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Digital Twin of the living environment for integrated spatial planning above and below the surface, using the key registry of the Subsurface (BRO) and the Cable and Pipeline Information Portal (KLIC) for the national spatial planning policy of the Netherlands

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Key words: *national spatial planning policy, energy transition, climate adaptation, housing policy, subsurface geoinformation, National Spatial Data Infrastructure, standardizing, utility network, integrated spatial planning above and below the surface, data driven policy making*

SUMMARY

The Netherlands faces important national challenges for the next decades such as the energy transition, climate change and population density growth. Although the subsurface is taken for granted and often not seen by policy makers and the public, it still is an important condition for spatial planning at the surface in a country below sea-level with subsidence and earthquake issues. All available information above and below the earth surface is essential to enable 3D integrated spatial planning of the living environment, and to maintain economic growth and quality of life. For centuries we have a rich history of collaboration and cooperation between central government, waterboards, provinces, and municipalities, the private sector and science in our continued fight to keep the water out and other external threats to our nation. So far this "polder model" has paid off and brought our nation a lot of socio-economical welfare.

Collaboration and cooperation is also the way we organize information about the subsurface: cables and pipelines are present almost everywhere in the shallow subsurface (0-5 m below ground level). Their location is important for spatial planning. A central 'cable and pipeline information centre' (Dutch: KLIC) has been available in the Netherlands for more than 10 years. It is the place where information of all cables cables and pipeline data, from all public and private network operators, can be requested. These data are available for every location in the Netherlands, and. In addition, the recently developed key registry of the subsurface of the Netherlands (BRO) provides information on both on the shallow (0-500 m below ground level) and deep subsurface (500 – 6000 m below ground level). This includes e.g. soil information, geotechnical data borehole data, groundwater measurements, natural resources license information, mining installations, oil & gas wells, geothermal installations (WKO), soil map for agriculture, 2,5D geomorphological models, 3D geological models and geohydrological models.

A new initiative as part of a continued development strategy of the National SDI involves the integration of the initial geographic key registries, that cover the earth's surface, with the BRO and KLIC in one 3D object registry of the living environment above and below the surface. This involves standardisation and harmonization of the current domain specific information models at a National Level and a data driven policy. With this initiative, the Dutch government aims to strongly improve the accessibility of spatial data information in order to support the required integrated 3D spatial planning policy above and below the surface at local, regional and national scale. As well to enable spatial and urban planners to use instruments as "Digital Twins" of the living environment in support of National Spatial Planning Policy (NOVI). Future development of the National SDI encompasses the incorporation of real time sensor data in the public space in order to enable monitoring of the effects of the policy measures, support the climate adaption strategy and manage uncertainties due to climate change and processes in the subsurface. Not only for the energy transition and climate adaptation strategy but also for other purposes such as protection of assets and underground infrastructure such as Fibre-optics networks, heat transport networks and Smart Grids.

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1. Introduction

The Netherlands is facing one of the biggest challenges since centuries. The effects of climate change, resulting in an acceleration of sea level rise, extreme rainfall and prolonged periods of droughts, threaten our flood protection system, urban areas, agriculture, transport networks and economic growth. The country is one of the most densely populated in the world, with a high level of tech socio-economic development, a complex infrastructure and a multimodal transport network, a conglomerate of well-connected smaller cities, an intensive agricultural land use and a high quality of living. Our trade economy is built on Mainport Rotterdam and Airport Amsterdam Schiphol, and our knowledge economy rests on Brain port Eindhoven and Food Valley University Wageningen. About 2/3 of the Netherlands is below sea-level and prone to flooding either from sea-level rise or from high water levels in major rivers like the Rhine and Meuse. Our flood protection consists of 17.691 km of dikes and a range of additional infrastructure. As of 2020, the Netherlands has 17.5 million inhabitants, living in around 7.8 million homes. About 4,5million residents live in the highly urbanised western part of the country, with the major cities of Amsterdam, Rotterdam, The Hague and Utrecht, covering an urban area of 4,300 km² on a total area of 41,543 km². The annual population density growth in this urban area is as high as 4.5 %. The Netherlands has a very dense utility network consisting of gas, electricity, water, telecom transport networks and sewage systems. In total, there are at least 1.75 million km of cables and pipelines in the shallow subsurface of the Netherlands (excluding the North Sea area). About 95 percent of Dutch homes are still connected to natural gas.

