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Innovation by Nature On the human dimension of innovation.

Farewell address by Wim van Vierssen
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KWR

Bridging Science to Practice

TU Delft Delft University of Technology

Peace! Peace!
To be rocked by the Infinite!
As if it didn't matter
which way was home;
as if he didn't know
he loved the earth so much
he wanted to stay forever.

From The Long Boat by Stanley Kunitz
https://bit.ly/2rMxAyc

Cover photo:
'Yesterday's Spirit'
Oil on board (13 x 38 cm)

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Summary

Innovation by Nature. On the human dimension of innovation.

Within the chair on Science System Assessment of water-related research, research was conducted, together with KWR Watercycle Research Institute, into the functioning of knowledge systems related to the safe and reliable provision of water. The water sector involves a number of small players. With its Water Top Sector initiative, the Netherlands expresses its considerable export ambitions and therefore also a strong interest in a well organised knowledge and innovation management. An efficient transfer of knowledge over the entire process, from idea to market, is a key factor. In this intricate sector, it is crucial that the innovation system be structured in a numerical manner with an eye to human nature, and that close attention be paid to the dimensioning. The optimal group size for innovative knowledge production (research groups), the support of large societal transitions (knowledge consortia), and the associated societal implementing organisations, are addressed on the basis of a number of propositions and examples. These implementing organisations are introduced as Sustainability Guilds. The themes that will confront the sector, and thus society, with major innovations and transitions are: Resilience of the water infrastructure; the transition to a Hydrogen Economy; Water Recycling; Risk Management; and Resource Recovery. Concrete examples of all these themes will be discussed. The conclusion is that the Netherlands, thanks in part to government direction in the field of innovation, is well on course internationally.

Prelude

Following a career that has spanned some 40 years since my graduate studies (1980-2018), it is inevitable that a farewell address that reflects on a little less than 10 years (2009-2018) will bear the traces of such a long prelude. Fortunately, an arrival does not signal the beginning of thinking; nor does a departure mark its ending. This farewell is therefore a snapshot; an old-fashioned photograph of where we stand now. When I say 'we' I refer to that section of society that is more or less structurally occupied with the conduct of science. Set in the context of my teaching remit, this address is therefore about the water-related knowledge system. In science it is of course the facts that speak most of all. But because a knowledge system is made up primarily of people and societies, a personal, cultural and international perspective is inescapable.

My discourse will take the following path. I want to begin by touching briefly on what inspired and motivated me at the start of my career. After all, I only began my teaching remit (on this specific topic) at a later age and was undoubtedly already shaped by the 30-year prelude. I then look at a number of the characteristics of humans as individuals and what these mean for their behaviour in groups. The latter I do partly with an eye on how we have institutionalised science over the last hundred years. I also bear in mind the context of a number of changing economic development paradigms over the period. The assumption is that these paradigms matter when it comes to the benefits of the science. This is followed by an examination of the significance of a future-oriented water sector for a number of emerging societal sustainability transitions. Lastly, I suggest what I believe to be an optimal organisational philosophy for a science that is in tune with the time, and thus relevant and productive. And of course citizens play a central role in this.

I should warn the reader that my farewell address draws on a wide variety of sources. This reflects the current reality in which citizens, scientists and professionals have access to a flood of information: scientific, peer-reviewed literature, grey literature, information on the internet, social media like LinkedIn, but also presentations and even Tweets.

Is what I'll be saying here true, then? In any event, it is my hope that it belongs to the 'truthful' category. What I mean by this exactly will come up later in my discourse. It is certainly not a scientifically-proven representation of the water-related knowledge system – not what it is and not what it should be. Rather, it is, as the compilers of the collection *'Moet dit een wereldbeeld verbeelden?'* ['Should this represent a worldview?'] (https://bit.ly/2wX7Wfc) put it, a worldview presented in *its fragmented unity*. My discourse is a grainy snapshot. Besides, I don't think there were many other options, despite, or because of, the huge volume of literature on innovation. With this in mind, I have chosen to refer to both a number of internet sources as well as to many supporting sources in my text. They are all listed in the references at the end. The list also includes 'motivating literature', which refers to inspiring work that provides direction without necessarily providing scientific underpinning to my statements and positions. In line with the essayistic and opinionated tone of my discourse, I do not include many references to literature sources as direct bases for proof. This also prevents my sometimes normative, and even slightly ideological, interpretations of what others have found from bothering them.

Inspiration

Change

You will surely take my word when I say that the world has changed over the course of my professional life. Perhaps people in all periods have, at a given moment, looked back on their lives and concluded that the world has changed very fast over during their existence. In putting this speech together, it occurred to me that since the year I was born (1951) our insight into objects at the two scale extremes, that is, the extremely small and the extremely large, has increased enormously. I have represented this in Figure 1, in which the global measurements of a number of objects are set on an absolute log scale.

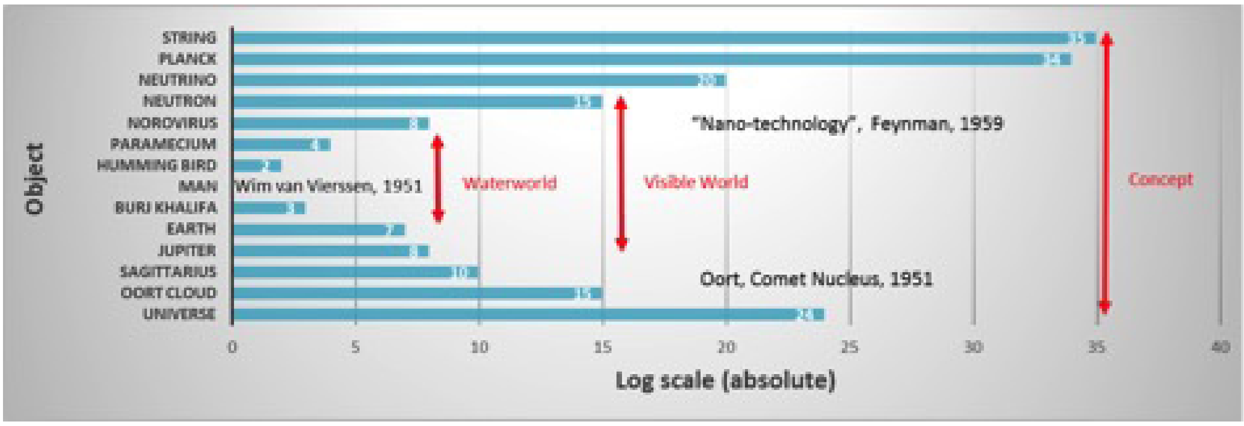

Figure 1: The relative (absolute log) scale of objects. The unit is the (absolute) power of 10 in metres (Earth: average order of magnitude 10^7, i.e., about 10,000 km)

Moreover, because of the huge band width, the boundaries are defined rather broadly. Our perception of the awesomely large and the infinitesimally small has expanded enormously over the past 50 years. So too has our grasp of the interconnection between things. This last point is pertinent to my discourse.

Scale

The Oort cloud, described around the time I was born by the Dutch astronomer Jan Hendrik Oort (1900-1992) is one of awesome dimensions. We're dealing with a scale beyond any category; a diameter of more than 10 billion km. The estimate of the dimension of the universe goes beyond this, but, by its very nature, remains quite speculative. We also have a more accurate perception of the very small. Beyond the scale at which the naked eye can distinguish objects (about 0.1-0.2 mm), our view and our capacity of controlling the world have increased considerably. Of course, well into the 20th century the light microscope was instrumental in this, but its practical limitation was reached at resolutions of about 1/1000 mm. Partly as a result of this constraint, we have been increasingly busy since the 1950s developing all kinds of other microscopy techniques, from Transmission Electron Microscopy to Atomic Force Microscopy. This effort ultimately resulted in our obtaining an image of reality at the scale of the atom. A conceptual precursor of the manipulation of the atomic structure was Richard P. Feynman (1918-1988): a visionary scientist, gifted teacher and dedicated populariser of complex scientific theories. His inspiring 'Feynman Lectures on Physics' actually opened up the world of physics to me when I was a young student. In 1959 he published an article with the title, 'There's Plenty of Room at the Bottom: An invitation to enter a new field of physics’, in which he predicted that we would eventually acquire the technical capability to structure atoms into any (physically stable) form we wished. Many see him as the spiritual father of what we later came to call ‘nanotechnology’. Actually, nanotechnology is an interesting example, because many of its applications – from electronics to home care products – have entered our daily lives, and a lot more are sure to follow. Besides the potentially negative environmental impact of nanotechnology, such as nanoparticles in surface water, the field is relevant to water-related research. I’ll return to this later on.

