Chapter 5
Networks as the Driving Force for Climate Design

Rob Roggema and Sven Stremke

Contents

Abstract In this chapter the potential transformation of an area and the role networks can play is discussed. For a far-future transformation, the current situation as well as the near-future, already taken policy decisions, function as the starting point for the design. Network theory is subsequently used to identify the crucial nodes in the networks where a potential transformation is likely to be successful. These nodes can be defined making use of the common rules of networks. Some points in networks are better (more intensively) connected with more links, than others. These hubs, the more attractive nodes to link with, get richer, which makes them even more attractive to link with, which makes them richer and so forth. The places where

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these successful nodes are located can be identified and calculated as has been shown in the exercise in this chapter. The number and importance of connections as well as the typology of the nodes (a place consisting of one type is less attractive than if three networks overlap) play an important role in determining the interesting locations. Once these are found they can be used in the design, as is illustrated in the Peat Colonies case study. The structure of networks, with spines, nerves and nodes, in combination with a clear and specific objective leads to challenging and sustainable designs.

Keywords Network theory • Nodes • Intensity • Climate adaptation and mitigation • Spatial design

5.1 Introduction

When a region needs to undergo a transformation and include more climate adaptive design measures and strategies, current planning frameworks are not sufficient, as has been outlined in Chap. 4. One of the most crucial elements to influence in the spatial system, are the networks. Changes in the network types, structures and intensities determine changes in the system as a whole. Three time-horizons can be distinguished: now, near-future and far-future. 'Now' is reflecting the current situation. Networks are taken as unchanged in thinking about future changes. 'Near-future' includes all kind of policy decisions and plans that are already taken. A map of the near-future situation includes the networks as if they were already realised and taken is the base for future change. 'Far-future' identifies the potentially optimal and beneficial nodes and connections as well as required adjustments in current or near-future networks. Networks, as well as the focal points, the most important nodes are seen as a crucial basis for planning. Following the layer approach they form the first pair of layers and determine the major spatial directions for the longer-term future.

In this chapter theories about networks are briefly discussed and used to identify spatially the most important nodes and connections in networks. Subsequently this information is used to form the basis of a spatial planning framework for climate adaptive planning.

5.2 Network Theory

In this section theories about networks are briefly discussed and the concepts that are relevant and useful in spatial planning are illuminated.

Network theory is a field of computer science and network sciences and is also part of graph theory (the study of graphs and mathematical structures). Network theory is often deployed to examine the method of characterizing and modelling complex networks. Many complex networks share some common features, such as scale-free degree distribution. Network theory is applied in multiple disciplines, including biology,

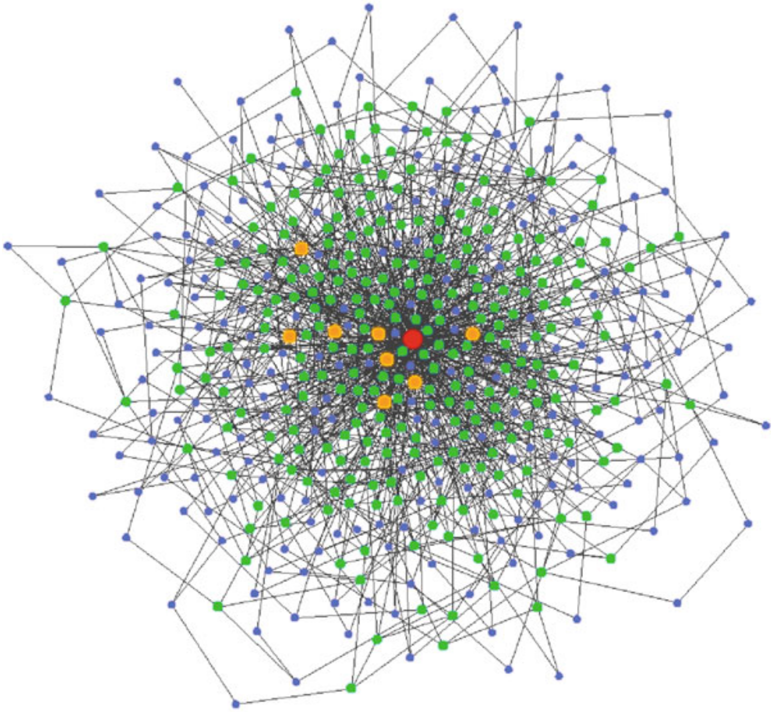

Fig. 5.1 Diagram of a scale-free network containing components with a highly diverse level of connectivity. Some components form highly interconnected hubs, while other components have few connections, and there are many levels of interconnectivity in between (Oikonomou and Cluzel 2006)

computer science, business, economics, particle physics, operations research and, most commonly, in sociology [www.techopedia.com/definition/25064/network-theory]. The interesting thing is that no matter for which discipline networks are used and analysed, the rules and laws are valid. The network architecture of evolution, the 'scale-free network' (Fig. 5.1), characterises the interaction network of proteins in yeast, worms, fruit flies and viruses, but also pervades social networks and computer networks, affecting, for example, the functioning of the World Wide Web (Oikonomou and Cluzel 2006).

All share common characteristics and many of the images showing striking similarities, such as social and self-organising networks (Fig. 5.2) the computer and economic networks (Fig. 5.3), the biological and neural networks (Fig. 5.4), the World Wide Web representations (Fig. 5.5) and the networks used in the Afghan stability operation (Fig. 5.6) and for the human genes (Fig. 5.7). In all the different networks some nodes are more crucial and have more connections than others. These are the nodes where major changes are more likely to take off. This information can be used to inform spatial planning. In Newman et al. (2006), the following network concepts are distinguished:

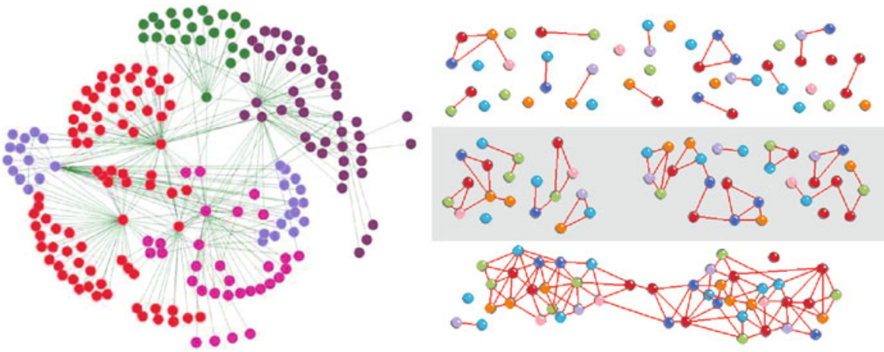

Fig. 5.2 Representation of a social network, *left* [http://en.wikipedia.org/wiki/Social_network, Copyrighted: Creative Commons] and self-organisation in networks, *right* (Nagler et al. 2011)

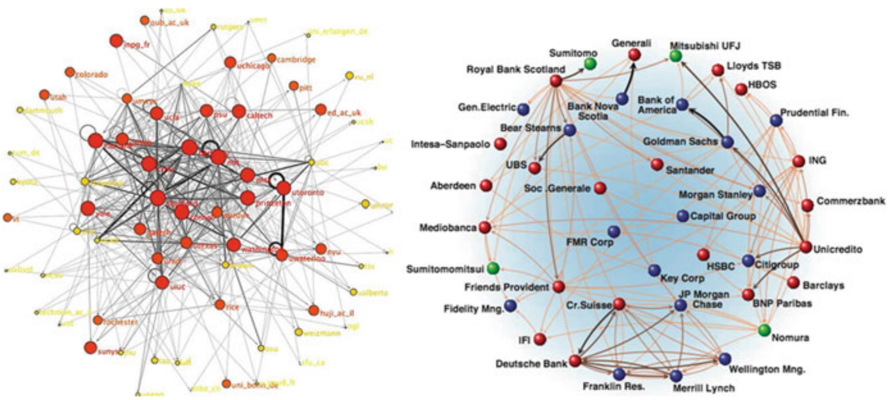

Fig. 5.3 Similarities in representation of a computer network, *left* [www.flickr.com/photos/anikarenina/238385060/] and an Economic network, *right* [www.mcn.ece.ufl.edu/public/YuejiaHe/network.htm]

1. For many years network theory was dominated by the belief that only random networks exist. The number of individual entities, nodes, was so large that whatever connections would be made, an even and equally distributed network would be the result. Only by adding edges, e.g. more contact points and therefore connections, the network, suddenly, gains quality. This theory of random network was developed and elaborated in several publications (amongst others: Erdós and Rényi 1960; Barabási 2003).
2. Later, dominant theory described the scale free network, in which certain nodes determine cores and other parts of the network then become periphery. This type of network can be described at any scale. The small world effect (Watts and Strogatz 1998) describes the characteristics of these networks: if the number of nodes in the network increases, while connected by a short path, which can be randomly added, the total length of paths will increase logarithmically and a high level of clustering will occur. These clusters are the core-groups in the network, connected by 'bridges' (Buchanan 2002), or the hubs and connectors (Barabási 2003);