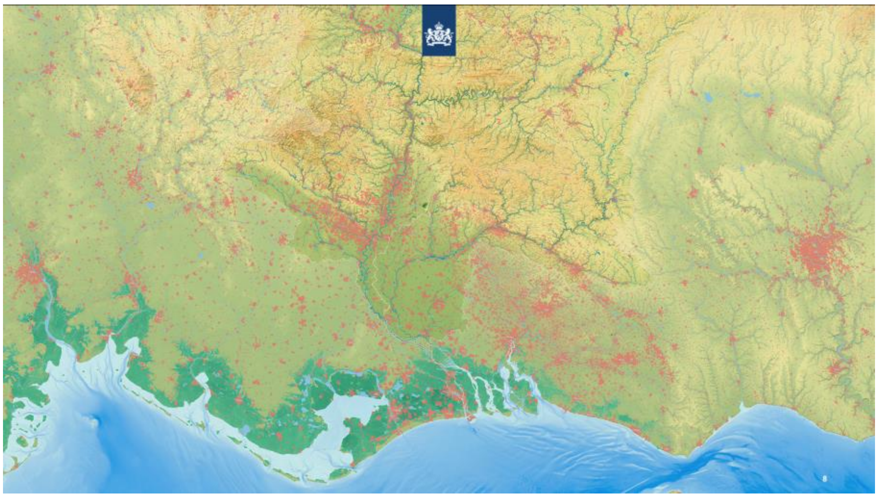


Fig 1: Map of the Netherlands from an other perspective:"a river delta".

Major issues in the coming decades

Housing policy: Based on the annual population density growth in the urban areas, the Netherlands Environmental Assessment Agency (PBL) calculated that one million additional new homes are required in the Netherlands until 2030. The Minister of Internal Affairs decided in 2018 that every year 75,000 new homes must be built in existing urban areas. Currently, the municipalities calculated that - purely in terms of spatial planning - about 500,000 homes in urban areas can be realized. For another 500,000 houses space still has to be found. Space in urban areas to build new homes is scarce.

Energy transition policy: All Dutch homes must be gas-free by 2050. Since 2019 75,000 new homes will be delivered gasless until 2030. The goal is to make 200,000 existing homes gas-free every year from 2021 onwards, and to have practically reduced the CO2 emissions of the built environment to zero by 2050.
There are two underlying goals:

1. To reduce the demand for natural gas in the Netherlands and the dependency on the Groningen gas field for security of supply.
2. The reduction in CO2 emissions of the built environment to almost zero to give substance to the climate goals in the Paris agreement.

Much still needs to be done before we can make large-scale use of residual heat and geothermal heat in the Netherlands. Extensive heat transport networks need to be installed. Moreover, buffer capacity is required in the form of underground heat storage. Meanwhile, more and more consumers and local energy cooperatives develop heat and cooling infrastructure by installing low enthalpy heat and cold storage pump installations in the shallow subsurface directly below their home, apartment complex or their neighbourhood. Industrial sites also see these facilities developed.

The energy transition has consequences for the electricity network. Traditionally, the network was intended for one-way traffic from supplier to end user. Meanwhile, more and more consumers and local energy cooperatives are generating their own electricity from, for example, the sun and wind. That is why the network operators make the electricity network suitable for two-way traffic. In addition, network operators are looking for smart and efficient solutions to absorb and bridge the peaks in supply and demand.
Both the heat transport network as the electricity networks require intelligent monitoring at local, regional and national scale for load balancing and operations to become Smart Grids. Hence a large high bandwidth of the fibre-optics network as key 'conductor' in the telecommunications is required, together with an upgrade to 5G for the mobile telecom network to enable high speed data connections across the entire country.

Climate adaptation strategy: The Netherlands are facing the largest dike reinforcement task in the country's history. Due to stricter safety standards adopted by the Dutch government, facing the acceleration of the sea-level rise due to climate change, 1,100 km of dikes have failed to pass the safety tests and will require repairs and maintenance by the year 2028.

Annually a total investment of 4 billion euros will be made. The strategy consists of creating space for rivers to overflow. Smarter strategies to enforce the dykes depending on innovative technology: small and high where possible and wide and strong where absolutely necessary, in order to minimise the impact on the living environment and society.

