Air Pollution in Istanbul

Commissioned by the Netherlands Enterprise Agency

AIR POLLUTION IN ISTANBUL

A report on air pollution and its sources in Istanbul and the current Dutch developments that can contribute to a better air quality in Istanbul.

ABSTRACT
This report will provide an overview of the current situation regarding the air pollution in Istanbul and ultimately serve as an advisory report which Dutch knowledge and knowhow can be implemented in Istanbul.

Orkide Nur Kara
04/07/2018
Executive summary

Air pollution is a problem that accumulates with urbanization and threatens human health. The quality of the air we breathe is even more important for a mega city like Istanbul, having the busiest traffic flow and highest population in Turkey. This report presents an analysis of the concentration of air pollutants in 2017, which is used to estimate the air quality in Istanbul. Furthermore, Dutch knowhow that can contribute to a better air quality in Istanbul has been analyzed.

The air quality in 2017 has been measured with the data retrieved from National Air Quality Monitoring Network, which is coordinated by the Turkish Ministry of Environment and Urbanization. The results of the analysis, which are verified with the Air Pollution Report 2017 published by the Turkish Chamber of Environmental Engineers, show that Istanbul has a serious air pollution problem. The main sources of the air pollution in Istanbul are identified as traffic and industry emissions and urban renewal.

A program is already prepared by Ministry of Environment and Urbanization and an Air Quality Index is formed Turkey-wide to reduce air pollution. Currently, air pollutants are being monitored via many stations in Turkey. Monitoring the change of the concentrations of the air pollutants within time and estimating their trends is necessary to increase the air quality in Istanbul. However, measurements at the stations are not done on a regular basis. Furthermore, not all air pollutants are being measured in the stations.

There are two recommendations in order to improve the air quality in Istanbul: better and/or more air quality measurement systems need to be adopted and concrete measures need to be taken to improve air quality. USP InnovatieLab Leefomgeving is a Dutch initiative that could increase the reliability of data and provide more accurate information on the air quality in Istanbul. In order to reduce the traffic emissions, measures need to be taken to decrease the use of (diesel) vehicles in the city. The scrapping scheme and the banning of old (diesel) cars in the city are some of the measures in the Clean Air Package of Rotterdam that Istanbul can benefit from.

To decrease industry emissions, it is suggested to introduce circular principles in the automotive sector, which has a large share in the Turkish sector distribution. Istanbul is not familiar yet with the concept of circular economy and therefore has not many applications in this field. The adoption of circular principles in the automotive sector will minimize the environmental impact and positively influence the air quality. Considering the growth potential of this sector, it seems wise to come up with circular approaches in this sector. BlackBear seems to be the Dutch circular innovator in this field, which owns the knowhow to recycle old carbon black tires and thereby decreases the environmental impact.
Foreword

Before you lies the report 'Air Pollution in Istanbul'. This report presents the situation regarding the air pollution in Istanbul, based on a qualitative and quantitative research. The aim of the report was to investigate the causes of air pollution in Istanbul and the Dutch technologies and knowhow that can contribute to a better air quality in the city. This report is the result of a 5-month internship at the economy department of the Consulate General of the Kingdom of the Netherlands. The internship was a new and very instructive experience for me and I would therefore like to thank a number of people who have guided me in this process.

First of all, I want to thank my supervisor Sylvia Deepen for her constructive criticism and personal involvement. During my internship she gave valuable feedback on my work. In addition, I would also like to thank other colleagues who were always willing to make time for my questions and who helped me to collect the necessary information in this way.

I wish you a lot of reading pleasure.

Orkide Nur Kara

Istanbul, 4 July 2018
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1. Introduction

1.1. What is air pollution?

Air pollution is the contamination of air. Burning fossil fuels releases gases and chemicals into the air. Air pollution does not only contribute to climate change but is also exacerbated by it. By trapping the earth’s heat in the atmosphere, greenhouse gases lead to warmer temperatures and all the hallmarks of climate change. There are various substances that pollute the air. The most important are nitrogen dioxide (NO₂), particulate matter (PM₁₀ and PM₂.₅), carbon dioxide (CO₂), sulfur dioxide (SO₂) and ozone (O₃). Carbon dioxide, a greenhouse gas, is the main pollutant that is warming earth. Other greenhouse gas includes methane—which comes from such sources as swamps and gas emitted by livestock. NO₂ and SO₂ can contribute to the formation of particulate matter and ozone.

1.2. Causes

The air quality is determined by the amount of harmful substances present in the air. Our air naturally contains particulate matter and nitrogen dioxide. Road and maritime traffic, emissions from factories and industries, urban renewal, agriculture, mining operations and indoor air pollution increase these concentrations and wear them to the air pollution. In order to come up with solutions to air pollution and thereby increase the air quality, we need to understand the factors that cause the contamination of the air and risk our health. The causes of air pollution can be categorized into:

1) Burning of fossil fuels

Most of the air pollution comes from the burning of fossil fuels, such as coal, oil, natural gas and gasoline, which are used for domestic heating and transportation. Figure 1 shows a comparison of emissions from residential or commercial combustion of different heating fuels – coal, No. 6 (heavy) fuel oil, No. 2 (light) fuel oil and natural gas. It is obvious that coal is responsible for all four types of air pollutants. An analysis of the European Environment Agency (EEA) shows that 45.8 percent of the NOₓ emissions in Turkey is the result of energy use and production. The second important source of NOₓ is road transport, whose contribution is 35.2 percent. Furthermore, it seems that 62 percent of SO₂ emissions comes from energy production and 23.2 percent from use of energy. This means that 85.6 percent of SO₂ emissions in Turkey can be attributed to the use and production of energy. The figures 7 and 8 in the Appendix present the trends of the emission sources of SO₂ and NOₓ in Turkey. Figure 7 in the Appendix shows that the contribution of road transport to the amount of NOₓ emissions has increased over the years.

2) Exhaust from factories and industries

Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air and thereby deplete the air quality. Petroleum refineries also release hydrocarbons and various other chemicals that pollute the air and also cause land pollution.

3) Urban Renewal

Due to the implementation of many big infrastructure and construction projects in Istanbul, the urban renewal seems to contribute to the air pollution in the city as well.
4) Agricultural activities
Ammonia is a very common byproduct from agriculture related activities and is one of the most hazardous gases in the atmosphere. Use of insecticides, pesticides and fertilizers in agricultural activities has grown quite a lot, which cause the emission of harmful chemicals into the air.

5) Mining operations
Mining is a process wherein minerals below the earth are extracted using large equipment.

6) Indoor air pollution
Household cleaning products and painting supplies emit toxic chemicals in the air.

1.3. Solutions
Several attempts are being made worldwide on personal, industrial and governmental levels to curb the intensity at which air pollution is rising. We are seeing a series of innovations and experiments aimed at alternate and unconventional options to reduce pollutants. As individuals, we can contribute by supporting leaders who push for clean air and water and responsible steps on climate change. The following approaches can be distinguished that can reduce air contamination:

- **Make use of green transportation or public mode of transportation.** Use of public mode of transportation, electric or hybrid cars minimize the release of emissions.
- **Circular economy.** Products, parts and materials are used, cared for, repaired, reused and recycled as much as possible.
- **Emphasis on clean energy resources.** Renewable energy generates electricity from sustainable sources like wind, solar, and geothermal power with little or no pollution.
- **Energy efficiency.** Energy efficient devices reduce the energy use.

1.4. Conclusion
Air pollution refers to the release of pollutants into the air that are detrimental to human health and the planet as a whole. Environment Protection Agency (EPA) determined six criteria air pollutants. These pollutants are particulate matter (PM), lead (Pb), carbon monoxide (CO), sulfur dioxide (SO₂), nitrogen dioxide (NO₂) and ozone (O₃). Table 1 provides the main sources of each type of air pollutant. This table shows that vehicles cause emissions of many air pollutants. In general, the main sources of air pollution can be classified as: vehicle and industry emissions, mining operations, agriculture and households. Most of the air pollution in Turkey comes from energy use and production, which is used for domestic heating and transportation, amongst other things.

The most basic solution for air pollution is to end its root causes: quit coal and move away from fossil fuels, replacing them with clean, renewable energy. In the short-term, there are many intermediate solutions for air pollution. The use of renewable energy sources, introducing cleaner fuel standards and switching to electric vehicles are only a few of the measures that can be implemented. However, all of these solutions require governments to recognize the impact of air pollution on public health and the economy, and take action accordingly.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Main sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>Fossil fuel burns and vehicle emissions</td>
</tr>
<tr>
<td>NOₓ</td>
<td>High temperature combustion processes and vehicle emissions</td>
</tr>
<tr>
<td>PM</td>
<td>Industry, vehicle emissions, fossil fuel burns and agriculture</td>
</tr>
<tr>
<td>CO</td>
<td>Incomplete combustion and vehicle emissions</td>
</tr>
</tbody>
</table>

*Table 1 Pollutants and their sources*
2. Air pollution in Istanbul

2.1. Introduction

Istanbul has experienced a complicated period from an ancient metropolis to a sprawling megacity, growing from just over 2 million registered inhabitants in 1970 to 15 million today. Due to the migration from the other cities, its population has increased more than six fold between 1970 and 2010 (Tayanc et al., 2009). Rapid urbanization and development of society and economy, with the increased migration from the less developed regions of the country at the end of the 1980s, caused a significant increase in the population and an expansion of the built-up areas in the city. The influx of people from other cities caused a rapid increase of the urban population and thereby gave rise to the construction sector. Not only the rapid increase of the urban population, but also the establishment of many small and medium sized industries in and around Istanbul, caused many environmental problems.

Beginning with the oil crisis in the 1970s, households in Istanbul switched from fuel oil to coal for domestic heating. Throughout the 1970s and 1980s Istanbul experienced worsening air quality coinciding with population growth and increased use of coal for domestic heating. The coal being used was primarily a Turkish lignite coal that was relatively low quality and high in sulfur. Istanbul’s primary strategy in addressing its air pollution problem was to provide an alternative residential heating fuel. In the late 1980s and beginning of 1990s, Istanbul has experienced significant particulate matter and sulfur dioxide episodes due to the fossil fuel burning for domestic heating and industry. The city, then, formed a gas distribution company called IGDAS, that began installing the necessary infrastructure to distribute gas to Istanbul residents. Although Turkey has no significant domestic natural gas production, Istanbul and other cities in Turkey were able to take advantage of Turkey’s growing role as an energy hub at that time, as several major pipelines from Central Asia, Russia, the Caucuses, and Iran began transmission through the country to supply part of Europe’s gas. In 1992, the Istanbul city government banned the most polluting lignite coal. IGDAS started to distribute natural gas in January 1992. By 1998, natural gas was supplying approximately half of the residential heating needs in Istanbul. In addition, the city and IGDAS established an international research center in 1999 to adapt the technical norms to the local market and train the IGDAS staff. The industry around Istanbul has also started to switch fuels and the air pollution due to industry has also decreased. Starting in 2005, Istanbul Metropolitan Municipality (IMM) launched a series of pedestrianization projects to reduce the negative effects of vehicle traffic on tourist and commercial activities and improve the quality of life in the area. Since 2010, 295 streets in Istanbul have been pedestrianized by IMM in collaboration with WRI Turkey. The municipality has also implemented supporting infrastructure for pedestrianized areas such as re-pavement, signalization, and reorganization of waste management services.