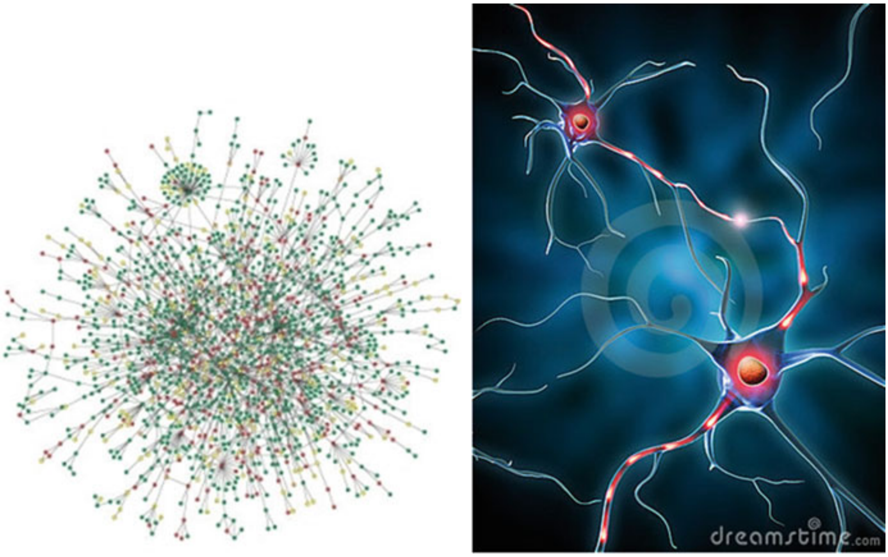

Fig. 5.4 The Biological network [www.thp.uni-koeln.de/~lassig/projects.html] and the Neural network [www.dreamstime.com/royalty-free-stock-photography-neural-network-image11819917]

3. The distribution of small and large hubs is described through a power law: there are only few (big) nodes in the network with many links and there are many small nodes with only few links (Barabási 2003; Buchanan 2002). Nodes that already have many links are more attractive to link with than small nodes, and the result of this is that rich nodes become richer;
4. The connectivity between nodes is increased through randomly additions of shortcuts and connections. The seemingly random new links will connect the nodes that are fittest in competing for links (Bianconi and Barabási 2001). This fitter-gets-richer (Barabási 2003; Buchanan 2002) phenomenon helps to understand the evolution of competitive systems in nature and society;
5. Robust networks are formed by interconnected nodes, which are highly clustered and know a minimum distance between any pair of randomly chosen nodes (Solé et al. 2002). This 'topological' robustness is rooted in the structural unevenness of scale free networks. The chance that a failure hits one of the few highly connected nodes in the middle of an endless amount of small nodes is minimal, which allows the network to recover and to keep functioning (Barabási 2003; Buchanan 2002);
6. Directed networks, such as for instance the World Wide Web, consist of a core (a giant strongly connected component), links-in and links-out as well as other islands and tendrils, represented visually by Broder et al. (2000) as a bow-tie (Fig. 5.8) (Barabási 2003);

When these network characteristics are translated to spatial structures and elements, as demonstrated by Castells (1996) or Graham and Marvin in their Splintering

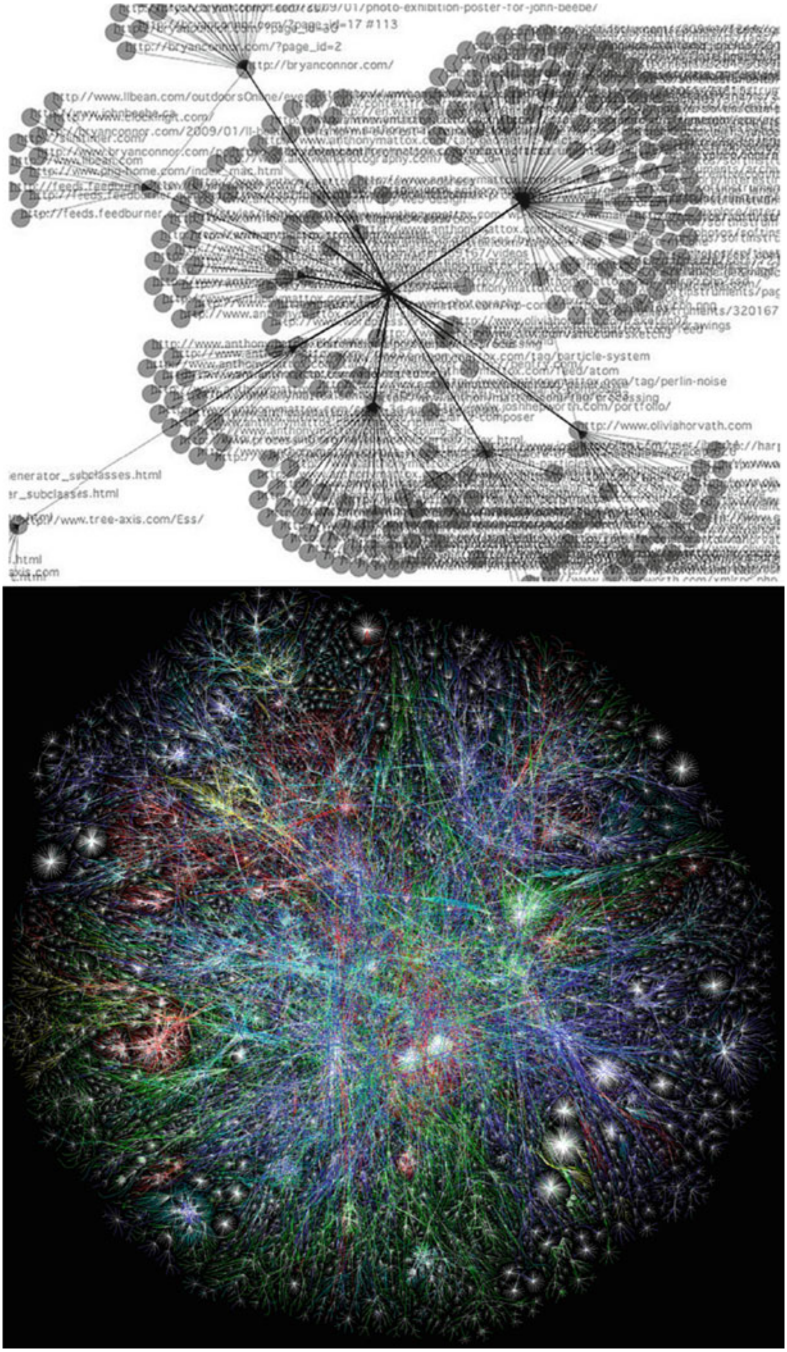

Fig. 5.5 Representations of the World Wide Web, *left* [www.flickr.com/photos/amattox/3236510649/], and *right* [www.mirror.co.uk/news/uk-news/20th-anniversary-of-world-wide-web-381974, Copyrighted: http://creativecommons.org/]

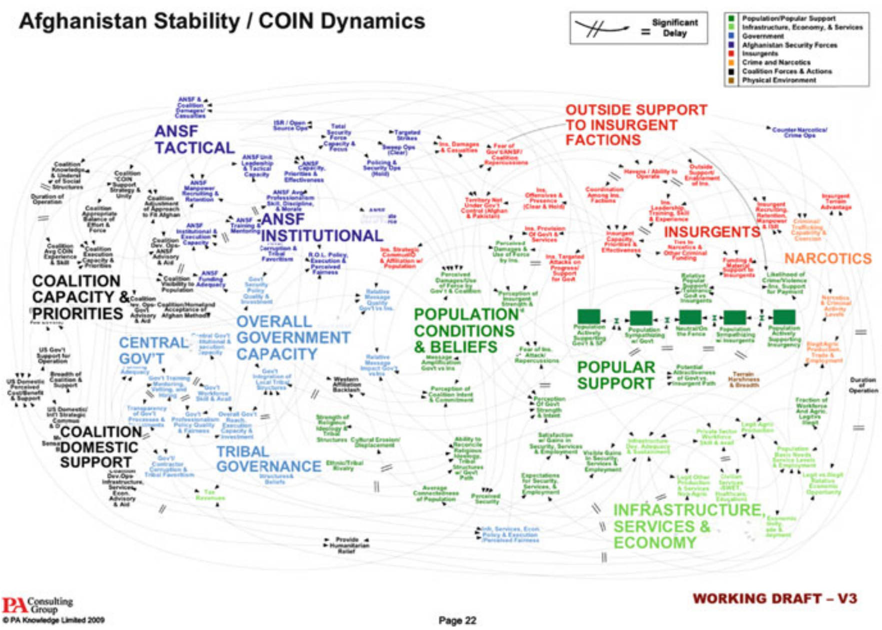

Fig. 5.6 Strategic network for the Stability operation in Afghanistan (PA Consulting 2009)

