DK 2050

Future possibilities
Present actions

Metrics of green conversion

Assessing the effects on transportation, energy, waste and water in Denmark 2050

Compiled by Rambøll

DK
2050

Compiled by

Rambøll

Based on DAMVAD & Kairos Future's four future scenarios for Denmark through to 2050

Part of the DK2050 project

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1. Introduction

DK2050 is an ambitious project, connecting delegates from 10 big and smaller municipalities, four ministries, three regions, foundations and private enterprises in order to encourage innovative thinking and come up with concrete scenarios for how we will live in cities and city regions in 2050 with a goal of securing a green transition. The Danish Architecture Centre is the developer and leader of the project, and Rambøll is participating as a partner in the project.

As part of the project, a scenario report called 'Green growth in Denmark towards 2050' has been compiled, describing four possible roads for Denmark as well as Danish cities and city regions in the green transition through to 2050. This report is developed by DAMVAD and Kairos Future.

Rambøll's job has been to use our professional knowledge to qualify the four scenarios, eg. for use in the architectural and artistic processing of the scenarios which has been handled by three firms of architects, MUTOPIA, SLETH and WE architecture.

The description of the four scenarios – Green state, Green networks, Green guerilla and Green compromises – in report 'Green growth in Denmark towards 2050' has acted as the base of the professionl descriptions.

This report contains a description of the professional evaluations that we have made within transport, energy supply, resources and water.

Furthermore, we have acted as professional sounding boards for the three firms of architects during their work with the project.

Transport, energy supply, resources and water have been chosen as priority areas because of their importance for the green transition towards 2050. Our energy supply especially plays a huge part when it comes to reaching our goals of having freed Denmark from fossil fuels by 2050.

We describe the state of affairs in Denmark in 2014 within each of these fields, and present possible drafts of a state of affairs in 2050 for each of the four scenarios. This is based on our interpretation of the descriptions of the four scenarios.

There is a big difference in the level and degree of details in the discussion of the four professional topics. This reflects both the focus there has been on the topic during the development of the DK2050 project and the frames that were set up for the project.

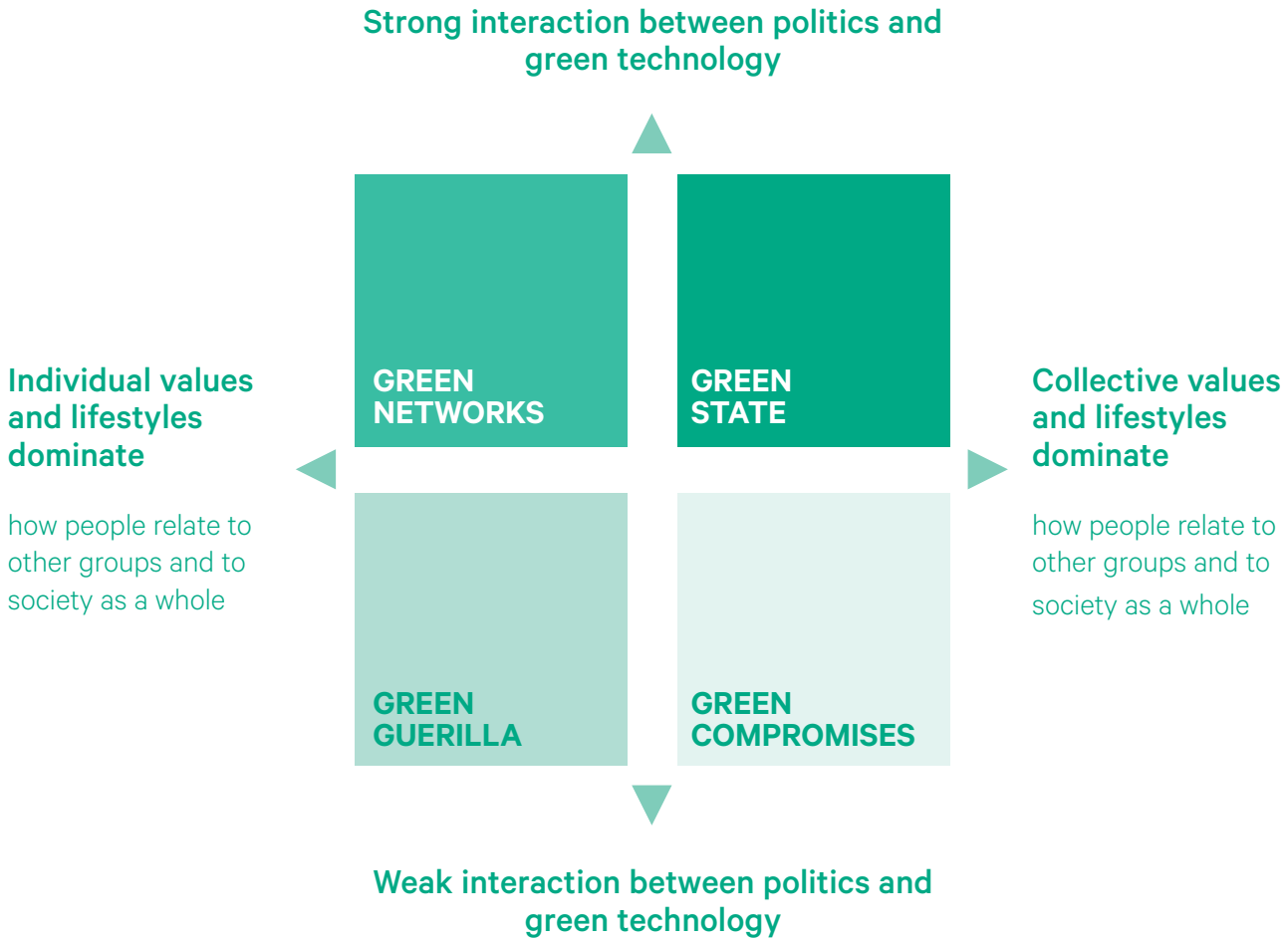


Figure 1.1 The four scenarios of DK2050

2. City structure

Determining city structure in DK2050 in each of the four scenarios is a pivotal premise when it comes to qualifying the scenarios.

The city structure suggestions are determined based on the premises/descriptions of report 'Green growth in Denmark towards 2050'. Here, cities are divided into these three categories:

- Small city regions (< 50,000 inhabitants)
- Medium-sized city regions/suburbs (50,000-200,000 inhabitants)
- Big city regions (the capital, Aarhus, Odense, Aalborg)

The development of all three categories is described further in the scenarios of the report.

In the following material, the classical physical connections have been dissolved in order to view Denmark as divided into national plan areas based on commuter regions cf. The National Plan Review 2013[1] (commuter regions are defined by the fact that 80 percent of people who are employed live and work within the region).

In order to maintain recognizability in Danish settlement geography and for the 10 cities of the project kan recognize themselves, the five largest cities as well as other cities with more than 25,000 inhabitants in each commuter region are mapped out. For the capital area, cities which are thought of as 'connected urban areas' by Statistics Denmark (ie. Greater Copenhagen Area) are seen as one city. The same goes for Aalborg and Nørresundby.

Figure 2.2-2.5 shows the city development trends in the commuter regions in the four in the scenarios.

1 Cf. figure 2 in http://naturstyrelsen.dk/media/nst/Attachments/ForslagTilLandsplanredegoerelseSKAERM.pdf

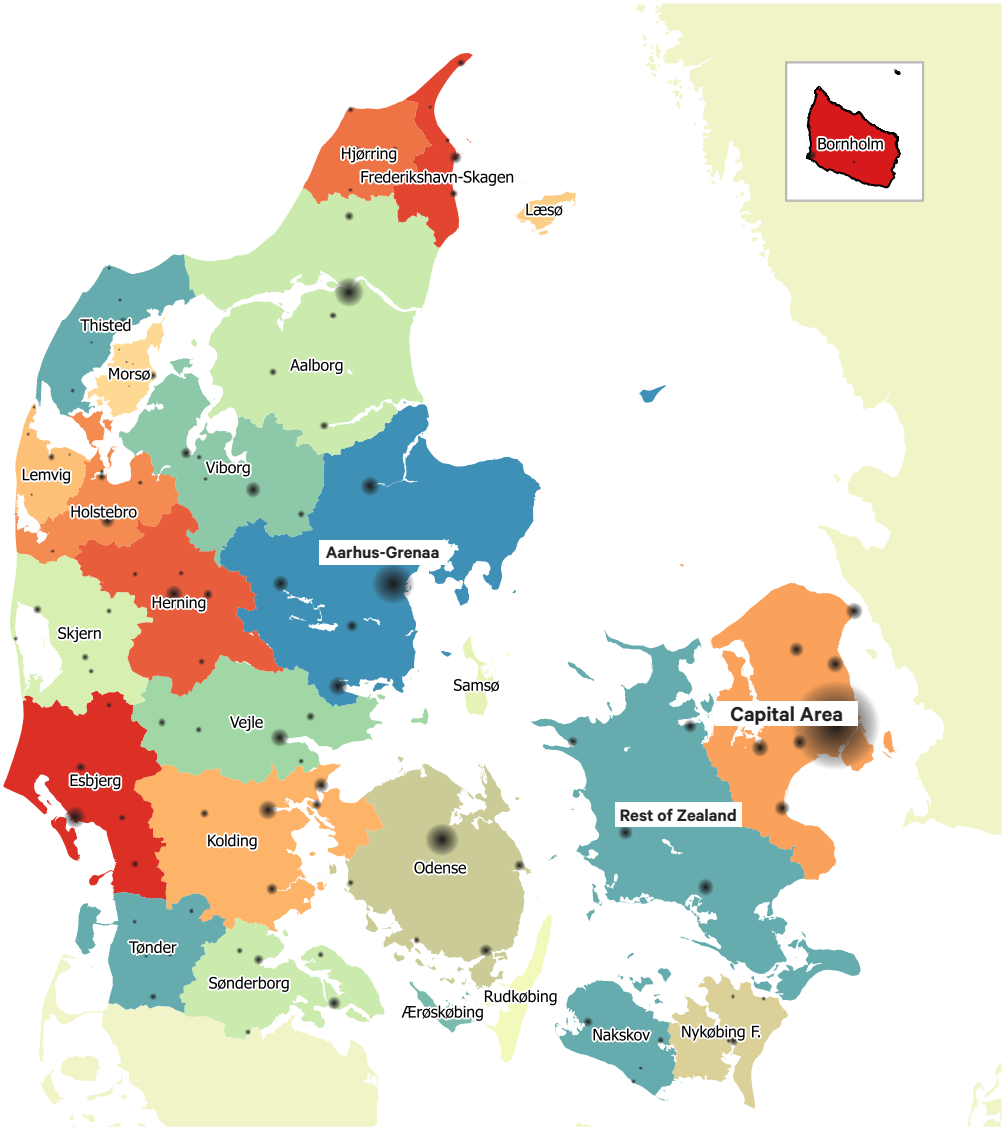
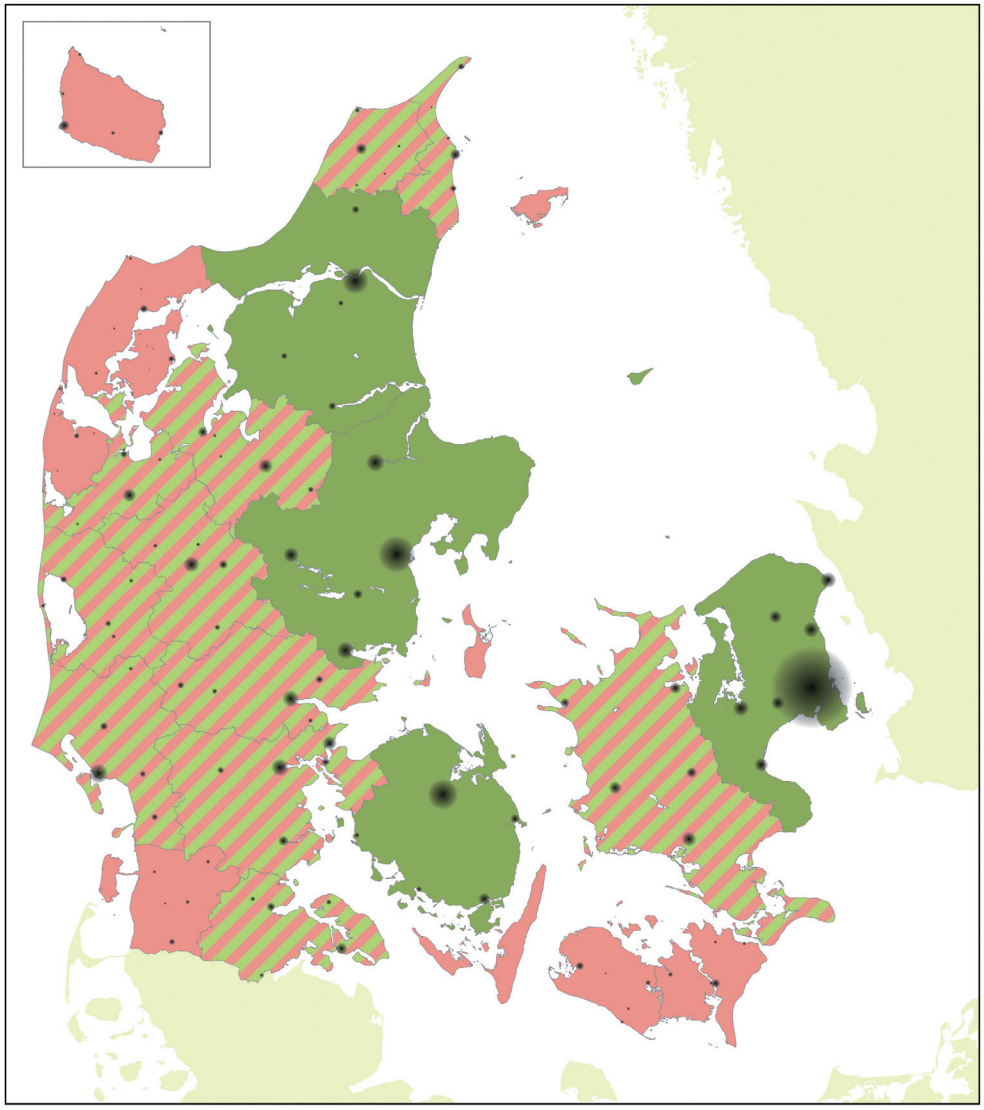


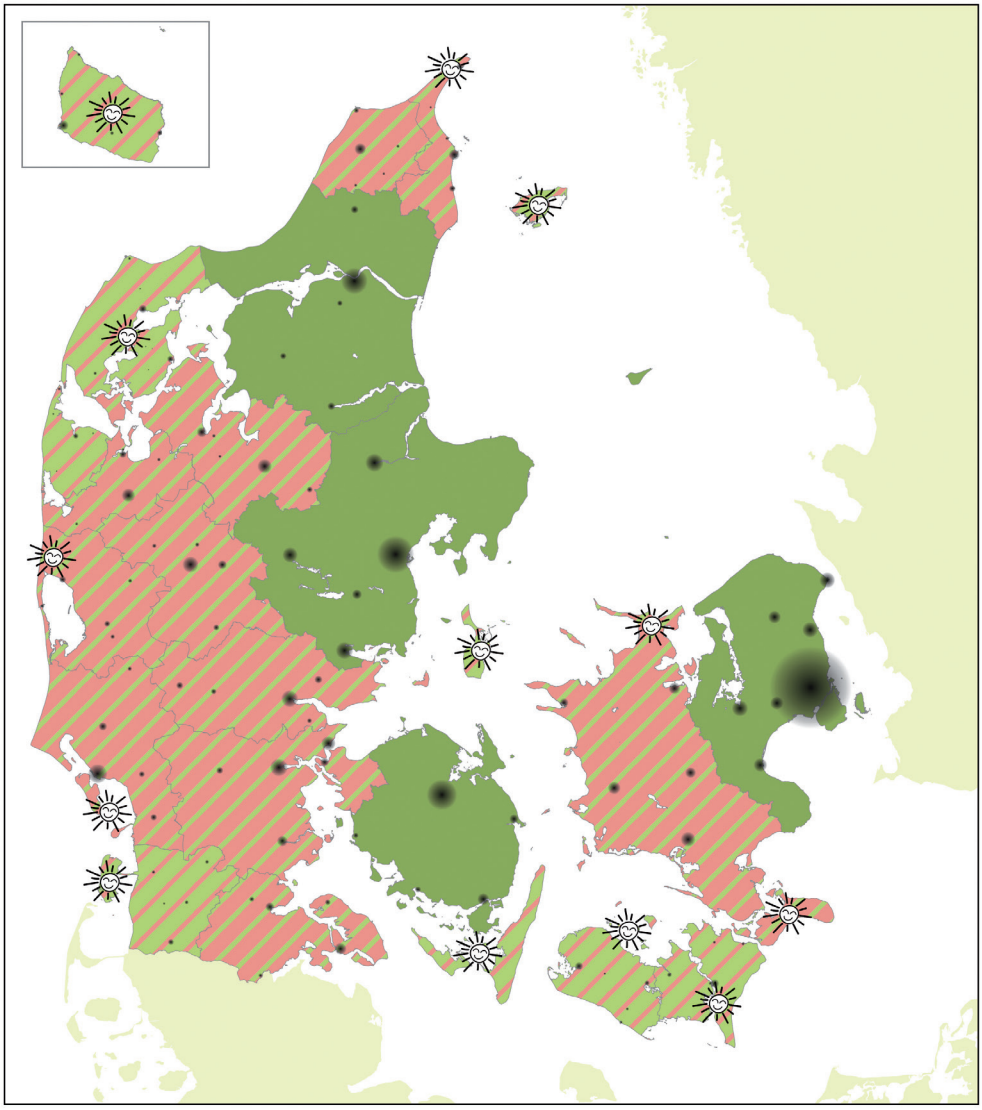
Figure 2.1: National plan areas/commuter regions cf. The National Plan Review 2013



Green state Development trends in commuter regions

- Large growth centralized around the big cities
- Some medium-sized cities do well, others not so well
- Stagnation in small towns

Figure 2.2: City development trends in Green state scenario



Green networks Development trends in commuter regions

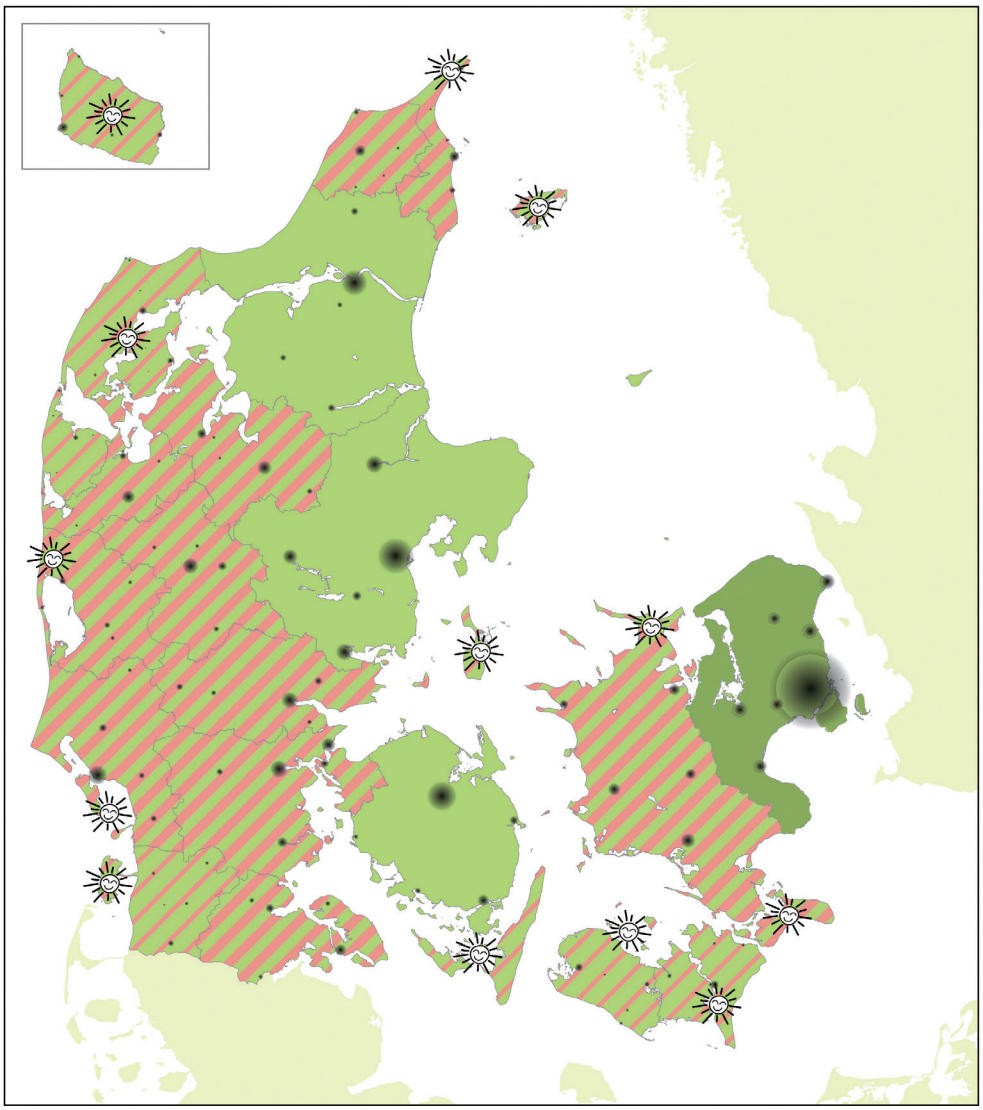
Large growth centralized in enterprising cities

Growth in few medium-sized cities, stangnation in many others

Growth in many enterprising small towns, stangnation in a few towns

Growth because of quality of life etc.