2.2. Measurement of air pollution in Istanbul

In Turkey, 81 air quality measurement stations were established by the Ministry of Environment and Urbanization between 2005 and 2007 in order to measure the air pollution correctly, to create air pollution policies in all of the provinces and to improve the air quality in the framework of these policies. In addition to the stations set up by the Ministry, the transfer of stations established by different organizations and institutions and the establishment of 20 new stations in 2014 and 2015 contributed to the expansion of the National Air Quality Monitoring Network to a total of 195 fixed and 4 mobile stations. The data from the local monitoring station for SO\textsubscript{2}, NO\textsubscript{2}, PM\textsubscript{10}, PM\textsubscript{2.5} and CO can be accessed via www.havaizleme.gov.tr, the air quality monitoring system website coordinated by the Ministry of Environment and Urbanization. In addition to the stations of the government, the
measurements made in the other stations are included in the weather monitoring system and shared with the public. A total of 195 station measurements are made in Turkey.

Almost all of the provinces in Turkey have stations to monitor air quality, but not all pollution parameters are measured in all stations. Figure 9 and 10 in the Appendix present the locations of the stations in Turkey and the real time air quality index respectively. Only 31 of the stations are located in Istanbul. In most of the air quality measurement stations in Istanbul, only the measurement of PM$_{10}$, SO$_2$ and NO$_2$ concentrations are done. PM$_{2.5}$, which is not yet set a limit value, is still not measured in many stations. Table 2 presents the number of stations in Istanbul that measured the concentration of a particular air pollutant in 2017.

Turkey has its own limit values and alert thresholds for air pollutants, which are mentioned in the "Air Quality Assessment and Management" regulation of the country. The limit values determined by the European Union (EU) and the comparison of these values with Turkish limit values are given in Table 13 in the Appendix. This shows that the limit values that are used in Turkey are higher than the limits determined by the EU. Turkey aims to adapt to EU standards by decreasing the air quality limit values which are important for human and environmental health. The limit values for PM$_{10}$, PM$_{2.5}$ and SO$_2$ will be phased down until 2019 and equalized with the European Directives.

### Table 2 Number of stations per air pollutant in Istanbul

<table>
<thead>
<tr>
<th>Air Pollutant</th>
<th>Number of stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{10}$</td>
<td>28</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>4</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>24</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>21</td>
</tr>
<tr>
<td>CO</td>
<td>13</td>
</tr>
</tbody>
</table>

#### 2.3. Air quality in 2017

The air pollution in Istanbul in 2017 has been measured with the data gathered from www.havaizleme.gov.tr and compared with the European air quality standards. Only the following air pollutants are included in the analysis: PM$_{10}$, PM$_{2.5}$, NO$_2$, SO$_2$ and CO. Furthermore, the results of the analysis have been verified with the Air Pollution Report 2017, prepared by the Chamber of Environmental Engineers (CMO).

**Particulate matter (PM$_{2.5}$ and PM$_{10}$)**

The Turkey map in figure 2 gives how many times the P$_{10}$ limit in each province is exceeded in a year. There are only six provinces that are regularly monitored by the PM$_{10}$ parameter and do not exceed the PM$_{10}$ limit (Artvin, Bitlis, Eskisehir, Yozgat, Kirsehir and Kirikkale). Measurements done in all stations in Istanbul indicate that the PM$_{10}$ limit value is exceeded many times. According to the European directive, the PM$_{10}$ limit may not be exceeded on more than 35 days per year. The data shows that 21 of the 28 stations in Istanbul that measured the PM$_{10}$ concentration exceeded this constraint. With respect to the air pollutant PM$_{10}$, it can be concluded that Istanbul’s air is polluted.
PM$_{2.5}$, which has not yet been set a limit value in Turkey, is still not measured in many stations. Only four stations in Istanbul made measurements throughout the year, of which two stations have not performed measurements for more than 130 days. The PM$_{2.5}$ values that are measured, show that the limit value of the World Health Organization (WHO) is exceeded many times at all stations. Figure 3 shows the PM$_{2.5}$ values in a few districts of Istanbul and the limit set by the WHO for the air pollutant. It can be seen that the limit value set by the World Health Organization (DSÖ in the figure) is exceeded especially in the winter months. The exceedance of the SO$_2$ concentrations during the winter months is the result of coal which is used for heating purposes. According to the data provided in the Air Pollution Report 2017, the limit of the EU directive is exceeded in 21 of 46 stations.
**Sulfur dioxide (SO$_2$)**

According to both the EU directive and the regulation of the country, SO$_2$ concentrations should not exceed the determined limit more than 3 times per year. According to the data received from www.havaizleme.gov.tr, SO$_2$ limit set by the European Commission is not exceeded in Istanbul. However, looking at the number of days no measurement is done, it can be seen that all stations in Istanbul did not measure for more than 3 days. Due to limited amount of data, it is difficult to do a statement about the pollution of Istanbul with regard to the SO$_2$ pollutant. Figure 4 presents the number of not measured days in the districts of Istanbul.

<table>
<thead>
<tr>
<th>Number of days not measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>İstanbul - Yenibosna</td>
</tr>
<tr>
<td>İstanbul - Üsküdar</td>
</tr>
<tr>
<td>İstanbul - Ümraniye-MTHM</td>
</tr>
<tr>
<td>İstanbul - Ümraniye</td>
</tr>
<tr>
<td>İstanbul - Şirinevler-MTHM</td>
</tr>
<tr>
<td>İstanbul - Sultangazi-MTHM</td>
</tr>
<tr>
<td>İstanbul - Sultanbeyli-MTHM</td>
</tr>
<tr>
<td>İstanbul - Sariyer</td>
</tr>
<tr>
<td>İstanbul - Maslak</td>
</tr>
<tr>
<td>İstanbul - Kartal</td>
</tr>
<tr>
<td>İstanbul - Kandilli-MTHM</td>
</tr>
<tr>
<td>İstanbul - Kağıthane-MTHM</td>
</tr>
<tr>
<td>İstanbul - Kağıthane</td>
</tr>
<tr>
<td>İstanbul - Kadıköy</td>
</tr>
<tr>
<td>İstanbul - Esenyurt-MTHM</td>
</tr>
<tr>
<td>Istanbul - Esenler</td>
</tr>
<tr>
<td>İstanbul - Besiktas</td>
</tr>
<tr>
<td>İstanbul - Başakşehir-MTHM</td>
</tr>
<tr>
<td>İstanbul - Avcilar</td>
</tr>
<tr>
<td>İstanbul - Alibeyköy</td>
</tr>
<tr>
<td>İstanbul - Aksaray</td>
</tr>
</tbody>
</table>

*Figure 4 Number of days SO$_2$ is not measured in Istanbul in 2017*

**Nitrogen dioxide (NO$_2$)**

It can be observed that the NO$_2$ values in many stations of Istanbul have exceeded the maximum allowed concentrations determined by both the European Commission and the country many times. It appears that 16 of the 24 stations in Istanbul exceeded the EU-limit in the stations. According to the European directive, the number of permitted exceedances per year is 18. It seems that the NO$_2$ limit is exceeded more than 18 times in 6 stations in 2017. The number of hours the NO$_2$ is exceeded in the different districts of Istanbul can be seen in figure 5.
Carbon monoxide (CO)

Only thirteen stations in Istanbul made measurements of the air pollutant CO last year. Looking at the data gathered from these stations, it can be seen that the limit value is not exceeded in the stations. Furthermore, it is observed that two stations have made no measurements during the year and at many stations measurements were not made on a regular basis. Due to the low reliability of the data, it is difficult to make a statement about the pollution in Istanbul caused by CO emissions.

2.4. Conclusion

The air pollution problem experienced in Istanbul has reached a significant level since 1980s. Similarly, the pollutant concentrations have exceeded the air quality standards several times. According to the Air Pollution Report 2017 of the Chamber of Environmental Engineers, air pollution in Turkey is increasing due to the increase in population. The high population rate results in an increase in urbanization, industrialization and transportation.

The data that is provided by the Ministry of Environment and Urbanization reveals the following:

1) Measurements in the stations are not done on a regular basis.
2) Many of the stations still do not make any measurements of particular air pollutants.

Due to insufficient data with respect to the concentrations of SO₂ and CO pollutants, it is difficult to make a statement about the pollution that is caused by these pollutants. However, the values for the PM₁₀, PM₂.₅ and NO₂ prove that Turkey faces a serious air pollution problem. This can be seen by the number of times the European air quality standards are exceeded. Table 3 presents the number of times the limits are exceeded, the number of times no measurement is done and the maximum observed number of times where no measurement is done and the limit restriction is exceeded. The frequencies for the PM₁₀, SO₂ and CO values are given in days and the NO₂ values are given in hours. The table shows that the number of allowed exceedances per year is exceeded for PM₁₀ and NO₂.
Baran Bozoglu, the chairman of the Chamber of Environmental Engineers, talked about the Air Pollution Report of 2017 which was published in January 2018. Bozoglu explained that only 6 of the 81 provinces in Turkey do meet the Turkish standards and have a clean air. The remaining provinces are polluted with respect to the amount of particulate matter and sulfur dioxide (SO2). According to the Air Pollution Report, Turkey’s most polluted city is Istanbul, which is followed by Ankara.

2.4.1. Main contributors in Istanbul
According to the Air Pollution Report, Turkey’s air is getting more and more polluted and this pollution is growing rapidly. Particulate matter (PM), in particular, is still a problem and it is getting worse. This pollution parameter seems to be rising due to heating and the use of vehicles resulting from the increase of population. According to Bozoglu, the main sources of air pollution in Istanbul are traffic emissions and urban renewal. Industry emissions also play a significant role in the air pollution in Istanbul. According to 2011 figures, industrial activities in Marmara Region account for 52 percent of the total industrial movements1.