And finally, beyond exploring the immense and the minute, scientists have also been attempting to unify all the laws of physics in their quest for a Theory of Everything. String theory provides an example in its attempt to encompass the beginning. The development of such integrative thinking has also affected the environmental world over the last decades. This goes beyond multi- and interdisciplinary thinking. It refers notably to transdisciplinary thinking, based on the actual or intuitively sensed interconnection of things. In this thinking the questions people ask themselves frequently transcend the disciplines. In view of the complex problems we’re confronted with, this is very understandable. Insight and interconnection regarding the scales, as I’ve discussed here, has motivated me, while also presenting me at many levels with opportunities for deeper insight.

The practical significance of the above for daily life is great. Over the last few decades, a better educated and more empowered population has brought with it an increased interest in the interconnection of things. One sees this for instance in the strong interest in the lectures of a former president of the Royal Netherlands Academy of Arts and Sciences, Prof. Robbert Dijkgraaf, on complex issues in mathematics and physics, at the DWDD University. This is good news in a society that is becoming increasingly complex, and in which more and more decisions are being taken with potentially great consequences for society and our planet.

Key messages

- Science has hugely deepened its insight at different spatial scales over the past half century.
- Insight into the interconnection of things has grown.
- This has inspired an increasingly better educated and more empowered population.

Motivation

Double track

The more or less dualistic beginning of my academic education played an important part in shaping my career. Undergraduate studies (a BSc we'd call it now) in biophysics meant, around 1970, at the relatively new Nijmegen Faculty of Mathematics and Physics, exams in biology, physics and mathematics. At the time there was no talk yet of interconnected biophysics. In practice this meant you found yourself on a double track. On the one hand you learnt about pretty universal and established laws of physics and, on the other, about the bewildering biological world of the individual, population and the ecosystem. In this latter world, relatively speaking, quite a bit of lawlessness seemed to prevail. This was the case because notions such as a genetic programme, selection and adaptation are, in practice, frequently difficult to translate to the system level and to the everyday world. This exciting mix of the established laws of physics and the bewildering world of biology ultimately generated my interest in the behaviour of 'complex adaptive systems'. Early in my career I had the opportunity to do a lot of traveling and field work along the coasts of Europe, as well as in the west and along the east coast of the United States. Surrounded by wonderful nature (and a swimming suit always at hand). Then, for a period of ten years, I was able to work a lot with colleagues in developing countries in confronting their water problems. This didn't involve much fieldwork, but I learned a great deal about the practical and administrative aspects of water management. I felt like Monday's child.

Today's talk focuses on the role that the knowledge system can play in connecting phenomena at different scale levels. This is critical for the water sector. After all, issues such as water scarcity and water sustainability are relevant on a world scale, while the water sector itself is small-scale and, most of all, is organised at the local level. Here we have an instance where the well-known slogan, 'Think Globally, Act Locally', applies to a tee.

An important psychological impetus to start thinking about sustainability policy worldwide arose in 1969, the year I began my university studies. For the first time a lunar mission made it possible for a human being to see our own world from another celestial body. It confirmed what we long knew: that we, as a planet, are home to a unique amount of liquid water. The term 'Blue Planet' was born. So too was the idea of the 'wholeness' of the Earth, particularly in connection with the growing awareness of the finite nature of the Earth's natural resources. It also confirmed that action was necessary to get politicians to pay attention to this.

Key messages

- Humankind recently began to realise the great importance of the 'wholeness' of the Earth as the 'Blue Planet'.
- The challenge is to connect the large (Earth system) with the small (local).
- It is therefore time to implement the slogan: 'Think Globally, Act Locally'.

Science

Earth system

To get a good grasp of the water sector and the challenges it faces, we need to understand the system context we're operating in. Figure 2 essentially presents the relative situation the Earth system finds itself in. According to Crutzen (2002) and Crutzen and Stoermer (2002), since the middle of the last century we have been in the so-called 'Anthropocene' era. This means that we're in a period in which, simply put, human action has become so dominant that its impact on the Earth system is measurable and is having a real impact on the system's behaviour. This proposition has stimulated public debate and citizen involvement all over the world.

System ecologists who work with water systems frequently illustrate the system-level reactions to external disturbances by referring to biological systems in shallow lakes. This relates to the contamination of water in these systems caused by nutrient-enrichment (eutrophication). We have a very good understanding of how they react to external disturbances and how the reactions are interlinked. A well-known example in the Netherlands is the research on the Randmeren lakes. The lakes were formed in 1934 as a consequence of the closing off of a brackish inland sea, the Zuiderzee. The project's main objective was to create more agricultural land. The Randmeren lakes were formed for water management purposes in a number of newly-created polders. In the 1960s and 70s the lakes became turbid, partly as a consequence of the increased phosphorus load in the Rhine river. The result: long-term cyanobacterial (blue-green algae) bloom – a 'green soup' instead of clear, shallow waters. The very characteristic underwater vegetations, with a rich and diverse biological life, disappeared. Interestingly enough, the system didn't react immediately when the phosphorus load was cut back. To the surprise of many, the system seemed to be stalled in a stable, negative state, with its very turbid water. The situation provided an example of hysteresis: of two stable states (clear water and turbid water) – so-called 'attractor' states – occurring under the same phosphorus concentrations. Such a stable state is often characterised by a certain level of resilience. By 'resilience' we mean the capability of a system to recover rapidly and completely from an external disturbance. This occurs by means of a variety of feedback mechanisms which, of course, have natural limits. The degree to which a system can continue to fulfil its key functions under such conditions we call the system's 'robustness'. If critical limits are exceeded, then a system can shift to another stable state (see also Beisner et al., 2003, for an overview of the theory). In this connection, Figure 2 illustrates two important characteristics with regard to the Earth system. In the first place, the phenomenon of alternative stable states (the different troughs with the balls) under identical environmental conditions. And secondly, the degree to which a stable state can show variations – for instance, the increase in extreme weather events under climate change. The figure effectively illustrates how the theory about 'complex adaptive systems' has been shaped over the past half-century for different scale levels (from lake to the world).

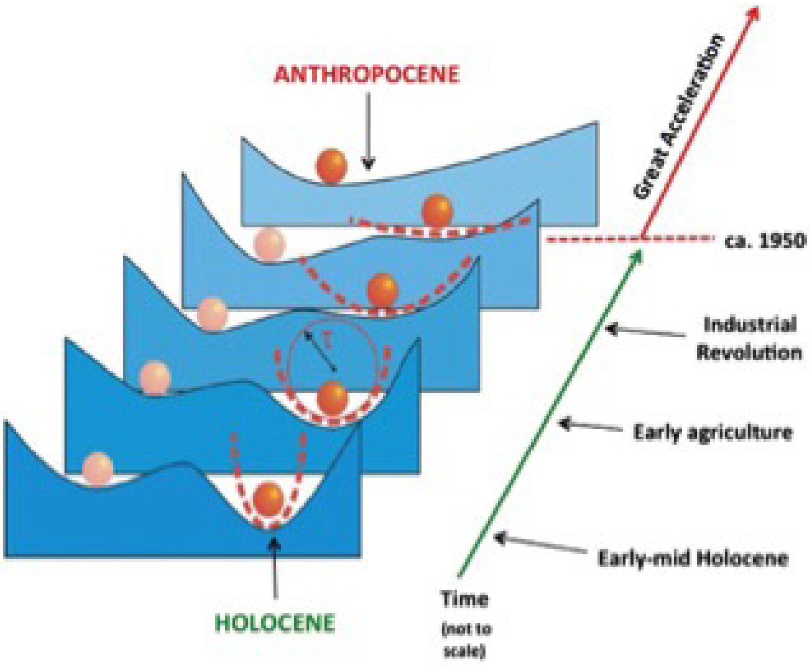

Figure 2: The 'alternative stable states' theory applied to the evolution of the Earth system (Will Steffen; https://bit.ly/2ke4Bzl).