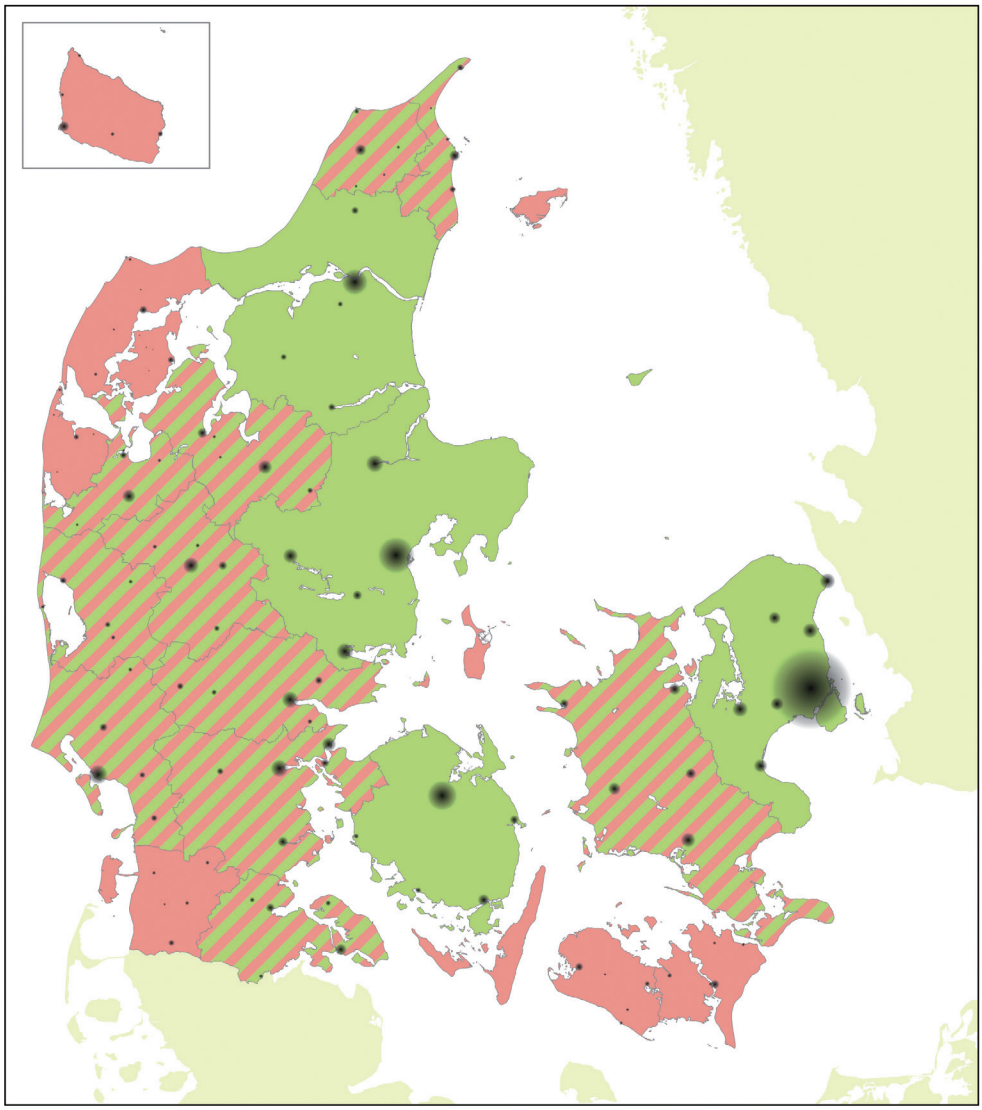
Figure 2.3: City development trends in Green networks scenario



Green guerilla Development trends in commuter regions

- Large growth centralized around big citiese
- Medium growth centralized around big cities
- Growth in enterprising medium-sized cities, stagnation in others
- Growth in many enterprising small towns, stangnation in a few
- Growth because of quality of life etc.

Figure 2.4: City development trends in Green guerilla scenario



Green compromises Development trends in commuter regions

- Medium growth centralized around big cities
- Some medium-sized cities do well, stagnation in others
- Stagnation in small cities

Figure 2.5: City development trends in Green compromises scenario

3. Traffic

3.1 STATUS 2014

In 2014, 73 percent of all the domestically driven kilometres transporting people is done by car, 23 percent by public transportation, and 4 percent by walking or biking.

Domestic flights make up 0.5 percent, and domestic sailing make up 0.2 percent of the travelled kilometres.

The maps on the following pages show the 2014 status for the transport networks in Denmark, roads, railroads and air transport. The maps show the existing networks as well as decided and comtemplated future systems for each network.

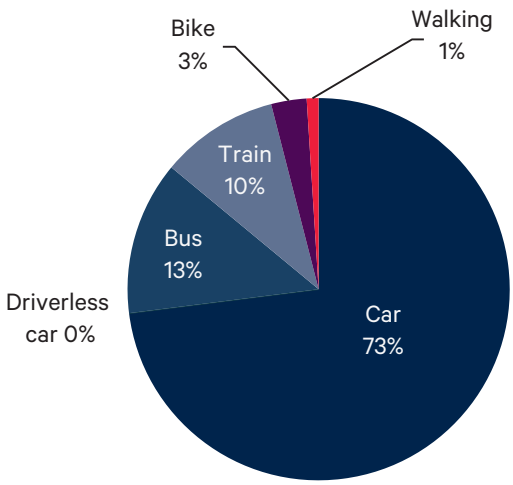


Figure 3.1: Distribution of domestic people transport (travelled kilometres) on means of transportation in 2014. Source: Green growth in Denmark towards 2050 supplemented by data from Transportvaneundersøgelsen (a review on habits of transportation) (TU)

Road system

Status 2014

- Existing motorways
- Existing primary roads
- Decided extension/upgrade
- Contemplated extension/upgrade

Decided, but not yet made:

- New motorway between Holstebro and Herning
- New motorway at Silkeborg
- The Fehmarnbelt connection
- New inlet connection at Frederikssund
- 1st and 2nd stage of the Frederikssund motorway

Comtemplated bigger new roads:

- Harbour tunnel in Copenhagen
- Tunnel Helsingør-Helsingborg
- Ring 5
- New East-West connection, either a permanent connection trough Samsø (including motorway for Kalundborg), a connection Bogense-Juelsminde and a new Little Belt bridge
- Central Jutland motorway (several alternative lines).

Figure 3.2: Map of existing as well as decided and contemplated bigger future road systems
Source: 'En grøn transportpolitik – Afrapportering af de strategiske analyser', Ministry of transport 2014 et al.

Decided but not yet made railroads:

- Togfonden DK
- New railroad to Aalborg Airport
- Aarhus Light Rail
- Light rail in Ring 3
- Permanent Fehmarnbelt connection and upgrade of the Copenhagen-Rødby railroad
- Metro Cityring as well as metro for Nordhavn and Sydhavn

Contemplated future new railroads:

- Railroad connection across the Kattegat (through Samsø)
- Highspeed railroad Helsingør-Helsingborg to Fehmarn
- Light rails Nørrebro-Gladsaxe Trafikplads, Glostrup-Brøndby Strand station, Aarhus stage 2 and 3, Odense and Aalborg
- Highspeed connection Aarhus-Hamburg.

Figure 3.3: Map of existing as well as decided and contemplated future railroads
Source: 'En grøn transportpolitik – Afrapportering af de strategiske analyser', Ministry of transport 2014 et al.

Air transport
Status 2014

Figure 3.4: Map of existing airports

3.2 DECISION TIMELINES FOR CONTEMPLATED INFRASTRUCTURE PROJECTS

Figure 3.5 shows the expected timelines for some of the contemplated infrastructure projects described previously as well as GPS based roadpricing.

The timelines are arranged according to the presumption that they will be politically passed within the next few years, so that construction can begin in 2020.

Thus, the figure is not to be seen as an estimate of the political realism of the projects or a suggestion on when they will be finished – it's a rough estimate of the time the projects need to be carried through technically.

The timelines are based on existing reviews on each project.

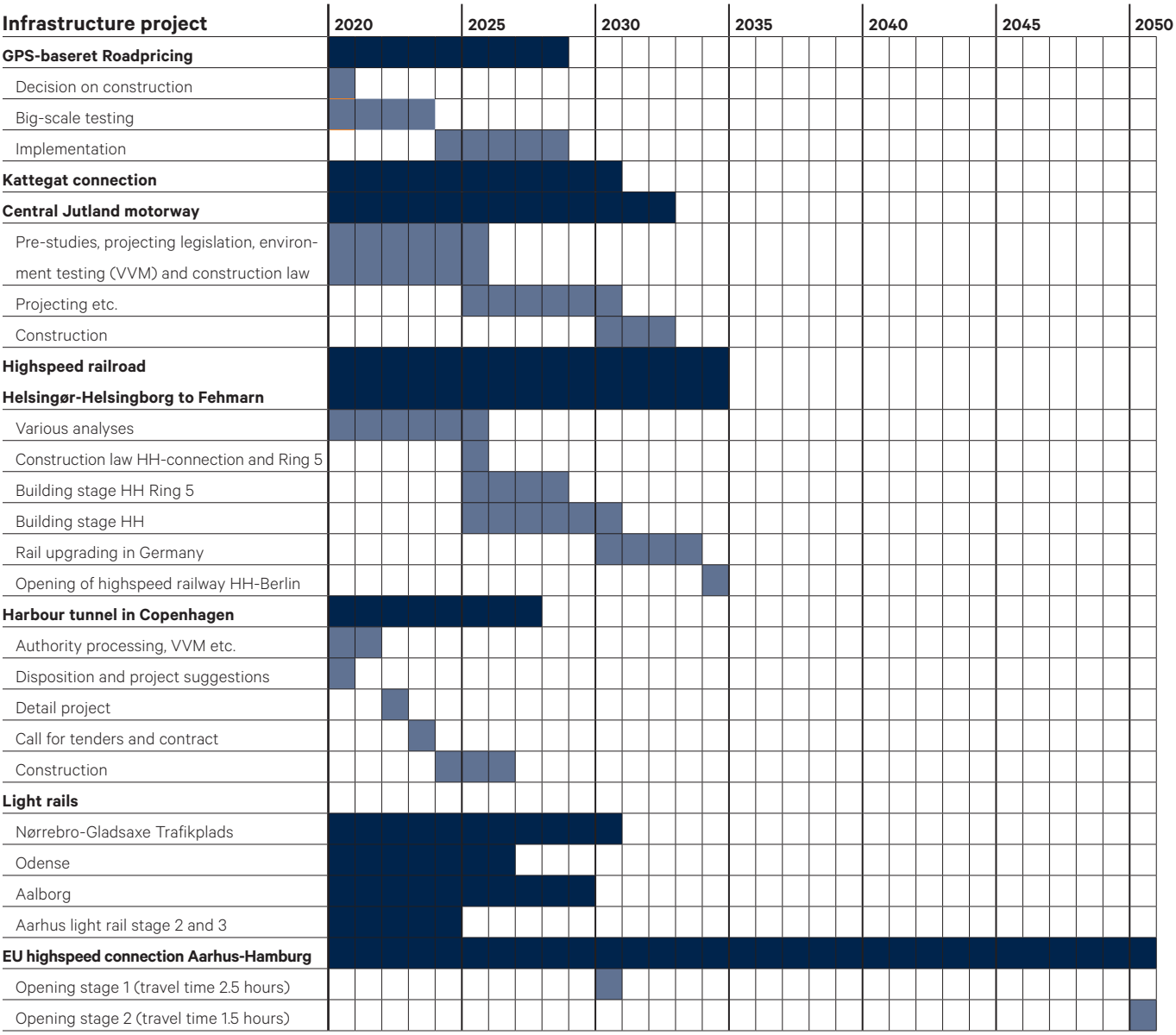


Figure 3.5: Illustration of expected timeline for some of the considered infrastructure projects

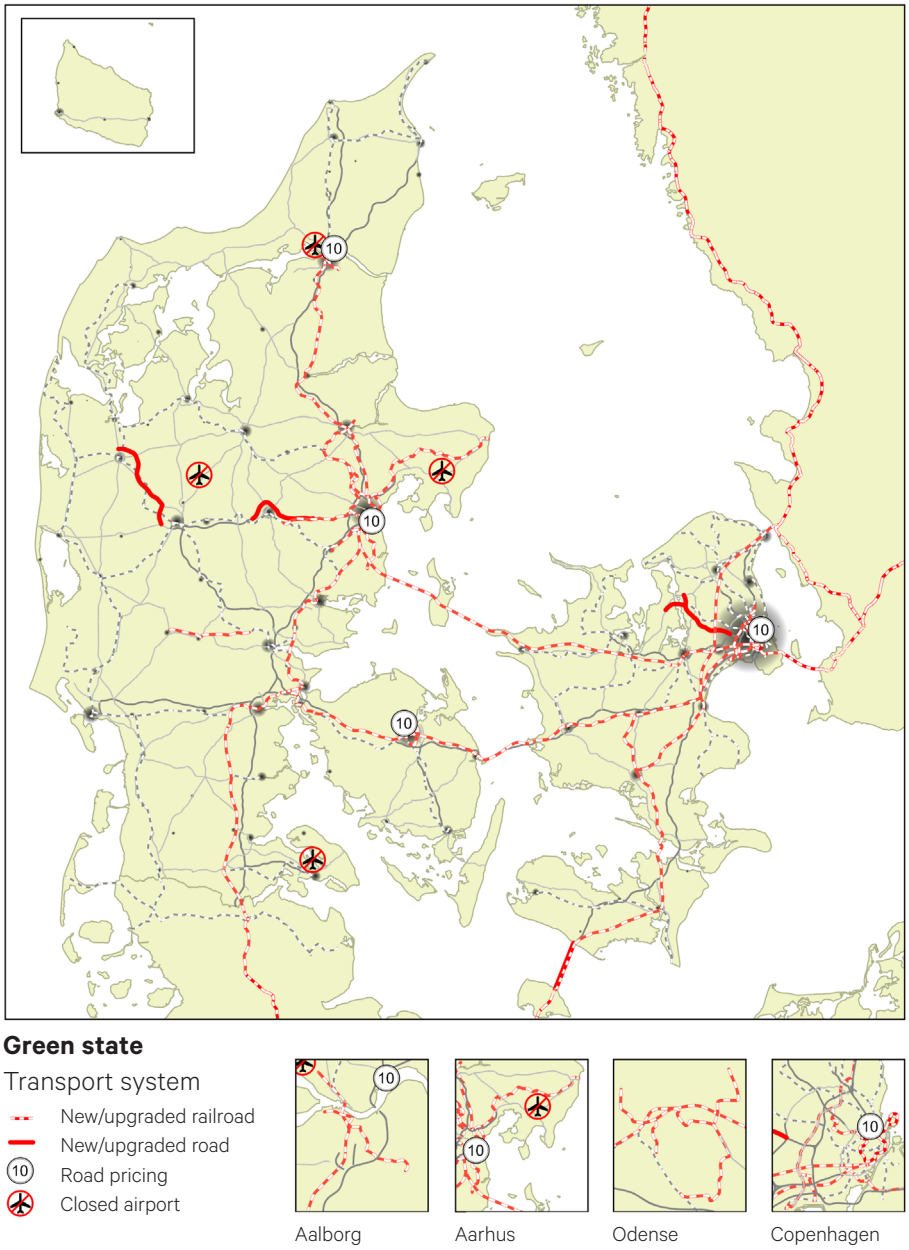


Figure 3.6: Suggestion of a 2050 transport system in the Green state scenario

3.3 GREEN STATE

The following pages contain ideas on what the transport system could look like in 2050 in Green state, as well as how the transport of passengers is divided on different means of transportation.

