Deal mark it as a very ambitious policy document indeed. It is certainly remarkable in its breadth, as it covers all sectors of the economy, notably transport, energy, agriculture, the built environment and industries such as steel, cement, ICT, textiles and chemicals. Another remarkable feature of the European Green Deal is found in its recognition of the social and ethical dimension of the radical transformation ahead: "*The European Green Deal sets a path for a transition that is just and socially fair. It is designed in such a way as to leave no individual or region behind ….*"

In this chapter, we take an infrastructure perspective in exploring the challenges contained in the European Green Deal. Understanding the role of infrastructure is key to identifying the deep-rooted hurdles in the societal transformation ahead and to accepting how it will affect all of us. In the words of Frans Timmermans: "…. *this is not just an economic change, this is not just a change in how we produce and live, this will affect every single institution upon which society is based and that helps society function as it does.*" In his opinion: *"…. the technology, the science, the money is not the problem, so why is it difficult? I think the essential issue is one of governance.*" (EC, 2020a).

With a focus on the Netherlands, Frans Timmermans' home country, we will explore why and how the governance of infrastructure, and energy infrastructure in particular, is crucial to accomplishing the policy goals of the European Green Deal. Revisiting and potentially reshaping the current governance structures then is the next inevitable step that will determine whether and how the promises of the European Green Deal will be delivered by 2050.

Structure and Purpose of This Chapter

In this chapter, we will first focus on the nature of infrastructure, which extends far beyond its technical dimension. We therefore introduce a definition of infrastructure which includes the services provided through infrastructure, thus highlighting the social dimension of infrastructure. Indeed, it is only through the services it provides that we appreciate infrastructure. For example, society is not interested in a few extra kilometres of railway track as such. What matters to us is that we now can travel faster from A to B. Our appreciation will also depend on the price of the ticket, the comfort of the carriages and the timetable. All these aspects are a matter of governance. Only if we include the provision of infrastructure services, we can see how current governance affects the performance of infrastructure for society, in the sense that not all groups in society may be adequately served. At the same time, it is also possible to observe that some people may be disproportionately disadvantaged because their living environment is negatively affected by the external effects of the provision of infrastructural services to others.

Then we will sketch a picture of trends and patterns in the infrastructure landscape, which already have had a considerable impact on society. We argue that these should be accounted for in the reshaping of infrastructure governance in the EU and its Member States, if the European Green Deal is to deliver on its promise that no one will be left behind in the great transformation ahead. A dominant trend is the ever more intensive interdependency between infrastructural systems, which comes to light in the energy transition in particular. Other important trends are the digitalisation of infrastructure, the technological and administrative decentralisation of infrastructure development, and the metamorphosis of the formerly passive end user into an active player in the infrastructure system, in a new role as a provider of services.

We explore the interconnections between these developments and illustrate how they have an impact on our society. Our exploration signals a number of risks. Unless all citizens can participate and share in the benefits springing from changes in the infrastructural landscape, situations may arise that are perceived as unfair and where citizens affected may feel excluded. Impairment of social justice and inclusivity can erode support for socially desirable infrastructural transitions that require major investments. Moreover, there are ethical values at stake. Conversely, we also see that broadly shared feelings of social injustice can be a decisive factor initiating change. For instance, wide public consensus in the Netherlands about the plight of the citizens of Groningen, the Dutch province plagued by gas extraction induced earthquakes, made the Dutch Minister of Economic Affairs and Climate (EZK) decide to accelerate the phase-out of gas extraction in Groningen. It also persuaded many municipal governments in the Netherlands to phase-out natural gas altogether by 2030.

Obviously, social values are facts to be reckoned with in shaping the future of infrastructure. Nevertheless, in the practice of infrastructure policy, infrastructure is associated first and foremost with technical solutions, with economic value, with the support of economic activity, and with stimulating economic growth and productivity. In this chapter, we posit that this perspective does not acknowledge the rich social and cultural value which infrastructure creates for society. In this chapter, we shall attempt to interpret and delineate that social value, after having demarcated first what we understand by 'infrastructure'.

Note that this chapter is largely based on the state of infrastructure and infrastructure governance in the Netherlands. Between countries, even within the European Union, we see large differences in the details of infrastructure governance. The Netherlands, however, provides relevant illustrative material on the consequences of infrastructure policy. Firstly, the Netherlands ranks 4th in the 2019 Global Competitiveness Ranking Index 4.0 of the World Economic Forum, among others thanks to its excellent infrastructure quality (ranked 2nd in the world, after Singapore) (WEF, 2019). Secondly, it belongs to the group of most 'equal' societies in the world in terms of disposable income distribution among the population.[1] In the WEF report on the EU's progress on the way to achieving the competitiveness goals set in its 'Europe 2020 Strategy to achieve smart, sustainable and inclusive growth', the Netherlands ranked 4th for social inclusion (after Sweden, Denmark and Finland) (WEF, 2012). Yet, even in the Netherlands, social inclusiveness is not a given. As we will illustrate in this chapter, infrastructure policy decisions are of huge significance in that respect. We will advocate that infrastructure policy decision making should explicitly be assessed on its positive or negative consequences for the inclusiveness of society.

Defining Infrastructure

Infrastructure is an indispensable component of the human habitat in sedentary societies. Historical civilisations cleverly took advantage of the natural infrastructure of mountain passes, waterways and other vantage points when choosing places for settlement. The geography dictated where the demands of safety were compatible with the possibilities for subsistence and the needs for connection with the rest of the world. Moreover, the natural geography could be improved by waterworks, such as irrigation systems, fortifications and so forth. Today, the term infrastructure primarily brings up associations with man-made systems. In its original meaning, the term infrastructure was used to indicate the system of defensive works and military installations intended to protect society against enemy powers. As a river delta, the very existence of the Netherlands as a country hinges on the protective system of sea defences, river dikes and water level control. The meaning of the term infrastructure has gradually shifted to public works and amenities of general public interest, with an emphasis on their economic importance: networks for transport of people and goods, networks for electricity, fuels (for heating and transport), drinking water, sewerage, telegraphy, fixed-line and mobile telecommunication and data transport.

[1]See a.o. Eurostat, Gini coefficient of equivalised disposable income – EU-SILC survey, 15 December 2019.

In short, infrastructure involves the systems that accommodate the basic metabolism and signal processing of society in industrial and post-industrial economies.

While most infrastructure networks have changed hardly at all in the previous century, apart from significant expansion in capacity and density, radical technological developments have occurred in the telecommunications sector. Millennials and younger generations have no idea of things like a telex, a telegram or a fax message and no longer associate telephony with copper wires. Since the 1990s the telecommunications sector has seen a proliferation of new, digital, fixed-line and mobile networks, via which we communicate by means of speech, image, messages, data files, and so on. That development is not over yet. Alongside the development of the post-industrial economy and society we see the use of the term infrastructure shifting more and more to 'intangible' assets and services; terms like financial infrastructure, cultural infrastructure, and healthcare and knowledge infrastructure are common vocabulary by now. That indicates that our ideas about what services we consider essential are changing with the development of society and the degree of specialisation of the economy (Frischmann, 2012). That is not to say, however, that the infrastructure services that were once essential to the industrial society are not so anymore.

According to Wikipedia, "*infrastructure is the set of fundamental facilities and systems that support the sustainable functionality of households and firms, including the services and facilities necessary for its economy to function. Infrastructure is composed of public and private physical structures such as roads, railways, bridges, tunnels, water supply, sewers, electrical grids, and telecommunication (including internet connectivity and broadband access). In general, infrastructure has been defined as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions and maintain the surrounding environment*".[2] While it may be easy to reach agreement on a definition as provided in Wikipedia, the devil is in the detail when it comes to data collection.

Considering the crucial importance of infrastructure for the economy and society, it is surprising that basic data about infrastructure are largely lacking. Data about infrastructure e.g., about investments and capital stocks, are not consistently collected and if they are, it turns out that the data of different countries cannot be compared because of different definitions of infrastructure being used. Indeed, a common definition of 'infrastructure' is lacking in the international standards for compiling official macroeconomic statistics. Neither the 2008 System of National Accounts (UN, 2009), nor the European System of Accounts 2010 (EC, 2013) provide a clear definition of infrastructure and a clear delineation of what investment categories and assets to (not) be included. The struggle with a clear definition is also seen in the diverging definitions of infrastructure used in the United Kingdom, Canada and the USA in developing satellite or extended accounts on infrastructure. The definitions differ in the categories of infrastructure included. The UK Office of National Statistics sticks to a narrow set of six categories of physical capital assets, jointly referred to as

[2] Wikipedia "Infrastructure". Consulted 03–20-2021.

"economic infrastructure", where the flow of services or benefits accrues to multiple industries beyond the industry possessing the assets, like transport, energy, water, waste, communications and flood defences (ONS, 2018). The delineation used by Statistics Canada is much wider, including not only the aforementioned economic infrastructure assets, but also schools, colleges, universities and other educational buildings; libraries; hospitals; public security facilities; recreational facilities; memorial sites and so forth, which are often denoted as "social infrastructure" (Statistics Canada, 2018). What the UK ONS and Statistics Canada definitions of infrastructure have in common is that they focus on tangible assets.

The definition of infrastructure that we use in this chapter is in line with the UK Office of National Statistics' delineation of the so-called economic infrastructure: the collection of systems that protect us from flooding and drought, provide us with water and energy, communication, data and physical transport services, and ensure the hygienic removal of waste and wastewater. Thanks to that infrastructure, two thirds of the Netherlands' population can live and work in areas prone to flooding. Thanks to that infrastructure, we have energy and clean water at our disposal at all times and we can count on our waste and wastewater being discharged and processed hygienically. And thanks to that infrastructure, we are connected with each other and with the world around us.

In the way we define infrastructure in this chapter, however, we depart from the traditional 'hard infrastructure' definition. Rather than only referring to a class of physical and technical assets, we also include the intangible assets and systems required to produce the service providing functionality of infrastructure. For instance, a railway track as such cannot provide a safe and reliable public transport service, without access facilities, without appropriate carriers, and without traffic management and control systems. After all, the value of infrastructure manifests itself only through the services it provides for society and the economy. Hence, we define infrastructure as an essential services-providing socio-technical system. As all of the essential services provided by infrastructure hinge on a supply chain, or a set of interdependent supply chains, our infrastructure system definition thus covers the collection of supply chains which provide us with flood protection and water management, energy (electricity, heat, transport and heating fuels), transport of people and goods (overland, by air, water and rail), information and telecommunication (including digital communications and data transport), safe drinking water, sanitation and solid waste management.