So, science now has a well-founded vision at the level of the Earth system. Whether its exact predictions are correct or not is not decisive for our purposes. What matters is that we create a logical and coherent framework for debate among scientists and dialogues with citizens. Naturally the citizen has good reason to expect us to estimate the paths of developments correctly. After all, a lot could be at stake in the different scenarios (climate discussion).

This example also makes it clear that to set up a scientific discipline at the Earth system level in practice demands transdisciplinary rather than exclusively monodisciplinary knowledge and expertise. This integrative scientific approach is especially important because we are seeing that more and more scientific questions are connected to important societal decisions; decisions which have high stakes, but which also are surrounded by high levels of uncertainty. All of this will in the future require very well-trained managers at all levels of administration, policy and implementation.

Contamination of water and environment

At a practice level many in the water sector naturally had long been aware that things were not well when it came to the environment – and consequently also when it came to water quality. It was not for nothing that the Dutch Pollution of Surface Waters Act came into force in 1970. The law was intended to put a stop to the enormous load endured by surface water in the Netherlands, and in particular to do away with the image of the Rhine river as the open sewer of Europe – and therefore also of the Netherlands. The same year was declared European Nature Conservation Year. It was also the year that the Club of Rome, two years after being set up, convened its first formal meeting in Rome. The group commissioned Jay Forrester, as a system thinker and computer modeller, to take stock of the world's situation. This would ultimately result in the publication of *Limits to Growth* (https://bit.ly/1n8EMMP), which raised the question of the future of humankind on a planet with finite resources. A completely unique initiative, in part because of the fact that it was a private initiative taken outside of the regular political order of interest groups. Figure 3 shows the key players at the time, with, at the centre, Donella Hager-Meadows, the lead-author of the report that had so much impact.

Figure 3: The group responsible for the publication of The Limits to Growth of the Club of Rome; from left to right: Jorgen Randers, Jay Forrester, Donella Hager-Meadows, Dennis L. Meadows and William W. Behrens III.

Incidentally, most of the report's predictions were not borne out. But that is of no matter: they weren't what made the report important. What made it indeed of revolutionary importance was the fact that, for the first time ever, the sustainability problem of the Earth was examined in a structured manner.

The individual

How does the citizen deal with all this, then? How does the average person absorb all the information he or she is exposed to? Aren't we all slowly becoming numb to all the bad news about the Earth and the environment? And how do modern scientists position themselves in all this? Such questions are not without importance in the design of effective knowledge systems. We can in fact judge important, complex (societal) issues along three different dimensions. This can occur using different approach routes, each of which separately relates to a person's different 'truth' worlds. The first one refers to the physical, material and factual situation a person confronts. This is the world of the 'true', which we discussed above. A world, you might almost say, in which natural scientific facts are paramount. Secondly, our judgement works with what we consider 'truthful'. This reflects our inner reality. And thirdly, we also judge situations on the basis of what we consider 'just'. This third world involves social reality, in which normativity, and thus also norms, form an important element. This terminology is borrowed from Jacobs (2002), who developed these sorts of perspectives and qualifications in relation to three landscape types that he defines. I think that it is important to mention these dimensions, because they play – separately and in combination – a part in shaping the opinions and decisions of citizens, and also in the choices we make concerning the kind of society we want to live in. This will prove to be important in the course of this story.

Jacobs's approach consists of an experiential perspective concerning the relation between the individual as a citizen and his or her environment. But scientists, as a numerically select group of citizens, have another, and very different, perspective in this regard. To clarify this difference, in my talk I'll be making a distinction at the level of the individual between two specific roles: the individual as citizen, and the individual as professional/scientist.
As a citizen, an individual will undoubtedly be touched by the 'truthful' and the 'just'. While as a professional an individual's vision of the 'true' is of fundamental importance, it seems to me. In his work, Pielke (2007) discusses the four different modes of societal engagement that scientists can archetypically adopt. Scientists in the 'true scientist' and the 'science arbiter' modes to a certain extent stay seated on their scientific throne. They don't seem to be very concerned about the societal fate of their work. These modes profile science as almost a value-free and objective referee in conflicts about substance. The 'true-not true' idiom plays a primordial role. Apparently the 'just' plays a decisive role here. Scientists in the 'issue advocate' role, on the other hand, select their scientific arguments on the basis of their own taste and outcome preferences. To me it seems that the true and/or truthful disposition

here stands in the way of an independent judgement. Pielke's 'honest broker of policy alternatives' mode however provides an approach that has room for all of the dimensions. A healthy and functional pallet of arguments are put forth in processes in which a careful scientific quest for truth in a largely practical setting is important. Moreover it is highly likely that, in our actual behaviour, we will find all of these dimensions to a greater or lesser degree. This is often difficult, awkward and sometimes unethical – that too. But scientists are sometimes no more than people.

Key messages

- The Club of Rome initiative issued a wake-up call about the Earth system.
- We understand more and more about the dynamic behaviour of systems, including the Earth system.
- There is a growing amount of environmental legislation, including in the area of water management.
- We are developing insight into the different roles that individual citizens and scientists play in the environmental field.

The human being

A key feature of our period is that we associate many local and regional environmental problems with world-scale problems. Accordingly, local flooding is for instance quickly attributed to global warming. Because water management is at the same time a local, or at its best a regional, phenomenon, water managers are faced with two important needs: first, to get a clear understanding of the events (cause-effect relations) and, secondly, to implement good response strategies. The former is connected to big, international agendas and the latter to making sensible investments. This illustrates the phenomenon that, as environment professionals, we are increasingly living in different, parallel worlds: the local, national and international. The water sector is well organised all along this scale range. At the local level, we have municipalities, at the regional level water utilities, Water Authorities and provinces, at the national level in the Netherlands we have an organisation like Rijkwaterstaat, while at the international level there are still many more, for example: EurEau; https://bit.ly/2wU6YQK , WsstP; https://bit.ly/2rU8Xji , UN Water; https://bit.ly/1amOXHI , World Water Council; https://bit.ly/2rZlqRN) , but also the International Water Association (IWA; https://bit.ly/YAhUNT). But even if we are well organised, the question is how we can successfully connect with each other in such parallel worlds. Given the considerable difficulties we face in the worldwide global agenda, we will need to find a way to coordinate the actions we take at the different levels. This is a considerable challenge and the question is whether we will succeed in meeting it. Underlying this is the more essential question as to whether we, as humans, are actually biologically equipped for all these institutional connections and multitasks. Is there anything we can say about this?

Group size and Complexity

When you look at how humans organise themselves in groups you're immediately struck by two important facts. The size of the brain does not really play a role, rather it is the extent of the brain's specialisation that is decisive. Not size per se, then. If, for example, the weight of the brain relative to total body weight played an important role, then elephants, walruses and dolphins would be our intellectual superiors. The human brain differs from that of other mammals because it has a very well-developed neocortex, the newest part of the brain from an evolutionary perspective. Complementing the so-called reptilian brain (safety, basic functions, procreation) and the limbic brain (affection, love, attachment), the human neocortex is where a number of more intellectual functions (creativity, language) are orchestrated. Language is a unique communication capability. One of the special properties of language is that it is recursive, which means that it reinforces itself and its structure through internal positive feedback. This occurs through the combination of words, allowing for the formation of new images and meanings. This means that the relations between people also become more complex and differentiated thanks to the increased range of expressive possibilities.

