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Master’s Thesis 2020

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THE SIGNIFICANCE OF IMPLEMENTING THE ISO 50001 ENERGY MANAGEMENT SYSTEM FOR REDUCING GREENHOUSE GAS EMISSIONS AT A FERTILIZER PRODUCTION SITE

Examiners: Professor, D.Sc. (Tech) Risto Soukka
CIM, M.Sc. (Tech) Elina Hakala
Supervisor: CIM, M.Sc. (Tech) Elina Hakala

ABSTRACT

Lappeenranta-Lahti University of Technology LUT
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Keywords:
ISO 50001, energy management system, energy efficiency, fertilizer production, life cycle, GHG emissions

The aim of this Master's thesis is to plan a site-specific framework for the ISO 50001 energy management system (EnMS) for the fertilizer production site, Yara Uusikaupunki, and assess the significance of implementing the requirements of the standard on reducing greenhouse gas emissions. The assessment considers both reducing greenhouse gas emissions at the fertilizer production site and from a broader fertilizer life cycle perspective. Several data sources were utilized in this case study to provide a comprehensive theoretical background upon which the empirical part, including the ISO 50001 EnMS implementation plan, was built. The starting point for the work was to examine current energy management practices at the site, after which the suggestions for execution possibilities and assessment of potential impacts on reducing greenhouse gas emissions could be provided.

It was discovered that, locally, procurement and design activities will play an important role in terms of improving energy performance at Yara Uusikaupunki. For successful implementation of the EnMS, it is suggested to establish an energy management team with clear roles, address the discovered shortcomings at an early stage, consider adding or improving energy performance as a priority at the top management level, and to cooperate with the other Yara sites in Finland. Implementing the ISO 50001 EnMS at Yara Uusikaupunki was assessed not to have a significant impact on reducing greenhouse gas emissions at the site nor from a broader fertilizer life cycle perspective. The impact was assessed to be minor due to the nature of the activities at the site, as well as both the certain levels of freedom and limitations regarding the application of the requirements of the standard.

TIIVISTELMÄ

Lappeenrannan-Lahden teknillinen yliopisto LUT
LUT School of Energy Systems
Ympäristötekniikan koulutusohjelma
Sustainability Science and Solutions

Mia Rouvinen

ISO 50001 -energianhallintajärjestelmän käyttöönoton merkittävyys kasvihuonekaasupäästöjen vähentämisessä lannoitteiden tuotantolaitoksella

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Tämän diplomityön tarkoituksena on suunnitella ISO 50001 -standardin mukainen energianhallintajärjestelmä Yara Uudenkaupungin tuotantolaitosten tarpeisiin sekä arvioida kyseisen energianhallintajärjestelmän käyttöönoton merkitystä kasvihuonekaasupäästöjen vähentämisen näkökulmasta. Arvioinnissa huomioidaan itse tuotantoalueen päästöjen lisäksi standardin vaikutus lannoitteen elinkaaren aikana syntyviin päästöihin. Tässä tapaustutkimuksessa hyödynnettiin useita eri tietolähteitä kattavan teoreettisen tietopohjan luomiseksi, jonka avulla soveltava osuus, mukaan lukien energianhallintajärjestelmän toteutussuunnitelma, voitiin toteuttaa. Työn lähtökohtana oli tutkia toimipaikalla käytössä olevia energianhallintakäytäntöjä, jonka jälkeen voitiin antaa ehdotuksia energianhallintajärjestelmän toteuttamiseksi sekä arvioida sen mahdollisia vaikutuksia kasvihuonekaasupäästöihin.

Työn tuloksena havaittiin, että hankinta- ja suunnittelutoiminnot tulevat olemaan keskeisessä roolissa energiatehokkuuden parantamisessa Yara Uudenkaupungin toimipaikalla. Toimipaikalle erityisesti suositeltavia toimenpiteitä ovat selkeät roolit omaavan energianhallintatiimin perustaminen, havaittujen puutteiden pikainen huomiointi, energiatehokkuuden merkityksen korostaminen johtoryhmätasolla sekä yhteistyö muiden Yara Suomen toimipaikkojen kanssa. ISO 50001 -standardin mukaisen energianhallintajärjestelmän käyttöönotolla ei arvioitu olevan merkittävää vaikutusta kasvihuonekaasupäästöjen vähentämisessä toimipaikan sisällä eikä lannoitteen elinkaarinäkökulmasta tarkasteltuna. Vaikutus arvioitiin vähäiseksi sekä toimipaikan toiminnan luonteesta että standardin vaatimusten soveltamismahdollisuuksista johtuen.

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The journey into the world of energy management and its concrete application in the case company brought me both tricky challenges and joyful moments of success and learning. Accomplishing this Master's thesis would have been more of a struggle without the kindest of help that I received from all around me.

Therefore, I want to genuinely thank the wonderful staff at Yara Uusikaupunki for our time together, the interesting commission, and all the help I received regarding this work during these past few months. Special thanks goes to my supervisor and second examiner, Elina Hakala, and to all the others I bothered during this period of work for all of your most generous advice and support (you know who you are)! Another round of thanks goes out to Risto Soukka, for the helpful advice and supervision along the way. Dear Sustainability Crew: Thank you for all the countless fun and happy moments throughout our studies together. Last, but definitely not least, I cordially thank my dear family and friends, as well as my trusted proofreader, Christopher minn, for your endless love and support. Thank you for believing in me.

In Uusikaupunki, 11th June 2020

Mia Rouvinen

TABLE OF CONTENTS

LIST OF SYMBOLS

Subscripts

°C	degree Celsius
CO_2-eq	carbon dioxide equivalent
EJ	exajoule
GJ	gigajoule
GWh	gigawatt-hour
MWh	megawatt-hour
t	ton

Abbreviations

BAT	Best Available Technique
BREF	Best Available Techniques Reference Document
EEAs	Energy Efficiency Agreements
EnB	Energy Baseline
EnMS	Energy Management System
EnPI	Energy Performance Indicator
EED	Energy Efficiency Directive (Directive 2012/27/EU)
EES+	Energy Efficiency System
EMS	Environmental Management System
EU	European Union
GHG	Greenhouse Gas
HESQ	Health, Environment, Safety, and Quality
HOPS	HESQ Operational Standard
ISO	International Organization for Standardization
KPI	Key Performance Indicator
L1	Lannoite 1 (Fertilizer plant 1)
L2	Lannoite 2 (Fertilizer plant 2)
NSCR	Non-Selective Catalytic Reduction
SCR	Selective Catalytic Reduction
SEU	Significant Energy Use
SNCR	Selective Non-Catalytic Reduction

SOP	Standard Operating Procedure
T2	Typpi 2 (Nitric Acid Plant 2)
T4	Typpi 4 (Nitric Acid Plant 4)
TOPS	Technical and Operational Standard

List of Chemical Elements and Compounds

CFCs	chlorofluorocarbons
CO	carbon monoxide
CO_2	carbon dioxide
HFCs	hydrofluorocarbons
HNO_3	nitric acid
H_2O	water
H_2SO_4	sulphuric acid
H_3PO_4	phosphoric acid
N	nitrogen
K	potassium
KCl	potassium chloride
KN	potassium nitrate
K_2O	potassium oxide
NaCl	natrium chloride
NH_3	ammonia
NH_4	methane
NMVOCs	non-methane volatile organic compounds
NPK	nitrogen, potash, potash (N, P_2O_5, K_2O)
NOx	nitrogen oxides
N_2	nitrogen
N_2O	nitrous oxide
O_3	ozone
P	phosphorus
P_2O_5	phosphorus pentoxide
SO_2	sulfur dioxide
SOx	sulfur oxides
VOCs	volatile organic compounds

1 INTRODUCTION

A changing climate, an increasing energy consumption, emissions associated with energy consumption, and dwindling resources have increased attention toward the management of energy consumption and use, as well as the promotion of energy efficiency in both business and social activities. By managing energy consumption and use, it is possible to affect the energy-related costs, promote the use of desirable energy sources and reduce the associated climate and environmental impacts. For companies, sensible energy management practice can also provide a potential competitive advantage.

The growth and development of modern economies is highly based on energy access, and global energy use has been rapidly increasing at a rate close to 2% per year since the Industrial Revolution (Grübler et al. 2012, 112–113; Johansson et al. 2012, 36). EIA (2020) projects a nearly 50% increase in global energy use by 2050. This increase is predominantly driven by worldwide population and economic growth, an expanding middle class, lifestyle changes, as well as the accelerating use of more energy-intensive technologies both in homes and workplaces (Johansson et al. 2012, 36).

Even though attributing causation to the factors and underlying drivers that influence GHG emissions is sometimes challenging due to their complex direct and indirect interactions, a stable upward trend in GHG emissions has been associated with carbon dioxide emissions from the use of fossil fuels (Blanco et al. 2014, 367, 396). In 2005, energy supply and use was estimated to contribute to around 80% of carbon dioxide emissions and 30% of methane emissions, in addition to still other substances. Moreover, energy systems are evidently linked to land and freshwater use due to their dependence on water and land resources that are needed to generate energy. They are also associated with air quality and ecosystem services through particulate matter and atmospheric pollutant emissions. (Johansson et al. 2012, 39.) Warming of the climate system, largely driven by the release of human-made carbon dioxide and other emissions into the atmosphere, has increased the average surface temperature of the planet by 1.1 degrees Celsius since the late 19th century, and the changes in climate have already had an effect on natural and human systems globally (IPCC 2014, 47; NASA 2017).

The industry sector is a remarkable energy user, and it contributed to 37% of the final energy use and 24% of emissions in 2017 (IEA 2019a). The biggest industrial energy users are the chemical and petrochemical industries (30%), followed by the iron and steel industries (19%) and the non-metallic minerals industries (9%) (IEA 2007, 25, 39). Industrial energy consumption follows the global trend and has been continuously increasing by 1% per annum since 2010, mainly due to the sustained increases in production at energy intensive industry subsectors, such as in chemicals, iron and steel, and cement sectors (IEA 2019a).

Fertilizer production is one of these aforementioned energy-intensive chemical industry subsectors, and it accounts for about 2–3% of the total global energy consumption (The Fertilizer Institute 2016, 9; European Commission 2007, 3). Global fertilizer consumption has been steadily increasing for years (Figure 1). The evolution of planted areas and yields, crop mix, crop prices, fertilizer subsidy regimes, and nutrient management regulations are some of the variables affecting this demand. Global fertilizer consumption is expected to continue its steady increase due to the growing global population and economic growth, which, for example, means increasing food demand and a change in diets. (Yara 2018a, 17, 20, 54.) Such as industry sectors in general, the production and use of fertilizers also cause non-energy related GHG emissions, either directly or indirectly, during their life cycles. The GHG emissions during a fertilizer life cycle are discussed more in-depth later in this work.

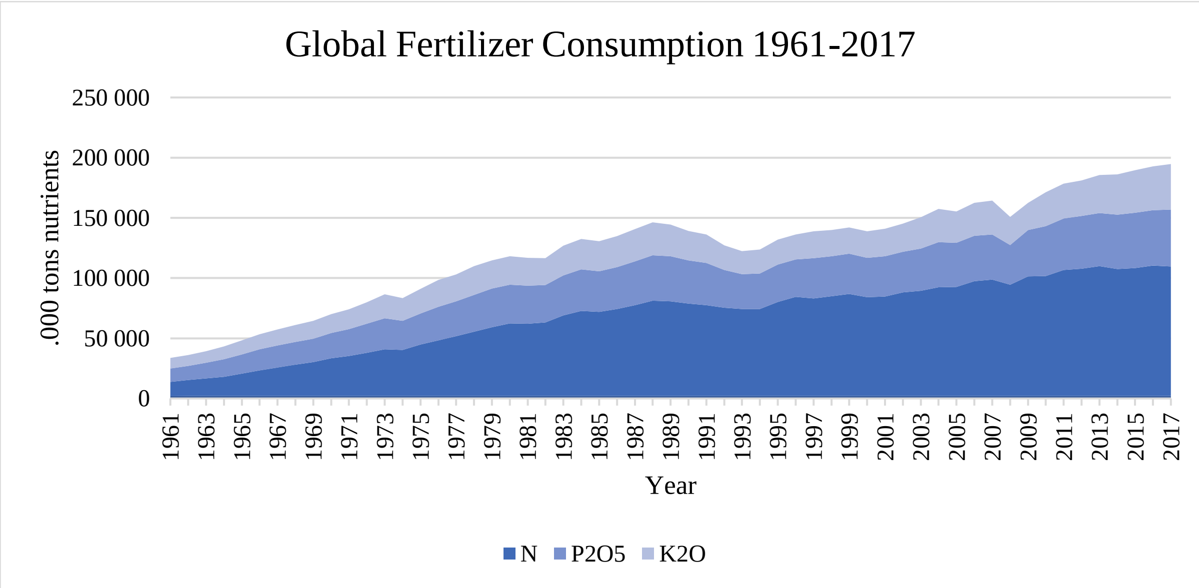

Figure 1. Global fertilizer consumption 1961–2017 (adapted from: IFA 2019).

To promote the reduction of GHG emissions, a variety of legislative instruments in relation to climate have been established globally. According to a database provided by the Grantham Research Institute on Climate Change and the Environment and the Sabin Center for Climate Change Law, there are currently over 1,800 climate-related laws and policies worldwide. The European Union, which is amongst the top three energy consumers in the world, has about 30 laws and policies that can be considered as climate laws. (LSE 2020a; LSE 2020b; European Commission 2017, 12.) Some of them, such as the Energy Efficiency Directive (2012/27/EU) (EED) and the Industrial Emissions Directive (2010/75/EU), are directly related to energy efficiency improvements and enhancing low-carbon solutions. Improving energy efficiency is largely recognized as a cost-effective approach to cutting GHG emissions (Yang & Yu 2015, 3).

In addition to legal obligations, other means have been developed to improve energy management and reduce energy-related GHG emissions. As an implication of recognizing the need of industry to effectively respond to climate change and noting the proliferation of national energy management standards, The United Nations Industrial Development Organization (UNIDO) requested the International Organization for Standardization (ISO) to develop an international energy management standard in 2007. ISO had already identified energy management as one of its primary areas to develop international standards for, and thus, a project committee was soon established in 2008 to complete the work. As a result, the first version of the ISO 50001 standard - ISO 50001:2011 *Energy management systems - Requirements with guidance for use* - was published in 2011. (Harris 2019, 145.) Since then, ISO 50001 has been gaining popularity amongst industry actors and other organizations - in 2018, the number of total valid certificates for ISO 2011:2018 was around 18,000 at around 47,000 different sites (International Organization for Standardization 2019a).

The ISO 50001 standard, which provides a systematic and dedicated framework around energy efficiency through the implementation of an energy management system (EnMS), assists organizations to establish systems and processes that help to realize untapped energy efficiency potential. These organizations are not only benefitting from cost savings and potential competitive advantages, but they also contribute to climate and environmental protection - such as sustained carbon dioxide reductions. (Harris 2019, 144.) ISO 50001 EnMS also creates transparency in terms of energy management, promotes the overall reinforcement of good energy management practices and behaviours inside the organizations, and contributes to energy efficiency throughout the supply chain (Scheihing 2014, 49).

The commissioner of this Master's thesis and fertilizer and nitric acid production site, Yara Uusikaupunki, is aiming to join these organizations and improve their own energy performance through the adoption of an energy management system (EnMS) according to the ISO 50001 standard. When considering GHG emissions associated with energy consumption, there is legitimate potential to reduce the impacts on climate through implementing an EnMS. Therefore, in addition to planning for future EnMS, there is interest in the significance of the potential for reducing GHG emissions, both at Yara Uusikaupunki and from a fertilizer life cycle perspective, by way of the establishment of an EnMS.

1.1 Methodology, Objective, and Research Questions

This Master's thesis is a case study. The term "case study research" refers to a methodological technique that has an individual, group, program, event, or activity as the unit of analysis, which has an ultimate goal to provide suggestions for action, such as in this work. In case study research, several sources can be utilized in data collection, such as interviews, observations at the site, and analyzing available data sources. Case studies are often classified as being qualitative research, due to possessing data that focuses on conceptual meanings, rather than quantitative research, which focuses on statistical and numerical observations. (Tardi 2019, 1, 4, 12.)

Data for this work is collected from various sources. In addition to researching relevant literature, several interviews and questionnaires were performed to obtain necessary information about the site and its current energy management practices in order to plan an EnMS implementation according to ISO 50001 for Yara Uusikaupunki and to assess the impact of the planned actions on energy-related GHG emissions. The material and data provided by Yara Suomi Oy were also utilized to create a feasible framework for the future standardization process. This work, however, includes characteristics of both qualitative and quantitative research methods due to the nature of the commission, which requires numerical data for demonstrational and information enhancement purposes.

The main objective of this thesis is to plan a site-specific framework to establish, implement, and maintain an EnMS in order to certify Yara Uusikaupunki as ISO 50001 compliant in the near future. This work also aims at assessing the significance of implementing the ISO 50001 EnMS at Yara Uusikaupunki as a tool for reducing GHG emissions at the site, as well as in terms of affecting the fertilizer life cycle. Thus, the following two main research questions, and the two sub-questions, are addressed in this work:

1. How can an ISO 50001 energy management system be implemented at Yara Uusikaupunki?
2. How significant is the implementation of an ISO 50001 energy management system for reducing greenhouse gas emissions at Yara Uusikaupunki, and are there secondary effects on the life cycle of the fertilizers produced at the site?
    - What is the extent of the potential for Yara Uusikaupunki to influence others to mitigate GHG emissions via a site-specific energy management system?
    - Can an ISO 50001 energy management system be recommended as a greenhouse gas emissions reduction tool for other fertilizer industry operators?

1.2 Structure and Boundaries

This Master's thesis consists of theoretical and empirical parts. The theoretical parts aim to provide a comprehensive background upon which the empirical part is built, in accordance with the needs and expectations of the commissioner of this work, Yara Uusikaupunki. These chapters include a description of the fertilizer life cycle, including raw material extraction, production of the main fertilizer products and intermediate products, transport, application of the fertilizer, and the related GHG emissions and mitigation possibilities, as well as a section for introducing some tools through which organizations and other actors can mitigate GHG emissions of their operations. Finally, the structure and requirements of the ISO 50001 standard are described.

The empirical part is based on theoretical sections. The empirical part includes, in addition to the implementation plan, a description of the commissioning site and its main processes. The implementation plan of the EnMS is carried out in accordance with the ISO 50001, ISO 50004, and ISO 50006 standards, as well as the utilization of supportive information from the implementation guides and other applicable literature. An example of the method for naming significant energy uses to which resources are allocated is provided in order to demonstrate the requirements of the standard on a smaller scale. The impacts of the standard's requirements regarding possibilities for the reduction of GHG emissions at the site and a consideration of the fertilizer life cycle are discussed in their respective chapters.

The starting point for this work is to examine current energy management practices at the site, then provide suggestions for the execution possibilities at Yara Uusikaupunki to fulfill the standard's requirements. An undetailed analysis of energy consumption based on available data is provided to give an overall picture of energy consumption at the site and to provide more up-to-date information for the future development of an energy review. It is, however, Yara Uusikaupunki's responsibility to make guidelines on the basis of which the final EnMS will take form and be implemented. Answers to the research questions and suggestions for improvements of the actions at the site to effectively operate the future EnMS will be proposed in the discussion chapter of this work (see chapter 7). The implementation plan is not strictly time-bound, as actual implementation and fulfilment of the requirements of the standard is initially planned to be completed by the end of 2021 at the earliest.

On the basis of surveying the main processes at the site and the EnMS implementation plan, the significance of implementing the ISO 50001 EnMS at Yara Uusikaupunki in terms of reducing GHG emissions at the site and from a fertilizer life cycle perspective is assessed. The analysis is an estimate based on the literature and other attained information regarding the fertilizer life cycle and Yara Uusikaupunki's functions, and is not based on computational verifications. This document focuses solely on the standard implementation plan of Yara Uusikaupunki and is, therefore, not applicable for the needs of other chemical industry actors as such. This document is not an integral part of the EnMS of Yara Uusikaupunki but rather an operational and informational guidebook for feasible implementation practices in order to fulfill the requirements of the ISO 50001 standard.

2 FERTILIZER LIFE CYCLE, GHG EMISSIONS, AND MITIGATION

Beginning in the form of composed or enriched organic matter, fertilizers have been used for centuries. The introduction of inorganic fertilizers took place during the Industrial Revolution, during which the fertilizers provided increases in production and productivity, raising the standard of living. Fertilizers enhance the supply of nutrients that are important for the growth of plants. (Valencia 2013, 189.) The three essential macronutrients for plant growth and in fertilizer production are nitrogen (N), phosphorus (P), and potassium (K). Additionally, secondary nutrients (e.g. calcium and magnesium) and micronutrients (e.g. chlorine and copper) are also needed to support growth, but in smaller quantities. (The Fertilizer Institute 2020.)

Nitrogen is an important part of the formation of proteins for plants. Since most plants cannot get their nitrogen directly from the atmosphere - which is approximately 78% nitrogen by volume - nitrogen fertilizer becomes essential. Phosphorus is involved in several processes of plant development, such as in photosynthesis. Lastly, potassium - also called "potash" - both helps plants resist wilting and is a part of the synthesizing of carbohydrates and starches. Only about 2% of potassium is available to plants, which makes potassium fertilizer needful for crop production. (The Fertilizer Institute 2016, 7.)

The fertilizer industry is primarily focused around procuring these macronutrients into forms that are accessible to plants. In documents related to the fertilizer sector, nitrogen is expressed as N, while phosphorus and potash are expressed as phosphorus pentoxide (P_2O_5), potassium oxide (K_2O), and also as the elements themselves (P/K). Ammonia is the main feedstock of nitrogen fertilizers, phosphoric acid is often the basis of phosphate fertilizers, and potash is used as such. (European Commission 2007, 1–2.) The fertilizer production chain can be roughly divided into three main categories: 1. raw material acquisition, 2. production of intermediate and final fertilizer products, and 3. application of fertilizer on fields. Figure 2 shows the production chains of the main fertilizer products, excluding the application of fertilizer on fields.

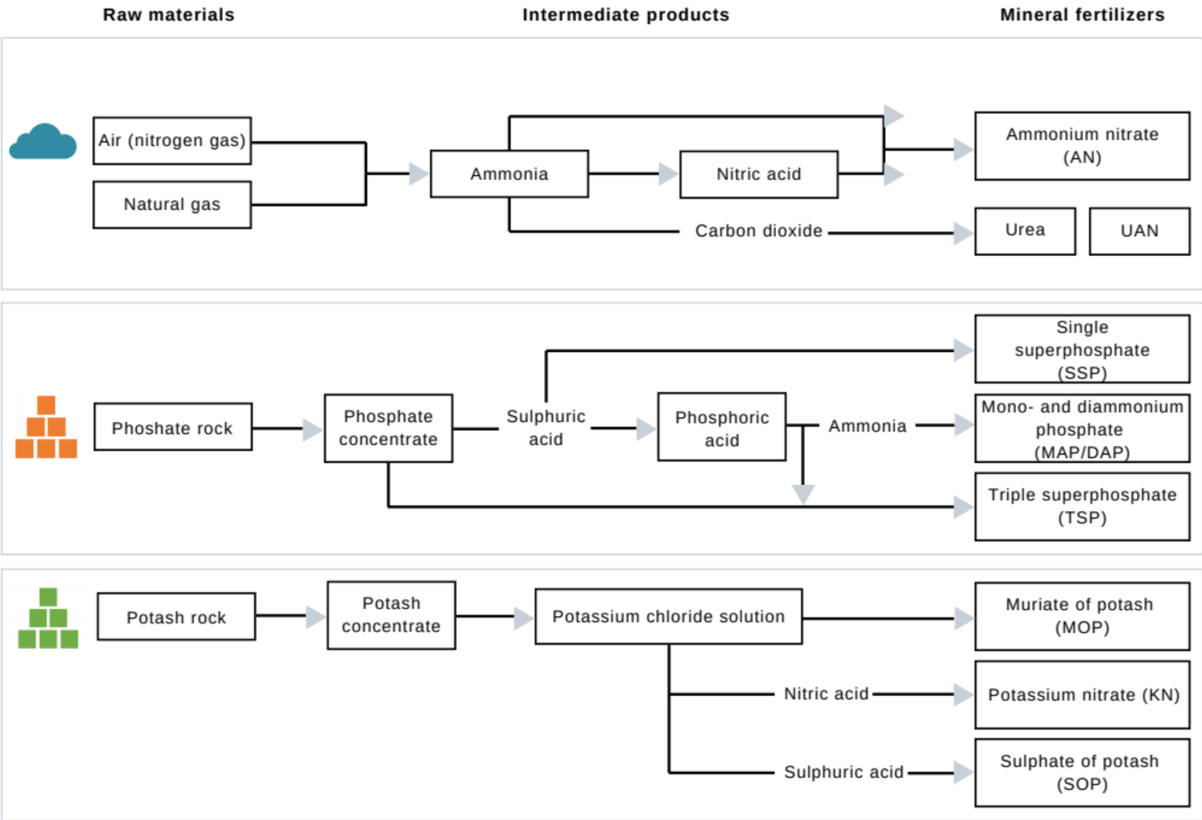

Figure 2. The production chains of the main fertilizer products (Fertilizers Europe 2016, 10).

As in industry sectors in general, the production and use of fertilizers cause GHG emissions either directly or indirectly during their life cycles. Gases considered as GHGs are naturally occurring gases, such as carbon dioxide (CO_2), methane (NH_4), water vapor (H_2O), nitrous oxide (N_2O), and ozone (O_3), as well as human-made GHGs, including gases such as chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs). (NOAA 2020.) In addition, there is a set of gases that, despite not being included in global warming potential-weighted GHG emission totals, are still reported in GHG inventories due to their indirect impacts on atmospheric warming. These gases include carbon monoxide (CO), oxides of nitrogen (NOx), non-methane volatile organic compounds (NMVOCs), and sulfur dioxide (SO_2). For example, in the presence of sunlight, CO, NOx, and NMVOCs contribute to the formation of O_3, which is noted as a direct GHG. Moreover, SO_2 and NH_3 contribute to aerosol formation. (Gillenwater et al. 2006, 7.4.)

Carbon dioxide and nitrous oxide are the main direct and indirect GHG emissions contributed by the fertilizer industry through the different life cycle stages (IFA 2009, 1). The shares of emitted GHG emissions in different fertilizer life cycle stages (excluding raw material extraction) are shown in Table 1.

Table 1. GHG emissions directly related to fertilizer production (IFA 2009, 1).

Activity	Share of global GHG emissions
Fertilizer production	0.93%
Fertilizer distribution	0.07%
Fertilizer use	1.5%
Total	2-3%

Furthermore, as noted earlier, fertilizer production is energy-intensive, and energy consumption is associated with GHG emissions (see chapter 1). A majority of the energy use is attributed to nitrogen fertilizer production done with natural gas, which is the principal source of hydrogen in the production of ammonia. Ammonia and/or other fertilizer elements derived from ammonia are used in over 90% of nitrogenous fertilizers. **(**Gellings & Parmenter 2009, 130.) The energy requirements of the life cycles of different fertilizer types differ. Table 2 shows the energy requirements of nitrogen, phosphorus, and potash fertilizers.

Table 2. Average energy requirements of nitrogen, phosphate, and potassium fertilizers (Gellings and Parmenter 2009, 130).

	Average energy requirement (world) (GJ/t)		
	Nitrogen	**Phosphorus (phosphate)**	**Potash**
Production	69.5	7.7	6.4
Packaging	2.6	2.6	1.8
Transport	4.5	5.7	4.6
Applying	1.6	1.5	1.0
Total	78.2	17.5	13.8

It is noted that the chemical industry has invested tremendously in energy efficiency improvements and the reduction of energy consumption across the world; Europe being amongst the leading regions (Valencia 2013, 171). The drop in energy consumption in the EU has been almost 25% between the years 1990–2017, with nearly half of the decline resulting from a reduction in gas consumption as an energy source (Cefic 2020, 50). The chemical industry has also managed to reduce its GHG emissions by implementing energy management practices and through technical solutions. In the EU, between the years 1990–2017, total GHG emissions of the chemical industry have fallen drastically - by nearly 60% from the 1991 levels

- when, at the same time, the production has grown by almost 85%. The decline in GHG emissions is associated with a shift to less carbon-intensive energy sources as well as the abatement of nitrous oxide, which has a higher global warming potential compared to carbon dioxide. Additionally, the development of cleaner technologies and an increase in energy efficiency - both in the processes of the chemical industry and downstream users - by way of innovations in the chemical industry have been many of the reasons behind this desired reduction in GHG emissions. (Cefic 2020, 65, 72.)

This chapter describes the life cycle of fertilizer and discusses the release of GHGs into the atmosphere during the different stages of the inorganic fertilizer life cycle. The following stages are included in the aforementioned as well: raw material extraction (including nitrogen, phosphate, potash, and natural gas), production (including the production of intermediate products and the final product), and transport and application of the final product on fields. Due to the energy-intensity of especially the production stages, optimal energy consumption, energy use, and the improvement of energy efficiency can also be claimed to play a role in terms of emissions reduction opportunities, although it is not necessarily deemed as separate in the following sections.