Not only the dikes need reinforcement due to climate change. Extreme rainfall and prolonged periods of droughts require that urban areas be made climate proof. All Dutch municipalities have to adapt the urban living environment to cope with heat and also have to perform a water stress test. Nearly 85% of the municipalities have to upgrade the capacity of the sewage system and create water retention areas, underground buffer and storage capacity in existing urban areas. Urban spatial planning for new housing and neighbourhoods are using the existing geomorphology for creating urban wadi's to retain water during flash floods and to cool in hot periods. The municipalities, provinces and waterboards plan to invest a total investment of 28.5 billion euros per year until 2030 for the implementation of the climate adaptation strategy, circular economy and energy transition.

Transport network: Substantial investments will have to be made in mobility to maintain economic growth and to fulfil the reduction in CO2 emissions. The capacity of the national railways and light rail network has to increase substantially to accommodate for daily commuters in the urban areas in order to keep up with the increasing population density. A new infrastructure has to be built for electric cars and trucks in the urban area and along the motorways. In addition, economic growth of Rotterdam harbour and Amsterdam Airport demand space in already densely populated urban living environment.
The implementation of the above-mentioned policies and ambitions compete for space in a densely populated country. They are also interdependent: e.g. the housing policy is linked to the energy transition and the gas-free ambition by 2050. The climate adaption strategy is evident to protect the urban area and vital economic infrastructure. Hence the subsurface and utilities network play a vital role in both the realisation of the energy transition and climate adaption strategy.

Therefore, integrated 3D spatial planning above and below the surface is required, combining both the surface geographic objects with subsurface objects both natural (endogenic: e.g. soil, groundwater) and manmade (anthropogenic: e.g. cables and pipelines, cold-heat storage (WKO), tunnels and parking garages). For the new Environment and Planning Act (Omgevingswet) and the National Spatial Planning Policy (NOVI) this is essential. It is also needed for legislation on environmental impact assessment (MER) to be in line with the EU. The geographic objects in the living environment at the surface are visible to policymakers, spatial planners, and citizens. However, the cables and pipelines and soil types, geological formations, groundwater and geothermal potential are hidden below the surface. They can only be made visible in 3D virtual models of the subsurface. Hence integrated spatial planning of the living environment above and below the surface can only be executed in a 3D virtual representation combining both geographic objects at the surface (GIS), utilities and manmade constructions (3D BIM) and Geoscientific 3D Models (Soil, Geology, groundwater) of the subsurface in a “Digital Twin” of the living environment

2. Literature review

European Cost *Sub-Urban Action* (TU1206) Urban Geology examples of integrated spatial planning of the subsurface and interference of function in a number of capital Cities in Europe. Very local scale, it lacks the regional and national scale as well often related to a single issue tunnel construction, energy transition or water management. Sub-Urban is a European network of Geological Surveys, Cities and Research Partners working together to improve how we manage the ground beneath our cities. Iincreasing urbanisation throughout the world challenges the sustainable development and resilience of cities. Despite this, the importance of the ground beneath cities is under-recognised and often overlooked. The main aim of the Sub-Urban Action is to provide a long-needed contribution to greater interaction and networking, and so transform the relationship between experts who develop urban subsurface knowledge and those who can benefit most from it - urban decision makers, practitioners and the wider research community. Their focus is mainly on urban planning, urban geology, and subsurface and cities like A Coruña; Bergen; Dublin; Glasgow; Hamburg; Helsinki; Ljubljana; Nantes; Novi Sad; Odense; Oslo; Rotterdam.

Resilience Brokers Programme (Peter Head : https://resiliencebrokers.org/) and The European Institute of Innovation and Technology (EIT) Climate-KIC, Europe's largest public-private partnership, using systems innovation to build resilient, net zero-carbon cities. Also focusses on a local city scale, however also on the natural system in the region surrounding an urban area. The national scale is ignored.

Adaptive marine spatial planning in the Netherlands sector of the North Sea by Leo de Vrees of the Ministry of Infrastructure and Water Management, Rijkswaterstaat is integrated regional spatial planning approach however not at a national level, also less relevant for the urban areas.

