TECHNICAL AND LEGAL REQUIMENTS OF A METHANE DISTRIBUTION SYSTEM

Lappeenranta–Lahti University of Technology LUT

MSc in Environmental Engineering – Circular Economy, Master's thesis

2023

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ABSTRACT

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LUT School of Energy Systems

Environmental Technology

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Technical and legal requirements of a methane distribution system

Master's thesis

2023

63 pages, 7 figures, 2 tables and 5 appendices

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Keywords: Biogas, Filling station, Official process, High pressure storage, Gas compressor, Equipment requirements.

This master's thesis was done for Sauter-Biogas Finland. Goal was to examine the construction and authority process of a gas filling station, starting with the building permit and ending with post-inspections of the finished gas filling station. In addition, the work examined the approval and permit process of gas equipment, i.e. high-pressure gas storages, gas compressors and gas dispensers in Finland. In the work, Finland's requirements and laws were compared with the requirements and laws of other European countries regarding gas appliances, both domestic and European-wide laws. For the literature review, information was collected from scientific publications, laws, reports, association guidelines and interviews.

The results of the official gas station process are very simple and include a clear process and instructions on equipment, requirements and permits. Based on the interviews conducted in the work, it can be concluded that the legislation and requirements related to gas filling stations in Finland differ from other European countries. Assumptions of possible changes to Finland's gas laws are completely theoretical. Based on data, it can be concluded that Finnish gas legislation lags the rest of Europe and changes are possible. In addition, it should be considered that laws that are perceived to already work elsewhere in Europe may also work in Finland.

TIIVISTELMÄ

Lappeenrannan–Lahden teknillinen yliopisto LUT

LUT School of Energy Systems

Ympäristötekniikan koulutusohjelma

Veli-Pekka Itkonen

Metaanin jakelujärjestelmän tekniset ja lailliset vaatimukset

Diplomityö

2023

63 sivua, 2 taulukkoa, 7 kuvaa ja 5 liitettä

Työn tarkastajat: Apulaisprofessori TkT (Tech.) Ville Uusitalo
Apulaisprofessori VTT Jarkko Levänen

Hakusanat: Biokaasu, Tankkausasema, Viranomaisprosessi, Korkeapainevarasto, Kaasukompressori, Laitevaatimukset.

Diplomityö tehtiin Sauter-Biogas Finlandille ja sen tavoitteena oli selvittää kaasutankkausaseman rakentamis- ja virallistamisprosessi alkaen rakennusluvasta ja päättyen valmiin kaasutankkausaseman jälkitarkastuksiin. Lisäksi työssä tarkasteltiin kaasulaitteita eli korkeapainekaasuvarastojen, kaasukompressorien ja kaasuautomaattien hyväksymis- ja lupaprosessia Suomessa. Työssä verrattiin Suomen vaatimuksia ja lakeja muiden Euroopan maiden vaatimuksiin ja lakeihin kaasulaitteiden osalta sekä kotimaisten että koko Euroopan kattavien lakien osalta. Kirjallisuuskatsausta varten tiedot kerättiin tieteellisistä julkaisuista, laeista, raporteista, yhdistyksen ohjeista ja haastatteluista.

Tulokset kaasutankkausaseman virallisesta prosessista ovat hyvin yksinkertaisia ja sisältävät selkeän prosessin sekä ohjeet laitteistoista, vaatimuksista ja luvista. Työssä toteutettujen haastatteluiden perusteella voidaan päätellä, että Suomen kaasun tankkausasemaan liittyvät lainsäädännöt ja vaatimukset eroavat Euroopan muista maista. Arviot ja olettamukset Suomen kaasulakien mahdollisista muutoksista ovat täysin teoreettisia. Aineistosta voidaan päätellä, että Suomen kaasulainsäädäntö on jäljessä muusta Euroopasta ja muutokset ovat mahdollisia. Lisäksi tulee ottaa huomioon, että muualla Euroopassa jo toimiviksi koetut lait voivat myös toimia Suomessa.

ACKNOWLEDGEMENTS

First of all, I would like to thank Sauter-Biogas Finland and the team that made this topic possible, and especially Janne Ekholm, Ville Uusitalo and Jarkko Levänen, who acted as my instructors. I would also like to thank Nathan Dietz and Jent Topa, who helped me with the German-language laws. Also, big thanks to my friends and I would like to especially thank my fiancée Krista for her help and support throughout the work.

In Tampere 02. May 2023

Veli-Pekka Itkonen

Abbreviations

TUKES	Finnish Safety and Chemicals Agency
EU	European Union
LUT	Lappeenranta–Lahti University of Technology
BAR	Metric unit of pressure
CBG	Pressurized biogas
CNG	Compressed natural gas
LNG	Liquefied natural gas
LBG	Liquefied natural gas
FINAS	Finnish Accreditation service
FIMEA	Finnish Medicines Agency
MEE	The Ministry of Employment and the Economy
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
CLP	The Classification, Labelling and Packaging Regulation
LVM	Ministry of transport and communications
MMM	Ministry of agriculture and forestry of Finland
SM	Minister of the Interior
STM	Ministry of social affairs and health
YM	Ministry of the Environment
EMAS	Eco-Management and Audit Scheme
MRL	Land Use and Construction Act
MRA	Land use and building regulation
SFS	Finnish standards association
VAK	Transport of dangerous goods
ADR	International Carriage of Dangerous Goods by Road
TPED	EU transportable pressure equipment directive
NVG	Natural gas vehicle

Chemical abbreviations

CH_4	Methane
CO_2	Carbon dioxide
H_2O	Water
O_2	Oxygen
N_2	Nitrogen
S	Sulfur
H_2S	Hydrogen sulfide
NH_3	Ammonia

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1 Introduction

Climate change is one of the biggest challenges we face now and in the future. In order to solve this, it is necessary to find, among other things, new sources of energy, to make food production more sustainable and, from the point of view of the circular economy, to recycle energy and materials. One significant way to increase energy production and reduce emissions is biogas production from, for example, manure, where methane is collected and usefully used, for example in electricity production, heat production and as a vehicle fuel. While energy is created from biogas in the biogas reactor, we also implement a circular economy, where the obtained methane is used as energy and the remaining digestate can be used as fertilizer in the fields. Biomethane produced from biogas can possibly replace other fossil fuels in energy production and as a fuel, because for example, the carbon dioxide produced from organic material in composting is harmful to the climate, so it is more useful to produce biogas from organic material, to produce energy and fertilizer, than not to use it and release into the atmosphere. Refining biogas into biomethane and using it as fuel is a better alternative than using other fossil fuels. For example, carbon dioxide in oil is bound deep underground and thus does not itself cause carbon dioxide emissions, but carbon dioxide from organic matter would probably have been released into the atmosphere in any case, in which case the production and utilization of biogas is logical. (Kiviluoma-Leskelä 2010, 10-17; Motiva 2022; Mwacharo et al, 2020, 6-34)

The goal of the work is to clarify the official process from the construction of a gas filling station all the way to refuelling. This includes instructions for the law, certificate and standard requirements for equipment and structures. One of the goals is to go through the official process, which authorities are included in the process and what are the duties and responsibilities of the authorities and furthermore reviewing and clarifying the technical requirements for equipment coming to gas filling stations. Interviews with experts and authorities, as well as the interpretation of laws, regulations, and standards, also aim to compare these with European laws, regulations, standards and practices when it comes to the construction of a gas filling station. This comparison aims to find out if it is possible that things are done differently in Finland than in other regions and if it is possible that regulations, requirements, and laws could be changed in Finland to be similar to those in other countries that have more experience with gas handling. (Kiviluoma-Leskelä 2010, 10-17; Motiva 2022; Mwacharo et al, 2020, 6-34)

1.1 Background

Biogas is a renewable energy source, and its use can reduce greenhouse gas emissions for example, compared to methane from biowaste and manure that would be released into the atmosphere without utilization, or natural gas can be replaced with biomethane. Replacing natural gas with biomethane reduces emissions, because manure and bio-waste release emissions into the atmosphere even without utilization, but natural gas itself stores methane and is usually only released due to human influence and use as fuel.

Methane produced in agriculture and waste treatment utilization in energy production reduces methane emissions to the atmosphere, although without organic waste and agriculture methane emissions would decrease effectively. As long as waste treatment, organic waste and agriculture produce methane emissions, biogas production is profitable from an environmental point of view, and in many cases biogas production is economically profitable, but the economics are case-specific. Methane is over 20 times more powerful greenhouse gas than carbon dioxide, reducing methane emissions helps curb climate change. In addition, the use of biogas as a source of energy may reduce dependence on fossil fuels and imported energy. (Abbasi et al, 2012; Karjalainen, 2021, 4,8; Khoiyangbam et al, 2011, 1-5; Kiviluoma-Leskelä, 2010, 17-21; Perkiö, 2020, 1-3; Wellinger et al. 2013, 1-5; Motiva 2022; Biokaasu 2022)

Biomethane has been identified as the most environmentally friendly option for light commercial vehicles and 12-ton heavy goods vehicles when looking at greenhouse emissions. (Joint research Centre 2020) Biomethane is produced by cleaning and upgrading biogas, resulting in about 97% pure methane, the remaining 3% are other impurities, for example carbon dioxide. As justification for the claim in the study, the manufacture of electric heavy vehicles requires a lot of natural resources and produces a lot of greenhouse emissions, so biomethane is less harmful in terms of greenhouse gas emissions. (Kiviluoma-Leskelä 2010, 17-23; Mwacharo et al, 2020, 6-8, 19; Council of the European union 2022 proposal; Joint research Centre 2020).

Probable future European legislation and in this case the European Commission's extensive legislative package (Fit for 55), however, promote the use of biogas only for electricity generation because electricity production with biogas had not been classified out and biomethane as transport fuel is reaching its end, because according to this regulation, in 2035 no more combustion engine vehicles can be manufactured in Europe, including biomethane and natural gas. Biomethane as a transport fuel must therefore be produced without a special position in relation to fossil fuels and in addition compete for both other renewable fuels and natural gas, with electricity generation and waste incineration. The production and refining of fossil oil is currently in normal amounts, but in the coming years this will possibly decrease, due to European legislation and regulations to reduce the number of vehicles running on fossil fuels. Although vehicles that run on biomethane are included in this, studies on the low pollution of biomethane as a fuel during its life cycle may still have a positive effect on Europe's position and allow the use of biomethane as a fuel and thus have a positive effect on the competitiveness of biomethane as a fuel. (Council of the European union 2022 proposal; Euroopan unionin neuvosto 2022; Joint research Centre 2020).

Sauter-Biogas produces biogas plants that differ from traditional biogas plants. Sauter biogas plants does not have a mixer but a with a nozzle that breaks the surface of the feedstock with pressure injection in the reactor and mixes the mixture, which reduces the plant's own energy consumption. The gas produced in the reactor is about 60% pure methane, depending on feedstock. If the gas is to be used for road transport, then the biogas must be refined into biomethane, where almost all impurities are removed, and almost pure methane remains. A filling station is necessary if the purpose is to refuel with biomethane, and the construction of a gas filling station involves numerous laws, regulations, and regulations, depending on the equipment, structures, and size of the station. The thesis is related to the biomethane distribution systems and more specifically to the biomethane filling stations and the necessary authority process and other requirements related to the filling station as a whole to build the filling station. The topic has been obtained from Sauter-Biogas Finland, as the company needs information on the gas filling station permit process, requirements, and regulations, so that the company has the knowledge to build a gas filling station (including equipment, pipelines, gas quality and structures). (Wellinger et al, 2013, 1-5)

1.2 The goals of the research

The main goal of the work is to study for Sauter-Biogas Finland what does the gas filling station official permit process include, and how does the permit process work in practice. More specifically, the filling station includes gas compressors / compressor that pressurizes the biomethane to a certain pressure, a high-pressure storage in which the biomethane is stored, and a gas distribution, i.e., a dispenser, gas pipes, safety equipment, gas quality and other necessary equipment, which is required from a gas filling station. The work therefore includes what requirements equipment's have, what permits and certificates the equipment industry must have and what requirements are involved in construction. All of these are examined through standards, Finnish legislation, and requirements.

The second goal is to investigate the differences between the requirements of Finland and other European countries for gas filling stations and/or equipment by comparing expert interviews and European legislation. By studying and comparing the differences between the gas laws and requirements of Finland and other countries, it is possible to find something to improve in safety, simplify the permit process, reduce equipment requirements, or reduce the costs related to the construction of a gas filling station by loosen the requirements.

1.3 Scope and limitations of the thesis

The study is limited to, the biomethane distribution station and equipment authority process and the tasks associated with these processes and the necessary permits to make the distribution station operational, and to study and compare the gas legislation and requirements of Finland and European countries, regarding the gas filling station as a whole. The study addresses the construction of a biomethane distribution station, the permitting process for equipment's and other necessary material, and what certificates and measures are required of equipment's. Master's thesis is limited to the gas filling station permit process, what requirements for equipment, gas and the station are required by the authorities and the law, the process of the permit process in practice, which authorities and experts are involved in the process, which laws, regulations and laws related to the gas filling station must be followed, as well as research on European and Finnish laws, regulations and requirements related to the gas filling station and equipment.

The aims of the study are to be achieved by examining the authority's decisions, standards and legislative work related to the construction and approval of a biogas plant's filling station by the authorities in Finland. Problem areas will be tentatively resolved directly on Tukes website, by researching standards and searching for information and guidance on the Internet. The approval of a filling station and equipment requires the application of a number of standards and regulations that ultimately apply to this particular filling station. The work was done in 2021 and 2022, and the essential change during this period was the knowledge that in Europe there will very likely be a law to abandon the production of combustion engine cars by 2035 and move to other energy methods for these. The preliminary steps are therefore to search for law data, apply it to gas filling station and then write the so-called instruction clean. The work steps are finding the right information, authority, and expert interviews, apply information to the target and formulating the information, instructions, and interviews for the thesis.