2.1 Raw Material Extraction

Two of the three main macronutrients used in inorganic fertilizer production are obtained by mining. In commercial fertilizers, most phosphorus is obtained from phosphate rock which often remains in sedimentary deposits in marine environments from which it is mined and converted into phosphate fertilizers (The Fertilizer Institute 2016, 7; Jasinski 2013). The term “phosphate rock” is vaguely defined, and it can mean both unprocessed rocks as well as beneficiated concentrates (IFDC & UNIDO 1998, 90). In the field of agriculture, the term “rock phosphate” is also frequently used (Chandrajith & Dissanayake 2009, 153). Potassium is often obtained from mineral deposits of potassium chloride, after which it is crushed and purified by removing the rock particles and salt (The Fertilizer Institute 2016, 7; Yara 2020a). Nitrogen, on the other hand, originates from the atmosphere (Yara 2020a). Natural gas, which is considered the fastest burning and cleanest fossil fuel, is obtained underground (IEA 2019b; Bowden 2015, 14).

The emissions arising from natural gas extraction are mainly linked to its properties. Because natural gas is often a byproduct of the oil drilling process, it sometimes ends up being burned in a process called flaring, due to difficult and expensive capture and transport, which significantly contributes to global warming. The turning of natural gas into liquified natural gas is one possible solution for easing capture and transport, and thus avoiding the wasting of usable resources. (Bowden 2015, 14.)

Before entering the international market, most phosphate ores must be concentrated or beneficiated, giving space for a variety of beneficiation techniques and thus to further variations in the finished product. This puts pressure on phosphoric acid technology, which has to rely on the uneven consistency of raw materials and must be constantly ready to adapt to meet new variables within raw materials. (European Commission 2007, 216.) Fertilizers Europe (2016, 29) states that beneficiation is often necessary, which, in a practical sense, means that the mined mixture of rock, clay, and sand is turned into a slurry and directed to the beneficiation plant where it goes through a series of steps, such as washing stations and vibrating screens. UNEP (2001, 14) studied the environmental aspects of phosphate and potash mining and discovered emissions that might affect air quality. These include exhaust gases and particles, such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur oxides (SOx), volatile organic compounds (VOCs) originating from fueling and a variety of workshop activities, and methane (CH_4), which can be released from geological strata. (UNEP 2001, 14.)

Because the emissions from raw material extraction originate mostly from exhaust emissions from power generation, engines, and product dryers of mining activities, improvements in energy consumption and emissions reduction technologies - as well as the improvement of utilized fuels - could reduce the related emissions, particles, and gases (UNEP 2001, 26). Opportunities for utilizing recycled material as sources for phosphate, potash, and nitrogen in the future have also been identified (Yara 2018b, 37).

2.2 Production

The production of fertilizers is highly fragmented. The top five global fertilizer companies account for only about 17.5% of the market share (Statista 2020). In Europe, there are over 120 production sites with a total of 75,800 employees, including supply chains (Fertilizers Europe

2019, 8). The production of fertilizers can be divided according to the main nutrient content into nitrogen fertilizer, phosphate fertilizer, and potassium fertilizer production. GHG emissions from the production of different fertilizer types vary. The ranges of GHG emissions from the production of nitrogen, phosphorus, and potassium fertilizers are shown in Table 3 below. As seen in Table 3, the production of nitrogen fertilizers releases the majority of emissions amongst these three fertilizer products.

Table 3. GHG emissions from the production of nitrogen, phosphate, and potassium fertilizers (Kirchmeyr et al. 2016, 21, 24, 27).

Fertilizer product (nutrient)	**GHG emissions [CO_2-eq/t nutrient]**
Nitrogen fertilizers (N)	1.13-8.65
Phosphorus fertilizers (P_2O_5)	0.55-1.18
Potassium fertilizers (K_2O)	0.41-0.64

The main pollutant exhaust gases that rise from three-component (NPK) fertilizer production are nitrogen oxides (NOx) from the dissolution of phosphate rock in nitric acid and ammonia (NH_3), which mostly originates from neutralizing ammonia with nitric acid to produce ammonium nitrate. Also, fluorine compounds may be released from phosphate rock, but in practice, most of these compounds are embedded in the final product, and only a part of them are released in their gaseous form. (European Commission 2007, 288–299.) In terms of the carbon footprint of intermediate products and fertilizer production as a whole, ammonia production uses the most energy and, therefore, causes the most energy-related emissions - such as CO_2 - whilst nitric acid production is the main source of N_2O emissions (Gowariker et al. 2009, 215; Yara 2020k).

Optimum exhaust gas treatment depends on several variables, such as the type of production process at play or the source of emissions. The treatment of exhaust gases may include different techniques, such as scrubbing, filters, or vapor neutralization. Also, techniques such as SCR (selective catalytic reduction), SNCR (selective non-catalytic reduction), and NSCR (non-selective catalytic reduction) are commonly used to reduce production-related NOx and N_2O emissions. Production-related emissions can also be reduced by careful raw material selection. (European Commission 2007, 132, 241, 288–299, 320.)

In short, SCR is based on using a catalyst (often oxides of metal, e.g. platinum) to render NOx gases into nitrogen and water vapor. Ammonia works oftentimes as a reductant at fertilizer production plants since it is easily available. (European Commission 2007, 132; Fertilizers Europe 2000a, 18.) SNCR technology also renders NOx gases into nitrogen and water at a high temperature, but without a catalyst (European Commission 2007, 73). In the NSCR process, fuel (e.g. natural gas) reacts with NOx and free oxygen over the catalyst and produces nitrogen and water. The process is called non-selective, because oxygen in the tail gas is depleted first, before NOx and N_2O, which the process also removes simultaneously. (European Commission 2007, 130; Fertilizers Europe 2000a, 17.)

2.2.1 Nitrogen Fertilizers

The most consumed nutrient in fertilizer production is nitrogen, accounting for about 60% of the total consumption (Yara 2018a, 17, 20). Nitric acid - an intermediate product in fertilizer production - is one of the most produced chemicals globally (European Commission 2007, 95). Another intermediate product, ammonia, is a raw material for nitric acid production and, eventually, for nitrogen-based fertilizer production. A majority of emissions into the atmosphere from inorganic nitrogen fertilizer production are N_2O and CO_2 (Antman et al. 2015, 190).

Ammonia is a feedstock for about 97% of nitrogen-based fertilizers, and its production is the most energy consuming process in nitrogen fertilizer production (European Commission 2007, 2; Woods et al. 2010, 3002–3003). The ammonia production process accounts for 80-90% of the total energy use of the fertilizer industry (Valencia 2013, 60). More than 96% of ammonia is produced by a method called the Haber-Bosch process, which happens under high pressure, high temperature, and in the presence of a catalyst. Hydrogen, which is often derived from natural gas, is combined with nitrogen captured from the atmosphere. (Smith et al. 2020, 332; Yara 2018a, 67.) The Haber-Bosch process alone is currently responsible for 1.2% of the global anthropogenic CO_2 emissions. Currently, the best available technique (BAT) is to use methane-based processes in ammonia production. (Smith et al. 2020, 332.) Although natural gas - mostly consisting of methane - is the most common source of hydrogen in nitrogen fertilizer plants used to produce ammonia, any type of hydrocarbon or coal can be used in production. The development of technology in the 20th century and the change of the energy base have improved energy efficiency of the process. (Yara 2018a, 69.) The Haber-Bosch process is presented in Figure 3.

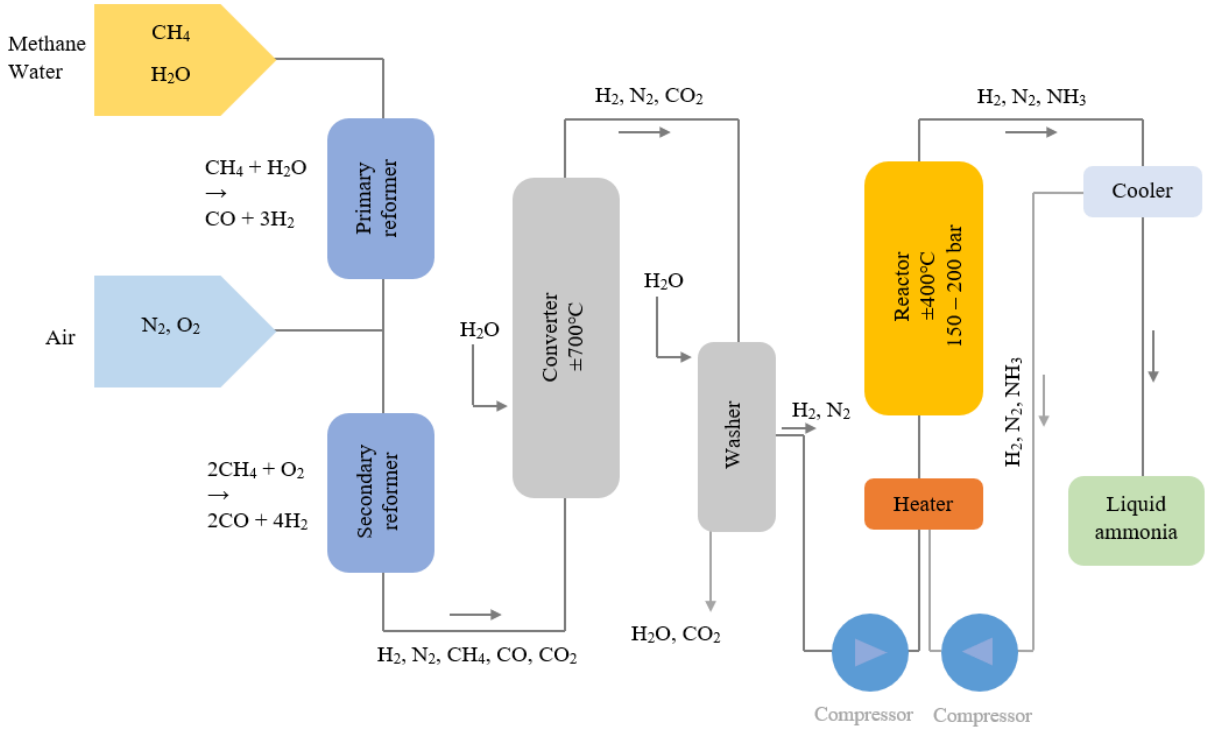

Figure 3. Ammonia production by the Haber-Bosch process (Fertilizers Europe 2016, 28).

The emissions from ammonia production are mainly CO_2 emissions due to the use of fossil fuels as a feedstock, but also fewer amounts of sulphur and NOx are emitted. Ammonia can also enter the atmosphere through leakages, which can be prevented, for example, by adequate storage, handling, and transportation practices. (Gowariker et al. 2009, 215.) Some of the CO_2 which is produced as a byproduct of ammonia production can be utilized at the urea plants for use as a feedstock for the production of urea fertilizers, but CO_2 captured in urea will eventually be released after being spread on the fields (Gowariker et al. 2009, 215; Yara 2020j). CO_2 can also be treated with CO_2 removal systems, such as by scrubbing with a solvent. NOx emissions can be controlled e.g. by SNCR technology, or by using low NOx burners - which is based on controlling combustion circumstances. (European Commission 2007, 73, 75, 87.)

The opportunities to reduce emissions and improve energy efficiency of the methane-fed Haber-Bosch process (and the chemical industry in general) include, for example, the electrification of the process, improving of energy efficiency, and powering the energy-intensive ammonia synthesis process with renewable energy (Hawtof et al. 2019, 1; Smith et al. 2020, 333). In this case, methane could in theory be replaced, as both a feedstock and a fuel, by a renewable energy source, which could fulfill all the energy requirements (Smith et al. 2020, 333). This is to answer the environmental, energy-related, and social challenges posed by the process, which still consumes more energy and causes more GHG emissions compared to any other process associated with high-volume global chemical manufacturing (Hawtof et al. 2019, 1). Because the majority of direct CO_2 emissions from the Haber-Bosch process originate from the use of methane as a feedstock rather than using it as a fuel, shifting the hydrogen production method from a methane to a renewable energy -powered electrolysis of water would remarkably reduce direct emissions into the atmosphere. This so-called green ammonia would also offer important opportunities for the storage of renewable energy. (Smith et al. 2020, 333–334, 338.) Fertilizers Europe (2019, 17) recognizes that electrolysis is a climate-friendly, but not currently economically viable way to produce the hydrogen needed for ammonia production.

Nitric acid is produced by combusting (oxidizing) ammonia (NH_3) in a process called the Ostwald process (Figure 4). Globally, most nitric acid is used for the production of fertilizers. Depending on the application, weak (50–65%) and strong acids (up to 99%) can be produced. Nitric oxides (NOx) and nitrous oxide (N_2O) are unintentionally formed byproducts of ammonia oxidation. (European Commission 2007, 95.)

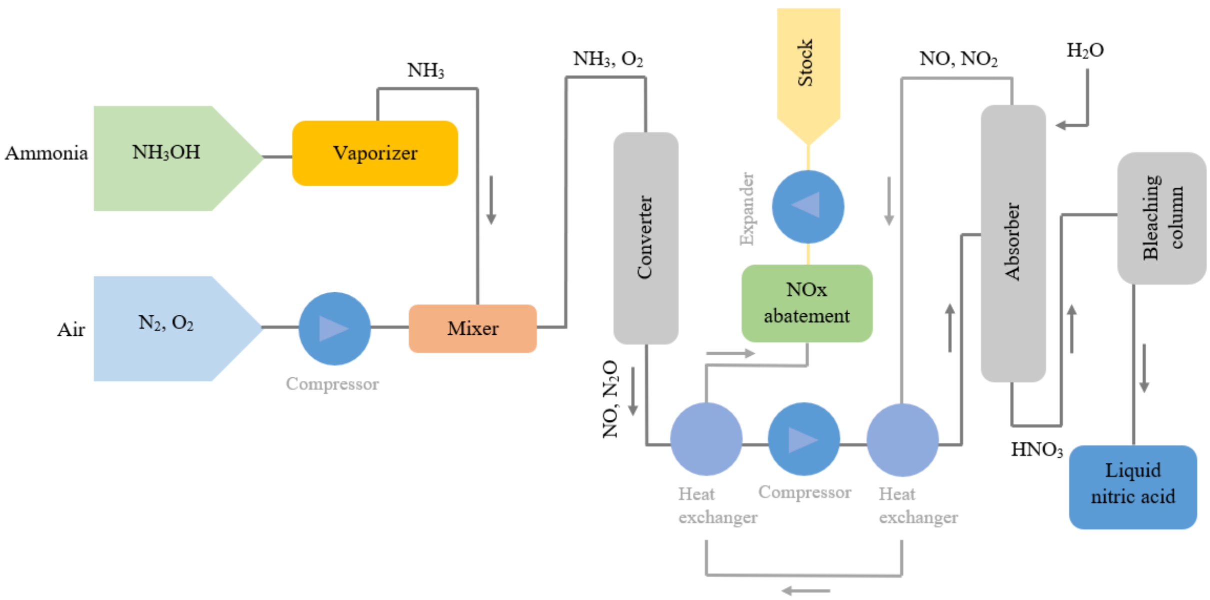

Figure 4. Production of nitric acid by the Ostwald process (Fertilizers Europe 2016, 29).

Nitrous oxide emissions of the chemical industry were reduced by a remarkable 63% during the years 2008–2011, mostly because of the introduction of emission reduction measures (the development and introduction of catalysts) at Yara Suomi Oy's nitric acid plants in Siilinjärvi and Uusikaupunki (Statistics Finland 2013, 28). Today, about 70–90% of N_2O emissions leaking into the atmosphere from nitric acid plants are estimated to be captured and catalytically destroyed (Woods et al. 2010, 3003). Also, NOx and N_2O emissions reduction techniques, such as alterations of the combustion process by e.g. controlling temperature or pressure - as well as SCR and NSCR technologies - can be used for NOx and N_2O emissions treatment at nitric acid plants (European Commission 2007, 99, 113).

The production of the final product - nitrogen-based fertilizers - begins with reacting nitric acid with ammonia, whereby concentrated melt is formed. The melt is then solidified later by way of granulation or another similar process to produce the final product - nitrate-based fertilizers, such as ammonium nitrate (AN) and calcium ammonium nitrate (CAN). As mentioned earlier, ammonia can also be mixed as such with CO_2 to form urea. Furthermore, AN and urea can be combined and mixed with water to obtain a fertilizer solution called urea-ammonium nitrate (UAN). (Fertilizers Europe 2016, 28.)

2.2.2 Phosphate Fertilizers

Phosphate-based fertilizer production starts with digesting phosphate rock with a strong acid (such as sulphuric acid, H_2SO_4) to produce a single superphosphate (SSP) or phosphoric acid. The obtained phosphoric acid can either be reacted with ammonia to form fertilizer products - such as diammonium phosphate (DAP) and monoammonium phosphate (MAP) - or it can be reacted again with phosphoric acid to get triple super phosphate (TSP). Oftentimes, phosphate is reacted with nitric acid in a process called the "nitrophosphate process" to attain several types of NPK fertilizers. (Yara 2018a, 67; Fertilizers Europe 2016, 29.) The production process of phosphoric acid is shown in Figure 5.

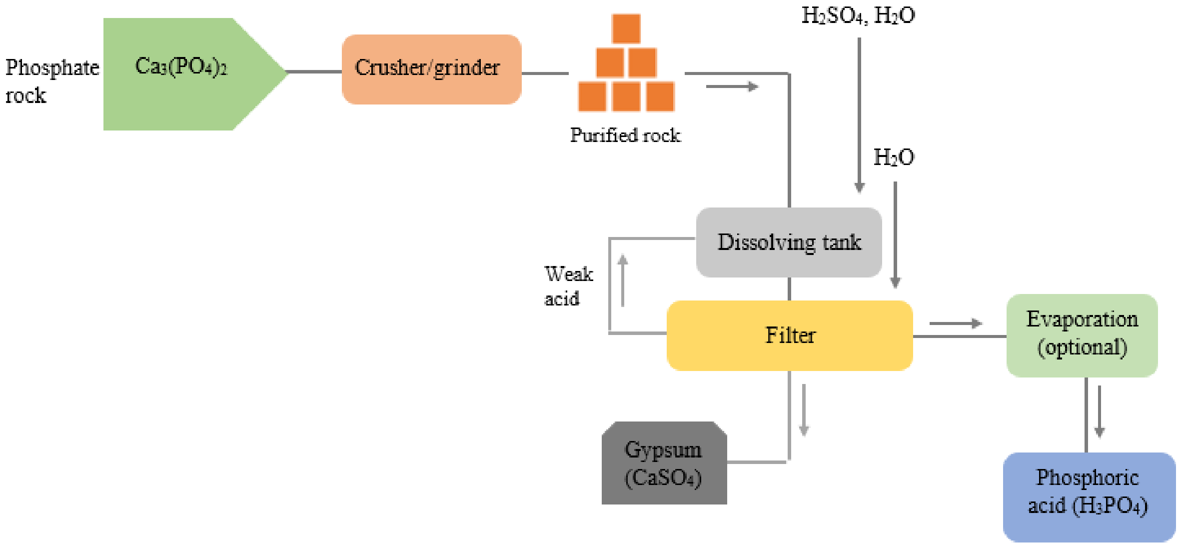

Figure 5. Production chart of phosphoric acid (Fertilizers Europe 2016, 29).

70% of phosphate fertilizers are derived from phosphoric acid (H_3PO_4), which itself is a water-soluble, colourless compound (European Commission 2007, 2, 213). Although most GHGs (mainly CO_2) in fertilizer production are emitted due to the use of fossil fuels in the production of ammonia, reactions of sulphuric acid with phosphate rock also cause emissions to a lesser extent (Hasler et al. 2015, 46). Regarding NOx emissions from the phosphate rock digestion process and other stages of fertilizer production, the amount of released emissions can be minimized by, for example, scrubbing, temperature control, or careful phosphate rock selection (European Commission 2007, 297, 312). Some of the other emissions, such as ammonia and fluorine, are scrubbed with water and/or acids. Additionally, emissions formed during the granulation stage can be treated, for example, with cyclone separators. (Gowariker et al. 2009, 215.)

Also, gypsum is formed as a co-product of phosphoric acid production (European Commission 2007, 221). Emissions related to the atmosphere are most probably caused when gypsum is transported to its storing place, places for possible disposal, or for utilization. The purity of gypsum, which is dependent on the purity of phosphate rock, is relevant in terms of its further utilization opportunities (European Commission 2007, 221). It could be argued that the more this byproduct can be utilized, the less energy is wasted in the production of phosphoric acid, and the more energy is saved with regard to the new application. Gypsum is suited especially well for reducing phosphorus leaching into clay soil, further reducing the erosion and leaching of dissolved and soil-bound particulate phosphorus into water bodies with runoff water (Ollikainen et al. 2018, 4, 10).

2.2.3 Potassium Fertilizers

Since mined potassium ore often includes plenty of potassium and sodium chloride salts, these components need to first be separated from each other by using processes such as thermal dissolution (Figure 6). Muriate of potash (potassium chloride, MOP) is first attained in the separation process, after which the potassium fertilizer can be treated further with sulphuric or nitric acid to produce sulphate of potash or potassium nitrate. (Fertilizers Europe 2016, 10, 30.) Blanco (2011, 23) states that, contrary to nitrogen and phosphorus fertilizer products, the production of potassium fertilizer does not have as significant an effect on environmental quality. Finding more accurate information related to the GHG emissions of potassium fertilizer production was found to be challenging.

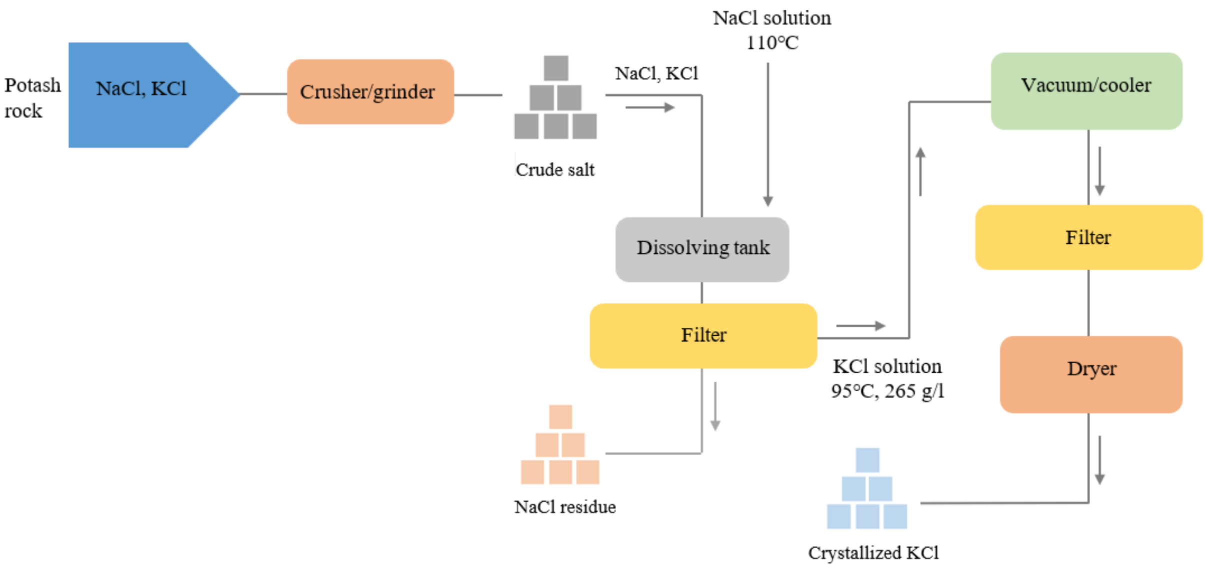

Figure 6. Production of muriate of potash (MOP) via thermal dissolution process (Fertilizers Europe 2016, 30).

2.3 Transport and Application of Fertilizer

The transportation of raw materials, fertilizer pre-products, and final products has many stages, including transport at the mining and manufacturing sites, as well as during the distribution of the products to different retailers, and finally, to the fields on which they are used. The need for transport of the fertilizer raw materials and the final product highly depends on the locations of the raw material sources, different production sites, and final application sites. For example, in Europe, a majority of the raw materials that are needed to produce fertilizers - including natural gas, phosphate, and potash - are found only to a limited extent, and are, therefore, often imported from outside the continent. (Fertilizers Europe 2016, 25.) GHG emissions from traffic mostly originate from the use of fossil fuels. The emissions caused by transportation can be reduced, for example, by reducing the mileage for transport, improving the energy efficiency of the vehicles used, and by increasing the use of renewable energy sources (Soukka 2018, 48). Also, producing fertilizers with a high nutrient content, consolidation of freights, and emissions abatement techniques can be used to address the emissions caused by transportation (IFA 2009, 3).

In addition to energy used for the application of fertilizer on fields, emissions into the atmosphere can also be caused by the inorganic and organic fertilizer application. Emissions depend on the fertilizer type. The total GHG emissions of the application of nitrogen, phosphate, and potassium fertilizer are in Table 4.

Table 4. The global average GHG emissions from the use of N, P_2O_5 and K_2O fertilizers (Kool et al. 2012, 13).

	CO_2-eq per kg N	**CO_2-eq per kg P_2O_5**	**CO_2-eq per K_2O**
Global average	5.66	1.36	1.23

As seen in Table 4, most of the GHG emissions originate from the use of nitrogen fertilizers, and emissions arising from the use of fertilizers is, therefore, often focused on nitrogen fertilizers. These GHG emissions from nitrogen fertilizer use mainly consist of N_2O and other gases, such as ammonia. An optimum application rate, adequate fertilizer formulation, the right timing, and right placement (applying fertilizer as close to the crops' root zone as possible) are the most common management practices used for the reduction of N_2O emissions. The results also depend on soil and weather conditions. The other mitigation techniques - such as selecting low N-demanding crops and irrigation management - have also been studied. (Millar et al. 2014; Yara 2020j.) To optimize use and decrease harm for the environment via inadequate or excessive use of fertilizers, fertilizer companies promote crop-specific nutrition advice and fertilizer management tools, software, and services (Marshall & Duncan 2007, 237; Yara 2020j). It can be concluded that excessive fertilization also affects the amount of energy consumption and energy-related emissions, as well as other production-related emissions at the earlier stages of the fertilizer lifecycle due to need for higher production volumes - which, again, makes the optimization of fertilizer use rational.

3 TOOLS FOR COMPANIES TO ASSESS AND MITIGATE GHG EMISSIONS

The Paris Agreement, which was adopted in 2015 by the United Nations Framework Convention on Climate Change (UNFCCC), commits the participating countries to take action in order to globally respond to the threat of climate change and limit the increase of global temperature to well below two degrees Celsius above pre-industrial levels (Paris Agreement 2015, art. 2). The agreement has established a strong basis for GHG mitigation tools to be created and assist with meeting the climate goals.

Companies of different sizes can have a variety of motivational drivers for cutting their GHG emissions, such as achieved savings and improved competitiveness through e.g. decreased need for emissions trading allowances, enhancement of reputation, and other external and/or internal requirements and targets. This section discusses some of the tools through which the companies can assess and mitigate environmental impacts from the perspective of GHG emissions. The tools covered in the following chapters are the GHG Protocol standards, the science-based targets, and the ISO 14064 standard. The ISO 50001 standard on energy management systems - which could also be used as a tool for GHG mitigation - will be discussed separately and more in depth in chapter 4 due to the standard being the main focus of this work.

3.1 The GHG Protocol Standards

The GHG Protocol, which was convened in 1998 by the World Resources Institute and the World Business Council for Sustainable Development, works with governments, non-governmental organizations, industry associations, and business and other organizations, and provides standard**s** and calculation tools for measuring GHG emissions as well as guidance for accounting for GHG emissions throughout value chains (The Greenhouse Gas Protocol 2020a; Newton & Cantarello 2014, 90). When the GHG emissions are recognized and measured, they are more convenient to manage due to having the fact-based information. To answer the need for standardized measurement of GHG emissions, the first edition of the GHG Protocol

Corporate Accounting and Reporting Standard (Corporate Standard) - which provides requirements and guidance for preparing a GHG emissions inventory - was published in 2001 (The Greenhouse Gas Protocol 2004, 3). A majority of companies use the tools and standards from the GHG Protocol to measure and manage the GHG emissions from their own operations as well as from their value chains (The Greenhouse Gas Protocol 2020a; Newton & Cantarello 2014, 90).

The GHG Protocol divides scopes for accounting emissions into three categories - scope 1, scope 2, and scope 3 - to clearly define direct and indirect emission sources, improve transparency, and aid a variety of climate policies and organizations. Scope 1 emissions are direct emissions which originate from sources that the organization owns or is able to control. Scope 2 covers GHG emissions from the generation of purchased or other electricity that is otherwise brought inside the organizational boundaries. Finally, scope 3 accounts for the treatment of other indirect emissions that are not owned or controlled by the organization. An example of scope 3 activity is the extraction of purchased raw materials. Scopes 1 and 2 should always be included, whereas inclusion of scope 3 varies. (The Greenhouse Gas Protocol 2004, 25.)

Since the choice of scope (operational boundaries) affects which emissions will be covered, it presumably also has an effect on how large-scale the GHG emission reductions will be. Oftentimes, the amount of indirect emissions that can be excluded from the GHG inventory practices can be significant. For example, the Finnish postal service's (Posti Group Oyj) sustainability report shows that the scope 3 emissions in 2018 accounted for about 55% of total emissions (Posti 2018, 54). Still more jarring, a case study of the transportation and logistics company, DHL Express Nordic, found that outsourced transportation services accounted for 98% of the company's emissions in Sweden (The Greenhouse Gas Protocol 2004, 30).