One might take the period of the Sumerians (about 5000-6000 years ago) as a good watershed to mark the importance of spoken and written language in society. For the first time, we encounter expressive images of humans and observe that things are set down in writing. And we believe that this language had rhythm and structure. The indications are that humans have only actually had language with this sort of capability for about 10,000 years. In the context of my address, it is of course nice that these early developments occurred in a water-based society. The Euphrates and the Tigris fed and largely shaped the societies of old Mesopotamia. There is also perhaps a connection between the development of language and the ability to manage such a complex water-rich environment. Part of this particular water-based society remained intact deep into the 20th century. It was the explorer, Wilfred Thesiger, who gives an account of this way of life in 'The Marsh Arabs' (1964; for photos see the Pitt Rivers Museum; https://bit.ly/2GrdoGL).

As the neocortex developed so too did the size of groups in which humans associated; Figure 4 shows this relationship. As mentioned above, it is not the relative or absolute brain size that determines group size, but the neocortex size (Social Cortex; Dunbar, 1998). On this basis, it appears that the optimal, natural size of a human group is of around 150 individuals. This seems to be about right, when one thinks of the skills and energy required to communicate and coordinate relations, roles and actions in a hostile environment. There is probably also a numerical maximum to the number of relations, which this number also suggests. One can a little too hastily see this as a numerical dimension that only applies to primitive peoples. But when considered more closely, the number seems to provide a pretty general rule-of-thumb that has lasted through time. Dunbar (2011; originally 1993) gives a series of examples from prehistory, such as the group size of hunter-gatherers (30-50), but also the number of individuals in temporary night camps. In this connection, he also refers to ‘Clans’ (about 100-250). These groups can then come together through the common sharing of hunting grounds and water holes – these larger groups he calls ‘Tribes’ (500-2000). And lastly, at a higher numerical level still, in which language and other practices are shared, he speaks of ‘Culture’.

There are also indications that in our period the circle or people with whom we maintain close relations in a specific area is also limited. Take for instance the number of people you exchange Christmas cards with, or how the army or a company are organised. Dunbar points to the case of Wilbert (‘Bill’) Gore (of Gore-Tex), who split up his company whenever it became too big. He constantly adjusted the size of the production units according to what he saw as the optimal operational group size of one hundred employees. He did this on the basis of his experience that production quality was lower at high staffing levels.

In short, the number of people with whom we can sustain an optional functional relationship (with a view to a specific objective) is limited – the optimal number seems to be 100-150 individuals. In the Netherlands we have a well-known political example that has been cited for over 50 years. It refers to a statement by Jan Mertens, trades union leader, from a famous speech he gave in 1968:

> "In the Netherlands we have an economic system that looks like what I would call a ‘game of interconnected lines’. We recently established that our country’s entire economy is in the hands of about 200 people. A group of individuals who know each other well and frequently meet on various councils. It is a group that is as professional and financially powerful as it is frightening."

This perception is still shared today and the phenomenon has come to be known in the Netherlands as ‘the Mertens 200’. Today we’d refer to them as a lobby or a cartel; I would call them a ‘Clan’. Other examples of this kind of small economic lobbies, clans – including the power they exercise – are extensively described in the US context by Robert Monks (https://bit.ly/2rVLu0k). I’ll return to this latter under the heading Society, when talking about its significance for the nature of the science system.

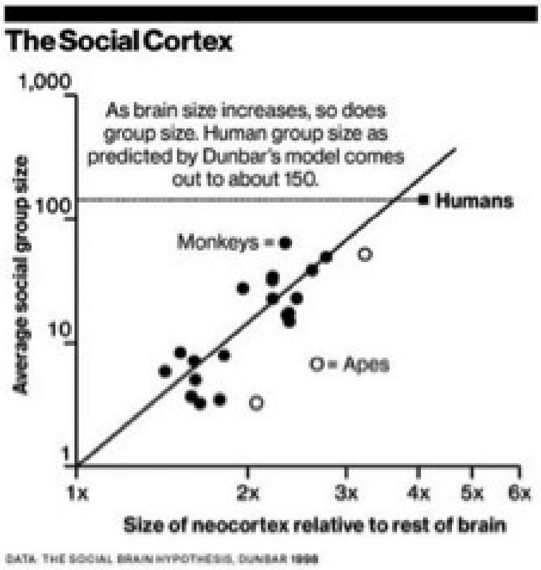

Figure 4: The relationship between the relative size of the neocortex and average social group size (Dunbar, 1998).

Size of Institutions

I once raised this question of group size in science in an article posted on LinkedIn: 'Do research institutes need to be big? I believe in a golden ratio in institutional size. It matters to professionals' (https://bit.ly/2lxkAss). I was responding to a piece in the 'Times Higher Education Group' of LinkedIn by the departing president of Stanford, John Hennessy, in which he questioned the effectiveness of 'global university alliances'. My conclusion was that big is not always good. But the desire to be big in academia is also an issue in my own country, where for instance there are plans to merge universities. The underlying idea is that a critical mass is needed for purposes of power of influence. Critical mass seems to make sense, but to what end? This issue is connected to the recurring discussion about the role of management in organisations and thus in scientific institutes as well – where, be it noted, managers are not at all popular! My personal experience runs the gamut from working as an independent researcher to heading an organisation of about 1000 people. Based on this quasi-experimental experience, I would distinguish between five numerical organisational levels, each with its own institutional value and specific demands on the leadership. Independently of Dunbar's analysis, about which I had no knowledge at the time, I concluded the following about the five levels, with regard to number of staff, objectives and required leadership type.

Table 1: Typology of organisational levels

Type	Interest	Knowledge	N	Type	Goal
Self	Connection	ME	1	Brand	Curiosity
Hunters	Prey	US	10	Team	Innovation
Clans	Resources	HOME	100	Discipline Institute	Profiling Professional Field (KWR)
Tribes	Culture	HOUSE	1,000	Strategic Knowledge Unit	Societal Transition (TNO)
Guilds	Societal Goal	BUILDING	10,000	Implementation	Design & Implementation (Rijkswaterstaat)

I think the numerical boundaries between the different organisational types can be nicely quantified using a logarithmic scale of 0-4. I'll deal with each one of them here, since what I see as the resulting *institutional archetypes* form an important component of my subsequent discourse. I've attached a kind of textual emoticon to each of them in the form of single word (see the 'Knowledge' column in Table 1). The aim is to give an idea of the emotional load that the staff members attach to the different institutional configurations. I should add that what I have to say here is essentially based on my own personal experience, so I bear sole responsibility for the conclusions.