1.4 Materials and methods

Research methods can be divided into qualitative and quantitative research. Qualitative research aims to be comprehensive to understand the quality and meaning of the object and to answer the questions: Why, how, and what kind. In qualitative research, the researcher is the interpreter of the subject and examines the material in a multifaceted and detailed manner. Quantitative research, on the other hand, is based on to interpret the object using numbers or statistics. These methods are often described as opposites, but they can nevertheless be used in the same study. The study uses a qualitative method, because the study focuses on facts and look for exact information about problems from a large number of materials. However, the work also includes a bit of quantitative research because the work involves the interpretation of extensive material and laws, and the work progresses from general to individual cases. This thesis uses qualitative method as it involves interviews with opinions and experts own interpretation of the issues, these interviews do not change the results of the official process of the gas filling station but clarify and justify them. Primarily, the interviews and interpretation of the law have sought to find differences in the regulations and equipment requirements of Finland and other European countries. The methods and procedures are searching for information on the Internet and laws, using LUT Primo to search for standards, researching Finnish legislation and conducting interviews remotely with videos and recording if possible.

2 Theory

The theoretical part of the literature review is presented in the following subsections. Topics covered include biogas production and how biomethane is produced, gas filling station equipment, as well as authorities, experts, laws, and standards. Biogas and methane are essential in relation to the work because methane refined from biogas is a fuel that is refuelled at a gas filling station with gas refuelling equipment. Gas station equipment plays an essential role in the work, as the requirements of these equipment are studied and compared in the thesis. The last subchapter deals with the authorities, experts, laws, and standards that define the requirements for the gas filling station and equipment, and that are involved in the official process in one way or another.

Biogas is formed when almost any organic material undergoes anaerobic digestion, that is, where bacteria decompose this organic material under oxygen-free conditions, i.e., under anaerobic conditions. Biogas mainly contains methane approximately (CH4 40-75%) and carbon dioxide approximately (CO2 25-60%), and biogas also contains water (H2O) oxygen (O2) and small amounts of nitrogen (N2), sulfur (S2), and hydrogen sulfide (H2S). The amount of methane in biogas is affected by characteristics of organic matter the biomass contains. (Abbasi et.al 2012, 1; Bak et al, 2019, 1; Deng et al, 2020, 201-205; Wellinger et al, 2013, 1-5)

The most significant reason for biogas production is the high methane content of biogas, which can be used, for example, as a fuel and in electricity generation. Unfortunately, biogas includes also other gas compounds and thus biogas is usually purified from other gases and water before cleaner biomethane is obtained. Purification and upgrading of biogas to the purest possible methane is done if it is used as a transport fuel and thus provides a better energy density for the combustion process, otherwise, as in heat production, this is not necessary. (Chen et al, 2017, 65-66; Deng et al, 2020, 201)

2.1 Biogas and biomethane production

This chapter describes how biogas is produced and how biomethane can be produced from biogas, and a good example of this entire process is given in Figure 1. Figure 1 shows how nutrients are fed into the biogas reactor, where the gas produced is either refined into biomethane or produced directly into heat and electricity. In addition, the digestate from the biogas plant can be used as fertilizer.

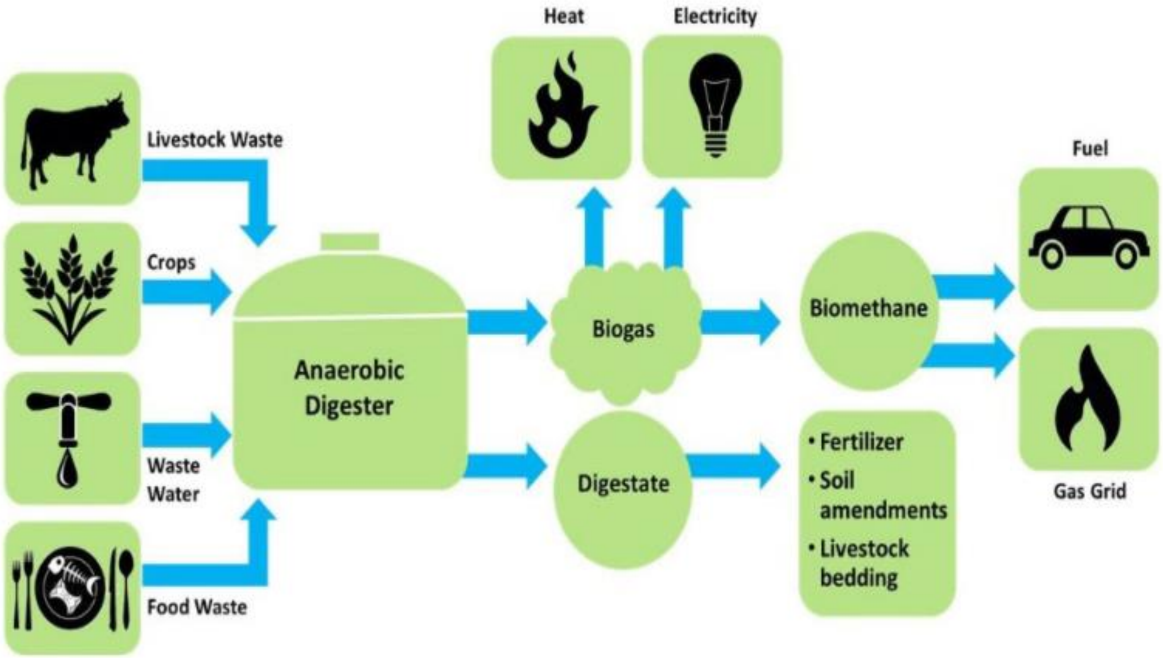

Figure 1. Biogas production and refining process. (Eesi 2017)

2.1.1 Biogas production

Anaerobic Digestion

Biogas production under anaerobic conditions usually takes place in a biogas reactor. In a biogas reactor, biogas production process can be implemented as either a mesophilic or a thermophilic process. Mesophilic biomass digestion takes place at 35-38 ° C and thermophilic digestion at about 50-55 ° C. In Finland, biogas plants have usually used a mesophilic process, as this is a more stable process and better able to withstand process disturbances. The mesophilic process uses less energy to operate because the process operates at a lower temperature and thus improves the energy efficiency of biogas plant. (Abbasi et.al 2012, 7; Aresta et al, 2012, 428; Deng et al, 2020, 22)

Biogas can be produced from biomass, either by a dry or wet process. In the dry process, the dry matter content is generally 20-50% and in the wet process, the dry matter content is only 5-15%. Traditionally, the wet process is used in Finland, as the wet process is easier to control and has the advantage of more secure automation. Other advantages of the wet process are its easy mixing mechanically and biomass transfer by pumps. However, due to its high liquid content, the disadvantage of the wet process is the lower gas production per reactor volume than in the dry process. The advantages of the dry process, on the other hand, are the higher gas production per reaction volume and the lower energy requirement for heating the feed. The disadvantages, on the other hand, are cumbersome mixing, it requires durability from structures and due to the high dry matter content, biomass cannot be transferred by pumps, but by belts and screw conveyors, for example. (Aresta et al, 2012, 423; Khoiyangbam et al, 2011, 19-37; Perkiö. 2020, 6-8)

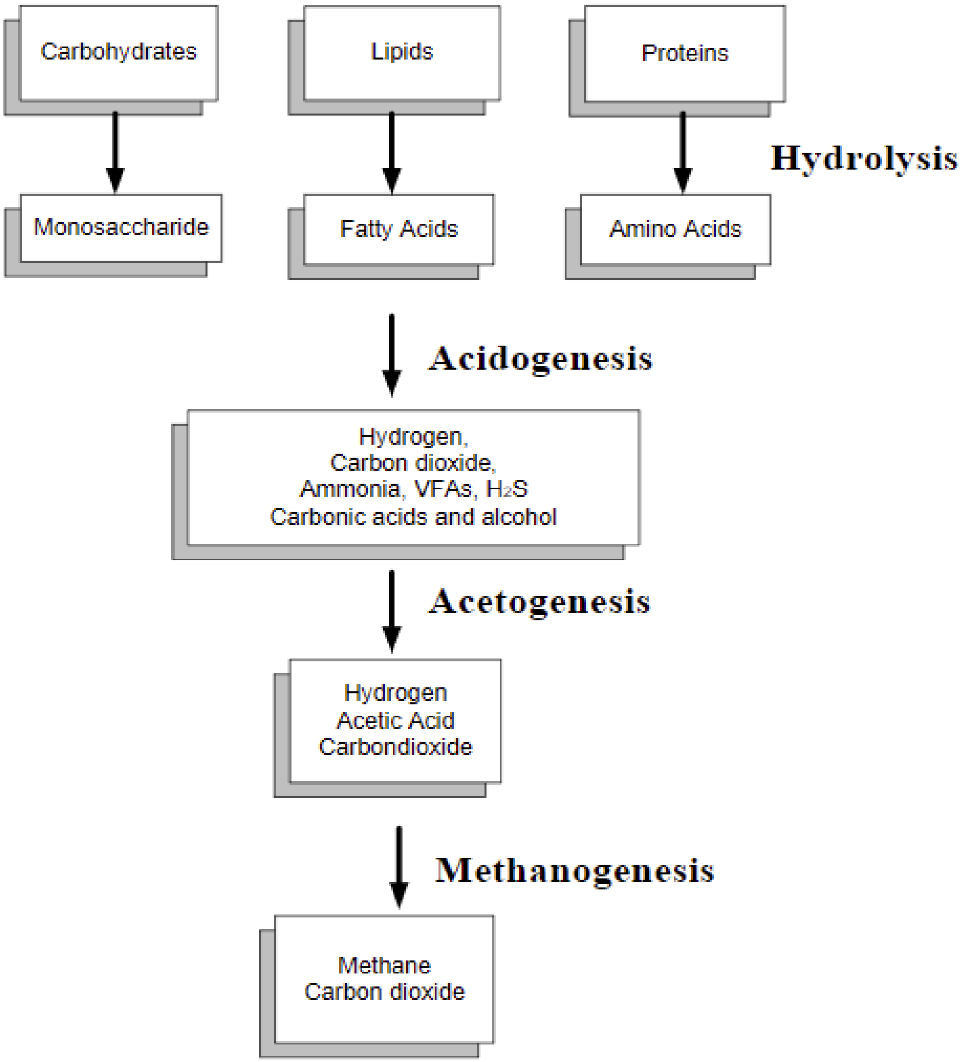

Figure 2. Biochemical process of biogas production (Litonjua et al, 2012, 53)

Biogas production in a reactor is a biochemical process in which biomass is broken down by bacteria to create biogas and this biochemical process has four stages, acidogenesis, acetogenesis, methanogenesis and hydrolysis as seen in figure 2. (Deng et al, 2020, 5-10; Khoiyangbam et al, 2011, 19-37)

The first step in biogas production in a reactor is hydrolysis. In the hydrolysis process, extracellular enzymes (cellulases, amylases, proteases, and lipases) are released to break down particulate and insoluble substrates into smaller substrate molecules. In this process, insoluble organic polymers (lipid, carbohydrate, and protein) are dissolved, after which the polymers can be biodegraded, and this process is the hydrolysis by bacteria. (Abbasi et.al 2012, 3; Deng et al, 2020, 5-10; Litonjua et al, 2012, 52-53)

The second step in the process is acidogenesis. In the process of acidogenesis, the hydrolysis products continue to decompose, resulting in the formation of volatile fatty acids such as ammonia, hydrogen sulfide, carbon dioxide and other by-products, and this is the first step in the process that produces energy. The third step is acetogenesis, which produces acetic acid, hydrogen, and carbon dioxide, with acetogenic bacteria converting organic acids. (Litonjua et al, 2012, 52-53; Deng et al, 2020, 5-10; Vico et al, 2017, 46-47)

The fourth and final step in the anaerobic degradation process is methanogenesis. In methanogenesis, two groups of methanogenic organisms produce methane. The first group, called aceticlastic methanogens, produce methane and carbon dioxide by decomposing acetate. Another group is hydrogen-utilizing methanogen, which in this process produces methane using hydrogen and carbon dioxide. (Litonjua et al, 2012, 52-53; Deng et al, 2020, 5-10)

Anaerobic digestion, in other words a biochemical process under low-oxygen conditions, occurs when organic biomass is broken down by microorganisms and the product of this natural biochemical process is biogas, and the remaining organic digestate, which can be used as a fertilizer, for example. (Litonjua et al, 2012, 50-53; Deng et al, 2020, 4-10)

2.1.2 Upgrading biogas to biomethane

This section discusses what contaminants in raw biogas usually are, how they affect equipment, what harm they do, whether they are dangerous to organisms, and what technologies are used to remove these contaminants. In order to get biomethane from biogas, biogas must be purified and upgraded by various processes and the remaining biomethane is ready for use either for fuel, heating, or other needs. Biogas should be cleaned and upgraded, as some contaminants can negatively affect gas use, such as corrosion and mechanical wear in equipment. (Tabatabaei & Ghanavati 2018, 239-248) Removal of contaminants is the primary process of biogas purification and upgrading, and these contaminants include carbon dioxide (CO2), water (H2O), hydrogen sulfide (H2S), oxygen (O2), nitrogen (N2), ammonia (NH3), volatile organic compounds and particles. (Litonjua et al, 2012, 91-93; Deng et al, 2020, 201-240; Krich et al, 2005, 47; Mwacharo et al, 2020, 19; Ryckebosch et al, 2011, 1633-1644)

Carbon dioxide

After methane, most of biogas is carbon dioxide in biogas production, carbon dioxide is formed through several different production processes where several different substrates are used. (Vico et al, 2017, XI) In the formation of methane, the electron acceptor of bacteria is carbon dioxide. In biogas, carbon dioxide reduces the energy production capacity of gas, as carbon dioxide reduces the proportion of methane in gas and usually gas is required to have a high energy content, as a result of which carbon dioxide must be removed from gas. If carbon dioxide is not removed from the gas, then it is possible that in converting gas to energy, carbon dioxide together with water forms carbonic acid which condenses in the energy production process and reduces the energy obtained from the gas and can cause corrosion in piping and equipment. (Litonjua et al, 2012, 94-102; Deng et al, 2020, 201, 230; Krich et al, 2005, 51-59; Mwacharo et al, 2020, 16, 18-20; Ryckebosch et al, 2011, 1633-1644)