Other GHG accounting standards by the GHG Protocol include the inter alia Corporate Value Chain (Scope 3) Standard on assessing the emissions of the entire value chain, GHG Protocol for Cities, and Product Standard, which allows the organizations and public actors to understand the life cycle emissions and greatest GHG reduction potential of their products and/or operations (The Greenhouse Gas Protocol 2020b). After finding the potential, organizations are able to set GHG reduction targets. For instance, the technology company, Intel, managed to reduce its emissions by 60% below 2007 levels by the end of 2012 via the combination of developing renewable energy installations, renewable energy purchases, and improving its server systems (Russell 2014).

3.2 The Science Based Targets

The Science Based Targets initiative is a collaboration between the Carbon Disclosure Project (CDP), the United Nations Global Compact (UNGC), World Resources Institute (WRI), the World Wide Fund for Nature (WWF), and one of the We Mean Business Coalition commitments. The Science Based Targets initiative aims at driving corporate climate action by committing the corporations to a set of science-based targets to foster their competitiveness and profitability when transitioning to the low-carbon economy and striving to meet the climate targets set in the Paris Agreement. A target is “science-based” if it is in line with the current statements of climate science - which are needed in order to limit global warming to 1.5 ℃ and avoid the worst consequences of climate change. In addition, setting science-based targets is expected to increase innovation, reduce regulatory uncertainty due to being a step ahead of future policies, bolster credibility and investor confidence by being noticed as a responsible actor, and taking the lead on climate issues. (Science Based Targets 2020a; see Paris Agreement 2015.)

Joining the initiative includes four steps: 1. A commitment to work on setting the science-based emission reduction targets, 2. development of the target, 3. submission of the target for verification, and 4. announcement of the target. In addition to the criteria set by the Science Based Targets initiative, the criteria for verification partly follows the Corporate Standard, Corporate Value Chain (Scope 3) Standard, and Scope 2 Guidance by the GHG Protocol. (Science Based Targets 2020a; Science Based Targets 2020b, 3.) After setting the science-based targets as a part of business practices, the companies have a clear pathway to operate in the future by specifying how much and how rapidly their GHG emissions need to be reduced (Science Based Targets 2019, 5–6).

The number of companies which have joined, representing several business sectors, was around 700 in 2019. Science-based targets of 285 companies have been approved by the initiative. Achieving the targets of these companies means a reduction of one third (265 million tons of

CO_2-eq) of their baseline emissions, which corresponds to shutting down 68 coal-fired power plants. (Science Based Targets 2019, 3, 19.) 15 Finnish companies had set, or were about to set science-based targets in 2019 (WWF 2019).

3.3 ISO 14064 on GHG Accounting and Verification

Briefly, the International Organization for Standardization (ISO) is a non-governmental, non-profit, international organization which aims to make products compatible, identify safety issues of products and services, and share ideas, solutions, technological know-how, and best management practices by means of the ISO standards. An international standard is a document containing best practice and practical information, and it also often describes guidelines for doing something or provides a solution to a global problem. (International Organization for Standardization 2019b, 3–4.) ISO 9000 on quality management and ISO 14000 on environmental management are some of the most widely-used and well-known ISO standard families (International Organization for Standardization 2020).

ISO 14064 is a part of the ISO 14000 family on environmental management, which provides requirements, guidelines and approaches for the organizations to measure and control their GHG emissions through preparing and producing GHG inventories (Gonçalves & Pao 2011, 5). The standard has three parts: the first part sets requirements for the design and development of the GHG inventory of the organization; the second part defines requirements for measuring, monitoring, and reporting of GHG emission reductions; and part three gives both requirements and guidelines for validating and verifying the GHG data. These parts can be used either as stand-alone standards, or as an integrated entity (Estrada 2011, 4.) The main aim of the ISO 14064 standard is to improve both the transparency and credibility of accounting and reporting GHG emissions (Gonçalves & Pao 2011, 5). The GHG Protocol Corporate Standard is consistent with the ISO 14064 standard (Bhatia & Ranganathan 2011).

4 REQUIREMENTS OF THE ISO 50001 STANDARD

The second edition of the international standard for energy management systems, ISO 50001:2018, was approved in August 2018, cancelling and replacing the previous edition, ISO 50001:2011. The changes of the new edition aim to ensure a high level of compatibility with other management system standards, emphasize the role of top management, clarify language, terms, and concepts, and so on. (SFS-EN ISO 50001:2018, 1, 4.)

The ISO 50001 EnMS can be applied to diverse organizations, taking into account the available resources, degree of documented information, and complexity of their systems. Implementation of an EnMS enables an organization to set and achieve objectives and energy targets, as well as to take necessary actions to meet them. In addition to objectives and energy targets, the key elements of the EnMS include establishing an energy policy and an energy management team, creating action plans related to energy use, energy consumption, and energy efficiency, and creating processes for measuring energy performance. Requirements of the standard do not apply to the activities outside the set scope and boundaries. (SFS-EN ISO 50001:2018, 6.)

The EnMS described in ISO 50001:2018 is based on an iterative Plan-Do-Check-Act model which aims at embedding energy management into existing organizational practices. *Plan*, in this context, refers to understanding the context of the organization, establishing an energy policy and energy management team, conducting an energy review, identifying significant energy uses, and establishing energy performance indicators, energy baselines, and action plans in order to achieve the set objectives and energy targets. *Do* refers to the implementation of the action plans, controlling operations and maintenance activities, and communication. In addition, energy performance must be taken into account in the design and procurement steps. *Check* refers to monitoring, evaluating, reviewing, analyzing, and auditing the EnMS and energy performance. Finally, *Act* aims at taking actions to address nonconformities and, therefore, to continually improve both the EnMS and energy performance of the organization. (SFS-EN ISO 50001:2018, 6.) The content and sections of the ISO 50001 standard are in Figure 7. Note: The sections in this thesis do not follow the specific format of the standard.

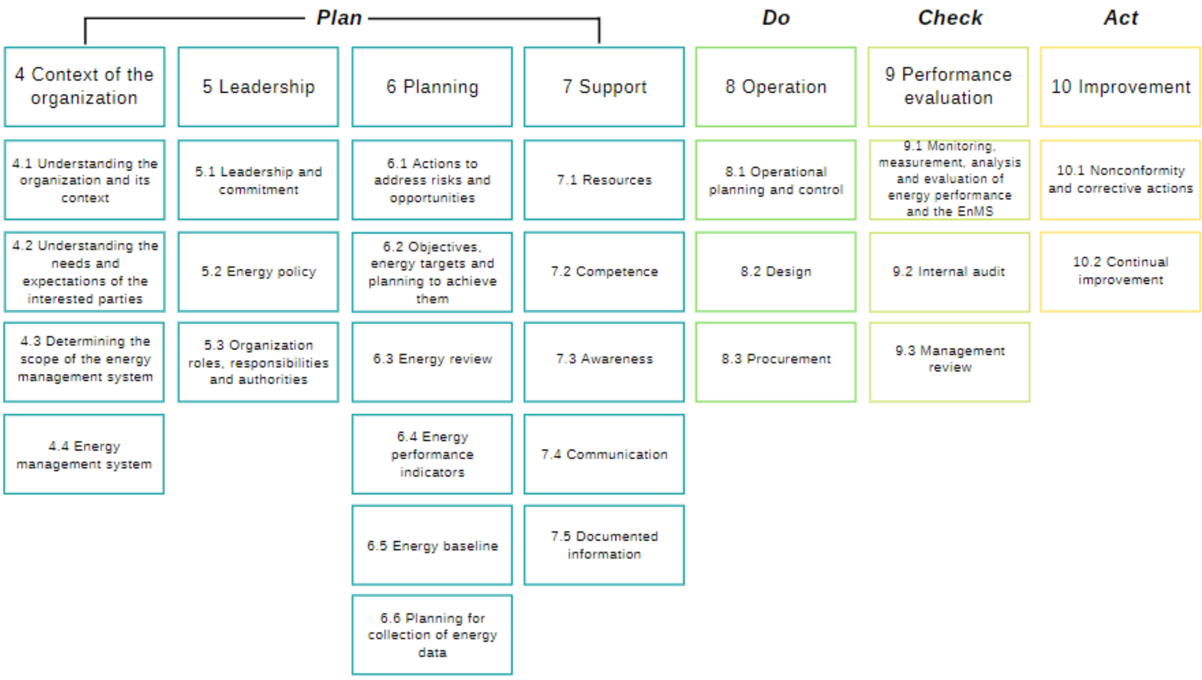

Figure 7. The structure of the SFS-EN ISO 50001:2018 standard (adapted from NQA n.d., 11).

The ISO 50001 standard for energy management systems is promoted as a tool for providing organizations guidance and requirements for establishing an EnMS through which they can continually improve their energy performance, improve competitiveness and reduce their energy-related GHG emissions (SFS-EN ISO 50001:2018, 6, 8). An effective implementation of the standard can be claimed to hold a legitimate possibility to mitigate climate change through energy management practices, since energy consumption and use are known to be a remarkable contributor to emissions into the atmosphere. McKane et al. (2017, 278, 285) project that an uptake of the standard at a level of 50% in the industrial and commercial sectors could result in a cumulative energy savings of approximately 105,000,000,000 GJ (105 EJ), which is comparable to the removal of 210 million passenger vehicles from traffic.

4.1 Context of the Organization

First, the organization shall determine external and internal issues that are relevant to its purpose and affect its ability to achieve the intended outcome(s) of its EnMS and improve its energy performance. To assess the capability of the organization to achieve its energy targets, external and internal issues relevant to its purpose must be determined (SFS-EN ISO 50001:2018, 15). The issues, that can affect energy consumption and the ability to positively or negatively reach the intended outcome(s) can be, for example, available human and financial resources, existing development plans, the existing stage of energy management culture, legal requirements, weather conditions, and so on (see Figure 8) (SFS-EN ISO 50001:2018, 28).

Internal issues

- Core business objectives and strategy
- Asset management plans
- Financial resources
- Maturity and culture of energy management
- Sustainability considerations
- Plans for interruptions in energy supply
- Maturity of existing technology
- Operational risks and liability considerations

External issues

- Issues related to interested parties (e.g. national and sector objectives, standards, requirements)
- Restrictions or limitations on energy supply, security, and reliability
- Energy costs or the availability of types of energy
- Effects of weather
- Effects of climate change
- Effect on greenhouse gas (GHG) emissions

Figure 8. Examples of internal and external issues affecting energy consumption (SFS-EN ISO 50001:2018, 28–29).

In addition to determining external and internal issues, the organization shall also understand the needs, expectations, and possible requirements of interested parties (later referred to as "stakeholders") (SFS-EN ISO 50001:2018, 15, 28). Identifying stakeholders with regard to energy performance and the EnMS allows the discovery of views and issues that the company might consider as possible legal and other compliance obligations for the future EnMS (NQA n.d., 13). The organization must ensure that legal and other requirements related to energy use, energy consumption, and energy efficiency are available and assess how these affect the organization's energy consumption and energy efficiency. These requirements must be taken into account in the planning of an EnMS and reviewed at specified intervals. (SFS-EN ISO 50001:2018, 15.)

The extent and breadth of the EnMS is set when the context, interested parties, and their needs and expectations are comprehensively understood (NQA n.d., 13). Defining this extent is limited by the fact that the organization must be able to manage energy performance within the set scope and boundaries. Also, no energy type within the scope and boundaries shall be excluded. (SFS-EN ISO 50001:2018, 15.) The scope and boundaries can be extended later if doing so is considered necessary. The new changes shall be documented, then the certification authority informed and then included in the surveillance inspections and recertification visits to follow. (Cosenza et al. 2018, 15.)

4.2 Leadership

Top management holds the overall accountability for meeting the requirements of the ISO 50001 standard, even if, for instance, it delegates the responsibilities of the energy management to a founded energy management team (SFS-EN ISO 50001:2018, 29). Regardless of the motivational drivers behind establishing the energy management program, the role and commitment of top management is essential to ensure successful establishment, implementation, and continual improvement of the EnMS (Smith & Parmenter 2015, 47). Top management must commit to continual improvement of energy performance and the effective application of the EnMS in the organization (SFS-EN ISO 50001:2018, 16).

The first task of top management is to define and create an energy policy that sets the basis for the future EnMS and the activities therein. In practice, the energy policy can be a one-page commitment signed by top management including a commitment to legal compliance, continually improving energy performance and the EnMS of the organization, effectively supporting energy performance improvements in procurement and design activities, and ensuring the availability of adequate information and resources in order to reach the objectives and energy targets. The documented policy needs to be communicated within the organization, available to interested parties steadily or upon request, and reviewed and updated if necessary. (SOGESCA 2017, 22–23; SFS-EN ISO 50001:2018, 16–17; SFS-EN ISO 50004, 32.)

It is the responsibility of the top management to make sure that the energy management team with the relevant roles is formed and that the corresponding tasks are clear. The energy management team consists of person(s) with the responsibility and authority for the effective implementation of an EnMS and improving energy performance by making sure that the EnMS requirements are met, implementing the action plans, reporting on the performance, and establishing criteria and methods to ensure that the operation and control of the EnMS are effective. When determining the size of an energy management team, the size and nature of the organization, in addition to available resources, are considered. The energy management team can also consist of a single person. (SFS-EN ISO 50001:2018, 10, 16–17.) However, establishing a cross-functional team with members from all sections of the organization is considered good practice, especially in large organizations, since this approach engages different parts in energy planning and may also enhance, for example, the information flow inside the organization. The required level of competence for persons working within the EnMS is fully defined by the organization. (SFS-ISO 50004:2018, 7; SFS-EN ISO 50001:2018, 32.)

4.3 Planning

The energy planning process can be thought to consist of three parts, which are the planning inputs, planning itself, and planning outputs. The energy planning process is represented in the outline in Figure 9.

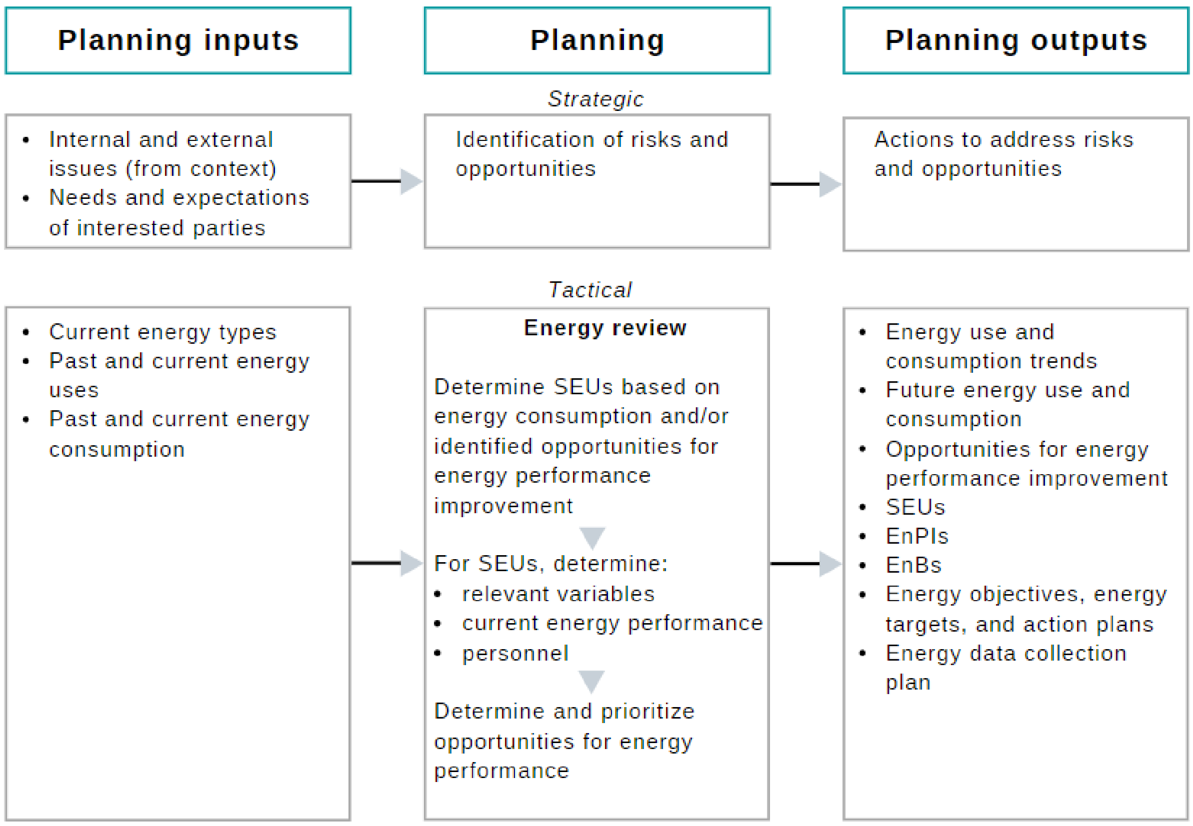

Figure 9. The energy planning process (SFS-EN ISO 50001:2018, 30).

The determination and evaluation of existing and potential risks and opportunities can prevent or reduce undesired effects and assure to a certain level that the EnMS of the organization can achieve the energy targets it has set. To address these discovered and analyzed risks and opportunities, the organization shall plan the necessary actions, how to integrate and implement them into the EnMS, and evaluate their effectiveness. (SFS-EN ISO 50001:2018, 17–18.)

The organization shall set and document the objectives and energy targets that can be both quantifiable (e.g. electricity consumption is reduced by 2% in process X by the 4th quarter) or qualitative (e.g. improving the culture of energy management at the site). These objectives and energy targets must be in accordance with the energy policy, measurable (if possible), monitored, effectively communicated, and appropriately updated. Also, all the applicable requirements, SEUs and the additional requirements related to them, and energy performance improvement opportunities must be taken into account. (SFS-EN ISO 50001:2018, 18, 30.) The rule of thumb is that the set energy targets need to be Specific, Measurable, Achievable, Relevant, and Time-based (SMART) (SFS-ISO 50004:2015, 16). Action plans of how these objectives and targets are achieved must be documented and include the answers to the following questions: what will be done, what are the needed resources, who is responsible, when will the action be completed, and how are the results evaluated (SFS-EN ISO 50001:2018, 18).

The organization must establish and conduct an energy review - a data-based analysis of energy use, energy consumption, and energy efficiency - based on which SEUs and opportunities for improvement of energy performance are discovered. The energy review must be regularly updated and respond to remarkable changes, but not all the parts of it need to be updated simultaneously. In addition, energy review can also take security and the availability of supplies into account - if it is considered appropriate by the organization. (SFS-EN ISO 50001:2018, 15, 19, 30–31.) The main goal is to understand what the near- and long-term trends regarding energy use are. For example, the amount of energy use, seasonal variations, coverage of the database, temporal variations in energy use, and past trends in energy costs are some of the variables that might be useful to be considered. Data needed for energy review can be gathered from facility records, invoices, inventories of equipment, production statistics, and so on. The smaller the data collection interval is, the more problems can be revealed, such as systems still operating while intended to be off. (Smith & Parmenter 2015, 51, 53.)

The methods and criteria used for its development, as well as the obtained results, shall be documented. As for the development of an energy review, according to the standard, the organization shall:

- Identify current energy sources and analyze past and current energy use and consumption;
- Estimate future energy use and consumption;
- Based on the analysis, name and assess SEUs - i.e. facilities, systems, processes, or equipment;
- Determine current energy performance, personnel, and other variables affecting the SEUs;
- Determine, prioritize, and document the opportunities for energy performance improvement. (SFS-EN ISO 50001:2018, 18–19.)

Identification of SEUs is done to set priorities for the allocation of resources, energy management, and energy performance improvement. When selecting the number of SEUs, it is important to consider available resources the organization has, since careful attention is paid to SEUs and there are several requirements directly related to them. Selection can be based on substantial energy consumption, which may include determining the energy uses that account for a certain percentage of total energy consumption or opportunities for energy performance improvement, or both. (SFS-ISO 50004:2015, 11–12.)

By utilizing the information acquired from the energy review, the organization can set energy baseline(s) (EnB) - considering a data period suitable to energy use and consumption of the organization - against which to measure improvements (Cosenza et al. 2018, 26). EnB(s) are revised if the static factors have been prominently changed (e.g. introducing or removing a significant energy consumer), energy performance indicators (EnPI(s)) are no longer reflecting the energy performance, or according to a predetermined method. EnPI is a measure or unit of performance which is defined by the organization and which is also based on the energy review. EnPI(s) shall be appropriate for measuring and monitoring energy performance. The methodology for determining and updating EnPI(s) shall be documented. EnPI(s) are monitored and compared to their respective EnB(s), as is appropriate, to demonstrate possible energy performance improvement (Figure 10). (SFS-EN ISO 50001:2018, 12, 19.)

Because some variables such as weather, production schedules, operating hours, building occupancy, and some measures of productivity are very likely to influence energy use patterns, these variables should be taken into account for energy planning. For example, EnB and EnPI values should be normalized if necessary. (Smith & Parmenter 2015, 51; SFS-EN ISO 50001:2018, 19.)

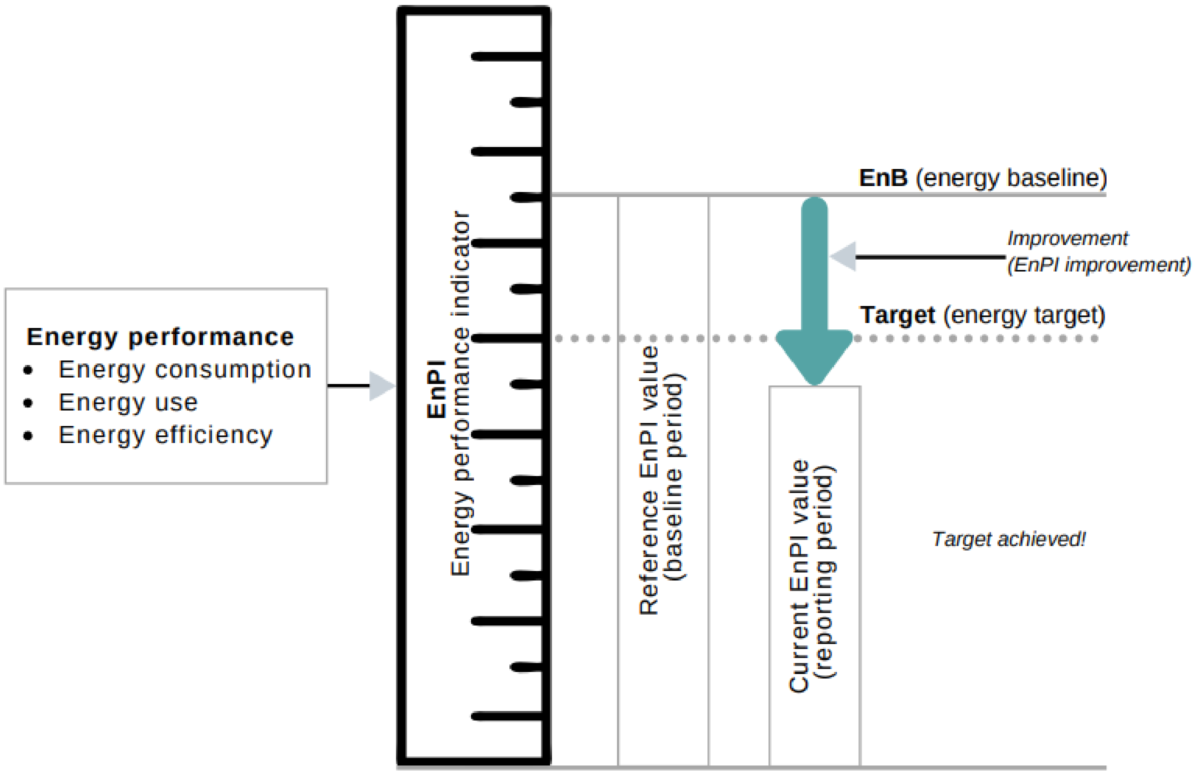

Figure 10. Relationship between energy performance, energy target, energy baseline (EnB), and energy performance indicator (EnPI) (SFS ISO 50006:2014, 4.)

According to the ISO 50001 standard, a data collection plan, which specifies how and at what frequency the key characteristics shall be collected and retained, needs to be established. The plan for data collection ensures the data availability needed for maintaining the energy review as well as the measurement, monitoring, analysis, and evaluation processes - which consequently allow continual improvement (NQA n.d., 18). Standard (SFS-EN ISO 50001:2018, 20) describes the following data to be collected and retained:

- SEU-specific variables;
- All energy consumption data related to SEUs and to the organization;
- Criteria for operations regarding the SEUs;
- Static factors, if deemed relevant;

- Data which is agreed upon to be gathered and is specified in action plans.

4.4 Competence, Training, Awareness, and Communication

The organization is expected to determine and provide the necessary resources to continually improve the energy performance and the EnMS. Resources in this context include e.g. technological potential, data collection infrastructure, human resources, specialized skills, and financial resources. Regarding awareness, personnel working under the organization must be aware of the energy policy and how the future EnMS implications may impact their roles, including the impacts of their activities in terms of energy performance and outcomes of not complying with the EnMS requirements. (SFS-EN ISO 50001:2018, 20, 32.)

The greatest challenge in order to support the requirements of the EnMS is oftentimes providing competent and knowledgeable personnel, due to the subject area of energy being highly technical and specialized. Therefore, filling the gaps in proficiency may sometimes require appropriate consultants to assist the employees of the organization. (NQA n.d., 20.) The level of necessary competence for person(s) addressing energy performance and the EnMS is, however, determined by the organization. The organization shall still ensure that these persons have the needed competence in the forms of education, training, skills, and/or experience. The organization must act to define the required competence for the person(s) involved and evaluate the effectiveness of follow-up actions taken therein. Evidence of competence is documented as deemed appropriate. (SFS-EN ISO 50001:2018, 20.)

Effective communication is essential to ensure the effective implementation of the EnMS (NQA, n.d., 20). The organization shall determine the extent and methods of internal and external communications relevant and consistent to its EnMS, including what needs to be communicated, when and how it is communicated, who the recipients are, and who carries out the communications. When the communication process is established, the organization must then establish and implement a procedure by which any person working for or on behalf of the organization is able to make comments or suggestions for improvement of the EnMS. Documentation of the suggested improvements is voluntary according to the standard. (SFS-EN ISO 50001:2018, 21; Cosenza et al. 2018, 30.) However, documentation of potential improvement opportunities could be an initial important step towards improving energy performance and should, therefore, be considered.

4.5 Documentation

Generally, an EnMS shall include the documented information that is defined in the ISO 50001 standard as well as all the information the organization finds important for the effectiveness of the EnMS and for demonstrating improvements of energy performance. Some common approaches for document handling include establishing an energy manual or a documentation matrix. It is noted that, for example, the size of an organization, its types of processes, the complexity of these processes and their interactions, as well as the competence of the involved persons may affect the extent of documented information for an EnMS. Considering the addition of energy management related documentation into the existing documentation is sensible. Documented information of external origin that is determined to be necessary for the planning and operation of the EnMS - such as laws, regulations, manuals, building codes, and standards - must be identified and controlled. (SFS-EN ISO 50001:2018, 21–22, 32; SFS-ISO 50004:2015, 21.)

To ensure feasibility, the organization needs to outline practices for document identification and description (e.g. title, date), format (e.g. language, graphics), media (e.g. paper, electronic), review, and approval. Control of the documentation shall be taken care of by ensuring its availability and suitability for use, as well as adequate protection. If applicable, distribution, access, retrieval, use, storage and preservation, control changes, and retention and disposition of documented information should also be addressed. (SFS-EN ISO 50001:2018, 21–22.) As has been said (see chapter 4.4), even though documentation of suggested potential improvements shall be considered but is not mandatory, it is still advisable.

4.6 Operation

Cosenza et al. (2018, 35) find operational control as the most technical part of an EnMS. The standard requires the organization to plan, implement, and control the processes related to its SEUs and ensure that they are consistent with the objectives, energy targets, and plans to achieve them. Operating criteria must be established for control processes where their absence could lead to “significant deviations” in energy performance according to the organization’s definition. Control processes include the effective operation and maintenance of facilities, equipment, systems, and other energy-using processes. Criteria need to be communicated to the relevant persons. (SFS-EN ISO 50001:2018, 22; NQA n.d., 22.) For example, if heating, ventilation, and air conditioning (HVAC) were considered as a SEU, a good operational control would be to have processes for maintaining the appropriate apparatus (Cosenza et al. 2018, 35). Operational control can be taken care of in several ways, including documented procedures, instructions for operations, devices, and different maintenance techniques (SFS-ISO 50004:2015, 22).

Planned changes shall be controlled and the possible consequences of the unintended changes reviewed. Outsourced (i.e. purchases) SEUs or processes related to them shall be controlled. To ensure the planned quality of carrying out the processes related to SEUs, the documentation must be kept at an adequate level. (SFS-EN ISO 50001:2018, 22; NQA n.d., 22.) It is worth noting that, although the extent of documented information is not specified, it is considered good practice to document operational and maintenance practices related to energy - including, for example, work instructions and standard operating procedures (SOPs) (Suryanarayanan 2018**,** 98).