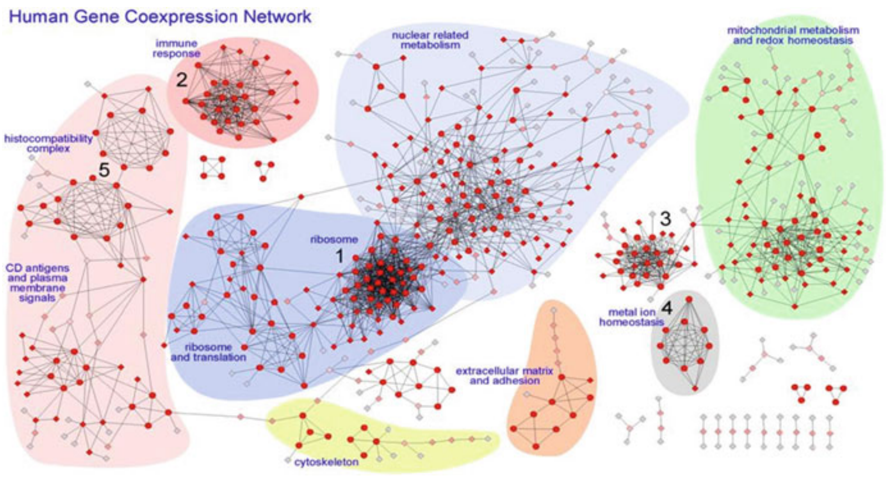

Fig. 5.7 Graphical view of the Human gene co-expression network, where the nodes correspond to genes and the edges to co-expression links (Prieto et al. undated)

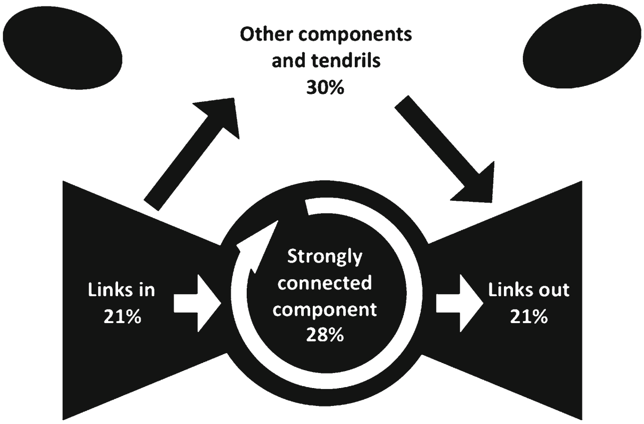

Fig. 5.8 The 'Bow-tie', with a core, links and islands and tendrils (Broder et al. 2000)

Urbanism theory (2001) of super-positioning intertwining infrastructure,[1] the following general rules of network theory made useful for spatial planning were found:

- The amount of nodes in combination with certain random connections (creating a 'small world');
- Presence of 'rich' cores with many connections;
- Existence of 'fit' nodes, attractive to connect with;
- Clustering and minimal distances in combination with peripheric areas where small nodes with few links and longer distances are found;
- 'Islanding' of several parts only accessible for specific functions, connected through a giant strongly connected core.

These principles determine specific spatially defined locations within networks, where the most likely changes might take place. When an area needs to transform to a more resilient region, these starting points for change or, where novelties can be developed that offer the change of changing the current stable regime, need to be identified.

5.3 Explorations on Intensities

The application of the above principles is in essence an exercise to discover the intensity and importance of nodes in the network. The places where a clustering of strong and important nodes occurs are seen as the richest and fittest nodes. Where

[1] Graham and Marvin (2001) describe the intertwined infrastructures of electropolis (energy), hydropolis (water), cybercity (Internet), railcity (train) and autocity (car) super-positioned on top of each other.

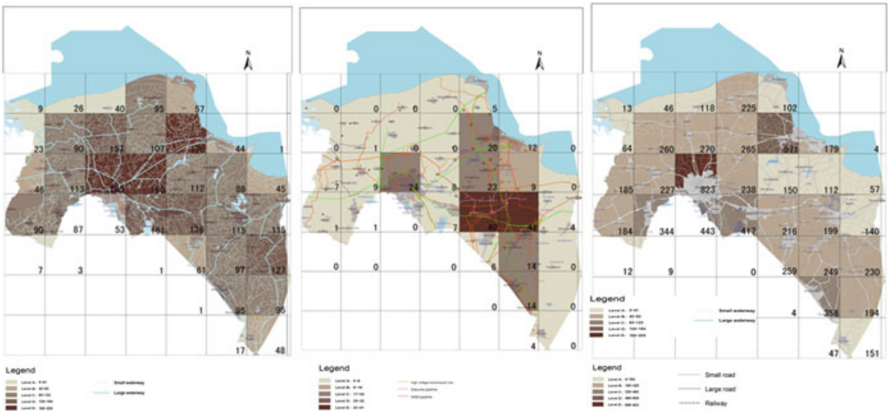

Fig. 5.9 The network maps of water, energy and transport (Hao and Wang 2010)

many nodes are present within a small area the connectivity is higher. This intensity represents the richness of the node. Where nodes of many different functional types, such as water, energy or transport, exist, the more attractive it is to link. The combination of the two reflects an overall value for an area. The higher the value the more likely new links will develop, adding strength and growth to the existing cluster.

This exercise has been conducted in Groningen province (Hao and Wang 2010). The networks were analysed in three steps: (1) the density of individual nodes per area and (2) the number of different overlapping network types at one physical location. The final step (3) in this exercise was the combination of the two steps in one overall value per grid-cell.

1. The first step examined the density of nodes, defined as: the number of nodes within a grid-cell of 10 × 10 km, combined with their importance (the bigger, the more important). In this study the importance was weighted as follows: a minor infrastructural element, such as a small local road, a little stream or a household electricity gridline counts for a factor 1, a mediocre element counts for a factor 3 and a major element, such as a freeway, high voltage power-line or a main canal or river counts for a factor 5. The number of nodes times their respective importance gives the value for each grid-cell. The results, in the form of specific maps for energy, water and transport, are shown in Fig. 5.9, in which the darkest colours represent the most intense places;
2. The second step analysed the number of different network types that form a node: single (only water, energy or transport), double (overlap of any combination of two out of three) or triple (all of them overlap) nodes. In case of a double node, the calculation is multiplied by a factor 10 and in case of triple node by a factor 100. Within each grid cell of 10 × 10 km, each node was multiplied with the appropriate factor and the total value was calculated by adding all node values to reach a total score per cell;

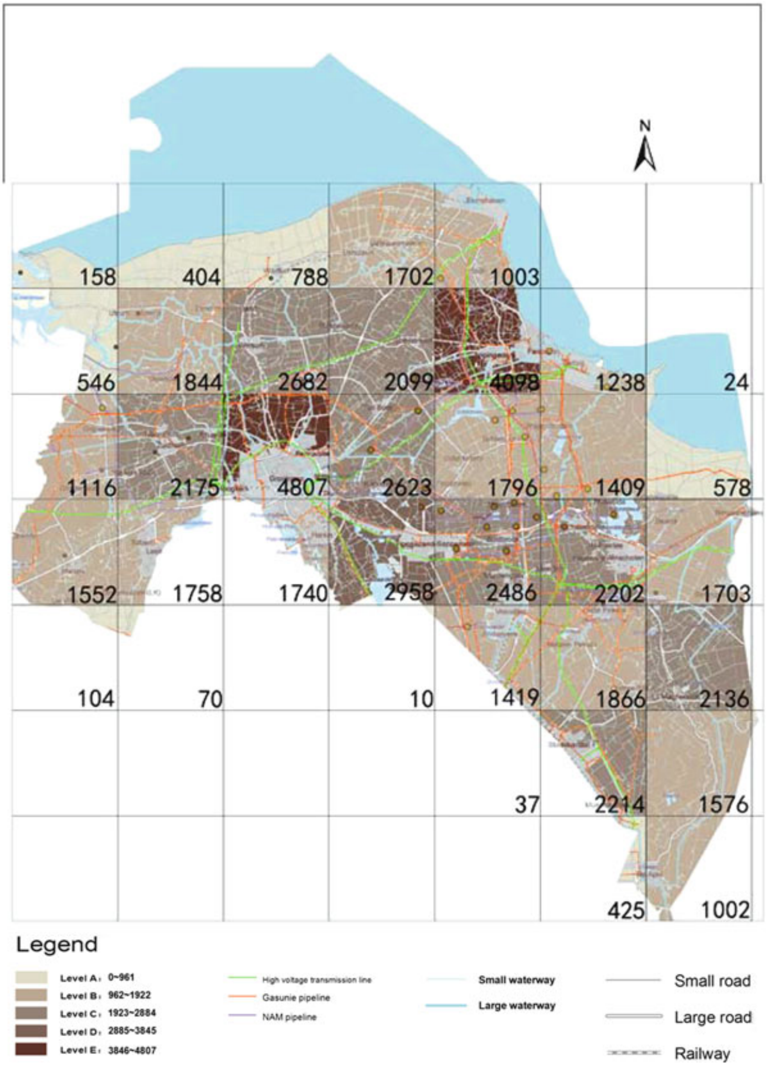

Fig. 5.10 Integrated intensity of networks for Groningen area (Hao and Wang 2010)

3. In step three, the values of first step, individual networks and second step, network types were added to give the total score for each grid cell (Fig. 5.10). The darkest colour represents the highest values. Higher values imply stronger and more intense, well-connected clusters, where change is more likely to occur.