3.3.1 Premises

These are the premises for infrastructure and transport in the scenario based on the descriptions in report 'Green growth in Denmark towards 2050':

- 'The Internet of Things' means a physical ditigitalization of our everyday lives and a reduced need for transportation
- Traffic is regulated and controlled by digital systems and massive data
- We buy more locally and the need for transport of goods is therefore reduced
- Air transport is under presssure and travelling by air is a luxury for the few who can afford it
- Electrical cars is the chosen individual means of transportation
- Government investments in green public transportation
- Highspeed trains binds Europe closely together
- Big cities have elaborate public systems
- Public transportation is used by most people for trip in the cities as well as nationally and internationally
- Highspeed train between Copenhagen and Aarhus (via permanent Kattegat connection)
- Biomass is used in heavy vehicles
- Road pricing is introduced in larger cities (around 2025)
- It's forbidden to drive your own car in the cities and on motorways (around 2030)
- Delivery drones deliver everyday necessities and packages (around 2040)
- Domestic airports are under pressure. Only Kastrup, Billund and Bornholm remain. Kastrup, however, closes one terminal (around 2045)
- Other air transportation is fueled by bio fuels

3.3.2 Projects

The following changes in infrastructure are thus expected to have changed between 2014 and 2050 in the Green state scenario:

Road:

- The changes decided upon in 2014 (see 3.1)
- Road pricing has been introduced in Copenhagen, Aarhus, Odense and Aalborg

Railroad:

- The decided changes from 2014 (see 3.1)
- Rail connection over the Kattegat (via Samsø) (no road connection)
- Highspeed rail Helsingør-Helsingborg to Fehmarn
- Light rail Nørrebro-Gladsaxe, Glostrup-Brøndby Strand station, Odense, Aalborg and Aarhus light rail stage 2 and 3
- EU highspeed train connection Aarhus-Hamburg

Air transport:

- Only Kastrup, Billund and Bornhold airports remain, the rest have been closed

3.3.3 Distribution on means of transportation

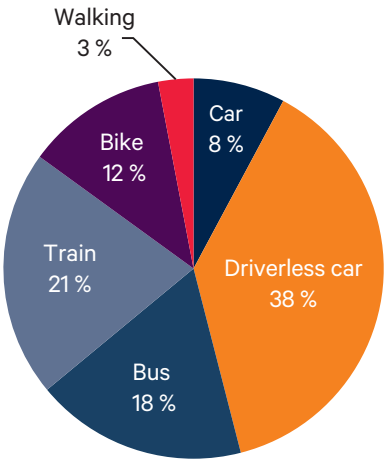
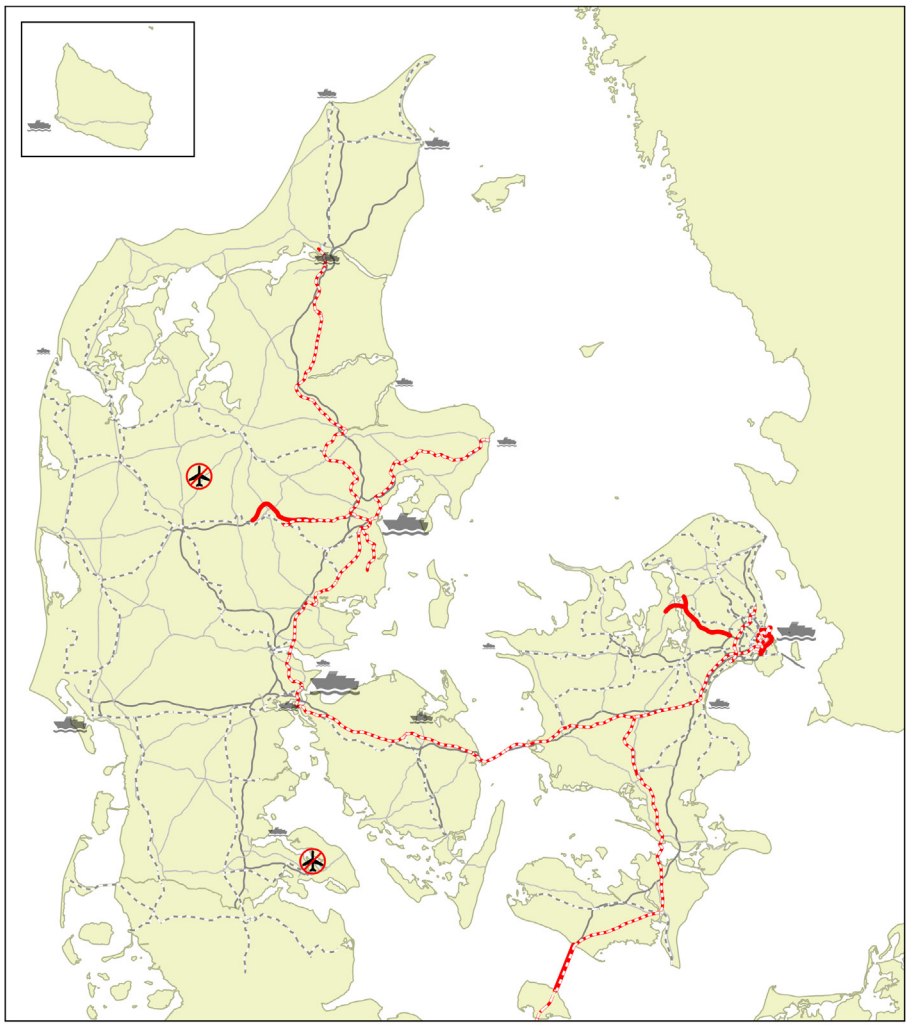


Figure 3.7: The division of passenger transport (travelled kilometres) on means of transportation in 2015 according to the Green state scenario.
Source: Green growth in Denmark towards 2050



Green networks

Transport system

New/upgraded road

New/upgraded railroad

Increased transportation by ship

Closed airport

Figure 3.8: Suggestion of a 2050 transport system in the Green networks scenario

3.4 GREEN NETWORKS

The following pages contain ideas on what the transport system could look like in 2050 in Green networks scenario, as well as how the transport of passengers is divided on different means of transportation.

3.4.1 Premises

These are the premises for infrastructure and transport in the scenario based on the descriptions in report 'Green growth in Denmark towards 2050':

- Crowding in the big cities (around 2015)
- Digital possibilities reduce the need for transportation (around 2040)
- Decreased transportation of goods due to 3D printing etc.
- Public transportation has been downgraded
- Progress for energy-efficent indivual means of transportation: electric cars, hybrid cars, electric bicycles, shared car systems etc.
- Small electric cars in the cities (around 2025)
- We share and rent like never before (around 2025)
- Driverless vehicles gain footing as do bans on driving cars in cities and on motorroads (around 2030)
- No Kattegat connection
- Smart grid with eg. electric cars and electric trains that can store electricity
- Walking and biking is increasingly popular in the big cities
- A large share of long-distance transportation has been moved from planes to ships

3.4.2 Projects

Driverless cars have gained footing, and a strong collaboration between politics and green technology means that these cars are also part of organized systems for shared transport and the creation of 'road trains' on the roads.

The capacity utilization rate of the existing road system has increased considerably, and the extension of the road system outside of the capital area (where the population growth is vast) har therefore been limited.

The following changes in infrastructure are thus expected to have changed between 2014 and 2050 in the Green networks scenario:

Roads:

- Among the decided changes from 2014 (see 3.1), the motorroad between Holstebro and Herning has not been made. Only the Fehmarnbelt connection, the motorroad at Silkeborg and the Frederikssund motorway have been realized.
- Among the researched projects from 2014, only the harbour tunnel in Copenhagen has been made because of a big growth in population.

Railroads:

- The decisions from 2014 (see 3.1) have all been realized.
- None of the researched but not yet decided projects from 2014 have been realized (see 3.1).

Air transportation:

- The airports in Karup and Sønderborg are closed.

3.4.3 Distribution on means of transportation

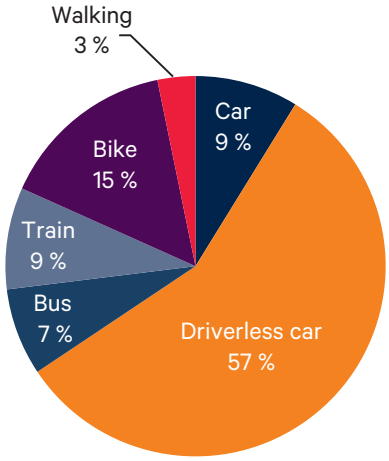
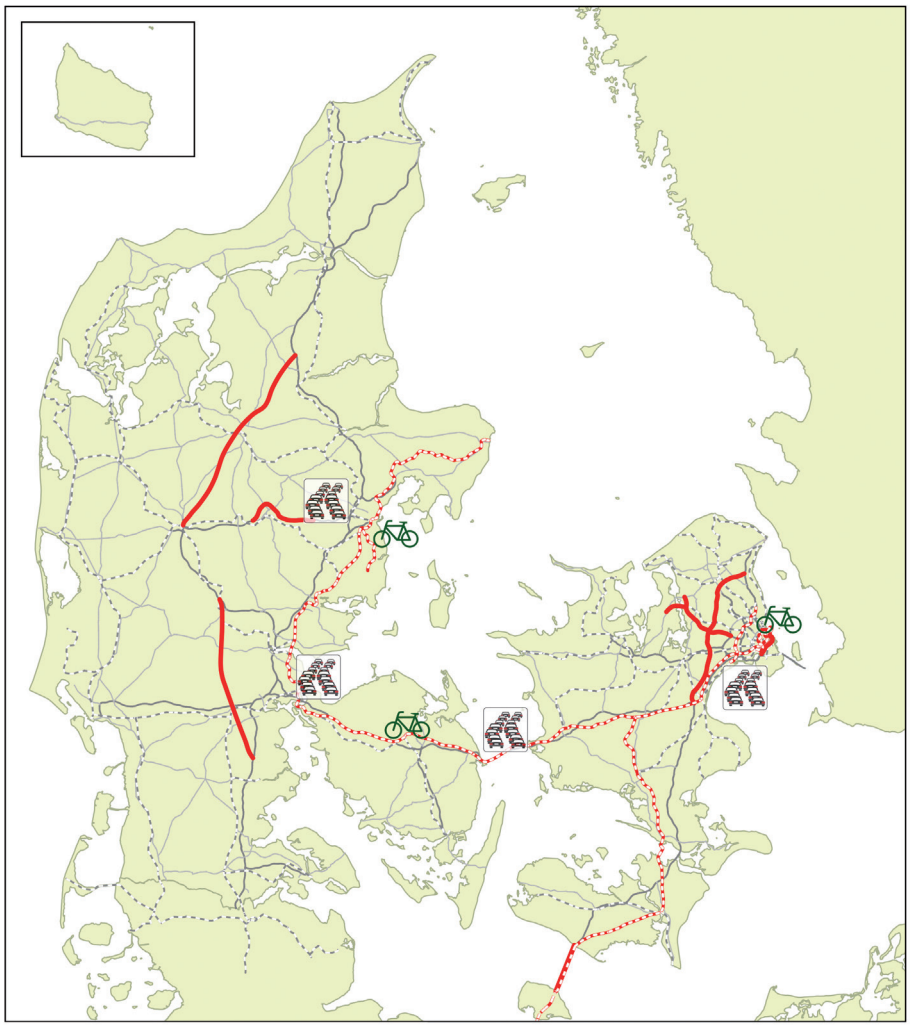


Figure 3.9: The division of passenger transport (travelled kilometres) on means of transportation in 2015 according to the Green networks scenario.
Source: Green growth in Denmark towards 2050



Green guerilla

Transport system

New/upgraded road

New/upgraded railroad

Bicycles have taken over traffic

Crowding

Figure 3.10: Suggestion of a 2050 transport system in the Green guerilla scenario

3.5 GREEN GUERILLA

The following pages contain ideas on what the transport system could look like in 2050 in Green guerilla, as well as how the transport of passengers is divided on different means of transportation.

3.5.1 Premises

These are the premises for infrastructure and transport in the scenario based on the descriptions in report 'Green growth in Denmark towards 2050':

- Cars are transport of choice, running on both gasoline, electricity, hydrogen and hybrids
- Crowding is vast (around 2020)
- No Kattegat connection
- In some cities, bicycles have taken over the urban landscape
- Public transportation has not been developed
- The agreement about the train foundation is broken (around 2015)
- Some cities have collective systems for larger groups (company busses etc.)
- Shared driving and cars etc. is attractive and put public transportation under pressure (around 2030)
- Public collective lines are closed and taken over by the private sector with no public support (around 2035)
- Those who can afford it travel by jet plane
- Kastrup is a smaller airport
- A large share of commodities transportation is done by drones
- Trucks run on both diesel and electricity

3.5.2 Projects

A lack in underlying services (eg. crowding data in the GPS system), individual driverless cars that don't explore the potential for shared transport, a more scattered settlement as well as the closing of public lines add to crowding. This leads to a focus on expanding the road system.

The following changes in infrastructure are thus expected to have changed between 2014 and 2050 in the Green guerilla scenario:

Roads:

All the decided and contemplated changes (see 3.1) have been realized apart from these:

- The motorway between between Holstebro and Herning has not been realized because of depopulation in the area
- A new connection between eastern and western Denmark
- The tunnel between Helsingør and Helsingborg

Railroads:

- The agreement on the train foundation has been broken, and the upgrade has only been realized between Copenhagen and Aarhus
- All other decisions from 2014 (see 3.1) have been realized
- None of the contenplated but not yet decided projects (see 3.1) have been realized

3.5.3 Distribution on means of transportation

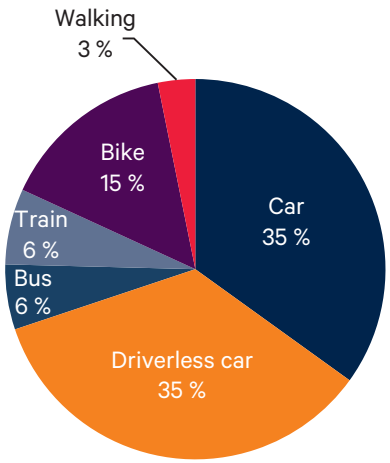
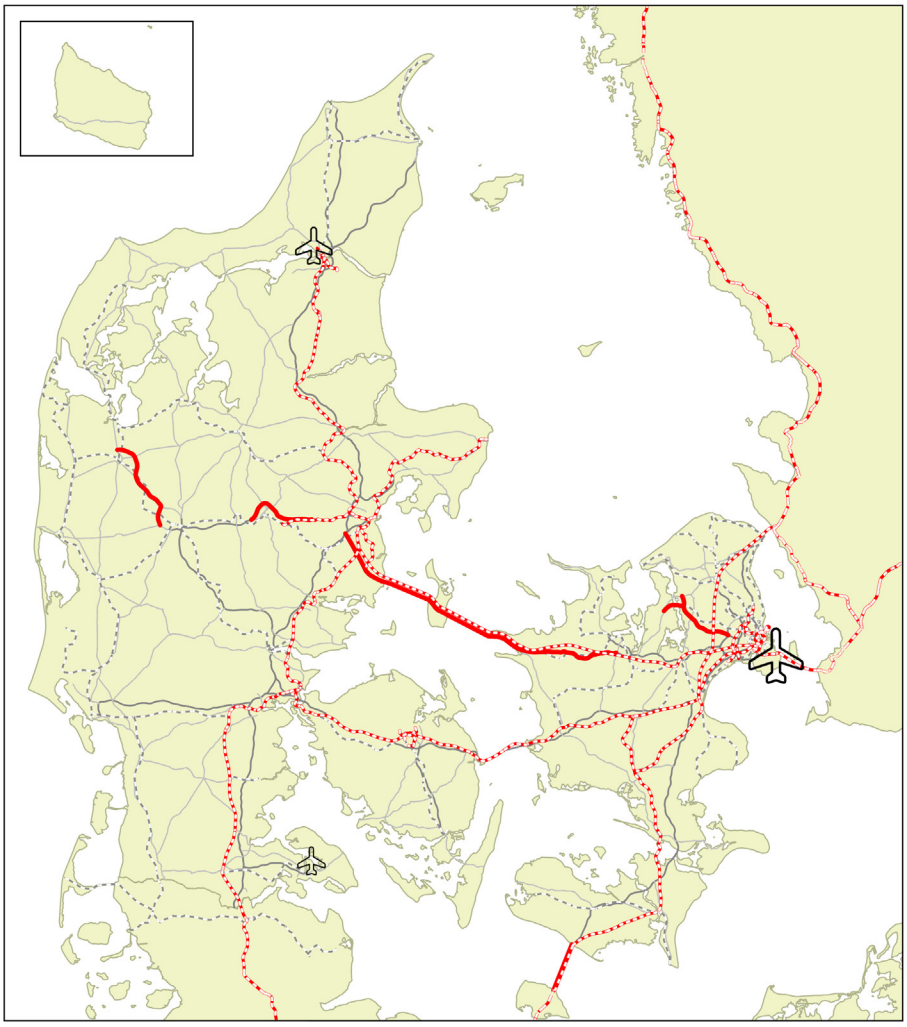


Figure 3.11: The division of passenger transport (travelled kilometres) on means of transportation in 2015 according to the Green guerilla scenario



Green compromises

Transport system

New/upgraded road

New/upgraded railroad

Increased air traffic

Figure 3.12: Suggestion of a 2050 transport system in the Green compromises scenario

3.6 GREEN COMPROMISES

The following pages contain ideas on what the transport system could look like in 2050 in Green compromises, as well as how the transport of passengers is divided on different means of transportation.

3.6.1 Premises

These are the premises for infrastructure and transport in the scenario based on the descriptions in report 'Green growth in Denmark towards 2050':

- Global passenger transport has increased due to population growth
- Private car transport is prioritized, eg. in the big cities
- Driverless cars are introduced in the cities (around 2035)
- Forbidden to drive your own car (around 2045), only driverless cars are allowed
- Large investments in public transportation, eg. agreement on a better European railroad system passed by the EU around 2030
- Digitalization has made public transportation more competitive
- The Kattegat connection has been established in 2048 as a bridge for both cars and trains
- The transport of commodities is still based on road traffic
- Planes are an important means of transportation and Kastrup an important hub
- The airports in Aalborg and Sønderborg are growing too

3.6.2 Projects

The following changes in infrastructure are thus expected to have changed between 2014 and 2050 in the Green compromises scenario:

Roads:

- All the decided projects from 2014 (see 3.1) have been realized
- Furthermore, a permanet connection over the Kattegat through Samsø has been established (a combined road and rail bridge)

Railroads:

- All the decided and researched changes from 2014 (see 3.1) have been carried through

Air traffic:

- The air traffic into and out of Kastrup has increased, and the airport has expanded. The airports in Aalborg and Sønderborg have grown too

3.6.3 Distribution on means of transportation

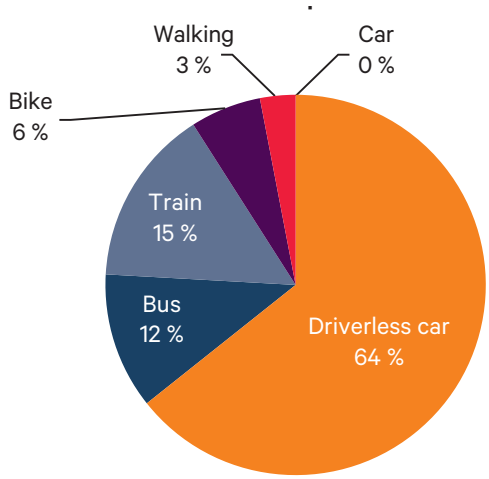


Figure 3.13: The division of passenger transport (travelled kilometres) on means of transportation in 2015 according to the Green compromises scenario

3.7 EXAMPLES OF DILEMMAS THROUGH TO 2050

There are a lot of dilemmas in the development of passenger transport, particularly dilemmas between green transition, crowding and the urban environment towards 2015. For instance:

- Green cars will reduce CO_2 emissions, but can also make it environmentally correct to drive a car resulting in increased car traffic, reduced traffic safety and a bad urban environment
- Driverless cars can reduce some of these problems. They can be 'packed' more 'tightly', both when they are on the raod and when thet are parked
- Driverless cars in a collectice system where you don't own your car, but just call for the nearest one, would probably be able to reduce the number of cars. However, it will introduce empty running in passenger cars
- A collective system with driverless cars could be a tough competitor to traditional means of public transportation. Driverless cars will be public transportation 'on demand' and will probably be able to provide the users with shorter travel times and more direct travels. However, on lines with big travelling masses, it is expected to be less energy-friendly than eg. trains since all driverless cars are 'one motor per person' and there will be some empry running
- Largely all means of transportation (cars, trains, ships, planes, drones) wil be able to run on green bio fuels. But a possibly limited amount of these can necessitate prioritizations and rejections of the most energy-efficent means of transportation, ie. planes and individual cars

4. Energy

4.1 SUMMARY

The energy and climate goals in the four DK2050 scenarios (Green state, Green networks, Green guerilla and Green compromises) are based on a number of parameters (freedom from fossil fuels, carbon-neutrality, the share of renewable energy, energy-efficiency) that can be used to determine the degree of green transition in our society. The pivotal point in the green transition from an energy and climate political perspective is the reductions in CO_2 emissions from our energy consumption and transport system, and in order to succeed with the green transition, we need masive investments in renewable energy as well as energy savings.

Other environmental parameters that are just as important to handle, such as NOx, SO2 from power stations, dioxin from waste etc. are not discussed, just as emissions (eg. methane and laughing gas) from the agricultural sector aren't taken into account here. The CO_2 emissions from air traffic, and international fights particular, are not accounted for either, since the focus is on energy consumption, energy supply and transport in Denmark, and because the energy and climate policies on this field are regulated by the EU and internationally. This means a limitation to what can be done nationally, regionally and locally.