Water and removal process

Biogas always contains water, because in anaerobic digestion water is always present and evaporates and merges with biogas produced and thus biogas leaving the reactor is always contaminated with water. The pressure and temperature in the reactor affect the proportion of water in biogas. The share of water in biogas creates many different problems. For example, the higher the proportion water in biogas, the lower the calorific value and the high proportion of water in biogas can increase fluid resistance in biogas pipelines. (Tabatabaei & Ghanavati 2018, 243-247) It is also possible that a large proportion of water in biogas creates an acidic compound with carbon dioxide and hydrogen sulfide and this acid can cause corrosion and blockages in metal piping, flow meters, compressors, gas tanks and engines. (Litonjua et al, 2012, 93; Deng et al, 2020, 201-212; Krich et al, 2005, 51; Mwacharo et al, 2020, 7, 17-18)

The physical and chemical methods used to remove water are usually adsorption, absorption, or condensation. In the condensation technique, water is condensed out of biogas by means of a temperature change. In the adsorption technique biogas passes through the solid absorbing surface and the water is thus separated from biogas. In the absorption technique, water is removed from biogas using a dewatering agent, in counter current contact with biogas. For example, calcium chloride and silica gel are such an absorbent. (Litonjua et al, 2012, 93; Deng et al, 2020, 208-212; Krich et al, 2005, 51; Mwacharo et al, 2020, 17-18)

Hydrogen sulfide and removal process

Hydrogen sulfide is also one of the common pollutants in biogas. The biomass and the digestion process affect how much hydrogen sulfide is in biogas. For example, the more protein-rich and sulfide substrate-containing biomass in the digestion process produces the higher hydrogen sulfide concentration in biogas. The use of biogas can lead to corrosion in compressors, gas tanks and engines if biogas contains hydrogen sulphide, as hydrogen sulphide forms sulphuric acid when oxidised in the presence of water. (Tabatabaei & Ghanavati 2018, 243-250) If hydrogen sulfide containing biogas is burned sulfur dioxide is emitted. When combined with other combustion products sulfur dioxide forms sulfurous acid which causes corrosion at low temperatures in equipments. Hydrogen sulfide is also highly toxic and can lead to significant health risks. (Litonjua et al, 2012, 102-106; Deng et al, 2020, 203, 212-228; Krich et al, 2005, 47-51; Mwacharo et al, 2020, 23)

Hydrogen sulfide must be separated from biogas and the technologies for separating hydrogen sulfide from biogas are in-situ microaeration, adsorption, absorption and biofiltration. The simplest way to remove hydrogen sulfide is In-situ microaeration, where oxygen, or air, is introduced directly into biogas reactor. The bacterium Thiobacillus, present in biogas reactor, uses oxygen to break down H2S to S. This technology is an effective way to remove hydrogen sulfide as up to 99% of the hydrogen sulfide is decomposed by this technique. Another technology for hydrogen sulfide removal is adsorption, in which a highly porous solid "sucks" hydrogen sulfide out of biogas, due to the bond formed by gas. A third technology for hydrogen sulfide removal is absorption, where biogas is in contact with water or solvent through packed columns and shower towers. In this context, H2S is absorbed into water, or converted to elemental sulfur, or metal sulfide. Biofiltration is the fourth technique by which hydrogen sulfide is removed from biogas by microorganisms. In the first stage, impurities are removed from gas stream to a liquid film, followed by adsorption. In the second stage, with the help of microorganisms in the liquid and solid phases, the impurities are biodegraded. (Litonjua et al, 2012, 102-106; Deng et al, 2020, 212-228; Krich et al, 2005, 47-51; Mwacharo et al, 2020, 23)

Oxygen and nitrogen and removal process

In biogas production under anaerobic conditions, oxygen and nitrogen are generally not present. But coincidentally, both can be found in the finished biogas if air enters the process. Facultative anaerobe slowly consumes oxygen if it is present in the process. But if nitrogen is present, then it can usually be a sign of air leakage in the process, or de-nitrification. Excessive oxygen can create a very flammable mixture in biogas with methane, so it is important to control the amount of oxygen. (Litonjua et al, 2012, 101; Deng et al, 2020, 203, 229-230; Krich et al, 2005, 57-58; Mwacharo et al, 2020, 16, 25)

Activated carbon, or membrane, can be used to remove oxygen and nitrogen from biogas. It is important to include this process, because although the amount of oxygen and hydrogen decreases with the hydrogen sulfide removal process, oxygen and nitrogen are not completely lost from biogas. Although the removal of oxygen and nitrogen from biogas is difficult and expensive removal of these is needed to obtain enough pure biomethane from biogas so that it can be used as fuel. It is therefore advisable to prevent oxygen and nitrogen from entering biogas rather than removing them. (Litonjua et al, 2012, 101; Deng et al, 2020, 229-230; Krich et al, 2005, 57-58; Mwacharo et al, 2020, 16, 25)

Volatile organic compounds and removal process

Volatile organic compounds in biogas are mainly alkanes, siloxanes and halogenated hydrocarbons. The substrate used in biogas production, affects what type and how high concentrations of these compounds are in biogas. Siloxanes are usually found in biogas if the biomass from which biogas is produced contains siloxanes because some of these compounds evaporate. Siloxanes cause corrosion and damage to engines when burned, as the quartz and silica resulting from combustion accumulate in valves, cylinders, and spark plugs.

Halogenated hydrocarbons are hydrocarbon molecules that contain chlorine, bromine, or fluorine. These halogenated hydrocarbons, when burned, can cause corrosion and acidification and destroy the engines and metal parts. The removal of ammonia, siloxanes and benzene gases usually takes place already during the removal of nitrogen sulphide and water. (Litonjua et al, 2012 106-109; Deng et al, 2020, 230-240; Mwacharo et al, 2020, 22)

Ammonia and particles and removal process

Ammonia is usually found in biogas and ammonia is classified an impurity. Ammonia is formed in a hydrolysis process that contains proteins. Large amounts of ammonia in a biogas reactor can prevent methane formation. The removal of ammonia, siloxanes and benzene gases usually takes place already during the removal of nitrogen sulphide and water. (Litonjua et al, 2012, 109-111; Deng et al, 2020, 230-240; Mwacharo et al, 2020, 8-12)

There are almost always particles in biogas. Water droplets often condense into clumps formed by these particles and particulate matter accumulates in the compressor and gas tanks, causing blockages and eventually the particles can cause wear to the parts, due to the abrasive properties of these particles. The removal of particles takes place in connection with the removal of water from the biogas. (Litonjua et al, 2012, 109-111; Deng et al, 2020, 230-240; Mwacharo et al, 2020, 8-12; Ryckebosch et al, 2011, 1633-1644)

Biogas upgrade process

The main purpose of biogas upgrading process is to remove carbon dioxide from biogas and thus to increase the proportion of methane in the final product with good calorific value. However, before biogas upgrade process, biogas must be cleaned, as explained above. Biogas upgrading process can be implemented with six different techniques. These six different techniques are, pressure swing adsorption, water washing, organic solvent physical absorption, organic solvent chemical absorption, high pressure membrane separation, and low temperature upgrading. (Litonjua et al, 2012, 91-94; Deng et al, 2020, 230-240; Krich et al, 2005, 47-48; Mwacharo et al, 2020, 19-21)

2.2 The equipment of the gas filling station

The equipment of a gas filling station typically consists of a gas dispenser, high-pressure gas storage, a gas compressor, a control system, and the necessary protective buildings, devices, and canopies. The purpose of the equipment is to pressurize the gas to the required pressure, store the gas in high-pressure storage, and the gas dispenser measures the amount of gas and distributes it to the vehicle, the safety devices and shelters aim to prevent accidents at the filling station, and the canopies protect the equipment and refuelers from weather conditions. (Turvallisuus ja kemikaalivirasto et. al. 2021a)

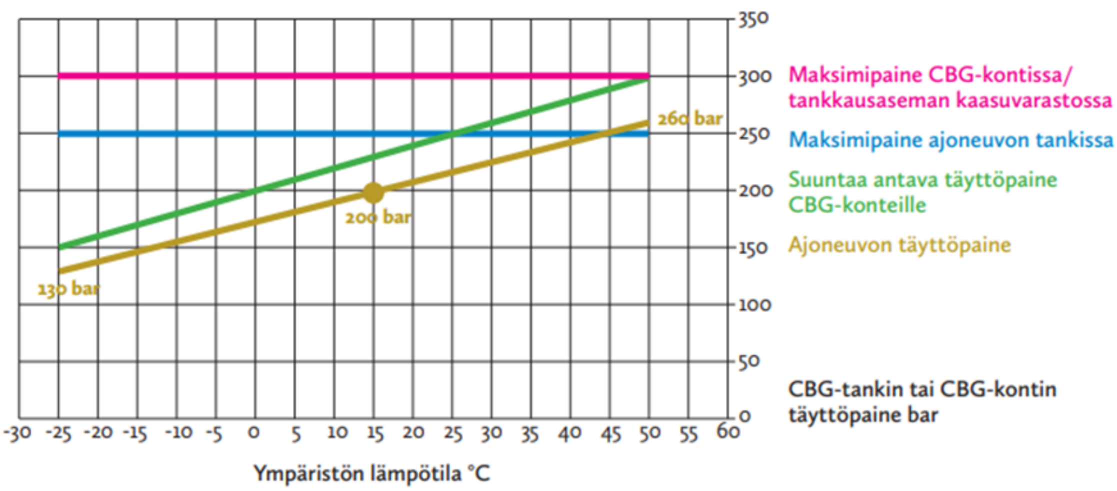

Figure 3. Table of gas pressure requirements per temperature. (Turvallisuus ja kemikaalivirasto et. al. 2021a)

2.2.1 Gas compressor

Once biogas has been purified and upgraded to biomethane, the next step is biomethane pressurization because pressurizing biomethane to, for example, 200 bars improves the energy density in the volume, and because there is more gas in a given volume, more gas can be transported in pressure vessels and it enables higher biomethane amount storing in to a tank of vehicle and the vehicle can travel a longer distance than if biogas is not pressurized but refuelled at normal atmospheric pressure. Normally, the pressure of the biomethane is determined by the pressure requirements of the piping, but this work involves filling station systems and, in this case, the biomethane should be pressurized to the pressure required by the vehicle or storage. It must be borne in mind that the higher the pressure at which biomethane is pressurized, the more energy it consumes and the more economically unprofitable it is. As shown in Figure X, the filling pressure of the vehicle according to Finnish legislation must be between 130 and 260 bar, where 250 bar is the maximum pressure. In addition, the figure 3 shows the pressure for pressurized biomethane CNG containers. The biomethane should be pressurized for vehicles to a pressure of about 200 bar and the container to a pressure of about 250 bar as seen in figure 3 and it is important to consider the effect of temperature on pressure. It is important to pressurize biomethane to high pressure, as this will provide as much fuel as possible for the vehicle filling it. (Mwacharo et al, 2020, 33-34; Krich et al, 2005, 74-75)

It is important that the biomethane is pressurized with an oil and dust free compressor so that biogas to be pressurized is not contaminated. When choosing a compressor, it should be taken into account what is required of the compressor. The flow rate, ATEX-zone, climate temperature and the required pressure are important factors in deciding the compressor. (Mwacharo et al, 2020, 33-34; Krich et al, 2005,74-75)

2.2.2 High-pressure gas storage

Biogas and biomethane can both be stored. Gas buffer storages, i.e., high-pressure storages, are useful, for example, when the power of the gas compressor is too low for quick refueling, in which case the already pressurized high-pressure storages can quickly fill the desired device. If, on the other hand, the flow of biomethane in cubic meters per hour to the compressor is high and the gas compressor is efficient enough to transfer pressurized gas to the vehicle quickly, then a high-pressure storage is not necessarily needed. Biomethane in this case will be refuelled in high pressure depots, where many vehicles can be refuelled at high pressure, and while pressure drops in the high-pressure depot, the compressors will tend to pressurize new biomethane in addition. In this case, biomethane will be stored in high-pressure storage facilities. In high-pressure storage, gas can be stored at high pressure, thus saving space. High pressure stocks should be equipped with pressure valves that release excessive pressure if needed. Biomethane is important to be stored in high-pressure storages because the energy value per volume of biomethane at atmospheric pressure is low, and thus much more energy is obtained in a small space when biomethane is pressurized to high pressure. (Mwacharo et al, 2020, 33-34; Krich et al, 2005, 74-75)

2.2.3 Gas dispenser

Once the biomethane has been pressurized and stored in a high-pressure warehouse, the next step is to refuel a vehicle, or a larger tank. Care must be taken when filling gas, as a poor connection can lead to gas leakage into the air. Filling with biomethane works in such a way that the filling hose should be installed tightly at the site to be refuelled and locked airtight, as there is usually a high pressure in both the vehicle and the high-pressure storage, pipes, or compressor and this connection must be secure. (Krich et al, 2005, 6-7, 63, 73-75)

2.3 Authorities, specialists, laws, and standards

This chapter explains the importance of authorities, experts, laws, and standards, and what these mean in practice. In particular, the emphasis is on presenting to those concerned what these different bodies, laws and standards mean and mean in practice.

2.3.1 Authorities

In figure 4, the authorities are shown and what role do the authorities have in the process of building a gas filling station and in relation to the acquisition, inspections, and placement of equipment.

