BioGas2020

Guide to Establishing a Biogas Filling Station at a Logistic Centre

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Preface

This guide is an update of a report under the title “Plan concept for implementing alternative fuel hubs in Transport & Logistic Centres” issued in December 2015, which was funded by the Danish Energy Agency and conducted by The Association of Danish Transport and Logistics Centres (in Danish: Foreningen for Danske Transportcentre,). The report was revised in 2017 by Phuong Ninh and Krzysztof Janko in cooperation with Kent Bentzen, Managing Director of NTU ApS. The rationale for this update is to supplement the findings of the 2015 edition with new insights gathered through Biogas 2020 project, the establishment of a new gas filling station in Høje-Taastrup Transportcenter (Chapter 7 to be expanded), as well as to update on changes in relevant legislation.

The aim of this guide is to ease the transition towards sustainable fuel alternatives in heavy transport. Logistic centres can play an instrumental role in increasing the utilization of sustainable sources in the heavy-transport sector. The EU’s White Paper: *Roadmap to a single European Transport Area – Towards a competitive and resource efficient transport system* indicates that transport corridors enabling sustainable movement of goods and people are a necessity (European Commission, 2011). These corridors should also be equipped with supply infrastructure for clean fuels, such as biogas, hydrogen or electricity. At the same time *Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure* requires Member States to ensure “that an appropriate number of refuelling points accessible to the public for the supply of CNG or compressed biomethane to motor vehicles is built up, in order to ensure that CNG motor vehicles can circulate in urban/suburban agglomerations and other densely populated areas as well as throughout the Union, at least along the existing TEN-T Core Network. … As an indication, the necessary average distance between refuelling points should be approximately 150 km” (European Parliament and Council, 2014c). In this legislative context, the logistic centres can fulfil this expectations since they benefit from strategic locations along the transport corridors as well as having good access to the gas grid.

The EU has not only placed demands on the Member States, but also offered a financial instrument to support projects aiming at decarbonisation of all transport modes, including the establishment of alternative fuel stations. This instrument, called Connecting Europe Facility, through grants, guarantees and other financial instruments offers incentives to develop new technologies and innovations through the aforementioned types of infrastructure along the TEN-T Core Network (European Parliament and Council, 2013b). The support in the case of such projects can amount to

20% of eligible costs, that include capital expenditure encompassing the costs of equipment and infrastructure, environmental studies and VAT.

The Planning Concept is an overarching approach, indicating how logistic centres can induce, through planning, the transition to more sustainable, alternative fuel mix. Each of the analysed sustainable fuels has unique characteristics, which means that all of them can play an important role in the future. The report focuses on the utilization of methane gas, as its characteristics are suitable for long-distance transport and it is a well-known technology, used widespread across Europe.

Having a strategic location and serving as a focal point in the management of goods, logistic centres are a critical starting point in the transition, thus making it a necessity for them to be frontrunners. In the planning process, there are several regulations, authorities and procedures essential to be aware of, which the plan concept consolidates. It therefore works as a helping tool, guiding through the whole transition process, including site selection, technology, policies and economy, and therefore lays foundations for the inducement of sustainable fuels in the heavy transport sector.

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1. Introduction

In an EU-context, the transport sector was the biggest energy consumer with 55 % in 2010. Of the energy used in this sector, 93.9 % was from oil-based, of which 84 % was imported, which costed the EU 1 billion euros each day (European Commission, 2013). In this regard, the green transition has become a pivotal point on the agenda of Europe, in terms of the dependence on fossil fuels, which needs to be phased out and replaced by sustainable alternatives. The EU has, as a part of a global effort, put up a goal of reducing greenhouse gas emissions by 80-95 % by 2050 compared to the level in 1990 (Ibid.).

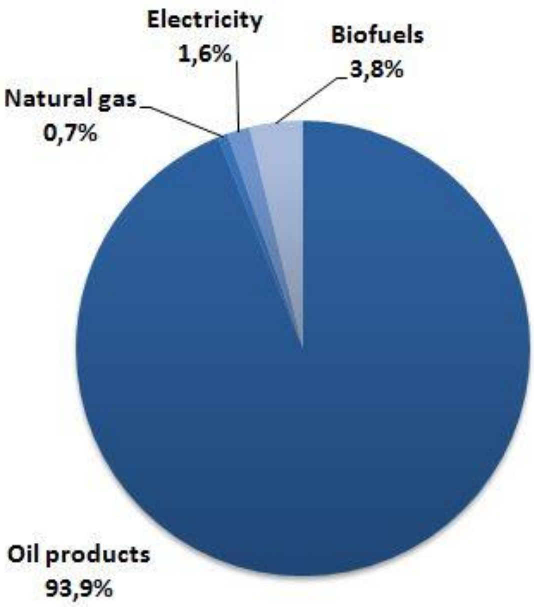

Figure 1 – Final energy consumption in the EU transport sector by type of fuel (European Commission, 2013)

CO_2 is the main greenhouse gas, as it comprises 80 % of the total amount. The greenhouse gasses are a natural thing in the earths system, but according to the UN's Climate Panel, if the atmosphere contains too much greenhouse gasses, it disturbs the earth's temperature. Along with the other greenhouse gasses, such as NO_x and SO_x, human-made CO_2 thus contributes to global warming (Energi-, Forsynings- og Klimaministeriet, 2014).

In this tussle, Denmark has set an ambitious goal of 100 % renewable sources throughout the energy- and transport sector by 2050 (Kebmin, 2013). Furthermore, Denmark has set a goal of 37 % reduction of greenhouse gas emissions in 2020 compared to the level in 1990, which clearly expresses the commitment, and obliges Denmark to act on a short-term as well as on a long-term basis.

The energy sector has been – and continues to be – the most polluting sector in Denmark and is therefore a key sector for the Danish fossil fuels phasing-out strategy. This has led to, as also seen in Figure 2, an almost exclusive focus on the energy sector, whereas the other sectors haven't received the same attention. For example, the emissions from the transport sector have actually increased, which makes it important to place focus on this part simultaneously with the energy sector.

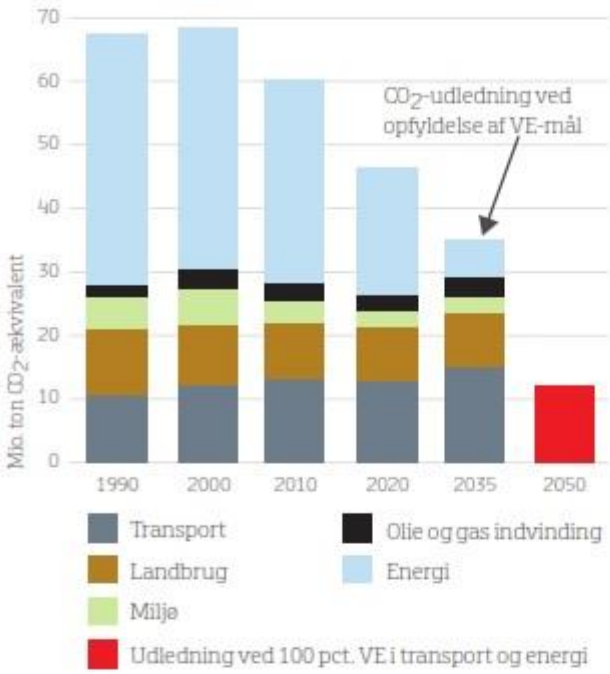

Figure 2 - The Danish goals for CO2 emissions (Kebmin, 2013)

In 2013 the transport sector emitted 1/3 part of the total Danish CO_2 emissions, of which passenger transport was the primary source with 57 %, followed by the heavy transport with 37 % (Kebmin, 2013). Generally, the road transportation emitted 12 million CO_2-equivalents out of the 13 million CO_2-equivalents the transport sector totally emitted in 2010, as visualized in Figure 3, which thus makes road transport an essential part of the green transition.

The Danish Climate Policy Plan has furthermore acknowledged that the total emissions in the transport sector will increase due to the continuous growth in the transport sector, which is why more focus on the green transition in the transport sector is needed. The Energy Agreement from 2012 assumes an ambitious development for a more extensive utilization of biogas, based on increased financial support –also applicable to the transport sector (Ibid.).

As the transport sector is a part of the green transition and there is a Danish objective of 100 % sustainable energy sources, this sector has to go through a significant transition over the next decades. In Denmark, there are anno 2015, 450,000 heavy vehicles (busses, vans and trucks) and 2,330,000 passenger cars, which, as previously mentioned, emit 37 % and 53 % respectively of the total CO_2-emissions in the transport sector.

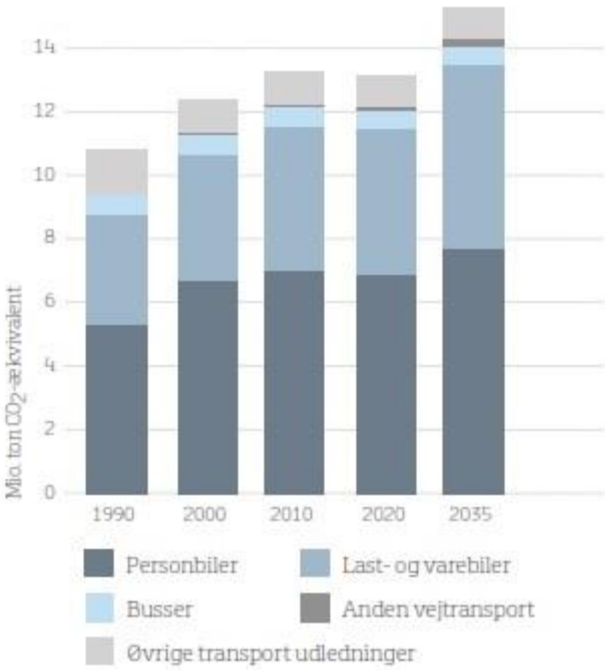

Figure 3 - The emissions of the Danish transport sector (Kebmin, 2013)

This shows that, even though the passenger cars are responsible for the major part of the total emissions, the heavy vehicles emit 4 times as much CO_2 per vehicle. At the same time the heavy vehicles – especially the trucks – play a vital role in transporting goods, making the European economy dependent on this sector. It is therefore important that the transition regarding this sector happens, not only in terms of sustainable fuels, but also with technologies that can compete with the fossil-fuel-dependent technologies, to secure the prosperity of this sector.

Looking at the international context, the transition to alternative fuels for transport is also receiving more focus. The European Parliament and Commission implemented a regulation, 1315/2013, on Union guidelines for the development of the Trans-European Transport Network (TEN-T) concerning implementation of alternative fuels in the transport sector (European Parliament and Council, 2013a). In this regard, the Connecting Europe Facility (CEF) were established to accelerate investments in the field of TEN-T and to leverage funding from both the public and the private sector. Analysing the list of projects funded through the CEF’s first call from September 2015, it can be concluded that the European Commission values maturity of the project and the general level of impact very high.