The Green compromises scenario can be perceived as a baseline scenario or an 'all things being equal' scenario where only already decided political initiatives and measures are carried through until 2050. Thus, this is the least ambitious scenario.

The three other scenarios can be seen as three different roads with different degrees of green transition, with Green state and Green networks being the most ambitious and Green guerilla the least ambitious. A complete green transition to 100 percent renewable energy and independence from fossil fuels, massive energy savings and CO_2-neutrality are only obtained in the Green state scenario.

There are big costs connected with the green transition, and only the socially and financially most profitable investments are carried through. This is also the reason why the green transition is ot successful in the Green guerilla scenario, since the strong state who is mainly responsible for creating the frames for the socio-economically good solutions when it comes to investing in renewable energy, energy savings and a sustainable transport system is missing. This doesn't mean that the green transition stands still, but it is mainly up to the citizens and businesses to create green solutions. This will primarily happen with energy solutions and systems and projects on a smaller scale, which is why we won't see a strong development within offshore wind parks.

The two ambitious scenarios (Green state and Green networks) continue the development of the Danish energy system of the past 30-40 years, supported by collective values in the form of central energy systems for the bigger cities based on district heating, natural gas, central CHP plants, windmills by land and by sea, large-scala solar energy, local waste systems etc.

Converting the Danish energy system into 100 percent renewable energy is a huge task which demands that all players (government, municipalities, energy supplies, companies, investors, citizens etc.) get involved.

The ambition of freedom is even tougher to achieve when it comes to transport which demand that new technologies are implemented as well as a change in our habits and behaviour, from being very resource-consuming (today) to being more sustainable.

It is hard to predict the development of the green transition in each scenario (measured by development in CO_2 reduction) since it depends on national an global frame conditions. However, figure 4.1 shows how the CO_2 development could go by 2050.

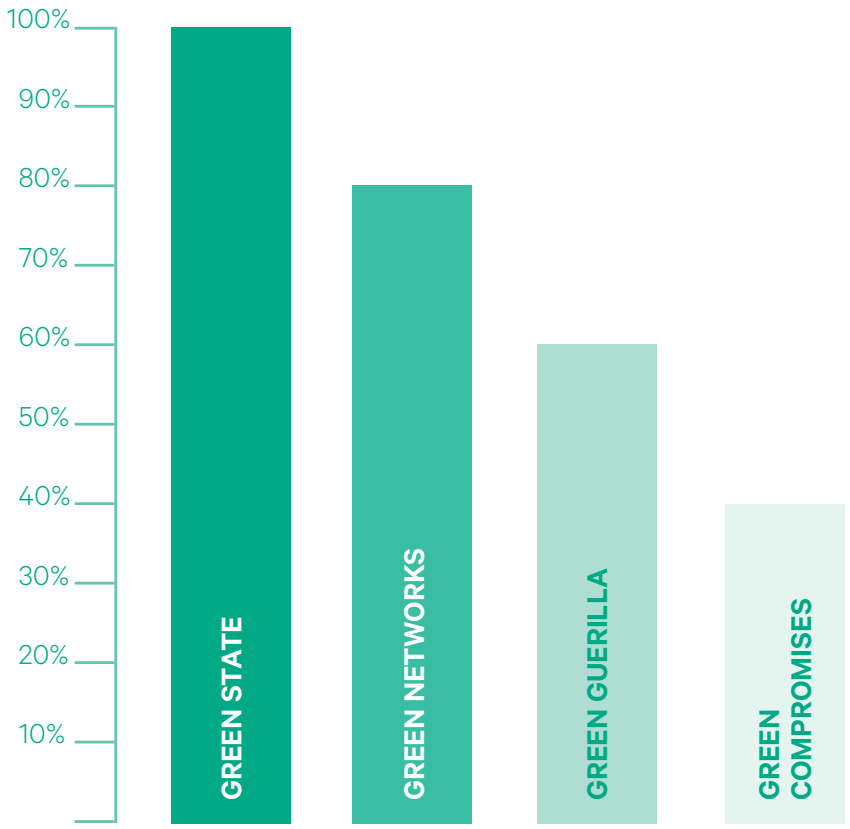


Figure 4.1: CO_2 emissions in the four scenarios by 2050

4.2 METHOD

In the following pages, we elaborate on the four scenarios for Denmark 2050, where the green transition in relation to energy and climate in Green state, Green networks, Green guerilla and Green compromises respectively, happens to various extents. The degree of transition is mainly measured according to these parameters:

- Independence from fossil fuels
- CO_2-neutrality
- The share of renewable energy-efficent
- Energy-efficiency

These parameters are quantified as well as qualified whenever possible, and supported by data and illustrated by charts and maps of Denmark.

4.3 STATUS 2014

Denmark's energy consumption today is charted in figure 4.2.

The energy system of today mainly consists of centralized and decentralized CHP plants, district heating plants industrial CPH plants and renewable energy plants (eg. windmills, solar heat, solar cells, bio gas).

The energy system of today consists mainly of these power and heat producing energy plants, see figure 4.4.

The Danish energy system is closely connected to the Nordic system as well as the German one, see figure 4.3.

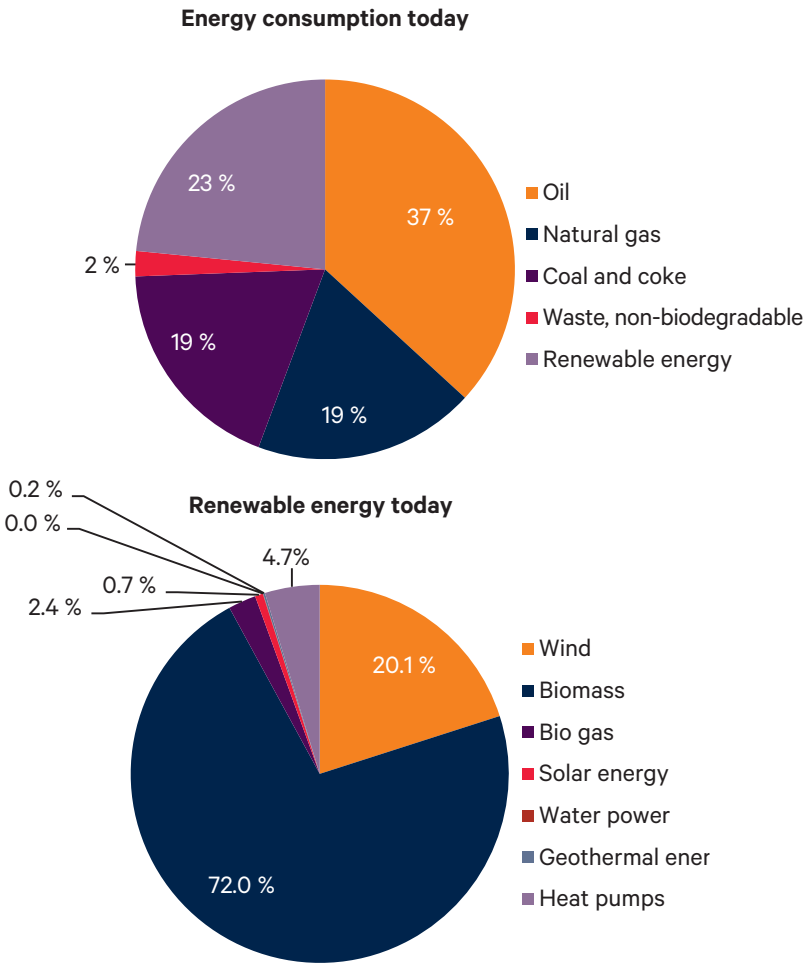


Figure 4.2: Energy consumption and renewable energy today (Source: The Danish Energy Agency, energy statistics 2012)

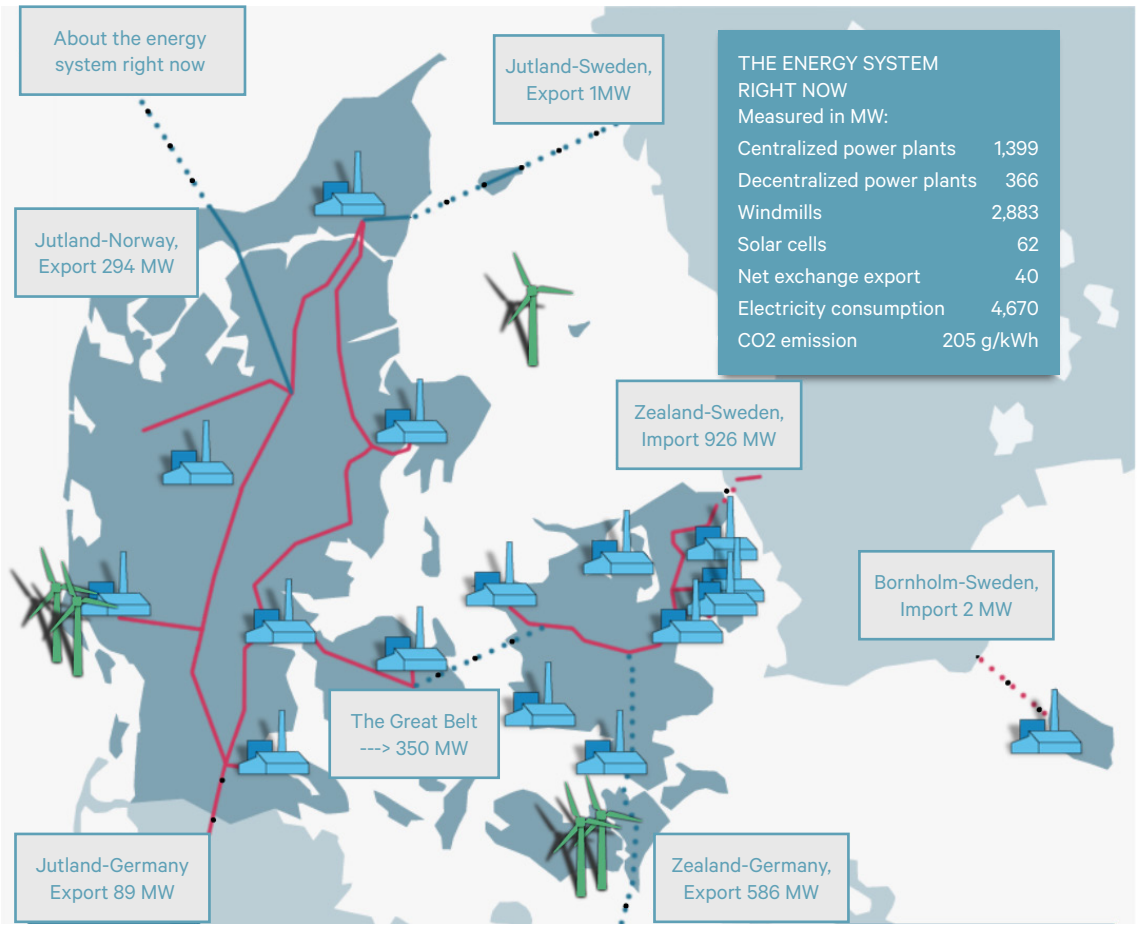


Figure 4.3: The energy system today (Source: Energinet.dk)

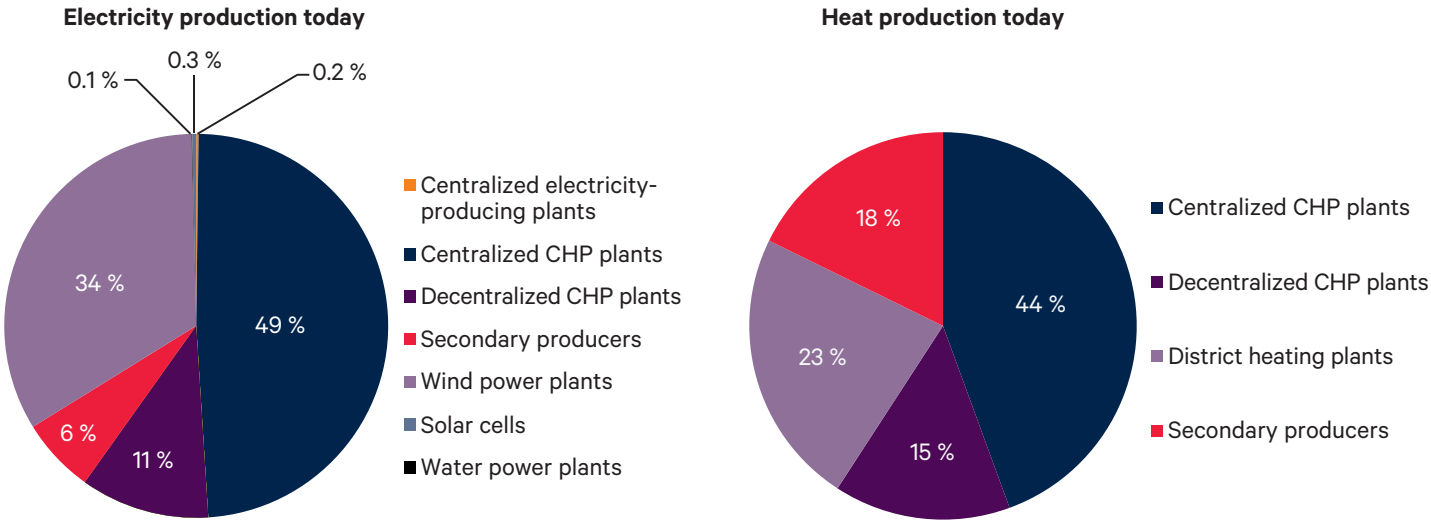


Figure 4.4: Electricity and heat production today

4.4 THE 'SAFE' DEVELOPMENT – WHAT'S ALREADY BEEN DECIDED, AND WHAT'S PLANNED?

The Danish Energy Agency has, on occasion of the energy-policy agreement of March 2012, made a basic projection of Denmark's energy production, energy consumption and energy-related greenhouse gas emissions. It shows a course with implementation of already passed initiatives but without further measures. In other words, a so-called 'other things being equal' scenario. The energy consumption in this basic projection is illustrated in figures 4.5 and 4.6:

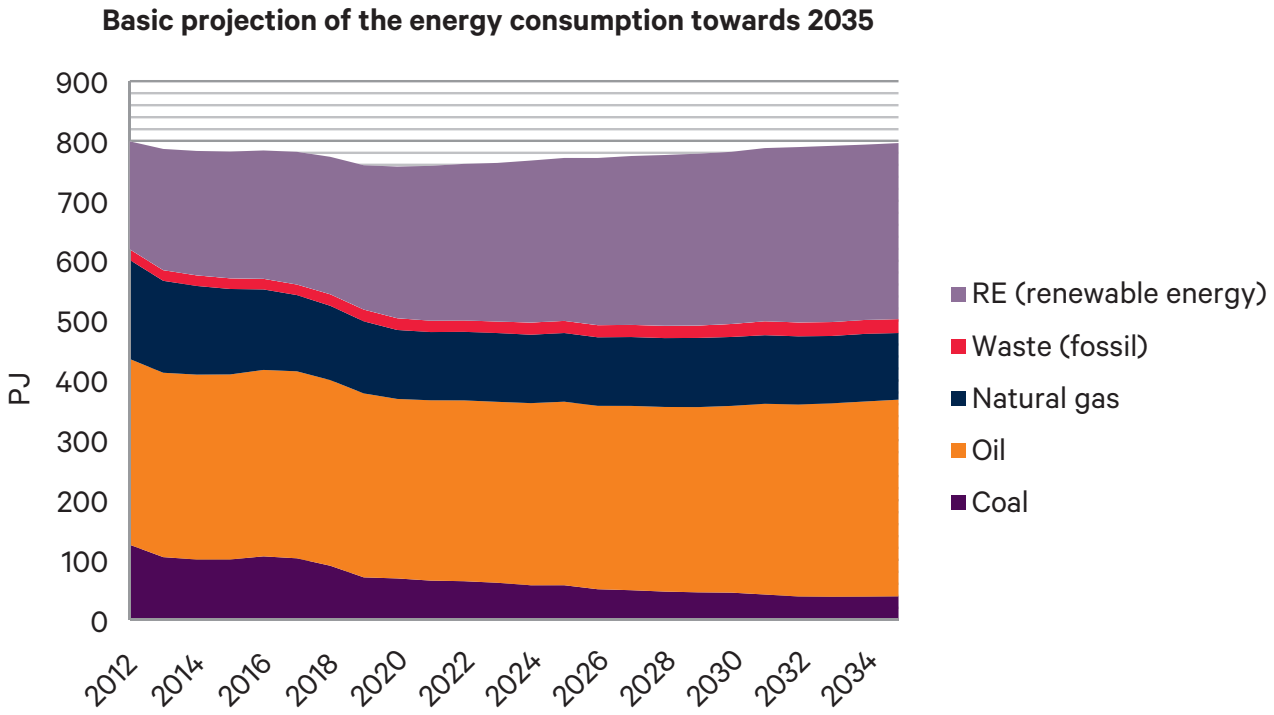


Figure 4.5: Energy consumption distributed on fuels towards the year 2035 (Source: Denmark's Energy Projection 2012)

The government's energy political goal is a 40 percent CO_2 reduction in 2020 compared to 1990. The goal should be viewed in the light of the EU's goals of a 80-95 percent reduction by 2050 which is based on the UN's climate panel IPCC's recommendations.

However, the government has already announced their vision of having freed Denmark from fossil fuels by 2050. The government's goal when it comes to renewable energy and energy optimization is that the share of RE should be at least 30 percent of the final energy consumption in 2020, while the gross energy consumption must be reduced by 4 percent in 2020 compared to 2006.

It is also an ambition to have all heat supply in Denmark come from RE as early as 2035, and to phase out coal from Danish power plants in 2030.

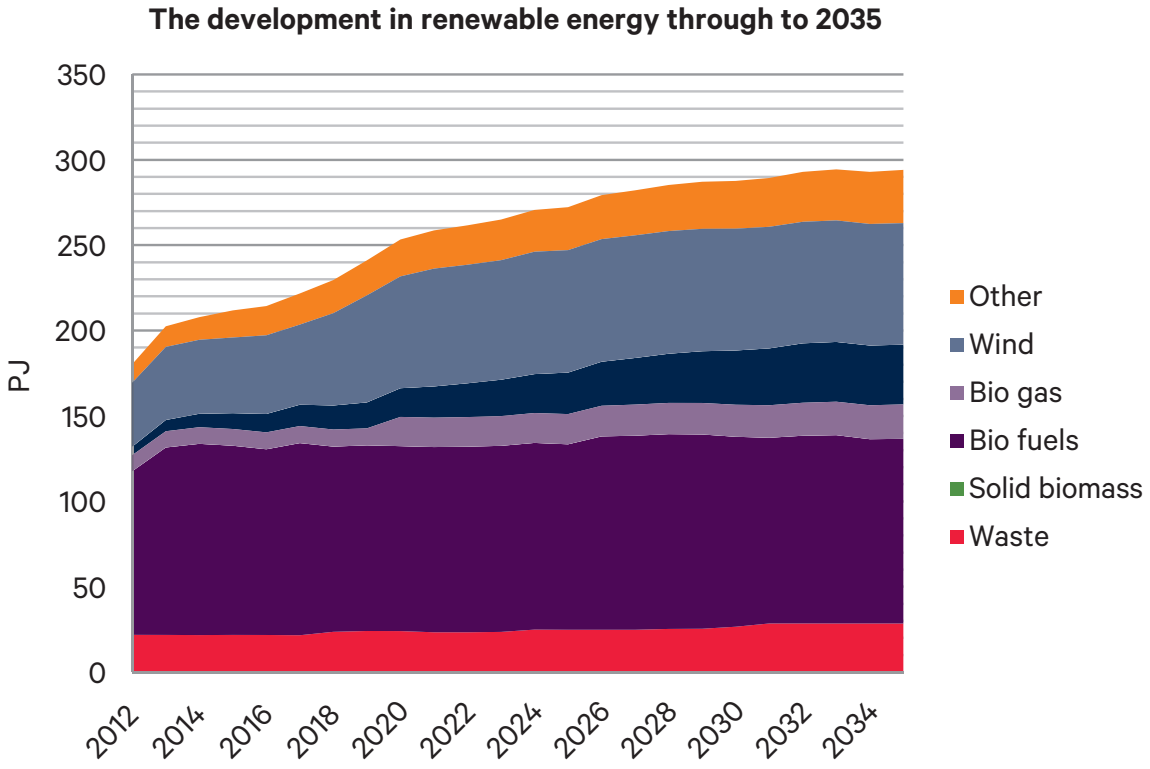


Figure 4.6: The development in renewable energy through to 2035 (Source: Denmark's Energy Projection 2012)

4.5 DK2050 SCENARIOS

The four scenarios in DK2050 should be seen in light of the political goals for energy and climate mentioned above.