Based on the data of the Ministry of Environment and Urbanization, we can conclude that the pollution in Istanbul is caused by the release of high amounts of particulate matter (PM2.5 and PM10) and nitrogen dioxide (NO2) in the air. The release of PM2.5 and PM10 can be attributed to the combustion of coal and oil particularly. Figure 12 in the Appendix presents the energy production in Turkey from different sources. Given that 33 percent of the energy production in Turkey comes from coal, it can be concluded that coal has a significant contribution to air pollution. Furthermore, 37 percent of the energy production comes from oil combustion, which is used in transportation and the industry. Diesel cars and trucks are an important source of particulate matter and nitrogen dioxide in Turkey. The number and proportion of diesel vehicles has increased in Turkey, while the consumer’s preference for gasoline and LPG cars has declined. The share of the diesel vehicles in the total number of registered cars in Turkey rose from 33.6 percent in 2016 to 35.4 percent last year2. As of the end of March 2018, 38.2 percent of the 12 194 330 registered cars in Turkey are LPG fueled, 25.7 percent are gasoline-fueled and 35.8 percent are diesel fueled cars.3 Figure 11 in the Appendix presents the proportion of cars with a particular fuel type in Turkey in March 2018. Turkey’s diesel imports also increased by 8.7 percent to 13.5 million tons in 2017, compared to 2016.4 The International Council Clean Transportation (ICCT) study showed that a typical diesel car emits around 10 times more nitrogen oxides than an equivalent gasoline car5. This means that the increase of diesel vehicles in Istanbul will worsen the air quality in the city.

1 http://dergipark.gov.tr/download/article-file/3336
3 https://www.dunya.com/ekonomi/trafige-945-bin-yeni-arac-girdi-haberi-413914
3. Stakeholders in Turkey

The tables below present the Turkish stakeholders that can contribute to the improvement of air quality in Istanbul. The stakeholders consist of the government organizations which are directly responsible to the air quality and NGOs and institutions which also have an (in)direct influence. Institutions, here, refer to the entities engaged in teaching, training and/or research. Non-government organizations consists of both companies and the nonprofit organizations. Collaborations between these stakeholders can result in a solution to the air pollution problem in Istanbul.

3.1. Governmental organizations

<table>
<thead>
<tr>
<th>Governmental organizations</th>
<th>Department</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMM - Istanbul Metropolitan Municipality</td>
<td>Transportation</td>
<td>IMM is able to develop projects, especially on urban transport subjects such as public transport, traffic management, passenger guidance systems, passenger information systems, journey planning etc.</td>
</tr>
<tr>
<td>IETT - Istanbul Electricity, Tramway and Tunnel General Management</td>
<td>Transportation Technologies</td>
<td>IETT, which works under IMM, is responsible for running the bus, metro bus, nostalgic tram and tunnel services, as well as the scheduling and supervision of privately owned public transport service providers.</td>
</tr>
<tr>
<td>Ministry of Environment and Urbanization</td>
<td>Air Management, Climate change</td>
<td>The Air Management department is responsible for the preparation of legislation and to set goals, principles, policies and strategies related to air pollution sources, environmental noise and vibration control and odor emissions. The Climate change department monitors and evaluates the national and international developments related to control, recovery and disposal of the substances causing climate change and ozone layer depletion. This department also carries out studies to determine and apply related policies and strategies.</td>
</tr>
<tr>
<td>Ministry of Transport, Maritime Affairs and Communications</td>
<td>Transportation</td>
<td>The ministry has comprehensive studies on improvement and arrangement of road sector and on the establishment of R&amp;D department for road and maritime sector. The ministry is also supporting the information and communication sector.</td>
</tr>
<tr>
<td>Ministry of Energy and Natural Resources</td>
<td>Renewable energy</td>
<td>The ministry is currently working on the launch of the smart coal strategy. Furthermore, many projects are ongoing to increase the energy efficiency in Turkey.</td>
</tr>
<tr>
<td>Ministry of Science, Industry and Technology</td>
<td>Environment &amp; Climate Change</td>
<td>The ministry’s activities include leading the export of technological products by taking part in international markets and</td>
</tr>
</tbody>
</table>
commercializing new products or products emerging as a consequence of R&D and innovation activities, in priority technology fields, to create added value to the country's economy.

<table>
<thead>
<tr>
<th>ISBAK - Istanbul IT and Smart City Technologies Inc.</th>
<th>Research &amp; Development</th>
<th>Istanbul IT and Smart City Technologies Inc. works on projects in the field of Smart Transportation Systems with traffic signalization being in the leading position.</th>
</tr>
</thead>
<tbody>
<tr>
<td>TŞOF - Turkey Drivers and Vehicle Association</td>
<td></td>
<td>TŞOF is carrying out various studies and educational services for social and economic development. The organization is in close collaboration with governmental organizations for the improvement and development of the service rendered, reduction of traffic accidents and to make necessary legislative changes and regulations.</td>
</tr>
</tbody>
</table>

Table 4 Governmental organizations

3.2. Institutions

<table>
<thead>
<tr>
<th>Institutions</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TÜBİTAK - Scientific and Technological Research Council of Turkey</td>
<td>TÜBİTAK acts as an advisory agency to the Turkish Government on science and research issues, and is the secretariat of the Supreme Council for Science and Technology (SCST), the highest S&amp;T policy making body in Turkey.</td>
</tr>
<tr>
<td>Marmara Research Center</td>
<td>The research center aims at becoming a world leader in science and technology production with its research, development and innovation capabilities widely shared by its Environment and Cleaner Production Institute and Energy Institute among other things.</td>
</tr>
</tbody>
</table>

Table 5 Institutions

3.3. NGOs

<table>
<thead>
<tr>
<th>NGOs</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>WRI Turkey</td>
<td>WRI in Turkey works on developing integrated solutions in the fields of mobility, urban development, energy efficiency and climate change.</td>
</tr>
<tr>
<td>TÜSİAD – Turkish Industry and Business Association</td>
<td>TÜSİAD’s activities are aimed at creating a social order based on the competitive market economy and sustainable development. Environment and Climate change is one of their focus areas.</td>
</tr>
<tr>
<td>TEHAD – Turkish Electric &amp; Hybrid Vehicles Association</td>
<td>TEHAD is working on electric and hybrid vehicles such as cars, motorcycles and buses. TEHAD also generates projects for having</td>
</tr>
</tbody>
</table>
market in Turkey for transportation vehicles with low CO₂ emissions.

**BCSD Turkey - Business Council for Sustainable Development Turkey**
The Business Council contributes to policy development through an approach of sustainable development. Their focus areas include circular economy and energy efficiency.

**CMO – Chamber of Environmental Engineers**
CMO was established under the TMMOB framework, a confederation of all chambers of architects and engineers in Turkey, to increase the professional co-operation of environmental engineers. CMO analyzes and identifies environmental problems in Turkey and works on solutions for the problems.

<table>
<thead>
<tr>
<th>Companies</th>
<th>Relation</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMA – Derindere Motor Vehicles</td>
<td>DMA seeks, through the use of the advanced technology that he developed, to contribute to the emergence and growth of the electric vehicles in Turkey.</td>
</tr>
</tbody>
</table>
4. Measures in Turkey

4.1. Government measures

The Ministry of Environment and Urbanization in Turkey has different measures to monitor and prevent air pollution in Istanbul. The main activities include the control of the fuel used for heating purposes and encouraging the use of natural gas. At various points in Turkey, the Central Organization and the provincial directorates of the Ministry of Environment and Urbanization are doing regular assessments concerning air issues. The government is regularly performing environmental audits in facilities and motor vehicles. Fines are imposed on businesses that violate the environment law and cause air pollution. Furthermore, regular inspections are carried out to prevent air pollution caused by heating. In order to increase the combustion efficiency of the fuels to be used in warming up and to reduce fuel consumption and pollutant emissions. The government gives attention to periodic cleaning of boilers, prevention of heat losses by isolating the heating installations and maintenance and cleaning of the entire heating system.

To reduce air pollution caused by motor vehicles, the government contributes by the dissemination of public transport systems and ensuring the use of quality fuel. Furthermore, the government states that it is of great importance that the necessary maintenance and exhaust emission measurements of all vehicles, including public transport vehicles (municipal and private public buses, minibuses etc.), which are heavily used in traffic, are carried out on time.

A lot of attention is also given to awareness. Different measures with respect to raising awareness are taken, including:

- informing the public in order to be sensitive about the precautions to be taken on days when air pollution is intense,
- announcement of the air pollution measurement results via www.havaizleme.gov.tr on a daily basis to increase public sensitivity,
- regulation of training programs on air pollution.

4.1.1. Coal measures

According to Berat Albayrak, Minister of Energy and Natural Resources, the existing and the upcoming thermal power plants to be established in Turkey will be adorned with the most environmental friendly technology with respect to flue systems. There are currently six old coal plants in Turkey. The government has already started the conversion of the chimneys of these old plants with latest technology. It is expected that these processes will be finalized before 2019.

Berat Albayrak announced during the 2nd Indigenous Coal Workshop in November that Turkey is working on a scientific strategy in the process of exploiting and extracting the coal mining, and using it for electricity generation. Domestic coal is of great importance to reduce external dependence on energy. This smart coal strategy has been built on three key approaches. The basis of this approach is human orientation. People are prioritized in every step, strategy and application. The second approach is science orientation, which refers to the use of developing technologies in all processes of coal mining. Finally, the third approach is transparent and open management.

4.2. Projects

The last 15 years have witnessed the completion of many mega projects. Istanbul has realized many major projects such as the Yavuz Sultan Selim Bridge, the Osmangazi Bridge, the Eurasia Tunnel and Marmaray, as well as high-speed railways, divided highways, freeways, airports and marinas. Eurasia
Tunnel, one of the recent projects, allows people to transit between the European and Asian sides without the effect of weather conditions. The time saving potential is one of the great features provided by the tunnel. The tunnel provided significant savings in fuel, environmental pollution and accident costs in one year period of time. The air quality measurements before and after the opening of the tunnel showed that 32 percent decrease in particulate matter and 23 percent decrease in carbon concentrations were achieved in the surrounding of the tunnel. Furthermore, 30,000 tons of fuel savings, which is worth 286 million TL, and 18 million tons CO₂ emission reduction, which corresponds to 23 million TL savings, were achieved⁶.

During the past years, the Turkish government has been focusing on energy and infrastructure projects. The government attaches a great deal of attention and importance to the improvement of roads and public transport and also wants to decrease its energy dependence on other countries. The process of setting up nuclear power plants continues. Until 2023, two nuclear power plants will be realized. The construction of one of the plants has already begun. 53 percent of the electricity generation facility investments in the last 10 years in Turkey came from renewable energy sources. According to Albayrak, Turkey will invest in solar and wind projects of 1000 megawatt each, in the next 10 years⁷. Furthermore, the Turkish government will hold the country’s first offshore wind tender this year, with the tender details set to be disclosed in the spring. The tender will be held as part of the country’s second Renewable Energy Resource Zone Project (YEKA) auction, after the first one was held in 2017. In addition, further renewable projects, specifically solar and energy storage, are also planned. Other current energy projects are the TANAP and the TurkStream which will deliver natural gas to Turkey. Natural gas is viewed as a good source of electricity supply for a range of reasons. It provides a major environmental benefit – it’s clean burning. Of the three fossil fuels used for electric power generation (coal, oil, natural gas), natural gas emits the least carbon dioxide per unit of energy produced, which is also shown in figure 1. Natural gas is versatile enough to be used in new vehicle technologies that could reduce pollution and reduce the reliance on foreign oil imports.

