This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

ICARUS Policy Brief

Integrated Climate forcing and Air pollution Reduction in Urban Systems

The ICARUS project

ICARUS is a Horizon 2020 project, whose main objective is to develop integrated tools and strategies for urban impact assessment in support of air quality and climate change governance in EU Member States leading to the design and implementation of appropriate abatement strategies to improve the air quality and reduce the carbon footprint in European cities. The project will develop detailed policies and measures for air pollution and climate control for the short and medium term (until ca. 2030). For the long term perspective (2050 and beyond) ICARUS will develop visions of green cities and explore pathways on how to start realizing these visions.

On board are experts of 19 Partner Institutions from 10 European countries, all with multidisciplinary expertise and experience in intersecting and complimentary research in research areas related to the climate and the environment and their interactions with health and wellbeing. The high scientific quality of the ICARUS team is based on the extensive and long-term experience of the partners, which include leading scientists and risk health research institutes in Europe.

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

KEY FACTS

What are the main health concerns with air pollution?

Ground-level ozone (O_3) is a gas formed by a number of chemical reactions between other air pollutants e.g. the man-made nitrogen oxides emitted from traffic and volatile organic compounds (VOCs).

Particulate matter smaller than 2.5 µm ($PM_{2.5}$) is solid or liquid particles emitted directly to the atmosphere or secondary particles formed chemically within the atmosphere. The sources can be both natural (e.g. sea salt and dust particles) or anthropogenic (e.g. soot particles from combustion processes).

Both ozone and $PM_{2.5}$ are associated with negative health impacts for humans. Particulate matter is known to be responsible for increased mortality linked to cardiovascular and respiratory diseases

- Polluted air was responsible in 2015 for 6.4 million deaths worldwide: 2.8 million from household air pollution and 4.2 million from ambient air pollution[1,2]. To get an idea of these numbers, in the same year, tobacco caused 7 million deaths, AIDS 1.2 million, tuberculosis 1.1 million, and malaria 0.7 million[3].
- Air pollution was responsible in 2015 for 19% of all cardiovascular deaths worldwide, 24% of ischaemic heart disease deaths, 21% of stroke deaths, and 23% of lung cancer deaths[3]. Additionally, ambient air pollution appears to be an important although not yet quantified risk factor for neurodevelopmental disorders in children and neurodegenerative diseases in adults[4]
- In the absence of effective and timely measures, ambient air pollution is estimated to cause to cause between 6 million and 9 million deaths per year in 2060[5].
- Ambient air pollution is responsible for great economic losses. These losses include medical expenditures—an estimated US$21 billion globally in 2015[5]—lost economic productivity resulting from pollution-related disease and premature death, and the cost of environmental degradation
- Air pollution and climate change are closely linked and may share common solutions (*win-win* solutions).
- Major emitters of carbon dioxide are coal-fired power plants, chemical producers, mining operations, and vehicles.
- Accelerating the switch to cleaner sources of energy will reduce air pollution and improve human and planetary health

[1] Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016; **388:** 1659–724.

[2] Prüss-Üstun A, Wolf J, Corvalán C, Bos R, Neira M. Preventing disease through healthy environments. A global assessment of the burden of disease from environmental risks. Geneva: World Health Organization, 2016

[3] Global, regional, and national life expectancy, all-cause mortality, and cause specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1459–544

[4] Grandjean P, Landrigan PJ. Neurobehavioural effects of developmental toxicity. Lancet Neurol 2014; 13: 330–38.

[5] Organisation for Economic Co-operation and Development. The economic consequences of outdoor air pollution. Paris: Organisation for Economic Co-operation and Development Publishing, 2016

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

INTEGRATED ASSESSMENT OF ICARUS POLICIES

Air pollution health effects

Air pollution is considered one of the major environmental threats for human health. According to WHO, air pollution kills an estimated seven million people worldwide every year. WHO data shows that 9 out of 10 people breathe air that exceeds WHO guideline limits containing high levels of pollutants, with low- and middle-income countries suffering from the highest exposures. Air pollution impacts on human health include both short- and long-term effects, that are not only related to respiratory diseases, but also to cardiovascular disease and impacts to the nervous system, resulting in both neurodevelopmental and neurodegenerative diseases. The main short- and long-term health effects of air pollution are illustrated in Figure 2.