– $10^0 = 1$. The individual. The textual emoticon here is **ME**. The researcher is the sole source of creativity. Recognition is connected to one's personal name and fame. The idea is that of a scientist as a 'brand'. The objective is curiosity-driven research. Over the course of a scientific career, it is usually during one's doctoral work that one becomes conscious of the challenge of creating something. For me this was between 1976-1980, when, as a PhD student, I was left to my own devices. My home basis was what now is the Aquatic Ecology and Water Management group in Nijmegen (https://bit.ly/2GzSgOq). At this level what matters is personal drive: one is one's own leader.
– $10^1 = 10$. The research team (tens). The textual emoticon is **US**. They form a core of permanent staff researchers who make up the large research departments, together with PhD candidates and post-docs. A small group of ideally closely-knit top researchers. Here, too, fame is connected to the person. The objective is innovation within a discipline. My first experience in this regard was with the team I set up for my postdoctoral work. That was in Wageningen (1980-1987), which later grew to become the internationally renowned Aquatic Ecology and Water Management group (https://bit.ly/2IxUVOw). Leadership involves scientific and creative leadership among equals.
– $10^2 = 100$. The institute (hundreds). The textual emoticon is **HOME**. Scientists sometimes truly feel at home here. My own experience involves a number of positions of top responsibility at NIOO (1992-1998; https://bit.ly/2IwmymV), IHE Delft (1998-2002; https://bit.ly/2wYE2aw) and KWR (2007-2018; https://bit.ly/2KzJgeH). This is the base numerical level at which one has to do with an institute with line management. An institute that moreover has a coherent disciplinary and corporate mission. It also has an explicit system of formal and informal behavioural codes. It shifts the boundaries of a scientific discipline and is therefore in competition with other leading international institutes. It values the personal fame of individuals as building blocks. It is structured organisationally in teams. The Netherlands has a number of so-called 'para-university' institutions of 'name and fame' that belong to this category. Leadership here requires a healthy combination of leading and following. The service character of the leader's role is also prominent.
– $10^3 = 1000$. Multi-disciplinary Institutes (thousands). The textual emoticon is **HOUSE**. Actually, from the outside, it is not recognisable as a coherent disciplinary entity. I think that the missions of such institutions involve

societal transitions. That is, their mission is not scientific but societal and they use science as the instrument to achieve it. The Netherlands Organisation for Applied Scientific Research (TNO), set up in 1932 by the TNO Act (1930), is a good example. The rationale for the initiative is rooted in 1917 and the extensive period of shortages following the First World War. Science had to come up with solutions. This accords with my belief that the ultimate goal of such entities relates to a broad, societal concern (https://bit.ly/2rSlZ0K). The fame of the institute can only be measured by its societal success, which demands a time perspective of at least 50 years. Its establishment thus calls for long-term strategic visions. Those responsible need to have a deep understanding of the societal challenges stretching into a relatively distant future. My own experience relates to my activities as director of what is now Wageningen Environmental Resources (https://bit.ly/2rVLU7D). Leadership in this kind of organisation requires good insight into societal issues, as well as good connections with the top management layers of the national sector concerned. At the same time, the role requires high levels of trust within the organisation, and support for what are often seen as somewhat bureaucratic decisions.

– 10^4 = 10,000. Implementing organisations. The textual emoticon is **BUILDING**. These kinds of entities don't occur in the form of scientific-research-driven organisations. Rather, they are created for practical implementation in areas that can be very knowledge-intensive. In the Netherlands, Rijkswaterstaat (staff of around 9000, https://bit.ly/2rWi6XQ) is a good example. It's a public organisation with a high level of professionalism, which focuses on implementation and is well connected with society at a regional and local level. It also has close connections with leading knowledge organisations in the field of water management, which in the Netherlands is of vital importance. I see this example of an implementing organisation as a focal point for what I call 'Sustainability Guilds'. I believe that we'll only solve the world's huge sustainability problems if we tackle them forcefully. To this end, I could see creating powerful Guilds to focus on new subject areas, analogously to Rijkswaterstaat. An example would be the COASTAR initiative (https://bit.ly/2KAUtf1) which was developed by Allied Waters, and whose motto is 'saline at bay, fresh on hand'. In my vision, Sustainability Guilds:
  - are societal collaborations that implement on a national level the internationally-agreed sustainability agenda;
  - enjoy the structured involvement of leading knowledge organisations;
  - are configured on the basis of up-to-date knowledge and coherently managed, both top-down and bottom-up;
  - operate, in collaboration with citizens, residents and entrepreneurs, in a clearly defined location;
  - have transparent financing, including participation of existing utilities (energy and water utilities and Water Authorities) as well as pension funds;
  - are by nature temporary and results-driven.

The type of leadership required in Sustainability Guilds is that of a political-administrative purebred. I don't think that a scientific profile is necessary, but an informed-decision-making approach is of essence.

Personal Networks

I have naturally wondered whether the personal networks that professionals maintain vary greatly according to the type of institute (as described above) they work in. I don't believe this to be the case. In any event, in my experience the individual behaviour and the size of the group within which they feel comfortable and productive don't vary much from one institute to another. Humans remain humans.

Scientists constantly work in parallel and simultaneous collaborations. I have noticed that the rules of the game, or mores, among the group members are often quite similar. And while group composition may vary a little, group size is usually limited to a few dozen individuals. In light of this, in my work in large national collaborations – like those dedicated to climate programmes – I have noticed that one needs to pay close attention to effectively coaxing the teams to work in partnership. I consciously use the word 'coaxing' instead of 'coordinating'. The scientific world is, after all, a truly bottom-up one that is averse to top-down organisation. A colleague of mine refers to the challenge as one of 'herding cats': a hopeless exercise. Looking ahead, this raises the interesting question as to whether our big societal challenges should be tackled through large research institutes, or through the creation of temporary collaborations in the shape of ad hoc coalitions drawing, for instance, on university research groups.

I am firmly convinced that the basis for the creation of critical research capacity for these big societal challenges is rooted in the manner in which individuals currently position and organize themselves. How you, as an individual scientist, develop and maintain your network of pertinent contacts in the outside world. Of course, in the first instance, you do this through your Clan. For many scientists, this takes place through ResearchGate for instance. This is where many of us increasingly create our own intimate scientific circle. But sometimes this is not all, or not enough. Compared to the past, today it is much easier to cast our net beyond our immediate circle. We do this more and more by exploring other professional fields for insights that might help us better address our own questions and develop solutions. By seeking contact with scientists who have a completely different perspective on the matter. And our digital epoch of course makes this extremely easy. But are these kinds of excursions effective?

This question is explored in one of the most cited classic papers on the utility of such 'stranger contacts' and on how human networks come about: Granovetter (1973; https://stanford.io/1qZLMfI). He makes the distinction between strong and weak ties. His key point is that it is primarily the weak ties that bind groups and the associated networks, and that the strong ties can actually lead to the isolation of groups. An example of a weak tie is a link with someone with whom you're connected via the social media but who you don't know personally. In the context of science, this is often someone who you don't count among your peers, but with whom you do feel you have a professional connection – often because you work in a similar environment, like the water sector. Of course these could be important contacts. Granovetter says for instance that professionals and managers more frequently notice information about vacancies through the weak ties (almost 28%) than the strong ones (almost 17%).

Granovetter's point is exactly the basis of one of the benefits offered by some social media like LinkedIn. Over the last couple of years, I have had social media accounts such as LinkedIn (https://bit.ly/2QEaaWa), ResearchGate (https://bit.ly/2rSctd4) and Twitter (https://bit.ly/2IyR27Q). On the basis of my own LinkedIn profile, I have checked to see where my first-degree contacts get me in terms of networks. Figure 5 shows the results of my modest survey. I checked how many individuals I was connected to through my first-degree contacts, per country. My contacts in the Netherlands (about 1000) connect me to about 100,000 second-degree contacts (a multiplication factor of 100). Assuming that Dunbar's findings also apply to my water contacts, this means that I have strong ties with about 100 Dutch colleagues. This number is therefore multiplied by a factor of 10 in my first-degree network, and by a factor of 100 in my second-degree network. The figure indicates that this is actually a pretty constant (100) factor.

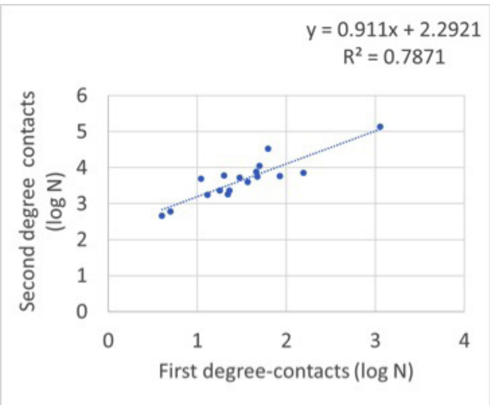

Figure 5: Relation between first- and second-degree contacts in my LinkedIn network for various countries (each point refers to a different country).