The trend of constructing and operating transportation and infrastructure projects continues in 2018 with new airports, tunnels and other infrastructure development. Ahmet Arslan, the Minister of Transport, Maritime Affairs and Communications, said 2018 would be a year of mega projects in transportation. Noting that the first phase of the Istanbul New Airport, also known as the Third Airport, will be completed and open for service on Oct. 29, 2018. Furthermore, the government is set to lay the foundations of one of the country’s biggest projects, Kanal Istanbul, this year.

4.2.1. Kanal Istanbul

Kanal Istanbul (Channel Istanbul) is a Turkish project for the artificial sea-level waterway, which is being built by the Republic of Turkey on the European side of Turkey, connecting the Black Sea to the Sea of Marmara, and hence to the Aegean and Mediterranean Seas. Kanal Istanbul aims to minimize shipping traffic in the Istanbul Strait.

It is expected that synergy will arise from the connection between Kanal Istanbul and the impact created by the third airport, especially in terms of maritime transport and trade. In addition to being a domestic and national source of revenue, the project will create huge added value for Turkey’s

economy. The project will provide city comfort in terms of transportation and change the density map of Istanbul in a positive way. The Environmental Impact Assessment (EIA) of the project has started end-February and is expected to be finalized around September 2018.

It is now the last stage of the project studies, as the canal’s route is determined. It was announced that after the completion of engineering in the first quarter of 2018, followed by preparation work, including financial models, the plan is to go to tender for the construction of the project.

4.2.2. TANAP
The Trans-Anatolian Natural Gas Pipeline is a natural gas pipeline from Azerbaijan through Georgia and Turkey to Europe. This project is of strategic importance for both Azerbaijan and Turkey. It will allow the first Azerbaijani gas exports to Europe, beyond Turkey. It will also strengthen the role of Turkey as a regional energy hub. Construction of the pipeline, which is 1,805 km long in total, began formally in March 2015. The project entered service on June 12, 2018. Turkey imports some 6.6 billion cubic meters (bcm) of natural gas from Azerbaijan via the Baku-Tbilisi-Erzurum pipeline and the amount will go up to 12.6 bcm as TANAP brings in an additional 6 bcm of natural gas. Therefore, the share of Russian gas in Turkey’s energy imports will decrease.

Natural gas is one of the most widely used fuel energy in Turkey. 35 percent of Turkey’s total energy production comes from natural gas, 27 percent from petroleum and 29 percent is made from coal.8 Natural gas is used predominantly in electricity generation throughout the country. Figure 13 in the Appendix shows that 49 percent of natural gas consumption was in electricity generation, 26 percent in industry and 19 percent in residential buildings. Since almost all of the consumed natural gas in Turkey is imported, the supply of natural gas from sustainable and economic prices has become one of the strategic goals of the country. In this regard, the TANAP project is of great importance for Turkey.

4.2.3. Türk Akımı
Türk Akımı (TurkStream) is a planned natural gas pipeline from Russia to Turkey. TurkStream has to become the second direct link to Russia’s transport of natural gas with Turkey via the Black Sea. In December 2016, the Dutch offshore company Allseas received the order to lay 900 kilometers of pipeline at the bottom of the Black Sea.

TurkStream’s first line will carry 15.75 billion cubic meters (bcm) of natural gas to Turkey which is planned to be operational in December 2019. The project will have a total throughput capacity of 31.5 bcm, thanks to the second line that will go to Europe.

Ankara and Moscow reached a retroactive agreement for a 10.25 percent discount on the natural gas and a payment of $1 billion will be made to Turkey, while the two sides also came to an agreement to complete TurkStream’s second line to Europe by 2019. Natural gas is very cheap in Turkey, compared to other countries. With the implementation of the TANAP and the TurkStream projects, it is expected that its price will be lower and that these developments will encourage the use of natural gas in Turkey.

4.2.4. Akkuyu
Akkuyu is a nuclear power plant under development at Akkuyu, in Mersin Province. It will be Turkey’s first nuclear power plant. The construction of the project started in April 2018. The first unit

is expected to become operational in 2023. According to Berat Albayrak, Akkuyu will meet approximately 6 percent of Turkey's electricity generation alone.

Nuclear power plant is not only an important source of electricity, resource diversity, supply security and environmental friendly energy. At the same time, it is important in technological terms for the development of products based on peaceful nuclear technology in Turkey.

4.3. Conclusion

Istanbul Metropolitan Municipality, briefly, continues its activities for providing high quality fuel (coal, fuel-oil), encouraging the use of natural gas, improvement of burning devices (stoves and furnaces) and systems, implementing heat insulation in buildings, monitoring and controlling of emissions from different sources, improvement of public transportation, using renewable and efficient energy systems, rising the public awareness and by urban planning. However, Turkey does not have any measures that aim to reduce the use of (diesel) vehicles in the city, which is one of the main contributors to air pollution in Istanbul.

According to the Air Pollution Report 2017, over the last few years, Turkey has increased the number of stations that monitor the air quality and the technical competence of the staff working in this field. Furthermore, Clean Air Centers are established in Istanbul, Samsun and Erzurum by the Ministry of Environment and Urbanization. The government plans to establish 8 Clean Air Centers in total and aims to increase the number of air quality monitoring stations to 330.

Currently, there are many projects ongoing that are not necessarily aimed at reducing air pollution. These projects include Akkuyu, TANAP, TurkStream and the smart coal strategy which will reduce Turkey's external dependence on energy. Furthermore, the government focuses on infrastructure projects and the improvement of roads which positively influence the traffic composition in Istanbul.
5. Measures in the Netherlands

5.1. Government measures

The Netherlands has approved the new UN Climate Agreement in 2016. The Dutch Council of Ministers has recently determined the government’s commitment to the Climate Agreement. This will give the starting signal for the discussions with the business community, social parties and other authorities about the Climate Agreement. The aim is to reach agreements in the summer of this year on how the Netherlands will reduce CO₂ emissions by 49 percent in 2030. These agreements will then be worked out in concrete programs in the second half of the year. The implementation of the Climate Agreement starts in 2019.

The rules for air quality in the Netherlands are based on the European standards for air pollutants. The Netherlands must adhere to these EU directives. The quality of the air in the Netherlands has improved considerably in recent decades. The emissions from road traffic have decreased by the use of catalysts and particulate filters. Tax incentives for clean cars have also contributed to air quality. In addition, aircraft and factories emit fewer harmful substances. The concentrations of particulate matter and nitrogen dioxide have dropped by over a third since the end of the last century. New measures must ensure that the average concentrations of nitrogen dioxide and particulate matter will decrease further in the future.

Air pollution arises in various places in the Netherlands. Factories, ships, aircraft, agriculture, households, housing and road traffic are all sources of nitrogen dioxide and particulate matter. That is why municipalities, provinces, Rijkswaterstaat and other national government organizations work together in the National Air Quality Cooperation Program (NSL). It is a collaboration between municipalities, provinces and organizations of the government. Together they ensure that the Netherlands adheres to the standards for nitrogen dioxide and particulate matter in good time. As road authority, Rijkswaterstaat is improving the flow on existing roads and with that the air quality.

Rijkswaterstaat is jointly responsible for managing the national roads to take measures if an exceedance of the standards along the motorways is imminent. Activities of the Rijkswaterstaat in order to reduce air pollution includes the placing of screens along the national road that ensure better and faster dilution of the concentrations of particulate matter and nitrogen oxide. Rijkswaterstaat is also working on improving traffic flow on the road. Slow traffic and traffic jams cause more emissions and that’s why extra lanes and rush-hour lanes are created and new roads are constructed. Rijkswaterstaat also issues permits for fast charging points for electric cars.

Important measures of the government

Measures are usually focused on road traffic and (industrial) point sources. A few measures related to traffic are influencing the composition of traffic, improving the traffic flow on the roads, city rings, other routing of (freight) traffic, use of clean buses and clean municipal vehicle fleet. Furthermore, the following measures are taken by the government:

Environmental zone for freight traffic

Municipalities can shut down (parts of) of the city with environmental zones for the most polluting trucks. An environmental zone is an area in the inner city of large municipalities where access for trucks that emit too much particulate matter and nitrogen oxides is limited. The purpose of the environmental zone is to ensure that the air quality meets the standards.
All new buses without CO₂ emissions from 2025

From 2025, all new buses for public transport will run without CO₂ emissions. The buses will run electrically or on hydrogen and the energy must be fully sustainable generated from solar panels or windmills. The government, all provinces and transport companies have signed an agreement for this on 15 April 2016.

Clean Air Package 2015-2018

In Rotterdam 40 percent less soot is emitted by traffic compared to three years ago. This positive result is a result of the Clean Air Package 2015-2018, a package of measures, which was drawn up in 2015 because of the high air pollution in Rotterdam compared to other Dutch cities.

Measurements and calculations by TNO and DCMR show that the emission of soot by traffic was already reduced by 36 percent in the middle of 2017. This is entirely in line with expectations and means that the 40 percent decrease in soot will be achieved in 2018. Furthermore, 6 percent less NOₓ was emitted by traffic. The decrease is mainly the result of the successful scrapping scheme and the banning of diesel cars from before 2001 and petrol cars from before 1992. Due to the scrapping scheme of the municipality, 5000 old, polluting cars have been removed from the road.

Various measures in this package have led to improvements in air quality, such as keeping old petrol and diesel vehicles out of the city center and installing more charging stations for electric transport. In addition, the municipality focused on cleaner fuels for trucks, buses and shipping and made its own fleet sustainable by 25 percent.

To improve the flow of traffic in the city, the Rotterdam Mobility Agenda (RMA) was adopted in 2016. The municipality promoted a better traffic flow in the city by catching cars on the outskirts of the city, expanding the public transport network and increasing the number of parking spaces for bicycles. Visitors to the city center were stimulated to park their cars at the P&R locations on the outskirts of the city.