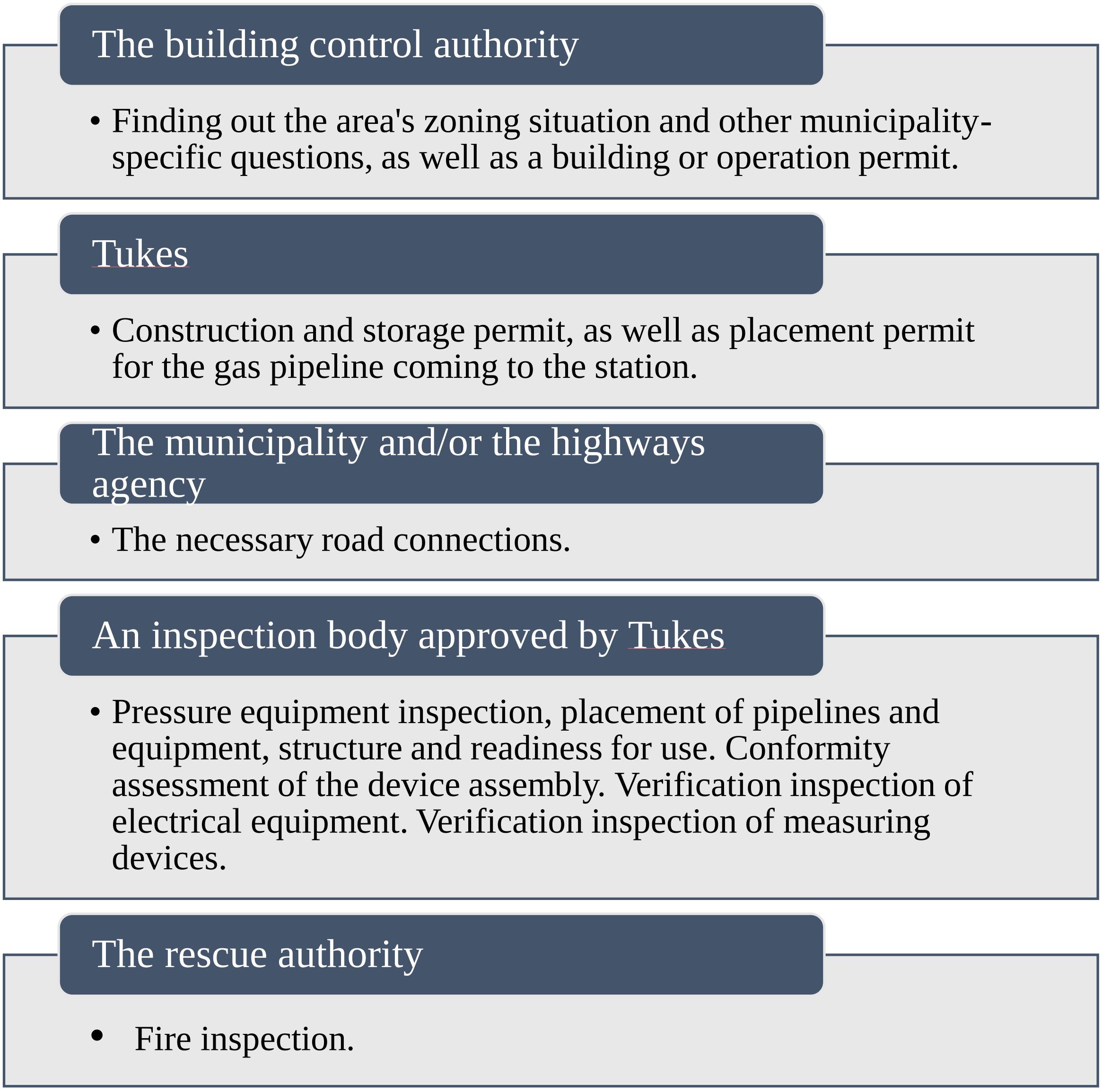

Figure 4. The authorities of the gas filling station authority process.

Safety and chemicals agency (Tukes)

The Finnish Safety and Chemicals Agency (Tukes) is a licensing and control authority that promotes the safety and reliability of products, services, and industrial activities.

Supervision of Tukes covers accidents up to major accidents. Tukes monitors products, services and production systems of the industries and enforces related legislation. The purpose of the activity is to protect people, property and the environment from risks and accidents. (Turvallisuus- ja kemikaalivirasto 2021a)

The Tukes organization consists of five units, chemical unit, industrial unit, product unit, Finnish accreditation service (FINAS) accreditation service, information, and development unit. The number of permanent staff is about 250. The Agency's offices are located in Helsinki, Tampere and Rovaniemi. (Turvallisuus- ja kemikaalivirasto 2021a)

Tukes operates under the direction of several ministries. The Ministry of Employment and the Economy (MEE) is responsible for the administrative guidance and supervision of Tukes. In addition, MEE and Ministry of transport and communications (LVM), Ministry of agriculture and forestry of Finland (MMM), Minister of the Interior (SM), Ministry of social affairs and health (STM) and Ministry of the Environment (YM) co-direct the agency in their respective fields. (Turvallisuus- ja kemikaalivirasto 2021a)

The chemical unit handles for example, enforcement tasks and controls related to chemical product control, EU REACH and The Classification, Labelling and Packaging Regulation (CLP), and biocides legislation, as well as tasks related to risk assessment, authorization, and registration of plant protection products. (Turvallisuus- ja kemikaalivirasto 2021a)

The industrial unit monitors the safety of production facilities and equipment, mining, contracting and installation activities, and inspection services. Control sites include industrial plants handling hazardous chemicals, liquefied natural gas sites, explosives plants and storage facilities, pressure equipment and production facilities using them, mines, mineral exploration, and gold leaching sites. The installation, operation and inspection of distribution networks and building electrical equipment, as well as elevator contracting and maintenance, are also our control targets. (Turvallisuus- ja kemikaalivirasto 2021a)

The product unit monitors the safety and technical reliability of the products on sale. The subjects of product control are for example, electrical equipment, consumer products such as toys, machinery and personal protective equipment, construction products, explosives and fireworks, packaging, and containers for the transport of dangerous goods, and rescue equipment. The FINAS accreditation service is Finland's national accreditation body, which certifies calibration and testing laboratories, certification bodies, inspection bodies, organizers of benchmarking, and emissions trading and Eco-Management and Audit Scheme (EMAS) verifiers. The information and development unit performs the Agency's administrative service tasks, participates in the development of regulations and operating models and information systems in the field, and provides information services. (Turvallisuus- ja kemikaalivirasto 2021a)

Building control authority

Land use and construction decree §4 divides the tasks of the building control authority into three sections: To supervise compliance with the zoning, to handle permits for construction and other measures, and to supervise the maintenance and management of the built environment and buildings (so-called continuous supervision). In addition to these, in accordance with §124 of the land use and construction decree, the task of the building inspectorate is to supervise construction activities in the public interest and to contribute to ensuring that construction complies with the provisions or regulations of land use and construction decree. The main objectives of the legislation are e.g., promoting a healthy, safe, and comfortable living environment (§12 of the land use and construction decree). In addition, the building control authority is also responsible for providing the general construction guidance and advice required by the municipality (§124 of the land use and construction decree). (Pöyry. 2019)

The task of the building control authority is to supervise and to direct construction, that is, to ensure that design and construction take place land use and building act and regulation (MRL, MRA) and issued under it in accordance with the rules and regulations (including building regulations) and the current zoning. (Pöyry. 2019)

Building control authority gives instructions and advice to builders, deals with construction and permits required to change the landscape, carry out inspections related to permits, responsible control of the built environment and manage the construction archive and information service. (Pöyry. 2019)

Through advice, guidance, licensing and inspection activities, and ongoing supervision aiming at high quality, healthy, safe, sustainable development, an energy - efficient building stock that is well suited to its environment; and built environment. (Pöyry. 2019)

Rescue authority

The state rescue authority is the ministry responsible for the rescue operation and the county governments. The municipal rescue authorities are the fire chief, and the rescue officers appointed by the municipality for these tasks, as well as the relevant multi-member institution of the municipality.

The rescue service takes care for example of following tasks: guidance, education and advice for rescue and preparedness for fires and other accidents, and for appropriate action in the event of accidents and incidents and for limiting the consequences of accidents, rescue control tasks warning the population in the event of danger and an accident and the necessary alarm system rescue missions. They have also other tasks such as: perform tasks belonging to the emergency care service if the organization of the emergency care service in co-operation between the rescue service of the area and the association of municipalities of the hospital district has been agreed on the basis of section 39 (2) of the Health Care Act (1326/2010), supports contingency planning for a municipality in a rescue area, if agreed with the municipality, takes care of oil spill response and other tasks provided for in the law for rescue operations in the area. (Pelastustoimilaki. 1999)

2.3.2 Specialists

Approved inspection bodies and installers

The final inspections of gas filling station are mainly carried out by inspection bodies approved by Tukes. There are inspection bodies in many different industries, and detailed list can be found on Tukes’s website. Inspection bodies are approved using several different criteria, which are:

- Legal entity registered in Finland
- Professional staff
- Tools, equipment, and systems required for the operation
- A system for storing and maintaining inspection certificates
- Functional and financial independence and impartiality

- Liability insurance according to the scope of activities and liabilities
-

The principles of good governance are required of these inspection bodies. These principles are:

- Principle of equality: customers must be treated equally and consistently
- Principle of purpose: Inspections must be based on legislation and must not be abused
- Principle of objectivity: inspections must be carried out impartially
- Proportionality principle: inspections must be carried out in a proportionate and reasonable manner
- Principle of protection of trust: customers must be able to rely on the permanence of audit interpretations

Tukes also supervises inspection bodies on a regular basis, and inspection bodies send annual activity reports on inspection tasks to Tukes. (Turvallisuus- ja kemikaalivirasto 2021b)

Installations of gas pipelines and equipment must only be carried out by Tukes-approved installation companies. The criteria Tukes considers to be sufficient professional personnel, sufficient equipment, tools, and systems required for the work. A list of approved installers can be found on the Tukes website. (Turvallisuus- ja kemikaalivirasto 2021b)

Sauter Biogas

Sauter-Biogas provides customers with biogas plants, from the design and construction phase to maintenance and upkeep to inspections. The Sauter-biogas biogas plant differs from normal biogas plants due to their patented irrigation system and thus there is no separate mixer in the reactor and the reactor sludge is maintained by a liquid circulation system. The company has delivered more than 80 biogas plants to several different countries, for example Germany, Belgium, Denmark and Finland. The company operating in Finland has a license agreement for the use of Sauter-Biogas GmBH's products and know-how in Scandinavia and the Baltic countries. Sauter-Biogas Finland Ky was founded in 2020 and the company is to conduct business throughout Scandinavia and the Baltic countries. Sauter-Biogas Finland

Ky supplies biogas plants and filling stations to private customers such as farmers and companies. The biogas plants that are delivered are very similar to each other, but for example the size is one important thing that can be modified, and it is also possible to make the biogas plant meet the customer's wishes by other means. For example, the areas of use, the amount and quality of the feed to the biogas plant may vary a lot, so for each customer the plant is designed to suit the needs. (Sauter Biogas GmbH 2021)

Sauter-Biogas Finland Ky also enables electricity and heat production, and biogas can also be refined into biomethane, making it suitable for fuel use. Sauter-biogas' biogas plants are very well suited to the processing of various feedstocks, and almost any bio-derived material is suitable as a feedstock, if enough methane is produced. Feeds include, for example, manure, straw, hay and biowaste from tofu production. As a result of the wet digestion process, biogas is produced in the reactor and the process begins by pumping the available feed into the reactor with a syringe, whereby the pressure breaks the surface of the feedstock, and the plant remains operational. The generated gas is used to produce electricity and heat with the help of CHP, but before this the biogas is cleaned into biomethane. The heat is mainly used for heating the reactor and for the customer's own needs, but excess electricity can be sold to electricity companies. Figure 5 depicts the operating principle of the biogas plant and gas processing in a general way. (Sauter Biogas GmbH 2021)

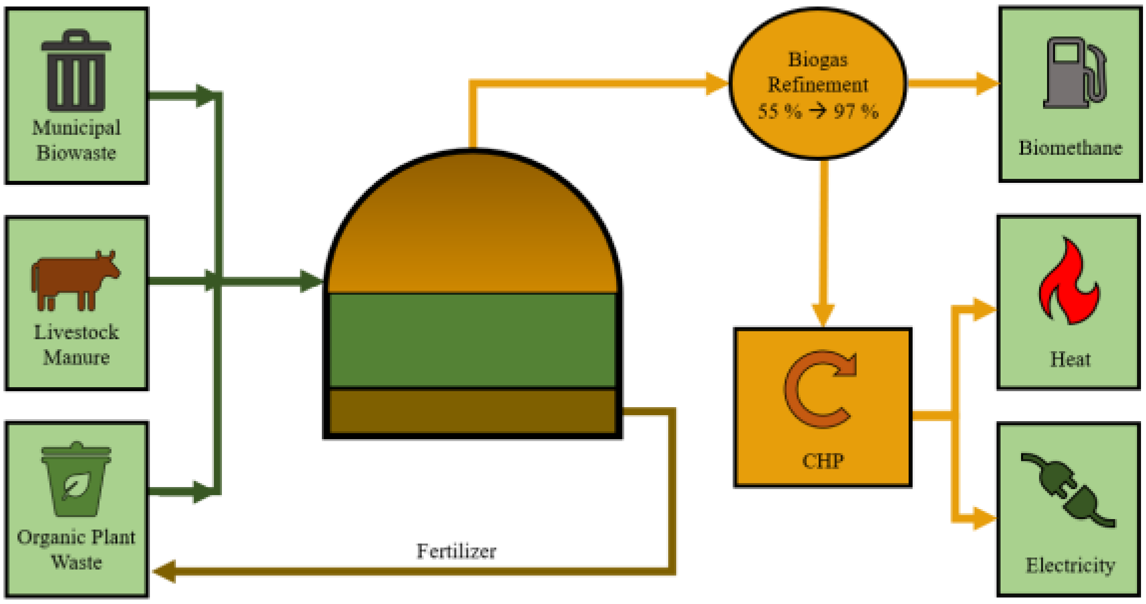

Figure 5. Sauter-Biogas sludge cycle. (Sauter Biogas GmbH 2021)

2.3.3 Legislation and standards

Legislation

Legislation means existing laws and regulations and, in a broad sense, all applicable law. Legislation can also mean activities related to the enactment of laws. A legal norm is a principle or rule of law that relates to the activities of individuals and legal persons. A legal norm means both the legal source containing the rule, such as a section of the law or a court decision, and the interpreted meaning of the legal source. Legal norms regulate the relations between legal entities in society by telling, allowing or denying to do something. The legal order is an entity formed by the legal norms in force. (Eduskunta 2021)

An act refers to a body of text containing a legal aid. Domestic regulations include, for example, laws, decrees of the President of the Republic and the Council of State, regulations of the authorities and the provincial laws of Åland. The most important legal acts are published in the Finnish Collection of Acts. Lower-level regulations are published in the collections of regulations of ministries and authorities. In addition to domestic regulations, the legislation in force in Finland includes the legislation of the European Union and the international agreements and obligations to which Finland is a state. (Eduskunta 2021)