The latter definition of infrastructure has been made operational by Statistics Netherlands in a validated method to estimate the contribution of infrastructure to the Gross Value Added (GVA) of the national economies of fifteen OECD countries and EU Member States over the years 1995–2016 (CBS, 2019). Despite huge differences between the fifteen countries in climate and geography, population density, spatial economy, economic structure, distribution of the population, and so forth, this study revealed that the share of infrastructure in the GVA of the national economy is quite consistently in the 10–15% percent range for all countries included in the analysis. For the Netherlands, throughout the years 1995–2016, infrastructure contributed 13.1%

(on average) to the GVA of the national economy. Critics may argue though that the infrastructure contribution as quantified in the Statistics Netherlands study still grossly underestimates the importance of infrastructure for the national economy, as ultimately all economic activity depends on the essential services provided by infrastructure.

Out of Sight, Out of Mind?

How Do We See Infrastructure?

In the Netherlands, as in most Western societies, we are used to take the availability of infrastructure for granted in planning and performing nearly all our everyday routines; at home, on the road and at our work place. We do not think about infrastructure, in the same way as we do not need to think about the functioning of the nervous system or the blood circulation in our bodies. In our sophisticated economy, we are hardly aware of the fundamental role infrastructure plays in the functioning of society, also because of the high reliability of infrastructure service provision.

Lack of awareness is caused further by the literal invisibility of much of the physical infrastructure, in the form of airwave frequencies and underground cables, pipes and ducts. In Western economies, most of those cables and pipes have been there for many decades and some of them much longer. Many of these assets have surpassed their technical lifetime and need to be replaced between today and 2030. That implies a massive investment challenge for the infrastructure network providers and for governments owning and managing infrastructure assets, such as the municipal governments in the Netherlands that run the sewerage systems. Whilst infrastructure renovation and replacement provide opportunities for innovation, their execution also causes great nuisance to end-users and local residents. In other words, when infrastructure ‘comes to light’, it is usually not a positive experience for citizens. And as long as the physical infrastructure assets remain buried underground, the motto seems to be: Out of sight, out of mind.

The linear infrastructure of roads, railways, waterways and high-voltage lines is always prominently present in our living environment, though. These links and the networks they are part of literally structure the spatial environment. The locations of roads, railways and waterways determine where we can live and work. The nodes in the networks of linear infrastructure are also nodes of business activities and social interaction. This is not only true for nodes in a narrow sense, such as railway stations, airports and ports. It also applies to nodes in a broader sense: cities developed historically around the nodes in infrastructural networks. Cities are nodes at the aggregated level of the infrastructure system-of-systems. Cities can exist thanks to infrastructural facilities and services. At the same time, successful cities also call for more and more infrastructural facilities to accommodate population growth and economic development. In many cases there is a self-reinforcing process of preferential connection with well-connected nodes (Barabási & Albert, 1999; Batty, 2008; Bettencourt et al, 2007). This process, also known as associative growth in networks, seems to account for the biased urbanisation patterns that we see in many countries, like the United Kingdom or France, where the urban agglomerations are dominated by one or a very few metropolis(es).

The distributed urbanisation pattern of the Netherlands is one of the few exceptions to the rules of associative growth. Historians diagnose the origin of this deviating urbanisation pattern in the fine meshed network of waterways in the Netherlands existing since the Middle Ages, and in later centuries supplemented with railways and motorways. This allowed the regional specialisation of the Dutch economy to develop at a relatively early stage, so that many comparatively small, connected cities developed, instead of one dominant metropolis (Van der Woud, 1987). In an international comparison, however, it would make sense, given the scale of the Netherlands and the relatively short travelling times, to regard the whole country as one coherent conurbation.

How Do We Experience Infrastructure?

Even when infrastructure is prominently visible, we often do not recognise it as infrastructure. Most infrastructure is deeply embedded in the spatial structure, both in the green and blue landscape and in the built environment. Thus, we experience a large part of the historical infrastructure as a self-evident part of the landscape and the urban environment. In the Netherlands, we can think of the rings of canals in many inner cities, the man-made dwelling mounds (terps) in areas prone to flooding, the star shaped fortifications with moats surrounding dozens of historical cities, and so forth. That historical infrastructure does not only create tourist attractions and cultural value. Many historical infrastructure assets still fulfil their original function, as do the canals which were constructed in the early nineteenth century by the Dutch king William I (nicknamed canal king). The function of the canals in our cities is being rediscovered as municipal governments are compelled to develop climate adaptation strategies. In several places filled-in canals are reconstructed, and in the development of new residential areas, canals and ditches often provide water storage and drainage functions. Most Dutchmen tend to forget that the quintessentially Dutch polder landscapes owe their existence, and their survival, to infrastructure, in the form of ring dykes and ring canals and pumping stations. The systems of river dykes and flood plains are infrastructure every bit as much as the dyke roads themselves. Indeed, only few Dutchmen will know that many of the nature conservation areas in their country originate in the historical energy transition from firewood to peat as the dominant energy carrier. Without historic peat extraction activities, many of the cherished lakes and landscapes in the Dutch provinces of Drenthe, Overijssel and North and South Holland would not exist (Van der Woud, 1987, 2020). On its website, the Dutch National Forest Service (*Staatsbosbeheer*) writes about a magnificent and seemingly pristine nature conservation area like the *Weerribben* in the north of Overijssel: *'Each meter of land here is man-made.'* Besides peat extraction, hydraulic engineering works played a major role in creating the land and the landscapes of the Netherlands which may be, more than any other country, a country defined by its infrastructure.

Historical infrastructure is often cherished as (pre-) industrial heritage, after its original function has been lost. This is true, for instance, for many old water towers, which are coveted today as residential and business premises, or for the old windmills and steam-powered pumping stations by means of which the Dutch polders were reclaimed in previous centuries. Throughout the world, there are countless examples of historical railway stations (e.g., Mumbai, Kuala Lumpur, and Dunedin) that are cherished as cultural heritage. Many of those stations are still functional, for that matter. Modern railway stations are often architectural highlights as well. Apart from their intended functionality they add aesthetic value to their environment, thereby contributing to a sense of place. The same goes for civil-engineering structures like bridges. Historical cross-river connections such as the Golden Gate Bridge and Sydney Harbour Bridge have become icons for San Francisco and Sydney, respectively, and in a similar fashion, the people of Rotterdam have embraced the Erasmus Bridge as 'their' swan.

Although modern infrastructure systems for drinking-water supply and sanitation are hardly visible, they are significant additions to the way we experience comfort, just like electricity and natural gas. Besides, hygienic drinking-water supply and wastewater discharge contribute significantly to the quality of the natural environment and public health. Thanks to these amenities, epidemics of cholera, typhus, dysentery and other water-related diseases are largely things of the past in our regions. In 2007 the readers of the British Medical Journal even elected the sewerage system as the most important 'medical' breakthrough since 1840 (BMJ, 2007).

How Do We Value Infrastructure?

Public health is of evident importance to the well-being of the population and thus brings significant economic value. The latter is not expressed, however, in the contribution of the drinking water infrastructure and sewerage to the gross value added of the Dutch economy. The contribution of drinking water, sewerage and waste management services combined to the Gross Value Added of the Dutch economy amounts to a mere 0.65% on average over the years 2006–2016 (CBS, 2019). Judging by the value added of the drinking-water infrastructure, it hardly 'pays' for the national economy to invest in that. It is evident that this reasoning does not take account of the actual function and value of a safe drinking-water supply for public health. For the energy supply sector,[3] the contribution to the GVA of the Dutch economy amounts to less than 2% (1.7% on average over the years 2006–2016). Yet it is evident that

[3]Covering the supply chains for electricity, natural gas and transport fuels (but excluding oil and natural gas production).

the crucial importance of energy services cannot be overestimated. Without energy services we would be miserable and the entire economy would collapse.

The current investment logic in the world of infrastructure is underpinned by a utilitarian perspective: infrastructure requires major investments, which are justified because infrastructure enables us to create more economic value. In this logic, benefits in the distant future weigh less heavily than benefits that may be realised in the short term. In the social cost–benefit analysis (SCBA) of infrastructural projects, aspects of non-economic value are represented only in monetary estimates. In today's practice this applies in particular to aspects of safety and public health—think of noise hindrance and air quality—, nature and landscape values. The current practice of SCBA falls short in acknowledging the rich variety of social and cultural values that infrastructure may create, like aesthetic quality and iconic value of prominently visible works of infrastructure. Such value aspects are not or hardly weighed in infrastructure investment decisions. In addition, the emphasis on (in) directly quantifiable economic benefits and their quantification in the SCBA system suggests that the economic benefits of infrastructural investments can, and should, be predicted, as a justification for building the infrastructure.

In this context it is a sobering fact that the relationship between investments in infrastructure and economic output still has not been clearly established scientifically. This is borne out among other publications by a meta-analysis of 80 macroeconomic models by the World Bank (Straub, 2008). Despite the well-recognised role of infrastructure as backbone of the economy, its exact economic value is difficult to determine (Aschauer, 1989; Carlsson et al. 2013; Munnell, 1992). From a macroeconomic perspective, it is clear that infrastructure contributes to economic development. In the Global Competitiveness Index, which is published every year by the World Economic Forum (WEF), the role of infrastructures changes along with the development level of the economy. According to the methodology applied by the WEF, in factor-driven economies the quality of the traditional infrastructural basic facilities accounts for 25% of the competitiveness score; this specifically concerns roads and railways, shipping and airline infrastructure, electricity infrastructure and networks for fixed-line and mobile telephony (WEF, 2017). It is easily understood that economic development is hardly possible when such infrastructural basic facilities are lacking. In more advanced efficiency- and innovation-driven economies, the competitiveness index calculations of the WEF indicate that the relative importance of such basic facilities decreases. In contrast, the accessibility and quality of fixed-line and mobile internet and communication facilities assumes a greater role. Then, the importance of infrastructure also declines in favour of other competitiveness factors, such as the efficiency of goods, labour and capital markets, the quality of the knowledge infrastructure, and the legal system.