USP Innovatielab Leefomgeving

The RIVM, Utrecht University and the Utrecht Science Park Foundation have recently opened the USP Innovatielab Leefomgeving, which is an innovative and fine-meshed sensor network to measure the current air quality. This sensor network consists of around 20 sensors spread across the Utrecht Science Park. The information provided by the latest generation of sensors will be collected and validated via the 4G network. The platform LivingLabAir.nl will then display the measurement data in real-time, making it possible for visitors and residents to obtain accurate information about the current air quality levels. This information can in turn be used to indicate the cleanest routes, to identify concentration peaks during rush hour, and to justify mobility policies. The USP Innovatielab Leefomgeving will connect a broad community of scientists, students and residents at the Utrecht Science Park in order to test or explore new ideas in open innovation or small pilot projects. Their results can then be used in other urban or rural areas. In so doing, the Innovatielab aims to act as a motor for improving the health of the living environment.

5.2. Dutch innovations for better air quality

'The lungs of the city'

Research conducted last year by Eindhoven University of Technology revealed that the technology's effect on air quality in the center of Eindhoven could be substantial when fine dust and soot is captured in underground car parks and cleaned to be released back into the city. The idea of

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capturing particulate matter in underground car parks originates from the environmental innovation company ‘ENS Technology’. Since the ventilation systems of the underground car parks are in contact with the streets and shopping zones above, these garages have a considerable influence on the air quality in the city center. By eliminating the particulate matter in these places and by ventilating clean air into the city, underground car parks act as cleansing lungs of the city.

Following the feasibility study, a validation project was started at the Stadhuisplein in the city center of Eindhoven, in December 2017. During a three month period, thirty air purification systems cleaned the city air via parking garage ventilation. Until the end of March 2018, the innovative air purification systems removed particulate matter and soot from the urban air and released clean air back into the city.

The feasibility study
In the first phase of the project, TU/e has investigated the potential of purifying the city air by implementing ENS Urban air purification systems in parking garages in the city center of Eindhoven. According to the researchers, underground parking garages equipped with air purification systems can reduce the amount of particulate matter in a city. This system not only cleans the air inside the car park, but a part of the surrounding city air as well.

Two scenarios were analyzed: one minimum scenario with 99 and one maximum scenario with 594 air purification systems. The research showed that application of 99 air purification systems decreases the concentration of particulate matter around the parking garages by 10 percent. With 594 air installations in parking garages, a reduction in particulate matter (PM10 and PM2.5) of approximately 70 percent can be achieved in the parking garages, while in the city air the concentration of these pollutants are reduced up to 50 percent, locally.10 The application of the Lungs of the City concept is by no means limited to car parks. The systems can also be implemented in tunnels, train and bus stations, viaducts, and busy traffic junctions.

Smog Free Tower
In Rotterdam, the innovative artist Daan Roosegaarde has developed world’s largest smog vacuum cleaner that purifies air. The so-called Smog Free Tower uses patented positive ionization technology and wind energy to produce smog free air in public space. According to Roosegaarde, the air around the tower is 55 to 75 percent cleaner than the rest of the city.

The tower, which has been used in Rotterdam, Beijing, Tianjin and Dalian, sucks up 30,000 cubic meters of polluted air per hour, cleans it at the nano level — the PM2.5, PM10 particles — and then releases the clean air back into the city. The tower is powered by solar energy and uses no more electricity than a water boiler. The artist makes rings and bracelets from the compressed smoke stones that have been filtered out of the air by the Smog Free Tower. Each diamond is representing 1,000 cubic meters of pollution.

The Smog Free Project was launched in Rotterdam on September the 4th, 2015. The workings of the Smog Free Tower have been validated by the results compiled by the Eindhoven University of Technology. The tower first rooted on Rotterdam soil, followed by Beijing, Tianjin and Dalian and since February 2018 in Poland. The project is expanding globally and Roosegaarde is planning to expand it in India too.

The Smog Free Tower allows people the experience to breathe clean air. It is a powerful statement that creates awareness for the fine dust problem whilst also providing a solution to this precarious

world health problem. A bag with smog or jewelry shows immediately what you normally get in your
lungs. The project is also meant to allow people to look at their surroundings differently, to let them
think about it. If you actually see what you get in and experience what clean air is, then you are
more likely to take the bike.

VFA Solutions BV, 85th place in MKB Innovation Top 100 2017
VFA Solutions is a Dutch company that specializes in air treatment, air purification and (indoor) air
quality. The company recently brought the ASPRA PMC in the market, an air purifier that is highly
effective, maintenance-friendly and sustainable for a healthy and comfortable working environment.
The ASPRA PMC has been specially developed by VFA Solutions for the industrial and commercial
market. This powerful and unique air purifier easily and effectively removes extreme dust
concentrations from large amounts of air.

The ASPRA PMC removes particulate matter (PM), including coarse dust and ultrafine dust from the
air. Scientific and practical tests have shown that the ASPRA PMC removes all atmospheric PM₁₀,
PM₂.₅ and PM₁ particles and thereby cleans the air. The technology is also particularly effective in
removing ultrafine particles and nanoparticles including microbes and viruses. This powerful air
cleaner collects the dust in a collection reservoir and on special collectors. Unlike conventional filters
and in addition to the 99 percent filtration efficiency, the ASPRA PMC has many additional benefits:
low energy consumption, self-cleaning mechanism and lower user costs. The ASPRA PMC is very
suitable for applications in, among others, the manufacturing industry, factory halls, agricultural
sector, distribution centers, public facilities, climbing and gymnastics halls.

The ASPRA PMC air purifier has attracted the attention of the Rijksdienst voor Ondernemend
Nederland (RVO), due to its unique characteristics. From January 1 2017, the ASPRA PMC air purifier
is on the MIA \ VAMIL / Environment list 2017, H4, code A 4480. This list consists of technologies
that are environmentally friendly and sustainable. Furthermore, the ASPRA PMC air purifier has been
recognized by The Chamber of Commerce as one of the 100 most tangible innovations of 2017.

Tropomi
The Dutch space instrument Tropomi, which accurately measures the pollution of the earth, has sent
its first images back to Earth last December. In the Netherlands, it were the researchers from KNMI
(Royal Dutch Meteorological Institute), and the Dutch spatial research institute SRON (Netherlands
Institute for Space Research) that converted the first data from Tropomi into images. SRON provided
an initial picture of the spread of carbon monoxide while KNMI offered a first look at nitrogen
dioxide. The first images already show that Dutch technology is invaluable for a targeted approach to
air pollution worldwide.

TROPOMI, which stands for Tropospheric Monitoring Instrument, is a satellite instrument that
carries out measurements at the bottom layer of our atmosphere, the troposphere. The Dutch
spacecraft was successfully launched in October 2017, in a satellite from space base Plesetsk in
Russia. TROPOMI monitors the air quality and the spread of greenhouse gases from space
worldwide, which yields interesting information about the sources and degree of pollution. It is able
to measure air quality more accurately than ever before and maps carbon monoxide, methane,
nitrogen dioxide and ozone, among other things. This Dutch space innovation is a solution to the
global challenge to make industry, transport and energy production more sustainable and to reduce
greenhouse gas emissions. The development of TROPOMI is a collaboration between Airbus Defense
& Space Netherlands, KNMI, SRON and TNO and is financed by the Ministries of Economic Affairs,
Education, Culture and Science and Infrastructure and Environment.
5.3. Conclusion
The Netherlands has been active in doing research on air quality measurement systems and the implementation of measures and initiatives to increase the air quality. Smog Free Tower and ‘Lungs of the City’ are good initiatives to attract attention to the air pollution problem and to increase awareness among citizens. Furthermore, ASPRA PMC is a nice innovation to improve the air quality in manufacturing and office environments. This can be useful in the production environments in Turkey as a large part of air pollution is caused by the emissions from the industry. The Clean Air Package of Rotterdam contains important measures that can be implemented in Istanbul. The scrapping scheme and the banning of old diesel vehicles are useful approaches to push back the use of diesel vehicles in the city. This is very important for Istanbul, as the number of diesel vehicles in the city increases over the years. USP Innovatielab Leefomgeving can also be considered as a good initiative to improve the measurement of air quality in the city. However, this approach is recently introduced in The Netherlands and hence should be followed for now. Due to its short design life (7 years), it is not expected that Tropomi will be an appealing measurement system to introduce in Istanbul. The Turkish parties might still be interested in the knowhow.
6. Circular economy in the automotive sector

As it is concluded in chapter 2, the main sources of air pollution in Istanbul are traffic and industry emissions. It is, therefore, interesting to focus on solutions aimed at reducing emissions from the transportation and industry. Transportation is responsible for air pollution due to the emissions resulting from the vehicle use in the city. The emission caused by the industry, however, also has a significant contribution to air pollution. Since the automotive sector has a significant share in the Turkish sector distribution, it is expected that this sector also is responsible for a serious amount of air pollutant emissions. In this respect, it will be beneficial to implement sustainable initiatives in the production of vehicles and/or vehicle components. This chapter analyzes the automotive sector in Turkey and introduces some circular possibilities in the transportation sector.

6.1. The automotive sector outlook

In line with population growth, exhaust gases from the rapidly increasing number of motor vehicles in Istanbul are an important factor in air pollution. In order to improve the air quality in Istanbul, we need to focus on the causes of the pollution. Approaching this problem from the root, will result in a direct effect.

Last months’ news highlighted the following headlines in the Turkish ‘automotive’ sector:

1) 21/04/2018: Automotive receives 21% share of the overall exports in March and 20% in Q1 2018. [www.emis.com]
2) 03/04/2018 Turkey’s auto sales up 5.47 percent in first quarter. At the end of March 2018, Turkey became 9th with 5.47 percent rise in European car sales rankings. [www.aa.com.tr]
3) 26/03/2018: Turkey last year exported rubber and rubber goods to 177 countries amounting 2.5 billion, while 1.1 million portion of the sales was made up of tires used in vehicles, such as cars, trucks, bused and agricultural vehicles. Netherlands, Italy, USA, UK, Spain, Egypt, South Africa, Morocco have been the leading countries in exports. [ww.dunya.com]
4) 26/03/2018: Turkey’s first domestically-produced car will be ready in 2019. [www.aa.com.tr]
5) 19/12/2017: Automobile production in Turkey reached new historic record. Total automobile production by the automotive industry in the January-November period of 2017 increased by 16 percent to 1.5 million compared to the same period of the previous year, while automobile production reached 1 million units with a serious increase of 24 percent. [www.dailysabah.com]

Automotive sector is one of the driving economies in Turkey. The sector is growing which can be seen by the increase in automobile production and number of exports, and even materials and components of vehicles like tires and other rubber goods are more and more being exported to many European countries, including the Netherlands. Furthermore, Turkey recently announced that the prototype of the first domestic car will be launched in 2019.