Standards

Standards are publications that record commonly agreed requirements, recommendations, or even features for products and their manufacture or testing, as well as systems or services. Without these common agreements, our daily lives would not be so smooth and secure at all. A standard is a document presenting solutions to recurring problems, based on the agreement of the parties involved and approved for this task by a recognized body. A standard is a written publication that defines, for example, the features and requirements of products and services or the operation of systems. Standardization is the development of good practices, solutions, and requirements for common practices. (SFS 2021)

SFS is a symbol that the standard has been confirmed in Finland. If, for example, it was a standard established in Germany, SFS would be replaced by DIN and Sweden by SS. The EN marking of the symbol indicates that the standard has been established as a European standard. ISO marking means that it is also a globally validated standard. (SFS 2021)

The use of standards is voluntary. However, it is possible that the authorities find the use of some standards so useful that it is recommended. Organizations may require the use of standards, for example, in tendering or subcontracting operations. The use of standards is often justified by their benefits. Standards make everyday life easier and smoother. They improve compatibility and security, reducing surprises and risks. Standards are widely used by a wide range of industries and actors, both companies and public authorities. (SFS 2021)

Product requirements

The CE mark is a mark by which a manufacturer of a product or his authorized representative declares that the product meets the essential requirements of the relevant EU directives and regulations. A product bearing the CE mark is allowed to move freely within the EU. The marking shall be affixed by the manufacturer or his authorized representative. The CE marking is not issued by any authority or other third party. (Turvallisuus- ja kemikaalivirasto 2021c)

The CE marking may only be affixed to products for which the CE marking is required by product legislation. If the CE marking is misused, product control authorities can intervene. If a product does not bear the CE marking required by law or the marking is non-compliant, the product may be ordered to be withdrawn from the market. Misuse of the CE marking can also be penalized. (Turvallisuus- ja kemikaalivirasto 2021c)

However, it is important to know that the CE marking is not a general safety mark that guarantees that the product is of a particularly high quality or easy to use to distinguish the superiority of the products. In some specific cases, it is important and required that the product have a conformity assessment approved by a particular facility. It is up to the manufacturer to take care of this. The assessment may concern, for example, the product and its characteristics, their production process and quality assurance. Only after the assessment has been approved can the manufacturer draw up a declaration of conformity or, in the case of certain product groups, a declaration of performance and affix the CE marking to the product. The CE markings in Finland are mainly monitored by Tukes, but they are also monitored by, for example, Traficom and Fimea. (Turvallisuus- ja kemikaalivirasto 2021c)

3 Methods of literature review and interviews

The work is a qualitative study, but it also partly uses quantitative research, which uses material-based research and analysis. The work uses qualitative content analysis, which aims to form a concise description of the study issue. Content analysis is typically used to analyse texts. In this thesis, content analysis aims to create a comprehensive picture of the official process of the gas filling station, equipment requirements and other necessary information related to the commissioning of the gas filling station from the perspective of the authorities and the law.

The work uses qualitative content analysis, which aims to form a concise description of the study issue. Content analysis is typically used to analyse texts. In this master's thesis, content analysis aims to create a comprehensive picture of the official process of the gas filling station, equipment requirements and other necessary information related to the commissioning of the gas filling station from the perspective of the authorities and the law.

In the theory part, information found on the internet is analysed and familiarized with it. Especially in the theory section, many studies are compared with each other, and by combining these, a very reliable theory base is obtained. Some of the information in the theory part is information from public sources, but some is from different studies that are not freely accessible. In the master's thesis, the laws related to Finnish natural gas have been particularly utilized, because firstly, the same laws are used for natural gas and biomethane, and secondly, the structure of the permit process and equipment requirements are created from these laws, along with TUKES' instructions. Regarding the equipment requirements, the information was very decentralized and the creation of a set of equipment requirements required the interpretation of many different laws and instructions. The information for the first part of the master's thesis, which deals with the gas filling station permit process, was all obtained from available public sources, as the information here is all about laws, regulations, requirements and TUKES guidelines.

The information regarding the second part of the master's thesis, i.e. interviews and comparison of the gas equipment laws and requirements of Finland and European countries, was mainly obtained from non-public sources, because, for example, German equipment requirements and space classifications are not publicly available, unlike in Finland. As mentioned above, in this master's thesis, interviews have been used in data collection and thus decentralized information has been made available centrally. Various studies, laws, reports, standards and guidelines are used as sources. These sources are collected mainly from TUKES websites, LUT Primo, Finnish government websites and other internet sites, both international and Finnish.

The interviews were conducted both face-to-face and in Microsoft teams. The interviews were held between the end of 2021 and the spring of 2022. The interview questions were open, so, the interviewees could answer them in their own words. The interview questions had been sent to the interviewees in advance, giving them the opportunity to prepare for the interview. The answers of the interviewees were compared to the legislation, regulations, standards, and requirements related to the gas filling station. The interview questions were mostly related to gas filling station requirements and legislation.

4 Results

In this chapter, the results of the legal and technical requirements of the gas filling station are presented, and in addition, the technical and legal requirements of Finland and other European countries are examined and compared. The focus of the results is on Finland's technical and legal requirements, as well as the means by which the results have been compiled.

4.1 Gas filling station technical requirements and recommendations

In this paragraph, we explain the technical requirements of the gas filling station in terms of equipment, structures, location instructions for the construction site, and recommendations.

4.1.1 Pipeline of a gas filling station

All pipelines of the filling station must be made of suitable material, The pipelines are designed for specific uses, temperatures, pressures, and material requirements, which must be followed. The pipelines of the gas compressor units are implemented with steel pipes, other pipelines are considered on a case-by-case basis. The compressed gas pipeline is usually placed underground or in a concrete channel, but this is also case-specific and can be evaluated on a case-by-case basis with the authorities. Stainless steel pipes are usually placed inside the protective pipe to prevent corrosion, and the pipe locations are marked with marking tape and the locations are noted in the documents. Pipelines can be located above ground if the space is restricted from outsiders. Exact instructions for installing the gas pipe on the ground can be found in the instructions made by the gas association. (Painelaitelaki 16.12, Painelaite asetus 29.12, Painelaiteturvallisuus asetus29.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

The refueling station must have safety valves and blow-outs so that, for example, in the event of a blockage in the pipeline, the pressure can be directed safely out of the safety valve. Usually, the blow-out exhaust pipe is located high above the filling station, away from the filling point. The gas filling station must have a main shut-off valve, which isolates the station from the gas source as follows: In the distribution pipeline, in the biomethane pipeline or 10 meters before the compressor room. In addition, shut-off valves must be installed between the units (high-pressure storage, compressor, distribution meter, etc.), which can be used to isolate the units from each other. (Painelaitelaki 16.12, Painelaite asetus 29.12, Painelaiteturvallisuus asetus29.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

4.1.2 High-pressure storage, compressors, and transfer containers

Permanently installed high-pressure storage tanks must be manufactured in accordance with the Pressure Equipment Directive 2014/68/EU and must be CE-marked. The high-pressure storage can be placed either in the same building as the compressor units, or in a separate space, or outside. However, compressors and high-pressure storages should be in their own premises for safety reasons. The outdoor storage must be covered and isolated with a protective fence or wall, so that outsiders cannot come into contact with the high-pressure storage and cause danger. The maximum operating pressure of the gas filling station's high-pressure storage is 300 bar. (Painelaitelaki 16.12, Painelaite asetus 29.12, Painelaiteturvallisuus asetus29.12, Vaatimustenmukaisuus asetus räjähdysvaarallisten tilojen laitteista 21.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

According to the current law, gas compressors are always required to have an ATEX equipment class 1 certificate, as this is not a condition-dependent explosive classification. The compressor is also required to have CE markings, and the operator of the station must be trained to use the compressor and the periodic maintenance and inspections must be known. The equipment must be tight without gas leaks and work in Finnish conditions. (Asetus räjähdysvaarallisten tilojen laitteista21.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

The gas filling station can also be used to refuel a gas transporter. A transfer container is a mobile multi-tank container consisting of gas bottles or gas tanks for transporting and/or storing pressurized gas at high pressure. There can only be three container spaces next to each other, if there are more at the station, there must be a protective wall between them for safety. (Turvallisuus ja kemikaalivirasto et. al. 2021a)

4.1.3 Gas dispenser

The compressed gas distribution meter should be located on the platform, as this can reduce the risk of the car hitting the meter. The temperature of the distribution meter must be suitable for Finnish conditions, i.e. it must withstand -40 celsius frost. The hoses must be designed for the purpose of use and withstand high pressure and installed with a hose break valve. The pipeline between the high-pressure storage and the distribution meter must be isolated with a shut-off device so that in the event of a leak, the gas from the high-pressure storage does not escape freely. The distribution meter must be equipped with a temperature-compensated filling system, or alternatively the temperature compensation can be located in connection with the compressor. Temperature compensation is a safety mechanism that keeps the pressure constant regardless of the temperature, for example, according to figure 3, the goal is that the gas has 200 bar at a temperature of 15 degrees Celsius, so in this case the pressure can only be 130 bars at -25 degrees Celsius. The refuelling connector must be type NVG1 or NVG2. The inspection body performs the meter's tare and inspection before putting it into use. Periodic inspection is performed every 2 years. (Painelaitelaki 16.12, Painelaite asetus 29.12, Painelaiteturvallisuus asetus29.12, Mittauslaitedirektiivi 26.02, Turvallisuus ja kemikaalivirasto et. al. 2021a)

4.1.4 Safety systems and other safety issues

The purpose of security systems is to protect users, personnel and everyone who moves in the area. The operating idea of the security systems is based on the government's aim to unload the gas away from people, if possible. The systems also aim to prevent the build-up of excessive pressure and prevent vehicles from being filled with too much pressure. (Kemikaaliturvallisuuslaki 21.05, Maakaasuturvallisuuslaki 09.07, Asetus räjähdysvaarallisten tilojen laitteista 21.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

Monitoring and an emergency stop system must be installed at the station, which informs the personnel of malfunctions and leaks. The purpose of the emergency stop system is to stop the entire equipment in the event of an emergency, thus minimizing the risk of a possible accident. The system must work in such a way that the filling station cannot be restarted without personnel checking the situation on site. The monitoring system is usually a gas detector system that detects the percentage of the desired gas concentration in the air and, based on the desired percentages, sounds an alarm and stops the entire filling station, this should also be automatically sent to the phone, for example, to the operator on duty. Gas detectors should be placed so that possible leakage points according to the risk assessment are within the detector's range. For example, compressor room and high-pressure storage room. (Kemikaaliturvallisuuslaki 21.05, Maakaasuturvallisuuslaki 09.07, Asetus räjähdys-vaarallisten tilojen laitteista21.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

The building supplies and materials used in the buildings and canopies of the gas filling station must comply with fire classification A1 or A2-s1, d0 class. It must also not be possible for gas to accumulate in the structures, i.e. wool, for example, is an excluded option. Crash protection must be installed at the station always in front of the distribution meter, and other locations are checked on a case-by-case basis. The gas station must be grounded, and all the main components must be included here. Potential equalization must be at least $16mm^2$ copper conductor. In case of lightning, the equipment and structures will have lightning protection for the main grounding. (Kemikaaliturvallisuuslaki 21.05, Maakaasu-turvallisuuslaki 09.07, Turvallisuus ja kemikaalivirasto et. al. 2021a)

The gas filling station must be equipped with compliant emergency stop buttons. The buttons should be marked so that they can be easily located in the event of an emergency. The following items must have an emergency stop button, a distribution meter, a compressor room, an equipment room, a gas storage room, an electrical room, and a transfer container filling point. It is recommended that the locations be confirmed with the authorities as they may have more experience in the optimal placement of emergency stop buttons. (Kemikaaliturvallisuuslaki 21.05, Maakaasuturvallisuuslaki 09.07, Asetus räjähdysvaarallisten tilojen laitteista21.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

The gas filling station must have a fire extinguisher according to the type of station. Frost-resistant fire extinguishers suitable for gas fires with a size of at least 12 kg are placed near the compressor of the distribution meter, the bottle storage, and other necessary spaces. The fire extinguisher in the electrical room must be at least a 5 kg carbon dioxide fire extinguisher. The electrical centre of the gas filling station must be located in its own space and separated from other equipment by a gas-tight wall in order to minimize the risk of explosion. (Kemikaaliturvallisuuslaki 21.05; (Maakaasuturvallisuuslaki 09.07, Turvallisuus ja kemikaalivirasto et. al. 2021a)

An explosion protection document must be drawn up for the gas filling station. The document assesses the object's risks and the explosion hazard assessment, and based on these, the necessary security measures can be added. The document also evaluates the space classifications of potentially explosive atmospheres, and equipment can be purchased based on these. The equipment must therefore correspond to the given explosive atmosphere classification, i.e. the ATEX classification. The gas filling station must operate at the following temperatures, i.e. the equipment must be proven to work at these temperatures. The temperatures are +40Celsius / -40Celsius outside and +40Celsius / -10Celsius inside the heated space. (Kemikaaliturvallisuuslaki 21.05, Maakaasuturvallisuuslaki 09.07, Turvallisuus ja kemikaalivirasto et. al. 2021a)

The gas quality requirements are based on SFS-EN-167232-2 Use of natural gas and biomethane in transport and supply of biomethane to the natural gas network. Part 2: Quality requirements for vehicle fuels. It should be noted that the dew point requirement of this standard has not yet been decided for Finland at the time of publication of this master's thesis, so the dew point follows the old requirement, which is -9 celsius at a pressure of 200 bar. The gas is also required to be odorized in accordance with the natural gas regulation, as a possible gas leak to which the detector does not react is noticed. To ensure a sufficiently low dew point, regular measurements of the gas are recommended. (Turvallisuus ja kemikaalivirasto et. al. 2021a)

The station must have instructions for refueling gas vehicles and signs and other signs. The distribution meter must be equipped with the following warning signs and instructions. Smoking/open fire prohibited, stop the engine, Ex marking, CNG marking, emergency operation instructions, piping diagram and station connection. (Kemikaaliturvallisuuslaki 21.05) (Maakaasuturvallisuuslaki 09.07, Turvallisuus ja kemikaalivirasto et. al. 2021a)

4.1.5 Inspections and maintenance during use

The following periodic inspections must be carried out at specified intervals at the gas filling station. Pipelines, equipment and objects in accordance with the Natural Gas Ordinance every 8 years (approved inspection body), periodical inspection of electrical equipment every 10 years (authorized inspector/inspection body), periodical verifications of measuring equipment every 2 years (measuring equipment statutory inspection bodies), functional inspection of safety devices regularly, at least every 4 years (operator , an approved inspection body is required for inspections of registrable pressure equipment and natural gas). In addition, the person responsible for the use and maintenance of the gas filling station must perform inspections according to the written service and maintenance program. (Turvallisuus ja kemikaalivirasto et. al. 2021a)

A designated person and trained staff are responsible for the maintenance, use, safety, and quality of gas sold at the gas filling station. The filling station must have an operator and a deputy. The owner of the station must ensure the adequacy and competence of the staff. The gas filling station must have complete and up-to-date operating and maintenance instructions. Any changes to the station must be updated in the operating and maintenance instructions. The station must have a written maintenance and maintenance program with maintenance and maintenance instructions for all equipment and components, who performs them and when, as well as inspection intervals and inspection actions. It is more than recommended that the rescue service be familiarized with the gas filling station and equipment. (Turvallisuus ja kemikaalivirasto et. al. 2021a)

4.2 Biomethane filling station authority and commissioning process

The outline of the gas filling station's official permit process and its dependent laws is described in figure 6. Figure 6 does not go through more detailed issues, but the purpose of this figure is to explain to the information seeker which authority to turn to at which stage of the process, and during this paragraph 3.2, the steps are reviewed in more depth.