The integrated map illustrates that in certain grid-cells change is more likely to start than in others. When an area needs to undergo change, these highly intense and well-connected clusters offer the highest probability.

5.4 Application in the Peat Colonies

A good example of how network analysis informs climate design is the Peat Colony area, where both adaptation and mitigation issues have been integrated in the design. The current Peat Colony area is typically characterized through large agricultural fields. Almost 60% of the area is arable land, followed by 14% cattle grazing. In contrast with the Hondsrug (‘Dog ridge’) in the west, the Peat Colonies contain only a small forest area (7%) and heather (2%). Considerable surface is devoted to industry (1,451 ha) and greenhouses (288 ha). With regard to network elements, the Peat Colonies have a dense and extensive network of small ditches (total of 1,974 km) and large ditches (656 km). The transportation system consists of streets (1,903 km), local roads (960 km), regional roads (378 km) and main roads (247 km). Currently, there is only 12 km of highways present. A total of 154 km of high voltage electricity lines are found in the region.

In order to envision alternatives futures for the long-term development of the Peat Colonies, it is not only important to map current conditions in the area but also necessary to have a good understanding of possible development in the near future (Fig. 5.11). Development of nature areas presents the largest possible land-use change in the near future.

5.4.1 Water Network

The Peat Colonies are known for their straight canal structure (Fig. 5.12), which was created to dry the area and transport peat to cities elsewhere in the country. Ditches less than 3 m wide (1.974 km) and canals between 3 and 6 m wide (656 km) constitute a fine grid of water network, which again are connected via the larger canals (189 km) (Fig. 5.12). The total surface of open water in the region amounts to 2.892 ha, which is about 4% of the total surface.

The water network is very dense and consists of numerous small and tiny ditches, especially in the North Western and central parts of the Peat Colonies. Several larger waterways cross the area from South to the North, of which the Hunze (the most western one), the Mussel Aa and Ruiten Aa (both in the East) are natural formed rivers. The major artificial canals, the Stads Canal and the Wildervanks Canal run from South East to the North. There is a string of waternodes found in the southern area, connected to the Verlengde Hoogeveense Vaart as well as between the two parallel running canals of Stadskanaal and the Wildervanks Canal all the way from Ter Apel in the South via Stadskanaal towards Veendam. A same string of potential rich nodes is identified in the parallel running Ruiten Aa and Ruiten Aa Canal to the East, but outside the study area. These (potentially) intense nodes (Fig. 5.13) form the points in the water network, which are most likely to be developed. In case new canals will be created, the nodes change accordingly.

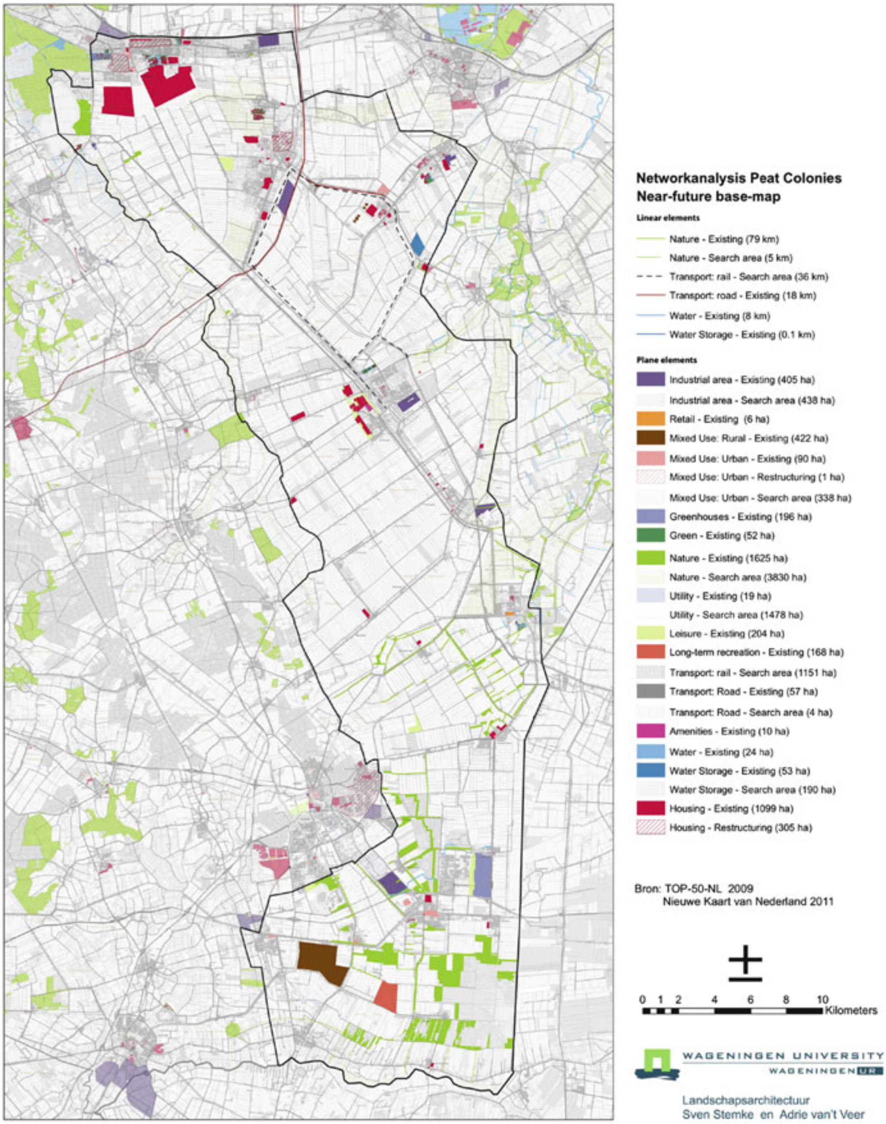

Fig. 5.11 Near-future base map Peat Colonies [www.kaart.nieuwekaart.nl]

5.4.2 Energy Network

The energy network (Fig. 5.14) of the Peat Colonies consists of high-voltage electricity lines (154 km), gas networks (national and NAM: 123 km) and regional and local gas pipelines (350 km), an old oil pipeline and at least two heat networks. The energy demand is for the largest part determined by industrial uses and built-up areas.

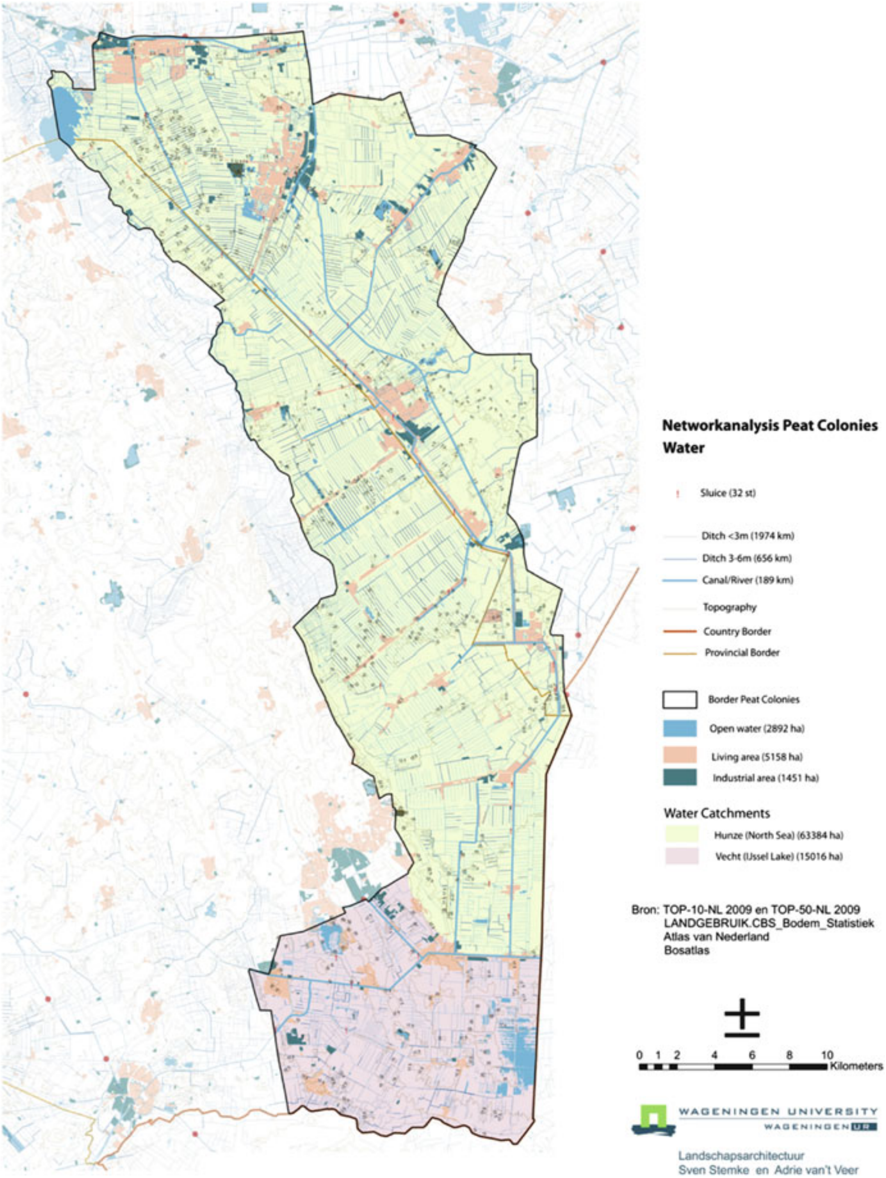

Fig. 5.12 Overview of water network in the Peat Colonies (Broersma et al. 2011)