From a microeconomic perspective, investments in infrastructure have direct and indirect effects. In general, the direct effects, for example as related to travel time reduction, can be quantified well (Romijn & Renes, 2013). By contrast, the indirect economic effects of infrastructure are far more difficult to prove. These may be business location factors, such as proximity and agglomeration effects, the increase in value of real estate, the growth or decline in local activities due to relocation and changes in commuting behaviour, and the effect of image—think of hubs and hotspots. Indirect effects of the implementation of infrastructure may also concern social effects, which are even more difficult to quantify in monetary terms, if at all. Many examples can be given of infrastructure investments which, contrary to the prognosis, did not yield a return or only yielded a return many years later than planned, and of investments which turned out to be far more profitable than anticipated or profitable in another way than anticipated. Recently the Netherlands Bureau for Economic Policy Analysis (CPB) reported that, in less than two years after the construction of the A2 highway tunnel in Maastricht, the increase in value of the building stock within a one kilometre-radius from the tunnel amounts to some 220 million euros. This is nearly twenty times higher than what was estimated ex ante. And this does not even include other quality-of-life benefits and the travel time reduction effect (CPB, 2018a, b). Especially indirect effects of infrastructure investments are surrounded by a great deal of uncertainty. It must be noted though that even the envisaged direct effects are often only realised very late. In the Netherlands, notorious examples are the Betuwe line (a dedicated freight railway line) and Groningen Seaports. In retrospect it becomes visible, however, that major infrastructure investments have usually had a tremendously positive impact on the relevant regions, even if they worked out differently than initially envisaged. Even though we still cannot properly foresee whether and how infrastructure investments will yield a return, we do know that the absence of infrastructure is a guarantee for socioeconomic development failing to occur. Indeed, all of the Sustainable Development Goals on the United Nations agenda hinge on investments in infrastructure (Thacker et al., 2019).

Moreover, in making investment decisions today, we should be aware of the fact that infrastructure investments throw a long shadow into the future. In accounting for these long-term effects, it helps to remind ourselves how decisive the infrastructure investments of our ancestors still are for the country in which we live and work in this day and age. The entire infrastructure in operation today represents a huge capital, which was largely invested in the past. Yet, infrastructure investments in the past were made for another society, with another economic structure and other societal priorities than we have today. Most of the Dutch canals, railways and ports were constructed deliberately to foster the development of large-scale industry, bulk transhipment and transport, in order thus to create employment and strengthen the international trading position of the Netherlands. The discovery of natural gas in the province of Groningen not only led to a rapid introduction of natural gas as a clean replacement for coal and petroleum in Dutch households and businesses in the 1960s; it also motivated the deliberate attraction of energy-intensive industry to the Netherlands. The Groningen natural gas reserves thus contributed significantly to the improvement of air quality as well as economic prosperity in our country. In hindsight, it may be said that this was achieved at great social and economic cost for the people in Groningen, who are now suffering from gas extraction induced earthquakes. Still, it is too easy to say that, with today's knowledge, those historical choices could not have been accepted as sustainable. Even if we assess these historical investment decisions as unsustainable, that does not imply that all of this historical infrastructure is now obsolete. Most of this infrastructure can be adapted for renewable energy carriers and sustainable processes in the future while adequately serving us today. We should also acknowledge that our views of sustainability have changed drastically and, like the generations before us, we cannot read the future either.

Given the evident uncertainties, it is good to note that the physical sustainability of infrastructure investments, which are deeply embedded in the spatial and economic structure, does apparently not impede a society in flux. Despite its physical inertness, established infrastructure has so far proven to be able to support a constantly changing society. A lot of old infrastructure still represents great economic and social value. However, over time we see a change in the values that society wants to create with infrastructure and the values it wants to enshrine in topical infrastructure development projects.

Traditional Values in Infrastructure Systems and Services

Traditionally, infrastructure makes us think of public amenities: provided, or regulated, by the government; the costs of which are socialised, because they benefit everybody or because nobody can be excluded from benefiting. Military defence works and flood defences are evident examples of such public amenities. Gas and electricity supply, drinking-water supply, public transport services and fixed-line telephony are examples of amenities which were brought about at a local scale by private initiative, but were soon taken over by the government with a view to economies of scale, characteristics of natural monopoly (with the appurtenant risks of abuse of market power) and positive network externalities in conjunction with public interests. Today, the collective nature of those amenities is no longer considered self-evident, though.

It is a moot question whether we would ever have realised the universal access to drinking water, sewerage, electricity and natural gas, which we take for granted in the Netherlands, if the neoliberal paradigm, which has been in force since the early 1990′s, had been leading in this pursuit. In many developing countries, we see that such infrastructure facilities and services are provided only in urban agglomerations, whereas the unprofitable connections to and within rural areas are not forthcoming. In the Netherlands, the principle of universal access to many infrastructure services is legally enshrined in the form of connection rights and obligations for drinking water, sewerage, electricity and, until 1 July 2018, natural gas. Furthermore, there are legally established quality requirements, intended among other things to guarantee safety and public health. All of these measures have been of significant importance for the high quality of infrastructure provision in the Netherlands. Meanwhile one may wonder whether access to fast internet has not become just as essential as electricity and water, and whether this implies that effective statutory obligations should ensue in this respect.

Access to essential services has not been realised equally well in all western economies, as we can see in countries like the United States. There we find persistent differences in the accessibility and affordability of essential infrastructure bound services between urban and rural areas, and between neighbourhoods with a high and with a low socioeconomic status—a separation that often runs parallel to ethnic lines. By no means all Americans get safe drinking water, in the countryside more than a quarter of the population does not have access to fast internet, and 85% of Americans cannot reach work, a hospital or shops without a car (Tomer, 2018a). Households in the lowest income quintile are forced to spend over 60% of their net income on drinking water, sanitation, electricity, gas, telecommunication and transport services. With housing costs added, the lowest income group has literally not a cent left for other necessities of life (Tomer, 2018b).

In the Netherlands, a conscious political choice for socialisation of infrastructure costs was made in the past to ensure the affordability of infrastructure services for all citizens. Nonetheless, in the Netherlands, too, there is inequality in access to and affordability of infrastructure services between citizens, between regions and between urban and rural areas. This is not a novel phenomenon. Differences between regions can be explained to a considerable extent by geographical conditions, such as the natural infrastructure of navigable waterways. In the topology of road, railway, electricity and gas networks, it is still visible that the so-called Randstad area[4] and other economically dominant urban regions were given priority in infrastructure development over the periphery. In the past, defence policy considerations played an important role in national infrastructure development decisions, particularly so with World Wars I and II still fresh in the collective memory. Later, economic profitability considerations (following the SCBA methodology) became dominant, putting a halt to daring ventures such as high-speed railway line (HSL) connections to the furthest corners of the country, incl. Groningen (Mouter et al., 2013).

In short, the dominant traditional values embodied in the design of infrastructure and infrastructure service provision can be summarized as (universal) Access, Affordability, Availability and Acceptability. Below we give a quick review of how these values are upheld per infrastructure sector in the Netherlands.

Information and Telecommunication Services

Thanks to technological innovation, the fixed telephone line met with competition from different forms of mobile telephony, which are no longer characterised by prohibitive costs for new providers wishing to enter this market. The natural monopoly of the fixed telephone line has come to an end as a result of competition with and between new fixed and mobile data networks. The same goes for digital information, which runs largely via the same networks. There are still quality differences between those networks, which manifest themselves mostly in terms of bandwidth and speed of data traffic. Providers of fast digital infrastructure must first recoup their investment before rolling out the new generation of telecom networks.

[4]The western part of the Netherlands spanning the cities of Amsterdam, Rotterdam, The Hague and Utrecht.

Moreover, they then seek a great density of connections. Consequently, the fastest service via a fixed fibre-optic network is still only accessible to a limited extent, depending on the region and municipality.[5]

In the 2018 Digital Economy and Society Index (DESI) of the European Commission, the Netherlands ranked first in Europe on the indicator of digital connectivity (EC, 2018),[6] with the Dutch top score for connectivity based especially on access to fast internet (72% of all households). In 2020, the Netherlands' performance had already fallen to the sixth position in the DESI 2020 ranking (EC, 2020b). Whereas the Netherlands still holds the top position in fixed broadband penetration (with 98% of households having a fixed broadband subscription), it is lagging behind other European member states as regards the penetration of ultra-fast internet in households. With respect to ultra-fast internet, Sweden is the front-runner in the EU, with almost 65% of households, thanks to spectacular growth in fibre to the home connections. The Netherlands seems to be slowed down by an inhibitory head start effect.

For entrepreneurs and citizens who cannot or not yet secure an optical fibre connection, this means that they are more limited in their options for business and personal development in the digital world than others who do have such connections. At present incremental innovation (Very-high-bitrate Digital Subscriber Line—VDSL—and bonded VDSL) can still improve the capacity of the existing copper network, as is true also for coax cable networks (with Docsis 3.1). Still, practice so far shows that new capacity is soon filled by higher user requirements: data use is increasing exponentially. This makes it questionable whether incremental innovation of existing networks provides enough new capacity to include all households even in the short term in data-intensive pricing systems (real-time or time-of-use) via smart grids, as is assumed in the energy transition.

Gas and Heat Provision

In the Netherlands, network providers have a statutory obligation to connect each household to electricity. Until July 2018, the statutory obligation to connect also applied to the natural gas network. For gas, an exception was possible only in case of an alternative connection to a heat network. Since April 2018, however, new dwellings will not be connected to the gas network anymore. The Municipal Executive may make exceptions in the event of compelling reasons of general interest, however. The manner in which heating services are provided, without natural gas, is left to the discretion of the municipal authorities, and private homeowners. At the national climate summit in October 2016, 77 Dutch municipalities signed the

[5]For the Netherlands, indeed, Bureau Stratix reported that the roll-out of optical fibre has stagnated for several years now.

[6]The indicator of connectivity measures the deployment and quality of broadband infrastructure, and considers both the supply and demand side of that infrastructure. This concerns fast (at least 30 megabits per second) and ultra-fast data connections (at least 100 megabits per second), both fixed and mobile.

manifesto ‘Setting to work with living without natural gas’ (‘Aan de slag met wonen zonder aardgas’), in which they declared to abandon natural gas as a heating fuel ultimately by 2030.