The integrated spatial planning method as described in the *Casus Amstelstad* by Joyce van den Berg of the Amsterdam Physical Planning Department integrates the higher levels of regional and long term planning into to the details of public space design. They search for new approaches and stimulate bottom up processes to integrate solutions in the field of urbanization, mobility and water management in multidisciplinary teams both above and below the surface.

In general, it can be concluded that in literature the integrated spatial planning above and below the surface often is limited to local urban areas and major cities. The above literature sources lack the regional and national scale. However, our experience in the Netherlands is that it is prerequisite for a national spatial planning policy.

3. Methodology

3.1 Data driven policy making

Since 2002 the Dutch government, as part of their open data policy, developed and implemented a National Spatial Data Infrastructure (SDI) based on the implementation of a limited number of geographic key registries. The large- and small -scale topography, (BRT, BGT), Buildings and Addresses (BAG) and the Land registry (BRK) are based on a national standard (NEN3610) and domain specific information models (IMGEO). In 2008 this SDI was extended with the Information Exchange Underground Networks Act (WION/WIBON) and the national Cable and Pipeline Information Portal (KLIC). In 2018 the key register of the Subsurface of the Netherlands (BRO) completed the initial SDI. Currently a new initiative as part of a continued development strategy of the National SDI aims at the integration of the initial topographic key registries at the earth surface with the BRO and KLIC in one 3D topographic object registry of the living environment above and below the surface. This involves standardization and harmonization of the current domain specific information models at a national level (the DIS GEO-3D program) and a data driven policy. With this initiative, the Dutch government aims to strongly improve the accessibility of spatial data information in order to support the required integrated 3D spatial planning policy above and below the surface at local, regional and national scale. And also to enable spatial and urban planners to use instruments as “Digital Twins” of the living environment in support of NOVI. Future development of the SDI encompasses the incorporation of real time sensor data in the public space in order to enable monitoring of the effects of the policy measures, support the climate adaption strategy and manage uncertainties due to climate change and processes in the subsurface.

3.2 NOVI with regional and local implementation agendas. geospatial analysis

According to a perspective for 2050, the NOVI presents a long-term vision. The national government aims to set and maintain a course to fulfil the national interests. These interests are clustered in four priorities:

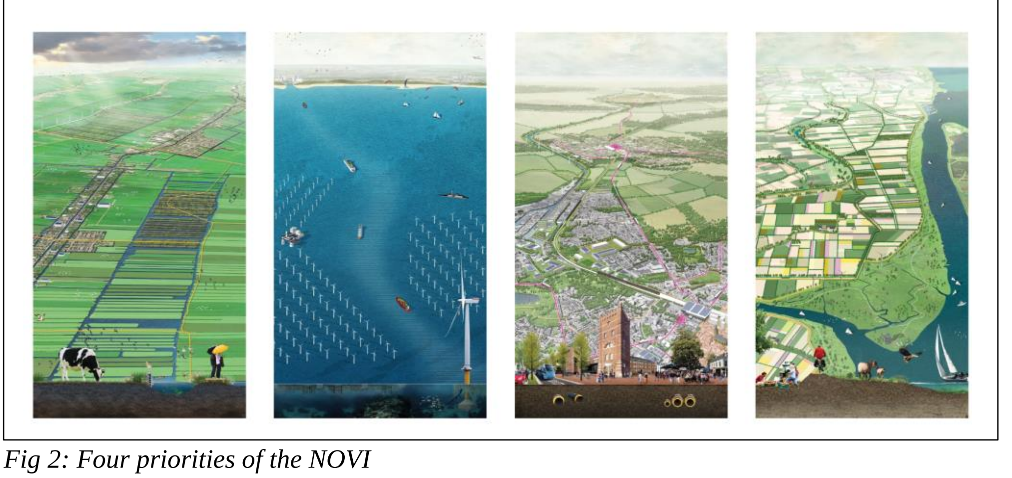


Fig 2: Four priorities of the NOVI

1. Space for climate adaptation and energy transition
The Netherlands must adapt to the consequences of climate change, such as sea level rise, higher volumes of water discharge via the rivers, flooding and longer periods of drought. By 2050, the Netherlands must be climate resilient and water robust. This calls for measures in the living environment, for example ensuring sufficient planting and space for water storage in our cities. A useful side effect is that these measures at the same time improve the quality of the living environment and increase opportunities for nature.