Designing energy performance improvement opportunities and operational control into the process of any project (e.g. designing new equipment) that can have a significant impact on energy performance shall be considered. The results of the energy performance evaluation must be incorporated into design, specification, and procurement activities of the organization - to the extent which the organization is able to control these activities. Energy performance related design activities must be documented. (SFS-EN ISO 50001:2018, 22.) Including energy efficiency and energy performance considerations into the projects already in the designing stage expectedly saves costs and benefits the organization’s operations at an earlier stage than if these changes were to be implemented later (SFS-ISO 50004:2015, 22).

Procurement is a viable opportunity to improve energy efficiency as well as environmental performance through the use of more efficient products and services. Criteria for assessing energy performance over the operating lifetime of energy using products, equipment, and services is created by the organization. Assessment of the operational lifetime in the context of

ISO 50001 means the evaluation of energy performance and business benefits against the total costs over the lifetime. A full life cycle analysis or management is not, however, required. When procuring energy using products, equipment, or services that are expected to have a significant impact on SEUs, the organization shall also inform suppliers that procurement is partly evaluated on the basis of energy performance. If possible, specifications for ensuring the energy performance of procured equipment and services - and the purchase of energy - shall be defined, then communicated by the organization. (SFS-EN ISO 50001:2018, 23, 33; Cosenza et al. 2018, 37.) When assessing energy consumption, use, and energy efficiency in a purchase situation, lifecycle costs, energy efficiency labels, or the expected impact on the system’s energy performance can be included as assessment criteria (SFS-ISO 50004:2015, 25).

4.7 Performance Evaluation

Evaluation of performance consists of the implementation of the data collection plan as well as a documented evaluation of energy performance improvements and the effectiveness of the EnMS (NQA n.d., 24). The organization must have a monitoring and measurement plan in use that ensures regular measurement, monitoring, and analysis practices to gain information about the EnMS and energy performance. The knowledge can also be utilized to identify places of corrective and preventive actions. (UL DQS 2011, 35; SFS-EN ISO 50001:2018, 20, 23.)

The effectiveness of the action plans, achieving energy targets and objectives, EnPI(s), operation of SEUs, and actual versus expected energy consumption are the key characteristics that need to be monitored and measured. The results should be documented in a way that is considered appropriate for the organization. EnPI values are compared against the corresponding EnB values to demonstrate energy performance improvements periodically over time. If significant deviations in energy performance are detected during the monitoring of energy performance, they must be investigated and reacted to. Before making the final conclusions about the deviations, the data accuracy, precision, measurement, and uncertainty should be taken into account. In addition, as a part of performance evaluation, the organization shall evaluate and record its compliance with its legal requirements and all other requirements that it treats the same way as legislation pertaining to energy efficiency, energy use, energy consumption, and the EnMS. (NQA n.d., 24; SFS-EN ISO 50001:2018, 23, 33.)

An effective internal audit process is fundamental to a dynamic EnMS and continual improvement therein (NQA n.d., 25). Internal audits to determine whether the EnMS is effectively implemented and maintained, conforms to the organization's own requirements for its EnMS, its energy policy, objectives, and energy targets, and, finally, conforms to the requirements of the ISO 50001 standard. An audit program and its schedule shall be established. The organization also needs to define criteria and scope for each audit, select auditors, report the results to relevant management, react to possible nonconformities, and retain documented information of the audits and their results. The auditors can be employees of the organization or external persons named by the organization. (SFS-EN ISO 50001:2018, 24, 33.) The standard also asks the organization to conduct audits in a way wherein the objectivity and impartiality of the audit process is ensured - which may be challenging, since internal auditors often have a close relationship with the organization being audited (NQA n.d. 25; SFS-EN ISO 50001:2018, 24). However, according to ISO 50001 (2018, 33), auditor independence can be adequately demonstrated when the auditor has no responsibility for the audited activity.

Finally, to evaluate performance, the EnMS is included into management reviews. Even though it covers the entire scope of the EnMS, the management review process does not need to take all the elements into account at once, but it can instead be spread over a period of time. The management review will consider the status of actions from previous reviews, new changes in internal and external issues and risks that are associated with them, relevant opportunities regarding the EnMS, and continual improvement. The energy policy is also reviewed. The review shall also take into account information on the EnMS performance, including trends in nonconformities and the related corrective actions, results of monitoring and measurement, results of audits, and results of the evaluation of compliance with legal and other requirements that pertain to energy efficiency, energy consumption, and energy use of the EnMS. (SFS-EN ISO 50001:2018, 24–25, 33; NQA n.d., 24.)

The following energy performance data is required as the minimum to be carried out for the management review: the level of achievement of the energy targets, the state of energy performance based on the results of monitoring (EnPI(s) included), and the current status of the action plans. As an output of the management review, the decisions related to continual improvement and possible changes are given. The decisions must consider the energy performance improvement opportunities, the energy policy of the organization, EnB(s) and/or

EnPI(s), opportunities for better integration with business activities, the allocation of resources, and the improvement of the level of competence and awareness, and the effectiveness of the communications. Also, the decisions related to objectives, targets, action plans, and other relevant elements of the EnMS must be considered, as well as the follow-up actions if they were not achieved. The results of the management reviews are to be documented. (SFS-EN ISO 50001:2018, 24–25.)

4.8 Nonconformities and Improvement

The organization has to "continually improve the suitability, adequacy and effectiveness of the EnMS", as well as demonstrate continual energy performance improvement. (SFS-EN ISO 50001:2018, 26.) In this context, "continual" as a term refers to an occurrence over a period of time - which can include pauses. The schedule of the continual improvement supporting actions are determined by the organization, taking into account its current circumstances. Improvement in energy performance can be proved in several ways, such as reduction in energy use inside the determined EnMS scope and boundaries. (SFS-EN ISO 50001:2018, 34.) Henceforth, the word "continuous" is used as a synonym for the word "continual", since the commissioner of this work, Yara Uusikaupunki, uses this word regularly in its activities and thus is more familiar with this term.

When evaluating the performance of the EnMS, or on other occasions, nonconformities may be identified. When nonconformities occur, the organization shall react to them as is appropriate, assess the need for measures for eliminating the cause(s) in order to prevent it occurring elsewhere, and implement the actions if necessary. The organization must review the effectiveness of the actions taken as well as make changes to the EnMS if needed. Information on the nonconformities and the ensuing corrective actions, as well as the results of these corrective actions, must be documented. (SFS-EN ISO 50001:2018, 25.)

5 FERTILIZER PRODUCTION AND ENERGY EFFICIENCY COMMITMENTS AT YARA UUSIKAUPUNKI

Yara International ASA is a global supplier of mineral fertilizers, industrial chemicals, and environmental solutions, headquartered in Oslo, Norway. Yara was established in 1905 as

Norsk Hydro and was demerged as Yara International ASA (later: Yara) in 2004. Today, Yara has over 16,000 employees in over 60 countries. In 2018, the company's fertilizer sales were 28.5 million tons, and it had a revenue of USD 12.9 billion. Yara is the leading global producer of ammonia, nitrates, calcium nitrate, and NPK (nitrogen, phosphorus, potassium) fertilizers. (Yara 2020b; Yara 2020c; Yara 2020d.) In terms of the market share of global fertilizer companies, Yara placed second in 2018, accounting for a global market share of 4.1% (Statista 2020).

The story of Yara Suomi Oy began in 1920, when Rikkihappo- ja Superfosfaattitehtaat was founded by the State of Finland. Later, the company changed its name to Kemira, became internationalized, and separated its fertilizer business and chemical industry from one another. The fertilizer business actor (Kemira Agro) seceded from Kemira and eventually became Kemira GrowHow. In 2007, the State of Finland sold its stake of Kemira GrowHow to Yara, making the company a subsidiary of Yara, named as Yara Suomi Oy. Today, Yara Suomi Oy has three production plants in Finland, located in Uusikaupunki, Siilinjärvi, and Kokkola. The open pit mine in Siilinjärvi is the largest in Finland and the only apatite (phosphate) mine in Western Europe. Additionally, Yara Suomi Oy has the Kotkanniemi research farm operating in Vihti and a sales office located in Espoo. Yara Suomi Oy employs around 900 people in Finland and has a total employment impact of more than 4,000 people. (Yara 2020e; Yara 2020f; Yara 2020g.) Yara Suomi Oy produces a majority of the fertilizers used in Finland (Antman et al. 2015, 190).

5.1 Fertilizer and Nitric Acid Production

The Yara Uusikaupunki site (Figure 11) produces mainly NPK-fertilizers for agricultural use and nitric acid both for industrial use and as a raw material for fertilizers. Yara Uusikaupunki has two fertilizer plants ("L1" & "L2"), two nitric acid plants ("T2" & "T4"), and a power plant. The production capacity is around 1,300,000 million tons of fertilizers and 500,000 tons of nitric acid per annum. Transportation of the products and raw materials is done through the site's own deep-water port, as well as by railways and roads. About 85% of the fertilizers produced are exported. The production site is a remarkable employer in the Uusikaupunki area, employing about 240 people directly and around 900 human-years indirectly. (Yara 2020h.) The following two subchapters (5.1.1 and 5.1.2) introduce the main processes at the site.

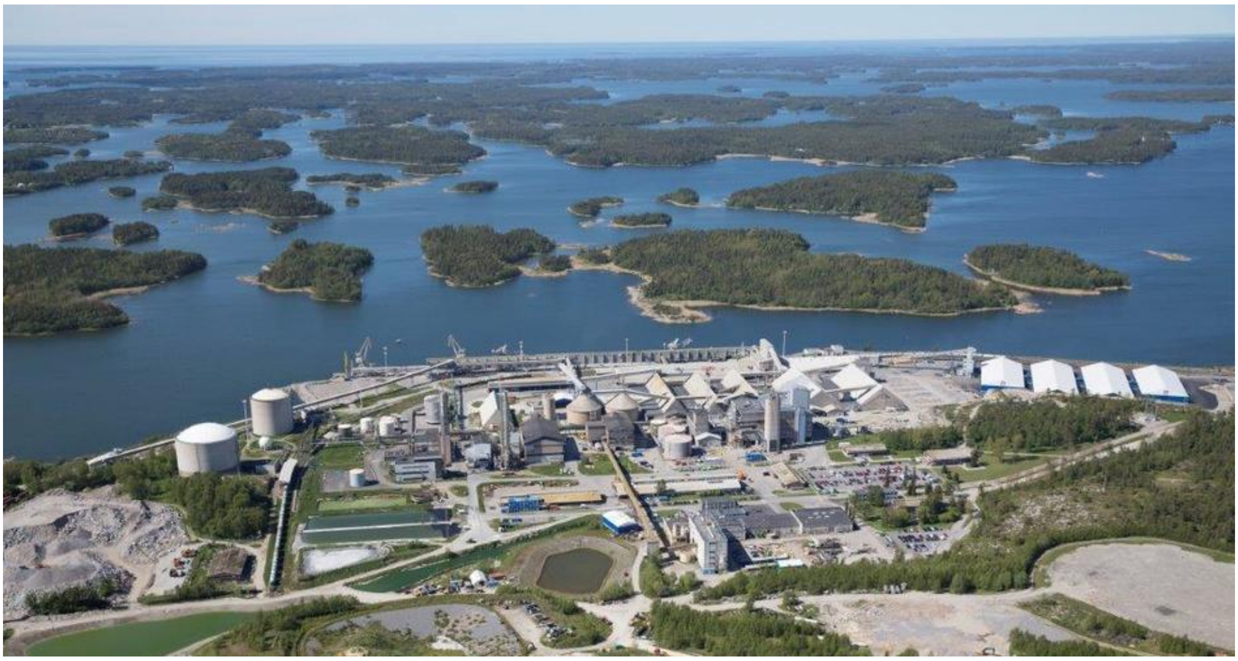

Figure 11. The production site of Yara Uusikaupunki (Yara 2020i).

5.1.1 Fertilizer Production

Apatite is the principal phosphate mineral in phosphate rock (Chandrajith & Dissanayake 2009, 153). Yara Uusikaupunki obtains the apatite used in its fertilizer production from the Yara Siilinjärvi site. The fertilizer manufacturing process starts with the dissolution of the phosphate rock in nitric acid, after which phosphorus is obtained in a water-soluble form, called phosphoric acid. In addition, calcium nitrate ($Ca(NO_3)_2$), hydrogen fluoride (HF), and some other volatile compounds, such as carbon dioxide (CO_2) and nitrous gases, can be emitted. The release of volatile compounds depends on the characteristics of the phosphate rock. **(**Fertilizers Europe 2000b, 8; Jalovaara & Grönberg 2016, 7.)

The acid mixture, which includes for example the remains of calcium nitrate and nitric acid, is then neutralized with ammonia in two neutralization reactors and mixed with sulfuric acid (H_2SO_4), phosphoric acid (H_3PO_4), potash, and other micronutrients (Fertilizers Europe 2000b, 8; Jalovaara & Grönberg 2016, 7). If necessary, the fertilizer slurry is colored prior to granulation (Jalovaara & Grönberg 2016, 7).

Granulation and the drying of the fertilizer take place in a rotary granulator. Hot and moist fertilizer slurry is injected and sprayed as a thin jet into a rotary granulator using compressed air. The size of the nuclear granules then increases. Meanwhile, hot gases are blown into the granulator drums to dry the granules. The heat sources are heavy fuel oil, steam, and warm gases from the cooling process. (Jalovaara & Grönberg 2016, 7.) A majority of the energy needed for drying originates from the neutralization reactions. The moisture content of the final product can be a maximum of 1%, and the rest of the moisture must be evaporated. Water can enter the process through for example nitric acid and other raw materials which include water, as well as in the form of rain or raw water. (Holvitie 2020a.)

Afterwards, the fertilizer granules are screened through two-level sieves (Jalovaara & Grönberg 2016, 7). The undersized fertilizer granules are returned to the granulation phase, and the oversized granules are crushed, then returned to the granulation phase (Holvitie 2020a). Product coming out of a rotary drum (at around 100 °C) is cooled in a fluid bed cooler and, if necessary, still further in a plate heat exchanger. Due to cooling, the chemical reactions stop, and the granules take on their hard, stable state. Before storing, the cooled fertilizer is coated with colorless oil and talc to withstand the stress caused by storage, transport, and distribution. (Jalovaara & Grönberg 2016, 7.)

The processes of the two fertilizer production lines ("L1" & "L2") differ: In L1, raw materials are fed to the reactor in liquid form, whereas in L2, the materials are dry. The granulation lines in L1 and L2 differ as well. (Jalovaara & Grönberg 2016, 7.) Unlike in L1, in L2, both the granulation and drying are achieved in the same inclined rotary drum (called "the spherodizer"), which is divided into two zones: one for granulation and the other for drying. There are three of these types of rotary drums: one of which is 12 m long and has a diameter of 4.5 m, and two smaller ones which are 10 m long and have a diameter of 4.0 m. (Holvitie 2020a.) A process chart of fertilizer production at Yara Uusikaupunki is shown in Figure 12. Today, 10–15 different varieties of fertilizers are produced per factory per month (Heikkinen 2020a). About 10% of the whole production site's GHG emissions - which are reported under the EU emissions trading scheme - originate from the fertilizer plants (Tomma 2020).

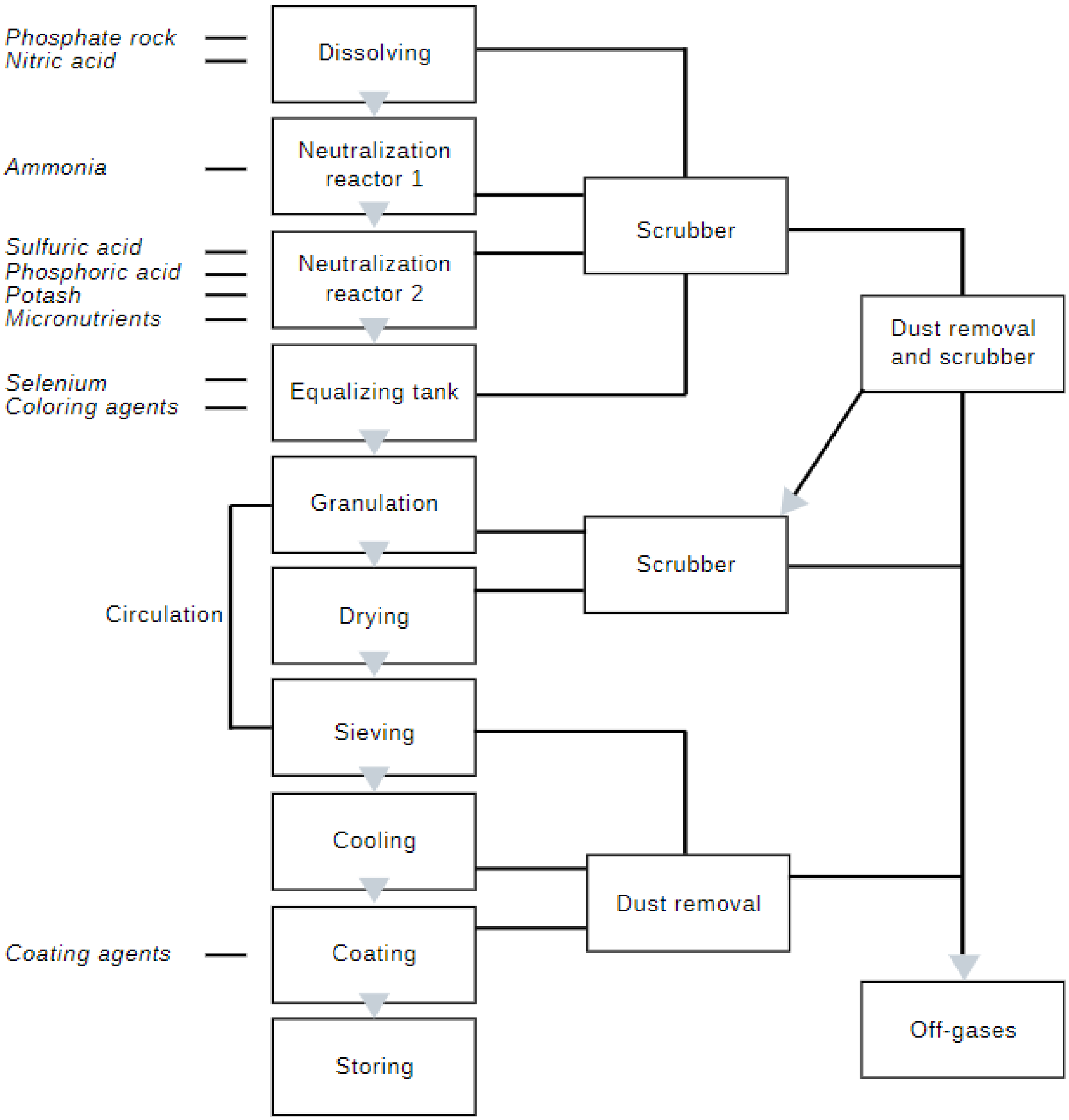

Figure 12. A process chart of fertilizer production at Yara Uusikaupunki (adapted from Jalovaara & Grönberg 2016, 8).

5.1.2 Nitric Acid Production

The ammonia used in the nitric acid production process at Yara Uusikaupunki is imported to the site in a liquified form. Both weaker and stronger acids are produced at Yara Uusikaupunki. Before combustion, ammonia is vaporized, superheated with steam, filtered, mixed with compressed air, and led through gauze catalysts. The highly exothermic reaction is carried out over a catalyst, during which ammonia (NH_3) decomposes into nitric oxide (NO) and water vapor (H_2O). A nitrous oxide abatement catalyst placed in a burner basket under the gauze catalyst splits about 90% of nitrous oxide (N_2O) - the unwanted byproduct formed during combustion - into nitrogen and oxygen. The nitric oxide is then cooled down in several phases immediately after combustion. (Grande et al. 2018, 10180; Turvallisuusselvitys Uusikaupunki 2016, 2–3.) A majority of the measured GHG emissions of the site (around 75%) originate from T4, and both T2 and T4 together account for around 85% of the GHG emissions (Tomma 2020). Yara Uusikaupunki is currently planning a project at T4 which, if completed, will cut around 70% of the GHG emissions of the whole site (Lehto 2020).

After cooling, the nitric oxide is reacted with oxygen to form nitrogen dioxide (NO_2). The nitrogen dioxide is subsequently absorbed in water in absorption towers to form nitric acid (HNO_3). An aqueous solution of nitric acid is then withdrawn from the bottom of the absorption tower and sent to storage tanks with a concentration of about 58–63.5%, depending for example on pressure, temperature, and the number of absorption stages. The ready product is sent to different storage tanks and distributed to inner and external customers. (Grande et al. 2018, 10180; Turvallisuusselvitys Uusikaupunki 2016, 3–4; European Commission 2007, 97.)

The waste gas (NOx) leaving from the top of the absorption tower is heated in heat exchangers, after which it is directed to be catalytically treated to remove the remaining nitrogen oxides before exiting into the atmosphere. After the treatment, the hot gases are led to the waste heat turbine in order to utilize the remaining energy for compressing the process air. (Turvallisuusselvitys Uusikaupunki 2016, 4.)

A simplified process chart of nitric acid production at Yara Uusikaupunki is shown in Figure 13. A summary of the reactions and enthalpy changes are shown in equations below 1–3 **(**Grande et al. 2018, 10180).

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g) \qquad \Delta H = -905.2 \text{ kJ/mol} \qquad (1)$$

$$2NO(g) + O_2(g) \leftrightarrow 2NO_2(g) \qquad \Delta H = -114 \text{ kJ/mol} \qquad (2)$$

$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g) \qquad \Delta H = -117 \text{ kJ/mol} \qquad (3)$$

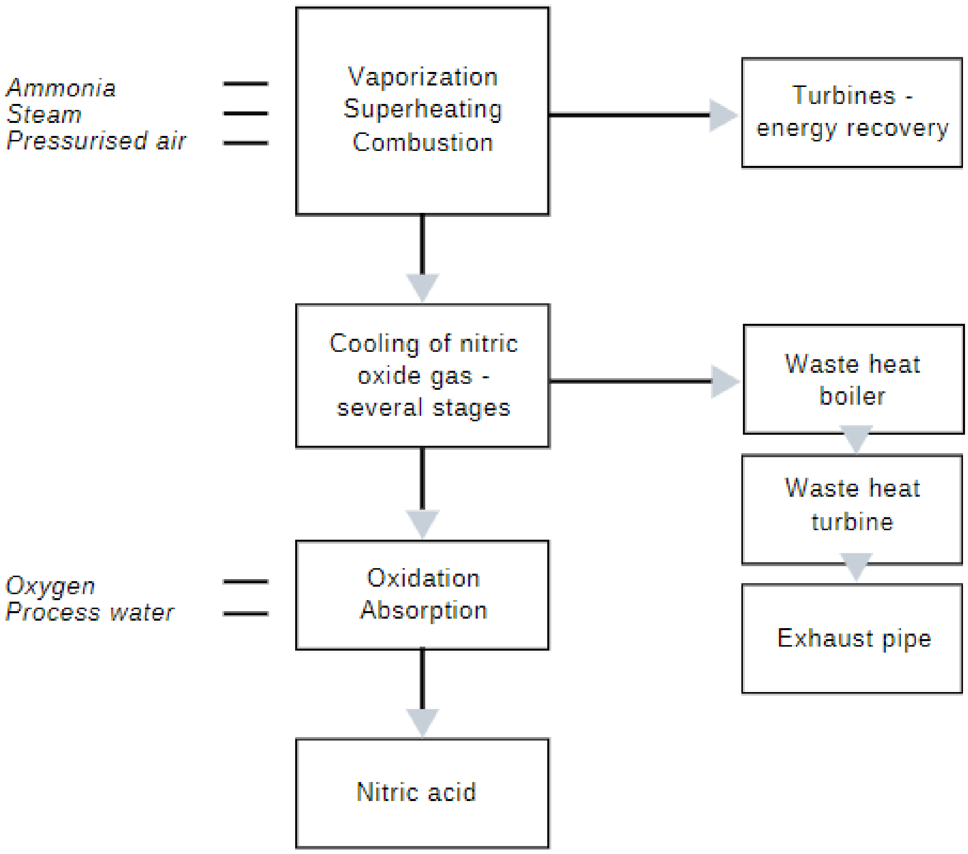

Figure 13. A simplified process chart of nitric acid production at Yara Uusikaupunki (adapted from Jalovaara & Grönberg 2016, 8).

As seen in the equations 1–3, the formation of nitric acid is exothermic. In addition to the main products, energy is also derived as a byproduct from nitric acid production. This energy, obtained in the form of process heat, is utilized at the on-site power plant to produce steam and electricity for the needs of the production site, as well as for district heat for the district heating network of the city of Uusikaupunki and for the site's buildings. (Yara 2020h.)

5.2 Energy Efficiency Commitments

Yara's production plants are amongst the most energy efficient fertilizer plants globally (Marshall & Duncan 2007, 237; Yara 2020j). Nonetheless, energy consumption is notable at Yara Uusikaupunki due to the nature of its activities; although the most energy-consuming process of fertilizer production - ammonia production - does not take place at the site. Thus, a need for energy efficiency has been recognized, and voluntary actions have been taken to improve energy management in accordance with the statutory obligations. Legal instruments and agreements directly related to energy efficiency that currently bound Yara Uusikaupunki, as well as the compliance measures at the company, are presented briefly in this section.

5.2.1 Legal and Other Instruments on Energy Efficiency

Legal and other instruments have been established in order to promote energy efficiency and the reduction of emissions - such as the Energy Efficiency Directive (2012/27/EU) (EED). With regard to energy management systems, Directive 2012/27/EU requires non-SME(s) (small and medium-sized enterprises) to undergo an energy audit on a periodic basis. Article 8 in the EED also states that these organizations are exempt from this requirement if the member states ensure that the management system concerned includes an energy audit which is in accordance with the minimum criteria based on Annex VI of the EED. (Directive 2012/27/EU, art.8, Annex VI.) Pursuant to EED, Finland established the Finnish Energy Efficiency Act (*Energiatehokkuuslaki*, Act 30 December 2014/1429), which decrees, for example, the promotion of energy efficiency, energy audits to improve energy efficiency, cost-benefit analyses to promote the use of high-efficiency cogeneration of electricity and heat, and the obligation for energy market companies to promote the efficient and sustainable use of energy by their customers (Act 30 December 2014/1429, 1 §).

The Finnish Energy Efficiency Act - which entered into force in January 2015 - places energy audits as the central element regarding the improvement of energy efficiency. The act obligates large companies to carry out mandatory energy audits every four years, which are managed and enforced by the Energy Authority (*Energiavirasto)*. (Act 30 December 2014/1429, 6 §, 33 §; Energiavirasto 2020.) A large company is defined as an organization that has more than 250 employees or has a turnover of over €50 million and a balance sheet of over €43 million. The energy audits are voluntary and subsidised for small and medium sized enterprises and municipalities. (Energiavirasto 2020.)

According to the Finnish Energy Efficiency Act (Act 30 December 2014/1429), large companies that are normally required to carry out an energy audit every four years are exempt from this requirement if:

- the company has adopted an ISO 50001 certified EnMS;

- the company has adopted both an ISO 14001 certified environmental management system and a national energy efficiency system (EES+) certified by a body accredited for the certification of ISO 14001; or
- the company is covered by an energy efficiency agreement scheme and adopts EES+ - which (EES+) does not need to be certified since the obligation of mandatory energy audits is regarded as fulfilled. (Energiavirasto 2020.)

Finland has also established voluntary Energy Efficiency Agreements (EEAs), which are a key instrument for fulfilling the state's international energy efficiency targets set in the EED. Along with the energy efficiency improvements, the agreement scheme helps Finland to reduce energy-related GHG emissions, improve self-sufficiency and security of supply in energy, and opens markets for clean technology solutions. EEAs are jointly chosen by the central government and participating sectors, covering over half of the national energy saving target for the implementation period of 2014–2020 without a need to introduce new coercive measures. The results are annually reported to the EU. (Ministry of Economic Affairs and Employment 2020; Energy Efficiency Agreements 2020.)

EEAs have been considered a functional and successful part of energy and climate strategy and a means to promote energy efficiency in Finland. At the beginning of 2015, the amount of energy saved on an annual basis was equivalent to the annual energy use of 600,000 single-family homes, correspondingly reducing CO_2 emissions by over 3.5 million tons, and, at the end of the EEAs of 2008–2016, carbon dioxide reductions reached 4.7 million tons per year, and annual energy consumption decreased by almost 16,000 GWh. (Ministry of Economic Affairs and Employment 2016; Motiva 2019.) The energy savings of the participating chemical industry actors were 66 GWh in 2018 alone (Energiatehokkuussopimukset 2020). In Finland, 95% of the energy consumption of chemical industry actors is included in the EEAs (Kemianteollisuus ry 2020a).

5.2.2 Compliance of Yara Uusikaupunki

The Finnish Energy Efficiency Act applies to Yara Uusikaupunki, and the first energy audit was accomplished by the deadline set for 5 December 2015 (Act 30 December 2014/1429, 33 §). Yara Suomi Oy is a large company and is, therefore, not eligible for subsidised audits.