Our evaluation of the ambition level in each scenario is illustrated in figure 4.8.

The percentage of each parameter is partly based on the criteria and descriptions of each scenario for the areas of energy and climate in the report 'Green growth in Denmark towards 2050' and partly on the energy and climate goals of the government, bothe short-term and long-term, as well as our own assumptions and linear interpolations.

A possible development for the CO_2 emissions in the four scenarios in 2050 is illustrated in figure 4.7.

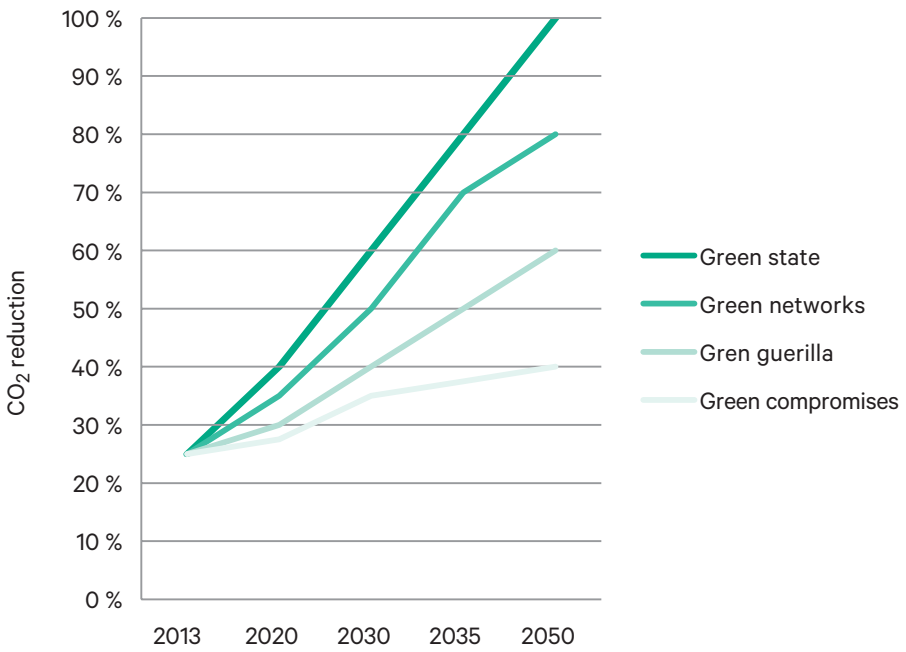


Figure 4.7: CO_2 reduction in the four scenarios

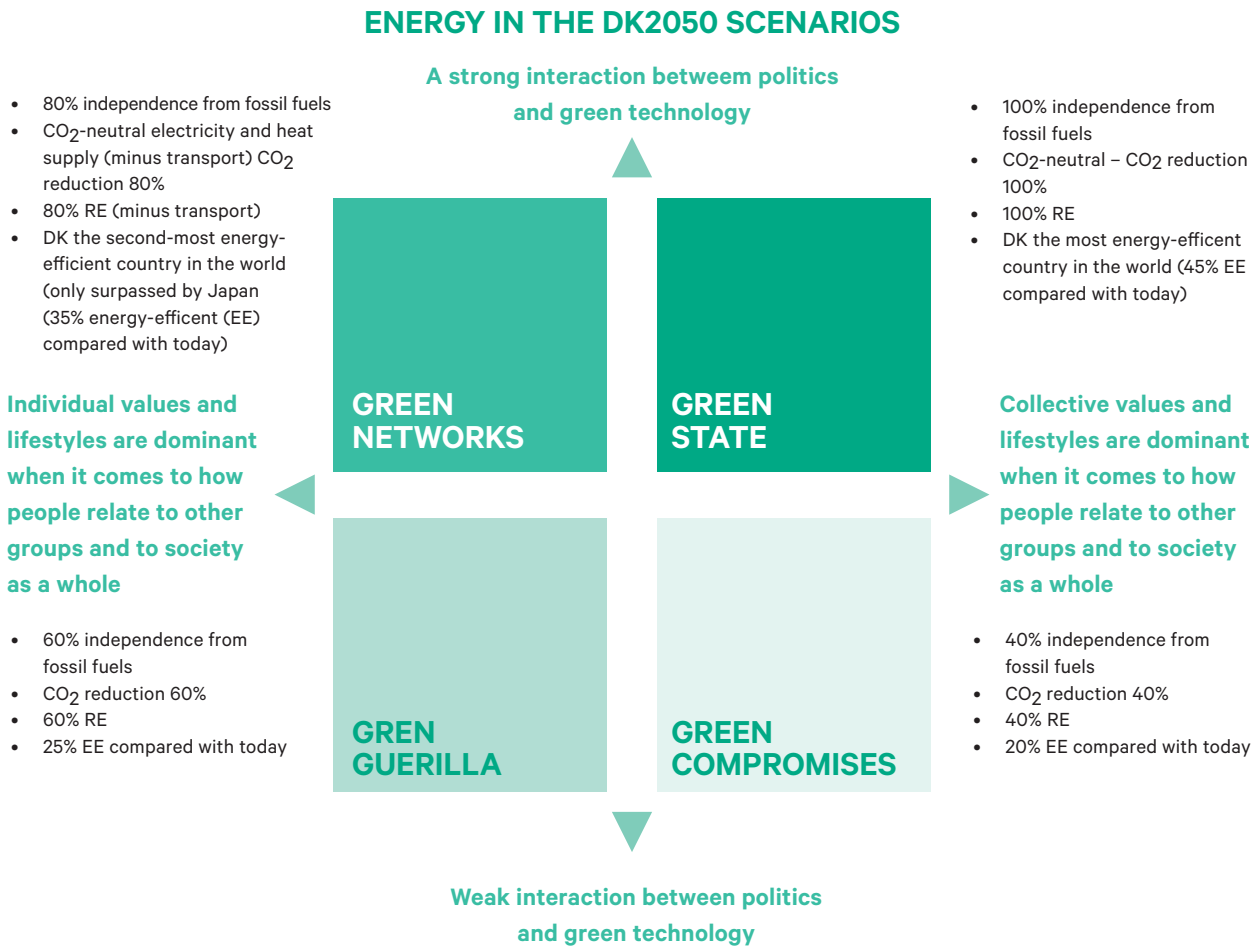


Figure 4.8: Criteria and goals for energy and climate in the four DK2050 scenarios

Green compronises is being treated as so-called 'baseline scenario, ie. an 'all things being equal' scenario, where no CO_2-reducing initiatives (eg. more renewable energy or energy-optimization) introduced, apart from the ones that have already been decided politically today (2013).

The three other scenarios should be viewed as three possible roads that 'build upon' this with CO_2-reducing initiatives and measures which lead to various degrees of green transition, Green state being the most ambitious, Green networks the second-most ambitious, and Green Guerilla having the lowest level of ambition.

In the ambitious scenarios, Green state and Green networks, the development from the past 30-40 years of the Danish energy system continues, supported by collective values in the form of centralized energy systems for the bigger cities based on district heating, natural gas, centralized CHP plants, windmills by land and sea, large-scale solar heat, local waste systems etc. In the national energy scenarios drawn up by the Danish Energy Agency and others, a continuation of this road is also a premise for Denmark being able to reach its goals of being free of fossil fuels, reducing CO_2 and increasing renewabe energy and energy-efficiency.

"A massive electrification of the transport and heat sector is carried through. The use of bio-energy is reduced to roughly 250 PJ, corresponding to the Danish potential and roughly 100 PJ more than today. Bio fuels are to a wide extent produced in Denmark, and the bio fuel factories are integrated in the electricity and heat supply. Wind power will be the principal technology in the production of electricity, but there will be contributions from solar cells and CHP plants as well. Heating is largely based on surplus heat (for central heating) from bio fuel factories, CHP and electrical heat pumps if needed at low and moderate temperatures. Heat sources for the heat pumps are outside air, sea water, waste water and geothermic heat. For medium and high temperatures in the industry, CHP, electricity and biomass. A large percentage of passenger cars run on electricity. The same goes for railroads and some delivery vans and busses. Other transports run on bio fuels and synthetic natural gas based on bio gas. There is a limited production of hydrogen from windmill power as a supplement for bio-energy use."

Source: 'Energiscenarier frem mod 2020, 2035 og 2050', The Danish Energy Agency, March 2014

Futhermore, we estimate that a Green guerilla-like development will mean more inidividual energy plants (eg. solar cells and micro-windmills on roofs), depending on the inidividual citizen's efforts and investments, without any concrete plan or strategic thinking from the municipalities, utility companies or the government based on socio-economic and business-economic criteria.

Here, we base our numbers and figures on energy scenarios drawn up by the Danish Energy Agency in report 'Energiscenarier frem mod 2020, 2035 og 2050' from March 2014. The energy scenario focusing on wind extension ('the wind scenario') ressembles the wind scenario drawn up by the climate commission, the Energy Agency's old wind scenario and Energinet.dk's wind track. We think this scenario is the most realistic to keep working on if our criteria for success are: climate-effect, cost efficiency and supply security. A short desciption of the scenario is given in the text box on page 34.

The wind scenario is scaled according to the four scenarios in DK2050: Green state, Green networks, Green guerilla and Green compromises. With scaling, we mean the meeting of goals in the scenario when it comes to the listed criteria and goals such as independence from fossil fuels, CO_2 reduction, share of renewable energy and energy-efficiency outlined in figure 4.7. It is not an exact, but rather an approximate scaling.

4.5.1 Energy resources

The following premises related to energy resources and energy consumption are the basis for the analysis of the four scenarios, see figure 4.9. The figure below is illustrated in diagrammes in 4.10.

DK2050	**Green state**	**Green networks**	**Green guerilla**	**Green compromises**
Energy resources	**PJ**	**PJ**	**PJ**	**PJ**
Biomass	171	137	103	68
Bio gas	42	34	25	17
Waste	42	34	25	17
Wind power	246	197	148	98
Other RE (solar cells, solar heat and surrounding heat)	86	69	52	34
Fossil fuels	0	117	235	352
Total	**587**	**587**	**587**	**587**
RE share	**100%**	**80%**	**60%**	**40%**

Figure 4.9: Energy resources in DK2050 scenarios

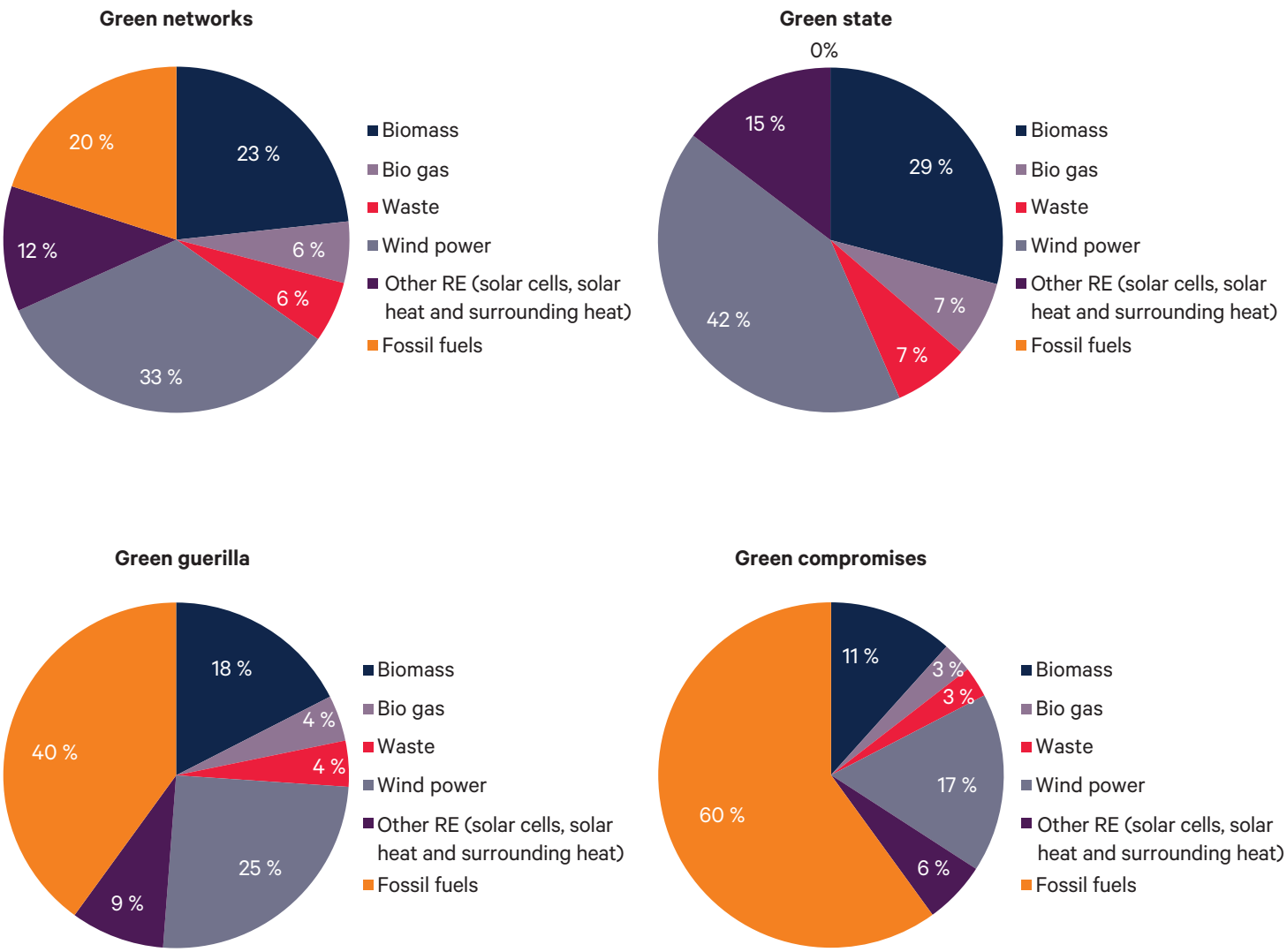


Figure 4.10: Use og energy resources in the four DK2050 scenarios

4.5.2 Renewable energy – technologies needed in play?

Figure 4.11-4.16 illustrate the RE-based energy system and technologies in the four scenarios.