The gas distribution network is very dense in built-up areas, but limited to the national grid outside these areas. The main gas-line crosses the area from North, where the gas is extracted, to the South. This gas-line crosses the area without having any relation within the area at the moment. There are potentially places where nodes of energy exchange can be created, for instance where the gas-line crosses main transport infrastructure, such as the provincial roads. These connection points form

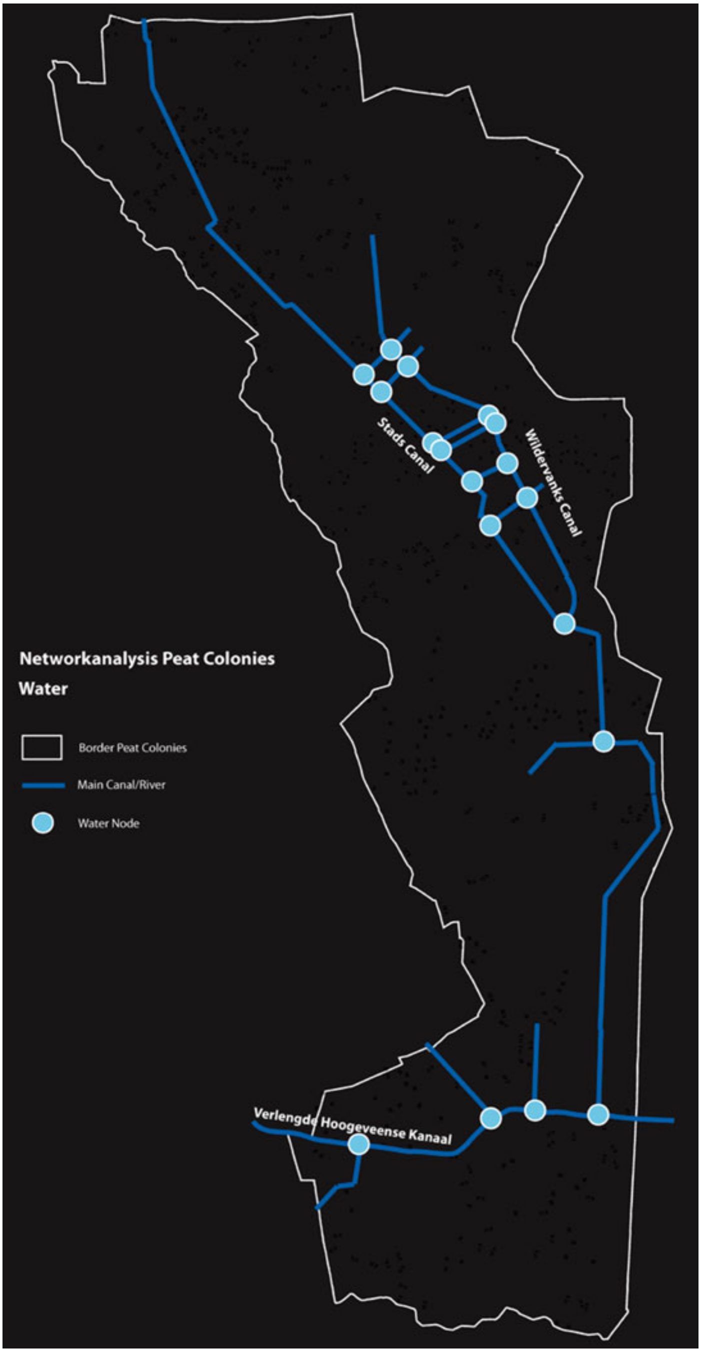

Fig. 5.13 Intense nodes in the water network

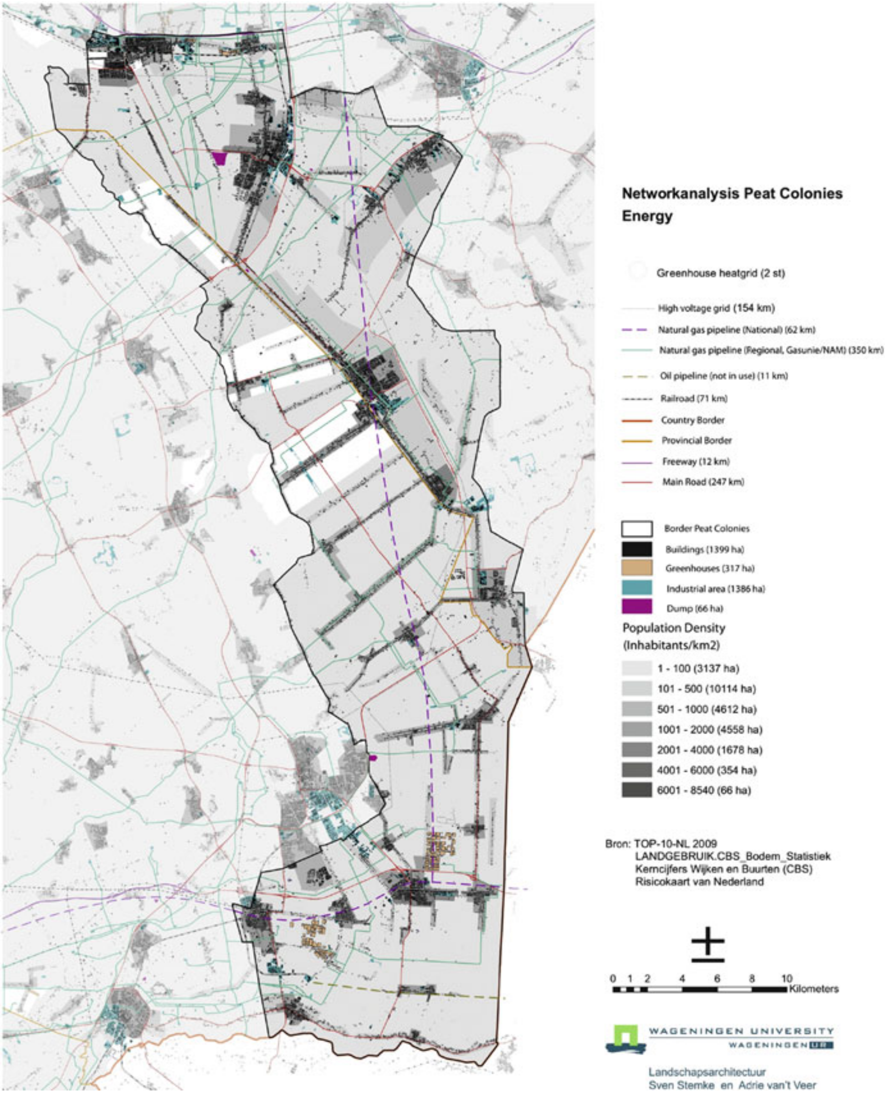

Fig. 5.14 Overview of the energy network in the Peat Colonies (Broersma et al. 2011)

nodes of intensity (Fig. 5.15), where new urban developments are more likely to start, given the presence of energy and access. Other potential development areas, are found where the gas-line and existing urban areas meet, such as near Emmen and Stadskanaal. The high-voltage line flows a slightly different route, but also crosses from North to South. For this line the same is true as for the gas-line; it hasn't many relations with the area yet. These might also be developed, for instance where this line crosses the main transport network, crosses the gas-line or can be directly linked with existing built-up areas, such as Veendam, Hoogezand, the Pekela's, Musselkanaal, Ter Apel and Emmen.