Yara Suomi Oy, alongside The Confederation of Finnish Industries (*EK in Finnish)*, is also committed to the obligations of the Energy Efficiency Agreement for Industries for the period of 2017–2025 (Yara 2020h; Energiatehokkuussopimukset 2016; Hakala 2020). The overall indicative energy savings target for the period of 2017–2025 - based on the energy consumption of the parties of the agreement - is 7.5%, and the intermediate target is 4% by 2020 (Energiatehokkuussopimukset 2016). The energy savings targets of Yara Suomi Oy are 1.41% by 2020 and 2.65% by 2025 (Energiatehokkuussopimukset 2017, 2). Energy efficiency improvement measures, as well as other actions aiming to improve energy efficiency, are reported annually to an online monitoring system by the agreement's participants (Energy Efficiency Agreements 2020). EEAs do not provide obligations for energy management at Yara Suomi Oy, since the agreement scheme is based on voluntary actions. However, achieving the agreed targets is in any case desirable, so that the tools for achieving the EU's energy efficiency targets remain obligation-free. Already, Yara Suomi Oy has reached the intermediate target set for the year 2020. (Savolainen 2020b.)

6 IMPLEMENTATION PLAN OF THE ENERGY MANAGEMENT SYSTEM AT YARA UUSIKAUPUNKI

No formal EnMS is currently implemented at Yara Uusikaupunki although some key elements of an EnMS in accordance with ISO 50001 guidelines are already available, since the site is already certified with standards ISO 14001 Environmental Management System (EMS), ISO 9001 Quality Management System, and OHSAS 18001 Occupational Health and Safety Management System (Yara 2020h). Energy consumption is also designated as an environmental aspect within the EMS for the site (Hakala 2016, 11). Yara Uusikaupunki's operations are steered by Yara's own standards, which are called TOPSs (Technical and Operational Standard) or HOPSs (HESQ Operational Standard). For example, Yara's HOPS 0-07 (Yara 2019, 2) on HESQ and Product Stewardship certification and internal audits requires all management systems to be integrated as much as possible.

Yara has highlighted the improvement of energy efficiency as one of the most important means of reducing its carbon footprint, especially with regards to ammonia production (Tomma 2020). To contribute to the objectives, the company has decided to certify all the bigger production sites under ISO 50001 (Yara 2018c, 3, 7). Yara Uusikaupunki aims to fulfill the requirements of ISO 50001 and, thus, be ready for certification by the end of 2021 at the earliest (Hakala 2020). The adoption of ISO 50001 would not only improve the energy performance of the site, but also release the site from mandatory energy audits required by the Finnish Energy Efficiency Act (Act 30 December 2014/1429, 6 §–7 §). Energy efficiency may become even more relevant to the site - and Yara as a whole - if the energy-intensive manufacturing of fertilizers and nitrogen compounds will be excluded from the industries eligible for compensation for the costs incurred for their inclusion in the EU emissions trading scheme (see Simon 2020; Tomma 2020). Currently, the purchase of energy is not a significant expense compared to total expenses at the site (Silanto-Helminen 2020).

The Gap Analysis - conducted in 2018 in order to evaluate the readiness of Yara Uusikaupunki against the EnMS processes detailed in ISO 50001 - discovered gaps for improvement from the following areas:

- Implementation of a local energy management team and an energy manager;
- Implementation of an energy review and the establishment of EnB(s) and EnPI(s), as well as setting energy targets;
- Development of the areas of awareness, training, competence, and communication; and
- Operational control of maintenance, procurement, and design. (Stilkenbäumer 2018, 2–3.)

To note, the GAP Analysis was conducted against an earlier version of the standard and, although it is not fully in line with the current version, several of the gaps discovered are still relevant. This chapter aims to propose feasible ways to meet the requirements of the standard based on the current practices of the site and, hence, work as a basis for actual implementation. It also aims to evaluate the possible relevance of the actions for energy-related GHG emission reductions at the site and possible secondary effects on the life cycle of the fertilizers produced at the site - if connections are discovered. An example of the criteria for naming significant energy uses regarding electric energy - to which resources are allocated - is provided to demonstrate the requirements of the standard on a smaller scale. The mandatory requirements, need for documentation, and suggested actions for Yara Uusikaupunki are compiled in tables at the beginning of each subsection. These tables can operate as checklists when the implementation of the EnMS is launched.

6.1 Operational Environment at Yara Uusikaupunki with Regard to the EnMS

To provide a comprehensive understanding of the external and internal issues at Yara Uusikaupunki that may have an effect on energy performance and the strategic direction, an analysis was conducted by utilizing the example listing of the ISO 50001 standard and evaluating the possible effects regarding the site in chapter 6.1.1 (see SFS-EN ISO 50001:2018, 28–29). The stakeholders with regard to the EnMS of the site are assessed in chapter 6.1.2. Chapter 6.1.3 discusses the legal and other requirements related to energy performance and the operations at Yara Uusikaupunki that should be taken into account when constructing the EnMS of the site. Finally, the scope and boundaries for the EnMS are suggested in chapter 6.1.4. The requirements checklist related to the context of the organization is below in Table 5.

Table 5. The checklist for addressing the requirements of the standard with regard to the context of the organization.

Requirement	Documentation required (yes/no)	Actions at Yara Uusikaupunki
Determine the external and internal issues relevant to energy performance targets and improvement	No	Assess the external and internal issues that may have an effect on the EnMS and energy performance of the site
Determine the stakeholders and their possible needs and expectations with regard to the EnMS and energy performance	No	Discover the requirements of the stakeholders that may act as possible “other requirements” Update the already existing stakeholder listing
Identify the legal and other requirements with regard to the EnMS and energy performance	Yes	Update and/or review the legal requirements (in Ecobio Manager), if necessary, and add possible other requirements (e.g. EEAs, building energy codes) or notify them in another manner Determine how the discovered requirements affect the energy performance, energy consumption, and energy use at the site Ensure access to the applicable energy performance -related legal and other requirements

		Review the legal and other requirements on a regular basis
Determine the scope and boundaries for the site's EnMS	Yes	Ensure that Yara Uusikaupunki has the full authority to control energy performance over the defined scope and boundaries of the EnMS Define the scope and boundaries Include all the energy types within the scope and boundaries

6.1.1 Assessment of Internal and External Issues

In this analysis, the effect on energy performance and the EnMS is assessed to be either positive (+, an increase of energy consumption) or negative (-, a decrease of energy consumption). If deemed necessary, lists of the issues are to be supplemented. External issues are inter alia international and national legislation, climate and weather, energy costs, sector objectives, and the availability of energy. The availability of energy is considered both as an external and internal issue due to the on-site energy production. Internal issues include the plans for an interruption in energy supply, strategies, targets, and financial resources, to mention a few. Some external and internal issues that are likely to have an effect on Yara Uusikaupunki's energy performance and the planned EnMS are listed and shortly described in Table 6.

Table 6. Some external and internal issues at Yara Uusikaupunki that are likely to have an effect on energy performance and the EnMS.

Issue	External/internal (E/I)	Effect (+/-)	Additional information
International and national legislation	E	-	External pressure for improvements.
Climate and weather	E	+/-	The yearly average temperature is 5 °C, being the coldest in February and March (-0.3 °C) and the warmest in August (13.1 °C) (Weather Atlas 2020). The climate is relatively mild in Uusikaupunki, which reduces the need for extensive heating and cooling. There are still monthly variations in terms of the need for heating.
Energy costs	E	+/-	Fluctuation of energy prices may affect the purchase of other energy efficiency improving solutions. Increasing costs may

			also be a driver toward more energy efficient production.
Sector objectives	E	-	The fertilizer industry is energy-intensive, and aiming toward more energy efficient production is wise both cost- and environment-wise. Sector objectives support the direction.
Availability of energy	E/I	-	The majority of energy is produced at the site, so there is a legitimate possibility to affect the way energy is produced.
Interruptions in energy supply	E/I	+/-	There is a possibility for equipment failure, both in the main grid and in the internal grid of the site (Lintula 2020a).
Plans for interruptions in energy supply	I	+/-	Yara Uusikaupunki has a backup power transmission line of 20kV. To ensure safety near ammonia-related functions, there is also a reserve power plant in case of power outages. (Lintula 2020a.)
Previously achieved standards	I	-	The already attained standards have similarities which are likely to facilitate the introduction of new requirements.
Strategy and targets	I	-	The commitment to improve energy efficiency is mentioned in the policy of Yara Uusikaupunki, and the need for improvements is recognized. To fulfill the requirements set by ISO 50001, additional statements shall be added. Yara mandates its bigger production sites to implement ISO 50001 EnMS. Yara Uusikaupunki is also committed to the targets of EEAs.
Financial resources	I	+	Yara Uusikaupunki currently has no extensive resources planned e.g. for hiring an energy professional to take overall responsibility for the planned EnMS. The targets are still, however, achievable by effective cooperation with Yara Siilinjärvi and between the site’s own departments. Yara Siilinjärvi aims to have ISO 50001 EnMS ready for standardization by the end of 2020 (Savolainen 2020a).
Maturity of existing technology	I	+/-	Yara Uusikaupunki has both newer and older technology at the site. The renewal needs are reviewed annually. (Lintula 2020a.)
Maturity and culture of energy management	I	+/-	A culture of energy management exists to some extent, but there is a need for systematic energy management. The implementation of the EnMS provides a basis for a systematic approach.
Consideration of sustainability	I	-	Sustainability is mentioned in the policy of Yara Uusikaupunki.

Operational risks and liability considerations	I	-	Operational risks as well as liability matters are well-recognized and regularly assessed.
Existing development plans	I	+/-	There are currently no ongoing projects directly related to energy performance improvement, but energy consumption is taken into account on a regular basis, and the need for energy efficiency and an EnMS is recognized (Lintula 2020a). Yara Uusikaupunki currently has no plan to hire an energy management professional to take overall responsibility for the planned EnMS, but it has been discussed (Viitala-Nokkonen 2020).

Because ISO 50001 does not specify the method for how the external and internal conditions should be assessed, Yara Uusikaupunki could also use, for example, the well-known SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats) or PESTEL analysis (Political, Economic, Social, Technological, Environmental, and Legal) in order to discover the factors that have an effect on energy performance and the EnMS. Table 6 can also be used for an initial assessment, able to be supplemented where necessary.

6.1.2 Stakeholders

A stakeholder analysis was conducted which included the expectations of both Yara Uusikaupunki and the stakeholders, possible channels of dialogue, and their evaluated relevance regarding the effectiveness of the EnMS and energy performance (see Appendix 1). According to the analysis, the most relevant stakeholders with regard to energy performance and the EnMS (relevance to the EnMS is assessed in order to be unambiguous) are the site's own employees, Yara Suomi Oy, the concern (Yara International ASA), authorities, governmental institutions, external contractors working at the site, suppliers, organizations, and associations. In addition, the local energy network, energy concern, and the city of Uusikaupunki are considered as relevant to the EnMS and energy performance of Yara Uusikaupunki to some extent. Yara Uusikaupunki has divided its stakeholders into internal and external stakeholders. A more detailed stakeholder list with regard to energy performance and the EnMS is in Table 7.

Table 7. Internal and external stakeholders of Yara Uusikaupunki with regard to energy performance and the EnMS.

Internal/authority /other external stakeholder	**Process/function/ unit**	**Specified name of stakeholder**	**Requirements/needs/expectations with regard to energy performance and the EnMS**
Internal	Yara Suomi Oy Uusikaupunki	Management team	Commitment with respect to the effectiveness of the EnMS and improvement of energy performance, overall responsibility over the EnMS, organizing, providing resources, continuous improvement.
Internal	Yara Suomi Oy Uusikaupunki	Local energy management team	Motivation, skill set, responsibility, reporting, and competence regarding the EnMS – improving energy performance in accordance with the requirements.
Internal	Yara Suomi Oy Uusikaupunki	Employees	Interaction with the other employees, awareness, motivation, skill set, education, and working methods affect the energy performance.
Internal	Yara Suomi Oy Uusikaupunki	Internal customers	Reliable and safe energy (electricity, steam, district heat) production and distribution for the needs of other departments inside the site, cooperation.
Internal	Yara Suomi Oy	Energy management teams	Exchanging know-how between the sites, communication.
Internal	Yara Suomi Oy	Management	Communication and relevant reporting - e.g. purchase activities happen at the Yara Suomi Oy level.
Internal	Yara International ASA	Management	The strategy and the targets, minimum requirements, reporting of energy performance of the sites.
Authority	Motiva	Motiva	Practical work regarding the energy audits program - e.g. support and checking of annual data with regard to EEAs (agreement participants report to Motiva).
Authority	Energy Authority (Energiavirasto)	Energy Authority (Energiavirasto)	Managing and enforcing mandatory energy audits, the authority responsible for EU emissions trading, majority of administrative duties related to EEAs.
Authority	Ministry of Economic Affairs and Employment	Ministry of Economic Affairs and Employment	The authority responsible for the EEAs scheme and the energy audit program. A contracting party of the EEAs.

Authority	Confederation of Finnish Industries (EK)	Confederation of Finnish Industries (EK)	Commitment to promote the targets set in the EEAs. A contracting party of the EEAs.
Other external stakeholder	Contractors	Contractors working at/for Yara Uusikaupunki	Interaction with the other employees, awareness, motivation, skill set, education, and working methods affect the energy performance.
Other external stakeholder	Fertilizers Europe	Trade association in Europe and its programs	BAT/BREF expertise and statements.
Other external stakeholder	Kemianteollisuus ry (The Chemical Industry Federation of Finland)	Trade association for the chemical industry in Finland	E.g. negotiating collective agreements (EEAs for chemical industry), industry lobbying, developing competitiveness, programs, and their results (e.g. Responsible Care program).
Other external stakeholder	Suppliers	Equipment, feedstock, and raw material suppliers	Reliable and safe feedstock (e.g. ammonia) production and distribution to ensure energy and other production at Yara Uusikaupunki, communication. Equipment related to energy consumption and use is up-to-date and appropriate.
Other external stakeholder	Local energy network	Vakka-Suomen Voima	The purchase and sale of energy, communication, cooperation, compliance with requirements, reliability.
Other external stakeholder	Energy concern	Pohjolan Voima	The purchase of electricity, communication, cooperation, compliance with requirements, reliability.
Other external stakeholder	City	City of Uusikaupunki	Cooperation in the Hinku-program and the pursued GHG emissions reductions (see Haapala 2010).

As for possible compliance obligations for the EnMS, at least the above-mentioned stakeholders and their requirements should be considered when the EnMS is constructed further. In a practical sense, face-to-face meetings are a considerable way to identify the views of interested parties and to fully meet their needs in terms of the EnMS.

6.1.3 Legal and Other Requirements Regarding the Planned EnMS

Yara Uusikaupunki already has a tool and procedure for reviewing compliance for legal requirements (Ecobio Manager). The compliance is reviewed by the responsible persons annually, or in three months if a new legal obligation has been established (Lanne, Ritola &

Annala 2019 14, 16). The legal and other requirements that are already relevant to Yara Uusikaupunki and are related to energy performance are listed in Table 8. Listed legal documents have been utilized in descriptions and when analyzing the potential effect on energy performance and by management at the site. The listing can be used as an initial checklist of legal and other requirements, and, if necessary, it must be supplemented.

Table 8. A compilation of the relevant legal and other requirements of Yara Uusikaupunki with regard to energy.

Legal/other requirement	**Short description**	**Effect on energy efficiency, energy use, and energy consumption**	**Management at Yara Uusikaupunki**
Energy Efficiency Directive (2012/27/EU)	Directive for setting targets for energy efficiency inside the EU. Had to be transposed into the legislation of the EU member states.	Sets an energy efficiency improvement target of 32.5% by 2030 in EU member states. The energy efficiency improvement target for 2020 is 20%.	Monitors changes.
Finnish Energy Efficiency Act (*Energiatehok-kuuslaki* 30 December 2014/1429)	National law of Finland for promoting energy efficiency, pursuant to the directive 2012/27/EU.	The scope includes energy retailers, large enterprises, district heating and cooling networks, condensing power plants, and plants in which residual heat may be generated. Energy audits are a central element. Energy audits are mandatory for large enterprises (30 December 2014/1429, 6§).	Mandatory energy audits every four years at the corporate level (Yara Suomi Oy).
Energy Efficiency Agreements (EEAs)	Voluntary agreements to improve energy efficiency and thus to fulfill the energy efficiency obligations set for Finland by the EU without resorting to coercive measures, such as legislation (Energy Efficiency Agreements 2020).	Sets energy saving targets for participants.	Site-specific energy saving targets between Yara Suomi Oy sites are set and aimed for. Annual reporting of the energy performance and energy efficiency improvements to Motiva.

Industrial Emissions Directive (2010/75/EU)	Directive for prevention and control of pollution that originates from industrial activities, as well as prevention of the generation of waste, and prevention or reduction of emissions into the atmosphere, water, and land. The main objective is to achieve a high level of environmental protection. (Directive 2010/75/EU, art. 1.)	Sets energy-related principles and requirements for the EU member states including applying BAT, efficient energy use, granting of permits, and public involvement.	Monitors changes.
Finnish Environmental Protection Act (*Ympäristön-suojelulaki* 27 June 2014/527)	National law of Finland for promoting overall environmental well-being, pursuant to the directive 2010/75/EU.	The directive installation's environmental permit shall, where appropriate, include provisions for improving the energy efficiency and effectiveness of the operation, and provisions for providing information to the supervisory authority (27 June 2014/527, 74 §).	The law obligates Yara Uusikaupunki but is not applied regarding energy efficiency measures. According to the law, the provisions are not necessary if the organization has signed EEAs or has committed to another similar voluntary arrangement (27 June 2014/527, 74 §).
Emissions Trading Directive 2003/87/EC	Directive for establishing a scheme for GHG emission allowance trading in the EU (Directive 2003/87/EC, art. 1).	Encourages the development and use of more energy efficient and low-carbon technologies.	Yara Uusikaupunki is obligated to participate in the EU emissions trading scheme.
The revised EU ETS Directive 2018/410	Directive for amending the directive 2003/87/EC for GHG emission allowance trading in the EU and enhancing cost-effective emission reductions and low-carbon investments. Directive will apply to the emissions trading scheme period of 2021–2030.	Encourages the development and use of more energy efficient and low-carbon technologies.	Yara Uusikaupunki is obligated to participate in the EU emissions trading scheme.

Finnish Emissions Trading Act (*Päästökaup-palaki 311/2011)*	National law of Finland for emissions trading, pursuant to the directive 2003/87/EC.	Encourages the development and use of more energy efficient and low-carbon technologies.	Yara Uusikaupunki is obligated to participate in the EU emissions trading scheme.
Act 291/2019 (*Laki päästökaup-palain muuttamisesta*)	National law of Finland for emissions trading and promoting cost-effective emission reductions and low carbon investments, pursuant to the directive 2018/410.	Encourages the development and use of more energy efficient and low-carbon technologies.	Yara Uusikaupunki is obligated to participate in the EU emissions trading scheme.
Act 24 February 2017/138 (*Laki päästökaupasta johtuvien epäsuorien kustannusten kompensoimi-sesta*)	National law of Finland for aid that is meant to compensate for the increase in electricity in sectors exposed to a significant risk of carbon leakage (Act 24 February 2017/138, 1 §).	The subsidy is granted only on the basis of the consumption of electricity wherein the price includes the cost of carbon dioxide emissions (Act 24 February 2017/138, 4 §).	Yara Suomi Oy is currently eligible for compensation for the indirect carbon costs. The amount of compensation depends on e.g. consumption of electricity (Kemianteollisuus ry 2020b; Act 24 February 2017/138; see also Decree 25 May 2017/311.)
Act 1168/2002 *(Laki sähkön ja eräiden polttoaineiden valmisteverosta annetun lain muuttamisesta*)	National law of Finland considering tax refunds for energy-intensive companies.	See 8a § (Act 1168/2002).	Yara Suomi Oy is eligible for applying for tax refunds.
Act 29 December 1994/1472 *(Laki nestemäisten polttoaineiden valmisteverosta)*	National law of Finland considering taxation on liquid fuels.	See 9 § (Act 29 December 1994/1472).	Yara Suomi Oy is eligible for applying for tax refunds.

6.1.4 Scope and Boundaries of the Future EnMS

Setting the scope and boundaries is an essential part of implementation of the EnMS. Finalizing the scope is sometimes found challenging at the beginning of the project, but some noting of the scope must be documented within the EnMS (NQA n.d., 13). All the energy types within the scope and boundaries of Yara Uusikaupunki must be included. Energy types at Yara Uusikaupunki include:

- electricity used e.g. for motors and lighting;
- steam used for e.g. needs of production, production of electricity and district heat;

- district heat used for e.g. space heating;
- heavy fuel oil used for drying fertilizer and at the power plant;
- liquified petroleum gas used e.g. as an ignition gas at the fertilizer plants;
- light fuel oil used for e.g. the needs of reserve power generators;
- ammonia used e.g. as feedstock; and
- other fuels used for e.g. on-site trafficking.

ISO 50004 (2015, 10) notes that the feedstock should be considered in the EnMS as an energy source if it contributes energy within the defined scope and boundaries, and if not, it should be excluded from the energy review. Although ammonia at Yara Uusikaupunki is the feedstock of fertilizer and nitric acid production, it also contributes energy by being a source for process heat through the aforementioned chemical reactions.

The scope of the earlier-achieved management system certificates covers the local operations that are under Yara Uusikaupunki’s control, including the production of plant nutrients and technical chemicals, logistics of raw materials and products, and customer deliveries (see e.g. DNV GL 2020, 3). When setting the scope and boundaries for the EnMS, Yara Uusikaupunki must be able to control its energy efficiency, energy use, and energy consumption within the scope and boundaries. In terms of energy, Yara Uusikaupunki is fully able to control the functions related to the production and the site’s own transport (e.g. transportation of the product to storage). Off-site transport and the management of its energy (fuel) use, is more challenging to control, because the operators are external.

Therefore, the scope and boundaries for the site are suggested to be the same as the previously attained certificates. No energy type within the scope and boundaries of Yara Uusikaupunki shall be excluded. As for the other media, at least the water flows are suggested to be included in the monitoring plan, since the knowledge can be utilized in measuring the energy performance of the water pumps, for example. Once the new standard is implemented at Yara Uusikaupunki, it is likely to be integrated into the same certification and certification audit program as the already existing standards (Ritola 2020a). The final extent of the EnMS partly defines how wide the impacts of the planned actions might happen locally in terms of energy performance improvement and hence the energy-related GHG emissions.

6.2 Leadership, Roles and Responsibilities

Top management at Yara Uusikaupunki has noted that developing eco- and energy efficiency is an increasingly important part of the future strategy, and the site is taking part in several programs supporting the targets. Implementation of the EnMS in accordance with ISO 50001 is the next step toward a more energy efficient site and cutting energy-related GHG emissions. From a point of view focused purely on GHG emission reductions, it would be advisable to consider applying e.g. the previously mentioned tools (see chapter 3) for assessing and mitigating GHG emissions alongside the ISO 50001 EnMS to take it a step further.

As discussed earlier, top management is responsible for fulfilling the requirements of the standard. This chapter describes the current state of management tools with regard to energy performance and assesses the current policy statement of Yara Uusikaupunki's addressal of the requirements of ISO 50001. Last, possible roles and responsibilities for the suggested energy management team, are provided. A checklist of the requirements related to leadership is in Table 9.

Table 9. The checklist for addressing the requirements of the standard with regard to leadership.

Requirement	**Documentation required (yes/no)**	**Actions at Yara Uusikaupunki**
Commit to ensuring the functionality of the EnMS in accordance with the principles of continuous improvement	No	Demonstrate leadership and commit to continuous improvement of the energy performance Make sure that the EnMS is an integral part of the site's operations and that it has the necessary resources for operating Ensure the establishment of the energy management team and assign the responsibility of the EnMS to the team
Establish an energy policy	Yes	Update the former general policy statement of Yara Uusikaupunki to fulfill the requirements of ISO 50001, or create a new energy policy Regularly review and update the energy policy

Establish an energy management team	No	Establish a cross-functional energy management team and assign the team with the relevant tasks and responsibilities

6.2.1 Commitment and Tools

The sites of Yara Suomi Oy prepare annual plans in accordance with the guidelines issued by Yara's production segment, which include cost budgets, site KPIs (Key Performance Indicators), and investments, as well as the plans of the major departmental or function-specific projects and development projects. The sites' KPIs are reported monthly. KPIs are used to form departmental-, team-, or sometimes personal goals. Based on the agreed goals, the staff receives feedback on their performance. The management of the site has the overall responsibility for monitoring the implementation of the set targets. (Menettelytapa Uusikaupunki 2018, 2; Käsikirja Uusikaupunki 2018, 1–2.)

When the time for the implementation of the ISO 50001 EnMS approaches, the process must be considered an achievable and legitimate target to be carried out in the planned implementation year, and the implementation of an EnMS should be added to the action log of the management and steering groups to follow its progress. If it is deemed necessary, top management should consider the allocation of a budget for the implementation of the EnMS for e.g. possible training, consultant meetings, and metering instruments.

Emphasizing the importance of energy management inside the organization can be done, for example, by considering the addition of one or more of the discovered energy performance indicators as part of a rewarding scheme, or to consider one or more of them as KPI(s) in order to ensure the regular measuring of Yara Uusikaupunki's performance against the set energy targets. Improvement of energy management is not currently a target of Yara Uusikaupunki's departments, which causes the topic to not be emphasized in day-to-day operations. Instead, the focus is on GHG emissions, which has its own KPI in place (Lehto 2020). No site-specific KPIs have been defined for energy efficiency per se, although the already calculated energy consumption per metric ton of produced fertilizer could work as such with adjustments. The meter is quite inaccurate, such as there being differences in energy consumption for the production of different fertilizer varieties - for example, the production of fertilizer varieties which have a higher water content using more energy due to the need for more drying

(Heikkinen 2020b). Energy efficiency KPI(s) and the method by which they are determined should be easily understood and clearly indicate the status of their energy performance.

The standard (ISO 50001:2018, 29) also suggests other employee involvement activities, such as motivation, recognition, and training. There are already existing theme days at Yara Uusikaupunki in which energy performance could be embedded to boost motivation and share knowledge. Specific training is suggested to be organized separately for the key personnel working within the EnMS. The status of implementation of the EnMS and reviewing of energy performance targets and related indicators should also be incorporated into the management practices, including observation discussions, meetings, and management reviews.

6.2.2 Energy Policy

Regarding energy performance, the general policy statement of Yara Uusikaupunki states that the company is committed to improving energy efficiency (Uudenkaupungin tehtaan toimintaperiaatteet 2019). The general policy is updated regularly. With regard to environmental objectives, Yara Uusikaupunki is committed to reducing its environmental impact in accordance with the agreed targets and action programs. Yara Uusikaupunki is committed to the principle of continuous improvement. (Uudenkaupungin tehtaan toimintaperiaatteet 2019.) The policy statement is mostly in accordance with the requirements of the standard, but it does not directly refer to the improvement of energy performance and, particularly, to the improvement of the EnMS, and, thus, the policy statement of Yara Uusikaupunki must be updated to meet the requirements of the standard.

To fulfill the requirements of ISO 50001, a commitment to improving energy performance in accordance with the agreed targets and action programs - alongside the commitment to reducing environmental impact - is added in the general policy statement. In addition, commitments to effectively take energy efficiency into account in all the functions and operations, and to ensure the availability of necessary resources and information to achieve the energy-related objectives and targets, are added.

Another viable option is to separately create and approve a whole new energy policy and to add it as a part of the management system documentation, or alternatively, place it in the beginning of an optional EnMS manual. Regardless of the method of implementation, it is important that the energy policy is in an easy-to-understand form, that its existence is communicated on site, and that it is regularly reviewed and updated.

6.2.3 Roles and Responsibilities

A simplified organizational chart of the Yara Uusikaupunki site is shown in Figure 14**.** HR stands for human resources, HESQ for health, environment, safety and quality, and ROT for regional operations team. All the departments have management representatives who, together with the plant manager, make up the core management team. Deputies have been appointed to all management representatives in the event of them being prevented from attending the planned actions. Yara Uusikaupunki also has its local information technology (IT) team to assist with limited types of issues; but the majority of issues related to IT are solved at a global level. Regarding current, binding energy management actions, a continuous improvement manager (CIM) is the person at Yara Uusikaupunki responsible for EEAs, while the energy manager of Yara Siilinjärvi has an overall responsibility for the EEAs of Yara Suomi Oy (Energiatehokkuussopimukset 2017, 1, 4).

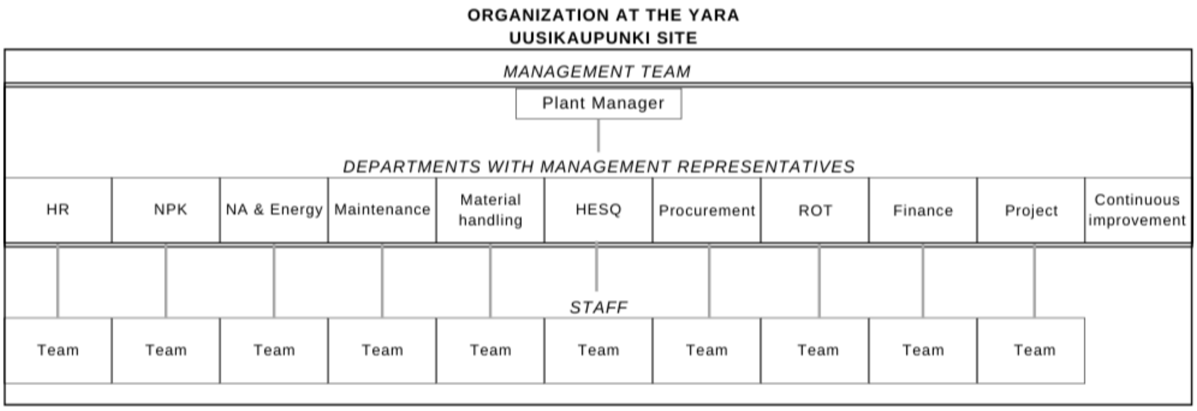

Figure 14. A simplified organizational chart of Yara Uusikaupunki.