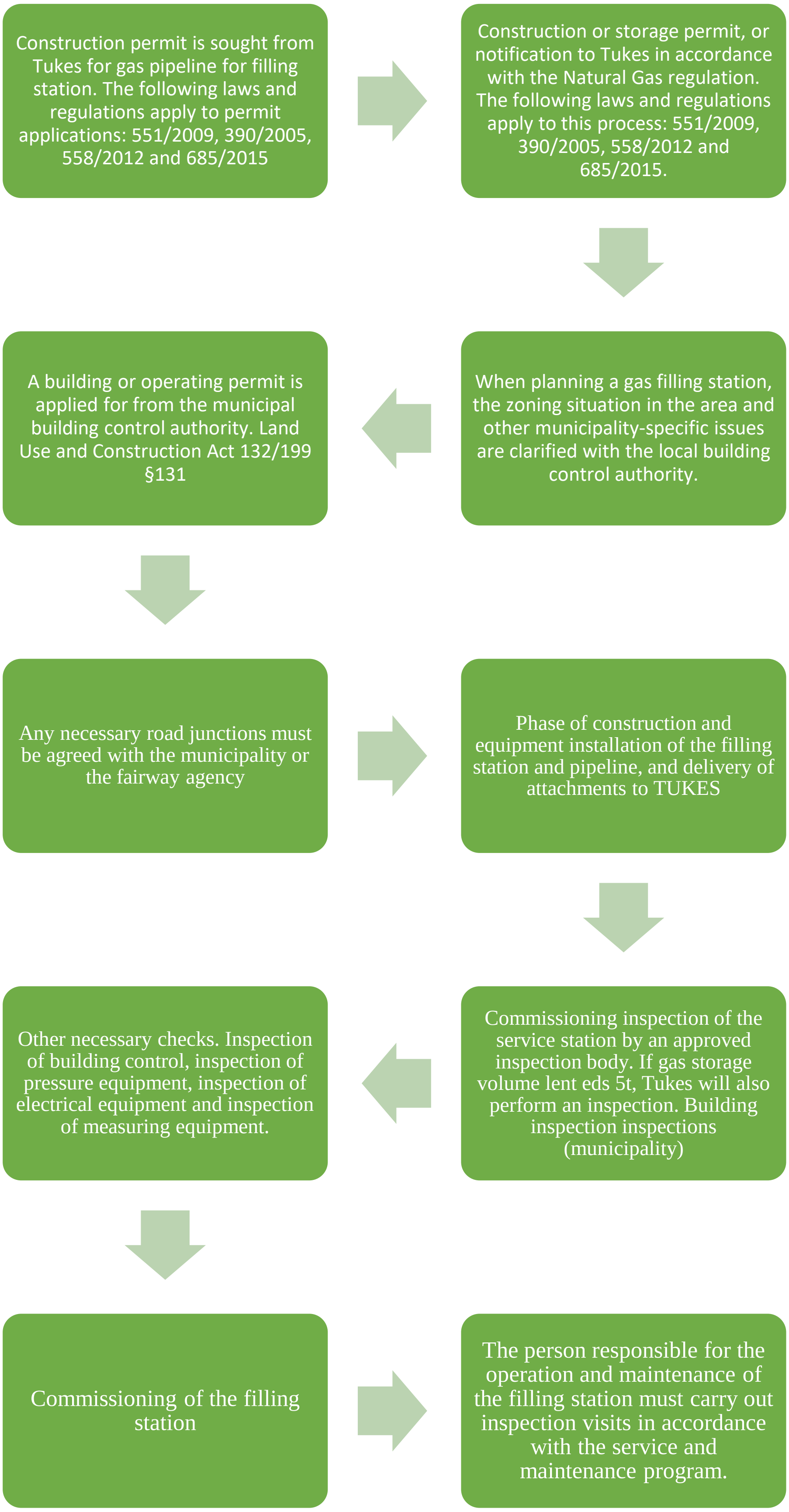

Figure 6. Gas filling station official permit process in general

4.2.1 Laws and standards related to the gas filling station

Table 1 describes the laws related to the construction and licensing of a gas filling station, as well as the specification of the law if necessary. The purpose of Table 1 is to simply illustrate the laws related to gas filling station.

Table 1. Laws affecting the gas filling station.

Law	**Further explanation**
Act 390/2005 on the safety of the handling of hazardous chemicals and explosives regulates the handling and storage of hazardous chemicals and explosives.	Section 7-9 general safety principles for the operator. Sections 10-12 organization of activities in the production plant. Sections 13-16 design and construction of the plant. Sections 17-20 location of production plant.
Pressure equipment act 1144/2016 and the decrees issued pursuant to it (1548/2016, 1549/2016).	Technical requirements, registrations, and inspections of pressurized equipment (LNG/LBG pipeline and LNG/LBG tank).
Pressure equipment Act (1144/2016).	Structural requirements for natural gas service pipelines and gas station pipelines, related equipment and installations, and demonstration of compliance.
Government decree 1439/2016 on the conformity of equipment and protection systems intended for use in potentially explosive atmospheres.	Defines the technical requirements for gas station equipment and security systems.
Measuring devices act 707/2011	Regulates the requirements set for measuring devices and methods and the measures related to their certification. The law applies to the type and certification inspection of compressed gas distribution meters.
The Government decree on the safety of natural gas processing 551/2009 (natural gas decree).	
Government decree 856/2012 regulation of hazardous chemicals industrial on safety requirements for handling and storage.	
Government Decree 685/2015 regulation of hazardous chemicals handling and storage control.	
Land use and building act 132/1999 provides for zoning and the issuance of building permits.	
Rescue Act 379/2011 tasks of rescue authorities and the obligations of the operator to prevent accidents.	

In table 1, all laws related to gas filling stations are listed that must be followed when planning and building a gas filling station. In this section 3.2.1, the purpose and scope of the laws are briefly reviewed. The purpose of Act 390/2005 is to prevent personal, environmental and property damage caused by the manufacture, use, transfer, storage, preservation and other handling of dangerous chemicals and explosives. In the case of a gas filling station, the purpose of the law is also to promote public safety at the stations. Pressure equipment act 1144/2016 is intended to set requirements, restrictions on pressure equipment and natural gas pipelines related to filling stations and thus prevent damage caused by high pressures. Government decree 1439/2016 has been laid down regarding equipment requirements for potentially explosive atmospheres, i.e. ATEX classes and which classifications are required for equipment in each category of potentially explosive atmospheres. Measuring devices act 707/2011 regulates the operation of measuring devices, the reliability of measurement methods and measurement results, and the inspections and requirements of the devices. The Government decree on the safety of natural gas processing 551/2009 in this decree stipulates the storage and technical use of natural gas and the pipelines and equipment intended for the transfer, distribution, use and fuelling of natural gas, and this decree also applies to the technical use of biogas and the recovery, transfer, for pipelines and equipment intended for distribution and use. Government decree 856/2012 stipulates the safety requirements for the industrial handling and storage of dangerous chemicals referred to in the Act on the Safety of Handling Hazardous Chemicals and Explosives (390/2005). Government Decree 685/2015 provides for the industrial handling, storage and storage of dangerous chemicals, the related permit, notification and administrative procedures and supervision, as referred to in the act on the safety of the handling of hazardous chemicals and explosives (390/2005). In other words, acts 685/2015 and 856/2012 specify Act 390/2005. Land use and building act 132/1999 regulates the planning, construction and use of areas and buildings. The goal of rescue act 379/2011 is to improve people's safety and reduce accidents. (Kemikaaliturvallisuuslaki 21.05, Maakaasuturvallisuuslaki 09.07, Vaarallisten kemikaalien käsittelyn ja varastoinnin asetus 20.12, Vaarallisten kemikaalien käsittelyn ja varastoinnin asetus 20.12, Turvallisuus ja kemikaalivirasto et. al. 2021a)

Table 2. The most significant laws of the gas filling station.

The most essential standards for gas filling stations
SFS 3352 Flammable liquids distribution station.
SFS-EN ISO 16923 Natural gas fueling stations.
SFS-EN 16723-2 Use of natural gas and biomethane in traffic and biomethane supply to natural gas to the network. Part 2: Quality of vehicle fuels standard.
SFS-EN 15001-1 Gas pipelines.

In table 2, the most relevant standards are listed in terms of the gas filling station's official process. In addition, all standards related to natural gas are listed on the TUKES website, i.e. they also apply to biomethane, and this list also includes standards that are not related to gas filling stations. The other standards on the TUKES website are very detailed and mainly concern experts who work with equipment, pipelines, and structures. These detailed standards should be known to an expert installer. (Turvallisuus- ja kemikaalivirasto 2022)

The SFS-3352 standard is applied to the distribution station intended for the distribution of liquid fuel and also to the gas filling station. The distribution station includes the tanks, distribution equipment and buildings related to its operation. A distribution station is also considered a temporary distribution point from which fuel is handed over to fuel motor-driven vehicles. SFS-EN-ISO-16923 covers the design, construction, operation, inspection and maintenance of a CNG gas filling station and also covers equipment, safety and control equipment. The SFS-EN-16723-2 standard defines the properties required for natural gas and biomethane to be sold, for example methane content and dew point. An important note about this standard is that the standard contains a table for dew points at 200 bar pressure -10 celsius, -20 celsius and -30 celsius and a mention that the target countries must decide for themselves which of these dew points to follow, but Finland has not yet made this decision on December 5, 2022. So, according to the instructions of the authorities, we currently follow the old dew point, which is -9 celsius at 200 bar pressure. SFS-EN-15001-1 defines functional requirements for design, material selection, construction, inspection, and testing at different pressures.

4.2.2 The construction process, legislation and permits

The Biomethane filling station Authorization process requires several different processes, from the building permit to the final inspection. Applications for permits for biomethane filling station must consider that if the methane content is more than 80%, then the permit limits are usually the same as for natural gas. The application for a permit for a biomethane filling station follows a great deal of regulations and instructions related to natural gas. Tukes issues permits for biomethane filling station, gas pipeline, and storage. Figure 7 shows a summary of the gas filling station process designed by TUKES.

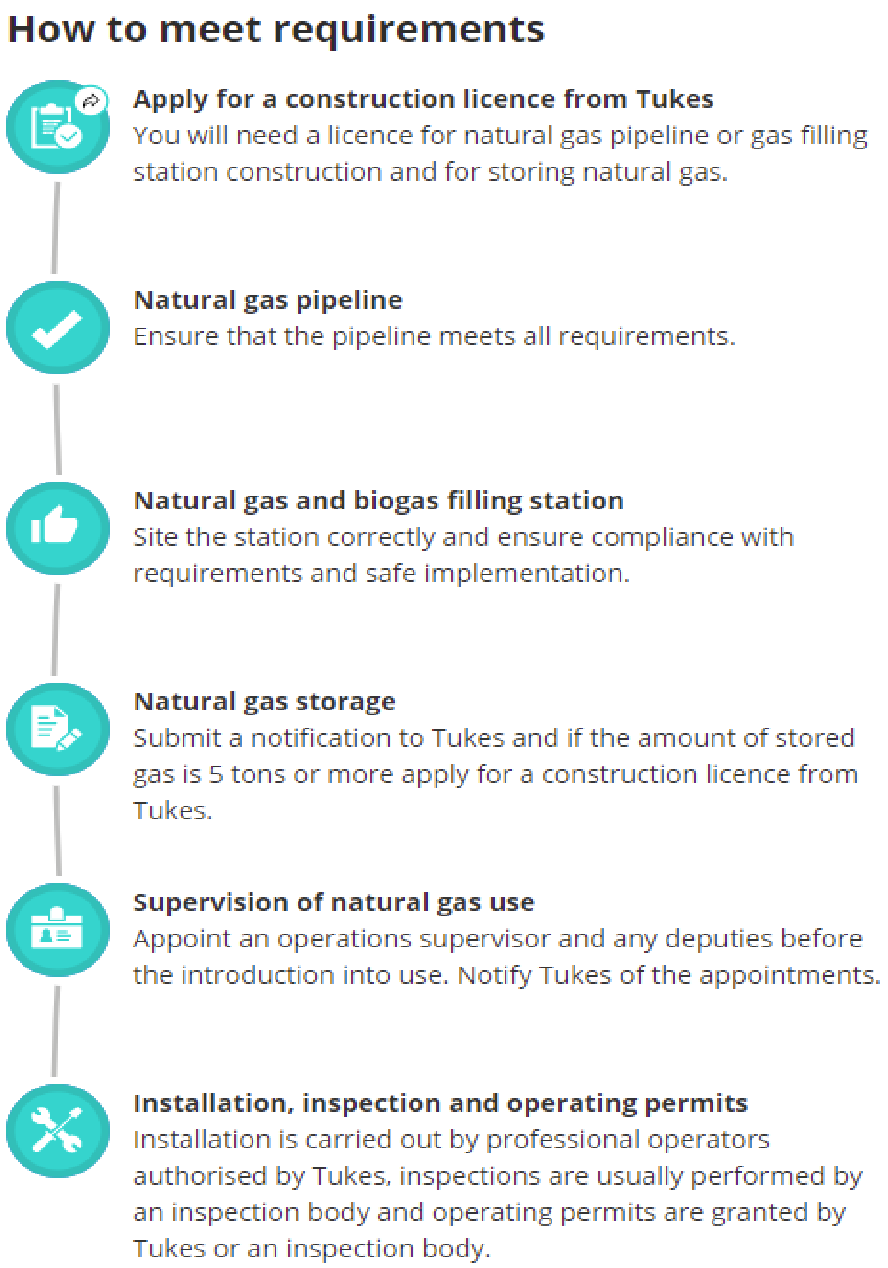

Figure. 7. Gas station official process TUKES model. (Turvallisuus- ja kemikaalivirasto 2021d)