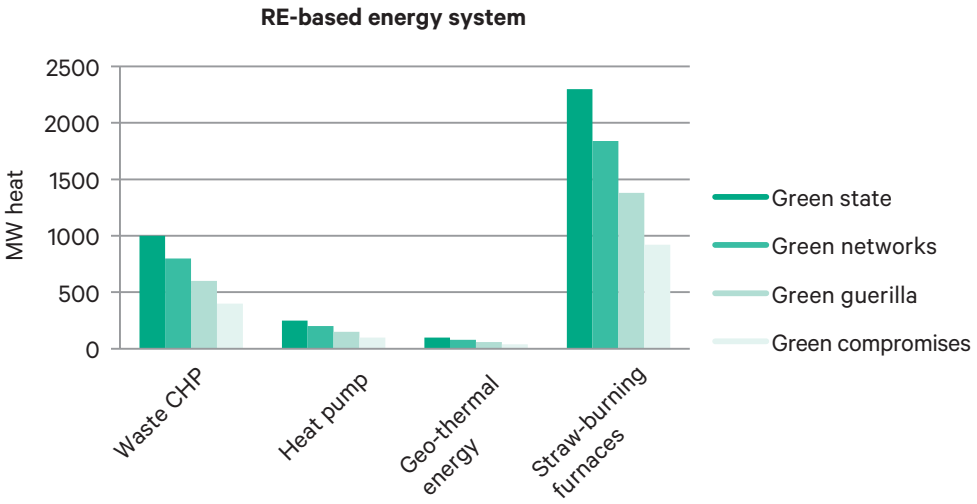


Figure 4.11: RE-based central heating in DK2050 scenarios

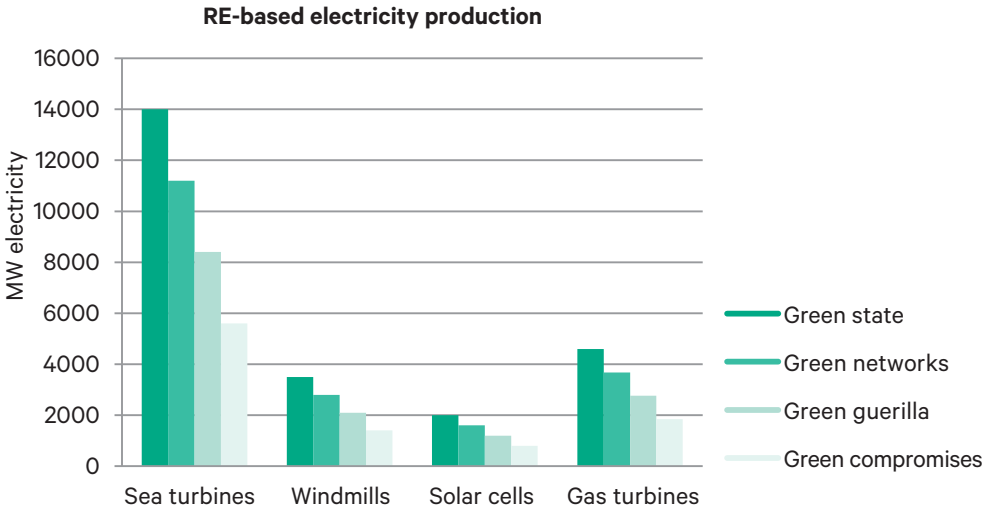


Figure 4.12: RE-based electricity production in DK2050 scenarios

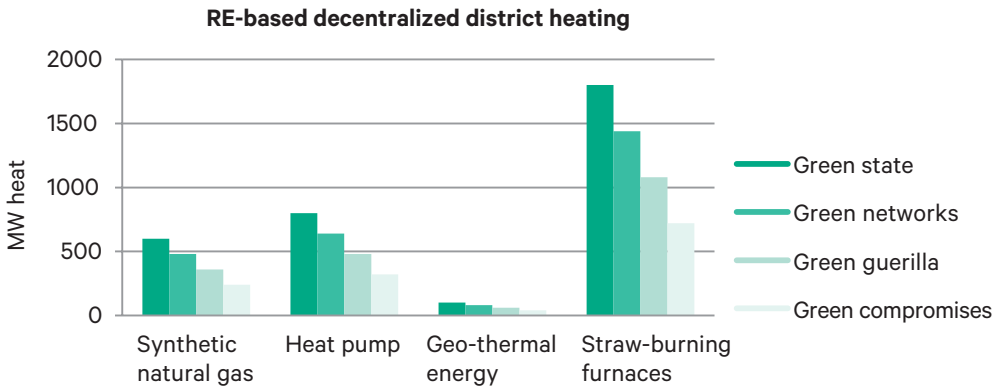


Figure 4.13: RE-based decentralized district heating in DK2050 scenarios

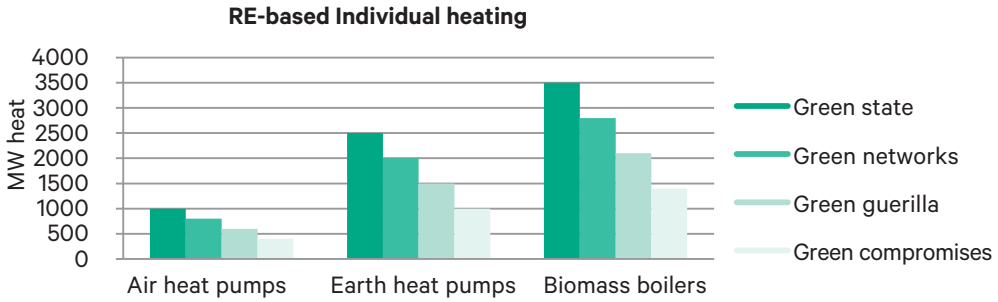


Figure 4.14: RE-based Individual heating in DK2050 scenarios

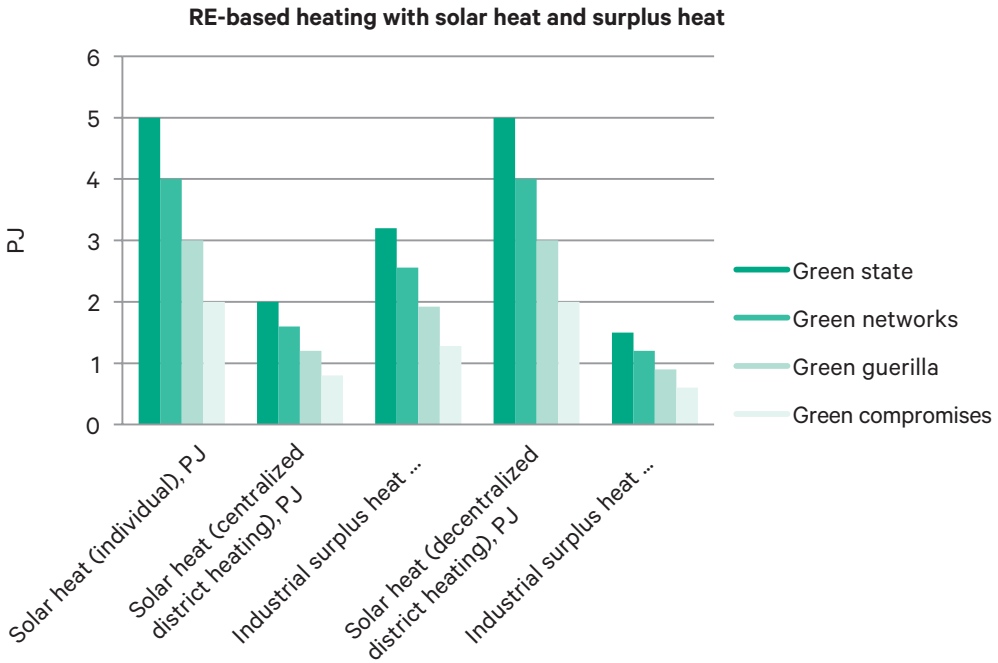


Figure 4.15: RE-based heating with solar heat and surplus heat in DK2050 scenarios

4.5.3 Extension with renewable energy

The above mentioned development in energy consumption and energy supply in the different scenarios is illustrated in figure. The starting point are the maps that show the status on windmill placements (installed kW effect) and heat supply, divided into district heating and natural gas areas today. These are supplemented by an estimate for the expected extension of the energy supply for certain chosen RE technologies/resources (windmills, geo-thermal energy, bio gas, solar cells and biomass or waste-based CHP production).

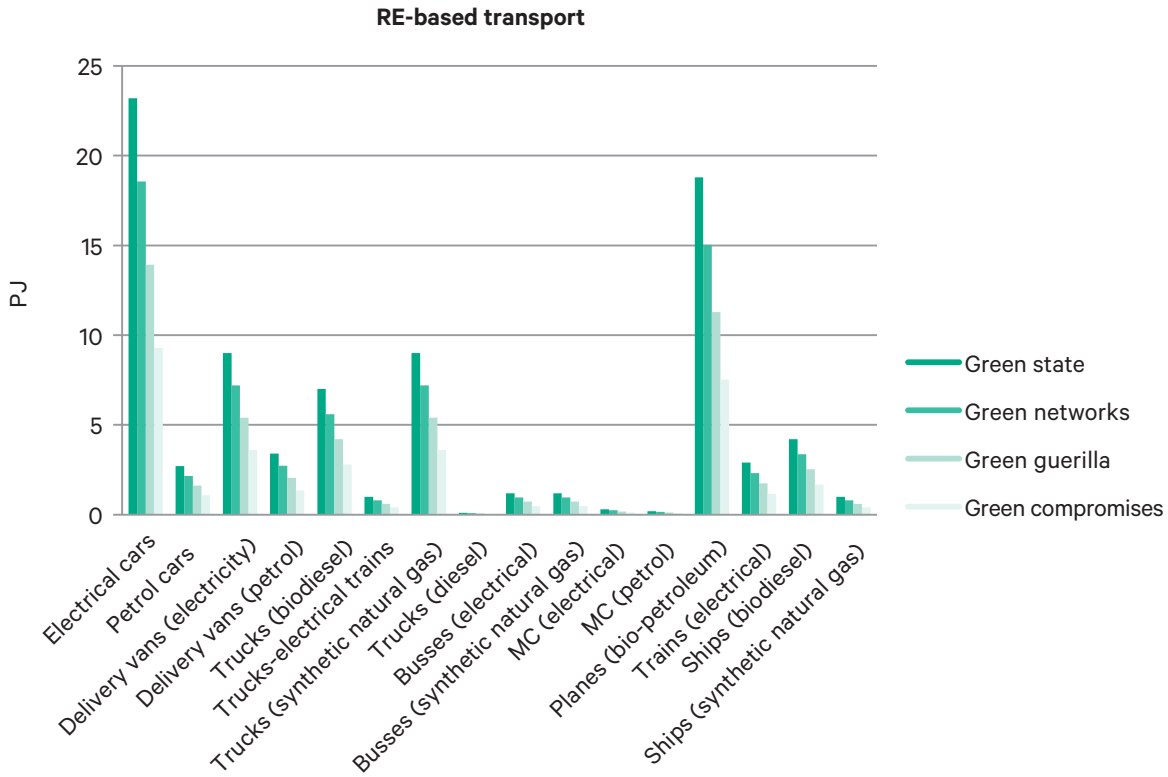


Figure 4.16: RE-based transport in DK2050 scenarios

Example of extension of chosen RE plants in the four scenarios is illustrated in the following figure 4.17.

Extension with new centralized energy plants in DK2050 scenarios

	Green state	Green networks	Green guerilla	Green compromises
Number of new offshore wind farms a 400 MW	28	19	10	2
Number of new geo-thermal energy plantsa 20 MW	7	5	3	1
Number of new bio gas plants a 0.4 PJ	100	78	55	33
Number of new solar cell plants a 6.5 kW	217.000	155.500	94.000	32.500
Capacity extension CHP plants in PJ (biomass/waste)	60	17	-26	-68

Figure 4.17: Example of extension with new centralized RE plants in DK2050 scenarios

4.6 CENTRALIZED VS. INDIVIDUAL ENERGY SYSTEMS IN THE CITIES

In the following, the energy systems expected to be established in the cities by 2050 are outlined and illustrated.

The Danish model with centralized energy systems is the one used by scenarios Green state and Green networks with different levels of ambition when it comes to the green transition, while the energy system in Green guerilla is characterized by individual energy systems which primarily appear in today's fringe areas and new cities.

4.6.1 Centralized energy systems

Nationally

Figure 4.18 shows an example of a centralized energy system supplying the cities with energy-efficent and environmentally friendly district heating/remote cooling based on biomass, solar heat, geo-thermics combined with big heat pumps and energy stocks gathering surplus heat from eg. waste CHP plants. The small islands are connected to the national/shared European electricity network and supplied primarily by wind power, while there are several individual heat supply plants on plot level with small heat pumps, solar heat plants, electrical radiators etc. compared to the big cities.

Figure 4.18: Example of the national energy system in the DK2050 scenarios Green state and Green networks

City level

At city level, the different utility systems (energy, waste and waste water, transport) integrated in a connected system securing a good utilization of existing and new energy technologies as well as accessible RE resources such as biomass, organic waste, geo-thermal energy for heating, sea water for natural cooling etc.). Windmill power is used to recharge electrical cars and to run the big pumps in the district heating systems. Futhermore, big heat stocks capable of gathering heat production will be established, so that cheap surplus windmill power that can be stored ad used in times of little wind energy.

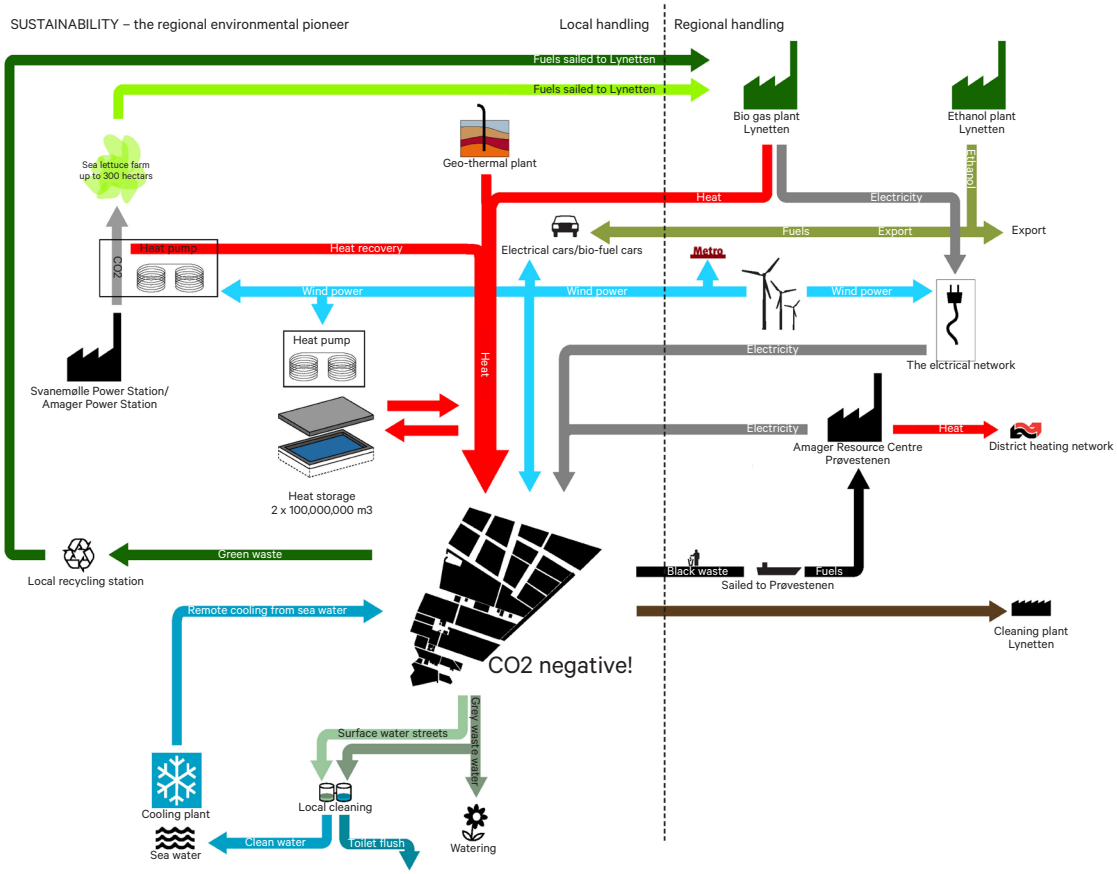
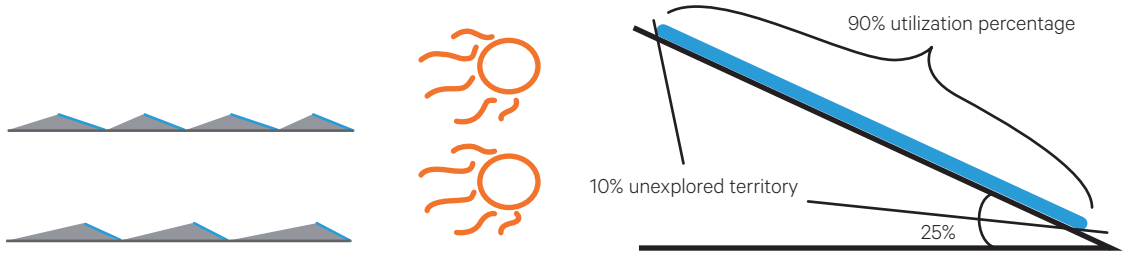


Figure 4.19: Example of energy system on neighbourhood level in the DK2050 scenarios Green state and Green networks. Source: Rambøll, COBE, SLETH and Polyform

4.6.2 Decentralized energy systems

Example of a decentralized heat supply system at individual level, supplied with eg. individual heat pumps, solar heat plant and solar cells on the roof. Buildings get their supply from energy plants on the lot. When it comes to electricity, however, homes are connected to the national network with the possibility of exchanging energy and its built-in flexibility. Other energy technologies such as small micro-windmills on the roof or fuel cells are also viable technologies if the user economy calls for it. Micro-windmills are seen as aesthetically unpleasant in cities and therefore only realistic in fringe areas, eg. rural properties and alike.



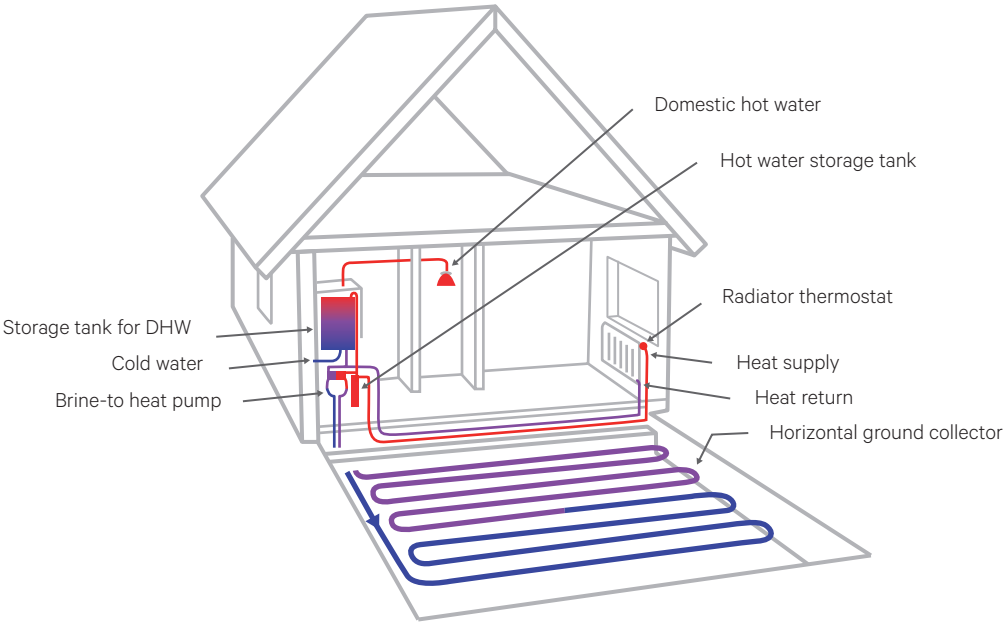


Figure 4.20: Example of a decentralized energy system in the DK2050 scenario Green guerilla

4.7 DECISION TIMELINE

The energy and climate political agreements as well as the frame conditions for extending particularly the centralized RE plants are expected to be a decisive factor in realizing the scenarios. The figure below illustrates when and which decisions must be made in order to realize each scenario. The decision-milestones generally take place roughly 10 years before reaching the goals of each scenario. If we want a 100 percent CO_2 reduction by 2050, we thus need to make the political decision to do so by 2040 as part of an energy-political agreement.

Each scenario is placed on the timeline according to degree of target fulfillment.

The biggest difference between Green state and Green networks in a CO_2 context is that the transportation is not CO_2-neutralized in Green networks. Since Green compromises is a kind of reference, nothing apart from what's already been decided, will happen. The timeline can therefore been seen as a kind of timetable for Green state and the scenario's relative position to the other scenarios.

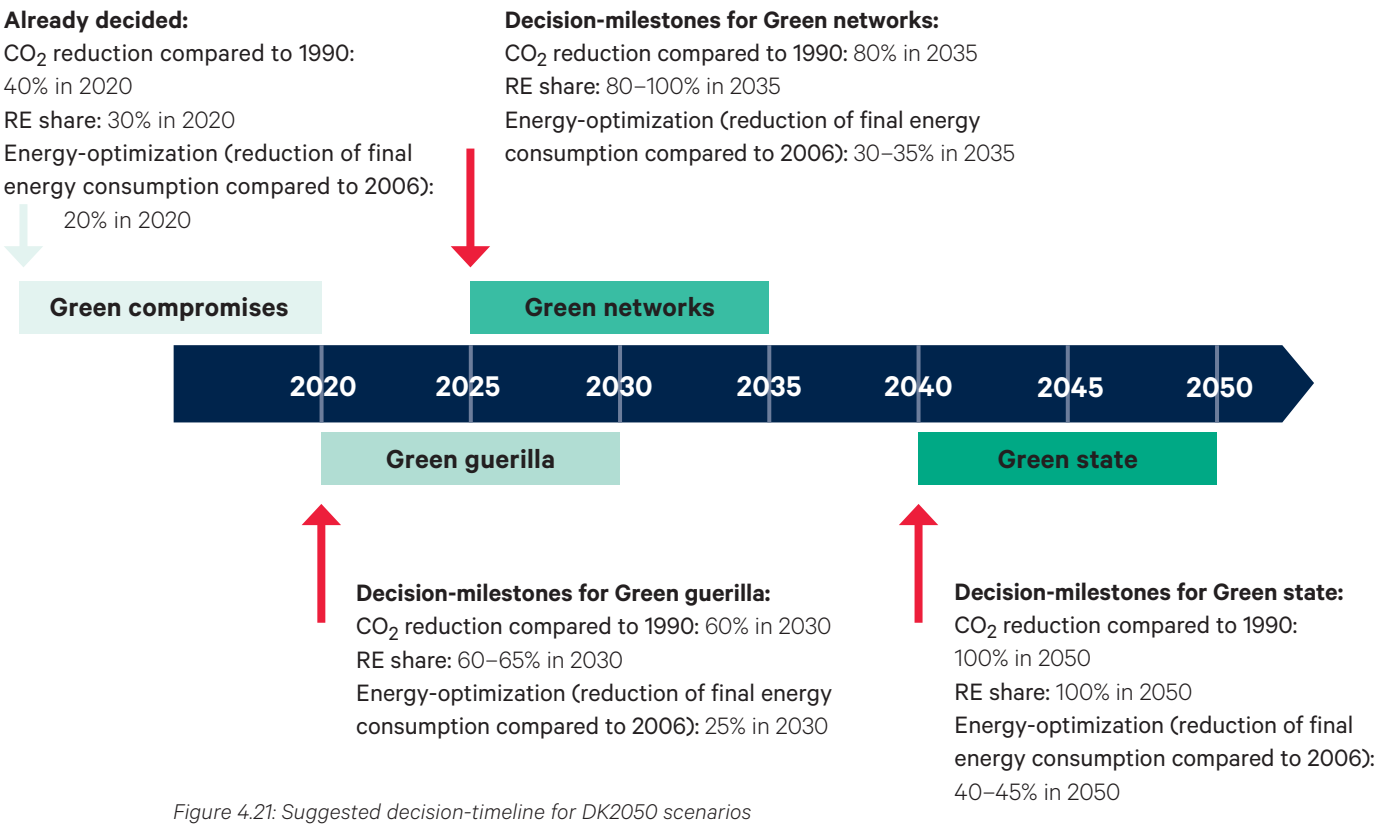


Figure 4.21: Suggested decision-timeline for DK2050 scenarios

4.8 ECONOMY – COSTS OF RE AND EE

Big investments in RE and EE are needed in order to adjust our current energy system from a fossil energy system to a more sustainable energy system free of fossil fuels. The costs include, according to the Energy Agency, eg. driving systems and fuel for cars, trucks, trains, ships and planes. They also include boilers, CHP plants, windmills, fuel factories and fuels for those. Furthermore, there are net and foreign connections as well as net trade with electricity and fuels, eg. 'storage' of wind power in Norway and Sweden.