The energy management team can include person(s) from several professional backgrounds, and, at Yara Uusikaupunki, multiple departments and the expertise of their persons could be efficiently utilized in the management of the EnMS. For instance, NPK, NA & Energy, and material handling departments are experts at their functions which consume the majority of energy at the site. The maintenance department is relevant e.g. in risk management and ensuring the proper operation of processes, systems, facilities, and other equipment. NA & Energy and maintenance departments also hold knowledge regarding energy monitoring and use. The HESQ department possesses the practical experience regarding the already certified standards, which is useful in terms of the implementation of the new standard. Energy efficiency considerations are directly linked to the activities of procurement. The finance department produces the financial information needed for decision-making and implementing the strategy, including the information about available monetary resources for the needs of energy management. The project department - which provides design, development, and project management services for internal clients at the site - can embed energy performance improvement opportunities into the project planning. The IT team takes care of IT related issues in production and is responsible - in cooperation with the local automation team and with system suppliers - for the functionality of the systems at the site. The CIM is relevant for planning and advancing performance improvement suggestions also related to energy management, such as the development of an EnMS. It can be discussed whether the CIM should also take on the role of an energy management team coordinator with regard to the EnMS.

Consideration may be given to whether the involvement of the energy management team is necessary in all functions or just to make some roles solely supportive. For example, the job description of a ROT mainly focuses on the activities happening outside the site that are not strongly related to energy management or are not necessarily included inside the scope and boundaries of the EnMS, such as demand calculations of raw materials and the coordination of exports. Also, many departments, such as HR, are relatively small, which is to be taken into account when compiling the team. All persons with an expertise and/or interest in energy management are doubtlessly a valuable asset on an energy management team, despite the official job description. It is worth noting that the current management team already consists of members from all departments, which already ensures that information reaches all said departments.

An energy management team at Yara Uusikaupunki is suggested to be established, and it is further proposed that it should initially consist of members from as many departments as possible - with specifically the main functions (fertilizer and nitric acid production and material handling) and HESQ being represented. An energy management team as a whole is recommended to possess robust knowledge of the operations and technology used at the site, as well as to have planning and motivational skills to comprehensively incorporate as many people as possible into the energy considerations. All employees must be aware of the energy management practices at the site and are responsible for their own actions. A reference about participation in carrying out the actions under the energy policy and participation in the maintenance of the EnMS can be added in the job descriptions of the departments. Energy management team meetings are proposed to happen regularly and at least once per quarter. The agenda could at least include checking the status of the action plans and status of achieving the set energy targets and EnPI(s), since these are inputs that will be needed for management reviews according to the standard (see chapter 4.7). The suggested roles and their tasks regarding the EnMS are in Table 10.

Table 10. Roles and tasks of the core energy management team.

Role	Tasks
Top management / Management team	Establish the energy policy, assign the responsibility and authority to the energy management team, provide resources, conduct management reviews, the overall monitoring of compliance with the requirements of ISO 50001, commitment, support
Management representative / Energy management team coordinator	Guidance, preparation, schedule meetings and audits, analyze the results of internal audits and management reviews, regular reviewing and reporting of energy performance and performance of the EnMS
Energy management team members	Practical work related to the implementation of an EnMS, communication and cooperation between the departments, expertise in different functions, data collection

The cross-functional energy management team can be expected to comprehensively take the organisation's operating environment into account in its operations. For instance, it can be assumed that, currently, the environmental department is a fixed part of several organizations. This environmental expertise can be utilized to combine information about the energy performance improvements with possible environmental benefits, and thereby provide another motivational factor for taking energy savings and energy efficiency actions. The same principle applies, for example, to the inclusion of the finance department in the energy management team, which provides up-to-date information on the financial benefits of energy performance improvements.

A framework for the responsibility matrix, which includes the requirements of the standard, frequency of actions taken, related documentation, and responsible person(s), was created for Yara Uusikaupunki, A framework for the responsibility matrix for the EnMS of Yara Uusikaupunki can be found in Appendix 2. The number of energy management team members in the matrix is limited to four for presentational purposes. The responsibility matrix is updated to meet the needs of the site by naming the members for the energy management team and assigning the responsibilities. This framework can also be utilized as an internal communication plan regarding the EnMS (see chapter 6.4.1). In addition, a column for extra information may be included.

6.3 Energy Planning

An energy review will be an essential part of the EnMS, since it assists in identifying and substantiating the potential SEUs and, hence, aids in allocating resources in a sensible manner. The energy review of the organization will most likely develop over time when the process has been established and regularly practiced. It is considered good practice to use the output of any type of energy audits and studies as part of an energy review. (SFS-ISO 50004:2015, 10.) The methods for implementing the energy review, as well as selection criteria for determining SEUs, are ultimately set by the organization itself, which may have an impact on what the extent of achieved GHG emission reductions through the EnMS are. Shifting the energy source from fossil sources to renewable energy is not considered an energy performance improvement (see SFS-EN ISO 50001:2018, 31). Thus, the motivation behind this type of desirable change is assumed rather to be in the goals for improving environmental performance than in implementing the requirements of ISO 50001.

Because coverage of the energy review partly depends on the available data, current methods and areas for improvement in terms of energy data collection are described in chapter 6.3.1, in order to contribute to the development of an energy review. Chapter 6.3.2 examines the current energy consumption of Yara Uusikaupunki based on numerical energy data collection and an energy review conducted in 2016 by consultants. It also aims to indicate some of the energy-related improvements and provide suggestions for improvement that have emerged as the work has progressed. The introduction of the method for targeting energy uses and indicating SEUs, using electricity usage as an example, is presented in chapter 6.3.3. Finally, a suggestion for an overall energy target is presented in chapter 6.3.4. The checklist for the requirements related to energy planning can be found in Table 11.

Table 11. The checklist for addressing the requirements of the standard with regard to energy planning.

Requirement	**Documentation required (yes/no)**	**Actions at Yara Uusikaupunki**
Address risks and opportunities	No	Assess risks and opportunities in different functions that might affect the site's energy performance, in order to prevent or minimize the undesired effect or to discover opportunities for improvement Utilize assessed issues and requirements presented in Table 6 (chapter 6.1.1) and Table 7 (chapter 6.1.2) for assessment - if deemed useful Plan how to address risks and opportunities and integrate the planned actions into the EnMS, then evaluate their effectiveness
Set the objectives and energy targets	Yes	Set the objectives and energy targets for the site Monitor and communicate the set targets regularly, updating them when needed
Establish energy action plans	Yes	When the objectives and energy targets are set, plan how to achieve them
Develop an energy review	Yes	Describe the methodology and criteria for completing an energy review, and prioritize opportunities for improvement Identify SEUs, find the relevant variables, research their current energy performance, and find people working with the selected SEUs Update the energy review regularly - or when significant changes happen at the site that may affect energy performance
Determine EnPI(s) and EnB(s)	Yes	Establish relevant EnPI and EnB values and make sure to compare them to each other on a regular basis Normalize EnPI and EnB values if deemed necessary

		Establish the method for determining and updating EnPI(s) Document EnB(s) and possible changes to them
Plan energy data collection	Yes	Establish a data collection plan and define e.g. what, why, how, and when data is collected, and who collects it Ensure that the relevant data related to SEUs is collected Review the plan regularly and update it if necessary

6.3.1 Collection of Energy Data

Despite not having a formal EnMS implemented at the site, energy consumption is monitored and reported periodically. The focus is on the electricity, steam, and fuels for production. Regarding energy performance, measures for energy efficiency improvements are collected and reported annually due to the participation in EEAs (see chapter 5.2.2).

Yara Uusikaupunki has transformer-, electrical distribution center-, and equipment-specific metering in use. Also, the nominal power of the electricity-using equipment is known. So, if needed, it is possible to obtain the energy consumption of electrical equipment computationally. Electricity metering data is available in the Honeywell-system, and it is reported monthly. (Lintula 2020a.) Despite the monitoring of electricity consumption being fairly accurate, there is room for improvement in terms of the coverage of the metering system.

Steam consumption is monitored with flow meters, and the system has been improved during the past years. The consumption of district heat can be acquired from the site's monitoring system. The consumption of district heat for the entire site is known, but the accurate uses are difficult to specify. When steam consumption, use, and production are calculated and reported, some generalizations are used due to e.g. constraints in measurement (Toimintaohje Uusikaupunki 2019, 1). Water consumption is monitored on a monthly basis and divided into different water types (e.g. raw water, sea water, drinking water).

Heavy fuel oil consumption measurements at the site are mainly based on the measurements of the supplier (consignment notes), but consumption is monitored in other ways as well. For example, daily readings of the amount of heavy fuel oil used at the fertilizer plant are acquired from the flow meters and written down in the production reports, after which the amounts of heavy fuel oil used in L1 and L2 are transferred to the SAP-system every 24 hours. The reading is the sum of the online flow meters of the burners, which all have their own meter. The fuel oil tank also has a surface measuring radar. (Holvitie 2020a.) The main reporting of heavy fuel oil consumption takes place on a monthly basis (Helle 2020).

In terms of other fuels, the amount of fuel used for trafficking is measured by utilizing the consignment notes. Consumption of light fuel oil - which is used in the reserve power generators - is monitored by recording refueling amounts in log sheets. Monitoring the consumption of liquified petroleum gas at the fertilizer plants is based on the number of cylinders used. At the power plant, the consumption of the gas is so low, that the amount of used gas is reported by weighing the cylinder. (Tomma 2020.)

There are only a few energy meters following individual energy uses at the site, although several new energy meters have been installed during past years. Whenever a new electricity distribution center is renewed, metering is also installed. All of these meters cannot be read yet due to issues in the data transfer of the automated system (Honeywell). (Lintula 2020b.) Thus, improvement possibilities in terms of metering rely on improving the coverage of the submetering to verify the alleged significant energy uses, as such tracing and specifying the actual energy uses, as well as to discover potential anomalies at an early phase. When the data transfer issues are solved, it is possible to build an energy monitoring system that covers not only electricity, but also steam and compressed air (Lintula 2020b). More accurate metering information can also be used as a basis for evaluating the energy savings potential during the operations. Currently, the energy consumption figures are looked at less frequently with a perspective of considering the potential energy savings (Helle 2020).

To fulfill the standard’s requirements and to improve energy data collection methods, energy data collection plan(s) must be established. It is suggested to create work instructions for energy data collection, an energy data collection plan, and guidelines for accomplishing an energy review to ensure that as many persons at Yara Uusikaupunki would be capable to work on the matter. In addition, it is suggested to review the currently used energy reporting templates for inaccuracies. The establishment of a data collection plan is further discussed in chapter 6.6.1.

6.3.2 Current Energy Consumption

The steam required by the nitric acid and fertilizer production is almost entirely generated from the process heat recovered at the nitric acid plants as high pressure steam (60 bar) (Jalovaara & Grönberg 2016, 16). One part of the acquired steam is directed to the condensing steam turbines of the nitric acid plants to produce electricity, and another part is directed to the power plant's back pressure turbine to generate heat, electricity, and low pressure steam (Turvallisuusselvitys Uusikaupunki 2016, 3). The low pressure steam (2 bar/6 bar) of the back pressure turbine is used both for the needs of the production processes and for the production of district heat. A small volume of 20 bar steam is also produced for the needs of the nitric acid plants. (Jalovaara & Grönberg 2016, 16.)

The needs of the nitric acid and fertilizer production processes consume the majority of steam, electric energy, and heavy fuel oil. Yara Uusikaupunki does not produce all of the electrical energy needed at the site. So, electricity is also bought from an external operator (Jalovaara & Grönberg 2016, 12). Heavy fuel oil used at the fertilizer plants and at the power plant - as well as liquified petroleum gas, light fuel oil, and other fuels - are sourced from external suppliers. Ammonia, which is also purchased from an external supplier, is imported to the site by train and tankers, and is directly used as a feedstock for the nitric acid and fertilizer production and indirectly as an energy source in the form of process steam.

According to the reported energy data at Yara Uusikaupunki in 2019, steam (78.0%) was the most consumed energy type at the site, followed by electricity (14.7%), heavy fuel oil (5.8%), and district heat (1.6%). An energy review that mainly considered energy consumption and the use of the nitric acid and fertilizer production was conducted in 2016. According to the energy review, most of the heat and electric energy is used in the production processes of the site (about 96%). The other uses, such as lighting, air conditioning, and space heating, account for around 4% of all energy used for production. A majority of heavy fuel oil is used at the fertilizer plants to heat the air used for drying the fertilizers. (Jalovaara & Grönberg 2016, 12, 16.)

Steam, electricity, heavy fuel oil, and district heat are included in the analysis of energy consumption due to there being rather easy access to the data. The values for electricity consumption (MWh), heavy fuel oil consumption (GJ), and steam consumption (t) are gathered from the site's energy reports. The amount of heavy fuel oil was converted to MWh by using the conversion base (3.6 GJ = 1 MWh). The amount of district heat consumption was calculated by using the daily medium power data from the site's monitoring system. Median power consumption (MW) was then multiplied by 24 h to get the daily energy consumption, after which the daily energy consumptions were summed up in order to get the whole year's district heat consumption in MWh. The energy acquired from steam in MWh was calculated by multiplying the amount of steam (t) by its respective enthalpy (see Table 12).

Table 12. Enthalpies used for energy content calculation at Yara Uusikaupunki (Toimintaohje Uusikaupunki 2019, 1).

Steam pressure [bar]	**Entalphy [MWh/t]**
60 bar	0.936
20 bar	0.778
6 bar	0.767
2 bar	0.761

The values of the energy consumption of steam, electricity, and heavy fuel oil are to be understood as being only indicative. It is possible that the calculations contain inaccuracies, as it is known that the reporting templates need to be reviewed. The results of the energy consumption analysis at Yara Uusikaupunki in terms of 60 bar and 2 bar steam, electricity, heavy fuel oil, and district heat consumption are in Figures 15, 16, 17, 18, and 19. Because of the remarkability of the energy consumption at the production sites, and the insignificance of other uses of energy, an assessment of the energy consumption of steam and electricity was only conducted for the main functions (T2, T4, L1, and L2). The analysis of heavy fuel oil consumption only considers the power plant and the fertilizer plants, since it is not used elsewhere at the site. Regarding the steam consumption analysis, 20 bar and 6 bar steam were excluded due to a high inaccuracy in the data and the minor significance in relation to the production volume.

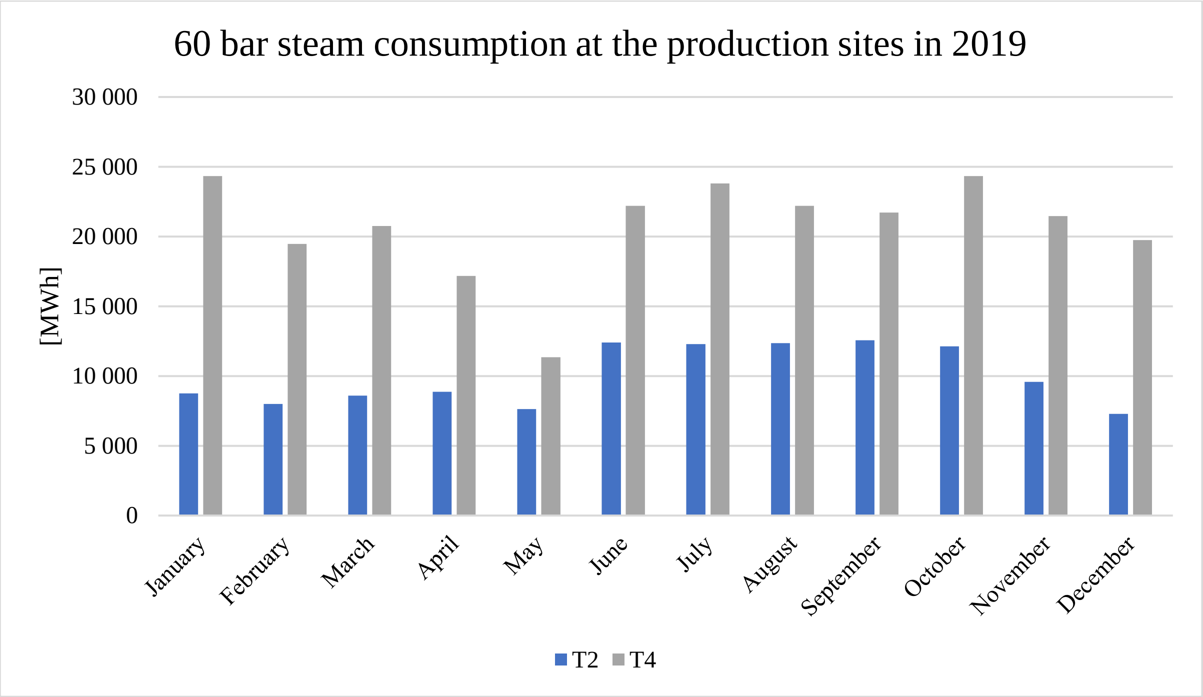

Figure 15. 60 bar steam consumption at the production sites in 2019 (Data source: 2019 HÖYRYRAPORTTI).

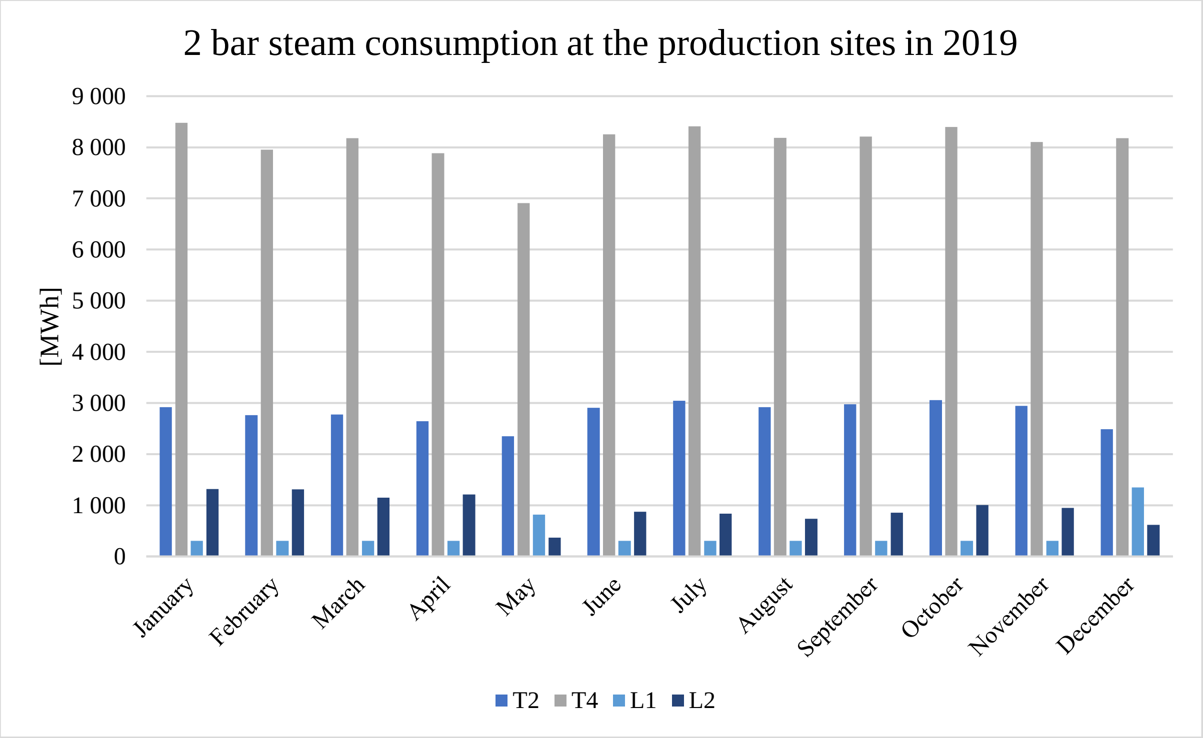

Figure 16. 2 bar steam consumption at the production sites in 2019 (Data source: 2019 HÖYRYRAPORTTI).

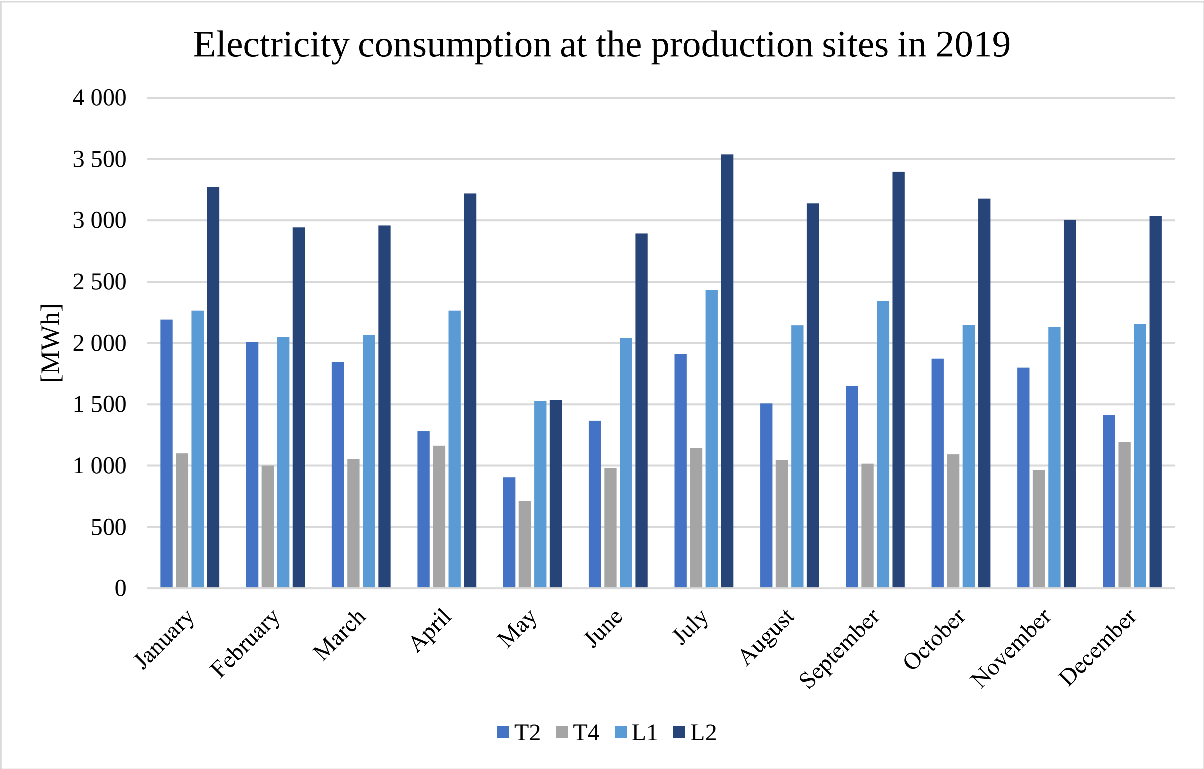

Figure 17. Electricity consumption at the production sites in 2019 (Data source: SÄHKÖRAPORTTI 2019).

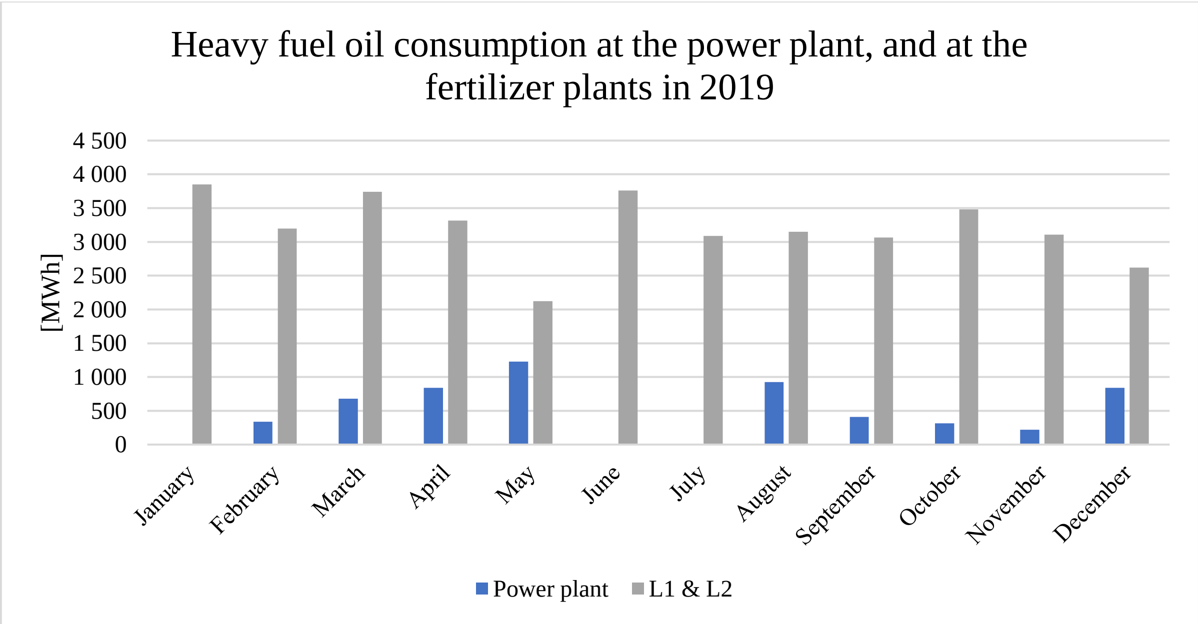

Figure 18. Heavy fuel oil consumption at the power plant and at the fertilizer plants in 2019 (Data sources: 2019 UKI Site Energy Consumption; 2019 Polttoöljyt).

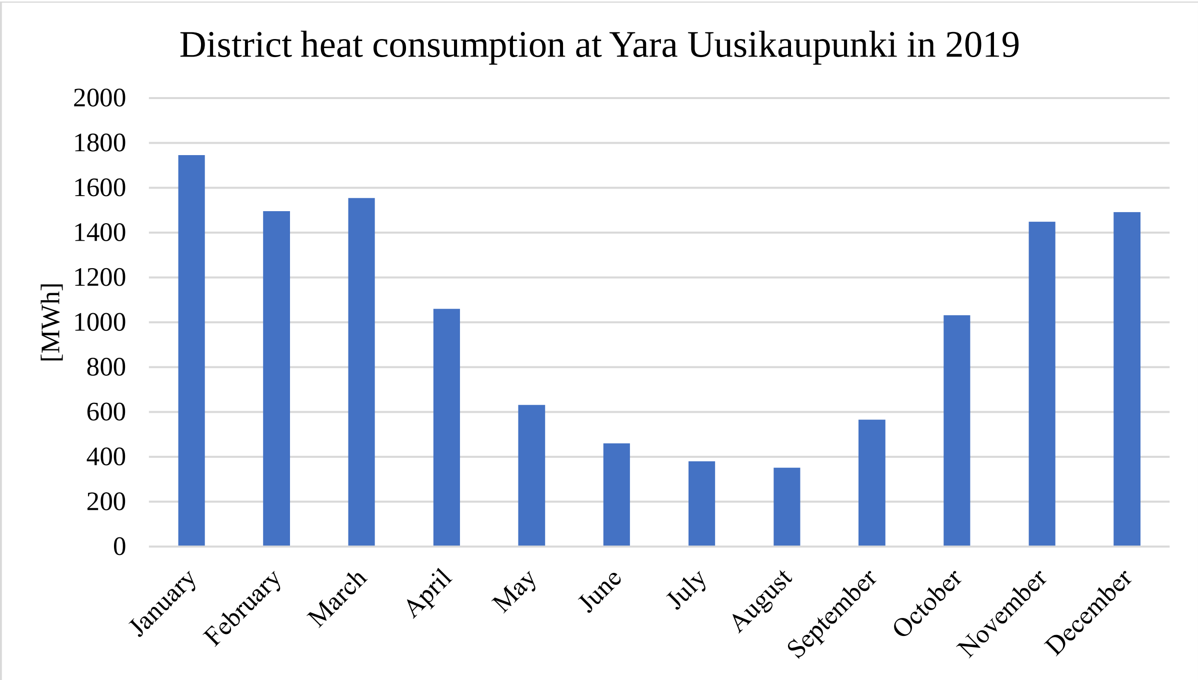

Figure 19. District heat consumption at Yara Uusikaupunki in 2019 (Data source: Lehtonen 2020a).

A majority of the steam is consumed at the nitric acid plants, during fertilizer production, and for the production of electricity, district heat, and lower-pressured steam at the power plant. The use of heavy fuel oil at the power plant is not as consistent as it is at the fertilizer plants, as the heavy fuel oil is required only during start-up for the nitric acid plants' production lines. (Jalovaara & Grönberg 2016, 16). As seen in Figures 15, 16, and 17, the levels of steam and electricity consumption are fairly stable throughout the year. It is important to note that the 2 bar steam consumption at L1 is only an estimate due to there being some issues in the steam consumption data collection in 2019. The decrease in May is due to an annual turnaround event, when all the functions at the site are shut down for about half a month for maintenance. The slight increase in heavy fuel oil consumption at the power plant in May 2019 (Figure 18) is likely due to the production lines at the nitric acid plants starting up again after the turnaround period. District heat consumption varies in accordance with the changing seasons and outdoor temperatures (Figure 19).