This is far from easy, given the fact that at this moment more than 90% of households are still connected to the natural gas network. Given the time horizon of 2030 that many municipal governments set to abandon natural gas, they do not see hydrogen as a viable alternative. Neither green nor blue hydrogen will be available in sufficient volumes and at an affordable price before 2030. Moreover, most likely, a primary candidate for the use of (initially scarce) green hydrogen will be industry, which has a very limited set of alternatives to generate high temperature process heat. Municipalities are focusing on alternative options for space heating that can be implemented sooner. However, there are great local differences in the options for municipalities to provide a sustainable alternative. In agricultural areas and in the vicinity of waste water purification plants there is a potential supply of biogas. Residual heat is abundantly available near industrial parks with a lot of process industry. The possibilities for heat extraction from surface water or for geothermal heat extraction are not the same everywhere in the Netherlands, and there are considerable differences between districts in the energy quality of the built environment. Energy neutrality is in the process of being defined as a statutory obligation for new premises and more and more new housing estates are already constructed according to standards of near-energy neutrality. Energy neutrality, however, is an expensive requirement for older buildings and houses. In the event of renovation, the heat requirement can be reduced substantially, but this comes with a hefty price tag. Given the different options at different locations in the Netherlands, it remains to be seen how the costs and the security of supply of heating services will develop in a natural gas-less future. Whereas today the principle of ‘No More Than Otherwise’, using natural gas as a reference, is still applied in the heat supply tariffs, it is not inconceivable that considerable differences in costs will occur in the future per region, per municipality and per district.

Electricity Provision

For electricity end-use an alternative is not under discussion. The consumption of electricity is only rising due to the increasing need for household comfort in an ageing society, due to the rapid advance of digitalisation—think of datacentres- and due to electrification of energy functions that were formerly fulfilled by other energy carriers -think of electric heat pumps and electric vehicles. The huge change taking shape here is the production of electricity from renewable energy sources, sun and wind in particular. These are partly large-scale developments, like the wind farms on the North Sea, while small-scale production is rapidly gaining ground as well. Many farmers already use their land, farmyards and buildings for wind turbines and solar PV parks, and increasing numbers of private homeowners put solar panels on their roofs, encouraged by attractive subsidy schemes and feed-in tariffs.

Consequently, we see more and more signs of inequality emerging in the supply of electricity from renewable sources, as the possibility to exploit their assets is available to landowners and homeowners, but not to tenants. Considering that it is not the poorest citizens who possess the financial resources to have solar panels installed, and that such activities also require due knowledge and 'acting ability' (WRR, 2017), we see a possible future scenario unfolding here in which inequality between citizens in the affordability of electricity, an essential service, increases. It is up to housing corporations to make the energy supply for their tenants sustainable. However, there are great differences between housing corporations, among others in the availability of financial resources. This implies, in practice, that different housing corporations do not serve tenants in a similar manner.

A scenario of increasing inequality in the electricity supply is becoming even more likely when we realise that the large-scale introduction of weather-dependent energy sources will inevitably lead to greater volatility on the supply side, whilst there are ever fewer traditional, coal- and gas-fired power plants which can be regulated up and down easily. This leads to rising pressure to bring about flexibility on the demand side. In industry a lot of flexible demand is available which is already being used cleverly to respond to price fluctuations in the wholesale market. Nonetheless, in the future an appeal will be made to households as well for flexibility in electricity demand. At this moment, the electricity demand in an average household is hardly elastic, but that may change in the future, as more households will have electric heat pumps and electric cars, and storage options for electricity and heat. There are incentive schemes available for such facilities, in the form of subsidies and easing of the tax and premium burden. Similar to investments in solar panels, it is a given that those benefits end up mostly with the relatively prosperous and highly educated section of the population that own their residences.

Other Infrastructure Services

It is less evident whether a trend towards unequal treatment of regions or citizens is coming up in other infrastructure systems as well. As in many other countries, the spatial demography is changing, as more and more people leave the countryside for better job and education opportunities in urban agglomerations. In rural areas where the population is shrinking, this may have an impact on the quality of infrastructure services. Provinces and municipalities are already contending with the organisation of adequate public transport facilities for a population of on average older and less mobile citizens. As a result, there are many locations in rural areas where only a very low frequency bus connection is offered, in some cases even manned by volunteers. The financial service provision by bank branches and ATMs and the social infrastructure such as schools, fire brigades, ambulance services, hospitals and other healthcare provisions are under pressure in those areas as well. As and when those facilities become scarcer, the mobility demand becomes greater and more urgent.

In general, less attention is devoted to the consequences of these demographic developments for the more basic service of drinking-water supply: As the user population in a region is dwindling, there is a threat of having an over-dimensioned drinking-water infrastructure. This may have a negative impact on drinking-water quality, unless investments are made in additional monitoring and possibly even in physical adjustments to the distribution network.

Another challenge, as an example, is that the combination of an ageing population and the current policy to treat sick patients outside the hospital as much as possible, and to let elderly people live in their own homes longer, will lead to an ever-heavier burden of household waste water with antibiotics and other medication. Today's sewage treatment plants are not equipped for the removal of such compounds and are facing new investments. In this case, there is actually little inequality between urban and rural areas, between more and less prosperous citizens, and between regions. In all regions, sewage treatment plants will need to be adapted so as to purify the wastewater from these new contaminations.

As we can see, the traditional core values of infrastructure (service) provision are still very much alive. The manner in which these values are upheld, however, has drastically changed with the reform of the traditional public monopolies that used to supply these infrastructure services, and still do so in the case of drinking water supply, sewerage, flood safety and wastewater processing. Following the introduction of market forces into other infrastructure sectors, we observe tendencies towards more inequality in the availability, quality and affordability of essential infrastructure services, like the supply of digital information, energy and transport services. This particularly affects users in rural areas, where profitable or even cost-efficient service provision is more challenging. It also affects the less affluent users, especially those who cannot benefit from financial incentive schemes for home improvements (thermal insulation), solar panels, heat pumps, electric cars and other measures designed to support the transition towards a sustainable energy system.

In the following sections of this chapter, we will focus in more detail on topical developments in the infrastructure sectors, especially in the energy infrastructure. We will identify some emerging coordination issues and examine the challenge of energy infrastructure governance in safeguarding the core values of infrastructure (service) provision in the years to come.

Decentralisation

Many people associate the energy transition with the rapid increase of installed capacity to harvest energy from renewable energy resources that they observe in their living environment. Wind turbines and large-scale wind parks have become prominent features in the landscape and solar roof panels are other visible signs of the energy transition. These new energy technologies are omnipresent unlike the large-scale fossil fuelled power plants of the past. The relatively small scale of many renewable energy technologies has drastically lowered the entrance barrier to the power generation market and thus enabled many new actors, including individual citizens, to enter this market. Indeed, government has actively encouraged citizens to engage in the use and self-generation of power from renewable energy resources by offering a range of stimuli e.g., information campaigns, subsidies, fiscal incentives and attractive feed-in tariffs. In the same vein, government has developed incentive schemes for home improvements, heat pumps and energy storage units. At the same time, new building standards are imposed, especially with respect to thermal insulation, and all homeowners who want to sell their property are required to apply for an energy label.

The smaller scale of renewable energy technologies is inviting to citizens who want to join in the combat of climate change as well as to citizens who are keen to reduce their energy bills. In an increasing number of neighbourhoods, energy cooperatives have been and are being established. The Netherlands counts a total of 582 energy cooperatives at the end of 2019, an increase of almost 100 new cooperatives since the previous poll in 2018 (HIER, 2020). These cooperatives were established for the goal of energy saving and collective power (and sometimes heat) generation, with the additional benefit of community strengthening. It turns out that cooperatives hardly engage in large-scale projects because these come with high uncertainty about the future tax incentive regime and thus with high uncertainty about the cost-effectiveness.

Whereas power generation used to be a capital and knowledge intensive activity reserved to highly specialised actors, the energy transition is bringing it down to the level of local communities and individual citizens. The ongoing decentralisation of power generation is enabled by the established power transmission and distribution infrastructure, which accommodates the natural variability of renewable energy resources. Seen from the solar roof owning citizens perspective, the electricity grid is the battery that absorbs temporal surplus production and supplies during times when generation falls short (Bakker de, et al., 2020; Hufen & Koppenjan, 2015; Verkade & Höffken, 2019). In many respects, this situation is comparable with the current practice of spatial heating in the Netherlands, where homeowners operate their own individual 'central' heating installation fuelled by natural gas, with natural gas being supplied through a fine-mesh grid with nationwide coverage. Here, the energy transition calls for a shift away from natural gas as a heating fuel. Many municipal governments are now in the process of implementing heat networks, especially in densely populated urban areas.

The energy transition does not only bring radical change in technology and physical structures, but also applies to new rules and coordination mechanisms for the parties that realise the provision of infrastructure and infrastructure services in a concerted action. Examples are the design of energy markets and network regulation, or the re-allocation of roles between the public and private sectors, and between the central government, the European Commission and local and regional authorities. We see that political decision-making has in recent years led to a pattern whereby the specifics of various policy domains, including infrastructure policy, are increasingly determined at the level of municipalities. The national government sets relatively broad frameworks, while the role of provincial authorities is limited. It is due to the network nature of most infrastructure systems that local infrastructure often forms part of regional, national and international systems, up to a continental or even global scale.

Now that the responsibility for infrastructure development is shifting more and more to local and regional authorities, this raises questions about the coordination between scale levels in the system of infrastructure. Development choices that are rational at a local level may be at odds with desired developments at national and international levels, and vice versa. The multi-scale character of infrastructure is not a new phenomenon, but conflicts of interests came to light less harshly when the top-down coordination by the government was still a matter of course. Now that the lead is simply thrown onto the desk of local authorities, the coordination issue becomes more pressing. Indeed, the coordinating and administrative capacity of municipalities is limited and differs per municipality. It also remains to be seen to what extent the present system of democratic representation in the municipal government is appropriate to shoulder the future administrative burden. Furthermore, the administrative decentralisation of infrastructure policy to the municipal level means that new risks arise of a potential increase in inequality in the provision of infrastructure, as a result of policy competition between municipalities and between regions.

Digitilisation of Infrastructure

In all future visions for electricity supply, there is a vital role to be played by active demand response, induced by time- and location-dependent price signals, in accommodating the variability of electricity production from renewable sources. In view of the short response times required to effectively utilize demand flexibility, this can be facilitated by automating that demand response. This is where the so-called smart grids come in, which enable digital communication between the electricity end-user (and end-use equipment) and the network operator. For other forms of energy supply, too, there is mention of intelligent networks that can support this active demand response, although the need for intelligence in heating networks or networks for ‘other’ gas e.g., biogas, hydrogen and synthesis gas, will be less pressing as indeed, there are realistic possibilities for storage.

Active demand response to time- and location-dependent price signals is an option, which has also been discussed for many years for road use within the context of combating traffic congestion. However, there it has so far resulted only in small-scale realisation for certain road sections. The kilometre charge for trucks announced in the Netherlands in the 2017 Government Coalition Agreement is not dependent on time or location, but is only differentiated according to emissions, in conformity with the model already being applied in other European countries e.g., Germany and Belgium. Up to now a national, more sophisticated system of kilometre charge for both passenger and freight traffic to mitigate congestion by means of time- and location-dependent stimuli has met with massive political resistance, even while public resistance is dwindling. Dutch Railways has applied a difference in train fares between peak and off-peak hours and according to the age of travellers. Still, most commuters do not regard this as a free choice, but as an inevitable peak-hour charge.