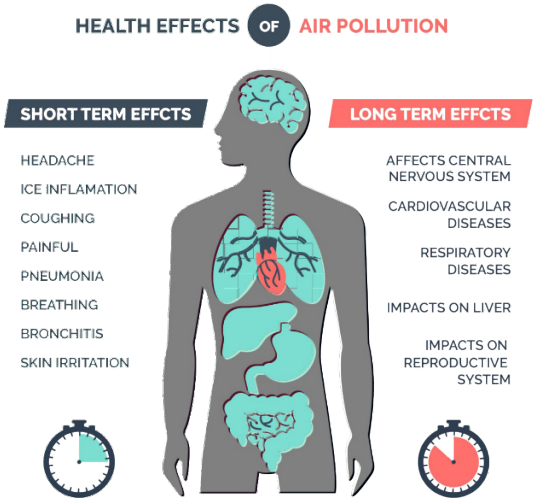

Figure 1. Short- and long-term effects of air pollution

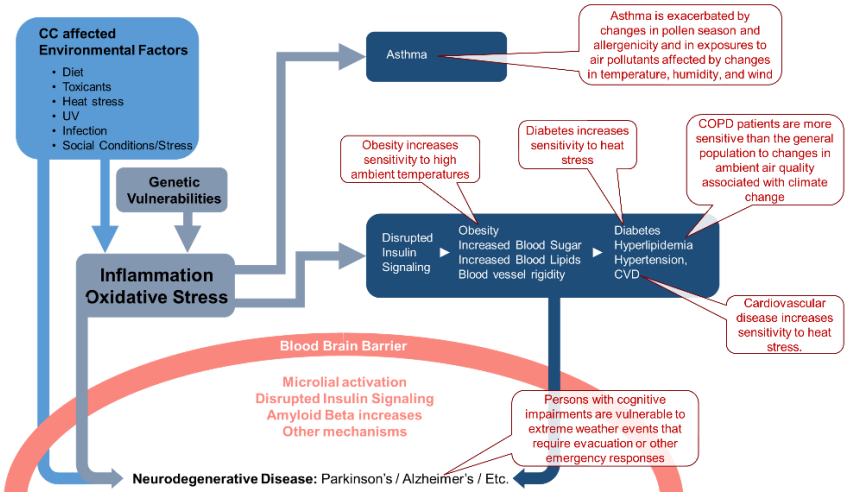

Figure 2. Interplay among air pollution, climate change and western diseases

However, what is of particular importance, is that air pollution, is involved in a cascade of health effects initiated from inflammatory processes, and together with other environmental stressors, result in the so-called "western diseases". It is also of particular importance, that the health effects related to western diseases, are further potentiated by climate change. In fact, the air pollution and climate change related western diseases involve asthma and respiratory disease, together with metabolic disruption (which in turn is related to obesity, diabetes and cardiovascular disease) and neurodegenerative disorders. Common air pollutants, such as PM, ozone, NOx, have been found to initiate inflammation (either local across the respiratory tract, or systemic), as well as to induce oxidative stress. These two mechanisms have been associated with the cluster of diseases mentioned above among many others. However, what makes things more complex, is that climate change amplifies these impacts, while some of these impacts enhance susceptibility to direct health effects of climate change, e.g. obesity increases sensitivity to high ambient temperatures, while cardiovascular disease increases sensitivity to heat stress. At the same time, people with neurodegenerative disease such as Alzheimer and other relevant cognitive impairments are vulnerable to extreme weather events that require evacuation or other emergency responses.

As a result, combating air pollution and mitigating climate change has multiple benefits for public health protection. In this sense, public health impacts of policies and measures combating air pollution and mitigating climate change within the frame of ICARUS are presented below.

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

Concept and scenarios analysed

The results of air quality improvements on environment, health and climate change brought by the potential implementation of selected measures and policy options (a) policies and b) measures towards integrated win-win solutions on the urban scale (measure/policy combinations) in an integrated manner, have been evaluated within the ICARUS project, according to the following workflow:

• Change in emissions of air pollutants including life cycle emissions in/outside cities for selected activities.