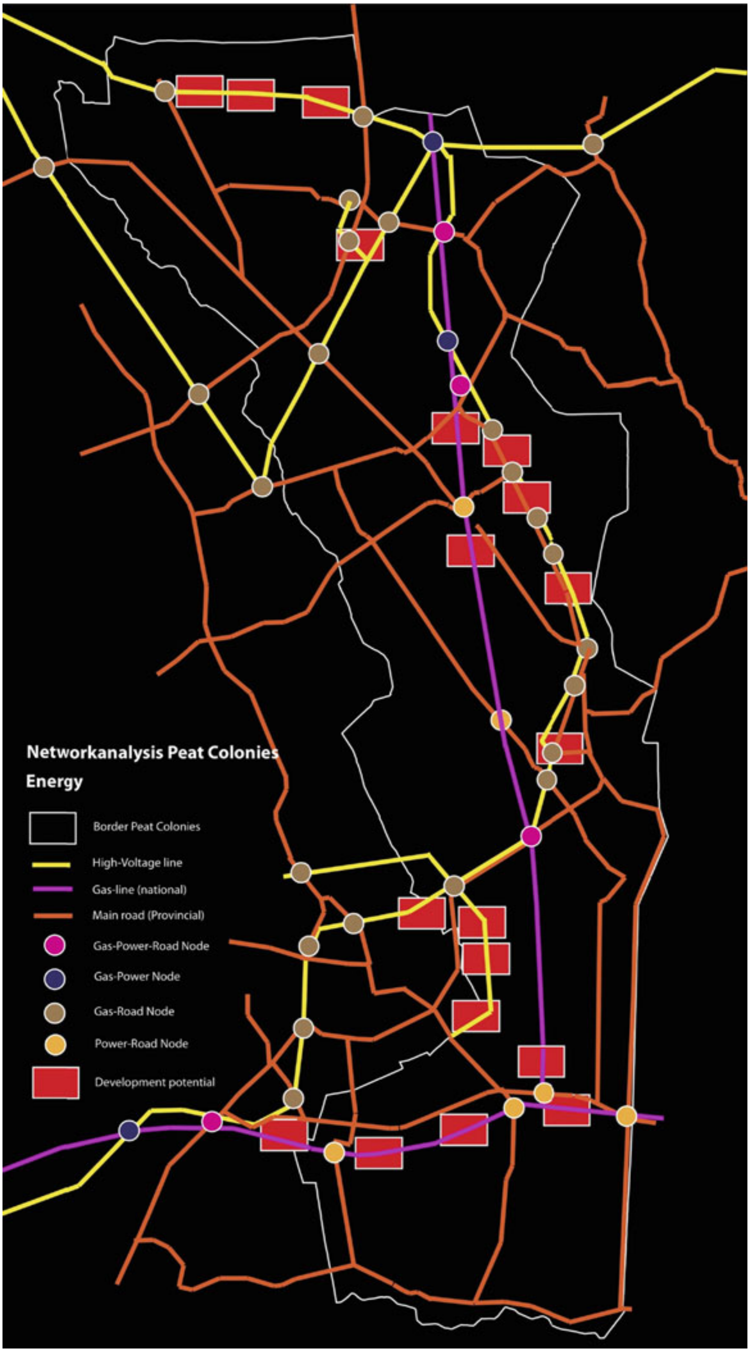

Fig. 5.15 Nodes in the energy network

5.4.3 Transport Network

The transportation network (Fig. 5.16) is similar to many other border regions and is rather underdeveloped. There exists an extensive road network (3.487 km). Railroads from the North and from the South are disconnected. An extensive bus transport network runs through the area and connects the main settlements.

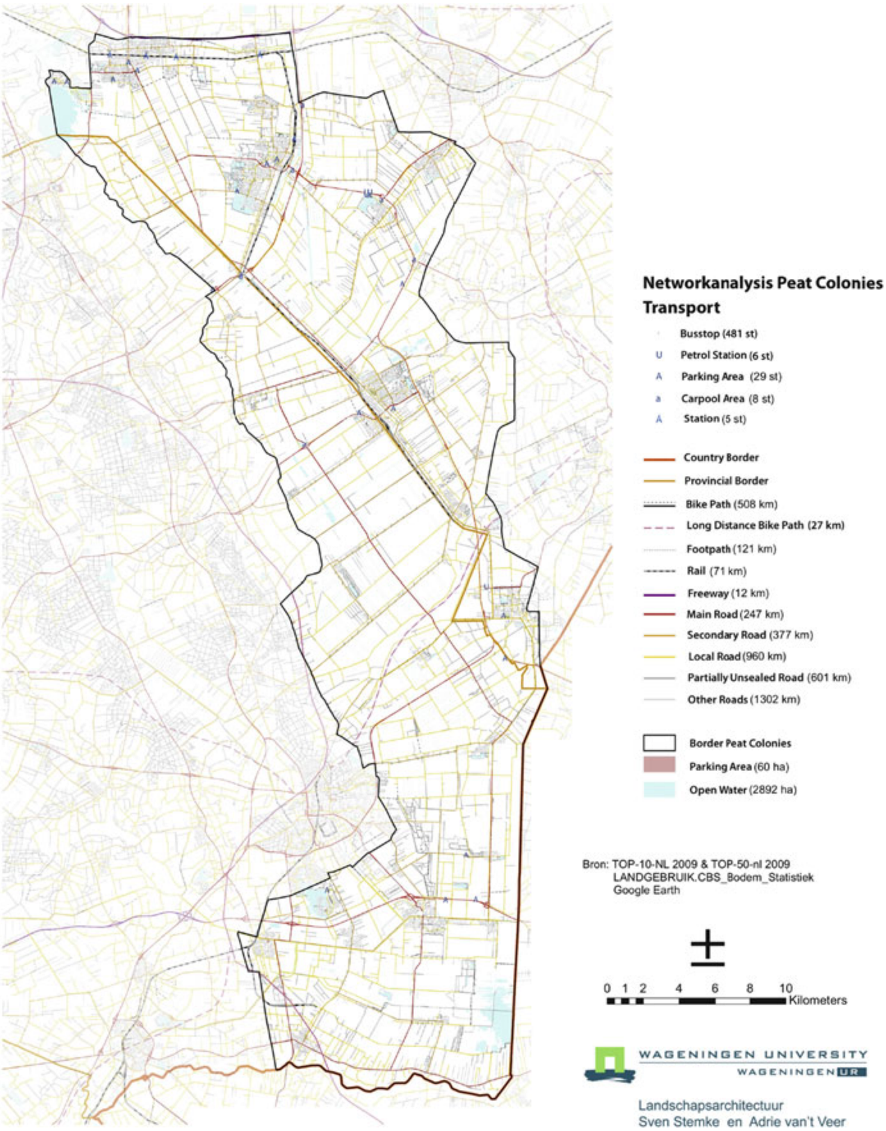

Fig. 5.16 Overview of transport network in the Peat Colonies (Broersma et al. 2011)

The main elements in the transport network are the main roads inside the area. Freeways are only present in the South and just outside the study area, North of Hoogezand. The main roads are of provincial importance and connect Ter Apel-Groningen and Emmen with Veendam. Both routes are crossing each other near Wildervank, which makes this a potential intense node in the transport network (Fig. 5.17). Where long-distance bike roads and railroads cross the car network, potential intense nodes are identified. These nodes and the existing petrol stations and railway stations complete the field of important nodes. Main infrastructure adjacent to existing built up areas, is potentially likely for emergent urban developments, in this case the most obvious, such as Emmen, Stadskanaal, Ter Apel, Veendam and Hoogezand.

5.4.4 Two Climate Designs for the Peat Colonies

On the basis of the network analysis of the water, energy and transport network two spatial models have been designed: 'Lonelycolony' and 'Peatcometro' (Broersma et al. 2011). The places where interventions are proposed were, in both models, determined through the location of the strongest, best-connected (the 'richest and fittest') clusters of nodes. Each of the climate designs take a sustainable energy supply as the starting point, but integrate climate adaptation strategies and measures in the designs.

5.4.4.1 Lonelycolony

The 'Lonelycolony' model (Fig. 5.18) is based on the aim to solve the energy demand on a scale as local as possible. Therefore, small-scale, decentralised renewable energy supply is proposed, which needs to lead to self-sufficiency within individual municipalities. All locally available energy potentials will be used to save energy and supply from renewable resources. As a result, in this model the Peat Colonies will become autonomous, e.g. it becomes independent from import and variable, rising oil prices. Because of the fact that many strategies and measures are found at the local scale, it improves opportunities for job creation and stimulates the regional economic development. Moreover, the short transportation distances imply minimal energy loss.