Between 2000 and 2017, original equipment manufacturers (OEM) invested USD 14 billion in their operations in Turkey. These investments significantly expanded their manufacturing capabilities, which in turn led Turkey to become an important part of the global value chain of international OEMs. According to the data from Prime Ministry Investment Agency, auto manufacturers increasingly choose Turkey as a production base for their export sales. This is evidenced by the fact that around 80 percent of production in Turkey was destined for foreign markets in 2017. Significant growth posted by Turkey’s automotive sector led to Turkey becoming the 14th largest automotive manufacturer in the world and 5th largest in Europe by the end of 2017.
The automotive industry is crucial to Turkey’s economy as it contributes a significant amount to the country’s overall GDP. In Turkey, the manufacturers are focusing more on sourcing components, spares, and accessories that are manufactured locally as it will help to impel growth opportunities for manufacturers of motor vehicle spares and accessories during the coming years. Additionally, it has also been observed that the Turkish government has been encouraging manufacturers of automotive spares and accessories to set up and expand their manufacturing facilities in the country by providing subsidies. These government initiatives, coupled with the recent increase in automobile production will attract investments from manufacturers of automotive spares and accessories, and will foster the prospects for growth in this market.

6.2. Circular economy in the Dutch automotive sector

One of the biggest priorities for the automotive sector in a circular economy is to universally achieve zero-emission vehicles. Fossil fuel sources are in dwindling supply and are a known driver of global warming, environmental damage, and air pollution. It is therefore critical to move quickly toward alternative fuel sources for vehicles. As mentioned earlier, air quality in Istanbul is mainly influenced by emissions from motor vehicles and the industry. The automotive production in Turkey is increasing and thereby covers a larger part of the industry. On this basis, we can expect that motor vehicle emissions and industry emissions in future will have even larger contribution to the air pollution in Istanbul. This requires sustainable initiatives in this sector to reduce the environmental impact.

Consumer demands for innovation and new mobility models are driving automakers towards a more circular economy. The principles of a circular economy stress innovation through improved design and new business models that support longer lifetimes of products and services. It also aims to reduce environmental impacts and generate less waste.

Circular strategies include using materials that can be easily reused, integrating modularity into the design of the car in order to make quick and affordable repairs and upgrades, and shifting ownership so that car manufacturers remain owners of the cars themselves. The table below presents some circular principles that are important for the automotive industry:

<table>
<thead>
<tr>
<th>Recyclable, low impact materials</th>
<th>developing innovative materials that deliver safety and light weighting while also ensuring recyclability and minimal environmental impact.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design for disassembly</td>
<td>designing for modularity to enable easier disassembly and recovery at the end of use.</td>
</tr>
<tr>
<td>Smart systems</td>
<td>creating intelligent and connected systems that enable greater monitoring and tracking.</td>
</tr>
<tr>
<td>Lifetime extension</td>
<td>providing maintenance, repair, and upgrade services at appropriate intervals to ensure continued functionality and long lifetime.</td>
</tr>
<tr>
<td>Revised &amp; upgraded parts</td>
<td>enabling a steady supply of revised and upgraded replacement parts to support continued functionality.</td>
</tr>
<tr>
<td>Take back</td>
<td>capturing the secondhand value of end-of-use car parts.</td>
</tr>
<tr>
<td>Parts recovery</td>
<td>harvesting reusable parts and components for further use in the industry after end of use.</td>
</tr>
</tbody>
</table>
The Dutch automotive industry, characterized by a dynamic mix of innovative part and component suppliers, is well-positioned to play a leading role in the transition to a circular economy. The principal strength of the Dutch automotive industry lies in the manufacturing of automotive parts and components. Dutch companies have key strengths in material and process innovation, new mobility propositions, and emerging technology solutions across the three key phases of a car’s lifecycle: design and production, use, and end of use. Some examples of Dutch leading circular innovators in the transportation sector are mentioned in the next section.

6.2.1. Dutch innovations in the automotive sector

**Black Bear**
Black Bear brings the circular economy to tires. The company has developed innovative technology to extract high quality carbon black from waste tires, allowing for industries to move away from the ‘polluting’ carbon black that is currently produced from crude oil. Carbon black is used in tires and rubber, and as pigment in coatings, plastics and inks. Through its innovative technology, Dutch company Black Bear can recycle the main raw material from old car tires carbon black, and turn them into new tires, rubbers and paint products. Black Bear’s recycling technology has two positive sides. It stops the pollution through the burning of the tires. Additionally, it makes using crude oil in the manufacturing process obsolete. The production and waste processing of tires are both environmentally harmful.

**Recycling plants globally**
A black bear plant can process up to 1.5 million old tires a year, this represents bigger CO₂ savings than can be absorbed by 1 million trees. The company plans to build around 800 recycle plants globally in the near future. They are currently hard at work exporting their expertise and technological knowhow. For instance, they are seeking out partners in Europe, Asia and the US to open up new plants. With 1 billion old tires every year, over 800 plants will be able to run at profit. Black Bear has formed over 30 customer relationships, including ones with tire giants such as Michelin and GoodYear and paint companies such as AkzoNobel. These companies have tested the Black Bear product with good results and are incorporating it in their production processes. Furthermore, Black Bear is supported by Nederland Circulair. Black Bear is named in the 2018 Global Cleantech 100. The Global Cleantech 100 represents the most innovative and promising ideas in cleantech that are best positioned to solve tomorrow’s clean technology challenges.

In summary, Black Bear is solving the issue of waste tires and at the same time reducing oil consumption through their circular innovative solution for carbon black users.

**DAF CF Electric VDL E-Power**
VDL Group and DAF Trucks recently presented their fully electric truck. Both companies from Eindhoven joined forces in the development of this e-truck and will deliver electric trucks to customers later this year. With this product, DAF and VDL are responding to the development that emission-free driving and the pursuit of noise reduction will become increasingly commonplace.

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especially in urban areas. The experiences of customers taking the first CF Electric trucks into use will determine when serial production will be carried out.

DAF is an international leading truck manufacturer and VDL is the European market leader in the electrification of heavy vehicles, such as buses and automated guided vehicles (AGVs).

6.3. Conclusion

The transportation industry has always been a major player in the Turkish economy. Many products from Middle East are moved to the European hinterland or elsewhere in the world, through Turkey and vice versa. Turkey connects Europe and the Middle East, which means a lot of traffic occurring due to transportation of goods and materials. The increase in the number of exports/imports causes a lot of transportation and thereby an increase in emissions. Furthermore, the increase in population and the increase in consumer’s preference for diesel cars in Istanbul, cause the increase in the number of (diesel) vehicles which are responsible for emissions. The transportation sector tops the air pollutant emissions and is also one of the highest consumers of fossil fuels (produced from oil, coal or natural gas).

Worldwide, there is an increasing interest in going circular as new regulations in many countries demand the reduction of CO₂ emissions in the automotive sector. Consumer trends are also driving circularity in the automotive sector. The consumer demand for greater innovation, the need for new mobility models, and the resulting shorter lifecycles of cars are forcing auto makers to take action towards a more circular economy. The interest in circular economy is still very low in Turkey. That is why circular approaches should be introduced in the Turkish sectors. In order to decrease the environmental impacts caused by the automotive sector, circular economy principles can be adopted in the production of cars, trucks, ships and other vehicles that burn fossil fuels. There are plenty of opportunities for sustainability: economical means of transport, more efficient transport and alternative fuels and drive technologies. In this chapter, examples of leading circular innovators like Black Bear are introduced that are mainly involved in recycling and upcycling of materials.

Black Bear brings the circular economy to tires and has developed innovative technology to extract high quality carbon black from waste tires, allowing for industries to move away from the ‘polluting’ carbon black that is currently produced from crude oil. Carbon black is used in tires and rubber, among many others. As it is also mentioned in section 6.1., Turkey plays a leading role in the exports of cars, rubber and many rubber goods including tires. Given that the automotive sector and the number of exports grow in Turkey, the knowhow of Black Bear can be of good use in this sector.

The e-truck, which is jointly developed by VDL Group and DAF Trucks, has been extensively tested in regular city traffic over the past period. The first e-trucks delivered will be used by the customers for heavier distribution in urban areas. Depending on the experiences, the serial production of the CF Electric will be started. In a next phase the further possibilities will be explored to develop other electric vehicles that enter the city or remain in the city.
7. Case study: Potential of electric ferries in circular economy

7.1. Introduction

Green transportation has become increasingly important. Nations are trying to reduce the environmental impact of human activities, mainly the greenhouse gas emissions, to improve the quality of living and to contribute to a greener, safer and a more sustainable environment. The transportation sector is one of the major sources of CO₂ emissions and thereby one of the main contributors to global warming. According to the European Environment Agency (EEA), approximately 26 percent of the greenhouse gas emissions in Europe are directly attributable to transportation—and in some regions, the proportion is even higher (EEA, 2017). The significant environmental impact of transport demands more climate-friendly transportation solutions. That is why in 2011 Norway's Ministry of Transport and Communications launched a competition to develop an environment-friendly ferry for providing service between two villages across Sognjeford, one of the western fjords of Norway. The Ministry aimed to develop a new ferry that was 15-20 percent more energy efficient than the ferry currently in operation, i.e. a diesel operated one. The Norwegian shipping company, Norled, won the competition with the electric ferry Ampere. The shipping company worked with the Norwegian shipyard Fjellstrand and Siemens, who co-developed this new ship as the world’s first electrically-powered car ferry. (Sandvik, 2014)

Electric ferries have gained a lot of attention through their environmental benefits and more ferry companies started to consider hybrid or fully electric ferries. This chapter serves as an analysis of the potential of electrical ferries in circular economy. In this regard, a simple life cycle assessment is used to find out the impact of an electric ferry on both nature and human life. Then, in sustainability monitoring, quantification is made of the environmental, social and economic sustainability indicators to analyze the impact of both diesel and electric ferries. Findings from the study of electric ferry Ampere is being used to quantify the indicators for an electric ferry. The report concludes with the benefits of the electric ferries over diesel ferries and the potential of the electric ferries in circular economy.

7.2. Life cycle assessment of an electrical ferry

As sustainable use of oceans, seas and maritime resources is goal 14 of the UN global goals, it is important to look at the environmental impacts that the electrical ferries can have. One of the UN’s specific goals is to significantly reduce marine pollution of all kinds by 2025. (UN, 2017) The pollution that can come from the electrical ferry can be assessed by a simple life cycle assessment. Starting with the input for the batteries of an electric ferry, which can come from renewable energy. For example, the electric ferry Ampere uses hydropower as its renewable energy source.