• Change in emissions of greenhouse gases including life cycle emissions in/outside city (thus changes in the carbon footprint caused by changes in sectorial activities).

• Changes in ambient concentration of air pollutants and greenhouse gases.

• Changes in the exposure to air pollutants taking into account important indoor sources.

• Changes in the associated impacts on human health.

• Societal and economic impacts, including costs for the emission source operator and for other actors of society, including health impacts, time losses or gains and wider impacts.

In total 40 policy scenarios were analysed, comprising approximately 5 scenarios for each ICARUS city.

More than half of the chosen policy scenarios were associated to the transport sector (23 out of 40). The most recurrent themes are:

- Reduction of motorized individual transportation by measures like
  - *Promotion of a switch from road transportation to more environmentally friendly transportation modes like public transportation, walking and cycling*
  - *Introduction of new metro lines and further public transport infrastructure expansion*
  - *Reserved infrastructure for public transportation and dedicated bus lanes*
  - *Construction of metropolitan bike lanes*
  - *New parking regulations according to air quality criteria*
- Introduction of Low Emission Zones and driving bans
- Increasing electrification of the urban fleet
- Renovation of the public passenger transport vehicle fleet (CNG, hybrid or electric buses)

A scenario representing the increasing electrification of the urban fleet – either private vehicles or urban buses – has been selected in Brno, Thessaloniki, Stuttgart, Ljubljana and Milan. The introduction of a Low Emission Zone has been chosen for further analysis in Stuttgart, Milan and Madrid – even though the specific design of the measure varies from city to city.

Apart from these major themes and strategies, actions with a specific relevance or interest have been analysed for selected cities. In Basel a scenario has been chosen that envisions the conversion of the shipping fleet to zero emission ships as the port areas contribute a considerable amount to the total city emissions. A scenario in Athens supporting walking and cycling simultaneously considers the promotion of eco-driving behaviour, whereas in Madrid one scenario is associated to a public-private collaboration in order to make urban logistics more efficient.

The scenarios of the transport sector are followed by the residential sector (in combination with the industrial sector) covering more than one quarter of selected scenarios (12 out of 40). The most recurrent themes are:

- Replacement of fossil heating technologies by technologies like
  - High efficiency gas boilers
  - Heat pumps and solar heating
- Implementation of energy saving measures by insulation and renovation of the building stock
- Green infrastructure and bioclimatic design of buildings and neighborhoods

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

The replacement of fossil heating technologies was analysed in the cities of Basel, Brno and Stuttgart. The implementation of energy saving measures by insulation and renovation of the building stock was chosen for evaluation in Brno, Stuttgart, Ljubljana, Milan, Athens. Promotion of building insulation accompanied by the implementation of green infrastructure is analysed in Madrid and Thessaloniki. Furthermore, one scenario in Basel dealt with a hypothetical ban on small combustion of firewood, whereas one specific scenario concerning the conversion of residencies to nearly zero energy buildings has been analysed for the City of Athens.

The selected scenarios associated to the industrial sector included the reduction of biodegradable and recyclable waste in landfills in Thessaloniki and Athens as well as the use of refused derived fuels in Thessaloniki's cement industry (3 out of 40). Two scenarios addressing the energy sector, or a combination of residential and energy sector, consider an increase of district heating systems and the replacement of existing coal combustion units for its generation (Milan and Ljubljana). Finally, one measure in Milan focuses on nature-based solutions such as urban greening and therefore causes an emission removal that cannot be assigned to any one sector. A summary of the number of scenarios distribution per sector are illustrated in Figure 3.

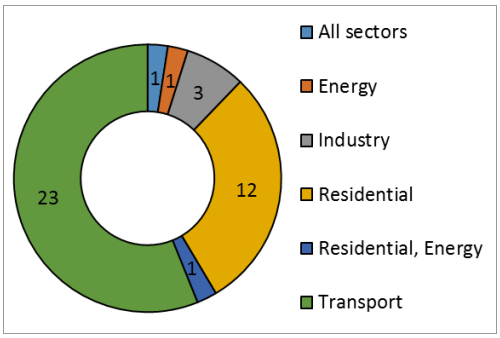

Figure 3. Number of scenarios distribution per sector analysed in ICARUS

Key findings

Measures such as

- large scale/city-wide sustainable mobility interventions covering synergetic effects of PT,
- walking, cycling focusing on all population groups combined with clean vehicles,
- combined with greater use of alternative fuels,

have shown the greatest potential for significant reductions in pollutant emissions and consequently health effects.