This report strives to analyse the possibilities for and guide a transition towards more sustainable energy sources in the heavy transport sector, by showing how to plan an alternative fuels hubs in the 7 Danish transport and logistics centres. Even though the report is based on the Danish experiences, it is also intended for a wider usage, as it can be also relevant in an international context in the European transport and logistic centres.

2. The Danish Transport & Logistic Centres

In Denmark, there are seven transport centres located along the highways near Aalborg, Herning, Hirtshals, Horsens, Høje-Taastrup, Køge and Taulov, as seen in Figure 4. The transport centres function as a base for activities linked to transport, logistics and distribution of goods – both national and international. All but one are placed by the TEN-T core network, making them important not only for the goods transport in Denmark, but also seen from transnational transport corridors. Operators at the centres can either own or rent buildings and facilities, including: warehouses for storing, offices,

Figure 4 - Danish Transport- and Logistics Centres

trucks and distribution centres. To create an optimal allocation of goods, it is important that the transport centres are serviced by several transportation modes, such as road, railway, maritime and aviation. In other words, it is a hub for heavy transport, with a lot of activity and vehicle traffic every day.

One of the main facilities of any such centre, is the refuelling station. The transport centres are hence an important actor on the market and are a fundamental for the transition to sustainable sources in the heavy transport sector.

Since the transport centres are in strategically chosen locations, they are also strongholds for many of the larger national distribution companies. Kent Bentzen, the president of FDT, underlines that more than 50% of all the goods imported, exported or passing through Denmark is managed by minimum one of the Danish Transport & Logistic Centres (Bentzen, 2015). The operating radius for several of these companies gives the possibility for using sustainable alternative fuels in competition with fossil fuels – provided the required range for the vehicles doesn’t exceed the range enabled by alternative fuels.

To understand the real potential, it would be highly relevant to start a dialogue with these companies on their current driving distances and their transportation behaviour, though it has not been possible to gather such data in the preparation of this report.

3. Sustainable fuel sources

There are several sustainable alternatives to gasoline and diesel as fuels to vehicles. The most relevant currently on the market include: biodiesel, methane gas (biogas), 2. Generation bio-ethanol, methanol, hydrogen, di-methyl ether (DME) and electricity, where this report primary will focus on the utilization of methane gas. All of the alternative fuels are described in more detail in Annex A.

To make the most of the local Danish natural resources – as well as to secure independence from a single energy source – a holistic planning approach needs to be considered. This entails not only focusing on methane gas or electricity, for example, but also on all of the sustainable fuels. Thus, it needs to be underlined that this report focuses on methane gas as a fuel, which represents only one pathway in setting up of alternative fuel hubs in Danish transport and logistics centres. Other alternative fuels could be integrated at the hubs, when the markets for these alternative fuels have matured.

3.1 Utilization of methane gas for transportation purposes

Methane is the simplest compound of the hydrocarbon configurations and has the chemical formula CH_4 – meaning *one* carbon atom bonds *four* hydrogen atoms – and has a gaseous form at room temperature under atmospheric pressure. The hydrocarbons are mainly used for energy purposes –

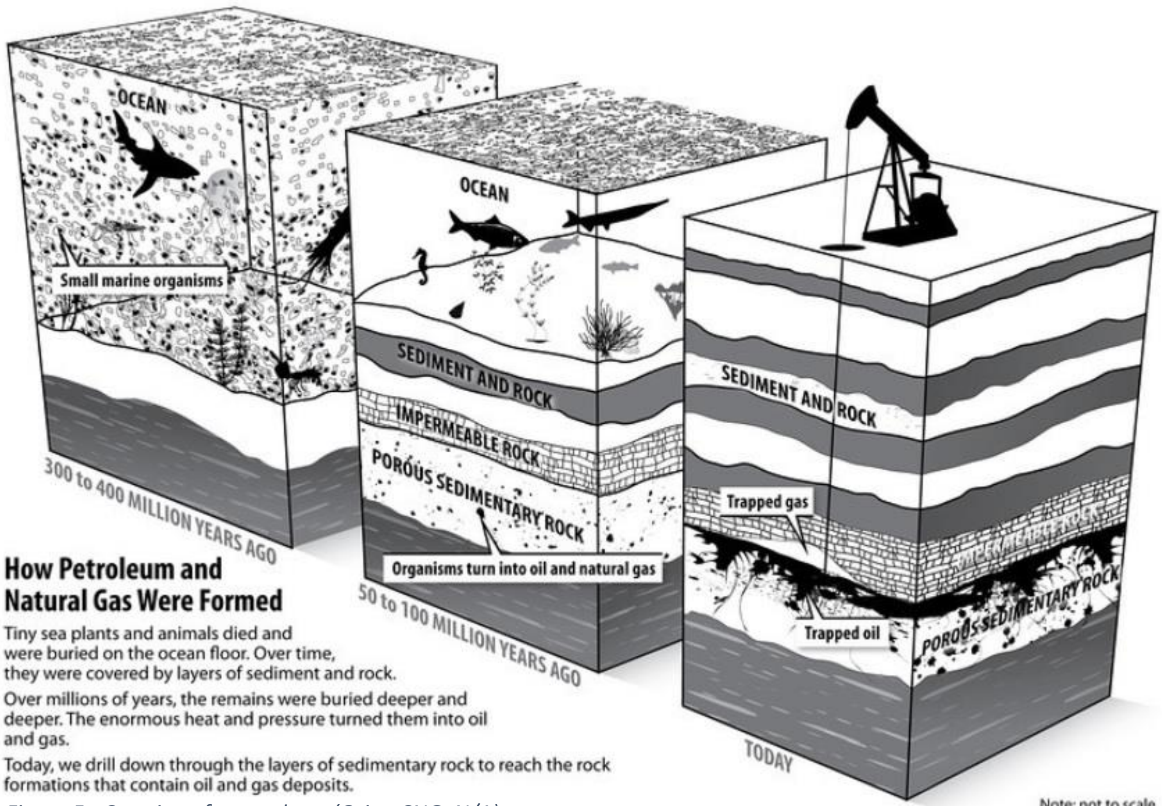

Figure 5 - Creation of natural gas (Oring CNG, N/A)

especially due to a good combustion characteristics. Besides methane, the most common hydrocarbons are butane (lighter gas), hexane, octane and decane, where the latter ones are the main components in gasoline, diesel and jet fuel. Methane gas is the main part of both natural gas and biogas. Natural gas is the outcome of organic molecules exposed to heat from the earth's core and high pressure in reservoirs deeply under the surface over 1000 of years, thus releasing the energy from the sun bound in the plants and animal matters buried – visualized in Figure 5 (Lavelle, 2012).

This makes it non-renewable and hence a fossil fuel as the process cannot be replicated in a short-term perspective. Biogas, on the other hand, is a renewable fuel as it can be produced by humans. Biogas is the by-product of microbes, or bacteria, breaking down organic molecules in an anaerobe (oxygen-free) environment also exposed to heat as it makes the process faster. The outcome is a gas composed of high level of methane and CO_2 and traces of other gases, as seen on Figure 6. The methane level is different dependent on, what kind of organic material is utilized in the process – meaning materials with abundance of carbohydrate gives the least outcome of gas and the lowest methane level, where materials with abundance of fat gives the highest outcome of gas and the highest level of methane (actually up to 80 %) (Jørgensen, 2009). The material utilized to produce biogas can be made of organic- and animal matter. Specifically, it encompasses agricultural residues, organic waste, animal excrements, sewage and other remnants from food production (Gerlach, Grieb, & Zerger, 2013). To utilize biogas in the transport sector, it needs to be upgraded so it has the same standard as natural gas regarding the methane level on approximately 97 %. The most common upgrade method covers a water scrubbing, or a purification, where the CO_2, H_2O (water vapour in the gas) and H_2S is cleansed by binding to the H_2O molecules from the water scrubber. By removing the CO_2, it firstly becomes a cleaner fuel in the combustion and secondly, it is easier to compress the methane. By removing the water vapour and the Sulphide, it minimises the risks of corrosion. Doing this, the biogas can be distributed directly through the natural gas system, which the tank station also is connected to.

Component	Formula	Concentration
Methane	CH_4	50-75 Vol.-%
Carbon dioxide	CO_2	25-45 Vol.-%
Water vapour	H_2O	2-7 Vol.-%
Sulphide	H_2S	0,002-2 Vol.-%
Nitrogen	N_2	< 2 Vol.-%
Ammoniac	NH_3	< 1 Vol.-%
Hydrogen	H_2	< 1 Vol.-%
Trace gases		< 2 Vol.-%

Figure 6 - Biogas composition

When utilizing the gas in vehicles it needs to be compressed for being competitive with other fuels. To explain the comparison, Figure 7 visualises what the amount of energy in one litre of diesel equivalents to in respectively; natural gas at room temperature and atmospheric pressure (NG), compressed natural gas at 200 bar (CNG) and liquefied natural gas at -162 °C (LNG). Transferring this to reality, it means for a CNG truck to drive as far as a diesel truck it takes 5 times (4,76) as much space in the tank capacity or 1,7 times (1,67) as much space in a LNG truck. Hence, to be competitive on the driving distance it will require a loss in another parameter e.g. load capacity.

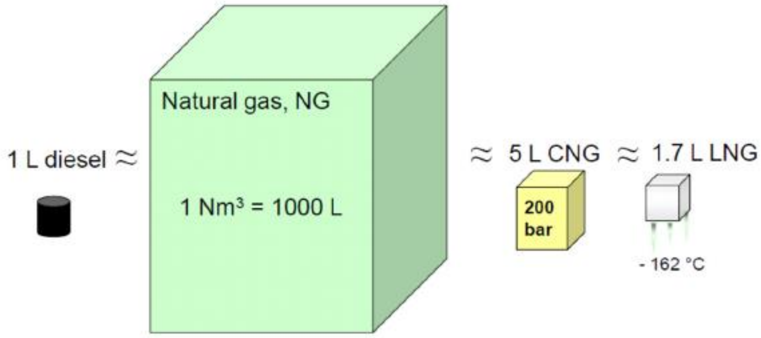

Figure 7 - Comparison of energy content in volume

Methane has a good lower heat value (LHV), compared to the other mentioned sustainable fuel alternatives, which is advantageous. So even though the storing of the gas has a large volume, it doesn't weigh as much as any of the other fuels – see tables of all the fuels in Annex A.