The introduction of active, momentary demand response is an essential change in the access to infrastructure, which will have a profound impact on the manner in which and the time at which citizens use the services provided by infrastructure. This may have a great impact on the organisation of their daily activities. A precondition for facilitating active demand response is a far-reaching digitalisation of infrastructure networks and end-use devices. Through the introduction of smart meters, remote monitoring and time-dependent pricing, the electricity supply is increasingly becoming an integrated system of IT, telecommunications and electricity supply. In the future, this amalgamated system will integrate with electric means of transport. Digitalisation is also transforming the infrastructure systems for transport (Uber), public transport, telecom, radio and television, enabling among others the provision of services on demand. Digitalisation, however, gives rise to a number of concerns.

Firstly, there is the reliability of the system. Although the network providers use self-administered IT and telecom systems independent of the public internet as much as possible for their own operational and management tasks, cyber vulnerabilities are unavoidable in the connections of electricity users with their energy suppliers. It is self-evident that these interfaces present vulnerabilities that may be exploited with malicious intent to disrupt society.

Secondly, there is the nature of the companies managing the data platforms. Making IT-controlled demand response operational requires detailed insight into the daily activities and personal preferences of citizens, for a large number of parties and platforms involved. A question that arises in this context is how the new digital platforms, which enable citizens to move in the market as producers and sellers of electricity, digital content, mobility services and such, should be regarded—and regulated—as part of the infrastructure system. The enabling data platforms are created or managed by companies that do not themselves contribute any infrastructural hardware assets. They 'merely' provide a platform to intermediate between supply and demand and thus enable private asset owners to exploit their assets commercially. This raises the issue as to whether the regulatory treatment of such data platforms is unfair where it concerns the enabling of retail services that compete with those provided by traditional firms, which are stuck with the maintenance of capital-intensive infrastructure. The positive network externalities of those digital platforms are so huge that the relevant companies have developed at unprecedented speed into virtually global monopolists, such as Uber, Airbnb and Google. At present, their business model is based on gathering and analysing data about our behaviour in data centres, with a specific location under a national jurisdiction. In the future, this will take place increasingly in a distributed cloud, on a large number of different systems distributed across the globe.

Although such companies are not giving rise to a natural monopoly, as is the case with capital-intensive physical infrastructure assets such as railways or electricity networks, but depend on positive network externalities, that does not detract from their market power. The risk of abuse of market power in a natural infrastructure monopoly can be curbed by ex-ante regulations. For globally operated data platforms, however, this kind of regulatory control is more complex. First and foremost, because these platforms operate in different jurisdictions. Besides, effective regulation requires access to and understanding of the specific algorithms which these platforms use to analyse the data and to manage the connected 'customers' in their transactions and behaviour. Even ex-post monitoring, by virtue of competition legislation, is very difficult and moreover hardly effective: then the damage has already been done.

Thirdly, there are ethical aspects at stake. The power of such platforms is that they facilitate a massive volume of transactions between connected customers, suppliers and service providers. Hence, they get to possess a great deal of information about the connected parties. Through clever analysis of the data, they can bring these different parties into contact with each other and make them enter into the most advantageous transactions. This means that supply and demand can be attuned to each other better and that the parties have far more options to realise their freedom of choice of products, suppliers or customers. Thereby such a platform also provides the option to discriminate very effectively, depending on the characteristics of suppliers and customers. It just depends on the kind of analysis and selection algorithms deployed and on who is given what information, and under what conditions. The degree of 'impartiality' of the platform is decisive for the way in which the information will or will not be used to discriminate between groups of users, on whatever grounds. Platforms can be smart and benign or smart and mean, depending on their business models.

Infrastructure Interdependencies

Apart from the organisation of vertical coordination between spatial and administrative scale levels within specific infrastructure networks, the increasing interconnectedness and interdependencies between infrastructure systems have also created new coordination issues. The dependencies between different infrastructure systems are big as they are and are becoming ever more critical, amongst others due to the progressive digitalisation in the operation and maintenance of physical infrastructure, in the operation of infrastructure markets and in the actual provision of infrastructure services. Digital infrastructure is already an indispensable part of electricity infrastructure as, indeed, it is in transport infrastructure. On a higher level, all infrastructure critically depends on energy infrastructure services: it is impossible to ensure water safety, safe drinking water, transport of people and goods, telecommunication and data services without a reliable supply of electricity and other energy carriers. In turn, data and telecommunication infrastructure relies on electricity to power masts and data centres. The processing of waste and of wastewater is closely connected with energy supply and demand, and energy supply is impossible without transport of goods and data. While these cross-sector interdependencies are not new, they are steadily evolving towards an intricate network of myriads of deeply embedded interconnections; to the extent that a cross-sector amalgamate system is emerging. Especially energy, transport and digital infrastructures are thus being fused together into a new complex system.

Far-reaching integration of energy, IT/telecommunications and mobility infrastructure means that the traditional 'walls' between those systems and their current sector-by-sector and network-specific regulations are not tenable anymore. In this context, it is telling that the Dutch Ministry of Economic Affairs needed an order in council to set up test beds for intelligent energy networks, in which the allocation of roles between market parties deviates from what is permitted within current legislation and regulations.[7] Also heated discussions arose about the allocation of roles between network providers and energy suppliers in the roll-out of charging points for electric vehicles and in the realisation and management of energy storage facilities for temporal surpluses of electricity produced by (both central and decentral) renewable sources. Today's legislation dictates that such new activities must be provided by the energy service providers in competition. Thereby, it denies the public energy network managers important options for a cost-efficient development of their networks and more efficient use of available network capacity. In fact, the coordination of interactions between networks and services for energy, telecommunication and transport still forms a gap in legislation and regulation.

The current structure of infrastructure governance and policymaking is organised by sector and, within sectors, by infrastructure. This siloed structure lacks mechanisms that do justice to the ever more intricate interwoveness of the infrastructural system-of-systems. It does not take account of direct effects of policy measures in one infrastructure domain on other infrastructure domains, and of indirect effects on society. In the Netherlands, the introduction of a new Environment and Planning Act [*Omgevingswet*] seeks to provide this horizontal coordination, albeit with a narrow focus on the physical environment. Although social aspects can be observed and incorporated into the development of regional and local Environment Visions and Environment Plans, the Environment and Planning Act does not make this mandatory. Besides, as indicated above, it is also a matter of concern whether, particularly at the level of local and regional authorities, there is sufficient well-organized capacity and knowledge available to fulfil the potential of the Environment and Planning Act. In this respect, major differences between competent authorities can in due course also be a source of inequality between cities and regions in the supply and quality of infrastructure services. Another matter of concern is the time horizon of decision-makers versus the lifespan of the infrastructure. Is there enough room to think beyond the needs of today?

[7] Decentralised Sustainable Electricity Generation (Experiments) Decree, published in the Bulletin of Acts and Decrees (Staatsblad van het Koninkrijk der Nederlanden) no. 99, 10 March 2015 (only in Dutch).

New Challenges for the Governance of Energy Infrastructure

Multi-scale and cross-sector interactions within and between infrastructure systems are a given in today's infrastructure world. The big change in historical perspective is that the coordination of these interactions has become both more critical and far more complicated. It is more critical since modern post-industrial economies, with their many long and specialised value chains, will simply collapse if the flows of data and energy are interrupted. It is more complicated as today's infrastructure is a kaleidoscopic (inter)national system with some subsystems residing in the public sector, some in the private sector and others in semi-public and semi-private realms. As the latter complication also occurs within infrastructure value chains, the uninterrupted supply of essential infrastructure services depends on the adequate coordination of transactions across many interfaces.

In the energy infrastructure sector, the constellation of public and private actor involvement widely differs by country, even within the European Union. While the European Commission imposes strict institutional requirements for the operation of physical infrastructure and infrastructure bound markets, the Member States still have a considerable degree of freedom in shaping their national energy sector. At the same time, the physical reality is that all power transmission grids in Europe are interconnected across national borders, including the transmission grids of non-EU Member States. The multi-scale complexity of electricity and gas infrastructure, physically and economically, implies the involvement of multiple national, regional and local governments, besides the European Commission. The governance of these systems steers their performance, and the consequences are felt by national economies and by individual citizens alike.

Coordination of Transactions in Energy Infrastructure

At the heart of the governance challenge is the question of how transactions across the energy value chains can best be coordinated. For this question, we refer to the seminal work of Oliver Williamson on transaction cost economics and efficient contracting, for which he was awarded a Nobel Prize in 2009. Williamson decomposes the value chain into bundles of transactions between different actors with specific roles in the system, which require certain investments. Relevant characteristics of the transactions are, first, their specificity, second, the extent of uncertainty in the transaction environment and, third, the costs of creating safeguards (to curb uncertainty) relative to the transaction value. As shown in Fig. 1, Williamson distinguishes seven configurations with respect to these transaction characteristics, where each configuration calls for a specific form of coordination.