In addition, further steps to make some of these clean technologies more profitable and accessible still need to be taken. What also speaks in favour of these measures is the fact that they can be easily scaled up to address the needs of a larger share of users in the city, helping to achieve even better AP reduction results without major changes of the system in future. Other important gains in this domain have been attained through the implementation of demand management strategies, such as access restrictions.

Additional air pollution reduction advances could be reached through policy measures that encourage cycling, either by improving cycling infrastructure or increasing the availability of bike-sharing systems and especially through their further integration with public transport.

Efficient logistics and freight distribution are policy measures that have shown significant environmental improvement potential – although their impact on air pollution is relatively small, they contribute to the quality of life and wellbeing in cities. In most cases, up-scaling might help to maximise their potential benefits.

Assessment of impacts has proved to be problematic in some cases, because the distribution of small-scale measure effects has been diluted in the city-wide air pollution model. In such cases full-scale deployment of the measure should be taken into consideration in order to show the potential long-term effects.

In the energy sector, significant air pollution and health-related improvements are only evident from large-scale implementation, such as the enhancement of district heating, which could be further increased by addressing the fuel technologies behind them. Individual policies often produced significant positive air pollution reduction and related health impacts. Still, integrated policies combining individual measures in cost-effective policy bundles are poised to have even larger synergistic positive effects.

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

ICARUS Policy Brief

Integrated Climate forcing and Air pollution Reduction in Urban Systems

The ICARUS project

ICARUS is a Horizon 2020 project, whose main objective is to develop integrated tools and strategies for urban impact assessment in support of air quality and climate change governance in EU Member States leading to the design and implementation of appropriate abatement strategies to improve the air quality and reduce the carbon footprint in European cities. The project will develop detailed policies and measures for air pollution and climate control for the short and medium term (until ca. 2030). For the long term perspective (2050 and beyond) ICARUS will develop visions of green cities and explore pathways on how to start realizing these visions.

On board are experts of 19 Partner Institutions from 10 European countries, all with multidisciplinary expertise and experience in intersecting and complimentary research in research areas related to the climate and the environment and their interactions with health and wellbeing. The high scientific quality of the ICARUS team is based on the extensive and long-term experience of the partners, which include leading scientists and risk health research institutes in Europe.

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

KEY FACTS

Air Pollution?

Ground-level ozone (O_3) is a gas formed by a number of chemical reactions between other air pollutants e.g. the man-made nitrogen oxides emitted from traffic and volatile organic compounds (VOCs).

Particulate matter smaller than 2.5 µm ($PM_{2.5}$) is solid or liquid particles emitted directly to the atmosphere or secondary particles formed chemically within the atmosphere. The sources can be both natural (e.g. sea salt and dust particles) or anthropogenic (e.g. soot particles from combustion processes).

Both ozone and $PM_{2.5}$ are associated with negative health impacts for humans. Particulate matter is e.g. known to be responsible for increased mortality linked to cardiovascular and respiratory diseases

- Polluted air was responsible in 2015 for 6.4 million deaths worldwide: 2.8 million from household air pollution and 4.2 million from ambient air pollution[1,2]. To get an idea of these numbers, in the same year, tobacco caused 7 million deaths, AIDS 1.2 million, tuberculosis 1.1 million, and malaria 0.7 million[3].
- Air pollution was responsible in 2015 for 19% of all cardiovascular deaths worldwide, 24% of ischaemic heart disease deaths, 21% of stroke deaths, and 23% of lung cancer deaths[3]. Additionally, ambient air pollution appears to be an important although not yet quantified risk factor for neurodevelopmental disorders in children5 and neurodegenerative diseases in adults[4]
- In the absence of affective and timely measures, ambient air pollution is estimated to cause to cause between 6 million and 9 million deaths per year in 2060[5].
- Ambient air pollution is responsible for great economic losses. These losses include medical expenditures—an estimated US$21 billion globally in 2015[5]—lost economic productivity resulting from pollution-related disease and premature death, and the cost of environmental degradation
- Air pollution and climate change are closely linked and may share common solutions (*win-win* solutions).
- Major emitters of carbon dioxide are coal-fired power plants, chemical producers, mining operations, and vehicles.
- Accelerating the switch to cleaner sources of energy will reduce air pollution and improve human and planetary health

[1] Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016; **388:** 1659–724.