All of this points to the extraordinary evolution that our personal networks have undergone. Particularly the way scientists can, with incredible ease, establish a second- or higher-degree contact with professionals from other fields or backgrounds, is nothing less than staggering. National borders no longer play any role at all.

Key messages

- Humans act optimally in relatively small groups (the Clan: 150 people on average).
- There are five different numerical levels (from 1 to 10,000) at which different scientifically-motivated roles are shaped through institutions. Their objectives range from satisfying curiosity (individual) to facilitating the implementation of a societal transition (Societal Sustainability Guild).
- Societal Sustainability Guilds: a new institutional concept.
- A model for such a Societal Sustainability Guild is offered by the COASTAR initiative, which focuses on the sustainable management of water through the use of the subsurface.
- Social media are important as a means of creating new connections between networks.

Society

Clashes between Clans and Tribes

But our discussion also requires us to distinguish between what all this means for an individual, on the one hand, and a group on the other. The individual is the sole source of creativity and human originality and is of recognized importance in science. But humans are also social animals and we tend to thrive as humans in group contexts. At all levels, we therefore face material facts, subjectivity in the shape of values, and a social reality in which norms form a communal judgment framework. All of these are brought together in a society.

The effectiveness of science in helping create welfare naturally depends on a number of factors. One very important factor is the kind of society of which the knowledge system is a product. In a 2016 LinkedIn post (https://bit.ly/2QKywh8), titled 'What Does Society Expect from Science? Let's Cast the Net as Wide as Possible!', I explore this subject. I distinguish between four different types of society on the basis of two dimensions I see as essential. The dimensions are Social Learning Capacity (high, low) and the extent to which the government feels it is responsible for different areas of policy, a dimension I call Scope (wide, narrow) (see Figure 6). For purposes of my discourse, it is the two most extreme forms of society that are useful. These are, on the one hand, a society in which the government, for example, shrinks its responsibilities to a minimal number of areas (for example, the military, basic infrastructure) and, on the other, a society in which the Social Learning Capacity is low (expensive education, highly unequal incomes). The chances are high that such a society will end up becoming a 'Corpocracy', as Robert Monks (2008) named it. This is a society in which a Clan, with an inner circle of a small number of large corporation and merchant bank CEOs, calls the shots. The absolute opposite of this is what I call a 'Just Democracy!'. Government in this society exerts leadership by determining the course for a large number of societal issues, including education and citizen empowerment. Knowledge and power is spread and the government is in permanent dialogue with the population; the two sides engage in ongoing, informed debate.

I think that both these extreme variants are actually pretty stable, since they contain many feedback mechanisms that underpin their continuity. I must recognise – as suggested by its name – that Just Democracy! is for me by far the most preferable form of society. 'That's enough! This isn't science any more, it's *ideology*!', I can here you thinking. Maybe so. But it is also true that an ideological battle has been raging since the end of the Second World War. A battle that has essentially been about the role of the state and realising human welfare.

In the 1950s and 60s many of those in power were guided by the structuralist theory of development. The world was getting back on its feet and it was thought that all kinds of damaged and stalled economies needed to be stimulated with extensive government programmes – read: subsidies. The idea was that this would only be done for a limited period. The underlying thinking was that the market would eventually have to start doing its work. This immediately makes one think of Keynesian economics, the policy named after John Maynard Keynes. The essence of Keynesianism lies in the use of interest rates, public projects and tax instruments to stimulate the economy. But in the 1970s and 80s the approach was countered by the revival of what is known as 'neoliberalism'. The legitimacy of the correction was rooted in the notion that government assistance rendered industry inefficient because it promoted all kinds of so-called 'rent-seeking' behaviour. It was proposed that one had to rehabilitate the old industries, let the market do its work, and keep government from holding back innovation through subsidies of all kinds. The period actually was labelled one of neo-classical resurgence. In the decades that followed (1980s and 90s), international development policy was also dominated by free-market thinking and, at a micro-economic level, by rational choice theory. Humans were everywhere seen as *Homo economicus*.

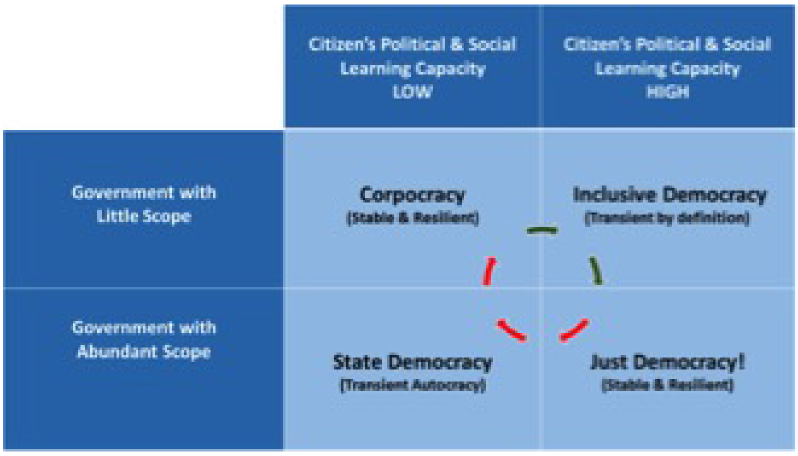

Figure 6: A world of difference: transient and stable systems.

A time of sharp neoliberal economic measures, then. The trend was championed at the time by Margaret Thatcher, as the politician, and Milton Friedman of the Chicago School of Economics, as the theoretical inspirer. Friedman and his monetarism was Keynes's counter-pole. Monetarism focused primarily on the supply and demand side of the money market, and Friedman was averse to government interventions à la Keynes. In 1992, this all seemed to be wrapped up nicely when Francis Fukuyama published *The End of History and the Last Man*. The book was seen by many to mark the moment at which capitalism, and thus neoliberalism, could be proclaimed as the world's economic religion. Moreover, with the end of the Cold War, Fukuyama argued that the historical moment had also arrived for the universalisation of the liberal-democratic form of government. As we all know, things turned out otherwise, beginning with the economic crisis of 2008 and its aftermath, which revealed all the moral bankruptcy of a large number of financial institutions.

The good news is that we then set out to redefine the roles of the state and of the banks. Partly by simply rethinking the options we have as governments along the Scope dimension (determining a state's fields of responsibility) and of Strength (the level of the state's effort), a subject Fukuyama (2004) has explored extensively (https://bit.ly/2rVmDtB; https://bit.ly/2GyrQge). But the rethinking has also involved looking at the original function of banks, namely, facilitating the circulation of money. Many have hoped that the social-facilitating role of banks could be developed to encompass investment activities in favour of the environment and sustainability. Thus, not so much as business banks but more as banks with a societal impact. It makes sense also to take another look at the level of government investments required in view of the sustainability crisis that the Earth system is in. The crisis is serious and extensive, and requires an unconventional approach and huge investments, affecting, as noted, both Scope and Strength (financing). There are therefore hopeful signs that we are slowly beginning to reassess the role of the state in the organisation of our economies. We are, after all, talking increasingly about the circular economy within which the notion of sustainability provides the required framework for all economic activities.

In 1994, two years after Fukuyama brought out his book, Chalmers Johnson published *Japan: who governs?: The Rise of the Developmental State*. Johnson accuses a number of economists in the neoliberal camp of distorting history. He claims that the state can actually be extremely effective in stimulating economic growth. He argues notably that the success of the industrialisation of Japan following the Second World War is primarily attributable to the sophisticated joint action by the public and private sectors. In Japan at the time, for a variety of cultural and thus business-cultural reasons, government was respected as an important investment partner. There was no neoliberalism, which was seen as inappropriate. Government was appreciated and its actions were directed at building a shared vision of economic development and, more particularly, at defining what this demanded of the public and private sectors. One key element in this effort was the stringent selection of a well-educated corps of public servants. The bureaucracy at the time was staffed predominantly with 'best of class' individuals. And this had to be the case for there to be any chance of successfully following the bureaucratic paradigm: 'politicians reign, while bureaucrats rule'. For me, as a Westerner, that 'reign' sounds rather royal. But it highlights the fact that politics firmly controlled the fervently desired public-private partnership. It also suggests that the public servants are loyal in such a system; all the more so because the second part of the paradigm – 'rule' – involves many exciting challenges for them.