It is expected, that the biggest change in terms of energy consumption patterns during the past years has taken place in the consumption of heavy fuel oil, as the third granulation line at the L2 fertilizer plant shifted its energy source for the drying process from heavy fuel oil to process steam in 2019 (Holvitie 2020a; Tomma 2020). The aim is to completely eliminate the use of heavy fuel oil in the fertilizer production, because, not only are there better alternatives for addressing environmental concerns, but heavy fuel oil can also cause malfunctions in the washer systems, and the use of heavy fuel oil in small quantities (under 70 kg) is not viable. (Holvitie 2020a.) One already-considered alternative option is to replace heavy fuel oil with process steam and to use liquified natural gas as an auxiliary energy source, which obviously requires technical changes at the very least (Heikkinen 2020a; Holvitie 2020b). The combustion of liquified natural gas releases fewer emissions compared to heavy fuel oil, although CO_2 emissions are still not avoided (Bowten 2015, 14). In addition to the environmental benefits, the adjustability of the gas in the combustion process at the fertilizer plants is significantly more convenient when compared to oil (Holvitie 2020b). To note, shifting from an energy source to another is not considered an energy performance improvement according to the ISO 50001 standard, although it is clearly beneficial in terms of the environment and the functionality of the systems at the site (see chapter 6.3). Concerning the other updates in general, changes to energy-using equipment have been made during the past years, such as updates on the sea water pumps and the installations of variable frequency drives (Lintula 2020a).

Other energy performance improvement opportunities at the fertilizer plants have also been discussed. For instance, the varieties of fertilizer with higher moisture content require more energy for drying. Therefore, control of the moisture content of the raw material is essential in order to reduce the need for energy used for heating. (Heikkinen 2020b.) Another method to save energy could be to minimize unnecessary operating time through more accurate monitoring (Lintula 2020a). Also, the energy released from the cooling of the fertilizer product has been considered for utilization, as most of it is currently removed from the process. The problem here, however, centers on the low recovery temperature combined with the high flow rate, meaning the heat recovery equipment could grow very large while the efficiency still remains low. (Holvitie 2020b.) At the nitric acid plants, possible energy efficiency improvement opportunities include e.g. improving the efficiency of the steam turbine at T4 and making better use of process heat (Lehtonen 2020b).

For further development of the energy review, energy uses should be more tightly linked to their energy sources. Present and past energy consumption as well as the use of recognized energy sources and energy uses must be evaluated. When the energy uses are identified, it is good practice to evaluate the past energy consumption and use by utilizing the data of at least a one year period at a monthly frequency, so that the analysis is as close as possible to the real situation and can be utilized to assess future trends. (SFS-ISO 50004:2015, 11.) It is up to the site how the energy review is conducted and what will be emphasized therein as long as the criteria is justified. It is proposed that a long-term plan for conducting energy reviews is created, including the subjects and frequency. For example, the objectives set for energy review could be rotated at specified intervals. Updating an energy review is especially important if major changes of any function are taking place.

6.3.3 Example Case: Potential SEUs Related to Electricity at the Site

In this example, the method for selecting SEUs is presented using electrical energy as an example. The data collected by the electricity submeters were linked with the electricity consuming functions in Excel. The gathered data is in Table 13, and the Finnish names of the functions are in italics.

Table 13. Distribution of consumed electrical energy at Yara Uusikaupunki in 2019.

Function	Name of the submeter	Electricity use in 2019 [MWh]	% of total electricity consumption
Wastewater treatment *(Jätevesien puhdistus)*	Jätevesilaitos	1779.5	1.6
Waterworks *(Vesilaitos)*	Vesilaitos Merivesipumppu AM2 Säkittämö (50%)	4521.6 0.0 1780.2	4.0 0.0 1.6
Power plant *(Voimalaitos)*	VO 1 omakäyttö T30 Voimalaitos kaukolämmitys	2080.5 384.3	1.8 0.3
District heat (*Kaukolämpö VSV)*	KL-Pumppu 402 KL-Pumppu 401	297.3 0.0	0.3 0.0
Ammonia storage *(Ammoniakkivarastot)*	AM2 kompressori AM2 AM1	0.1 3510.0 1374.3	0.0 3.1 1.2
Nitric acid plant 2 *(Typpihappotehdas 2, "T2")*	TY 2 moottori 4,2 MW TY 2 kompressori TY 2/1 50/5	1420.1 14995.2 3338.9	1.3 13.3 3.0
Nitric acid plant 4 *(Typpihappotehdas 4, "T4")*	T4 Moottori T4 Merivesipumppaamo T4 Tehdas	232.0 2905.5 9332.6	0.2 2.6 8.3
Strong nitric acid (*Väkevä typpihappo)*	Väkevä typpihappo	0.0	0.0
Fertilizer plant 1 *(Lannoitetehdas 1, "L1")*	Muuntaja T28 + Muuntaja T29 Muuntaja T15 Lannoitevarasto	18040.1 6838.3 1259.0	16.0 6.1 1.1

	Selkeytin	50.4	0.0
Fertilizer plant 2 *(Lannoitetehdas 2, "L2")*	Muuntaja T13	11570.5	10.2
	Muuntaja T11	6025.1	5.3
	Muuntaja T12	2709.9	2.4
	VÄ 1000/5	0.0	0.0
	Rikkivarasto 300/5	0.0	0.0
	JA Muuntajan 1	0.0	0.0
	Seleeni	0.0	0.0
	Happokukkula	171.1	0.2
	Muuntaja T35 L2/L3	8786.2	7.8
	Muuntaja T36 L2/L3	6851.9	6.1
Port (*Satama)*	Satama uusilaituri	204.3	0.2
	SA 301 Fos lastain	34.5	0.0
	Nosturi 1	109.3	0.1
	Nosturi 2	135.9	0.1
	Satama valaistus	0.0	0.0
	SA 401 Lastain 2	79.7	0.1
Sacking *(Säkittämö)*	Säkittämö (50%)	1780.2	1.6
Towboat dock *(Hinaajan laituri)*	Hinaajan laituri	0.0	0.0
Infrastructure and offices *(Tehdasinfra ja konttorit)*	RK20 varasto	0.2	0.0
	RK21 suunnittelu	69.1	0.1
	RK22 instrumentti	29.2	0.0
	RK23 rakennus	33.4	0.0
	LI konttori, ruokala, labr.	97.5	0.1
	LI korjaamo, pesula, autot.	173.5	0.2
Total electricity consumption		**113001.4**	**100.0**

Thereafter, meter readings were arranged based on the magnitude of electricity use. The data was based on 2019 cumulative electricity consumption data. A Pareto-analysis was utilized to name “substantial energy consumption” amongst the electricity uses, which, again, was based on the values of the submetering. The Pareto principle states that 20% of the reasons are accountable for 80% of the consequences. So, in this case, 20% of the electricity-using equipment is accountable for 80% of the energy usage. It is likely that focusing on these areas yields the most results. (Fawkes 2016, 95.) The Pareto-analysis of Yara Uusikaupunki’s electricity consumption in 2019 with the values obtained from submeters is in Figure 20. The red line is used to indicate which energy uses from the submeters could fulfill the criteria for being labeled as “substantial energy consumption” - electricity uses on the left side of the line account for 80% of the total electricity consumption at the site. Submeters with a reading of 0 have been excluded from the Pareto-analysis. As seen in Figure 20, submeters - until *AM2* from the left - account for about 80% of total electricity consumption at the site.

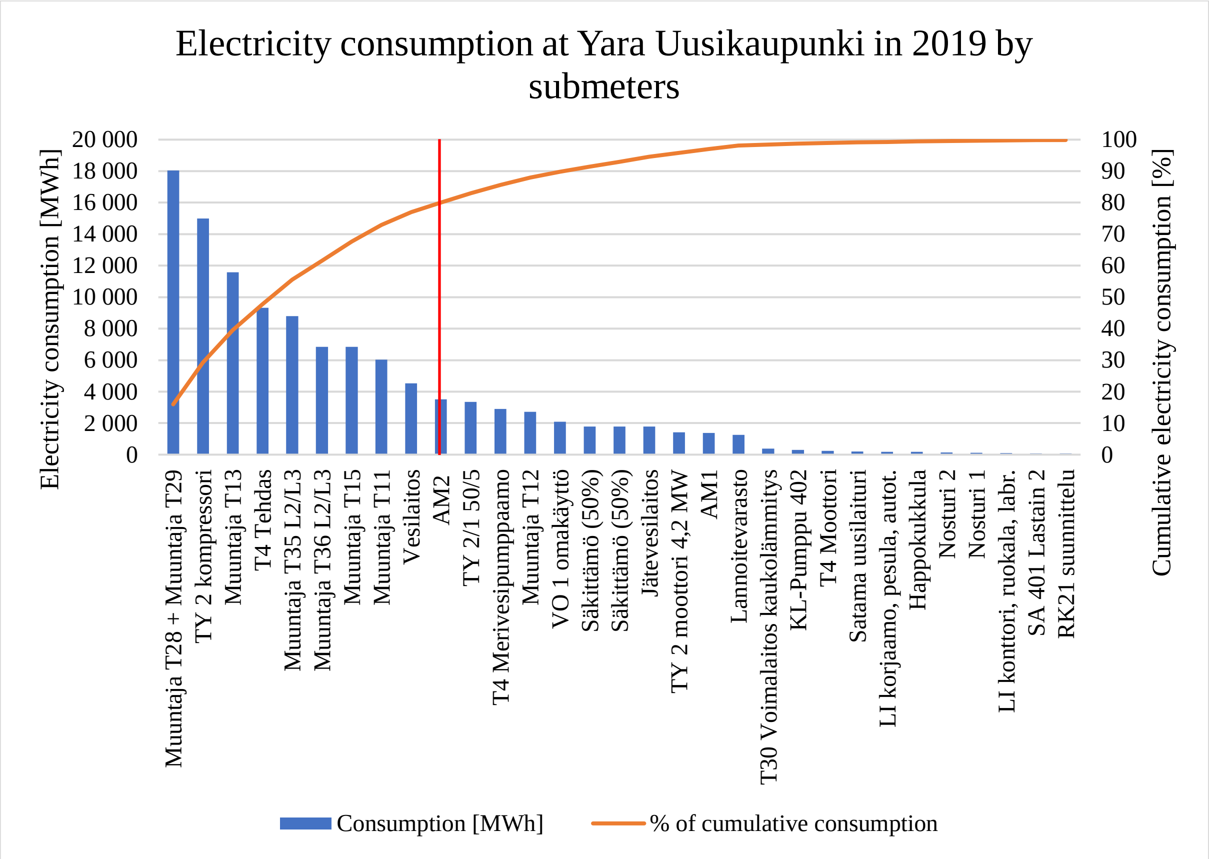

Figure 20. A Pareto-analysis of electricity consumption at Yara Uusikaupunki by submetering values in 2019.

A Pareto-analysis of electricity consumption by function was also conducted at the site. As seen in Figure 21, the processes at L2, L1, and T2 consume the majority of electric energy used at Yara Uusikaupunki. This more vast look at electricity consumption could also be used as a criterion for determining “substantial energy consumption”.

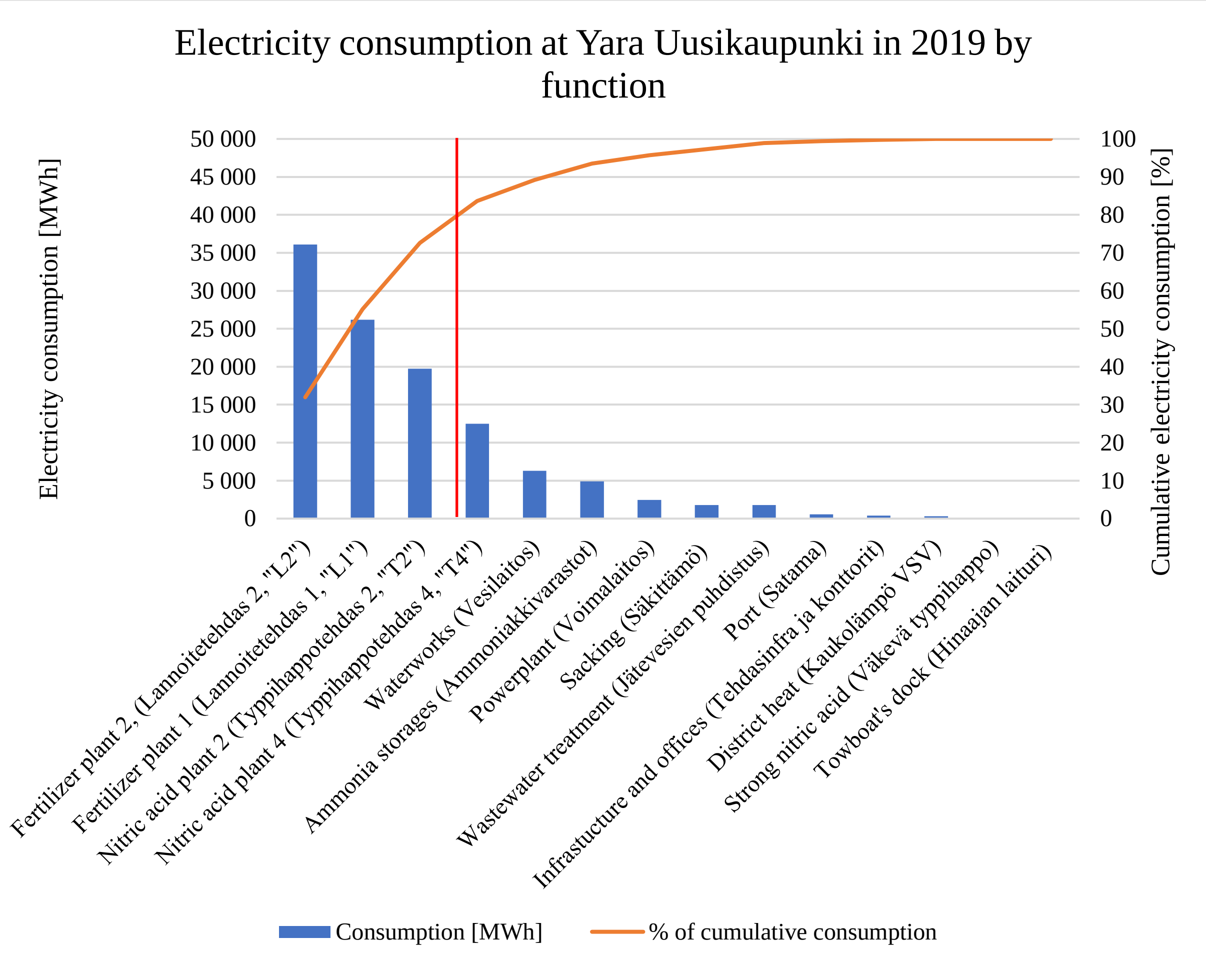

Figure 21. A Pareto-analysis of electricity consumption at Yara Uusikaupunki by function in 2019.

Specialists at the site provided more specific information about the discovered substantial electricity uses behind the submeters. According to interviews, *Muuntaja T28* + *Muuntaja T29*, located at L1, and *Muuntaja T13* at L2 measure electricity consumption of all the processes at the fertilizer production plant, and are not specific to any particular electricity-using equipment. *TY 2 kompressori*, located at T2, measures the energy consumption of an auxiliary air compressor utilized for nitric acid production. (Lintula 2020b; Helle 2020.) Thereafter, opportunities for energy performance improvements were discovered by interviewing experts at the site. Since the submeters *Muuntaja T28* + *Muuntaja T29*, located at L1, *TY 2 kompressori* at T2, and *Muuntaja T13* at L2 have measured the three highest electricity consumption values at their locations and account altogether for almost 40% of the site's total electricity consumption (see Table 14**)**, the interviews were conducted only for these locations for demonstrational purposes.

Table 14. The top three submeters that measured the highest electricity consumption readings at Yara Uusikaupunki in 2019.

Name of the submeter	% of total electricity use
Muuntaja T28 + Muuntaja T29 (L1)	16.0
TY 2 kompressori (T2)	13.3
Muuntaja T13 (L2)	10.2

The energy performance improvement opportunities of this particular auxiliary air compressor are assessed not to be significant. It is likely that the most sensible way to improve energy efficiency of the auxiliary air compressor would be to replace it with a new one, since the equipment is fairly old - the auxiliary air compressor was brought to Uusikaupunki from Yara Tertre in the 1990s. The equipment itself is over 50 years old. (Helle 2020; Lehtonen 2020b.) Renewing the compressor would be a significant investment (Lehtonen 2020b). At fertilizer plants, energy efficiency measures and their effects have been studied. One example of a study is one that involves replacing motors and installing variable frequency drives in pumps and fans. In the best case scenario, it has been found that the annual savings per pump exceed €10,000. However, the pumps in question were the biggest and most inefficient pumps, so it is worth noting that, in terms of smaller pumps, the savings are likely to be lower. However, presumably, the easiest way to save electricity at the moment is to modernize the electric motors, which oftentimes is done whenever investing in new sub-processes. (Holvitie 2020b.)

To conclude, in this example case, which takes only electricity use into account, the company selected both substantial energy consumption and opportunities for energy performance improvement as criteria for naming a process or an equipment as an SEU. “Substantial energy consumption” was defined by utilizing the results of a Pareto-analysis of submeter data as a criterion. The site could select either a more specific analysis based on single submeters (see Figure 20) as a criteria or use data gathered from bigger entities (see Figure 21). Also, a possible criterion for “substantial energy use” could be, for example, that the electricity use accounts for >10% of the site’s total energy consumption. The main idea is to discover the uses that are responsible for significant electricity consumption at the site.

Potential improvement opportunities were evaluated by utilizing expert interviews of the employees working at the site to suggest the actual SEUs, which is used as a criterion for “opportunities for energy performance improvement”. Potential improvement opportunities could have also been discovered by e.g. utilizing the results of former audits or studies. For example, a cost analysis of all the development ideas suggested at Yara Uusikaupunki was conducted in 2017 - and could be partially utilized, if the discovered SEUs are related to these (see Yara Uusikaupunki 2017).

According to the example case and conducted interviews, fertilizer production (process) and/or the auxiliary air compressor (equipment) would be legitimate options to be selected as SEUs, since they are both substantial energy uses at the site. However, energy performance improvement opportunities for the old auxiliary air compressor are unlikely to be significant, and a new replacement for the equipment would require a remarkable monetary investment. Instead of an auxiliary air compressor, the nitric acid production processes in general could be selected as a focus for which the resources are allocated, if this is deemed to be reasonable for the site. Moreover, the electric motors could be selected as SEUs if the site is able to verify the improvement of their energy performance. This could be done, at least, computationally by utilizing e.g. name plate information, operating hours, and efficiencies, by increasing the submetering, and/or by utilizing the specific, already existing electric energy submeter values before and after making changes to the motors.

When prioritizing the discovered "opportunities for energy performance improvement", it is suggested to include, at least, the ease of the planned improvements and payback time in consideration of the SEUs at Yara Uusikaupunki. In order to facilitate decision-making, it might be appropriate to establish, for example, a scoring method for these variables (e.g. ease of implementation 1–5, where 1=very easy to implement/no external workforce required, 2=easy to implement/some external workforce might be required, et cetera).

6.3.4 Objectives, Energy Targets, and Action Plans

When the energy review is completed, Yara Uusikaupunki is able to set objectives and energy targets. It is assumed that the scope and level of ambition of these objectives and energy targets will largely determine the energy performance improvements and, thus, the significance of reducing GHG emissions associated with reducing energy consumption.

Since the company already has site-specific targets set in EEAs, it would be applicable to use the same target as an overall energy target for the EnMS. The current EEAs are valid until 2025, so there would still be time for the site to pursue the same goal - assuming that the EnMS will be implemented by the end of 2021. The energy performance target can also be divided into sub-targets. If it is found that the site can take its energy performance improvement even further, objectives and energy targets should be set higher. The objectives and energy targets will be defined in accordance with the annual planning process of Yara Uusikaupunki.

To effectively achieve the named objectives and energy targets, action plans are established according to the available resources. Table 15 shows the minimum details to be considered in an action plan, using electric motors as an example. The energy objective in the example is to reduce electricity consumption, and the energy target is to improve the energy performance of the electric motors by 5% by 2025.

Table 15. Example action plan, wherein the energy target is to improve the energy performance of the electric motors by 5% by 2025.

Objective	Energy target	What will be done	Responsible person	Resources needed	Completed	How to measure improvements
Reduce electricity consumption	Improve the energy performance of the electric motors by 5% by 2025	Determine the motors that can be improved	X.X.	Working hours, finance	November 2021	Electricity submeters
		Design the project (Make a cost analysis, check availability of the needed equipment and services, etc.)	X.X.	Working hours, finance (if external design is needed)	November 2022	
		Procure the required equipment and services (variable frequency drives, new motors, etc.)	X.X.	Working hours, finance, tendering	February 2023	
		ETC.				

6.4 Supportive Functions

Defining and providing the resources needed for operating the EnMS and improving energy performance is an initial part upon which the EnMS is built. The consideration and targeting of resources will be addressed by the top management at the site. According to the standard, the sectors and characteristics that support the improvement of energy performance and the EnMS that need to be taken into account are competence, training, awareness, and an adequate level of communication. Also, keeping documentation at a comprehensive level not only supports meeting the requirements of the standard, but also the general operations at the site. A checklist of the requirements related to supportive functions is in Table 16.

Table 16. Checklist for addressing the requirements of the standard with regard to supportive functions.

Requirement	**Documentation required (yes/no)**	**Actions at Yara Uusikaupunki**
Determine the necessary resources for the EnMS	No	Define and provide the resources needed for operating the EnMS and improving energy performance
Determine the required competence	Yes*/no	Define the required competence for people having involved with the EnMS and energy performance in any way Discover the potential needs for additional training *Document information about competence as is appropriate
Ensure a level of awareness	No	Publish the energy policy for and inform persons working at the site Ensure that the staff is aware of the consequences of their actions for the EnMS and energy performance
Communication	No	Define the level and methods of communication, and share the information as planned
Suggest improvements	No	Ensure that it is possible for anyone working at the site to make improvement suggestions and give comments related to the EnMS and energy performance

		Maintain the current level of the documentation of suggested improvements and, if appropriate, improve upon it Note: The documentation of suggested improvements is not mandatory but is recommended
Adequate documentation	Yes	Ensure that all the ISO 50001 documentation requirements exist and that the documents are controlled and regularly updated

6.4.1 Competence, Training, Awareness, and Communication

The competence required from the personnel working within the EnMS is specified by the site. Development discussions are held twice a year at Yara Uusikaupunki. The emerging needs for training and competence development are evaluated during these discussions, after which the training plans can be prepared (Käsikirja Uusikaupunki 2018, 2). Special attention should be paid to the person(s) working with the selected SEUs and as a part of the energy management team. Collective and more compact training related to the EnMS could be included as a part of the departmental inductions, especially if the work task is assumed to have an effect on SEUs. Consideration may be given to including this topic in e.g. safety induction trainings, in order to make sure the relevant information regarding energy performance also reaches the contractors working at the site.

Top management and the whole energy management organization at Yara Uusikaupunki have multiple tools for communicating the requirements of the EnMS to the organization, such as meetings, events, online platforms, group emails, inductions, and trainings. Frequent communication with the external stakeholders regarding the EnMS is considered unnecessary, excluding the authorities. The need for communication with other external stakeholder groups, such as the contractors and consultants, can be considered separately according to the relevance of their tasks to energy performance and the EnMS. It is important to specify what information related to the EnMS is considered important to share and how it will be done. Plans for communication regarding the EnMS can be embedded into the responsibility matrix of Yara Uusikaupunki (Appendix 2). Top management and/or the energy management team must ensure that the persons working on behalf of Yara Uusikaupunki are aware of the consequences of their actions as they pertain to energy performance and the EnMS.

The standard requires the organization to establish a procedure that allows employees to give comments or suggest improvement ideas regarding the EnMS and energy performance. In terms of improvement ideas, Yara Uusikaupunki maintains a shared continuous improvement page on its internal Website, which also has energy efficiency improvement ideas as one of its themes. These ideas are sorted by the main departments and are divided into four categories: not implemented, processed, implemented, and completed. All the site’s employees have access to the page and are able to share improvement ideas. Currently, the ideas that have been gathered earlier from a workshop in 2016 or by CIM by interviews are reviewed twice a year. (Hakala 2020.) Evaluation of the implementation potential happens inside the departments, and the decision to proceed further is based e.g. on the current resources, the amount of energy savings, and profitability calculations. It is suggested that comments and ideas concerning the EnMS could be addressed on the same platform, and awareness about the page is suggested to be increased in order to ensure all ideas continuously end up on the page consistently. In addition, it is advisable that both the established action plans and related performance evaluation information are placed under the same title - such as on the continuous improvement page - wherein the essential information about performance improvement and the current direction could be viewed simultaneously.

Regarding the energy-related GHG emissions, the enhancement of competence, training, awareness, and communication mostly has an effect on the activities happening at the site - especially when external communication concerning the EnMS is not planned. Communication outside the organization, and the awareness that accompanies it, could help inspire other actors in the same field to pay attention to energy efficiency and the associated benefits. Training and the level of competence mainly play a role in the organization's internal operations, but the effects from the choices made can also reach further if, for example, energy efficiency is better taken into account in those activities that extend beyond the organizational boundaries - such as in procurement activities. A certain level of competence may also contribute to an improved recognition of energy efficiency improvement opportunities and deviations in energy performance.

6.4.2 Documentation Requirements

Yara Uusikaupunki has several document storage locations in use, such as the YMS (Yara Management System) in SharePoint, Yara Uusikaupunki's Intranet in SharePoint, and common drives. SharePoint - wherein Yara Uusikaupunki already stores its documentation with regard to already certified ISO standards - is compliant with the document control requirements . Yara Uusikaupunki is currently transferring its documentation from the site's own intranet to the YMS. The site maintains a listing of management system documentation.

The persons responsible for certain types of documentation, availability, and updates are named. The creation of new documentation regarding quality-, environmental-, or safety management systems should be notified to the quality manager who maintains a list of documentation. Management system documents are available for all the employees working on behalf of Yara Uusikaupunki. The documentation can only be accessed by an external customer, contractor, or partner with the permission of the persons responsible for the operations. The availability of a confidential document is determined by the person responsible for the document in question. In practice, access to recordings is restricted by the read permissions. (Toimintakäsikirja 2018a, 1.)

It is recognized that ISO 50001 and ISO 14001 on environmental management share a number of compatible requirements. According to Uriarte-Romero et al. (2017, 6), integration of the EnMS into the existing EMS not only avoids the duplication of documentation, but it also facilitates the deployment and implementation of the new system and saves time and resources by making use of already functional mechanisms, systems, processes, and procedures. Integrating the existing EMS documentation with the EnMS documentation would also be beneficial in terms of identifying shared perspectives and objectives. Since Yara Uusikaupunki already holds other standards with similar documentation requirements, integrating the required documented information of ISO 50001 into the existing management system documentation is considered feasible (Ritola 2020b). Responsible persons for the new documents will be named. A compilation of the documentation requirements of ISO 50001 is in Table 17, and it can be used as a checklist when implementing the EnMS. The section numbers are from the standard.

Table 17. Compilation of the documentation requirements according to SFS-EN ISO 50001:2018.

Section	Required Documentation
4.3 Scope and boundaries	The scope and boundaries of the EnMS must be documented.
5.2 Energy policy	The energy policy shall be retained as documented information.
6.2.2 & 6.2.3 Objectives, energy targets, and the plans to achieve them	The objectives, energy targets, and action plans must be documented.
6.3 Energy review	The methods and criteria used to develop the energy review, as well as its results, must be documented.
6.4 Energy performance indicator(s) (EnPI(s))	EnPI value(s) and the methods for determining and updating the EnPI(s) must be documented.
6.5 Energy baseline(s) (EnB(s))	EnB(s), relevant information and variable data related to EnB(s), as well as changes to EnB(s), must be documented.
6.6 Planning for the collection of energy data	Collected and documented energy data must include: ● SEU-specific variables; ● All energy consumption data related to SEUs and the organization; ● Criteria for operations regarding the SEUs; ● Static factors, if deemed relevant; ● Data that is decided to be gathered and is specified in the action plans. Also, documented information on measurement, monitoring, and other means of generating accuracy and repeatability shall be retained.
7.2 Competence	Appropriate documented information as evidence of competence shall be retained.
8.1 Operational planning and control	The organization shall plan, implement, and control its SEU-related processes that are needed to meet the targets and implement the action plans by keeping documented information to a necessary extent in order to ensure that the processes have been carried out as planned.
8.2 Design	Documented information of the design activities related to energy performance shall be maintained.
9.1.1 Monitoring, measurement, analysis, and evaluation of energy performance and the EnMS	Results of the investigations of significant deviations shall be retained. Appropriate documented information on the results from monitoring and measurement shall be retained.
9.1.2 Evaluation of compliance with legal requirements and other requirements	At planned intervals, compliance with legal and other requirements - related to energy use, energy consumption, and energy efficiency - shall be evaluated. The results of the evaluation of compliance and any actions taken shall be retained as documented information.
9.2.2 Internal audit	The documented information shall be retained as evidence of the implementation of the internal audit program(s) and the audit results.

9.3.4 Management review	Documented information of the results of management reviews shall be retained as evidence.
10.1 Nonconformity and corrective action	Documented information of the nature of the nonconformities, actions taken, and results of the corrective actions shall be retained.