The batteries that power the ferry are often Lithium-ion batteries. These batteries have a very low impact on the environment as they can be recycled. The batteries in an electrical ferry have to be replaced once every 10 years (Siemens A., 2017). According to research, the batteries in an electric ferry can be recycled for 99.7 percent (Gagatsi, Estrup, & Halatsis, 2016). The Lithium-ion batteries that are needed in the electric motor consist of magnets. The production of these magnets requires some rare earth metals which are in high demand and therefore can cause depletion in these particular natural resources. (Hernandez, Messagie, & De Gennaro, 2017)

The electrical engines that use these batteries have an average lifetime estimated to be 30 years (Einberger, 2017). After its service life the engine will need to be recycled. Also the ferry itself has an end to its service life. At the end, the ferry can be brought to a “green” shipyard where it will be disassembled and where each part can be recycled or reused. According to research, a ship can be
recycled or reused for 96.6 percent (Pruyn, Hopman, & Jain, 2017). This means that the ferry itself will have a minimal impact on the environment. So the environmental impact of the ferry and its engine is only restricted to the depletion of specific natural resources used for the magnets in the batteries.

The environmental impact of the electrical ferry on its surroundings is given to be much less than ferries with other propulsion systems. Whereas a diesel ferry can give off a lot of noise and vibration that can disrupt the nature, the electrical ferry is silent and has minimal vibration and thereby minimizes the disruption of nature during transportation. (Siemens A., 2017)

7.3. Sustainability monitoring

7.3.1. Sustainability criteria

In this section, the environmental, social and economic sustainability of diesel fueled ferries and electric ferries are compared with each other. The data from the report on Ampere is being used to quantify the sustainability indicators of electric ferries (CorvusEnergy, 2017). Table 8 presents the sustainability indicators that is being used to compare both scenarios.

<table>
<thead>
<tr>
<th>Sustainability category</th>
<th>Sustainability criteria</th>
<th>Sustainability indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Fuel consumption</td>
<td>Diesel (liter)</td>
</tr>
<tr>
<td></td>
<td>Emissions reduction</td>
<td>CO₂ (ton/year)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOₓ (kg/year)</td>
</tr>
<tr>
<td>Economic</td>
<td>Quality</td>
<td>Energy consumption (kwh/year)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy need per trip (kwh/year)</td>
</tr>
<tr>
<td>Social</td>
<td>Customer comfort</td>
<td>Noise</td>
</tr>
</tbody>
</table>

*Table 8 The sustainability indicators*

The sustainability criteria, fuel consumption and emissions reduction, estimate the environmental impact of the ferry operation. These indicators compare the main input, diesel consumption, and the by-products that are emitted from ferries. The energy consumption and the energy need per trip are the indicators for energy use and thereby represent the quality of the ferries. The energy consumption refers to the total energy use, which is the total electric energy transferred to the ferries. The energy need per trip is related to the efficiency of the engines. The efficiency of the motors and the batteries affect the amount of energy needed on board for the movement of the ferry. These indicators belong to the economy category as the amount of energy consumption describes the costs that are made. Finally, the noise represents the comfort that customers experience during their trip.

7.3.2. Sustainability input and output analysis

Based on the supply chain of both ferries, input-output models are constructed. The supply chain flow diagram of the electric ferry is given in figure 6.
Based on the processes defined in the supply chain diagram and the available data, an input/output matrix is constructed, which is given in the table 9. In this matrix, the electricity storage refers to the charging stations in each village and the transportation refers to the trip made by the e-ferry between the two villages. The 1MWh lithium-polymer battery pack on board is fully recharged during the night. During the ten minutes stops on either side of the fjord, the batteries are partially recharged with 410 kWh energy. The table below presents the total energy transferred to the ferry’s batteries and the electric energy that is used on board.

<table>
<thead>
<tr>
<th>Intermediate flows</th>
<th>Units</th>
<th>Electricity storage</th>
<th>Transportation</th>
<th>Final demand</th>
<th>Total output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity storage</td>
<td>kWh</td>
<td>0</td>
<td>410</td>
<td>0</td>
<td>410</td>
</tr>
<tr>
<td>Transportation</td>
<td>kWh</td>
<td>0</td>
<td>0</td>
<td>244</td>
<td>244</td>
</tr>
</tbody>
</table>

Table 9 Intermediate flows of the e-ferry Ampere

A total of 410 kWh is being transferred from the battery pack on shore to the vessel's batteries. The total energy needed to move the e-ferry is 244 kWh, which is the final demand of the transportation process. The energy use of the Ampere is between 150-200 kWh per trip (Siewers, 2014). Due to the 89 percent battery efficiency, more energy (244 kWh) is needed to make one trip (Einberger, 2017).

The flow diagram of the diesel fueled ferry is given in figure 2. The final demand of the transportation with a diesel fueled ferry is 606.15 kWh, which is the electrical energy required to make one trip from Lavik to Oppedal. The actual electrical energy required on board is 257.15 kWh, but due to the efficiency rate of the diesel motor, which is 42 percent, more energy (606.15kWh) is needed from diesel. The final demand and the emissions that result from the diesel consumption in conventional ferries are shown in table 10.

<table>
<thead>
<tr>
<th>Intermediate flows</th>
<th>Units</th>
<th>Transportation</th>
<th>Final demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>kWh</td>
<td>0</td>
<td>606.15</td>
</tr>
<tr>
<td>Wastes</td>
<td>Units</td>
<td>Transportation</td>
<td>Total waste</td>
</tr>
<tr>
<td>CO₂</td>
<td>ton/year</td>
<td>570</td>
<td>570</td>
</tr>
<tr>
<td>NOx</td>
<td>ton/year</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 10 Intermediate flows of a diesel ferry

The input-output matrices are used to estimate the environmental, economic and social sustainability of both ferries. It is already mentioned that the Ampere has zero emissions. From the matrices, it can be concluded that the electrical ferries have a lower energy consumption per trip. The reduction of the main inputs and wastes can be found in table 11.

<table>
<thead>
<tr>
<th>Reduction of main and primary inputs</th>
<th>Units</th>
<th>Transportation</th>
<th>Final demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>362.15 kWh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>570 ton</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NOx</td>
<td>15 ton</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 11 Reduction of inputs

Findings from the report on Ampere indicate that Ampere saves about one million liters of diesel of fuel, 2680 metric tons of CO₂ and 37 metric tons of NOx per year (CorvusEnergy, 2017). The reduction in energy consumption is estimated to be 4494282 kWh annually. This is equal to an approximate reduction of 60 percent. Furthermore, it seems that the electric ferry only needs 150-
200 kWh per trip, whereas a diesel ferry needs 257.15 kWh, which is a reduction of approximately 42 percent. Per sustainability category, the table below presents the total reduction of the inputs and wastes that can be achieved with electric ferries.

<table>
<thead>
<tr>
<th>Sustainability category</th>
<th>Sustainability criteria</th>
<th>Sustainability indicator</th>
<th>Diesel ferry</th>
<th>Electric ferry</th>
<th>Reduction in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Fuel consumption</td>
<td>Diesel (liter)</td>
<td>1000000</td>
<td>0</td>
<td>-100,00%</td>
</tr>
<tr>
<td></td>
<td>Emissions reduction</td>
<td>CO₂ (ton/year)</td>
<td>2680</td>
<td>0</td>
<td>-100,00%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>NOₓ (ton/year)</td>
<td>37</td>
<td>0</td>
<td>-100,00%</td>
</tr>
<tr>
<td>Economic</td>
<td>Quality consumption</td>
<td>Energy consumption</td>
<td>7522322</td>
<td>3028040</td>
<td>-59,75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Energy need per trip</td>
<td>3191232</td>
<td>1861500</td>
<td>-41,67%</td>
</tr>
<tr>
<td>Social</td>
<td>Customer comfort</td>
<td>Noise</td>
<td>High</td>
<td>Low</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 12 Overview of reduction per sustainability indicator

7.4. Conclusion

Ampere is the best example that can be used to analyze the potential of electric ferries in circular economy. Currently, Ampere operates between the two villages of Lavik and Oppedal, which is across Sognjeford, one of the western fjords of Norway. Just on this route, Ampere delivers significant savings in operational costs and greenhouse gas emissions. Powered by lithium-ion batteries, Ampere functions completely emissions free. By contrast, a conventional ferry traveling the same route, consumes around one million liters of diesel fuel, emits 2,680 tons of carbon dioxide and 37 tons of nitrogen oxide each year (CorvusEnergy, 2017). The vessel’s batteries are recharged using hydroelectric power from the electrical grid in each village. This makes the energy the ferry uses cheaper, compared to diesel. It also means that the ferry does not emit carbon dioxide, directly or indirectly. Furthermore, the e-ferry is only half the weight of a conventional ferry because it is made exclusively of long-lasting aluminum instead of the normally used steel (Moen, 2015). The long-life aluminum hull leads to significantly lower maintenance costs over the vessels lifetime. Due to the electric propulsion system, the electric ferry sails quietly with far less noise and vibration on board. Thereby, the ferry increases the customer comfort and decreases the disturbance of nature.

In 2015, Siemens published a report of a feasibility study conducted to analyze the potential of the electrical and hybrid ferries in Norway. In their study, they used data from Ampere to calculate the profitability of using electric or hybrid instead of conventional ferries for the other ferry routes in Norway. In this analysis, Siemens used the operational profile (such as crossing time and distance) of the ferries to analyze their potential. It became clear that electric propulsion systems are viable for ferry routes with a high number of trips. For these ferries, the savings in operating costs become so large that they can cover the investment costs – and even exceed them. Hybrid ferries are more suitable for longer routes with low trip frequency. In the report, it is concluded that it is profitable to substitute 127 of Norway’s 180 ferries with either battery-powered or hybrid alternatives. This
equates to over 70 percent of Norway’s ferry fleet. Of these 127 ferries, 84 ferries are suitable for battery operation due to crossing times of less than 35 minutes and running at least 20 trips in 24 hours. Replacing 84 ferries with battery-powered alternatives demands an additional investment of around € 384 million compared to costs of building diesel-driven ferries. Costs of land-based infrastructure, including recharging stations, are included in the total of € 384 million. The large portion of this additional investment comes from using aluminum which makes the ferry lighter and thereby reduces the use of energy. The study reveals that the investment in 84 ferries will result in a rapid return on investment, as the operational costs can be reduced by 77 million euro each year over a ten year period. In other words, this investment will pay of twice in a decade (Siemens, 2015).

Another study conducted by Siemens to analyze the electrification potential of the Denmark’s ferry services reveals that 39 of 52 ferries in Denmark are more profitable as e-ferries. According to the study, the substitution of 39 electrical ferries will save 11 million euro per year in operating and maintenance costs. Eventually, the conversion from diesel fueled ferries to electric ferries will give a return of investment of 4.7 million euro per year over a 10-year period (Siemens A., 2017).