The permitting process for a gas station includes many steps, from the required building permit to the filling station, to the required inspections during the operation of the filling station. The permitting process begins with applying for a building permit for a gas station from a local building authority and involves the required documents, which always vary by location and building, so this required information cannot be told in general terms that would be applicable at each site. The building permit is followed by applying for a gas pipeline investment permit from Tukes, after which a building or storage permit is separately applied for. For the permitting process to run smoothly, the piping and filling station equipment must comply with certain standards, as well to meet the requirements set for the equipment. (Asetus vaarallisten kemikaalien käsittelyn ja varastoinnin valvonnasta 21.05, Turvallisuus ja kemikaalivirasto et. al. 2021a)

As mentioned in figure 6, the gas filling station planning process begins by applying for a construction permit for filling station and pipeline that will come to a gas filling station. In figure 6, the first 4 steps are however very dependent on each other and the process of building a gas filling station can be started from any of these 4. The purpose of the permitting procedure is to ensure a safe location, construction and equipment of natural gas pipelines and equipment, compliance, and consideration of the surrounding area, traffic, housing, and other activities. Filling station, station gas storage and the construction of gas pipeline to the station requires permits issued by various authorities. When planning a station and looking for a location, the zoning situation in the area and other municipality-specific issues are clarified with the local building control authority. Permission for applications from TUKES and construction authorities is next for possible underpasses of roads and railways for pipelines, and these are to be reviewed with construction and railway authorities. When the permits are in order, it's time for the construction phase for the gas filling station and pipeline, this includes the requirements for equipment, pipelines, structures, and safety devices, which are discussed in section 3.2. Before the inspection of the gas tanking station, the required attachments and information must be submitted to TUKES. TUKES needs this information so that they can determine that the filling station complies with the requirements. The appendices and information required by the support are listed in appendix I, appendix II and appendix III. These appendices contain, among other things, equipment information, floor plans, piping drawings, test reports and piping information. After the appendices and information have been delivered to TUKES, it is the turn of TUKES to perform an inspection of the gas filling station by the inspection institutes authorized by TUKES, as well as the taring of the gas distribution point, so that a certain amount of gas can be obtained for a certain amount, thus the buyer can trust that the measurement result for the incoming gas and the price is accurate. The inspection includes, among other things, inspection of equipment requirements, inspection of pipelines, inspection of structures, inspection of safety equipment operation, and review and approval of attachments. If the inspector finds that everything is in accordance with the permits and requirements, then this will be a report to TUKES, which will give permission to officially put the gas filling station into use. After commissioning, however, there are periodic inspections during use according to the statutory deadlines. (Kemikaaliturvallisuuslaki 21.05, Maakaasuturvallisuuslaki 09.07, Asetus vaarallisten kemikaalien käsittelyn ja varastoinnin valvonnasta 21.05, Turvallisuus ja kemikaalivirasto et. al. 2021a)

Natural gas and processed biogas include Tukes' building permit, inspections of inspection bodies and the use of Tukes-approved installation companies as legal requirements. The Finnish natural gas network consists of transmission, distribution, and operation pipelines as well as natural gas filling stations. In addition, natural gas is stored at several sites. The distribution, use and operation of filling biogas are subject to the same requirements as natural gas. Natural gas and processed biogas are combustible gases, and their risks include various leaks, fires, fires, explosions, and the risk of carbon monoxide poisoning. The transmission, distribution and use of natural gas and biogas have been regulated throughout its history. (Turvallisuus ja kemikaalivirasto et. al. 2021b)

4.2.3 Gas pipeline and filling station permit / notification process

Building permit process is to clarify municipality-specific zoning situations and other relevant issues related to the building and zoning situation with the local building authority. The building permit application complies with the Land Use and Building Act 132/1999 and the building permit application must be accompanied by at least the following appendices according to §131:

- A statement that the applicant manages the construction site
- The main drawings included in the building plan

However, depending on the nature and scale of the project, it is normal for the building authority to require the following permits to be attached to the building permit application, which vary according to the project:

- Information not available to the building control authority
- Statement of the construction and foundation conditions of the construction site

- The method of establishment and other measures required by them
- An energy report
- Report on the health and height of the construction site
- Report on the condition of the building prepared by a qualified person
- Other relevant information

The permit process for the gas pipeline coming to the gas filling station is applied for from TUKES. The following laws and regulations apply to gas pipeline permit application:

- Government Decree 551/2009 on the safety of natural gas processing
- Act 390/2005 on the safety of the handling of hazardous chemicals and explosives
- Government Decree 658/2015 on the supervision of the handling and storage of dangerous chemicals

The annexes required by TUKES for the natural gas pipeline that goes to the gas filling station can be found in Annex I.

The information and attachments required by TUKES for the gas filling station and warehouse permit process can be found in appendix I, appendix II and appendix III. The following laws and regulations apply to the gas filling station permit process:

• Government Decree on the safety of natural gas processing 551/2009

• Act on the Safety of Handling of Dangerous Chemicals and Explosives 390/2005

• Government Decree 658/2015 on the control of the handling and storage of hazardous chemicals

4.2.4 Final inspection of the filling station, commissioning, and future inspections

The commissioning inspection of the filling station is carried out by an approved inspection body. If the amount of gas storage exceeds five tonnes (licensing facility site), the Finnish safety and chemicals agency Tukes will also carry out a commissioning inspection. The fire inspection is carried out by the rescue service. (Pelastuslaki 29.04, Pelastustoimilaki 30.04)

Prior to commissioning, the station must be inspected as follows:

- Construction supervision inspections (municipality)
- Location, construction and availability of pipelines and equipment (approved inspection body)
- Inspections of pressure equipment (approved inspection body, notified body if necessary)
- Conformity assessment of the assembly (filling station) according to module G (notified body)
- Verification of electrical equipment (authorized inspectors and inspection bodies) • Verification of measuring equipment / demonstration of conformity (approved inspection body / notified body)
- In addition, a fire inspection is performed by the rescue service before commissioning

When determining the operational readiness of the station, the following shall also be checked:

- Functionality of control connections
- Operation of gas detectors
- Emergency stop buttons
- Leakage of equipment

4.3 Differences between Finnish and European gas laws and possible future changes

Interviews were conducted with experts and authorities. The questions were always modified for the interviews according to the interviewee, and this took into account what perspectives the interviewee can give to the work, whether there are different opinions. Basically, the purpose of the interviews was to gain certainty on the busy issues related to the official approval of the filling station at first, but since the process itself is moderately straightforward, I ended up looking for different perspectives, interpretations of laws and standards. The interviews also involve Italian experts, from whom it is intended to obtain possible conflicts over the interpretation of European laws and standards, compared to the interpretation of Finnish laws and standards.

4.3.1 Requirements and authorization process in Finland

The interview with TUKES officers took place via video chat in a free format and we went through the following topics which are also presented in Annex IV. We discussed about automatic shut-off system for gas filling system and whether there would be such a reliable solution and whether this could be a possible change in the decree in terms of safety. The result of the interview was that the automatic shutdown system could do more harm than good in certain situations. The reasons for this are, among other things, that the automatic extinguishing system extinguishes the fire, but if the gas leak is not shut or the leak is unrecognized as cause of the fire, it can cause additional problems. Sure, all the situations are different, but based on this discussion, there is no need for automatic extinguishing system.

In the interview, I tried to find with the help of the interviewees if any loopholes could exist in decrees that should be corrected, but we couldn't identify any in the interpretation of the decree. After researching more of the sections and standards of the decree, I agree, because what I have learned in the permit process, the laws and standards are very clear, and there is no possibility of loopholes in licensing. The only thing one could think of would be through be that an approved gas installer required be used for installations, but just for sole pipeline installations, it is still required to follow the pressure equipment regulations and natural gas standards. But this is subject to interpretation and depends on who interprets the decree.

Inspections of gas installations, i.e. compressors, high-pressure storage, pipelines and transfer containers, may not need to be intensified in all cases, but there are certain areas where tightening the requirements of the decree would increase safety. For example, a gas transfer container subject to ADR regulations is required by law to be inspected every 2,5 (30 months) to 5 years depending on the material of the pressure vessels. An interval between inspections of too many years can significantly increase the risk of an accident because, as the transfer container is exposed to vibration and variable weather and inspections can also fail due to human error and this can further increase the risks.

The safety distances became a major consideration because, although the safety distances are precisely determined on national instructions, they are conservative, when the risk of a possible explosion and the flight distance of the fragments. Although the decree does not require greater safety distances, Tukes does advise to design lay-out so that the openings of the filling station be oriented in safe, un-hindered directions to where consequences poise no additional harm in the event of a possible accident.

4.3.2 Requirements and authorization process in other European countries

The interview took place with Cubogas experts who have a lot of experience in gas equipment sales and laws around Europe. In the interview we reviewed the following questions, which are also presented in Appendix V. It was discussed whether they have information about possible changes in the law or changes in standards in Europe regarding gas filling station equipment. The result was that even though they are one of the largest manufacturers in the field, there has been no information about possible changes, but they are constantly monitoring the changing situations in the field and, as equipment manufacturers, try to react to these changes as quickly as possible.

During the interview, it became clear that Gas equipment laws, standards and safety requirements differ somewhat from country to country, but mainly the main features are the same in the requirements. For example, Finland is one of the strictest countries in Europe regarding the space classification and requirements for gas appliances, as a gas compressor always requires space class-1, while for example France, Germany and Italy require space class-2. We compared the following space categories with each other: Space category-1 is a space where an explosive air mixture formed by air and a combustible substance in the form of gas, steam or fog is likely to occur randomly during normal operation, and space category-2 is a space where an explosive mixture formed by air and a combustible substance in the form of gas, steam or mist The occurrence of an explosive air mixture is unlikely in normal operation and it only lasts for a short time when it occurs. After comparing these space classifications, we came to the conclusion that space class-2 would be enough for a gas compressor, because the assumption is that under normal conditions gas does not occur in the space, and countries like Germany, France and Italy, which have more experience with natural gas and equipment, than Finland use space class-2.

Recommendations from the equipment manufacturer on what things the person in charge of the gas filling station should take into account when purchasing equipment. National guidelines for the temperatures at which the equipment must operate, space classifications for the equipment, whether there is a need for temperature compensation, i.e. a program that keeps the gas pressure at a specified pressure regardless of the temperature, gas pressure limits, requirements for gas and, in addition, other standards and laws that the equipment is required to comply with.

4.3.3 Comparing Finnish and German explosive space classification

As it became clear in section 3.3.2, Finnish gas laws differ from other European laws based on space classifications. For example, based on the standard SFS-EN IEC 60079-10-1:2021 explosive atmospheres part 10-1 classification of areas, the space class for a natural gas compressor that is outside, in an outdoor space, or in a well-ventilated indoor space would always be space class-2. (Maakaasuturvallisuuslaki 09.07)

According to the information revealed in the interview in chapter 3.3.2, Finnish gas laws differ from other European laws based on space classifications. For example, based on the standard SFS-EN IEC 60079-10-1:2021 explosive atmospheres part 10-1 classification of areas, the space class for a natural gas compressor that is outside, in an outdoor space, or in a well-ventilated indoor space would always be space class-2, of course this standard is not used in all countries (Finland and Germany among others). Standard EN 60079-10-1 has thorough calculations that justify the space classifications of potentially explosive spaces. The calculations take into account gas density, calorific value, evaporation, the strength of the room's airflow, whether the room is indoor or outdoor, pressure differences, etc., and based on these, the room categories have been very precisely justified and the dangers of the potentially explosive room have been assessed. In Germany, the space classification for gas station compressors is always considered according to space, ventilation and other variables on a case-by-case basis. In Germany, the classification is based on standards and tests, and all this information can be found in the guide entitled Explosionsschutz-Regeln (EX-RL) DGUV Regel 113-001, which contains numerous examples of space classifications. In Finland, the compressor farm is always farm class-1 and there is no more detailed justification for this in the law. In addition, the authorities are of the opinion that even if the compressor is completely outside in the middle of a field, then the surroundings of the compressor are also space class-1, i.e. the ventilation of the space is not important and for this reason natural gas compressors imported to Finland must always be space class-1 eligible. (Explosionsschutz 2022) (Maakaasuturvallisuuslaki 09.07)

5 Discussion

The production of biogas and its use in energy production as such or refining it into biomethane and using it as fuel, is an excellent way to reduce human-caused greenhouse emissions compared to the current situation, where methane would be released into the atmosphere without recovery. In this way, emissions can be reduced, in energy production, agriculture, waste treatment and as fuel. In this master's thesis, two different areas related to the same topic were studied. First, the construction and official permit process, equipment requirements, guidelines, and second, a comparison of Finnish legislation and requirements with laws and requirements of other European countries, regarding gas filling stations and equipment. Both results are reviewed in this section.