TABLE 1 *- Methane characteristics*

CNG/CBG		
T	20	°C
P	200-250	bar
RHO	131,62-164,52	kg/m^3
LHV	50,016	MJ/kg
LHV	6,583-8,229	GJ/m^3
LNG/LBG		
T	-182 - -161	°C
P	1,01325	bar
RHO	446,43-418,41	kg/m^3
LHV	50,016	MJ/kg
LHV	22,329-20,927	GJ/m^3

As mentioned, the biogas is put into the natural gas system, which gives a small percentage of biogas in the system in the beginning of the transition. Therefore, the first step in this phasing-out of fossil fuels and the dependence on oil, is transiting to natural gas, as it is also cleaner than oil – in general terms natural gas is defined to be 25 % cleaner than oil (Energinet, 2014). Then the second step is to phase out the natural gas with biogas over the next couple of decades. The reason why the transition aims for biogas, is not only because it is renewable, but also because it is considered CO_2 neutral, as the amount of CO_2 polluted in the combustion equals to the amount the plants has absorbed through their life cycle (Energinet, 2013). Even some consider it "CO_2 negative" because of the efficient way of getting rid of the manure. Putting the manure into a biogas production tank saves the environment for the greenhouse gas emissions polluted by the traditional way of getting rid of manure (Ibid.). Energinet describes it as gathering the pollution from the agriculture and use it for energy purposes instead of letting it soak into the atmosphere (Ibid.).

Natural- and biogas has also other characteristics, because of its high level of methane gas. Methane gas can be used to synthesize hydrogen, methanol or DME by adding water, heat and using the right catalyst. Additionally, the methanol or the DME can be used to synthesize hydrogen or ethanol. Furthermore, Methanol and ethanol can produce biodiesel. It is hence one big circle of interconnected relations, where methane can start the whole process – Making it just another incentive to focus on in the holistic transition.

3.2 Role for the vehicles

The different fuels have different characteristics and should be used efficient in the sectors where they fit best in. An example is the electric vehicles, as seen on Table 2, which cannot compete in range and therefore should mainly be used for short-range trips such as for urban transportation.

Vehicle							
Range	Urban	Short	Medium	Long	Short	Medium	Long
Electricity							
Hydrogen							
Biofuels							
Methane							LNG/LBG

Table 2 - Application of different fuels in different transport modes

“Biofuels” comprises both methanol, ethanol, DME and biodiesel, where “methane” comprises both CNG/CBG and LNG/LBG. Biofuels together with LNG/LBG has capabilities, which enables them to be for long-range transportation. The table indicates that CNG/CBG can mainly compete with the medium-ranged vehicles – together with hydrogen – making it best suited for passenger cars requiring more than urban-driving and for trucks servicing regional distribution. Of course, this doesn’t “bind” the fuels only to be used in these sectors, but is merely suggesting an efficient way of utilizing the resources optimally.

4. Gas grid in Denmark

To construct a gas filling station the first step is to identify the potential of gas supply. This means either connecting to the national gas system, connecting to a nearby production plant or having an onsite production facility. In Denmark, the natural gas system is widely spread, as seen in Figure 8, and therefore connecting directly to it is preferable to other gas supply options.

Figure 8 - Danish national gas grid and suppliers (Dansk Gasteknisk Center, N/A)

The gas grid comprises of, anno 2014 (Dansk Gasteknisk Center, N/A):

- Transmission lines
    - Pressurized with 50-80 bars
    - 925 km of steel pipes
- Larger distribution grid
    - Pressurized with 19-50 bars
    - 2,590 km of steel pipes
- Smaller distribution grid and service pipes
    - Pressurized with 0,022-7 bars – often around 4 bars
    - 15,612 km of plastic pipes

4.1 The gas grid near the Transport & Logistic Centres

Hence, the first step is to identify, if the national gas grid passes near the fuel filling areas at the centres. This identification is visualized below starting from the top with Hirtshals and ending at Skandinavisk Transportcenter, Køge cf. Figure 4 (page 8).

4.1.1 Hirtshals Transport Centre (HTC)

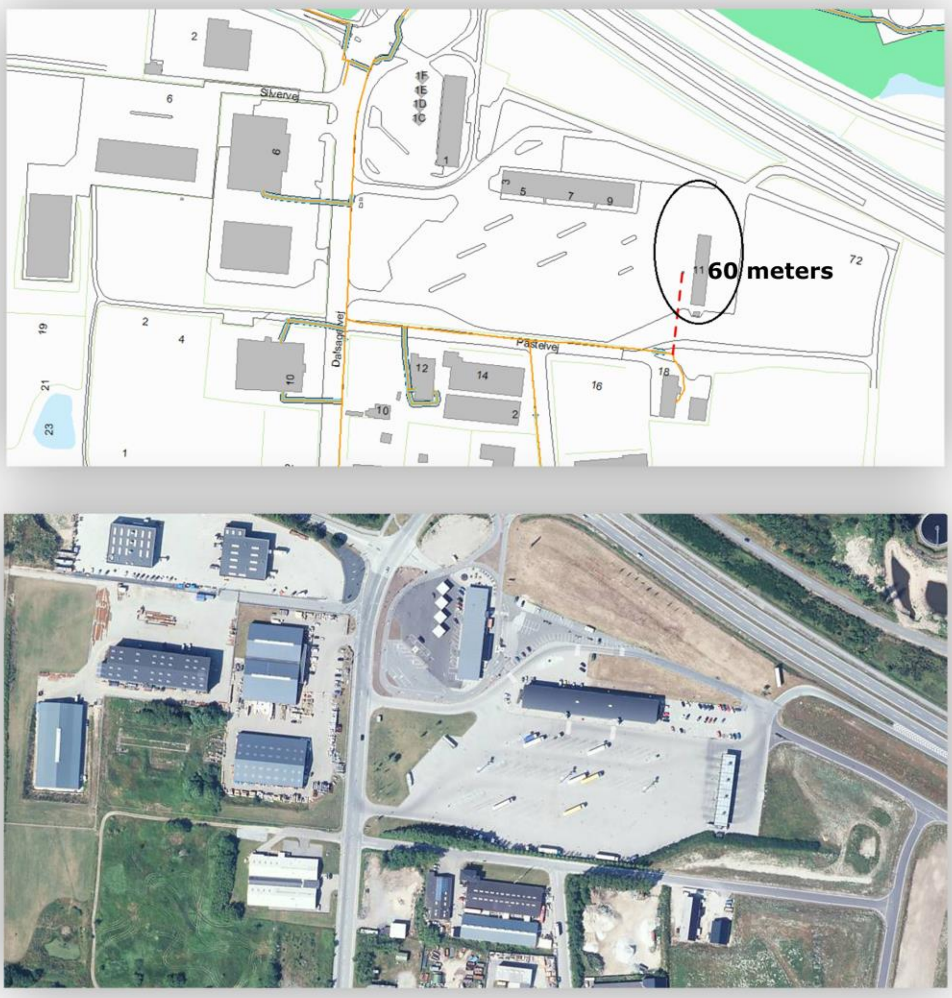

Figure 9 - Picture of fuelling area at Hirtshals Transport Centre with nearby gas grid

The fuelling area at the Transport Centre near Hirtshals are about 60 meters from a 4 bar distribution pipe.

4.1.2 Nordic Transport Centre (NTC)

Figure 10 - Picture of fuelling area at Nordic Transport Centre, Aalborg with nearby gas grid

The fuelling area at the Transport Centre near Aalborg are about 60 meters from a 4 bar distribution pipe.

4.1.3 Herning Transport & Logistic Centre (HTLC)

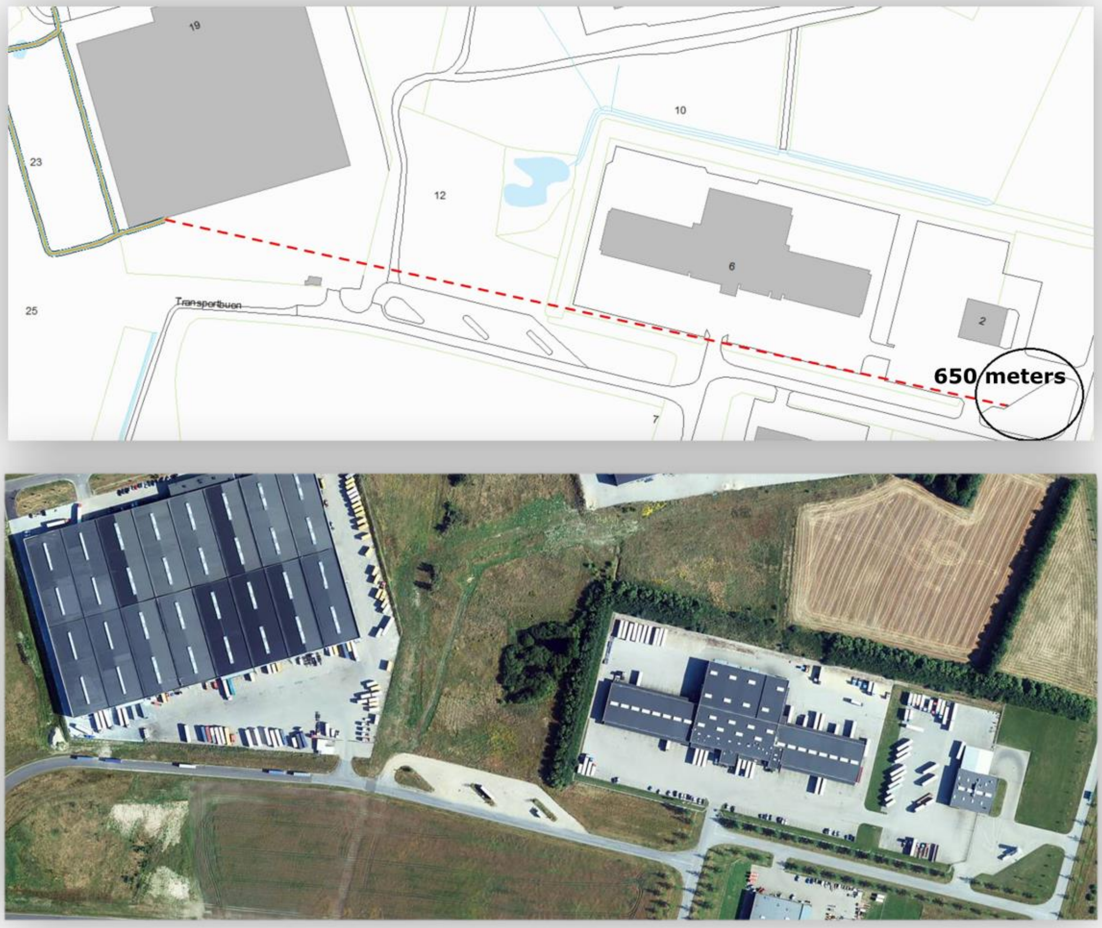

Figure 11 - Picture of fuelling area at Herning Transport & Logistics Centre with nearby gas grid

The fuelling area at the Transport Centre near Herning are about 650 meters from a 4 bar distribution pipe.