By 2050, energy supply in the Netherlands must be renewable. This requires space, for example for wind turbines and solar panels. The preferred option is offshore wind, but onshore wind farms will also be required. By clustering these facilities as far as possible, fragmentation across the landscape will be prevented, and will ensure maximum efficiency in the use of space. At all times, the essential precondition is that local residents be fully involved and retain influence over the use, and wherever possible can also enjoy the benefits. As far as possible, we must limit the construction of solar farms in the landscape. The preference is to install solar panels on roofs and facades. The national government will reserve sufficient space for the main energy system, on a national scale.

2. Sustainable economic growth potential
The Netherlands is working towards becoming a sustainable, circular, knowledge-intensive and internationally competitive economy by 2050. This will enable the country to maintain its position in the top five of most competitive countries in the world. This in turn requires good connections by road, rail, air, water and digital networks, and close collaboration with our international partners, both our immediate neighbours and other countries in Europe and across the globe. The Netherlands' aim is to achieve a solid and innovative business establishment climate, combined with good quality of life.

It is nonetheless essential that the Dutch economy becomes future-proof, in other words that it is competitive, sustainable and circular. The focus will be on the use of renewable energy sources and changes in production processes so that we are no longer reliant on finite, fossil fuels.

3. Strong and healthy cities and regions
First of all, new locations for housing and employment are needed in our urban regions, so that rural spaces between the various urban centres are retained. This will require optimal harmonisation and investments in mobility. At the same time, we wish to improve the quality of life and climate resilience of our towns, cities and villages. Cleaner air, sufficient green space and water and adequate public facilities where people can exercise (walk, cycle, enjoy sport and play), relax and come together. That in turn calls for excellent connectivity and accessibility. We aim to ensure that the quality and security of the living environment keeps improving. This means that before new locations are selected for urbanisation, it must be clear what requirements need to be met in terms of the quality and safety of the living environment, and which additional measures are needed when these locations are chosen. This will help guarantee the health of our cities and regions. We will however not be focusing exclusively

on growth. We also aim to strengthen vitality and quality of life in rural areas outside urban centres.

4. Future-proof development of rural areas
A new perspective is emerging for the Dutch agricultural sector as a pioneer in sustainable cyclic agriculture. In this form of agriculture, a healthy earning potential for farms is combined with a minimum effect on the quality of the air, soil and water. This approach also makes a positive contribution to improving biodiversity.
In certain peatland areas, water levels will have to be raised. Agreements must be concluded with the affected regions and users on how to bring this about, with due caution. In all cases, we will continue to develop the typical characteristics of the Dutch landscape, that represent an essential cultural historical value. Cluttering and fragmentation of the landscape, for example through the uncontrolled expansion of distribution centres, are undesirable.

Consideration principles
The pressure on available space in the Netherlands is so overwhelming that interests often collide. The national government will strive to achieve combined solutions and win-win situations, but this is not always possible. Sometimes, difficult choices have to be made and, in those situations, interests must be balanced.

Implementation
The NOVI outlines an Implementation Agenda which not only clarifies the efforts already being undertaken by national government, provinces and municipalities but also identifies which (joint) actions will be added, as part of the NOVI. The Implementation Agenda will be further elaborated to coincide with the final NOVI, taking account of the opportunities and risks identified in the Strategic Environmental Assessment (SEA – PlanMER).

The intention is that the NOVI will be adaptable to new developments, in a permanent and cyclic process, on the basis of a sound NOVI monitor.

National, provincial, municipal governments and water boards will work together as one body. The NOVI approach is a shared responsibility of all authorities. Individual citizens and businesses are not legally bound by the strategy in the NOVI.

Wherever necessary and possible, it is important that the environmental strategies of national government, provinces and municipalities are harmonised. To make that possible, the existing Area Agendas will have to be expanded into more wide-ranging Regional Agendas. These encompass the full scope of environmental policy and may evolve into the essence of a working system of environmental policy. These Regional Agendas will be drawn up in consultation with all levels of government, for all parts of the country.