Configuration A denotes a transaction that does not require very specific and/or highly specialized investments that would create strong interdependencies between actors. This type of transaction can best be coordinated in a competitive market,

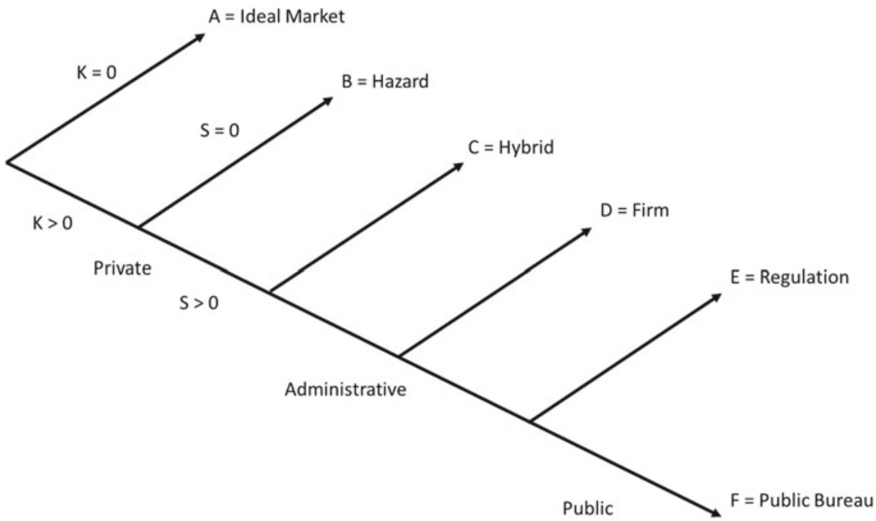

Fig. 1 Williamson's contracting scheme. *Source* Adapted from Williamson (1998). *Note* k represents a measure of transaction-specificity of the assets involved, while s denotes the safeguards needed to protect investments for transactions

if that market is characterised by sufficient numbers of actors on both the supply and the demand side. Configuration B represents a transaction that requires specific investments, creating a potential hazard for one or more actors, but where the level of uncertainty is fairly limited, so that contractual risks can be accounted for in the price setting in the market. Configuration C is concerned with a higher level of uncertainty (than configuration B), where it is assumed, however, that actors have sufficient insight into the nature and consequences of uncertainties to be able to create adequate contractual safeguards. In configuration C, these safeguards will typically involve long-term risk management, as a hybrid solution between the market and full integration. Configuration D involves transactions with high risks and high potential benefits, which are fully integrated and equally shared between the private parties involved in the transaction, for example, in a joint venture. Transactions in configuration E are characterised by high uncertainty and by large asymmetry in information and risk exposure between private parties. In this configuration government involvement is needed as an independent regulator and/or arbiter, setting and enforcing the market rules for such transactions. In configuration F, the uncertainties and associated risks are of such magnitude that no private investors are willing to take those risks in return for a societally acceptable fee. In this case, only government remains as a potential provider of the good or service. Configuration F thus leads to the establishment of a public entity that bears all the risk.

We can see the logic of Williamson at work in the way the neoliberal reform of the electricity sector has taken shape in the Netherlands, and in the European Union at large, since the 1990s. The production of electricity and the supply of electricity services are both seen as type B and C transactions, with a sufficient number and diversity of actors at both the supply side and the demand side of the competitive spot markets, or engaging into longer-term contracts. The electricity market operates under the scrutiny of regulatory oversight as regards price formation and abuse of market power. In contrast, the transmission and distribution segments of the value chain, given their natural monopoly characteristics, cannot be provided in a competitive market. For these segments a hybrid solution E was chosen with regulated private or public companies (national and regional monopolies) operating the networks. The network companies are heavily regulated with a focus on cost effectiveness, which enhances the affordability of electricity service provision.

With respect to the provision and creation of new network capacity, the network providers are expected to follow what the market needs with respect to transport capacity, rather than proactively enabling or incentivising particular market developments. Indeed, as enshrined in the EU electricity and gas directives, their primary task is to provide least cost solutions for the transport of energy from the producers to the consumers. The competitive commodity transactions dictate the need for transport capacity and its locational structure. The focus on efficiency in the regulation of the transmission and distribution networks, the complex procedure in awarding new investments and the consequent risk averse character of the distribution system operators create a relatively slow process of adjustment of the infrastructure. This explains why investments in transmission and distribution network capacity are lagging behind the much faster development of installed power generation capacity from renewable resources. For example, in many rural parts of the Netherlands (and other European countries) local distribution network capacity falls short for the connection of newly built solar and wind parks. At the same time, distribution network capacity can hardly keep up with the fast development of new demand in urban areas, for example, in the Amsterdam metropolitan area where many data centres have been (and are being) established. It also remains to be seen if the current configuration of the power generation market can be maintained if, for instance, nuclear power plants turn out to be needed to achieve climate policy goals.

The reform of the natural gas sector was given shape in a similar way, with many actors, retail companies as well as distribution network providers, playing double roles in both the gas and electricity sector. While the national transmission network operators for gas and electricity are different entities, most regional distribution network operators provide both gas and electricity distribution capacity, and most energy service providers sell both gas and electricity. The gas sector is facing drastic change as natural gas is bound to be phased out for space heating purposes while industries are also looking for climate neutral alternatives to satisfy their high temperature heat demands. For the future, many municipalities have turned their hopes to heat networks, all-electric solutions involving heat pumps, and hydrogen-based systems, the latter to replace natural gas by hydrogen or to provide flexibility in interaction with the electricity infrastructure (energy storage and conversion). It is obvious that there is a strong dependency between the choice of energy supply system(s) and the necessary infrastructure layout for a specific location. Moreover, the technical and economic interdependency between electricity, gas and district heating systems is bound to increase, given the need to create supply and demand flexibility, which represents a radical break with the demand driven systems of the past.

Transaction Cost Economics in Heat Networks

To date, more than 90% of Dutch households still rely on natural gas for space heating. In the Netherlands, in 2018, the share of natural gas in the total final energy consumption amounted to 34.1%, which is far more than in any other EU Member State (averaged over the EU 27, the share of natural gas in the total final energy consumption was 20.8% in 2018) (EC, 2019c). Around 400,000 households are connected to local district heating networks. It is worth noting that most of the current networks are not supplied by renewable heat sources, but depend on natural gas-fuelled Combined Heat & Power (CHP) units. So far, private actors have shown little interest in establishing and operating sustainable heat networks. In reviewing the potential configurations shown in Fig. 1, it is evident that the ideal and less ideal market configurations do not fit with the transactions involved in investing in a district heating system and its long-term operation and exploitation. The necessary market is at best in a nascent stage. It will take a long time before it will have matured in terms of a sufficient number of competitive suppliers, sufficient diversity in supply and demand profiles, and costs. The return on the massive investment required will have to be realised over decades (40 years rather than 30), which is a period wrought with uncertainty given the technology dynamics in different types of heat sources (waste heat, geothermal heat, aquathermal heat, etc.), types of energy carriers (waste, biomass, green gas, hydrogen) and different scales of operation (from apartment buildings to neighbourhoods, districts, cities, regions etc.). Given the large differences in scale, complexity and flexibility of the different heating technology options, it is highly unlikely that a stable market will evolve soon.

Besides the technology dynamics, the heterogeneity of local heat supply and demand is a complicating factor. The choice of technology not only depends on the local availability of renewable heat sources, but also on the nature and quality of the local building stock. On both ends, different regions, different cities in the same region and even different neighbourhoods in the same city may be widely different. While the quality of the building stock defines the required temperature level of heat supply, it is highly uncertain if and how fast the building quality can be improved to the extent that low temperature heat supply would be adequate.

For many renewable heat sources, such as surface water, ground heat and deep geothermal heat, additional uncertainties are in store as climate change unfolds. The availability of underground heat and surface water may be affected by an increasing frequency and intensity of droughts and periods of rainfall. Geothermal heat extraction poses risks for contamination of groundwater aquifers that are now used for drinking water. These and other uncertainties require coordination with public actors and government bodies and imply an extent of risk exposure which private actors are not willing to accept.

For renewable or at least climate neutral heat supply to be accomplished in the future—if it is to be distributed through district heating networks—municipal governments are the authorities to take responsibility and to move first. The municipal government level fits best with the natural scale of heat networks, as dictated by the technology of heat distribution. It is evident that private actors cannot be expected to enthusiastically engage in such risky transactions, whether in the initial investment to bring a heat network into being, or in its long-term operation. If private actors are willing to take that risk, governments should be wary of the rewards these actors claim to cover their risk exposure. It is quite unlikely to be a good deal for the end-users that are, other than in the case of natural gas, captive users. With regard to natural gas services, consumers have a choice between different retailers. In the case of heating services, however, consumers are captive of the local service provider, which according to the current legal framework will be a vertically integrated private monopolist holding a long-term concession for the implementation and exploitation of the local heat network. That implies that extra caution is due for the protection of end-users, and that safeguards are needed in a long-term perspective. Such caution requires a high knowledge level with the municipal government, which may be lacking in many of the smaller cities. Even more stringent knowledge demands should be imposed on the municipal governments, if they themselves are to build and operate local heat networks, as public providers, which in fact is the optimal solution suggested by Williamson's theoretical framework.

Considering the knowledge position and operational experience of the energy distribution companies, including their deep insights in the energy needs and use patterns of their end-users, they seem to be the most appropriate actor to build and operate heat distribution networks. If and when hydrogen will be considered an appropriate substitute for natural gas in boilers and home-scale central heating systems, the established natural gas distribution networks may be used again. In the meantime, the established gas networks are being kept in mint condition for safety reasons. Even in districts where municipalities plan to phase out natural gas by 2030, planned maintenance and replacement works on the natural gas system cannot be relaxed or delayed. The natural gas networks can quite easily be adapted for the safe distribution of hydrogen, at relatively little cost in comparison with the construction and operation of heat distribution networks. Given the time horizon of 2030 that many municipal governments set to abandon natural gas, however, they fail to see hydrogen as a viable alternative, despite the obvious advantage of the availability of the network for its distribution. Indeed, to become a large-scale viable solution, a large enough production of green and blue hydrogen is required at an affordable price. It is questionable if this condition can be satisfied by 2030. Moreover, the process industry is most likely the primary candidate for hydrogen consumption, as its alternative options to generate high temperature heat and to change to low temperature electrochemical conversion routes are limited.

So far, according to the current energy acts in the Netherlands, heat (networks) should be provided in competition (for a concession to supply a certain area), and energy distribution companies are not eligible as heat network providers. Given the present institutional configuration, the projected outcome of the emerging heat 'market' is a patchwork of local heat networks with large differences in the quality and costs of service, depending on the local availability of sustainable heat sources, the topology of supply and demand, and the quality of the local building stock. It remains to be seen, however, if Dutch society is willing to accept significant cost differences for heat services between neighbourhoods, between cities and/or between regions. A public debate on the acceptability of such cost differences, parting from the principle of cost socialisation as traditionally followed in the provision of electricity and gas services, has yet to begin.

Emerging Value Tensions in Energy Infrastructure Governance

As we can see, the guidance provided by Williamson's framework for the institutional design of energy infrastructure (services) provision is wearing out as new societal priorities are coming to the fore. The focus of Williamson is primarily on creating an optimal contracting structure, from the perspective of economic efficiency. And indeed, the energy infrastructure restructuring of the 1990s and subsequent development of the sector was essentially driven by a focus on economic efficiency, through the creation of markets and competition for the electrons and gas molecules, and through regulation of the transport networks. Over time, this single-objective orientation has been replaced by a variety of objectives, as expressed and articulated by society. Today, first and foremost, CO_2 emissions are to be reduced, leading us to the selection of a collection of new technologies, which dictate different spatial patterns of production and transport. The proposed European Climate Law, however, which is intended to make the European ambition of net zero greenhouse gas emissions by 2050 a legally binding target, has yet to be adopted and come into force. While some Member States have embedded renewable energy and greenhouse gas emission reduction target in national legislation, most have so far been reluctant to take legally binding measures. In this respect, also the Netherlands' government was criticised for its lack of long-term political commitment to climate policy goals, and a corresponding lack of firm institutional safeguards (Faber et al., 2016).