[2] Prüss-Üstun A, Wolf J, Corvalán C, Bos R, Neira M. Preventing disease through healthy environments. A global assessment of the burden of disease from environmental risks. Geneva: World Health Organization, 2016

[3] Global, regional, and national life expectancy, all-cause mortality, and cause specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 2016; 388: 1459–544

[4] Grandjean P, Landrigan PJ. Neurobehavioural effects of developmental toxicity. Lancet Neurol 2014; 13: 330–38.

[5] Organisation for Economic Co-operation and Development. The economic consequences of outdoor air pollution. Paris: Organisation for Economic Co-operation and Development Publishing, 2016

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

ICARUS KEY FINDINGS

Policies and measures for meeting environmental and climate aims should – at least in the long run - be efficient, i.e. the benefits should outweigh the costs

- Benefits include the reduction of damages and risks to humans, ecosystems and materials by reducing air pollution and climate change.
- Costs include financial costs (including capital costs and operations and maintenance costs) and other negative impacts including time losses or reduction of comfort.
- Comparing the economic value of such benefits and losses involves placing monetary values on these costs and benefits, where possible, and comparing them across time.

In general, in most cases in the ICARUS cities the benefits of mitigation actions outweigh the costs when health co-benefits are considered

However, this is not always the case and different city level actions will be merited which consider factors such as differing baselines, different urban forms and differing priorities for citizens and policy makers.

- Fully integrated cross-cutting environmental policies are needed, which consider the multifaceted nature of "wicked" environmental issues. Climate mitigation policies cannot be made in a silo from air pollution, health and other environmental strategies.
- Policies and measures, that reduce greenhouse gas emissions, in most cases also change – reduce or increase – emissions of air pollutants and vice versa. Thus, if one department of an environmental authority prepares an air pollution control plan and another one a climate protection plan, inconsistent policies may arise. A combined, coherent set of environmental policies is needed to deliver optimal solutions addressing societal concerns.

The indicator that should be regulated to reduce the damage caused by air pollution should be the averaged exposure to the pollutants or the averaged intake by inhalation of the pollutants, and not the concentration at certain outdoor measurement stations.

- Health risks of air pollution mostly stem from inhalation of pollutants. And by far the highest health risks are caused by inhalation of PM2.5 and NO2 over a longer time period of several to many years.
- Thus, the average exposure or intake over a longer time period should be used as indicator, as it is obviously correlated with chronic diseases and especially chronic mortality.
- Exposure means the average concentration of a pollutant in the inhaled air over a certain time period, intake is the amount (mass or number) of pollutants inhaled into the respiratory system during a certain period.

Strategies to reduce damages caused by air pollution can take advantage of novel sensor technology to improve the targeting of restrictions

- The technology around sensors is improving and becoming less expensive over time. Personal sensors, like those used in ICARUS, can give better indication of the exposure of individuals to air pollution and further use of these technologies may enable more targeted actions to reduce individual exposures. Increased use of sensors across cities will give better insights into where damages are the highest resulting in a much better evidence basis for action that traditional air pollution monitoring offers.

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

Indoor Air Quality: Lessons from ICARUS

- Indoor air pollution poses a significant health risk and policy action may be needed
- People in Europe stay most of the time indoors. The project results show that in Europe about 24% of exposure to NO2 and about 45% of exposure to PM2.5 are caused by indoor sources.
- Indoor air pollution arises both from indoor sources of pollution (including cooking and cleaning) and from air pollution that comes from outside.
- Actions to address indoor air pollution will include measures to encourage
  - Better ventilation (e.g. better standards for extractor fans or cooker hoods),
  - behaviour change for individuals and, potentially,
  - the use of smart monitors in homes.
- More investigation of particular sources of indoor air pollution, including the use of incense sticks and wood burning stoves, is needed. Actions should be carefully designed to avoid unintended consequences.
- Concentrations of PM2.5 and PM10 in underground train and metro stations should be regulated; The measured concentration of PM2.5 and PM10 are much larger in underground train and metro stations than in urban street canyon stations. The high pollution is caused by abrasion processes. Thus, a reduction (e.g. use of filters) would be beneficial.