The network analyses on water, energy and transport are used to design this model. The main choice has been to create strong clusters in core settlements in each of the municipalities. The crucial clustering is located where the central spine in the water network, the main canal with its ramifications, links with the transportation network. The places where locally available energy potentials make a self-sufficient energy supply possible form the core developmental areas. In each of the municipalities one or two of these small-scale places the heat supply (rest-heat from industry, geothermal heat and greenhouses) is provided through underground networks. Each individual house is stimulated to generate its own energy, but can use centrally generated electricity

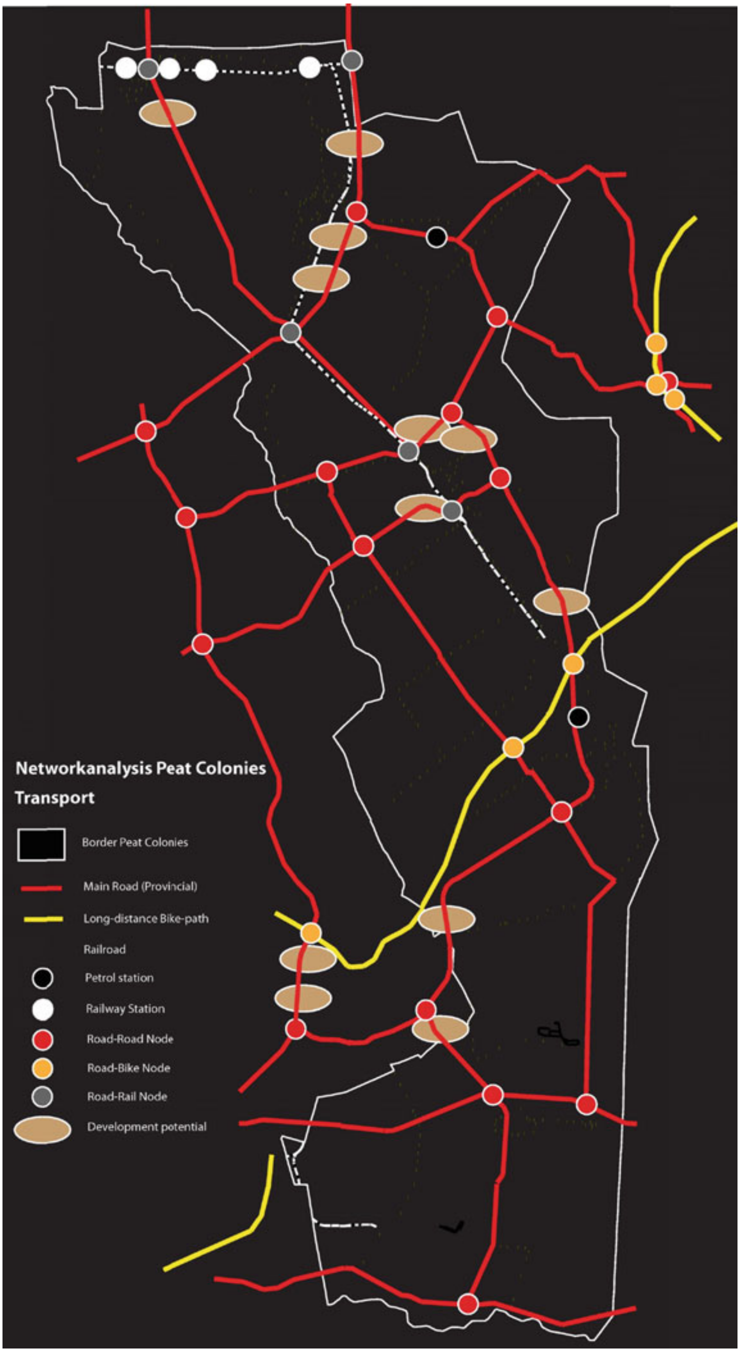

Fig. 5.17 Nodes in the transport network

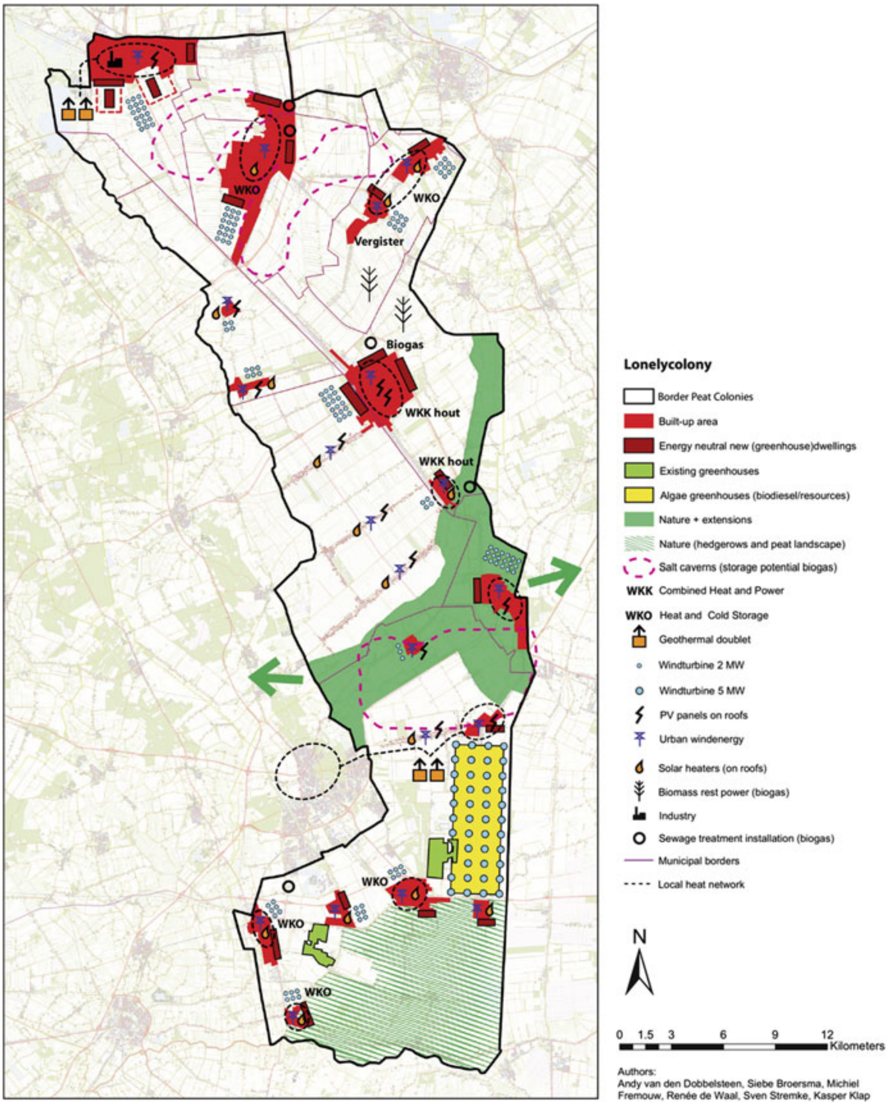

Fig. 5.18 The climate design ‘Lonelycolony’ (Broersma et al. 2011)

from small wind-turbines, of which several are placed in each core. New houses can be built under the condition that they will be made energy-neutral. Outside these core areas, households need to provide their own electricity and heat supply (PV, solar heating and small-scale wind-power). In addition, centrally located extensions of existing greenhouse complexes and a wind-park supply the residual demanded heat and electricity.

The most intense places in the water network determine the location for an area, where additional water-storage, nature- and forest area is developed. From this area the surplus of biomass, is used to produce heat and electricity using bio-CHP's (biomass Combined Heat and Power installations).

5.4.4.2 Peatcometro

The 'Peatcometro' model (Fig. 5.19) uses the available renewable resources efficiently and on a large-scale. On top of the ambition to become fully self-sufficient in the Peat

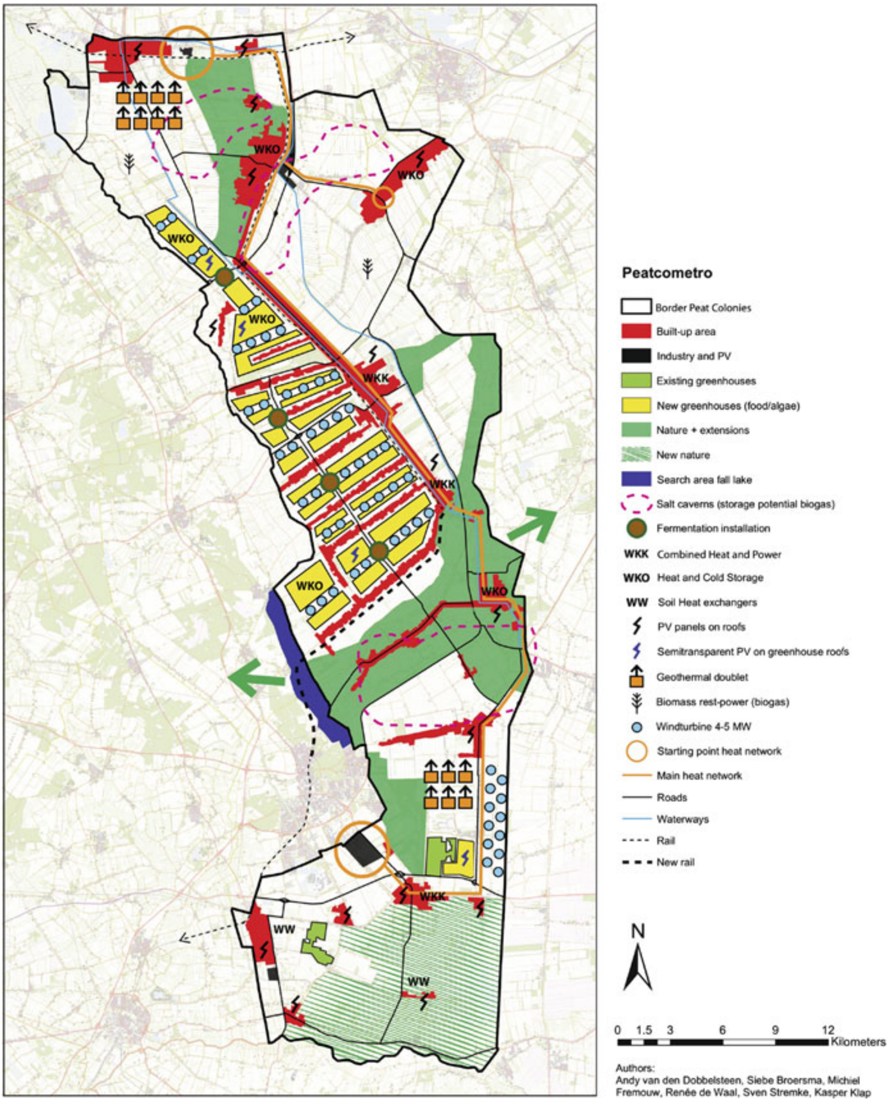

Fig. 5.19 The climate design 'Peatcometro' (Broersma et al. 2011)