7.4.1. Electrification potential of diesel ferries

There is an increasing interest in going electric as new regulations demand the reduction of CO2 emissions from the maritime sector. In order to reduce the environmental impact, the technology looks at replacing diesel engines with electric engines. There is a lot of potential for a large portion of ferries to change from diesel propulsion system to fully electric. According to research, it is entirely technologically possible to replace diesel engines with battery-powered electric motors (Siemens A., 2017). When operating at a short distance, a ferry needs a battery that can be charged in the time they are in port. The charging time for short distance ferries is short and therefore the service of transport can stay optimal. For long distance ferries however, the high capacity batteries need longer to charge. For this, the technology is not yet developed to have these batteries charge fast enough in the time the ferry is in port. Still, the possibility of electrification has to be looked at per ferry individually, if optimality of service can be maintained with a full electrical engine (Siemens A., 2017).

7.4.2. Hybrid Ferries in the Netherlands

Currently there are no ferries in the Netherlands that are fully running on electric energy. There are, still, two hybrid ferries, IJ Ferry 60 and IJ Ferry 61, which have both electric and diesel motor on board. In addition to these two hybrid ferries that have been in use since last year, the Amsterdam transport company GVB has now plans to commission five fully electric car and passenger ferries. The Dutch C-Job Naval Architects has designed the concept for this series of five sustainable ferries. With the design, C-Job helps the municipality of Amsterdam realize its ambition of zero emission ferry transport from 2025.

Amsterdam’s waterfront, the IJ River, is one the busiest Dutch waterways connecting the Port of Amsterdam with the North Sea. Every day many passengers cross the IJ River with bicycles, mopeds or on foot, on the 6 free ferry routes which are operated by GVB – the public transport company of Amsterdam. GVB has a policy of reducing the emissions and environmental impact from its ferries, trams, buses and cars to an absolute minimum. In this respect, GVB ordered two new ferries from Holland Shipyards and decided to use battery hybrid technology to improve fuel efficiency and reduce pollution. The IJ Ferries 60 and 61 already fulfill the new stricter air pollution rules, which will apply from 2019/2020. This contributes to improving the air quality and reduces noise for the citizens of Amsterdam and for the millions of tourists using the ferries.
8. Conclusion and recommendations

8.1. Conclusion

Currently, we can identify two problems related to the air quality in Istanbul. The first problem is the unreliable data with respect to air pollutant measurements. It is remarkable that not enough and correct measurements are made in Turkey. Throughout the year, it appears that many stations don’t make measurements of the pollutants PM$_{2.5}$, PM$_{10}$, SO$_2$ and NO$_2$ regularly. Especially some stations in highly populated areas of Istanbul have not made any measurement during the year. The insufficient data affects the accuracy of the pollution parameter values and consequently provides unreliable information about the current state of air pollution in Istanbul.

Funda Gacal, the Turkey representative of the Health and Environment Alliance (HEAL), observed that some of the stations temporarily don’t give data, and that they don’t know the cause of this problem. “That is why Turkey should recognize the problem of air pollution, make accurate and comprehensive measurements, pull down the limit values and bring sanctions and a warning system,” she explained in an interview with the Duvar newspaper.

The location of the stations that measure the air quality are also determinant for a correct assessment of the pollution in Istanbul. There is an air quality monitoring system that is 24/7 published by the Ministry of Environment and Urbanization, called the National Air Quality Monitoring Network. There are approximately 200 air monitoring stations in Turkey spread over the cities and the districts. These stations are very important to evaluate the air quality and so are their locations. For example, there is a station in Besiktas, which is located in the garden of Yildiz Technical University. The pollution values are not expected to be too high here. However, some stations are by the side of the road and it is very normal to observe high pollution values there. The measured values indicate the pollution around the station and do not necessarily represent the pollution in a specific district.

All in all, we can conclude that Istanbul has a serious air pollution problem. Several locations in Istanbul fail to meet the air quality standards for NO$_2$ and particulate matter (PM$_{2.5}$ and PM$_{10}$). The main sources of air pollution in Istanbul are identified as industry and traffic emissions and urban renewal. Furthermore, it can be that concluded that the data of air quality measurements is not adequate. The unreliability of data can be attributed to the insufficient number of measurements throughout the year and the location of some of the stations. The available data which is insufficient to make a realistic estimation of the air quality, only shows a part of the air pollution problem in Istanbul, indicating that this problem is bigger than we think. This requires, firstly, to solve the problem with incomplete data on air quality measurements. In doing so, a better picture of the situation is obtained to manage the air pollution problem and also the progress can be followed. Next to adequate measurements, the focus should be on reducing the main air polluters in Istanbul.

The Turkish government is quite aware of the pollution in Istanbul, which can be deduced from the measures taken in the framework of sustaining a clean environment. The increase of the number of monitoring stations in the last couple of years and the establishment of clean air centers are some of the important measures of the Turkish government to monitor and prevent air pollution in Istanbul. It can be observed that most of the investments of the government in recent years are in the transportation and energy sectors, which are also the main contributors to the air pollution in Istanbul. TANAP, Canal Istanbul and Akkuyu are examples of these investments. Despite the big infrastructure projects that are intended to reduce traffic, no measures have been adopted to reduce the car use in the city. The Turkish government has currently no measures that aim to reduce
the use of (diesel) vehicles in Istanbul. According to the data of Istanbul Electricity, Tramway and Tunnel General Management (IETT), the share of road transportation in the public transportation in Istanbul in 2016 was equal to 78.0 percent, while the railway and seaway transportation were equal to 17.6 percent and 4.4 percent respectively. This shows that the air pollution resulting from transportation is mainly caused by roadway traffic. This requires sustainable solutions in the transportation in the city. Examples of sustainable initiatives can be the use of environment friendly vehicles, like electric cars and trucks, but also the adoption of circular principles in the automotive sector are considerable.

8.2. Recommendations

First of all, better air quality measurements need to be done in Istanbul. As it is also concluded in chapter two, measurements of pollutants are not done on a regular basis. This problem can be solved by a regular control of the stations for any defects and the analysis of the reasons for possible breakdown. Furthermore, not all pollutants are measured in all stations. In this regard, more stations can be installed in the city. This will consequently increase the reliability of data and thereby present more accurate figures of the pollution in Istanbul. The Ministry of Environment and Urbanization plans to increase the number of air quality monitoring stations in Turkey to 330. The realization of this goal should be tracked. It is also an option to introduce new Dutch air quality measurement systems in Istanbul. In this regard, the Turkish parties might be interested in the knowhow of Tropomi. The developments regarding the USP Innovatielab Leefomgeving should be followed for now.

Additionally, measures should be taken to improve the air quality in the city. It is likely that the poor air quality in the city significantly affects the health of the citizens. The air pollution in Istanbul will only increase with the increase of the use of diesel cars. The increase in the number of registered diesel vehicles and the number of diesel imports show that the emission resulting from diesel combustion will continue to play an important role in air pollution. The situations worsens with the high population rate which causes transportation problems and urban sprawl, amongst other things. The challenge that this big city faces is to reduce traffic emissions soon. In order to do that, the use of (diesel) vehicles in the city needs to be reduced. The scrapping scheme and the banning of old cars are important measures of the Clean Air Package that helped Rotterdam reduce the number of diesel vehicles in the city. In this respect, Istanbul might benefit from the experience of the municipality of Rotterdam.

As the industry emissions are an important source of air pollution in Istanbul, this report also presents the Dutch innovations that can be introduced in the Turkish industry. Looking at the trend in figure 7, we can see that the contribution of road transport to the amount of NO\textsubscript{x} emission in Turkey is increasing and thereby has a significant influence on the air quality. Furthermore, the launch of the domestic car and the number of exports indicate the growth of the automotive sector in Turkey. In this regard, it will be gainful to adopt sustainable initiatives in the Turkish automotive sector. Istanbul can reduce industry emissions by introducing circular principles in the automotive sector. Given the growth potential in the automotive sector, the knowhow of Black Bear can be useful in the recycling of tires. The company is solving the issue of waste tires and at the same time reduces oil consumption through their circular innovative solution. Black Bear seems to be one of the best Dutch circular innovators in this field and is currently exporting their technological knowhow and expertise and are looking for opportunities in Asia. The technology that has been

\[12 \text{http://www.iett.istanbul/tr/main/pages/istanbulda-toplu-ulasim/95}\]
developed by the company has been tested and approved by many companies. It can be interesting for both parties to open up a plant in Istanbul.

The electric truck that is the result of the collaboration between DAF Trucks and VDL Group, is also an opportunity. However, this project is still in the testing phase and therefore must be followed.


10. Appendix

Figure 7 Sources of NOx emissions in Turkey over years (Source: European Environment Agency).

Figure 8 Sources of SO\textsubscript{2} emissions in Turkey over years (Source: European Environment Agency).
Figure 9 Locations of stations in Istanbul (accessed www.havaizleme.gov.tr at 16:18 on May 9th, 2018).

Figure 10 Real time air quality index in Istanbul (accessed http://aqicn.org at 16:24 on May 9th, 2018).
Figure 11 The distribution of registered cars in Istanbul with a specific fuel (Source: www.aa.com.tr).

Figure 12 Energy production from different sources in Turkey (Source: http://www.enerji.gov.tr).
Consumption of natural gas per sector

Electricity Generation 69%  
Housing 17%  
Public institutions 19%  
Industry 6%

Figure 13 Natural gas consumption per sector in Turkey in 2014 (Source: EPDK).

Table 13 Limit values determined by EU and Turkey (Source: Air Pollution Report).

<table>
<thead>
<tr>
<th>Sınır Değerler</th>
<th>Türkiye (2017 yılı)</th>
<th>Türkiye (2018 yılı)</th>
<th>Türkiye (2019 yılı)</th>
<th>AB</th>
<th>Türkiye</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂ (Kükürt dioksit) (24 saatlik Ort.)</td>
<td>125 µg/m³</td>
<td>175 µg/m³</td>
<td>150 µg/m³</td>
<td>125 µg/m³</td>
<td>3 kez/yıl</td>
</tr>
<tr>
<td>PM10 (Partikül Madde) (24 saatlik Ort.)</td>
<td>50 µg/m³</td>
<td>70 µg/m³</td>
<td>60 µg/m³</td>
<td>50 µg/m³</td>
<td>35 kez/yıl</td>
</tr>
<tr>
<td><strong>PM2.5 (Partikül Madde) (Yıllık Ort.)</strong></td>
<td>25 µg/m³</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CO (Karbonmonoksit) (8 saatlik ort.)</td>
<td>10.000 µg/m³</td>
<td>10.000 µg/m³</td>
<td>10.000 µg/m³</td>
<td>10.000 µg/m³</td>
<td>**</td>
</tr>
<tr>
<td>NO₂ (Saatiık ort.)</td>
<td>200 µg/m³</td>
<td>270 µg/m³</td>
<td>260 µg/m³</td>
<td>250 µg/m³</td>
<td>18 kez/yıl</td>
</tr>
</tbody>
</table>