Figure 4.22 below illustrates the costs for RE and EE divided into investments, savings, operation & maintenance, fuels, CO_2 and the total for the four scenarios. The costs of the fossil part of the scenarios is not calculated.

We see that the costs for RE and EE in 2050 make up around 140-156 billion kroner.

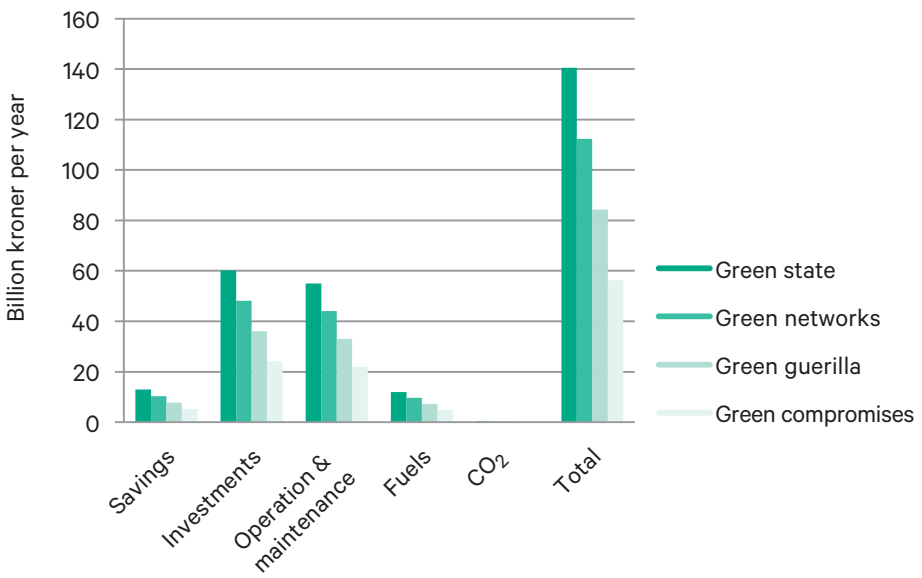


Figure 4.22: The costs of RE and EE in the DK2050 scenarios

4.9 INTERESTED PARTIES – WHO ARE THEY, AND WHAT PART DO THEY PLAY?

Adjusting the Danish energy system to 100 percent RE is a huge task that needs all interested parties (state, municipalities, utility companies, businesses, investors, citizens etc.) to be involved. The ambition of independence is even tougher when it comes to transport because it demands that new technologies are introduced, and that we change our habits and behaviour from being very resource-consuming (today) to being more sustainable.

The role of the state and the government in office is to give the general political frame conditions, meaning agreements, strategies, plans of action, instruments and financial incentives to power the development towards a society without the need for fossil fuels.

The municipalities need to make sure they implement strategies and plans of action on a local level in a close collaboration with utility companies, businesses and citizens. Strategic energy-planning is an important tool here, making sure that municipalities don't sub-optimize energy supply systems, but think across borders when it comes to eg. establishing bio gas plants to further socio-economically profitable solutions.

The utility companies need to be in charge of establishing future energy supply systems and will also be the ones to primarily invest in energy plants, infrastructure etc. to supply citizens and businesses. The utility companies need to make sure that these investments are made with regard to both socio- and business-economic profitability. They also need to be active partners in the strategic energy planning.

Bigger energy projects (wind parks etc.) can, just like today, attract private investments from pension companies etc. For smaller energy projects, co-op projects should be considered, where citizens and businesses get the chance to buy shares in eg. a windmill guild, large-scale solar heat plant or solar cell plants.

Businesses (especially manufacturing companies) can deliver surplus heat for local district heating networks instead of letting it go to waste, and also contribute actively to the strategic energy planning with a role as energy provider as well as lead the way when it comes to investing in RE and EE. There are a number of state grants that help companies to a green transition.

Citizens need to play an active part and make use of the various initiatives and possibilities to get rid of their old oil burners in return for district heating, energy-efficient heat pumps, solar heat or similar RE technologies. It will be a particular challenge to help citizens who live outisde of the centralized district heating and gas supply areas change to RE. The municipality can play an important part here with local plans, info campaigns, grants to turn citizens onto district heating or alternative types of RE. Homes also need to be energy-renovated since there is often a large potential for energy savings.

4.10 EXAMPLES OF DILEMMAS TOWARDS 2050

City level

- How visible are our energy solutions allowed to be in the cities? Would we rather have the windmills at sea, or are micro-windmills okay on roofs? Today, our energy plants and other industrial plants are located on the edges of the cities.
- How do we secure room in the cities for electrical cars, charger stations etc. who are meant to play a big part in balancing our energy system with many windmills?
- How do we make sure that new city development areas are sustainable and integrated in the existing infrastructure of the city if that's what's socio-economically most profitable? We have seen examples of the opposite trend in connection with a number of larger city development projects in Denmark.

Nationally

- Should trash be burned in the future for energy purposes or recycled to a larger extent?
- Should we only make use of local biomass in our power plants, or is it okay to import to a large extent, as long as this biomass lives up to sustainability regulation?
- How large a part should energy optimization play in the green transition? We can already build houses with zero energy consumption. However, socio-economically this is not necessarily the most profitable way to become green and carbon-neutral. How rigorous should our building regulations be in the future?
- How do we avoid cities/municipalities/regions making sub-optimized energy solutions that are not socio-economically optimal?
- How do we secure supply security at the same time as the green transition? More wind energy makes big demands on the energy system in the form of storage in eg. electrical cars, heat pumps, heat stocks and the use of smart grid etc.

Globally

- Europe's CO_2 reduction and green transition has partly succeeded by sending much of the industry-heavy production to China and other developing countries. However, the climate doesn't care abut this, since CO_2 emissions are a global problem. How do we avoid simply moving the CO_2 problem to other countries?
- How do we secure a sustainable utilization of global biomass resources? Deforestation can potentially become a bigger problem in the future because of a big demand for green energy. Climate-wise it might make sense to preserve and expand the rainforest instead of burning off the biomass in Denmark or in Europe.

5. Resources

5.1 THE CURRENT RESOURCE SITUATION

In October 2013, the Danish government released a resource strategy called 'Denmark without waste – Recycle more, burn less'. This resource strategy has since been followed up by a resource plan which states how to implement this strategy. The government's resource strategy very much indicates a wish to change directions in Denmark in the future.

Denmark is known for having a high degree of waste incineration, particularly when it comes to domestic waste, including garbage collection. Danes recycle 61 percent of the waste according to the government's resource strategy, which eg. covers a very high recycling percentage for building materials and a low recycling percentage for domestic waste. Only 22 percent of all domestic waste is recycled, and 75 percent is burned. The government wants to change these numbers.

Generally, the effort to recycle our waste is pretty good, but it's distributed on many hands, and it's up to each municipality to determine their own level of recycling. Several municipalities who have invested in incineration plants are faced with the fact that their investments are wasted if the amounts of waste to be burned are drastically reduced. This means that for a lot of municipalities, there is no incentive to recycle more materials.

The government's resource strategy sets the stage for the recycling share to be at 50 percent for domestic waste, and that there is increased recycling in a number of fields and for certain waste groups. One of the most important groups in the future will be organic waste which needs to be separated, biogases in order to gain energy from the waste and then compost it in order to lead phosphorus back into the earth.

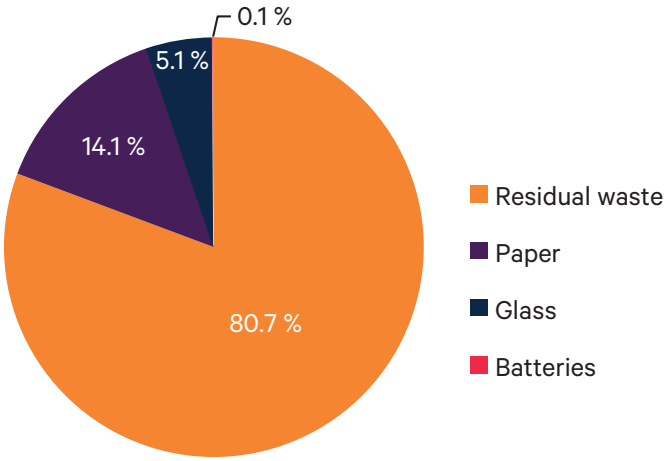


Figure 5.1: Calculated average for typical sorting out of daily refuse collection in Danish municipalities in 2012. It is obvious that the largest part of the waste is the residual waste which will be burned. The calculation is based on an average of empirical figures from Danish municipalities and is given in kg/household/year as share of the total amount of refuse collection in kg/household/year.

The main goal of 50 percent recycling of domestic waste is an average number, and it's up to the municipalities to make sure that we reach this goal together. Some municipalities have already come a long way with ways of securing a high recycling percentage, while others are still reluctant to move forward too fast if it turns out that the investments in new systems are wasted.

For many years, Denmark has had a leading position whn it comes to the environment, including energy-saving initiatives, recycling and environmental issues in general. A good number of countries surrounding us have taken considerable environmental steps over the past years and have in a lot of ways reached the same goals as the Danes, and even surpassed us sometimes – particularly when it comes to recycling materials.

The EU administrative environment agencies work with notions such as circular economy and linear economy which provide the basis for the work that Denmark is doing at the moment. Circular economy already exists in eg. aluminum cans where the material is mart of a circuit with a limited loss of material. But other groups of material aren't part of the circular economy, but get lost in a linear economy where materials end up at the incineration plant or, to a limited extent, the waste disposal site. Plastic is one of materials we aren't good at recycling, because many technical and material-related challenges stilt the development within this field.

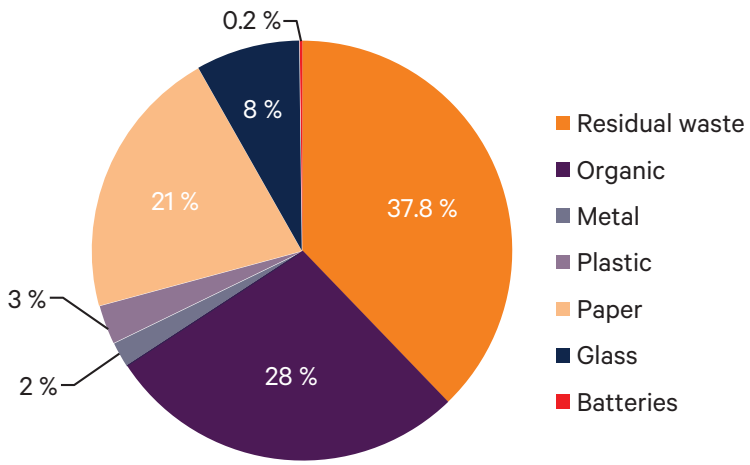


Figure 5.2: Calculated average of possible sorting out of dry, recyclable materials and organic waste from daily refuse collection in Danish municipalities. The calculation is based on an average of empirical figures from Danish municipalities and is given in kg/household/year as share of the total amount of refuse collection in kg/household/year.

5.2 GREEN STATE

In a situation where the state holds an important controlling position, waste management will be extremely streamlined. If the goal is to collect as many recyclable materials as possible in order to recycle them, as well as collect as much dangerous waste as possible so it can be handled correctly, a state-control will make it possible for all factions to become part of a general, collective system.

Denmark is a small country with few inhabitants and a limited geographical spread. The Green state scenario opens up the possibility of standardizing systems so that the 98 municipalities don't each have their own system, but a part of a national system. This will mean economies of scale, leading to a more stable financial foundation for creating 3-4 big waste sorting plants.

We will see a rationalization of waste collection systems meaning that citizens will see a limited number of containers where several different waste factions can be put into the same container and then be sorted somewhere else. A centralized sorting gives a higher level of cleanness in the collected factions and a higher sales value for the different recyclable materials.

5.3 GREEN NETWORKS

In a society with state-controlled goals and an individual approach to the green transition, enterprising businesses and entrepreneurs will probably set the agenda. With general national goals, based on objectives from the EU, and a number of subsidiary goals and milestones, the soil will be fertile for niche companies which can lead the way for new technologies within recycling. The ends can to a large extent justify the means, as long as the state's general objectives on environment, work environment etc. are observed.

Today, all citizens are forced to used the waste collection services of their municipality, but that needn't be the case in the future, if the general goal is simply to document that a give percentage of the waste is being recycled, and the limited rest energy-utilized.

One possibility is that we will see more individual garbage companies, and citizens can then subscribe to one or more state-approved refuse collectors, like it is the case with energy-providers today.

A broad individualization is not necessarily bad for the recycling goals, but we need to be innovative so that certain waste factions, such as composite materials, don't fall out of the systems and become a challenge to handle.

5.4 GREEN GUERILLA

In the Green guerilla scenario, where it is all about strong individualization and a weak state-control of society, the circular economy will be under pressure from market forced which, for good and for bad, will influence the general recycling percentage. In smaller circuits where house-shares and neighbourhoods connect via their norms and values, there is a foundation for shared composting or recycling of things and materials whereas the idea of actual recycling where materials are turned into something new belongs to larger circuits.

Large circuits, eg. recycling of metal, plastic and glass, are characterized by large material volumes, rationality and operations securing that complex and energy-heavy plants are profitable.
In a society marked by individualism, where one person's initiative can make business, the opportunity for developing small industries in the field of recycling are good. Enterprising business people will have an eye for that niche and start companies for the collection of various materials that can be sold and recycled. The drawback of these kinds of systems is that there will be factions that won't be collected because they don't have any value – among these composite materials, asbestos, concrete containing PCB etc.

The private initiative will blossom in many places and in different ways, and it will work at various levels of efficiency and rationality from one region to the next.

5.5 GREEN COMPROMISES

In a scenario where Denmark goes on as it is, it will be difficult for us to hold our own internationally, and we will not be able to reduce our consumption of the earth's resources. With a recycling percentage of 22 percent of the domestic waste refuse, it will be hard to seem like a pioneer country. The system with 98 municipalities' self-determination when it comes to waste management will be tested along the way.

For years, Denmark has been focused on the environment, and thar will hardly change, but with the current pattern of consumption that Danes have in general, it could be hard to meet the environment and resource challenges of the future.

If we go on at the same speed as these past decades, it will be hard for Denmark to uphold its leading position within environment and resources in 2050. A lot of the countries around us will have come up with the solutions needed to change the development and reduce the currently very high consumption of resources. This will influence Denmark's possibilities internationally where there is a need for our expertise. The development of the BRICS countries will mean that the growing middle-class will make the same demands on the environment and ressource consumption as we have in Denmark, and if we are not ahead in that field, others will take over the export of technology and knowledge.

5.6 EXAMPLES OF DILEMMAS TOWARDS 2050

- If we take materials from incineration plants in order to recycle them, the missing produced district heating needs to be substituted by another energy source.
- If we recycle a large part of the waste suitable for incineration, we will be left will a remnant with less heating value.
- If we create a society with many high-tech composite materials that are difficult to recycle, our possibilities of creating a circular economy are reduced.
- If many factions are added to the source sorting, we must find room for all the waste containers it takes in our cityscapes.
- If we hold on to the producers' right to choose materials and packaging quite freely, we need to be able to collect and recycle all of these very different types of materials.
- In order for 100 percent of all waste factions to be recycled, we need uniform refuse collection systems all over the country and an intervention in the municipal self-government.

6. Sea water level

The climate changes will primarily mean increased temperatures which will lead to a general sea level rise, a storm water level rise and a rising upper groundwater level. We don't expect to be able to change the climate development towards 2050, even if a full green transition is carried through in Denmark as well as large parts of the world. There will be a need to, no matter the CO_2 reductions we might see, adapt Danish cities to the climate through to 2050.

In 2013-14, the municipalities have drawn up the first climate-adaptation plans, so we now know about the climate influence, the risk of damages and the first plans for climate adaptation. These climate adaptation plans also include an estimate of the extent and the consequences of rising sea water levels and more frequent storm surges as well as plans on how to handle them. The climate adaptation plans from the municipalities include:

- The designation of a planning line where the area between the coast and the line is in danger of being flooded. If activities are planned withing the planning line, adaptation to sea level rises needs to be part of the project.
- Fixing the base level for new buildings located in areas at flood risk.
- Designing existing buildings so that the damages of flooding will be reduced, eg. with bulkhaeds at windows and doors.
- An emergency system consisting of sandbags that can be used as temporary dikes.
- The building of dikes along the coast to prevent flooding.
- The construction of sluices where streams run into the ocean (Aarhus is working on this solution) or on stretches of harbours to keep the water from storm surges out (Copenhagen).

6.1 DEVELOPMENT IN SEA WATER LEVELS

Due to rising sea water levels, the coast will be more prone to erosion than today. In low-lying areas with a stream running through it, there is also a risk of flooding from the stream, because of either more rain or a combination of more rain a rising sea water levels.

In Denmark, there is a huge geographical difference in water levels at high tide. At Vadehavet – the Wadden Sea – the flood height can reach five metres, while it only reaches 2-3 metres in Eastern Denmark and the inner seas. Figure 6.1 shows the expected development in sea levels as well as the uncertainty of the rise. Through to 2050, the general sea level is expected to rise 0.1-0.5 metres, and the storm surge level to rise 0.0-0.60 metres.

The Danish Ministry of the Environment has pointed out 10 areas at risk of flooding from streams, lakes, oceans and fiords. The 10 areas are chosen based on where flooding happens and how big the consequences (eg. financial building damages, environment, cultural heritage and people's health) of the floodings would be.

The 10 selected risk areas are shown in figures 6.2 and 6.3. Furthermore, there are examples of the size of areas that can potentially be maximum flooded. The municipalities with the 10 areas must draw up risk management plans for handling flooding before the end of 2014.