Future visions need to be developed to assist in developing appropriate strategies

- In ICARUS, we have shown the potential for developing city level actions based on visioning processes, which allow stakeholders to consider different potential futures and plan in different ways.
- The city of the future may look quite different from the city of today – and these futures may emerge sooner than expected. We have seen the effect of COVID on commuting – and as technology advances and our work lives change, so too will the demands society places on urban systems. Being prepared for change, and being proactive in determining the design of our cities to be adaptable to different futures, is important.
- Damages and risks caused by greenhouse gas emissions could be assessed by using worldwide marginal avoidance costs to reach agreed climate protection aims, especially the aim agreed during the 2015 United Nations Climate Change Conference, COP 21 in Paris.

Reduction of air pollution from outdoor sources

- For small wood and pellet firings the use of fine-dust filter should be mandatory. Furthermore, in cities with larger NO2 concentrations the mandatory use of SCR filters or the ban of these firings should be considered.
- The emissions of combustion processes in larger stationary and in mobile sources are now well regulated. A problem remains: small wood firings (< 1MWth). They contribute efficiently to the reduction of greenhouse gas emissions, but the damage caused by emissions of PM 2.5 and NOx is larger than the avoided damage of climate protection. Wood and pellet firings also emit more NOx than gas or oil firings (as the latter use low NOx burners).
- Contrary to combustion processes, diffuse processes like abrasion, bulk handling, demolition of buildings a.s.o. are less regulated; reduction possibilities should be investigated. For example, tire and brake wear could be efficiently reduced by developing and demanding tires and brakes, that last longer without worsening their grip.

This project has received funding from the European Union's H2020 Framework Programme under grant agreement No - 690105

Reduction of air pollution from indoor sources

- Important indoor sources in private households are passive tobacco smoking, cooking and frying, operation of open chimneys and older wood log stoves in living areas, burning of incense sticks and all kinds of diffuse abrasion processes. Reduction possibilities should be investigated. For example, ban of incense sticks or regulation to use effective kitchen hoods.
- Articulation of a road map towards cities that are climate neutral and without harmful air pollution is a realistic possibility nowadays that needs to be promoted across the EU.
- The thermal insulation rate for buildings should be enlarged to around 3%/a of all buildings, that are now (2020) not renovated. For all buildings, that get new tight windows, inserting mechanical ventilation systems with heat recovery should be mandatory.

Reduction of GHG emissions

- A strategy to reach the climate protection aims would be to implement a tax per t of CO2eq to be paid for each t of CO2 eq emitted for all sectors The tax would increase each year by a certain percentage (e.g.3%/a) until marginal costs per t of CO2eq to reach the Paris Agreement aims are reached in 2050. If costs decrease due to technical progress, the tax will decrease. The CO2 tax would also be levied from imports according to the CO2 eq emitted during production and transport, as long as the producing country does not raise an own GHG tax. For exports in countries without GHG tax the tax would be refunded. However, the authorities would have to finance research and development and market penetration of new products and might also have to finance the infrastructure needed for the new techniques (charging stations, hydrogen grids, ...)
- The development of not too expansive long-term electricity storage would be urgently needed. Furthermore, research and development concerning the conversion of electricity in hydrogen, methane and synthetic fuels and the transport of hydrogen is necessary. After a decision is made to use hydrogen, the natural gas grid should be enhanced to be able to transport hydrogen.
- The main problem with electricity production from wind and solar is intermittency, namely that electricity is only produced, when the wind is blowing and the sun is shining. Especially the occurrence of dark doldrums, that could last for several weeks, is a problem.
    - Solutions are either the storage of electricity in long term storage systems or the conversion of water using excess electricity in hydrogen and then the conversion of hydrogen and CO2 into methane and/or synthetic fuels.
    - The final products can be much more easily stored than electricity. Both options are currently still very expansive and need further development.
    - The production of hydrogen is cheaper as the further conversion into methane and fuels. On the other hand, the infrastructure for methane and synthetic fuels, is already available.

.