4.1.4 Horsens Transport Centre (HOTC)

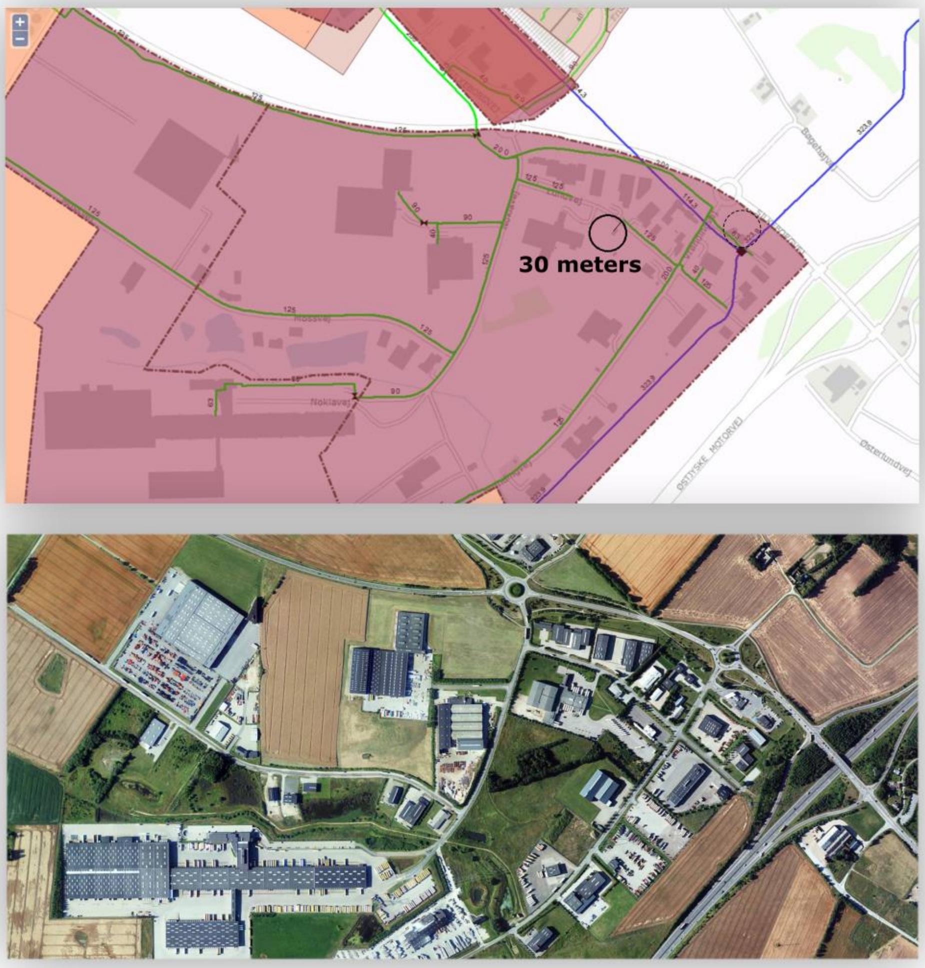

Figure 12 - Picture of fuelling area at Horsens Transport Centre with nearby gas grid

The fuelling area at the Transport Centre near Horsens are about 30 meters from a 4 bar distribution pipe. In this area, there are two fuelling stations; OK and Q8. Given to safety measures in terms of softer road users the OK station, market with a solid circle, has better opportunities for expanding the area to a hub for alternative for trucks.

4.1.5 Taulov Transport Centre (TTC)

Figure 13 - Picture of fuelling area at Taulov Transport Centre with nearby gas grid

The fuelling area at the Transport Centre in Taulov are about 110 meters from a 4 bar distribution pipe.

4.1.6 Scandinavian Transport Centre (STC)

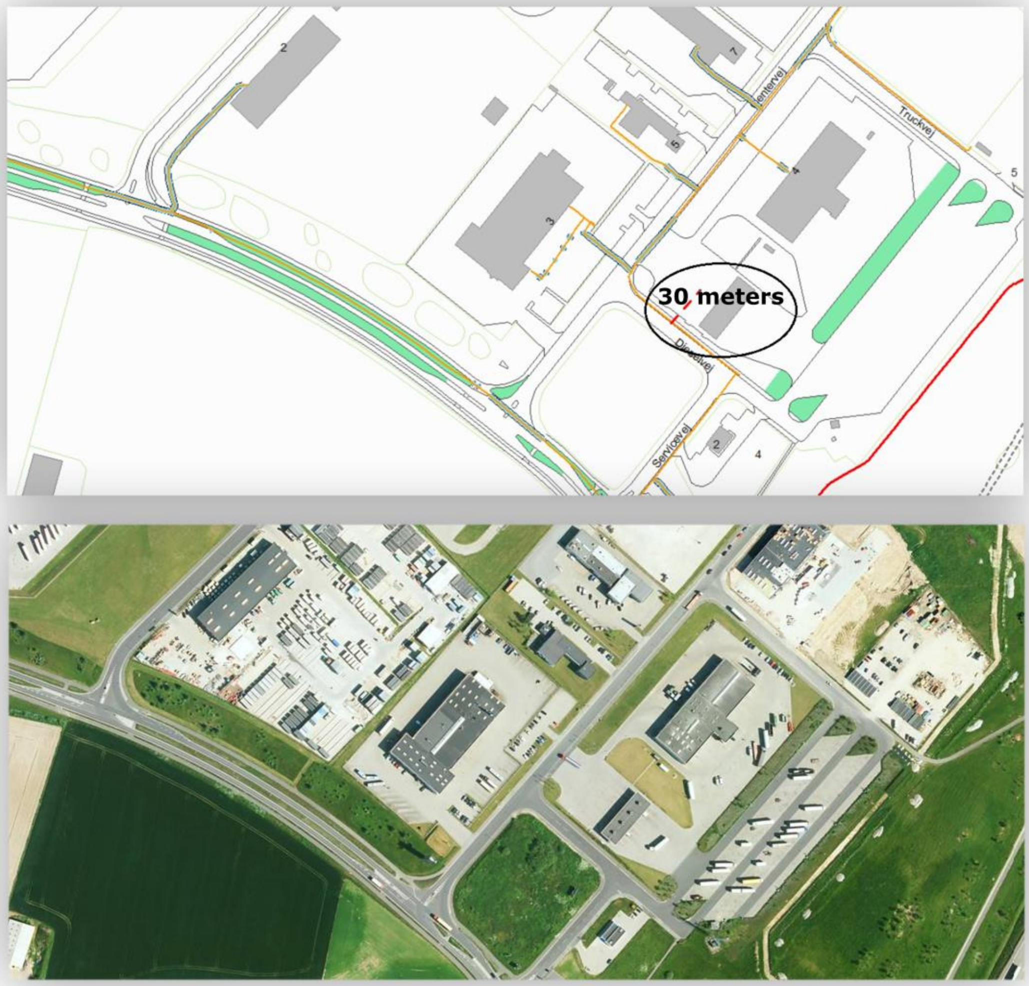

Figure 14 - Picture of fuelling area at Scandinavian Transport Centre, Køge with nearby gas grid

The fuelling area at the Transport Centre near Køge are about 30 meters from a 4 bar distribution pipe.

<u>As the Danish natural gas systems passes by all of the analysed Transport & Logistic Centres, within a radius of up to 650 meters, there is no rationale for choosing a biogas production facility on, or near, the centres. Thus, supplying gas to the site requires only a small connection pipe to the national system.</u>

5. Technical perspective

The gas near the Transport & Logistic Centres runs with a pressure between 4-50 bar, depending on which pipe it's going through – as elaborated above. This makes it necessary to implement a gas compressor at the site as the CNG/CBG utilized in the vehicles is pressured with 200-250 bars (Dansk Gasteknisk Center, 2013). Regarding the infrastructure for the gas station, there are two possibilities, whether it is a fast-filling station, Figure 15, or a time-filling station, Figure 16.

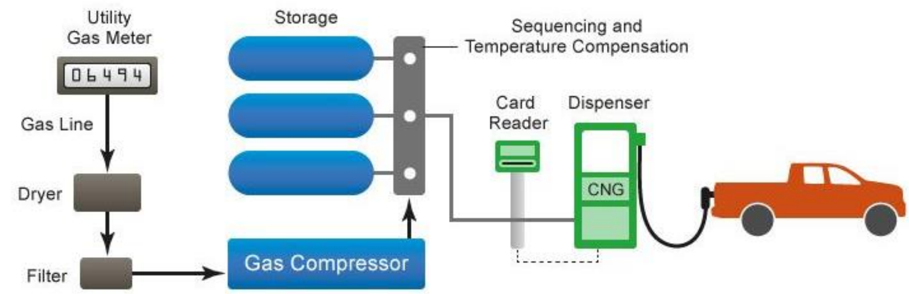

Figure 15 - Infrastructure for CNG fast-fuelling station (AFDC, N/A)

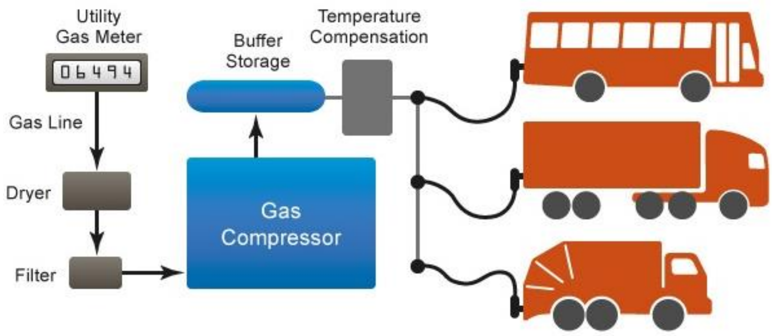

Figure 16 - Infrastructure for CNG time-filling station (AFDC, N/A)

The fast-filling configuration takes under 5 minutes to refill a 100-litre tank capacity – which thus is quite similar to a gasoline/diesel station (AFDC, N/A). The time-filling configuration is more difficult to determine because it depends on the compressor size and the number of vehicles connected to the station, therefore differentiating from several minutes to many hours (Ibid.). The difference in the configurations, as also seen on the Figure 15 and Figure 16, is the fast-filling has stored the necessary amount of compressed gas in large storage tanks ready to be injected to the vehicle, where the time-filling deliver gas directly from the compressor to the vehicle (thus a more time-demanding process).

The LNG/LBG station is more simple and similar to a gasoline/diesel station, as visualized on Figure 17.

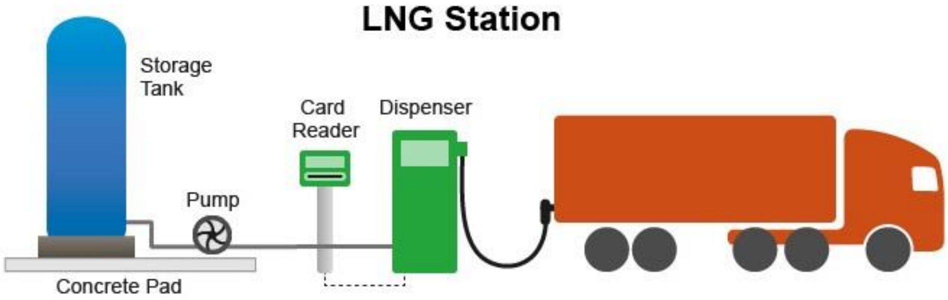

Figure 17 - Infrastructure for a LNG station (AFDC, N/A)

It consists only of a storage tank, a pump and a dispenser. The boiling point of natural gas is at -162^{O}C making it necessary to be stored in special constructed tanks – a technique called cryogenesis. A difference between the two fuels is the delivery method from the source to the station. As already stated, CNG/CBG is delivered through a pipe system under the ground, whereas LNG/LBG is delivered in large cryogenic tanks by trucks, or vessels in a maritime perspective, hence using the roads and using fuel. Another option is to set up a gas liquefaction plant onsite, which of course requires a small LNG plant to condense and refrigerate the gas from the pipes.