5.1 Gas filling station authority process

According to the results, the official process of the gas filling station is in the end a very straightforward process with precise specifications for structures, equipment, safety regulations, maintenance, inspections, and gas quantities. The only thing that causes challenges in interpretation is the quality requirements of the gas to be sold, for example what the dew point of the pressurized gas should be at 200 bars. The dew point of the gas plays an important role, because temperature sometimes drops low in Finland in winter, so any moisture in the pressurized gas condenses and can possibly freeze in tight pipelines or in the fuel system of cars.

The results of the master's thesis gas filling station's official process are based entirely on public information, but even though all the information was available, finding it presented challenges, due to the fact that the information was spread over many different laws and official regulations. For example, the equipment requirements and space classifications for gas equipment were challenging to be found. The sources used were publicly available laws and instructions from the authorities, so they can be considered reliable. As an exception there was room for interpretation, for example, the dew point required for gas was open to interpretation, because the authority requires compliance with the standard SFS-EN 16723-

2, which contains three special dew points that states follow, but Finland did not choose which of these should be followed. This matter was handled by discussing with TUKES and the matter was resolved, and the end result was that before the new rule comes into force, the old dew point will be followed. In order to support the existing information, more liaison work could be done with the authority and case-by-case reviews of gas station examples and based on the floor plan examples, requirements and instructions could be made, where the station would be reviewed point by point and the requirements and laws would be discussed, and thus a more detailed and approachable final result would be obtained. Challenges in the work were caused by the dispersion of information in different laws and regulations and the open interpretation of the authorities' instructions, but this only meant a temporary inconvenience. The process of the gas filling station as a whole, from the planning of the station to the periodic inspections of the finished station, also produced challenges, because the process had not been identified in more detail, but this too was only subject to more detailed investigation. However, the master's thesis showed that, although all the information is publicly available and there is a gas station design guide made by TUKES and the gas association, information is still distributed too much to different laws, regulations and instructions, so a more centralized and detailed source of information is always needed. Making a more detailed guide is possible and recommended, and especially, a guide where all the requirements are described with examples, although this requires more work and a lot of cooperation and updates with the authorities, because the laws change over time.

As the scope of the work was limited, the work did not consider the processing of biogas into biomethane, nor the official process related to the production. The work cannot be considered completely comprehensive, from gas production to refuelling, although it would certainly have been desirable to do so, because the official process of biogas purification and production is certainly also interesting and useful to summarize, even though the amount of work is large. A possible development idea could be to study the entire cycle of biogas from production to refining and possibly include the liquefaction of biomethane in the topic and study the legislation, requirements, and regulations of these.

In the work, the subject of review was the gas filling station's official process, station requirements, equipment requirements, piping requirements, gas requirements, and all regulations related to the gas filling station. The selection of the objects to be inspected was simple because the purpose of this work was to find out the official process from the construction of a gas filling station to periodic inspections. In the official process, the goals were divided, which authorities are involved in the process, and which permits must be applied for, which regulations are there for the gas station's equipment, structures, and pipelines, what is the required gas quality, inspections and required attachments for the permit process. The goals were therefore very straightforward and clear and did not change during the work.

When using the results of the work, it must be considered that only current legislation, regulations and instructions are involved, and these instructions may not be valid in a few years' time, and possible small differences in explosive atmosphere classifications between Finland and other European countries may possibly affect the legislation. In the results of interviews and comparisons of legislation, it should be taken into account that the comparison has examined a very small part of the totality of gas station legislation and this comparison was mainly aimed at equipment requirements and space classifications. It is possible that there are more differences, but not all differences in laws between countries are necessarily bad, because among other things, for example, the climate can affect the equipment requirements, which should be taken into account.

If it were possible to study the legislation and equipment requirements of other countries in Europe more, a much more detailed comparison could be made, and thus possible differences and similarities could be found and the reasons for these would be further investigated.

According to Finnish legislation, the explosive space classification for the room where the natural gas high-pressure compressor is located is ATEX class 1. The classification is not affected by whether the compressor is indoors or in the middle of an open field, because the surrounding space is always ATEX-1. Compared to other European countries, this is a very straightforward solution, because in other European countries, for example in Germany, the space class is considered on a case-by-case basis, which is affected by many different parameters, among other things, ventilation, evaporation of the substance in the event of a possible leak, and safety devices, and therefore the space class may not be so strict. It is worth considering whether a situation-specific evaluation of the potentially explosive space class is a better or worse solution than an automatic stricter potentially explosive space class, because safer equipment according to a stricter space class is also more expensive.

The gas station regulatory process and requirements, both for the equipment and the station, is mainly a straightforward process. Already, the gas filling station design guide made in cooperation between TUKES and the gas association, which contains the most important instructions and regulations for the filling station's official process, was very useful and served as a guideline in doing this work. As an addition to these already ready instructions, the work investigated in more detail requirements that the already existing instructions do not provide an answer to. All the detailed information was found in the laws related to the gas filling station.

6 Conclusion

This master's thesis shows that the official process of a gas filling station construction is very straightforward. In the results of the master's thesis, the technical requirements, regulations, and the official process are described, for this was thought to facilitate the interpretation of technical requirements, regulations and instructions, because before this thesis, information about these had been spread over many different sources and this can make interpretation difficult. The challenge is the dispersion of information into several different sources, and even though the guideline for the design of a gas filling station made jointly by TUKES and the gas association summarizes the most important things that are required from the station, or what authorities and technical requirements are required from the station, a more detailed and focused information would be useful. Mainly the requirements for the filling station, gas and equipment can be found in the laws and regulations, but one of the challenges was finding information about what the dew point requirement is for the gas sold in vehicles, and this was a challenge because in the new standard that Finland follows and which has requirements for the dew point of gas, Finland does not yet comply with the standard's Dew Point requirement, so the old requirement for the dew point is valid. The sequence of the official process of the gas filling station where one should start, and which step comes next is clear and accurately described in the results. The laws and standards, as well as the required permits, are described in the results, which are examined in detail. The pipeline permit process has also been clarified and this permit will be applied for from TUKES. In the permit process, the attachments and information required by TUKES have also been clarified in order to complete the permit process. The last official process is the Final Inspection, and after approval, TUKES gives an official permit for use, after which periodic inspections and maintenance begin.

The technical requirements for the gas filling station include all the requirements and information required for the equipment. The technical data of pipelines, compressors, high pressure storages, transfer containers, gas dispensers and protective devices have been clarified and reviewed. Many different laws affect these devices, and it is recommended that you clarify the device requirements with TUKES, as this can avoid possible misinterpretations. In addition, the periodic inspections of the gas filling station and other requirements are reviewed in the technical requirements.

The results of the master's thesis, which examines Finnish gas legislation and compares it to the legislation of other European countries, especially German legislation, in terms of space classification, reveals a significant difference in Finland. In the interview with the Finnish authorities, interesting facts came to light, which according to the law are not incorrect, but which would be good to re-examine with safety in mind. For example, according to the VAK directive, transfer gas containers only need to be inspected once every 10 years, and when you add the possibility of human error during the inspection, the possibility of a leak increases the longer the inspection interval becomes. The difference between Finland and other European countries is mainly in terms of gas equipment requirements, where Finland is stricter compared to other countries, according to the interview. In particular, when comparing the German and Finnish explosive space classification for gas compressors, it is clear that Germany has a case-specific space classification method, unlike in Finland, where the space of a gas filling station with a gas compressor is always ATEX-1, but in Germany it can be either ATEX-1 or ATEX-2 on a case-by-case basis. So, in Finland there are stricter requirements in this regard, and this means that a gas compressor that meets the stricter requirements is more expensive, which in turn can weaken purchasing power and competitiveness. But is there any harm in being overly safe, especially when dealing with an explosive gas? It is recommended that, as a follow-up study, the differences between Finland and other European countries are compared more thoroughly, in this way a much more comprehensive study of the differences and the causes of these differences can be obtained for the countries.

As can be seen from the results of the work and previous conclusions, the official process with its technical requirements is mostly clear and straightforward with a few exceptions, and it is recommended that when in doubt, seek advice from the authorities in order to avoid mistakes. There are differences between Finland and other countries, but this work does not take a position on what causes the differences and whether Finland should follow the model of countries with more experience in natural gas in terms of safety.

This master’s thesis does not fully present all the most detailed requirements for gas equipment but gives the main picture and understanding of the requirements and gives information on where to find more detailed facts about the requirements if necessary. If further research were done on the subject, it would be possible to get very detailed instructions that would answer every possible question, but is this necessary, because the laws and requirements are changing?

7 Summary

The production and use of biogas is an excellent way to reduce greenhouse emissions caused by human activities, and the further processing of biogas into biomethane enables the gas to be used as fuel. The production of biogas as a whole can reduce emissions in several different sectors, such as energy production, agriculture and logistics. Methane in itself is more than 20 times more harmful greenhouse gas than carbon dioxide, and based on this alone, it is justified to use a refined version of biogas, i.e. biomethane, as fuel, in which case carbon dioxide is produced in the combustion process and carbon dioxide is less harmful for climate than methane. Biogas can be produced from almost any bio-derived waste and substance.

The goal of the master's thesis research was to find out what the official process of a gas filling station is in general terms, what are the requirements for equipment, gas, safety, and other things related to a gas filling station. Another goal was to investigate possible conflicts in laws and requirements based on the interviews, and to investigate whether the hardware requirements are different in Europe than in Finland. The results revealed the main features of the official process, which authorities are involved, the laws and standards related to the gas filling station, as well as the requirements for equipment, gas, and safety. Maintenance and periodic inspections were also discussed. The results also revealed the information obtained from the interviews and small uncertainties related to security, as well as the differences between German and Finnish equipment requirements. In this master's thesis, an effort has been made to create an easily approachable gas filling station official process and, in addition, to combine information from different sources about the requirements and regulations for the station and equipment. The instructions and steps of the official process are explained as stated in the laws and regulations of the authorities, so that no contradictions can arise between the information.

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The required attachments for the gas transfer pipeline
Written construction plan
General arrangement drawing
Forced alignment maps
Longitudinal sections
Area class and station drawings
PI and flow diagrams
Corrosion protection
Length and nominal size
Design pressures and temperatures
Explosion hazard assessment
If necessary, explosion protection document Inc. Investment planning and an assessment of the significant environmental impacts of the pipeline and a plan for their prevention.

Information required for a gas filling station permit
Overview of activities
Project schedule
Actuators, i.e., a list of actuators and technical data
Basic piping information
Location of activities
Property IDs
Surrounding environment and zoning
Area management report
Process / function
Areas affected by accidents
Risk assessment
Equipment selection criteria
Explosion protection document
Structural safety report
Leak management statement
Control, management, and safety systems
Hazard detection report
Extinguishing and preparedness statement
Preventive care and maintenance report
Other guidance and training statement

Gas storage/refueling station application attachments
Written plan for construction
Filling station location, safety distances, written description, and position drawing
Planning and management of land and the environment
Location of filling station functions on the site (distribution meter, compressor, warehouses, etc.)
PI charts
Piping drawing and information on the pipelines to be built (materials, nominal sizes, main shut-off valve, connection methods)
Design pressure and operating pressure, design temperatures
Process description
Equipment specifications (compressor, dispenser, warehouses)
Quantities of land / biogas and other chemicals stored in the area
Safety systems and equipment (including gas leak monitoring and warning lights, camera and remote monitoring, hose break valves, temperature compensation, initial fire-fighting equipment, emergency stop buttons, collision protection, safety markings and instructions)
Safety data sheets
Risk assessment
The most significant accident scenarios and their consequences (distance analysis, distance drawings for thermal radiation and explosive pressure effects)
Explosion protection document incl. Space classification drawing, Ex equipment list
Overview of operations
A statement of the amount of natural gas to be stored and the storage methods
PI diagrams and lay-out drawings
Hardware and piping information
A statement of the zoning of the plot and the zoning of the immediate surroundings, as well as the right of possession of the area
Map showing the location of the site and the 500 m zone (incl. Buildings, sensitive sites, Nature sites, etc.)
Chemical Inventory (KemiDigi), Safety Data Sheets

Risk assessment
Safety automation
A study of the possible effects of other activities and production facilities in the vicinity on storage
A study of the most significant accidents and their scope and effects on people, the envi-ronment, property, and production facilities.
Calculations and maps of the effects of thermal radiation and pressure. The report shall indicate the analyses and evaluations to be carried out and the procedures for: ensure that results are considered in design, implementation, and operation.
LNG/CNG leakage control
Explosion hazard assessment and explosion protection document incl. Space classification drawing, Ex equipment list

Interview questions for Tukes experts

1) Should it be necessary to consider a flare as a mandatory precaution in Finland at a gas filling station, for example due to an excessive amount of gas?

2) Would an automatic extinguishing system be safer in the event of an accident at a gas filling station than manual extinguishing equipment, and would it be good to operate this way in the future?

3) Are there loopholes in the requirements related to gas station buildings that you think should be addressed?

4) Should precautionary measures and requirements be tightened in case of accidents dangerous to the environment, such as a methane leak?

5) Should periodic inspections of permanently installed gas storages and mobile containers be done more often and should monitoring of these be improved?

6) Should all gas filling station inspections be done more often?

7) Do you have any suggestions for improvement in general, or comments on the legislation/technical requirements concerning the gas station's equipment, piping, building and safety?

8) What is your opinion on gas filling station safety distances?

Interview questions for Cubogas experts

1) What European Union laws do you follow when designing compressors, high-pressure storages, and dispensers?

2) Do you have a similar line in gas legislation with European legislation, or do you use stricter requirements for your equipment?

3) What standards do you follow when designing compressors, high pressure storages and dispensers?

4) Are you aware of any changes to the laws related to gas legislation or standards that are coming up in the next few years that you are prepared for?

5) Have you noticed, with potential customers, that some countries have stricter standards and laws than required by the European Union?

6) Have you encountered any problems / challenges / changes in laws and standards when manufacturing your products and interacting with the customer?

7) In general, what important things should a service station Builder take into account when purchasing equipment from you (for example, the amount of gas to be Pressurized by the compressor and the bar limit for Pressurized gas required by law or ATEX)?