In addition, the public acceptance of existing and new energy production facilities, transport and storage infrastructure has become much more difficult. Processes of planning and permitting have become highly complex and politicised, even among different levels of public authorities. This relates to societal values related with the protection of landscapes and nature areas, the preservation of urban structures, buildings and 'views', and also to the (expected) hindrance experienced by the people living near such structures. Local resistance adds to the long leadtime of infrastructure capacity expansion and new investment projects, once proposed investment projects have been approved by the regulatory authorities. The latter, as discussed previously, are mainly weighing the criterion of cost-effectiveness in their assessment. In the current perspective on assessing infrastructure investment projects, transport infrastructure is expected to follow capacity demand. Proactive investment in infrastructure capacity is not encouraged, which explains why new solar and wind parks in relatively remote areas may have to wait many years for capacity expansion of the local electricity distribution network.

In addition to a perceived lack of distributional justice in the allocation of financial benefits between land owners and homeowners on the one side, and tenants on the other side, such feelings of unease are also felt with regard to national subsidies for renewables leaking away from the country. More than three quarters of the large-scale solar parks in the Netherlands are owned by foreign investors. Of the total of Euro 1.1 bln in subsidy paid for the 33 largest solar parks in the Netherlands, almost Euro 890 mln leak away across the national border. Similarly, public discontent is emerging with the long-term contracting of large volumes of windpower by newly established large-scale data centres, owned and operated by large data multinationals. On the positive side, these contracts provide certainty of income to these wind parks, thus supporting their development. Yet, on the other side, the people living near the wind farms feel burdened by the environmental impact without benefitting, while the data-centres ‘take away’ the scarce sustainable power generated from them and from other domestic users, without creating employment opportunities in return. At the same time, many of these large-scale data centres are built in cherished polder landscapes, thus destroying their cultural-historic value. These sentiments of perceived injustice may turn into a serious issue, as domestic consumers are blamed for not being green enough, while they are confronted with higher tariffs and while increasingly large amounts of power are contracted away by large industrial users, like data centres and, in the future, the huge industrial producers of green hydrogen.

Moreover, from a relatively homogeneous utility provided public ‘good’ in the past, electricity and gas have been transformed into experience, identity or lifestyle goods and services, by which consumers, producers and prosumers exhibit and express their ‘identity’ and their values and convictions. Consequently, a rather divergent set of (instable) values is projected upon the societal function of energy supply. While the values of universal access and of affordability and availability of energy services remain uncontested, the value set contained in the overall value of acceptability of energy services is becoming over-crowded. Traditionally, acceptability was mainly concerned with health, safety and environmental concerns. While these values remain important, a new range of personal, cultural, ethical and social values is emerging in relation to the energy system, such as privacy and cyber security, historic and aesthetic value, fairness and justice, transparency and legitimacy of decision-making, and social inclusiveness. Conflicts arise between local values, such as landscape protection, and global values, like combating climate change, in solidarity with vulnerable people around the globe. The conflict is often presented as a false dilemma between the noble global cause on the one hand, and local jobs and affordability of energy services on the other hand. Such value conflicts can only be solved in political decision-making. In this respect we also have to realise that this emergent set of values differs between cultures and countries, leading to different priorities and to differences in the way each value is interpreted and made operational over time.

The question then arises how the coordination and governance of such a multi-value driven system should be shaped. The economic efficiency focus of Williamson's contracting scheme will evidently not suffice any more. All the more so, because from the relatively singular objective of a national (and even EU-wide) focus on efficiency, the orientation is shifting to a more locally specific shape of local energy systems, with local values and characteristics to be sustained. Logically, however, (almost) no local energy system can function stand-alone, all the way, all the time. This is all the more so, when we take into consideration the fact that the goods consumed in a specific area 'contain' large volumes of energy that are 'imported' from other areas. Hence, the question of above-local coordination and interconnection remains of the utmost importance.

Infrastructure and Inequality

According to the Dutch Energy Research Centre ECN (2017) 2.6 million low-income households in the Netherlands spend on average 9% of their net disposable income on energy, and the percentage of households that spends more than 10% of the household budget on energy costs has increased by 40% between 2006 and 2009. The threshold value of 10% of the household budget is often regarded as an indicator of energy poverty. We are only talking about the costs of energy services, which in turn are determined strongly by the nature and quality of housing: in that sense the entire built environment could be regarded as part of the infrastructure. Investments in home improvement or in sustainable energy call for resources which lower-income groups generally do not possess, money, knowledge, space and so-called 'acting ability', a term devised by the Netherlands Scientific Council for Government Policy (WRR, 2017). Meanwhile higher-income groups and homeowners are reaping the benefits of incentive schemes for investments in home insulation, sustainable energy and expensive electric mobility. This is worrying not only from an ethical perspective of justice. A distribution of costs and benefits that is perceived as unfair carries the risk of undermining public support for the substantial investments that need to be made for a sustainable energy supply and climate adaptation. We can learn so from Germany, where support for the *Energiewende* is eroding, firstly due to the perception of unfairness in the apportionment of costs and benefits and, secondly, due to the promised benefits in terms of jobs and CO_2 emission reductions failing to materialise (Andor et al., 2017).

The transformation from a carbon-based to a climate neutral economy comes with the risk of aggravating inequality in society. This is not only about the inequality arising along the traditional lines of income differences. The phase-out of natural gas as a heating fuel from the Dutch energy system puts great pressure on home improvement, which will hit especially private homeowners hard financially. Almost 90% of privately owned homes in the Netherlands predate 2005; almost two-thirds predate 1985 (CBS et al., 2020). Making these residences suitable for the energy transition requires major investments. The Netherlands Environmental Assessment Agency (PBL) estimates that the average private home, with energy label D, requires an investment of approximately € 35,000 to achieve energy neutrality (PBL, 2020). As the intended arrangement stands, the private owners must pay this amount; if necessary, facilitated by a long-term loan. For most private homeowners these investment costs are prohibitive. Except for investments in solar roof panels, they will not see their investment paid back in savings on their energy bill over decades. Perhaps these investment costs can also be factored into the monthly energy bill. Homeowners and occupants of older houses who cannot or will not invest in home improvement run the risk of being stuck with unsaleable property. If not remedied by the government, the energy transition may thus imply a massive redistribution of wealth among the population. Tenants of private homeowners also constitute a vulnerable group; their energy bill depends on investments by the property owners. For the less educated homeowners and occupants it will by no means be easy to make a sensible and well-informed choice from the different options for heating supply without natural gas in their district.

Other forms of inequality can be caused by the digitalisation of infrastructure-related services. For less educated, semi-literate or digitally illiterate citizens it is hard enough as it is to assess the different offers of energy suppliers. Things will become even more complicated when they are also expected to take part in active demand response programmes. Part of the problem is that it will be difficult for them to make an informed choice between the schemes offered by different retailers. The real problem though arises from the fact that many of these citizens live in energy poverty, in energy efficient dwellings. As their energy use is limited to satisfying basic needs of comfort, implementation of automated demand response schemes can hardly contribute to reducing their energy bill. Their situation will only be improved by structural home improvements, requiring financial means they do not have.

Whereas the universal access to the supply of electricity and heating is in any case still regulated by law, that principle is not applied to the transport infrastructure nor for public transport. Although it is a responsibility of regional and local authorities to ensure that transport options in their regions and districts are sufficiently accessible to those who do not have or cannot afford a car of their own, there is no statutory basis or a hard norm for minimum accessibility e.g., in terms of maximum distance to a public transport boarding point, minimum frequency of the service or the tariff structure. In addition, for the time being there is no accepted indicator for transport poverty, expressed in the share of the necessary transport costs in the spending of the household budget. Although in comparison with other countries in Europe, and certainly in comparison with the USA, the Netherlands is amply furnished with good and affordable mobility options, in which bicycles are just one important element, transport poverty does exist in the Netherlands as well (Bastiaanssen et al., 2013). Transport poverty, like energy poverty, is a multi-faceted problem, which is found all over the world in developing as well as developed economies (Lucas et al., 2016a, b).

In the Netherlands, lack of access to or problems with the affordability of public transport affects inter alia the older population in regions with shrinking population. As other essential facilities such as medical services, shops, bank branches, ATMs become scarcer there, the transport demand of the carless population changes and they tend to face ever more transport poverty. Situations of transport poverty also occur in urban districts with a low socioeconomic status. Rotterdam-South is an example in kind. Admittedly, this district is adequately connected to the city centre via bridges, the Maas tunnel and the metro, but most of those connections are of importance mainly for car owners. For the majority of inhabitants of the Rotterdam-South district a car is an unattainable ideal, whereas the public transport network provides few opportunities to reach work sites in the region, certainly outside the city centre and outside normal office hours, aside from the costs of the metro or bus fare (Bastiaanssen et al. 2013). Transport poverty, whether in terms of affordability or from lack of physical accessibility, thus hits people hard in their development opportunities. It can make work and proper schooling inaccessible, as well as visits to friends and relatives (Bastiaanssen et al., 2020).

It is a fact that for investments decisions in transport infrastructure the interests of entrepreneurs and car owners have a relatively big weight, because their willingness to pay for savings in travel time is relatively strong. For financially weak groups in society investments in high-quality public transport facilities are hardly justifiable, if that consideration is placed primarily in an economic perspective, as it is in the SCBA methodology.

New Challenges for Infrastructure Policy

Inequality as such is not unacceptable and cannot always be avoided. Our society accepts a considerable degree of inequality. However, if inequality concerns the accessibility and affordability of essential infrastructural services, which everybody needs in order to function in society, this affects ethical values of justice. In that sense, the transition from natural gas to alternative forms of heating supply at urban, district or building level, as in the Netherlands, is more than just a technological transition. It is also a transition from a public amenity at national level, with socialisation of the costs, to an individual system or to a new collective service at the scale of the street, the district or the city, in which the solidarity principle of the natural gas infrastructure is abandoned. It is not self-evident that this transition will lead to strengthening of the social cohesion at district level, if there is no policy in place to guard against great inequality in the quality and affordability of heat services and level of comfort. There is most certainly a risk of new divides arising in the population. In many countries, such divides manifest themselves literally in the walls and fences around gated communities.