An advantage of the LNG/LBG is that it also possible to utilize in the maritime sector. As previously indicated, some of the Danish transport centres are in or near harbours (Nordic Transport Centre, Scandinavian Transport Centre, Taulov Transport Centre and Hirtshals Transport Centre) and are therefore directly connected to the maritime sector. A LNG/LBG infrastructure planned for both servicing trucks and maritime vessels is close to being ideal. However, LNG/LBG is not yet widely implemented for land-based transports, as the process of liquefaction and the cryogenic storage tanks are expensive, hence has only received marginal focus from truck manufacturing companies.

The point here is that the first steps in the transition will be to implement the infrastructure for CNG/CBG and have in mind the possibilities of LNG/LBG infrastructure – especially if there is a maritime connection to the transport centre. Until biogas becomes the main source of gas in the gas distribution network, and therefore the end-users will be sure that they are actually tanking biogas, the way to ensure that filling the tank with gas is actually contributing to development of alternative fuels is through the purchase of certificates of origin. In Denmark, the system is currently operated by Energinet, a public enterprise owned by the Danish Ministry of Climate and Energy, that issues certificates to biogas producers that inject biomethane into the gas distribution system. Hence, before establishing a biogas filling station it is important to guarantee that sufficient amount of gas is certified as coming from a biogas producer.

5.1 Holistic view

Methane gas can work as source to produce both hydrogen and ethanol through synthesis. Therefore, a hydrogen/alcohol-synthesizing plant could in some transport centres be implemented to service vehicles driving on these fuels and hence incorporate it in the holistic view of planning along with facilities to service ethanol, biodiesel and DME.

If electric vehicles and their batteries develop into the market of the heavy sector and long-distance driving, it might also be of interest to incorporate charging stations, or a battery swapping station on the site. At the same time, smaller vehicles, even vans, for city distribution will be compatible to do light-freight in local destinations, thus making it important to incorporate charging stations in the centres.

In terms of electricity, it is not only lighting and heating, but also compressing (CNG/CBG) or condensing (LNG/LBG) and the running the synthesizing plant – therefore it might be worth considering investing in the centres' own electricity supply i.e. a windmill or photovoltaics on the roofs.

The planning of an alternative fuels hub in a transport and logistics centre is an extensive process and needs to include the whole life cycle of the services provided to minimise the carbon footprint. To make the transition as smooth as possible, it is important to incorporate all of the sustainable fuels in an "one stop shop" solution.

5.2 Storage

There are two ways of storing the gases. The best solution depends on how much space there is for the storage tank and the amount needed. Preferably, CNG/CBG should be in spherical tanks under the

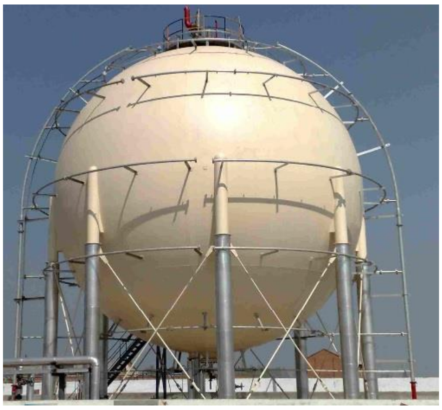

Figure 18 - Spherical CNG tank

Figure 19 - Hemispherical cylinder CNG tanks

pressure of 200-250 bars, as this configuration has an equal pressure all around the tank and thus does the least impact on the tank - Figure 18. The same counts for the LNG as a spherical tank has the smallest surface, which reduces the heat transmission to the gas. The second preferable solution is in hemispherical cylinder tanks - Figure 19 – as this storage tank has almost the same capabilities.

The LNG is better stored in a large spherical tank as it has the total smallest surface this way. Due to leak risks, CNG/CBG might be stored in several smaller tanks – here the hemispherical cylinder tanks are easier stacked. Hence, there are different possibilities to consider and the storage configuration depends on the size of the area, available for the storage.

6. Planning

The implementation entails several steps that needs to be done in the right order, as visualized in the timeline beneath, Figure 20. These steps will be elaborated further in the following section.

The planning and the construction evolve in consensus with responsible authorities, such as the Danish Labour Inspectorate, the Danish Safety Technology Authority and the municipality responsible for the environmental impact assessment (EIA), fire- and construction permits (Näslund, 2013).

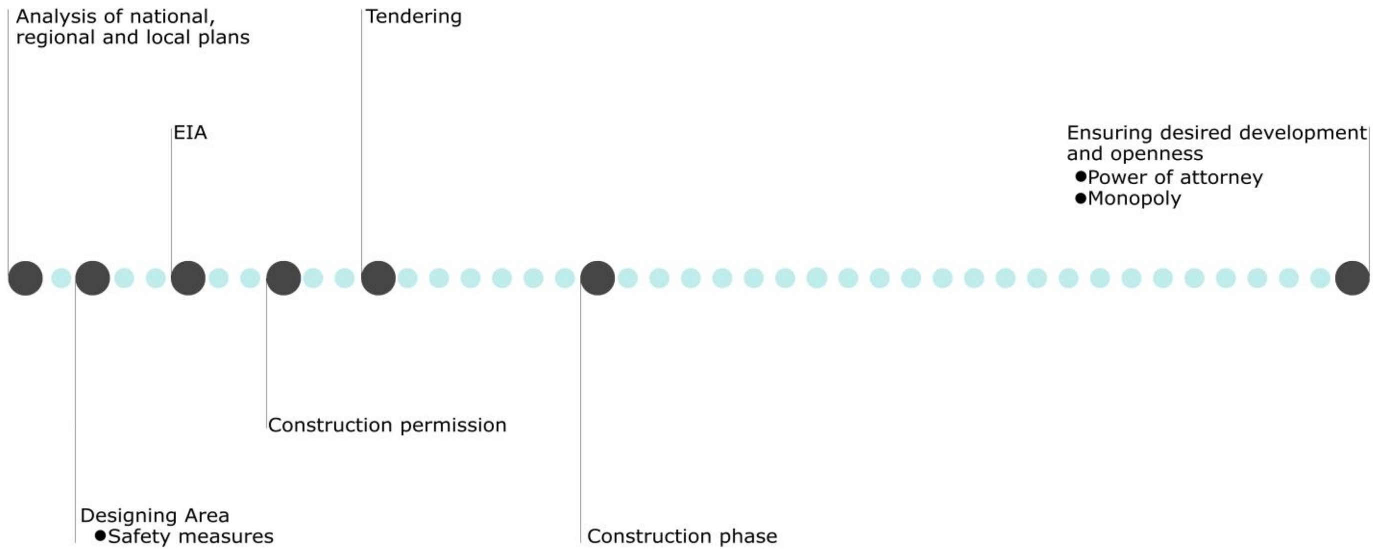

Figure 20 - Timeline for the implementation

The first steps in setting up a sustainable refuelling station is to look through the goals and strategies, i.e. the planning system, to see if the planned investment is compliant with the relevant plans. This means that the newly planned development cannot stand in opposition to the national targets or to the description of the desired future in the Regional Development plan, it doesn't contradict or exceed the framework conditions described in the Municipality Plan and lastly that it doesn't contradict or exceed the purpose of the Local Plan and its easements covering the chosen area. Normally the Local Plan for a transport centre has an incorporated purpose of implementing different fuel stations at the site – thus, it is not necessary to consider in such cases, but still relevant to be aware of.

6.1 Design Phase

When this first research is done and the new planned development meets the objectives and strategies of the mentioned levels, the design phase starts. There are many aspects that need to be considered, when designing the area regarding safety concerns, technical requirements, agreements and permissions. Therefore, an awareness of the authorities connected to each of them, knowing whom to go to for obtaining these, plays a crucial role.

The starting point is to identify all the technical and physical structures that need to be implemented and afterwards adjust them to safety standards and other regulative structures. To design an optimal development of the area, one including the possible future developments, an awareness of the number of users, both current and future ones, is critical. With this knowledge in mind, the technical and physical structures can be planned regarding:

- Number of filling dispensers
- Standards of dispensers
- Number of lanes
- Entry/Exit possibilities
- Turn radius
- Interconnection with other fuelling stations in the area
- Lightning
- Weather conditions (wind-, rain and snow deflections)
- Signs
- Storing area
- Supply

As mentioned earlier, the design of the area needs to foresee expansion opportunities for future technologies. This applies to several of the above-mentioned structures, ensuring enough room for trucks and being able to utilize all of the facilities on site.

6.1.1 Safety measures and agreements/authorities

Regarding safety, there are several regulations from different authorities that is important to follow. From a technical perspective, there are safety measures that needs to be procured, described in (Relevant links are composed in Annex B):

- The Executive Order on gas installations and gas equipment
- The Executive Order on technical regulations for gases

- The Executive Order on the utilization of equipment carrying pressure
- The Danish Gas Regulations

The Danish Labour Inspectorate

For implementations of pipelines with a maximum allowable operating pressure larger than 16 bar it is necessary to get a permission from the Danish Labour Inspectorate.

The pressure tanks, necessary for such an implementation, are encompassed in the regulations stated in the Executive Order for utilization of equipment carrying pressure (in Danish: *Bekendtgørelse om andvendelse af trykbærende udstyr*) no matter which gas type is used. These regulations define the surroundings and how to conduct inspections.

The Danish Safety Technology Authority

In general, the complex gas installation is encompassed in the Danish Gas Regulations (in Danish: Gasreglementet). The Danish Safety Technology Authority are the responsible authority for the safety linked to the different installations – but only for pipelines with a maximum allowable operating pressure below 16 bar, as the Danish Labour Inspectorate is the responsible authority for the larger pressured pipelines.

Danish Emergency Management Agency

Besides the Building Act and Building Codes, the Danish Emergency Management Agency are authorized to specify rules for companies that store and/or produce flammable fluids or gasses. These specifications encompass lowering the risks for fire hazards and securing the best rescue- and firefighting opportunities (Beredskabsstyrelsen, 2015).

Handling gases requires a permission from the relevant municipality, and additionally, in the case of storing larger quantities of gasses, the Emergency Management Agency will issue terms and conditions to the permission regarding specific requirements – as per the Emergency Preparedness Act (in Danish: *Beredskabsloven*) (Forsvarsministeriet, 2017).

6.1.2 Safety distances

There are regulations concerning the distances to other objects, meaning the locations of the station, storage and pipes matters and needs to be planned properly, cf. Annex C. The regulated minimum distances secure minimal impacts on nearby companies, roads, rails and other buildings, if a gas leakage or a fire occurs. If neighbouring buildings are too close to the gas object, it is possible to build a wall or a flame deflector to risks minimises.