Sea level		
Expected rise in sea levels	**2050**	**2100**
Average water level rise	0.1–0.5 m	0.2–1.4 m
Local factors		
Isostatic uplift	- (0.0–0.10) m	- (0.0–0.2) m
Wind contribution at storm surge	0–0.10 m	0–0.3 m
Estimate of storm surge, total	0.0–0.60 m	0.0–1.7 m

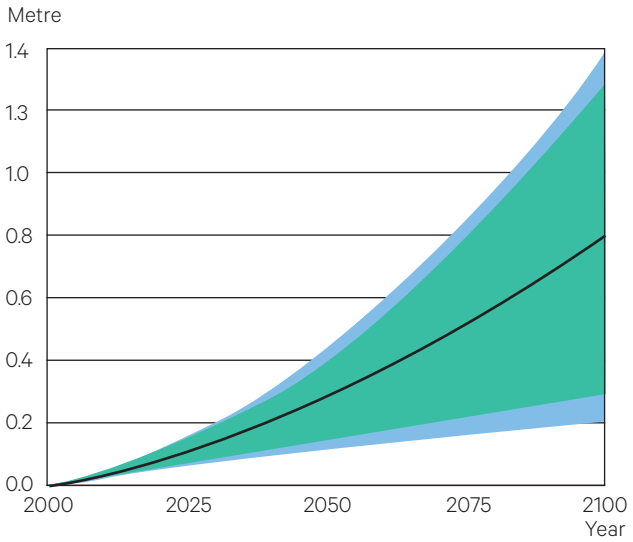


Figure 6.1: Graph of expected rise in sea water level, shown with the uncertainty of development.
Source: www.klimatilpasning.dk

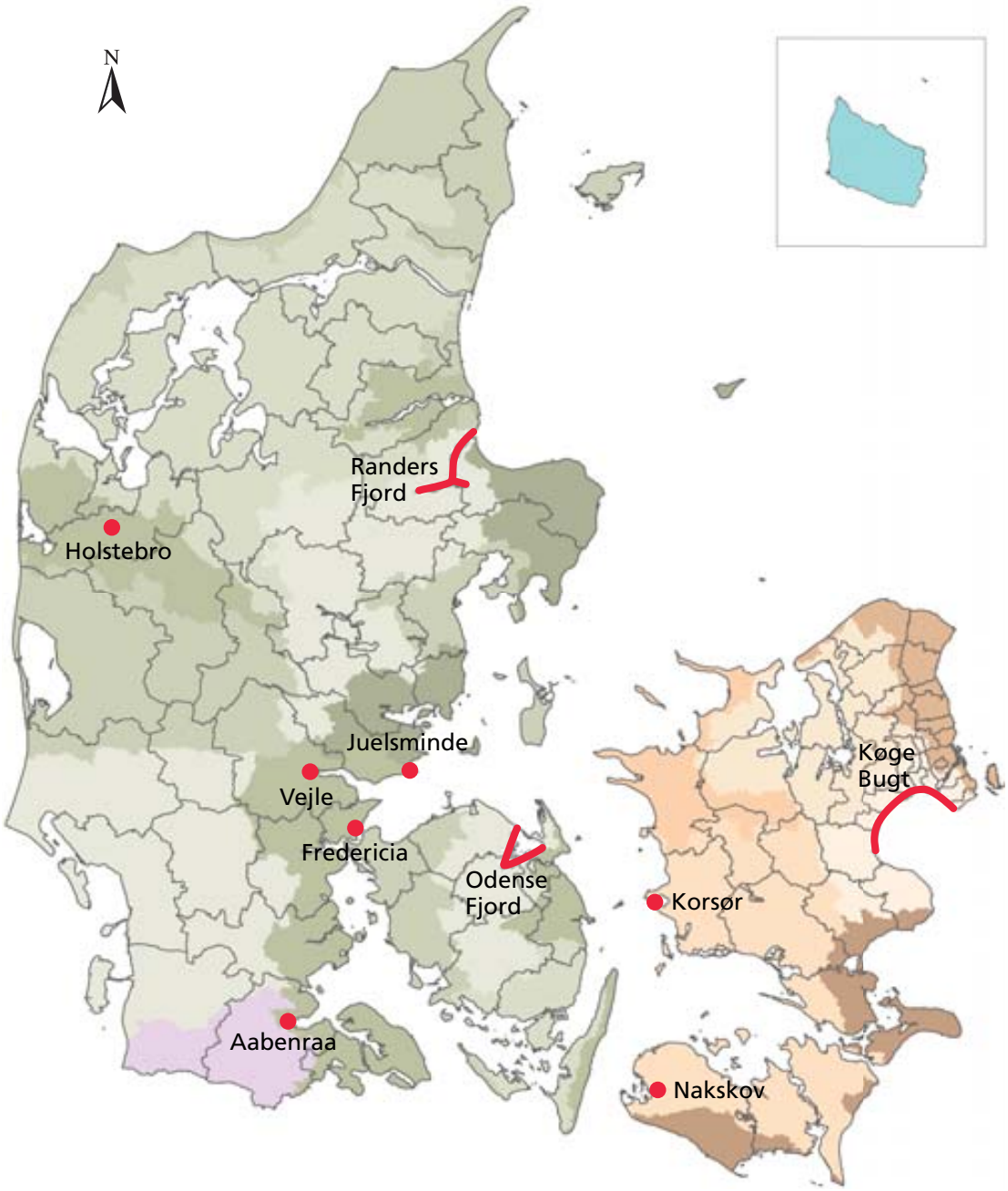
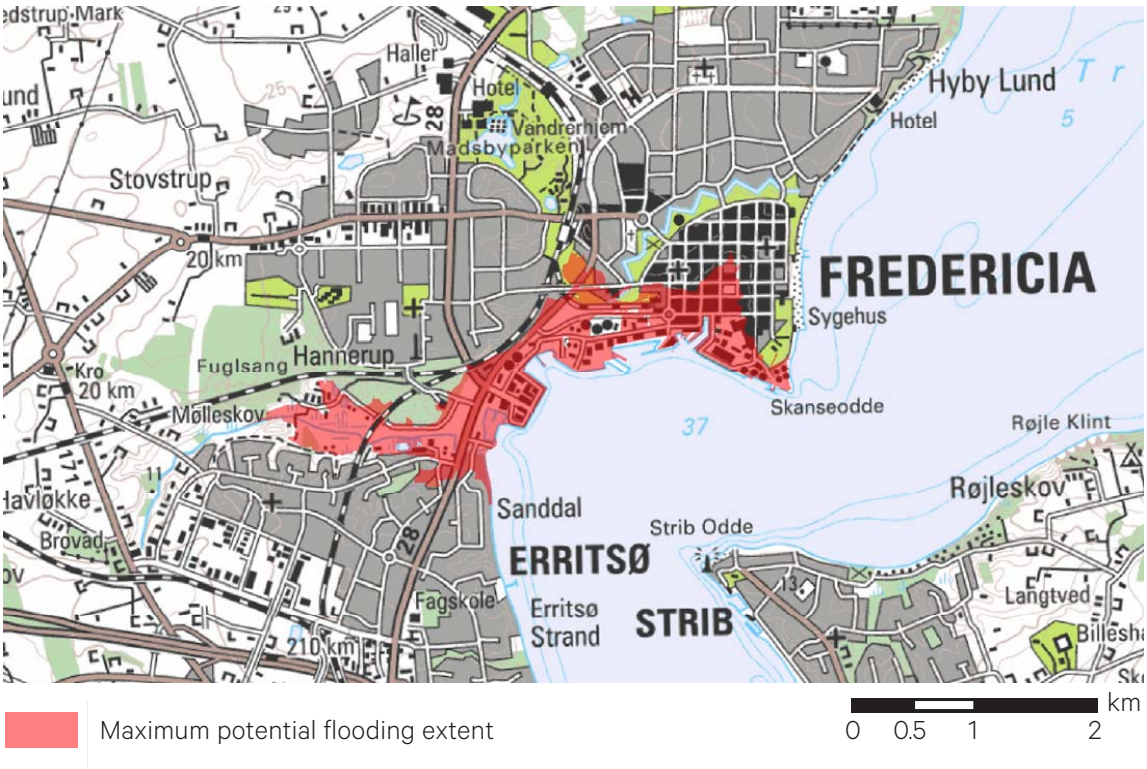
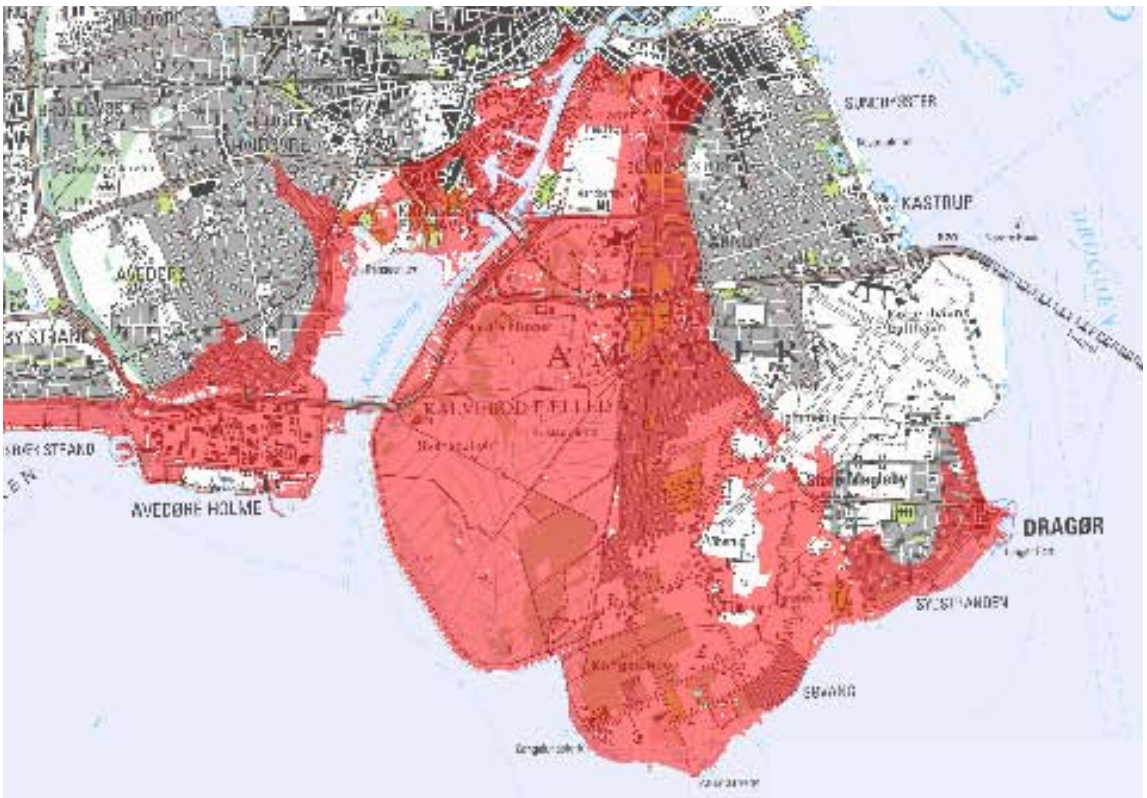


Figure 6.2: Designated risk areas for flooding from streams, lakes, oceans and fiords. Source: Naturstyrelsen (The Nature Agency). Final selection of areas at risk of flooding from streams, lakes, oceans and fiords, December 2011.



Maximum potential flooding extent

km
0 0.5 1 2



km
0 2.5 5 10

Figure 6.3: Examples of maximum potential flooding from the state's selection. Source: Naturstyrelsen (The Nature Agency). Final selection of areas at risk of flooding from streams, lakes, oceans and fiords, December 2011.

The four scenarios

Here, we describe how sea water levels could be handled in the four scenarios.

6.2 GREEN STATE

The urban space is planned, regulated and standardized, and the good of the community is valued over the individual. The public and private spheres collaborate on many levels. Plans for defending the coasts and harbour areas against sea level rises have been drawn up, so that both the private and public sectors gain from it.

Plans can be eg. long, connected dikes constructed in a way which adds value to the city or the community (eg. sand dunes, hills) or sluices that can keep water out of the harbour areas (like the ones the municipality of Copenhagen is working on). In all plans, areas have been pointed out as well as solid guidelines on how to design and protect these areas and adapt them to rising sea levels and storm surges. In some municipalities, citizens have been moved to other parts of the city and new coastal nature reserves have been created.

6.3 GREEN NETWORKS

The state has determined for the entire country which areas are at risk of flooding, and described possibilities and solutions that each homeowner can use. Denmark has developed a great number of solutions, both for using the areas that are at risk of flooding, for creating new types of housing and nature reserves and for protecting buildings.

Each individual is responsible for designing his house and its surroundings so they won't be damaged by higher sea levels and storm surges. Some build on poles and with high plinths so that water can't enter the house, others build dikes around the homes, while others yet have invested in sandbags and bulkheads to screen off doors and windows. In some areas, people have moved away from the areas at risk of being flooded, and these are now used as recreational spaces or for growing vegetables in raised beds.

6.4 GREEN GUERILLA

Each individual is responsible for protecting his or her property against rising sea levels. Many individual solutions have been developed, but there aren't any general guidelines on where the rising sea levels need to be taken into consideration.

The methods and ways of organizing society are the same as described in Green networks.

6.5 GREEN COMPROMISES

Storm surges are portended for certain, so that the cheap and non-permanent storm surge protection system can be put into action and protect the city from flooding from the ocean.

6.6 EXAMPLES OF DILEMMAS TOWARDS 2050

The climate will change, and there will certainly be a need to climate-adapt municipalities to higher water levels and storm surges. The question is how much the sea will rise and thus which areas will be affected.

Therefore, the dilemmas will deal more with how to handle the adaptation to climate changes than on whether or not this development is actually happening.

- It is uncertain how sea level rises and storm surge heights will change in the future and therefore also how large the affected areas will be.
- The law is currently leaving it up to each homeowner to be responsible (financially too) for protecting him- or herself against sea level rises. The homeowners who benefit from coastal protection pay for the construction and operation of it. There will be a big difference in how the coast protection and utilization of coastal areas will be in the future, depending on whether the homeowners or a more general authority are responsible (financially too) for planning and constructing the coastal areas.

7. Water supply and rainwater

As described in the chapter on sea level rises, the climate changes will mean more rainwater and more heavy cloudbursts. More rainwater and cloudbursts are currently mainly a problem in the big cities where the rainwater can't run off due to dense surface coating and a high level of pavement.

For the bigger cities (Copenhagen in particular), climate-adaptation is used as a lever to take the city in a bluer/greener direction. The plan is to create a new layer of infrastructure on the terrain surface that handles rainwater instead of it being led to the sewer pipes underground.

In Denmark, all drinking water comes from the groundwater, and we use drinking-quality water for basically all water-consuming activities. In areas with large water consumption, either because there are many people, eg. in the big cities (the Copenhagen area and Aarhus), or because there are many big water-consuming businesses (eg. Kalundborg), there is a focus on using water with another quality than drinking water (second-rate water) for activities that don't require drinking water quality water (eg. toilet flush, clothes washing, process water, cooling water etc.). In Kalundborg, the Kalundborg Symbiosen (the Kalundborg symbiosis) has worked on having internal water streams between companies, so that eg. cooling water from one company is used as process water in another. I Copenhagen, several plants have been constructed, where rainwater from roofs is used for toilet flush and washing clothes. The Nature Agency is also focused on propagating the use of second-rate water as a replacement for drinking water for activities that don't require drinking water quality.

Here, the four scenarios are analyzed in order to identify the conditions that might influence the water supply and handling of rainwater in 2050.

7.1 GREEN STATE

The Green state scenario is characterized by:

- The green transition have come far in all municipalities.
- A strong urbanization – the city space is planned, regulated, standardized, attractive, green and dense.
- The good of the community is valued over the inidividual. The public and private spheres collaborate on many levels.
- We would rather rent or loan.
- We take a collective responsibility for the environment – products must be recycled (water too).
- Our physical everyday life is digitalized.
- Large Danish export of green technology.
- More than half of all Danes live in multi-storey buildings.

Water

When it comes to managing water and the supply of drinking water, the estimate is that the following conditions will prevail in 2050:

- The municipality has planned the supply of water and the drainage of water, and it is an integral part of the new water circuit in the cities.
- Solutions are operated by utility companies, but can be local in some neighbourhoods or in a residential building.

7.2 GREEN NETWORKS

The Green networks scenario is characterized by:

- The green transition has come far in the municipalities, but there are large local differences.
- Very different cities because of different strategies. The city space in larger cities is diverse, tolerant, many-coloured, connected and green.
- Smaller cities are very different due to the preferences of the citizens. Some cities have semi-closed green circuits.
- Centralized solutions are under pressure. Many have individual solutions and local production.
- Being self-producing and self-sufficient gives social status.
- People tailor their own lives – personal preferences are dominant.
- Green roofs are developed for growing vegetables.
- Dansk Vandklynge pools resources and investments from the entire Nordic region. Attracts scientists and development from the entire world in the water field.

Water

When it comes to managing water and the supply of drinking water, the estimate is that the following conditions will prevail in 2050:

- Local water circuits have been established in individual homes or neighbourhoods.
- Water is recycled several times. Multi-stringed systems have been established in every home for different types of water depending on what it can be used for.
- Rainwater is collected and reused as a substitute for drinking water.
- There is a local recovery and infiltration of water to recreate the groundwater locally, so that pumping can be avoided.
- Technologies for cleaning arrangements and security have been invented.
- The citizens are responsible for their own water supply and drainage.

7.3 GREEN GUERILLA

The Green guerilla scenario is characterized by:

- New technology is run from below. No particular support from the political system.
- Green transition has come far in some municipalities, particularly in places where it's driven by local efforts.
- The big cities get bigger, but divided into very different neighbourhoods.
- Smaller city regions have growth because each one has specialized and prioritized differently. Very different cities.
- In some places, the supply is based on well-known technology, in other places it's 100 percent transitioned.
- Individually – bottom-up – drives the environmental development.
- Urban farming – vertical gardens.

Water

When it comes to managing water and the supply of drinking water, the estimate is that the following conditions will prevail in 2050:

- In some places, rainwater is still led into the sewer, in others it is collected and used in basically closed circuits within the city or in the big city within the neighbourhood.
- Water is recycled several times in some places, and different forms of water-sorting have been established, just like we know from our current waste sorting.

7.4 GREEN COMPROMISES

The Green compromises scenario is characterized by:

- The green transition is distributed very unevenly throughout the municipalities. The big cities have been most successful.
- The green transition is down-prioritized. Conservative values rule.
- The big cities are dominant. Shared planning philosophy.
- The big cities act as levers for the good life. Centralization and community dominate.
- Actions driven by economy. Green solutions are often more expensive than black ones.
- Focus on protecting Denmark against climate change. Sustainability is not a priority.
- Technological developments mean that everyone has full knowledge of the climate changes and can detect coming floods, hurricanes etc. early on.

Water

When it comes to managing water and the supply of drinking water, the estimate is that the following conditions will prevail in 2050:

- Solutions are driven by economy, and the cheapest solutions for draining water are always chosen. If that means sewers, that's the solution.
- Houses are adpated to the climate changes. It is almost 100 percent sure that cloudbursts will be portended so precautions can be taken.
- The supply of drinking water is still primarily taken from the groundwater, collected outside of the cities and pumped into the cities – even if this means pumping over large distances.

7.5 EXAMPLES OF DILEMMAS TOWARDS 2050

- Do we want to hold on to the policy that all drinking water is produced from clean ground-water, or could drinking water in the future also be produced from other kinds of water puryfied into drinking water quality with more advanced methods? The technologies are already here, but they demand more energy than the current water treatment method. On the other hand, more water could be recycled in the city and that would mean energy savings on pumping drinking water over long distances from spring sources outside of the city.
- Can we make space in the city for collecting and managing rainwater in terrain so that the water can become part of a recreational space, or will some of the water continue to be led away in underground pipes because the areas need to be used for buildings and infrastructure?
- If we get closed water circuits in each neighbourhood in city areas, the economies of scale and the security in the purifying of waste water in the large puryfying plants will be lost.
- Closed water circuits in each neighbourhood makes large demands on technology and security so that drinking water don't get mixed with non-drinking water, and there's no risk of it coming into contact with waste water. That would constitute a heath hazard.
- If we want a large percentage of water-recycling, we need different pipe systems for sorting the water and thereby for draining waste water and supplying drinking water and second-rate water.

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Participating municipalities

Copenhagen, Aarhus , Aalborg, Odense, Ringkøbing-Skjern
Sønderborg, Fredericia, Middelfart, Kalundborg and Høje-Taastrup

Knowledge panel

Professor Katherine Richardson Copenhagen University
Professor Mark Lorenzen Copenhagen Business School
Professor Brian Vad Mathiesen Aalborg University
Professor Gertrud Jørgensen Copenhagen University

Participating regions

The Capital Region of Denmark, the Region of Southern Denmark, North Denmark Region

Curator of the biennale exhibition

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