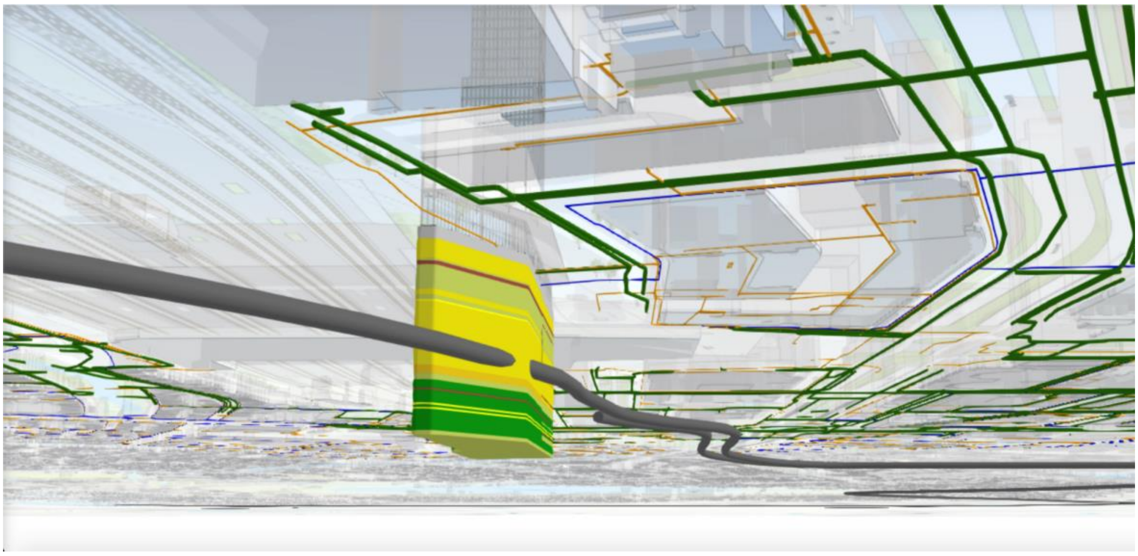
The convergence of the various national interests and the scale of the tasks mean that, in certain areas, arriving at suitable solutions will be a real challenge. In these areas, additional efforts on the part of national government, provinces, municipalities and water boards will be needed, since it is not possible to achieve the intended results within the existing frameworks. With that in mind, specific NOVI areas will be identified.

Open process
The NOVI was drawn up in consultation with the responsible Ministries, and municipal, provincial and water authorities. Input was also had from advisory boards, knowledge centres, private parties, civil society organisations and individual citizens. The dialogue with and between all these stakeholders will not cease when the (draft) NOVI is published. It will remain an open process in which public consultation represents an intrinsic part.

4. Conclusions

In order to meet the ambitions of the national government it can be concluded that integrated 3D spatial planning above and below the surface is essential and even legally required. For the new Environment and Planning Act (Omgevingswet) and the National Spatial Planning Policy (NOVI) this is essential. It is also needed for legislation on environmental impact assessment (MER) in line with the EU. Combining both the above topographic objects with subsurface object both natural and manmade.
The geographic objects in the living environment at the surface are visible to policymakers, spatial planners, and citizens. However, the cables and pipelines and the soil types, geological formations, groundwater and geothermal potential are not and remain hidden below the surface in the physical world. They can only be made visible in 3D virtual models of the subsurface. Hence integrated spatial planning of the living environment above and below the surface can only be executed in a 3D virtual representation combining both geographic objects at the surface (GIS), utilities and manmade constructions (3D BIM) and Geoscientific 3D Models (Soil, Geology, groundwater) of the subsurface in a “Digital Twin” of the living environment. A digital twin can either be a 3D static virtual representation or 4D dynamic in which the effects of changes can be simulated over time.

By a data driven policy and the new initiative as part of a continued development strategy of the National SDI involving the integration of the initial topographic key registries at the earth surface with the BRO and KLIC in one 3D topographic object registry of the living environment above and below the surface. The Dutch government aims to strongly improve the accessibility of all spatial data information in order to support the required integrated 3D spatial planning policy above and below the surface at local, regional and national scale. As well to enables spatial and urban planners to use instruments as “Digital Twins” of the living environment in support of National Spatial Planning Policy (NOVI). Future development of the National SDI encompasses the incorporation of real time sensor data in the public space in order to enable monitoring of the effects of the policy measures, support the climate adaption strategy and manage uncertainties due to climate change and processes in the subsurface. Not only for the energy transition and climate adaptation strategy but also for other purposes such as protection of assets and underground infrastructure such as Fibre-optics networks, heat transport networks and Smart Grids.