The minimum distance to neighbouring-, road- or path boundaries is 2.5 meters, but depends on the size of storage and surrounding environment, i.e. whether it's stored in a building or outside, Annex C, 1. The Danish regulations do not yet cover all aspects, hence a look at the Swedish regulations will be guiding for envisioned future Danish regulations. In this regard, Annex C, 2 shows the Swedish regulations concerning nearby buildings. As can be seen on **Error! Reference source not found.** - **Error! Reference source not found.** the Transport & Logistic Centres' fuelling areas are not in residential neighbourhoods, but there are larger buildings in the nearby area at several sites. The Swedish regulations also allow to reduce the distance, if a wall or flame deflector is build – i.e. in case the building is closer than the mandatory distance.

In the construction phase, an awareness of other pipe systems is necessary. In Annex C, 3, regulations regarding the minimum distance between the gas pipes and other pipe systems are shown. Swedish regulations require placing a sign above the area, where gas pipes coming out of the compressor were dug down, to inform that there are high-pressure pipes. Additionally, regulations determine distances to nearby buildings from the high-pressure pipe, deviating from 3-16 meters depending on the pipe diameter. The distances can be reduced by 50%, if digging-protection is implemented, such as a protection pipe or a slab of steel above it.

Furthermore, there are no Danish regulations regarding distances concerning shared location with a gasoline/diesel station – here also biofuels included. Hence, a look at the Swedish regulations (shown in Annex C, 4) can be a guide for future envisioned Danish regulations.

As mentioned, several transport centres have rail connections, thus making it necessary to be aware of the minimum distances between the gas pipes and different rail objects. The regulations are shaped by the Danish National Rail system (In Danish: DSB), and are shown in Annex C, 5.

Annex C, 6, shows the Swedish regulations regarding minimum distances to high-voltage cables, as these can pose a risk of electrical static ignition in an inflammable area – such as gas stations.

6.1.2.1 Other regulations

Besides these regulations, it is important to be aware of The Machinery Directive, the Directive on Electromagnetic Compatibility, the Directive on Atmospheric Explosions and the Directive on Low Voltage, to be sure to have the right European safety standards and that the necessary equipment is CE-marked.

6.1.2.1.1 The Machinery Directive

As the tank is in fact many small devices, the whole system needs to be approved for usage as a machine cf. the Machinery Directive. The Machinery Directive ensures the machine meets the health and safety standards, described in the directives Annex 1 (European Parliament and Council, 2006).

6.1.2.1.2 The Directive on Electromagnetic Compatibility

The Directive on Electromagnetic Compatibility (EMC) secures that the machine doesn't make electromagnetic disturbances – this could, for example, be electrical noise from the compressor. Simultaneously, the machine must be immune to electromagnetic disturbances – for example, electrical functions, like the dispenser unit's pressure stabilizer, cannot be disturbed by electrical waves, as the vehicle might not be fuelled with properly pressured CNG. If the machine meets the EMC Directives terms, it gets CE-marked (European Parliament and Council, 2014b).

6.1.2.1.3 The Directive on Atmospheric Explosions

The Atmospheric Explosions Directive (ATEX) concerns the safety in areas with risks of explosions. In this case, it could be leaks of gases. The Danish Emergency Management Authority needs to do a classification of the potential risks in the area (Beredskabsstyrelsen, 2012).

6.1.2.1.4 The Directive on low voltage

As the system requires power, e.g. the compressor, it needs to meet the objectives in the low voltage directive. It is not a requirement of direct technical standards, but to secure identical requirements across Europe in terms of design and safety (European Parliament and Council, 2014a).

6.1.2.2 Closed areas – only for truck drivers (fast tracking)

In regard to determining the target group of users, it is vastly important that the area is accessible only for trucks – unless it can be smartly and safely connected with the maritime or railway transport. This means that it is not desired to have soft road users and private transportation in the area. The design of the area will thus favour heavy vehicles to ease and optimise the transition.

6.1.3 Visualized example

To visualize how a fuel filling area could look like, an example based on the Høje-Taastrup Transport Centre is shown here. The area is planned to accommodate all currently available sustainable fuels, and diesel, to make the holistic perspective and secure a broad approach to the transition with possibilities for all types of trucks.

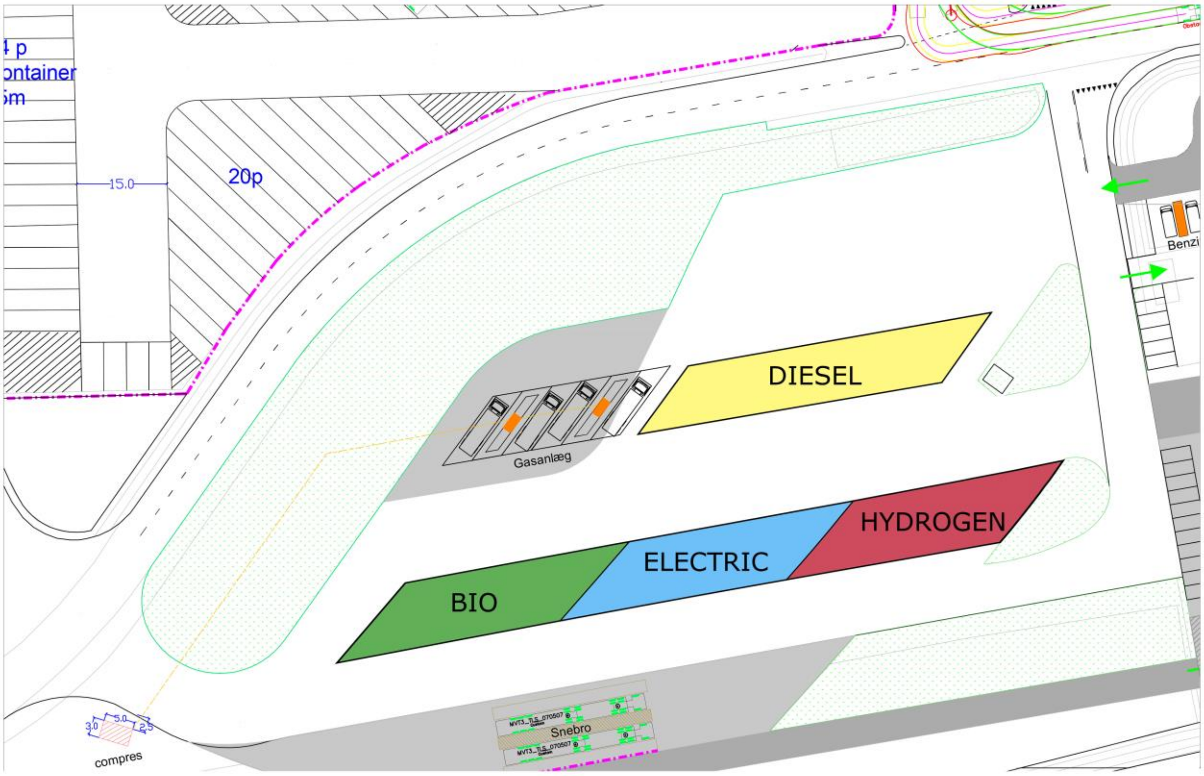

Figure 21 – Example of an alternative fuel hub

The biofuel on the visualization comprises both ethanol, methanol and DME. Electricity should be implemented as fast charging at the fuel station, whereas a slower, time-filling solution could be placed at the parking-lot area. The diesel area for now consist of normal diesel, but can in the future be substituted with biodiesel. The whole north and northwest area is currently an empty lawn and therefore gives the possibility for expansion with future technologies, more storing, synthesising plant or other future necessities.

6.2 Environmental Impact Assessment

EU makes every effort to ensure that new developments do not negatively affect the environment. Therefore, the European Parliament and Council adopted a directive in 1985 – last amended in 2009 – applying to: "an assessment of the environmental effects of those public and private projects which are likely to have significant effects on the environment" (European Parliament and Council, 1985). The directive obliges all member states to implement the policy, thus in a Danish context it was transposed via a so-called Executive Order under the title *“Bekendtgørelse af lov om miljøvurdering af planer og programmer og af konkrete projekter (VVM)”* (Miljøstyrelsen, 2017). According to this legislation, the term project comprises the execution of construction works. In this context, the developer needs to consider and consult public authorities, whether an environmental impact assessment (EIA) is needed. This is certainly the case with the establishment of a gas tanking station will.

The Executive Order lists the projects that are by definition EIA-obligated in the Annex 1. EIA-obligated projects must follow the steps in Part III of the Executive Order. Annex 2 lists the projects that do not automatically require an environmental assessment, but which under certain circumstances might fall under this requirement. Since gas fuel stations are not listed in Annex I, the EIA-obligation depends on the scope of the project. Annex 2, chapter 3, concerning projects within the Energy sector, identifies in point (d) and (e) projects that includes; *Surface storage of natural gas* and *Underground storage of combustible gases*. Either point (d) or (e) is a part of the implementation of a gas fuel station and the project is therefore required to do a screening, cf. § 21. The screening is performed by the competent authority according to a set of criteria specified in Annex 6 of the Executive Order, and may not take longer than 90 days from the date on which the developer has submitted the application. If the result of the screening determines that the project is not EIA-obligated, the decision, containing an extensive justification, is published and the process ends there. If on the other hand the result of the screening determines that the project is EIA-obligated, the process continues, and the developer is obliged to provide an environmental impact report (§ 20). The report should contain the following information:

1) A description of the project with information about the project's location, design, dimensions and other relevant features,
2) A description of the project's expected significant environmental impacts,
3) A description of the project's characteristics or the measures envisaged to prevent, reduce and, if possible, offset any expected significant adverse effects on environment,
4) A description of the reasonable alternatives that the developer has investigated and which is relevant to the project and its specific characteristics and an indication of the main reasons for the chosen solution, taking into account the environmental impact of the project,
5) A non-technical summary of the information referred to in points 1-4
6) Any additional information that is relevant to the particular characteristics of a particular project or project type and for the environment likely to be affected.

Subsequently, the relevant authority reviews the report and sends it to public consultation for at least 8 weeks (§ 24 and § 35). Next, the authority reviews the objections and comments to the environmental impact report, after which the final decision is made (§ 25-28). It is of utmost importance that the whole process is transparent and stakeholders are free to submit their comments, as this ensures that there is a common support for the project in a given location, when the project is finally executed.

6.3 Construction permit

Before the construction phase can start, §16 of the Danish Building Act requires the developer to obtain a construction permit. In general, almost every new building requires a permit. The application includes relevant technical data about the construction, comprising; accessibility, constructions, fire conditions, indoor climate, energy use and installations. It is sent to the Municipal Council, which decides if the construction fulfils the requirements cf. the Building Act and the Building Code (in Danish: *Byggeloven* and *Bygningsreglementet*). The Building Act is a framework law with the purpose of securing the application of safety measures connected to a construction and the quality of the construction (Transport- og Bygningsministeriet, 2016). The Building Code defines the actual restrictions and minimum-requirements regarding constructions.