Colonies, the potential to become a net exporter of energy is explored in this model. All local potentials to supply energy are fully used in order to provide the area itself and the surrounding, more urbanized, areas. Renewable resources are used to generate energy in a centralised way, occupying a large production landscape to maximise the supply of sustainable energy, such as large-scale algae-breeding, lairaged in innovative greenhouses, delivering bio-diesel. In between the green houses large-scale wind-turbines are realised producing, in combination with semi-transparent PV-foil a large amount of electricity. Both the placing of wind-turbines and the PV-foil on greenhouse roofs mean multiple use of space, a very efficient and intensive way of energy production. The rest-heat from the greenhouses, together with geothermal heat, is used to heat houses and for export to surrounding areas.

The networks of transport, energy and to a lesser extent water shape the Peatcometro design. Along the central spine of transport routes and its ramifications the exchange of energy is organised, allowing the production units, the greenhouses, which are positioned in between the side nerves of the system (consisting of existing water network, existing roads and additional energy transportation infrastructure), to connect easily to the network. The water in these side-nerves of the networks is essential to supply the algae production with enough, constantly available and clean water. The location of those side waterways determines therefore the structure of the climate design. At the end (or beginning) of these side nerves, new nodes and hubs are introduced where energy from the distributed production units links with the central exchange system. At several places the major networks connect with the surrounding areas in order to make further distribution possible. The major spines in the water network form the base to develop huge forest and nature areas.

5.4.4.3 Integrated Design

Both models were subsequently integrated in one renewable energy vision (Fig. 5.20), which formed the basis for a structure image, in which all ingredients were represented. The existing water network is taken as the basis for the structure image. The spatially open structure of canals, the ‘wijken’ (smaller side-canals), often refilled with water, and ribbons (linear villages) is reinforced. Within this main structure two low-lying areas are reserved for floating algae greenhouses, in combination with storage of surpluses of rainwater. These areas function as the connecting zones of ‘waterfarms’ between the eastern and western parts of the Peat Colonies. Economical, ecological, energetic and water functions are combined in these additions to both the water and energy network. The best-connected nodes in the energy network are used to form the starting points of the heat networks. These isolated areas function in the beginning as solitary elements, but can be connected with each other using the energy network, at a later stage. One big robust heat network emerges. Self-sufficient villages are combined with decentralised large-scale energy generation in the South East. Here the innovative Algae greenhouses

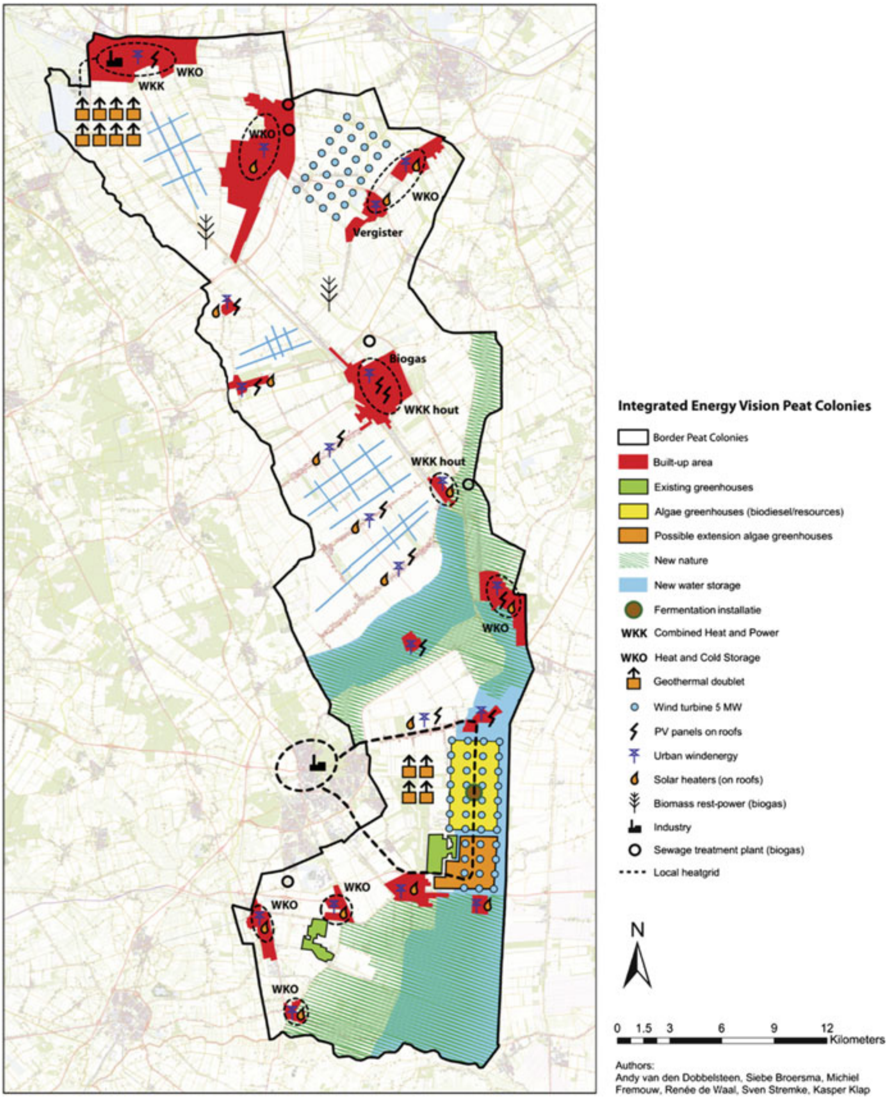

Fig. 5.20 An Integrated climate design for the Peat Colonies (Broersma et al. 2011)

are projected as well. A heat-ring is projected to connect these greenhouses with geothermal production areas and transport the heat towards consumers in the larger towns. Other towns and villages are provided with heat from local supplied renewable energy sources, of which the location is based on the local available renewable energy potentials of heat-generation and storage in the soil.

5.5 Conclusion

Network theory offers a wide range of insight, which can be made useful for spatial planning. Especially when a transformation in a certain area is required, and it often is in case of climate change, the rules and laws of networks are helpful to identify the places in the area where the transformation is likely to be started.

The intensity, richness and fitness of nodes in networks determine to a high extent the importance of these nodes. The more important they are, the more clustering takes place and the more links with other nodes are developed. This makes these intense clustered nodes the places where it is highly likely that new developments or innovation will kick off. In a spatial sense the places where these nodes are located, form interesting places to look for possible change and the start of transformation.

The exercise to identify these places in the Dutch province of Groningen can be seen as the successful first step in identifying the areas where these intense nodes can be found. The case illustrates for the water-, energy- and transport-network that both intensity (richness) as importance and attractiveness (fitness) can be determined and located. These results can subsequently be used in spatial planning and design to locate core areas for intense mixed use and combination of functions.

In the extensive example of the Peat Colonies the detailed network analyses of the three network of water, energy and transport forms the basis for two different climate designs. In these designs climate adaptation measures are combined with mitigation measures, mainly in the energy domain. The results show that the network analyses can be very well used to inform the designs and that, based on the same analysis two fundamentally different models can be designed, both meeting the requirements to become energy neutral and combine adaptation and mitigation measures. In the integrated design however, the strength of the models is somewhat decreased, due to necessary combination of measures originated from two fundamentally different models as well as the influence of 'regular policy', which pursued to support former policies. Despite the fact that the actual design problem was to design a region, which could become a net carbon-sink, a structural different assignment than ever before, recent policies, meant to deal with problems of the past, were pushed to solve the new problem. Which proves to be unsuccessful. It may be concluded here that, when a structural new type problem appears, the old policies need to be excluded from the process.

The Peat Colony example shows that taking a network based approach the major, well-connected nodes in the diverse network can be used in different ways to base the design work on. The spines, nerves and nodes of the networks, in combination with clear objectives ('the adaptive area as a carbon sink'), are easily useable in the design process and are capable of shaping in diverse ways interesting and sustainable designs.

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