Social cohesion is not the only issue in this context, though. It concerns individual development opportunities for every member of society. It goes without saying that those opportunities are not determined exclusively, but definitely to a significant extent, by the access to and affordability of infrastructure services. If work sites cannot be reached by a part of the population, society is not only compromising the interests of those citizens, but also the interests of society itself, by underutilising its supply of productive labour. This also goes for access to education, for access to healthcare and cultural facilities. When part of the population can only maintain their social contacts in the digital domain, there is a real risk that people who cannot travel physically may become socially isolated. That, too, does not affect only those citizens. It affects society as a whole, which will lose quality and cohesion.

The Covid-19 pandemic has exacerbated inequality in society. It has disproportionally hit people living in crowded households and in homes without outdoor space, and people without private means of transport. Children in households without access to the internet, whether by lack of a connection or by lack of access devices, have been deprived of schooling. Wherever physical infrastructure and infrastructural services are required for citizens in order to function as full members of society, public policy attention is needed. In this respect a statutory basis of standards for accessibility and affordability of fast internet and public transport options may be considered, or a more active stimulation of citizens' initiatives to close gaps in the public transport network and timetables. Now such bottom-up initiatives sometimes fail on account of alleged competition with the minimal public transport that is still being offered. Moreover, a perspective of justice can be made operational in indicators which can be incorporated into the SCBAs, for instance by means of standards for transport sufficiency (ref. Lucas et al., 2016a, b; van Wee, 2012). In the present practice of SCBA, however, such social values are not yet included.

An insidious shift towards more inequality in society that is inadvertently encouraged by today's 'infrastructure policy' is an important reason for examining that policy in more detail. Here we put infrastructure policy in inverted commas, because it does not only concern infrastructure policy in the classical meaning, like the development of roads, railway lines and gas networks, or inviting tenders for public transport concessions. It also concerns policy with a big impact on the future development of those classical infrastructure systems, especially climate policy. That policy does not only have far-reaching consequences for the technical development of installations and networks which will in the future fulfil our needs for energy and mobility. It will also affect us profoundly in our behaviour as consumers, citizens, entrepreneurs and employees. Authors like (Shove, 2003; Shove et al., 2012), Van Vliet et al., (2005) and Overbeeke, (2001) show that infrastructure services are strong determinants for our everyday social routines and practices. Social norms for e.g., personal and household hygiene, for comfort and social interaction changed drastically in the course of the previous century under the influence of infrastructure provisions for drinking water and energy, waste and wastewater discharge, telecommunication and internet (social media). The possibility to refrigerate and deep-freeze food at home had a great impact on the food supply, via the supply and the location of regional supermarkets, which have largely taken over the role of neighbourhood shops, bakers, butchers, greengrocers and fishmongers. The access to and the reach of transport options in the form of public transport or roads and motorways, does not only impact decisions about housing and work sites, but also the recreation and the sociocultural behaviour of citizens (Raspe, 2012; Steg & Vlek, 2009; Teulings et al., 2017; Van der Knaap, 2002; Van Wee et al., 2013). Infrastructure affects all of us profoundly in our daily lives.

The presence and nature of infrastructure provisions are not only strong determinants for the use of energy and water, the mobility of people and goods and other aspects of social and economic routines, but also for the possibilities we have to develop our capabilities (Nussbaum, 2001; Sen, 2010). This is true both for individual citizens and for groups in society, for districts and for regions. It means that big changes in the supply of essential services must be assessed not only for their direct effects—for instance savings in travel time in connection with the construction of new roads or reductions in CO_2 emissions in case of adjustments to the energy supply - but also for their indirect effects on society.

Towards a New Public Debate

An important conclusion of this chapter is that **not every citizen is affected to the same extent by the major changes that occur and will occur in the provision of infrastructure services**: whereas new development opportunities arise for some, others will be deprived of them. This influences an essential aspect of the role of infrastructure as a binding factor in our society. For a long time, infrastructure could be regarded as the fabric of society, on the one hand because infrastructure provision literally connected everybody, on the other hand because infrastructure equipped every member of society with more or less equal development opportunities. Postage stamp tariffs for private end users explicitly expressed the principle of solidarity in the world of infrastructure services. The ongoing technological and administrative decentralisation of infrastructure development, in combination with the introduction of market forces, may erode that binding role of infrastructure as the fabric of society. The question is whether the decision makers about infrastructure are sufficiently aware of this risk.

Inequality between citizens is a given. It is for good reason that we cherish our individuality. In this chapter, the focus is on inequality created by the organisation of infrastructure systems and changes therein, whether induced by new technologies or changing societal preferences. We need to be concerned about the bandwidth of the additional inequality that may be, albeit unintentionally, caused thereby and the balance in time. Public investments in innovative infrastructure services, which initially are not accessible to everybody and everywhere, are justified if such investments contribute to innovation, economic growth and new employment opportunities or to a more affordable or better functioning system that will in the longer term benefit all members of society. If, however, some regions or groups in society are excluded from those benefits, also in the longer term, there is every reason to recalibrate infrastructure policy.

This chapter is a plea to fundamentally reconsider the landscape of infrastructure provisions. On the one hand, a large part of the infrastructure is ageing; on the other hand, we are confronted with the new challenges of urbanisation, digitalisation, climate change, and so forth. Especially the energy transition will deeply influence all realms of the economy and society, as all economic activity, in each and every sector, depends on energy. Consequently, nearly all infrastructure systems are facing great investment issues. These are complicated issues, which we cannot solve one by one in isolation, given the interdependencies in space and functionality between different infrastructure systems. Accounting for these multi-scale and cross-sector interdependencies forms part of the challenge we face in infrastructure policy making and governance. Some countries have already added a cross-sector body to the siloed infrastructure governance structure in order to provide for a cross-sector assessment framework. As an example, we refer to the National Infrastructure Commission (NIC) in the United Kingdom, which was established as an executive agency in the Treasury to advise the UK government on all issues pertaining to long-term infrastructure challenges. Building on the National Infrastructure Assessment work of the NIC, the UK government presented its cross-sector National Infrastructure Strategy in November 2020 (NIC, 2018, 2020; UK Gov, 2020).

There is an accumulation of revolutions unfolding in the technological and institutional organisation of infrastructure systems. A cohesive overview of and insight into the consequences of this for society in the longer term are missing, among other things because the field is highly fragmented: in addition to citizens developing bottom-up initiatives, there is a large number of public and private actors involved in each of the infrastructure domains, all active at different geographical and administrative levels. Each infrastructure sector, or each infrastructure network, has its own legislative and regulatory framework, its own supervisory body, its own policy silo, at the national level and at the European level. Within those frameworks, actors operate according to the statutory allocation of roles and appurtenant mandates and responsibilities. This implies that the current institutional organisation of infrastructure policy generates few incentives for coherence across the boundaries of infrastructure domains. This is despite the fact that an intervention in one infrastructure system also affects other systems in the infrastructure system-of-systems, and that the consequences will affect every citizen and the relations between citizens.

What we also know for certain is that the infrastructure development choices we make today will have a far-reaching impact on the future. This creates a responsibility to future generations. It is because of that very responsibility that we should not rush into thinking in technical solutions, but should ask ourselves first: How do we want to live together? We are all inseparably connected with infrastructure, at least as end-users, and via infrastructure we are interconnected directly and indirectly. Infrastructure binds us as a society. In this context, we may cite the UK Prime Minister, Boris Johnson, in his foreword to the National Infrastructure Strategy, where he re-iterates his promise *"…. to unite our country by physically and literally renewing the ties that bind us together*" (UK Gov, 2020). Infrastructure makes it possible for us to live together and engage in various communities, in formal and informal relations of families, the neighbourhood, the city, in other social networks and all kinds of organised forms of activity. Infrastructure is not something outside society; it forms an essential part of it, not only as the connective fabric of the economy, but of society as a whole.

In that perspective, it makes sense to see ourselves as part of the infrastructure system. That perspective is a break with the past. Whereas infrastructure was traditionally regarded as a collection of technical components, managed by the government, we now see a system that is directed by a constellation of public and private actors. The image fitting with the current organisation of infrastructure is that of a sociotechnical system, a system that is determined as much by social actors and institutions as by technology. Apart from network managers, suppliers, traders, market operators, policymakers, regulators, and so forth, as users we also belong to the network of social actors that co-evolves with the physical networks. Moreover, our role in the infrastructure system is no longer that of passive end users. Now that we are being asked increasingly to present ourselves as active, flexible end users and even as service providers in the market, the role we play as actors in the system is acquiring a deeper meaning. For all the actors in the system their behaviour is directed by institutions. These include technical and operational standards, types of ownership and contractual arrangements, but also policy choices for regulation and market forces, as well as the standards and values of our society.

That knowledge enables us to enrich and deepen the infrastructure debate substantially. It is of great public interest that we should become aware of the values that are embedded in the infrastructure that serves us, and of the values which we would want to anchor in new infrastructure being developed today. Infrastructure development is no longer a matter of technocratic or unilateral economic policy; it is a matter of social debate and political choices.

In the present debate ever terser questions about social justice and inclusivity emerge. What are the dominant values of the society we want to be? And what do they mean for the governance of the infrastructure? How can those social values be expressed in policy documents, draft plans and implementation projects of infrastructure? In this context, we can also point to the European Pillar of Social Rights, which was proclaimed in Gothenburg by the European Parliament, the European Council and the European Commission on 17 November 2017 (European Commission, 2017). This Pillar mentions right of access to essential services like transport, energy, digital communication, water, sanitation and financial services as a social right for all European citizens.

We argue that the infrastructure debate should urgently pay more attention to the social values at stake in the big changes that are unfolding in society and in the transformation ahead, especially with regard to the energy transition. Without such explicit attention, society is at risk of an intensification of inequalities and of the emergence of new inequalities in the accessibility and affordability of infrastructure services, which are undesirable from a viewpoint of social justice. **The fundamental role of infrastructure as *fabric of society* appears to be a blind spot in reflections on infrastructure and largely unexplored territory in infrastructure policy and governance**. With this contribution we intend to spark a richer, strategic debate about the role that infrastructure can and should play in the future development of society.

After all, infrastructure is not an end in itself, but a means to enabling and shaping the society that we want to be. Society does not care about infrastructure, but about accessibility, connectivity, mobility, comfort, health, social connectedness, development opportunities, and so on. This is true for young and old alike, for rich and poor, healthy and disabled, computer literate and illiterate, highly and poorly qualified, in cities and rural areas. Infrastructure is essential to enable all citizens to take part in society and, with the means and possibilities at their disposal, to create new social and economic value for that society.

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