In Denmark, the application is in written form, but the technical data can be sent online on www.bygogmiljoe.dk.

6.4 Tendering

In Denmark, there are two main legal acts regulating public tenders: The Public Procurement Act from 2015 (in Danish: Udbudloven) and The Danish Act on invitation of tenders in the works sector from 2007 (in Danish: Tilbudsloven). The former applies to public contracts with monetary value exceeding set by the EU, i.e. EUR 5,225,000 (updated every two years), whereas the latter applies to all public contracts falling below this threshold. In the case of gas stations, the total CAPEX rarely exceeds DKK 5-6 million, therefore it is primarily Tilbudsloven that needs to be considered. The latter law applies to contracts awarded by public institutions (governmental, regional or municipal authorities), developers that receive public funding and contracts awarded to sub-contractors, when performing a contract granted by a public institution.

The developer is obliged to invite potential suppliers to obtain tender offers, regarding the management and execution of the construction work, providing a level playing field for every supplier (Økonomi- og Erhvervsministeriet, 2007). This secures no discrimination and competition on the market. The Act also obliges the developer to accept either the lowest price or the most economically beneficial in terms of fixed criteria (e.g. quality, construction time, technical value).

There are three ways of tendering, i.e. public tendering, limited tendering and direct agreement (Danish: licitation, begrænset licitation and underhåndsbud respectively). The public tendering is the broadest, hence also the most resource demanding, as the tender should be published through an advertisement in a paper or online, where anyone can bid. The limited tendering is aimed at a limited group of potential suppliers, so it is the contract awarding party, who decides whom to invite directly, based on their economic and technical potential (usually based on contractor pre-qualification). The direct agreement applies to construction works below the value of DKK 3,000,000, therefore this procedure is the least relevant in the case of a gas fuel station, as the value will most likely exceed this threshold. Here the entity granting the contract is allowed to gather offers from maximum three suppliers.

6.5 Construction phase

The construction phase needs to meet the regulations in the law on constructions (in Danish: *Byggeloven*) to secure a safe environment for the builders.

6.6 Ensuring desired development and openness

It is important for the development that a large area is available for the implementation. The holistic approach is vital for the optimal development and it is important to ensure the openness of the area for future developments, not to lock the transition to certain technologies, seen as optimal in the present-day.

6.6.1 Municipal power of attorney

The municipalities in Denmark are entailed by a set of unwritten rules defined as the Municipal power of attorney. The “rules” give the right to - and oblige - the municipalities to handle the municipal resources in order to meet the general requirements in their local society. This means, the activities need to be in the municipality populations’ interest. It is not allowed for a municipality to operate commercial activities, so to get the desired development, they can buy, sell or lease land. An example is the Høje-Taastrup Transport Centre where the municipality still owns a piece of land. The desired future is to have sustainable fuels in the transport sector; therefore, they can lease a piece of the land to a supplier that are allowed to operate commercial activities and through the leasing agreement determine the frames so they get the desired future.

6.6.1.1 Leasing agreement

The leasing agreement is made when the owner of something (land, building, company, service) leases the facility to another actor that wants to operate the facility. This can happen if the owner doesn't have the capacity or the skills to operate the facility, or like in this case a municipality not allowed to operate it. The owner often gets a part of the profit from the business or a monthly fee for the leasing. Several conditions need to be determined in the leasing agreement. It is in this all the responsibilities and regulations are consolidated, such as (Naturstyrelsen, N/A):

- Partners
- Period
- Scope
- The agreements' fixtures
- Opening hours of the facility
- Signs
- Leasing tax/fee
- Other expenses
- Maintenance
- Commencement and termination
- Conditions
- Security

Through these conditions, a municipality can tailor the contract for the desired transition.

6.6.1.2 Monopoly

An important part of the transition and therefore a part in the leasing agreement is to make sure the selected supplier will not have monopoly on selling fuels in the transport and logistics centre. A supplier cannot have a monopoly to sell only one service, e.g. biogas fuel, as the area needs to comprise many sustainable fuel alternatives – and have room for future technologies. At the same time, a biogas supplier cannot have monopoly in the area. The area is set out for open competition and two suppliers can be next to each other – if this solution is the best for the development.

7. Case Study – Biogas station in Høje-Taastrup Transportcenter

CHAPTER TO BE EXPANDED WHEN MORE INFORMATION IS AVAILABLE

On 6th October 2016, a brand-new biogas filling station was open in one of Denmark's largest logistic centres, i.e. Høje-Taastrup Transportcenter. The biogas station was established in cooperation between E.ON and OK, and it enables to fill the tanks with CBG. The biogas station is part of a larger project "Application of gas-powered trucks with point of departure in Høje-Taastrup Transport Center" co-financed by the Danish Energy Agency with DKK 3,140,000.

Figure 22 - Gas compressor

The filling station is up and running, although the implementation was challenging at times, mostly because of a delay in connecting gas supply to the station, which only took place in summer of 2017, more than half a year after the official opening. The lesson learnt here is to have a binding agreement with a gas supplier as early as possible. It is important to remember that if the pressure in the pipelines is larger than 16 bars, it is the Danish Labour Inspectorate (Arbejdstilsynet) that is responsible for the gas connection procedure.

Seen from a project timeline perspective, the whole project, from fling the application for funds until the final implementation, lasted from fourth quarter 2014 until fourth quarter 2016. The design phase took more than a year, allowing the construction permit to be issued in second quarter 2016.

The total investment amounted to ca. DKK 5.7m, with nearly one third corresponding to the cost of a compressor station, one fourth to the gas connection works and materials, and one fifth to the dispensers and the high-pressure gas pipework.

Figure 23 - Gas dispenser

8. Economy of a gas filling station

The economy of the gas filling station is shaped by its location and scale, i.e. the number of potential users. The profitability of a gas filling station, as with any other investment, depends on the interplay between capital expenditure (CAPEX), operating expenses (OPEX) and revenues. Below, a more detailed look into these specific factors has been presented.

8.1 Capital expenditure

The initial investment outlays consist of the cost of necessary permits, land purchase (if needed), machinery and equipment purchase as well as construction works. The total costs will depend heavily on whether fast- or slow-fill technology is used, however it is not highly dependent on the planned turnover, as long as no additional compressors are needed (COWI, 2014). The most expensive piece of machinery is the gas compressor, the size of which depends on the expected number of users. Gas-fuelling stations often work with two gas compressors for safety reasons, to ensure a backup if one of them goes out of service. Other machinery and equipment costs include: pump island, gas stands, lighting, signs, shelter belts, and fire safety equipment.

The construction works will usually include digging, pipework, electricity, fundaments, sewage work, coating and soil inspections. The exact extent and hence the cost of construction works depends predominantly on the already existing infrastructure that can be adapted to the planned gas station, and on the distance from the gas distribution grid. Therefore, in each of the stations these costs can vary more than the cost of machinery and equipment, since these will usually be quite similar across the different locations.

Below examples of Danish gas fuelling stations with their CAPEX and characteristics are presented:

Station	CAPEX (million DKK)	Capacity (m3/t)	Type
Skive	2.5	50	Fast
Gladsaxe	6	2*850	2*Fast
Tarm	6	2*300	Fast
Fredrikssund	6	2*165	Fast
Aalborg	5	2*155	Fast + Slow
Holstebro	5	2*130	Fast + Slow
Fredrikshavn	5	2*155	Fast + Slow
København	4.5	155	2*Fast
Fredericia	5.7	-	12 connecting pieces + 2*Fast

Table 3 - The cost of the Danish gas fuelling stations (COWI, 2014)

8.2 Operational expenses

A typical gas station located in a logistics centre will be an unmanned facility. Nevertheless, there are still some fixed and variable costs that need to be incurred. In general, there costs include:

- Electricity costs for compression plants, lighting, gas dispensers, etc.
- Maintenance
- Supervision
- Administration, etc.

The individual costs will depend on the size and location of the filling station. An installation established in connection with an existing station will only provide marginal additional costs. The operating variable cost amounts to DKK 0.5 - 2 per m^3 (Høje-Taastrup Municipality, 2013). The electricity bill will depend on how compressed the gas coming from the distribution grid already is. The power consumption of a CNG compressor station is approx. 0.28 kWh per m^3 of natural gas when compressed from 4 bar to 200 bar, but only 0.05 kWh per m^3 when compressed from 80 bar to 200 bar (COWI, 2014).

8.3 Revenues and break-even point

Unlike regular gas stations, a gas filling station placed in a logistics centre will rely exclusively on the revenues generated through the gas sale. To reach a break-even point, the station needs a turnover of ca. 6 GWh or 600,000-700,000 m^3, which equals to 40 garbage trucks using the station frequently, assuming a price of DKK 7.5 per m^3 (COWI, 2014; Høje-Taastrup Municipality, 2013). This break-even point is just an example and depends on the number of users, gas price, fixed and variable costs.

9. Summary

Green transition requires far reaching actions, and as has been identified in this report, the transport sector carries a vast responsibility along with the energy and heating sector. As a major contributor and enabler in the economy, and a significant source of pollution, the heavy transport sector's involvement is essential to advance the sustainability agenda. In the case of transport, apart from organisational efficiencies, including increased loading factors and better routing, this transition cannot be completed without the phasing out of traditional fossil fuels and promoting more sustainable alternatives. Due to its characteristic, biogas is seen as a very promising alternative, especially because of the range it offers.

The EU legislative framework is already in place to make this change possible. All but one of the discussed transport and logistic centres is located by the core TEN-T network, and are therefore eligible for financing under the Connecting Europe Facility. When coupled with the obligation to the Member States to establish alternative fuels refuelling stations along the TEN-T corridors, it becomes clear that transport and logistic centres have a pivotal role to play. It is also the role of infrastructure managers in the Member States to report to the EU on the progress of the development of the core network, and to ensure that this network is developed by 2030.

All transport centres have a designated area for fuelling, which, as can be seen in the analysis, are all located near the national gas distribution grid, making it easily accessible to connect a gas fuelling station to it. When designing a gas fuelling station there are different considerations to be made, whether it should be a fast-filling or time-filling station, what sort of storage tanks to use (spherical vs hemispherical), the type of compressor and the expected size of materials. Furthermore, several precautions need to be included in the design phase, such as minimum distances, technical standards, fire exits and responsible authorities.

There is a number of steps that need to be followed in the planning process. These are presented in this report to ease and guide the developer to ensure a fulfilment of the necessary stages both in a national and European context, ensuring that all legal requirements are met, especially regarding EIA.

The transport and logistic centres are critical points of contact, serving as the centre of gravity for goods transportation that make the whole distribution industry possible. Hence, they are best suited to play the role of frontrunners by establishing alternative fuel hubs, as the trucks already are refuelling their vehicles here. These centres can also take advantage of new ICT solutions that enable instantaneous communication with potential users, informing them about the availability of fuel dispensers and enabling them to reserve a specific time window to optimise their travel, and reduce refuelling times. This is especially important since refuelling with gas takes longer than with conventional fuels, making the organisation of the refuelling process crucial to delivering goods on time. Therefore, offering facilities accommodating all kinds of fuel alternatives will ensure a long-term prosperity and sustainability of the industry.