A number of the issues Johnson deals with were later revisited, in a refreshing and contemporary form, in Mariana Mazzucato's *The Entrepreneurial State. Debunking Public vs Private Sector Myths*, published in 2013 (https://bit.ly/2IWSN2f). The book constitutes a recent landmark in thinking about the role of the state in areas such as innovation. Countering mainstream thinking, she also points out that states have invested huge amounts in many areas, innovation being one of them – and not at all to the detriment of the private sector. Does classical Keynesianism occupy a bigger place under the Western sun than we thought, then? In her recent publication, *The Value of Everything: Making and Taking in the Global Economy* (https://bit.ly/2jlJ1rT), she further explores the question of who actually creates value in society today and how they are financially and socially rewarded.

I see Mazzucato's work as providing support for a critical self-reflection about our society, and contributing to the creation of a society that aspires to sustainability through the development of a circular economy. She recently advised the European Commission – specifically, Carlos Moedas, European Commissioner for Research, Science and Innovation – on the EU's forthcoming 9th Framework Programme. She has also penned a report, titled 'Mission-Oriented Research & Innovation in the European Union: A problem-solving approach to fuel innovation-led growth' (https://bit.ly/2EVi0Z4).

Based on the above, I think we can presume to be on the threshold of a new approach. This won't involve a political-economic hybrid of classic Keynesianism and the, now also classic, monetarism of Milton Friedman. I believe that we have to apply the lessons learned from both these archetypical models in a new political-economic model: a model based on the key premise that we will be establishing a sustainable society based on a circular economy; a society that permanently absorbs knowledge and attributes a central role to its organising capability.

For a number of reasons this society will be very knowledge-intensive. Its realisation will require that all scientific and professional hands be on deck. To achieve results that represent substantial progress, we will have to generate far more organisational capabilities than we have now. In this regard, among the surprising messages I retained from Bas van Bavel's *De Onzichtbare Hand* [The Invisible Hand] (2018) is this: innovation is the *consequence* of societal renewal and not the driving *force* behind it. This means that that we should, with a view to the future, begin mobilising citizens and lay our hands on the plough when it comes to sustainability. For me, the Sustainability Guild is the form that perfectly combines the required involvement, innovation and results. It is the ultimate form of citizen participation with an eye to sustainability. I'd call the state that reinvents itself in this manner the *New* Developmental State, echoing Chalmers Johnson.

Key messages

- A circular economic model requires a new approach, complementing Keynesianism and Friedman's monetarism.
- This new approach will give shape to what I call the *New* Developmental State, which involves a circular economic model that will bring about a sustainable Earth.
- The insights of Chalmers Johnson (*Japan: who governs?*), Mariana Mazzucato (*The Entrepreneurial State, The Value of Everything*), and Bas van Bavel (*De Onzichtbare Hand*), together provide an interesting compass for this course.

Water Trends & Sector Transitions

For the water sector – in other words, the urban watercycle – I see five key practical themes in the years ahead.

Resilience

The first theme involves a framework of action for the central issues of resilience and robustness. Earlier in my address, I spoke of these concepts in the context of the Earth system and the behaviour of systems in shallow lakes. Naturally, resilience is a central issue. Are our systems resilient enough to withstand a changing environment? But also, how will they behave in the context of changing external conditions? We will need to know how resilient our urban water infrastructure is. This is important with regard to its reliability under increasingly extreme conditions. Such knowledge is vital for a society that is changing – demographically among others – and is increasingly subject to more extreme weather events. Take for instance, the need for water supply security and for drinking water of impeccable quality. But the same issue is raised at the city level, with the complex interplay between different elements of the watercycle. How resilient is a city as a whole? Can one say something useful, in a quantitative sense, about this? We will certainly have to.

Water Stress

The second theme involves a framework of action related to water stress, a phenomenon of worldwide relevance. Although the Dutch people think that it rains a lot in their country, in fact it doesn't always rain when it is most desirable. Despite a precipitation surplus, we're increasingly experiencing a mismatch between supply and demand. We will have to adapt much more, both psychologically and practically, to the need for the temporary storage of surplus water for later use in times of need. And this has to occur regardless of the hurdles presented by sectors and compartments within sectors. It has also to be done both above- and underground (subsurface storage), and involve the collaboration of water utilities, Water Authorities, municipalities, provinces and industries. In this area there is good news. Over the last few years a large number of stakeholders have come together under the banner of Allied Waters (https://bit.ly/2KHj8ie) to institute coherent and sustainable water management in the Dutch Westland region. This is the COASTAR project, which I referred to earlier. The subsurface storage of water is part of a strategy which also includes the concept of a Waterbank, which is also unique to the Netherlands.

Solar Power to the People

The third theme relates to a framework of action around the connection between water and energy. The availability of green (and preferably deep-green), non-fossil energy is important to a circular economy. In a recent publication by Van Wijk et al., 'Solar Power to the People' (download https://bit.ly/2EGjRBJ), a compelling, systematic case is made for the feasibility and desirability of green hydrogen as a carrier of solar energy. A hydrogen economy is a technologically, societally and financially feasible and desirable course. But there is a lot more that is changing in the energy field besides the energy carrier. Customers and their behaviours are also changing. Whereas, until recently, we still spoke of producers (the energy utilities) and consumers (that's us, the citizens), now we're beginning to talk about 'prosumers' (https://bit.ly/2GzOncv). These are consumers who, based on local initiatives and measures, produce a net surplus over what they consume over a specific period. This category of people could even evolve to becomes 'prosumagers' (https://bit.ly/2IvMJhP): classic customers who have begun to use and produce, but can also store energy. Of course, if this occurs on a large scale it'll turn the market upside down. The drinking water sector could become an ideal partner in making the ultra-pure water needed for the hydrogen production. The relatively high heat-carrying capacity of water, and the availability of subsurface volumes, are interesting for heat storage in the subsurface (https://bit.ly/2GyQAVE), an activity this sector is also naturally active in. Such storage provides a buffer between supply and demand. The PtX (Power-to-X) project has been developed in Nieuwegein within this framework; in it a number of the components of the hydrogen economy are interconnected, as described above. A public-private consortium is currently developing a blueprint with the aim of actually realising the PtX system in practice (https://bit.ly/2LeobHO).

The Green-Blue Revolution

The fourth theme involves a framework of action aimed at having the water sector play a key role in the (re)design of water treatment processes of the future. There are multiple good reasons for doing so.

Take nitrogen for example. We're actually pretty casual about our reactive nitrogen. Only 1-2% of our global energy is used in the Haber-Bosch process to convert nonreactive nitrogen from the atmosphere into a reactive form that can be taken up by plants. However, the efficiency with which we then use the produced amounts is only 16%. This is a shame, given all that energy use, but also because of all that reactive nitrogen that unintentionally ends up in our fresh, brackish and saline waters, where it significantly contributes to their eutrophication. In 2008, Erisman et al. published a paper in *Nature Geoscience* entitled 'How a century of ammonia synthesis changed the world'. The article was published in the jubilee year of the patent for the Haber-Bosch process, which was registered in 1908. (Incidentally, Fritz Haber was awarded the Nobel Prize in Chemistry for his work.) The process of course has benefited the world immensely in the shape of the Green Revolution, but its negative impact has ultimately also been considerable. We therefore have a Green (food production)-Blue (clean surface water) revolutionary mission to fulfil.