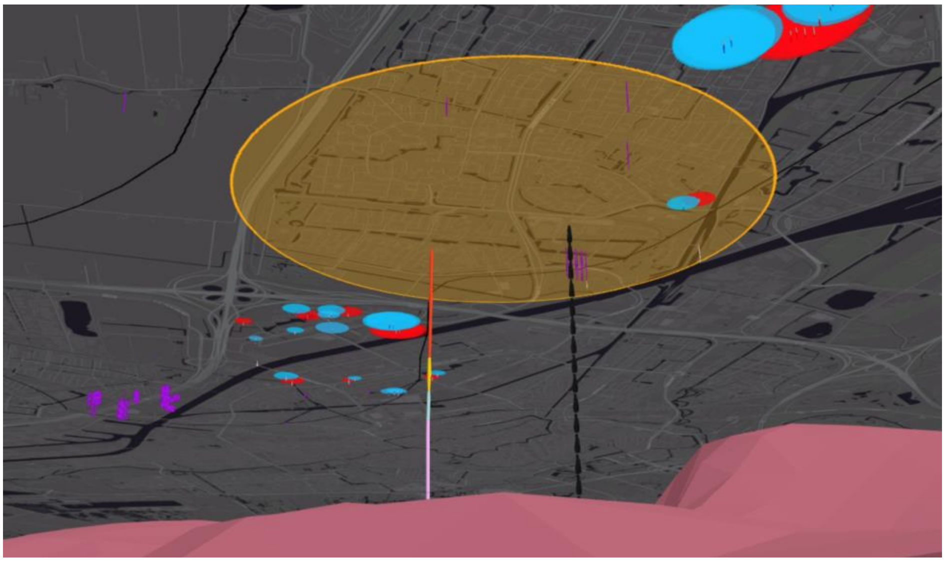


Fig 3 "Digital Twins" of the living environment in support of National Spatial Planning Policy (NOVI).

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Kamerbrief bij Ontwerp Nationale Omgevingsvisie
Minister Ollongren (BZK) biedt de Tweede Kamer het Ontwerp van de Nationale Omgevingsvisie (NOVI) aan.

Kamerstuk: Kamerbrief | 20-06-2019 Ontwerp Nationale Omgevingsvisie

De Nationale Omgevingsvisie (NOVI) biedt een duurzaam perspectief voor onze leefomgeving. Rapport | 06-06-2019 Toelichting Ontwerp Nationale Omgevingsvisie Rapport | 06-06-2019 Rapport | 06-06-2019 Achtergronddocument Ontwerp Nationale Omgevingsvisie Dit achtergronddocument bevat gebiedsbeschrijvingen op basis van de gebiedsdialogen die zijn gehouden.

http://sub-urban.squarespace.com/

BIOGRAPHICAL NOTES

Martin Peersmann : Since 2015 until present seconded by the Kadaster at the Ministry of the Interior and Kingdom Relations as Program manager Key registry of the Subsurface of the Netherland responsible for the implementation and legislation of this key registry. From 2008 until 2015 Director-secretary LSV GBKN; a public-private partnership between the Network operators, Kadaster and Central, provincial and municipal government. Responsible for the transition and implementation of the key registry Large Scale Base Topography (BGT). From 1997 until 2008 Head of Department responsible for management of all subsurface data and information of the Netherlands (DINO) including the Mining Law at the Geological Survey of the Netherlands (NITG-TNO).

Caroline Groot : Mrs Caroline Groot is Product Manager of the Cable and Pipeline Information Centre (KLIC) at the Cadastre, Land Registry and Mapping Agency in the Netherlands (Kadaster) and responsible for the national portal for digital information exchange of cable and pipeline information in the Netherlands. In the period 2006-2012 she was a senior consultant Strategy and Policy (2006-2012), focussing on topography, Spatial Data Infrastructures, subsoil, innovation processes and alliances. Before joining Kadaster, she worked as a GIS and Remote Sensing teacher at the International Agricultural College Larenstein in Velp, the Netherlands.

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