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11. Annex

11.1 Annex A

11.1.1 Alternative fuels

11.1.1.1 Diesel

Diesel oil is a fossil fuel distilled of crude oil. It has a high heating value and ignition temperature, which makes it a stable and effective fuel, with several utilization possibilities. Combined with a diesel engine's high efficiency and capability of attaining high torque, even with lower RPM, it has been an important fuel for industries working with heavy goods and transportation. The diesel vaporizes in the engine just before it ignites, which results in a certain amount of the oil doesn't succeed to burn, before the stamp pressures the exhaust out of the engine. These unburned carbon hybrids and particles are bad for the engine's efficiency, but also for the environment and people's health.

DIESEL

T	20	°C
P	1,01325	bar
RHO	856	kg/m^3
LHV	41,9	MJ/kg
LHV	35,866	GJ/m^3

Table 4 - Diesel characteristics (Turns 2012)

11.1.1.2 Biodiesel

The term biodiesel covers in general plant- and animal fat blended with an alcohol and possibly a salt. This process liberates the fatty acids from the glyceride, which thereafter esterifies, and convert the glyceride to glycerine. Afterwards the residues from the fatty acids separates from the glycerine.

Biodiesel are more viscous than diesel, which makes it not as easy vaporized, thus biodiesel pollutes more particles and unburned carbon hybrids. Biodiesel has been criticised to utilize the land meant for food production for humans, the so-called indirect-land-use-change effect (ILUC- effect). Therefore, a possibility is to use fatty residues from food production (including preparation) and naturally dead animals – which additionally help to reduce the food- and energy waste.

BIO-DIESEL

T	20	°C
P	1,01325	bar
RHO	879	kg/m^3
LHV	37,5	MJ/kg
LHV	32,963	GJ/m^3

Table 5 - Biodiesel characteristics (Turns 2012)

11.1.1.3 Ethanol

Both Otto and Diesel cycle motors can utilize ethanol as a fuel. Ethanol has a lower heating value than diesel with about 60 %, which means vehicles using ethanol has to sacrifice on another parameter, such as room, payload or distance compared to a diesel-driven vehicle. Ethanol's lower volumetric heating value is comparable with Liquid Natural gas (LNG) / Liquid Bio Gas (LBG), hence has about the same radius.

ETHANOL

T	20	°C
P	1,01325	bar
RHO	785	kg/m^3
LHV	26,7	MJ/kg
LHV	20,96	GJ/m^3

Table 6 - Ethanol characteristics (Turns 2012)

The LNG/LBG tank has to be made of other thicker and more expensive materials than the ethanol tank (which can use the same tank as the diesel fuel) (Ring-Hansen Holt, 2010). Ethanol weighs more, which equals up the advantage.

11.1.1.4 Methanol

Methanol has many of the same abilities as ethanol, but has a higher density, a lower heating value and a lower boiling point. This results in a vehicle driving on methanol will come approximately ¾ as far as a vehicle driving on ethanol considering same tank capacities. At the same time, the tank weighs more resulting in lower payload on the vehicle.

METHANOL

T	20	°C
P	1,01325	bar
RHO	791,8	kg/m^3
LHV	19,99	MJ/kg
LHV	15,828	GJ/m^3

Table 7 - Methanol characteristics (Turns 2012)

11.1.1.5 Di-Methyl Ether (DME)

DME is chemically quite similar to ethanol, as the two fuels consists of equally amounts of the same elements, but the difference is in the construction. It is possible to synthesise DME from methanol (Semelsberger, Borup, & Greene, 2006). It has a higher heating value than ethanol and methanol, but at the same time a significantly lower boiling point. This makes it necessary to keep it cooled down and under pressure to store it at its liquid form. DME in liquid form can create peroxides, which are highly explosive, thus making it less usable for as commercial fuel (Wray, 2015).

DI-METHYL ETHER

T	-25	°C
P	1,01325	bar
RHO	661	kg/m^3
LHV	28,62	MJ/kg
LHV	18.918	GJ/m^3

Table 8 - Di-methyl ether characteristics (Turns 2012)

11.1.1.6 Hydrogen

Hydrogen can both be utilized in a combustion engine and in fuel cells. In the combustion engine, the efficiency is up to 50 %, where the fuel cells has efficiencies up to 90 %. A fuel cell produce electrical power by disassembling the hydrogen molecules to two hydrogen atoms. Each atom disassembles to a proton and an electron. The protons transfer through a membrane, where the electrons transfer through a cable. This cable can then be connected to an electric engine operating a car.

There are several ways to produce hydrogen, but one of the most efficient is the steam modifications of natural gas or biogas, as the less CO2 there is the more hydrogen there will be (Sigurdsson & Kær, 2012).

BRINT		
T	20	°C
P	1,01325	Bar
RHO	0,0838	kg/m^3
LHV	119,96	MJ/kg
LHV	10,052	MJ/m^3
KOMPRIMERET		
P	250	bar
RHO	20,68	kg/m^3
LHV	2,481	GJ/m^3
VÆSKE		
T	-253	°C
RHO	70,8	kg/m^3
LHV	8,493	GJ/m^3

Table 9 - Hydrogens characteristics (Turns 2012)

11.2 Annex B

11.2.1 Relevant links

The Executive Order on gas installations and gas equipment:

https://www.retsinformation.dk/Forms/R0710.aspx?id=163404

The Executive Order on technical regulations for gases:

https://www.retsinformation.dk/forms/R0710.aspx?id=134984

The Executive Order on the utilization of equipment carrying pressure:

https://www.retsinformation.dk/forms/R0710.aspx?id=31045

The Danish Gas Regulations:

https://www.sik.dk/Virksomhed/Gas-kloak-vand-og-afloeb-for-fagfolk/Love-og-regler-om-gas-og-vvs/Gasreglementet

The Emergency Preparedness Act:

https://www.retsinformation.dk/Forms/R0710.aspx?id=188158

Law on constructions:

https://www.retsinformation.dk/Forms/R0710.aspx?id=183662

11.3 Annex C

1.

Minimum distance to neighbouring boundaries, road- and path middles and boundaries			
Object	Distance to neighbouring boundary	Distance to road- and path middle	Distance to road- and path boundary
Storage in building ≤ 1000 GOE	2.5	2.5	-
1000 - 10.000 GOE	5	5	-
Storage outside ≤ 1200 GOE	2.5	-	2.5
Storage outside 1200 - 5000 GOE	5	5	2.5
Storage outside 5000 - 10.000	10	5	2.5
Storage section outside			
≤ 1200 GOE	2.5	-	2.5
1200 - 5000 GOE	5	5	2.5

Table 10 - Minimum distance to neighbouring boundaries, road- and path middles and boundaries (Näslund, 2013)

2.

Minimum distance in Sweden to buildings not included in the gas station			
Component	Buildings in general - with inflammable material or companies representing a fire hazard	Vastly inflammable (cf. gas storage of middle size)	Exits from premises difficult to evacuate
Gas storage (litres)			
V > 4000 (400 GOE)	25	50	100
1000 < V ≤ 4000 (100 < V ≤ 400 GOE)	6	25	100
600 < V ≤ 1000 (60 < V ≤ 100 GOE)	3	25	100
Dispenser	6	25	100

Table 11 - Minimum distance in Sweden to buildings not included in the gas station (Näslund, 2013)

3.

Minimum distance between gas pipe and other pipes		
Location	Minimum allowed distance to parallel pipe	Minimum allowed distance to crossing
Water pipe	0.3	0.3
Sewage pipe	0.3	0.1
Low voltage cable <20kV, tele cable	0.3	0.3
High voltage cable <20kV, tele cable	0.3 (Metal pipe) 0.75 (PE-pipe)	0.3 (Metal pipe) 0.75 (PE-pipe)
District heating pipe	0.5 (Metal pipe) 2 (PE-pipe)	0.5 (Metal pipe) 1 (PE-pipe)
Wells and other alike constructions	0.5	0.5
Building fundaments	0.5 (Metal pipe with weld on connections) 1 (PE-pipe with ductile cast iron pipes)	0.5 (Metal pipe with weld on connections) 1 (PE-pipe with ductile cast iron pipes)
Land drain with diameter up to 15 cm	0.15	0.15
Other land drain	0.3	0.3

Table 12 - Minimum distance between gas pipe and other pipes (Näslund, 2013)

4.

Swedish distance regulations, when a gas station is located together with a gasoline station				
	Prohibited area	Gas storage >4000 l (>400 GOE) (m)	Gas storage ≤4000 l (≤400 GOE) (m)	Distance to dispenser
unloading area for vehicles with inflammable liquids - class 1	12	25	12	6
Fuse box (pump) for inflammable liquids - class 1	12	6	6	?
Cover for dip rod measurement in the cisterns with inflammable liquid - class 1	12	3	3	1.5
Vent estuary for the cisterns with inflammable liquids - class 1	-	6	6	6
Facility building (B-building)	-	12	6	6
Storehouse (C-building) with inflammable goods	-	12	6	6
The cisterns with inflammable liquids - class 1 above surface	12	25	12	3
Gasoline separator	3	-	-	-
Environment station for hazardous waste	-	12	12	12

Table 13 - Swedish distance regulations, when a gas station is located together with a gasoline station (Näslund, 2013)

5.

Distances between rail and natural gas facility	
	Distance (m)
Gas pipe > 4 bar to rail middle	15
Gas pipe > 4 bar to fundaments, masts, rail buffers	10
Gas pipes > 4 bar to bridges, buildings	20
Gas pipe to relay house	10
Gas pipe to relay box	5

Table 14 - Distances between rail and natural gas facilities - DSB regulations (Näslund, 2013)

6.

Construction tension (kV)	Distance to a hazardous area with inflammable materials in terms of risks for electrostatic charging (m)
12.0 - 72.5	15
82.5 - 170	30
245	45
420	60

Table 15 - Distance regulations to high-voltage lines (Näslund, 2013)

About Biogas2020

Biogas2020 is a partnership project within the EU-program Interreg Öresund-Kattegat-Skagerrak. The goal is to build strong networks throughout the biogas value chain. To reach this goal, one objective of the project is to develop a Scandinavian biogas platform where industry players can grow in partnership.
The project encompasses three countries and three regions taking a major step forward together, despite being in different situations and different stages in developing their biogas industry. The project 34 partners work on expanding biogas production, improving processes and creating infrastructure.
Within the project NTU ApS is the lead partner of Work Package 5 concerning the use of biogas for heavy transport. The activities within this WP include, among others, examining national and international funding opportunities, mobilizing the stakeholder network, setting up a biogas station map, presenting best practices, analyzing business models, disseminating knowledge on biogas use through articles.

http://biogas2020.se/

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