One idea consists of the systematic conversion of ammonium nitrogen from the urban watercycle (wastewater) into microbial biomass. This can be accomplished by using hydrogen-oxidising bacteria. It also involves the use of hydrogen, produced by electrolysis with green energy, ammonium from wastewater treatment reject water and CO2 from digestate. The aim is to produce cultures (microbiomes) with a relatively high concentration of protein, with the right composition for food (human consumption) and feed (animal consumption). This is based on the what is known as the Single Cell Protein. The production process is an enormous challenge. An extensive research programme is ongoing under the title of Power-to-Protein (https://bit.ly/2kcaYTG), in which the different aspects of the production process are being studied and optimised. The reach of our current knowledge and capabilities will clearly have to be extended. For instance, it is not obvious how we should design specific microbiomes or structure their proprietorship and, once these hurdles are overcome, we need to figure out how to radically increase the production process conversion speed so that the end-product is affordable. In this context, we might consider the use of magnetic venturi jets or even bipolar electrodes, which produce oxygen and hydrogen at a nano scale and can thus creep up very efficiently onto the microbes' 'skin'. Far into the future for the water sector. Alongside his colleagues, Willy Verstraete, emeritus professor at Ghent University in Belgium, has been responsible for much of the research activity involved. Last year, Verstraete was accordingly appointed Honorary Fellow at KWR Watercycle Research Institute for his knowledge, expertise, commitment and enthusiasm, which have indeed driven all these developments (https://bit.ly/2ICVhzi).

Risk Management

A fourth theme relates to a framework of action in which the water sector must prepare itself for a number or so-called 'Black Swans', that is, unexpected events with enormous impact. These relate to three areas: Cybersecurity, Antimicrobial Resistance (AMR) and what I'd like to call Asymmetry in the Truth Experience.

– Cybersecurity. The provision of drinking water involves one of the Critical Infrastructures in the Netherlands, and is therefore classified as a 'Category A' process. This is the highest category, which means that, in the event of an attack on these infrastructures, major damage can be feared in three areas: economic, physical and societal. Moreover, because of its interconnections with other sectors and processes, it is highly exposed to collateral damage. According to the report, 'Cyber Security Assessment Netherlands 2017', the current situation is still not satisfactory: its conclusion is that 'Digital resilience is lagging behind the increasing threat'. There's work to be done, then. When it comes to the water sector in Europe, the EU's first cybersecurity initiative is the Horizon 2020 STOP-IT project (https://bit.ly/2rX9TDm; Strategic, Tactical, Operational Protection of water Infrastructure against cyber-physical Threats). Naturally, nobody can claim to have extensive experience in this area, which is surrounded by a great number of uncertainties.
– Antimicrobial Resistance (AMR). In 2016 the O'Neill Commission's report shocked the world. It concluded that if we don't respond to the situation, we risk having up to 10 million AMR-related deaths by 2050. That's higher that today's cancer and diabetes mortality rates. And surface water plays a role in spreading antibiotic-resistant microorganisms and genes for AMR. The resistance genes are transferred in the water, and people are exposed to them when they drink or bathe in the water. Action is needed.
– Asymmetry in the Truth Experience. Citizens are more empowered and better educated than ever. Yet, it is not always easy to let the facts speak for themselves. The OpenDemocracyUK (https://bit.ly/2rT7toy) website has a clear message in this regard: 'Democracy needs informed debate'. But it then asks: 'How do we get it?'. It is apparently not obvious that facts speak for themselves. In the social media one observes very often that emotions have the upper hand over the facts. And sometimes fabricated news turns up in the social media. News that is nothing of the sort. Even the renowned journal Science recently published an article on 'The science of fake news' (https://bit.ly/2G6vj6W), which proposes two courses of action against the phenomenon. The first involves supporting individuals in their own search for truth; and the second involves trying not to let ourselves be exposed to fake news. In my experience I have found that it is easier to manipulate people's emotions with half-truths and full-truths than to properly inform them. Thus the asymmetry.

Key messages

– Resilience, Water Stress, Solar Power to the People, the Green-Blue Revolution and Risk Management are priority fields of action for the future.
– Within the Risk Management theme the spearheads are Cybersecurity, Antimicrobial Resistance (AMR) and the Asymmetry of the Truth Experience.

The Knowledge System

Based on all of the above, we can describe the contours of an innovation-directed knowledge system as follows. The core element is the need to focus a lot of attention on the researcher as an individual. The top researcher is a brand. This kind of researcher works in a team which comprises his or her intellectual home port. The evolving surrounding institutional setting is of prime importance if the knowledge produced is to take root in society; the Technology Readiness Level (TRL) (https://bit.ly/2iGC1XP) provides an excellent reference framework in this regard. The framework contains nine levels which, in ascending order, indicate how close the knowledge is to being taken up by the market. TRL 1 refers to basic, curiosity-driven research, while TRL 9 refers to a market-tested product. The earlier-described rules of group engagement apply to each of the levels. Disciplinary research institutes employ a maximum of a few hundred staff members. Then there are the national research institutes which have a big transition mission, and can employ a maximum of around 1000 people. With regard to implementation, these institutes are closely connected to an organisation that takes care of the task. In this system, the conceptual leadership comes from below, while the political and managerial leadership comes from above.

I'll draw on the Water Stress theme and the experience at KWR to look at how the system might work. The specific example I use is the COASTAR initiative and the associated knowledge system.

The initiative involves a great deal of disciplinary research at TRL 1-3; for instance, in the field hydrology this is conducted at a large number of stakeholders – such as universities (e.g., TU Delft), Deltares, WER-WUR and KWR. The KWR researchers actively maintain a large network of contacts both in the Netherlands and abroad.

All knowledge that is important in tackling Water Stress is 'encapsulated knowledge', in the form of models for instance. In other words, we're at TRL 4-6. Moreover, we have addressed the theme very systematically for are all domains present in the framework of the international Watershare platform (https://bit.ly/2Lhalo9). This involves, per domain, so-called Communities of Practice in which the 21 institutional members of the platform share worldwide best practices. Within the framework we're using here, Watershare would be considered an international Clan.

In addition, at TRL 7-9, KWR, in collaboration with a number of companies (Arcadis, RHDHV, W+B, AvecodeBondt/VolkerWessels, AquaMinerals, Avecom, BLUE-tec), has created Allied Waters (https://bit.ly/2rS5G3Z). This platform commercialises knowledge-intensive solutions originating in the water sector, particularly in areas where the Netherlands has something to offer the world and can develop interesting reference projects. This includes the example of subsurface water storage in saline areas, which could be delta areas or areas where a saline subsurface constrains the provision of freshwater. The ambition of Allied Waters is to design a number of robust sustainability transitions in the Netherlands. In the area of subsurface water storage (Water Stress) this is being done through the COASTAR projects.

I see COASTAR as a model for the first Societal Sustainability Guild in the Netherlands. It is a societal instrument to facilitate a transition – in this instance, a transition to secure the future supply of freshwater in the Westland region of the Netherlands. It does so with an eye to the circular economy and to preserving the liveability of region that is vulnerable because of its location (in a delta, below sea-level). A large number of stakeholders are part of the project. On 19 May 2018, a declaration of intent was signed between a number of them (scientific institutions, business, government, water utilities and Water Authorities), with a view to further developing COASTAR in the Westland region. A second eminently suitable initiative that could similarly develop into a Societal Sustainability Guild is Solar Power to the People.

In this whole effort, the Water Top Sector initiative and TKI Water Technology have played a crucial development role as (government) instruments. Over the last few years they have been decisive in the creation of a number of large public-private Allied Waters initiatives. The Top Sectors could also play a key part in framing the Sustainability Guilds. There are certainly plenty of reasons for moving in this direction in the fields of water, energy, agriculture and horticulture.

In any event, I believe, on the basis of personal experience, that we are well on track thanks to Top Sector Water.

Key messages

- The water sector has a very well-structured knowledge landscape.
- We have niche players at every one of the TRLs.
- Top Sector Water plays a key role in the commercialisation of knowledge.
- The COASTAR initiative operates, in practice, as a Societal Sustainability Guild.
- Solar Power to the People qualifies as a field in which to develop a future, national Societal Sustainability Guild.

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