The above mentioned documentation requirements will either be embedded into the already existing management system documentation as appropriate, or new documents will be established by the person(s) responsible for document modification and management. Then, any changes or documentation must be accepted by company protocol. Any new documents are to be added to a masterlist of management system documentation as they are completed.

6.5 Operation

Operation is the “do” -part of an iterative Plan-Do-Check-Act approach - which the ISO 50001 standard is based on - and the planning and controlling of operations according to the standard are largely centered around the discovered SEUs and fulfilment of the action plans. A checklist of the requirements related to operations, design, and procurement is in Table 18.

Table 18. A checklist for addressing the requirements of the standard with regard to operations.

Requirement	Documentation required (yes/no)	Actions at Yara Uusikaupunki
Control operations	Yes	Make sure that operation and maintenance activities related to SEUs are controlled and documentation is appropriate in order to ensure the planned quality of implementation and to avoid significant deviations as defined by Yara Uusikaupunki
Consider energy performance in design activities	Yes	Consider adding energy performance considerations into project design, and document the possible consequences of the choices made
Set procurement criteria	No	Make sure energy performance is an evaluation criterion for SEU-related purchases Clarify the criteria for assessing the energy performance of products, equipment, or services that may

		significantly affect the site's energy performance

6.5.1 Operation and Maintenance

The main processes at Yara Uusikaupunki operate 24 hours per day, year-round. Maintenance takes place throughout the year, but a planned, annual turnaround usually takes place in early May.

Once SEUs have been identified and energy targets and action plans have been defined, Yara Uusikaupunki should take these into account when planning their operations. As for site-specific implementation, Yara Uusikaupunki must determine what "significant deviation" means in terms of energy performance and the EnMS and define criteria for the processes related to SEUs in order to ensure that significant deviations are avoided. The criteria is communicated to persons working at Yara Uusikaupunki. Control of the processes regarding SEUs is established according to the set criteria and documented to the necessary extent.

The criteria created for SEU-related control and maintenance and the possible new work instructions can be added to the existing management system documentation. These can also already be discussed firstly in the induction of new employees. In the context of probable, novel work instructions resulting from the new operating and maintenance criteria, the training needs of old staff can also be surveyed. When looking at processes, it is also possible to examine, for example, whether deviations due to human factors could possibly be prevented by an increased automatization of operations.

Yara Uusikaupunki uses inter alia SOPs and work instructions to control its operations. It is advisable to create SOPs or work instructions for e.g. energy data collection practices and the persons who might have an effect on energy performance in order to effectively maintain the EnMS and to ensure that more person(s) are able to work with several matters. With regard to energy performance, special attention should be paid to SOPs and work instructions which concern the selected SEUs.

6.5.2 Procurement and Project Planning

Procurement at Yara Uusikaupunki is multi-level, and the organization consists of the central procurement (Yara concern) and the procurement of Yara Suomi Oy. The sites have their own procurement managers and procurement teams that cooperate at the Yara Suomi Oy -level. Central procurement has main control over the governance and excellence and procurement processes, and it sets the guidelines and the framework for procurement through its procurement strategy. The volume of purchases - i.e. the price of purchase - has an effect on how many levels of the procurement organization are involved in decision making. All areas of the procurement volumes are also divided into categories. Each category has its responsible person either at a global, regional, local, or the Yara Suomi Oy -level, and these categories are involved in the procurement process over regional and plant levels. At the local level, the Yara Uusikaupunki procurement department operates, monitors, and complies with e.g. the Yara Suomi Oy -level purchase instructions and legislation (e.g. the Accounting Act). (Jokinen 2020.)

Yara Uusikaupunki has its own department for project management that produces design, development, and project management services for internal customers and interfaces. The project department is especially in keen cooperation with the procurement, finance, and HESQ departments, as well as with external designers. Procurement at Yara Uusikaupunki is involved in project activities at an early stage. Energy efficiency is constantly integrated into plant development planning and investment design and implementation at Yara Uusikaupunki (Laksio et al. 2016, 4). The specification of the equipment, services, and other necessities takes place at the departmental level, after which external designers may be involved, for example, to map the scope of delivery (Jokinen 2020). External designers, if necessary, can also be involved in the pre-planning or feasibility study -phase. Energy efficiency is an integral part of the process design of at least one of the external consultants that Yara Uusikaupunki uses as well, but sometimes trade-offs between energy efficiency and e.g. investment costs or available space need to be made (Keskinen 2020). With regard to design activities and energy performance, it is viable to create criteria for when the energy performance of a process, service, or equipment is mandated to be taken into consideration - such as operations related to SEUs. When energy performance is considered, the effects of the actions taken should be monitored to verify the possible, obtained energy performance improvements.

Yara Uusikaupunki's procurement is not involved in the site's purchase of energy, excluding the local energy supply contracts. The selection and procurement of raw materials can neither be influenced at large nor on a local level, but it can address compliance with REACH chemicals legislation when necessary. (Jokinen 2020.) As Yara Uusikaupunki does not have the exclusive right to determine purchase instructions, the section of the standard which, if applicable, asks for specifications for the method for energy purchase and for ensuring the energy performance of procured equipment and services, does not apply in terms of site-specific implementation of the standard. For the same reason, it is challenging to directly influence energy-related GHG emissions locally - for example, due to the choice of energy type and the quality of raw materials, especially when considering the whole life cycle of the fertilizer. Anyhow, the local procurement department at Yara Uusikaupunki is still enthusiastic about exploring the possibility to fulfill these requirements of the standard at different levels of procurement, despite some procurement actions taking place outside the planned scope and boundaries of the EnMS.

Local procurement, on the other hand, is able to influence the energy performance of the equipment, services, or spare parts that it procures. It was found that, as for Yara Uusikaupunki, energy efficiency performance can also be verified in the most explicit manner in the technology category. Energy efficiency is already mentioned as a procurement criterion in terms of the procurement of technology. (Jokinen 2020.) However, it was discussed that the assessment criteria to be used when procuring products or services that are likely to have a significant impact on energy performance should be clarified. In order to develop criteria for assessing the energy performance over the life cycle of a product before the actual purchase takes place, interdepartmental cooperation is required. Procurement could also be part of the consideration of whether the price of energy could be reduced by changing energy sources or not.

SEUs selected by the site must be informed to procurement, so that the department is able to ensure energy efficiency is included as an evaluation criterion when equipment, products, and services related to SEUs are procured. The planned cross-functional energy management team facilitates the flow of information. In addition, as the function extends beyond the boundaries of the site, it was stated that energy efficiency and consideration of the SEUs could also be viable to include in the procurement’s work instructions at the Yara Suomi Oy -level. In addition to the aforementioned factors, it is clear that, with regard to the procurement department, cooperation with Yara Suomi Oy is necessary in order to create common guidelines for energy efficiency considerations. The guidelines should be applicable to the needs of local actors.

It is likely that of the requirements of ISO 50001, the requirements related to operational planning - including design and procurement - have the highest potential impact on the activities outside the organization. For instance, certain purchasing decisions support certain types of activities. It is up to the organization itself as to what level the operational criteria are set and, therefore, what impact these choices have on energy consumption and energy-related GHG emissions. Including energy considerations into design and procurement actions was discussed to be one of the most effective ways to improve energy performance and reduce energy-related GHG emissions at the site, especially when long-term investments regarding energy-using equipment and processes are made.

6.6 Performance of the EnMS

In general, depending on the target, Yara Uusikaupunki evaluates the progress and achievements of their targets on a daily, weekly, monthly, quarterly, or annual basis. The results are reported within the departments during the weekly and/or other meetings, and they are also made visible by e.g. using visual scoreboards. Regarding legal compliance, as stated earlier, Yara Uusikaupunki has a tool and procedure for checking their compliance against legal obligations. A person responsible for monitoring compliance with the legal and other obligations regarding energy performance and the EnMS will be named. Monitoring of the progress of the action plans to meet the objectives and energy targets, EnPI(s), operations of SEUs, and current energy consumption versus expected energy consumption can be embedded into the current performance evaluation practices. Procedures for performance evaluation through internal audits and management reviews also exist.

In order to evaluate performance, relevant information needs to be gathered and made available. Chapter 6.6.1 proposes an example for managing the evaluation of performance at Yara Uusikaupunki through the establishment of an energy data collection plan. Chapters 6.6.2 and 6.6.3 describe the current internal audit and management review practices at Yara Uusikaupunki and compare them to the requirements of the ISO 50001 standard. Finally, chapter 6.6.4

discusses the addressals of deviations and continuous improvement. A checklist for the requirements related to performance evaluation is in Table 19.

Table 19. A checklist for addressing the requirements of the standard with regard to evaluating and improving performance.

Requirement	Documentation required (yes/no)	Actions at Yara Uusikaupunki
Monitor performance	Yes	Establish an energy monitoring and measurement plan, and document the results as is appropriate
Evaluate performance	Yes	Compare EnPI(s) to correspondent EnB(s), and analyze the results on a regular basis Define “significant deviation(s)”, how to respond to these, and document the results of the actions taken Find out if Synergi Life -risk management software could be utilized in addressing the deviations, and, if necessary, create rating criteria Investigate possible significant deviations
Compliance with legal and other requirements	Yes	Ensure that at least the legal and other requirements regarding energy performance and energy efficiency mentioned in Table 8 (chapter 6.1.3) are listed in the current system, and update them if necessary Regularly evaluate the site’s compliance with the set requirements related to energy matters, and document the results and possible follow-up actions taken
Conduct internal audits	Yes	Create an internal audit plan of the EnMS, conduct audits, and report the results Include EnMS internal audits into the current audit plans
Conduct management reviews	Yes	Include the EnMS in the current management review procedures and document the results
Address nonconformities	Yes	If a requirement is not fulfilled, find out why, take action, and monitor the change

Continuous improvement	No	Demonstrate that the EnMS and energy performance of Yara Uusikaupunki are continuously improving

6.6.1 Energy Data Collection Plan

To ensure regular and structured monitoring and measurement, and thus gain data from energy performance and the EnMS, the establishment of an energy data collection plan is suggested. The energy data collection plan can be done in any form. A theoretical example of an energy data collection plan - taking into account the current measurement system at Yara Uusikaupunki - is shown in Table 20. It is sensible to define and be aware of other variables that might affect the results - such as temperature and production volumes - that may also assist in defining the methodology for selecting EnPI(s). For example, production volumes could also be added in the data collection plan. In addition, Yara Uusikaupunki must also define when the results are analyzed and EnPI(s) are compared against their corresponding EnB(s).

Table 20. An example of an energy data collection plan for Yara Uusikaupunki.

What is measured	Why it is measured	How it is measured	Frequency	EnPI	Person in charge	Final data location	Significant deviations and follow-up actions
Electricity	Energy review, EEAs, energy performance at the site	Monitoring system	Once per month	MWh	X.X.	SharePoint: Electricity report (Add the route)	Value exceeds or falls below the last year's value by X% Begin a procedure for finding the root cause
Steam	Energy review, EEAs, energy performance at the site	Monitoring system	Once per month	MWh	X.X.	SharePoint: Steam report (Add the route)	-||-
Heavy fuel oil (fertilizer plants)	Energy review, EEAs, energy performance at the site	Flow meters/ consignment notes	Daily/ once per month	MWh	X.X.	SharePoint: UKI site energy consumption	-||-

Heavy fuel oil (power plant)	Energy review, EEAs, energy performance at the site	Flow meters/ consignment notes	Once per month	MWh	X.X.	SharePoint: UKI site energy consumption / Fuel oils - report	-‖-
SEU 1: Electricity use of L1	Energy performance, EnMS	Monitoring system, submeters X, X, X, & X.	Once per month	MWh /ton of X	X.X.	X.X.	-‖-
ETC.							

Yara Uusikaupunki must ensure that the collected data of the most relevant characteristics (according to the site) is accurate and that the measurements are repeatable. If applicable, defining calibration frequency - which is used to measure the most relevant data (e.g. related to SEUs) - could be a useful endeavor. Currently, a calibration plan exists for the district heat meters (Lehtonen 2020b).

6.6.2 Internal Audits

Yara Uusikaupunki already carries out internal audits, which are a tool for the management of the site to monitor the implementation of the common procedures, provide direction for the development of operations, and support the comprehensive use of agreed operating models. An internal audit plan is prepared annually. In addition, the production sites are audited at the company level in four-year cycles, in which case the plan is prepared by the Yara Audit and Certification unit. Priority areas are typically defined annually and are to remain as focuses for at least the following year. The auditors are mostly HESQ experts working in various functions within the company who have a sufficiently comprehensive knowledge of the procedures and objectives of the Yara Steering System and are familiar with the audit process. (Käsikirja Uusikaupunki 2018, 2.)

Yara Uusikaupunki maintains a record of capable internal auditors, and auditors are trained when a need is discovered. An internal auditor can be any Yara employee who is sufficiently familiar with Yara's management system, local procedures, and objectives and procedures of the audit process. Auditors are required to be willing to carry out the audit operations in cooperation with the audited entity. Some of the internal audits are carried out in a process-like way over operational and responsibility interfaces, and consider the concurrent priorities. Deviations from the annual plans might be possible in cases such as organizational changes when, for instance, additional audits can be performed. (Käsikirja Uusikaupunki 2018, 2.)

Internal audits of the EnMS can be embedded into existing auditing plans. If deemed necessary, additional training with regard to the ISO 50001 EnMS can be conducted. It is suggested that Yara Uusikaupunki audits its whole EnMS at least once a year and in advance of the management reviews in order to ensure that bigger deviations are taken into account at the top management level. The audits at Yara Uusikaupunki should at least include considerations of the energy policy, objectives, energy targets, and action plans of the site, deviations in energy performance, measurement, and monitoring activities, documentation practices, and the previous audit results. In the case of a significant deviation, a new internal audit should be performed after the corrective actions, if appropriate. Also, it must be ensured that the auditors are objective - e.g. a person working on a function should not audit her/his own area of operation.

6.6.3 Management Reviews

Yara Uusikaupunki has a policy in place which calls for regular meetings for management reviews. The responsible persons prepare a summary of the implementation of strategies and/or objectives, the development of related indicators, and the progress of the projects. The summary must be in such a form that conclusions can be drawn and, if necessary, corrective actions identified. Currently, the objective of the management reviews is to assess the suitability of the policies, present plans for internal audits, level of environmental protection, and possible changes that might affect the management system and measures taken. Also, responsible persons and schedules of the necessary follow-up measures are decided, and the implementation of these measures will be monitored. (Toimintakäsikirja 2018b, 1–2; Ritola 2020b.) Energy efficiency as a topic is already included in the agenda (Johdon katselmukset -asialista 2020). The sections of the EnMS that need to be considered according to the standard are added to the management review agenda and objectives. The minimum amount of information that is needed in order to carry out the management review includes the current stage of the pursuit of meeting the objectives and energy targets, results of monitoring, energy performance metrics (EnPI(s)), and status of planned actions; this is suggested to be gathered by the energy management team coordinator.

6.6.4 Deviations and Continuous Improvement

If Yara Uusikaupunki deviates from the requirements set by the ISO 50001 standard, nonconformity occurs. These occurrences must be reacted to and, if necessary, changes to the EnMS made. Yara Uusikaupunki uses Synergi Life -risk management software for the notification and investigation of deviations. Deviations are classified according to extent and severity, and persons responsible for follow-up actions and investigations are to be named. All deviations are briefly discussed in weekly or other meetings. The progress of corrective actions is to be monitored. Deviations related to energy management and corrective actions can also be recorded in the existing system. The classification method for deviations regarding energy performance is to be modified if necessary. Finding the root cause behind a deviation may also reveal other issues that are not only specifically related to energy performance. For example - with regard to GHG emissions - deviations in energy performance may reveal issues, such as malfunctional emissions control devices.

In addition to maintaining a page of ideas for improvement and ensuring that energy performance and the EnMS are continuously improving, it could be useful for Yara Uusikaupunki to set a constant target for energy performance or energy efficiency improvements. For example, Yara Siilinjärvi has set a target of 20 energy efficiency improvements per year (Savolainen 2020a). To note these improvements, verify the obtained benefits (e.g. energy cost savings), and ensure these improvements are also noted in yearly reporting with regard to EEAs, it is important to establish clear reporting instructions. In general, when energy-related improvements are made, the following effects on energy performance and/or cost savings should be presented.

6.7 Schedule of the Implementation

According to online research, implementation of the ISO 50001 EnMS may take from about six months up to two years. By utilizing the estimation for the implementation of an EnMS by

Cosenza et al. (2018, 11), a vague schedule tailored to the needs of Yara Uusikaupunki was constructed (Figure 22).

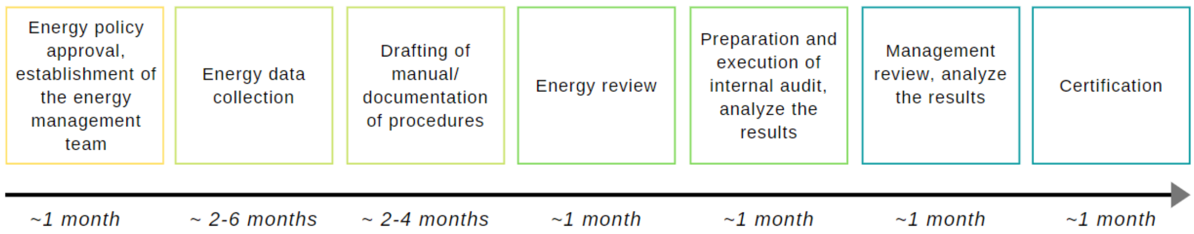

Figure 22. An estimated timeframe of the establishment of an EnMS at Yara Uusikaupunki.

In addition, once the energy management team has been convened, it could be useful to provide training related to the implementation of the standard and assess current resources and activities regarding energy matters. Since the main gaps with regard to establishing an EnMS at the site have already been discovered, and certain practices and earlier achieved standardizations exist, it is probable that Yara Uusikaupunki can meet the requirements of the standard and achieve the certification earlier than the estimated maximum time presented above. Proper planning, leadership, robust commitment, utilization of expertise related to the ISO 50001 standard, and close collaboration between the site's departments and other Yara sites all contribute to keeping with a desirable schedule.

7 DISCUSSION

Chapter 7.1 concludes the main remarks about the implementation plan of an EnMS at Yara Uusikaupunki, discusses opportunities for improvement, and aims to compile an answer for *research question 1*. Chapter 7.2 aims to assess the significance of an EnMS applied at Yara Uusikaupunki on GHG emissions at the site and from a fertilizer life cycle perspective, and it focuses on answering *research question 2*.

7.1 Implementation Plan of the ISO 50001 EnMS

Research question 1:

How can an ISO 50001 energy management system be implemented at Yara Uusikaupunki?

The first research question focuses on how ISO 50001 could be standardized at Yara Uusikaupunki in the future. To answer the question, a framework for the implementation plan of an EnMS, in accordance with the current resources of Yara Uusikaupunki and the requirements of the ISO 50001 standard, was designed as much as is currently possible and took into account current resources and operating methods. The provided examples and methods of implementation are suggestions that are based on interviews, standards for energy management systems, guidebooks, and material provided by the company.

It is likely that the most convenient way to improve energy performance at Yara Uusikaupunki is to emphasize the role of design and procurement activities and to take energy performance into consideration at an early stage and monitor the actual consequences of the decisions made - although other improvement opportunities cannot be underestimated either. Also, according to the interviews, the levels of technical expertise about and approach toward energy management were particularly commendable, and thus likely to advance the fulfilment of the standard's requirements. A systematic approach to energy management is expected to highlight energy matters during daily operations, assist in recognizing improvement opportunities, and even observe already attained benefits through energy performance improvements that might have been left unnoticed or were forgotten to be brought forth.

Due to the earlier established and certified environmental -, quality -, and occupational health and safety management system standards, several common procedures with ISO 50001 already exist at the site. The process of implementing a new standard is likely to be facilitated most of all because of the well-established management system documentation processes, into which the documentation of the EnMS can be partially embedded. Various energy performance improvement opportunities have been discovered at the site, and this knowledge can also be utilized when naming SEUs to which resources are allocated.

In general, the main limitation of the planning work was the novelty of the standardized, structured energy management at the site. Due to the novelty of the project, complexity of the functions, and a relative freedom regarding the ways of implementing the standard's requirements, several of the implementation proposals mentioned in this work are likely to change and be modified to meet the needs and resources of the site more adequately as the implementation project proceeds, and a majority of the departments will be intimately involved.

Therefore, this document could not aim to create permanent structures for an EnMS at Yara Uusikaupunki, but rather it provides different ideas for implementation and a basis for the establishment of an EnMS. Although many procedures and activities related to management systems and energy management exist at the site, when planning the introduction of the EnMS at Yara Uusikaupunki, some areas for improvement emerged, the improvement of which would help facilitate the management of the EnMS in the future.

It was discovered that the site’s main processes use the most energy and energy consumption is monitored, but the accurate energy uses are difficult to specify due to the limited coverage of the monitoring system. In particular, accurate measurements of steam users were found challenging. Yara Uusikaupunki has improved and is currently improving the coverage of its metering system, but there are still challenges regarding e.g. data transfer. When the encountered issues in the data transfer of the automated metering system are resolved, the site is then able to build an energy monitoring system which covers electricity, steam, and compressed air. A planned increase in sub-metering will further improve the accuracy and ease the uncovering of anomalies in energy performance. If resources are sufficient - and thus, energy uses more precisely monitored - Yara Uusikaupunki could name more specific objects as SEUs instead of only processes. Comprehensive coverage of submetering would reduce the time required for computational verifications if the site decides to choose, for example, particular equipment (e.g. electric motors) as an SEU. If appropriate, it would be reasonable for submetering to specifically target the monitoring of the detected SEUs, in order to accurately verify energy performance improvements. When the implementation stage of the EnMS becomes closer, these needs can be assessed and prioritized.

As this thesis work progressed, it was also discovered that the reporting of energy consumption of different energy types is relatively scattered. It is suggested that the basis for systematic energy monitoring and reporting is refined and developed further well in advance of the actual implementation of the EnMS, since this task is assumed to require significant resources - especially regarding the NA and energy departments. To begin updating the energy reporting procedure, it is proposed to add instructions for filling in the existing Excel spreadsheets and reviewing the calculation formulas which lead to the creation of work instructions. It is generally expected already that the introduction of an EnMS improves systematic monitoring practice and control over energy performance.

Another challenge of the comprehensive implementation of an EnMS will probably be to motivate the key persons working with energy management and evenly share the relevant tasks between them. In order to flexibly manage the EnMS and share the workload, it is necessary to define clear roles and responsibilities for the persons assigned for running the EnMS. Also, it is essential that top management is highly committed to energy management in order to successfully implement and improve energy performance and the EnMS at the site. The above mentioned points are important, because it is likely that a professional solely responsible for energy management will not be hired in the near future, and the people in charge of the EnMS will, therefore, most likely consist of people who already have their own roles and responsibilities. In order to ease the even distribution of tasks and ensure that the requirements are fulfilled, a framework for a responsibility matrix for Yara Uusikaupunki was constructed (Appendix 2). Also, information flow is presumably better the broader the skill set of the energy management team is, since experts at the site are broadly aware of areas of development regarding energy in their fields of expertise.

Finally, the creation of EnPI(s) that can clearly express energy performance may be challenging in such a complex and large organization as a fertilizer production site. Measuring the amount of energy consumption per ton of fertilizer produced is valid as a general idea, but inaccuracy in the meter is to be expected, as the energy consumption per a type of fertilizer product varies. Regarding the setting of EnB(s) and EnPI(s), simplification could be a temporary placeholder method until resources are sufficient for refining the metrics. If this simplified method is used at first, since in addition to the amount of production volumes, most all of the significant energy consumption is strongly related to operating hours, then these variables are always worth considering.

The other Yara Suomi Oy production site, Yara Siilinjärvi, aims to have an ISO 50001 EnMS ready for standardization already at the end of 2020. Creating a shared energy management system according to the requirements of ISO 50001 between the Yara Uusikaupunki and Yara Siilinjärvi sites was not considered feasible for the time being. The reasoning for having separate energy management systems between Yara Uusikaupunki and Yara Siilinjärvi relies upon the existing management systems at both sites that are primarily created to be site-specific, and thus, the workload of creating a common EnMS was considered vast when taking into account the current resources. Cooperation between the energy management teams of the sites might, however, be reasonable, since Yara Siilinjärvi already has an energy management professional available with energy efficiency as one area of his responsibility. The production of fertilizers and nitric acid are also shared areas of operation, meaning that the similarities in these operations could especially further the planning of EnPI(s). In addition, operations of the procurement department are multi-level, and hence, it was discovered that at least the procurement departments of Yara Suomi Oy as a whole must cooperate in terms of planning procurement criteria in accordance with the requirements of the ISO 50001 standard. Considering these variables, cooperation and the sharing of know-how between the energy management teams of the sites could save the time and effort of the personnel working with the matter and support both the site-specific energy management targets as well as the common targets set in energy efficiency agreements.

7.2 The ISO 50001 EnMS and GHG Emissions

Research question 2:
How significant is the implementation of an ISO 50001 energy management system for reducing greenhouse gas emissions at Yara Uusikaupunki, and are there secondary effects on the life cycle of the fertilizers produced at the site?

- *What is the extent of the potential for Yara Uusikaupunki to influence others to mitigate GHG emissions via a site-specific energy management system?*
- *Can an ISO 50001 energy management system be recommended as a greenhouse gas emissions reduction tool for other fertilizer industry operators?*

The second research question and two sub-questions aimed at addressing the significance and impact of implementing the said standard on GHG emissions both locally at Yara Uusikaupunki as well as in terms of a fertilizer life cycle. The relevance of planned actions concerning the EnMS and sections of the standard for energy-related GHG emissions were discussed alongside the implementation plan (chapter 6).

It is known that energy consumption is responsible for a significant amount of GHG emissions released into the atmosphere, and the chemical industry is the most significant industrial energy consumer amongst industrial actors. Improving energy efficiency is known as a cost-effective way to mitigate GHG emissions, and the ISO 50001 EnMS is expected to assist in finding the energy performance improvement potential to meet emissions reduction goals. During the literature review about the fertilizer life cycle, it was discovered that at least one-third of the GHG emissions of a fertilizer life cycle originate from fertilizer production. A majority of energy-related GHG emissions from this production are caused during the highly energy-intensive production of ammonia, in which the production process currently relies on the use of fossil fuels.

Therefore, when looking at the fertilizer production sector as a whole and its energy efficiency and energy-related emissions, the focus is on sites where ammonia production takes place. The potential for a remarkable reduction of emissions and energy performance improvement is largely related to the replacement of fossil fuels with electrical energy, the use of energy-efficient electric motors, and the production of necessary electrical energy with renewable energy (see Smith et al. 2020, 336). The introduction of the ISO 50001 EnMS can encourage ammonia production sites and other fertilizer producers to take these new opportunities and innovations into account in their operations due to the need for continuous energy performance improvement. It can also encourage other fertilizer producers to pay attention to how their feedstock is produced and what kind of role these operations play in their own energy- and emissions performance. The ISO 50001 standard, however, does not itself set absolute energy targets for the organizations to meet nor mandate them to consider energy matters outside their organizational boundaries and control - wherein many actors creating scope 3 emissions (indirect emissions that are not owned or controlled by the organization) often takes place.

At the local level, it is noted that Yara Uusikaupunki has areas for energy performance improvement, but the potential for reducing site-specific, energy-related GHG emissions through implementing an EnMS is, however, unlikely to be significant. This is due to the nature of the activities at the site (e.g. no highly energy-intensive ammonia production), as well as both the freedom (e.g. no absolute energy targets) and limitations (e.g. limitations regarding authority) for applying the standard’s requirements. It was also found to be likely that reducing GHG emissions at Yara Uusikaupunki is more significant when attained through e.g. smart operation procedures, technical choices, sensible plant design, and through procedures aiming directly at GHG emission reductions, rather than through improving energy performance. For example, Yara Uusikaupunki is planning a project at its nitric acid plant 4 that would cut a remarkable amount of the GHG emissions of the whole production site.

Ammonia is used as a feedstock at the Yara Uusikaupunki plant but is not produced at the site. Instead, most of the GHG emissions from Yara Uusikaupunki originate from nitric acid production, drying fertilizers, and the power plant - due to both the used-fuel type and release of unwanted byproducts. One limitation regarding the standard that affects energy-related GHG emission reductions at the site is that the ISO 50001 EnMS does not directly require e.g. switching energy sources from fossil to renewable sources, although this aspect is recommended to be taken into account; neither is it (the installation of a renewable energy type) considered an energy performance improvement according to the standard. As was mentioned earlier in this work, heavy fuel oil can be a somewhat tricky energy source used at fertilizer plants due to its qualities. Thus, the motivation for shifting energy sources at Yara Uusikaupunki is more likely to originate from the urge to reduce emissions, issues in operations related to the use of heavy fuel oil, and reduction of costs due to decreased emissions (due to the emissions trading scheme), rather than reducing emissions through energy efficiency. The reasoning for why shifting energy sources is not considered an energy performance improvement was also affirmed at the site - after heavy fuel oil was partially replaced by steam at fertilizer plant 2, the amount of GHG emissions decreased, but energy consumption remained nearly the same (Tomma 2020).

Second, the scope, boundaries, objectives, and energy targets are set by the organization itself, which clearly defines how far-reaching the effects of energy management will be. In addition, although Yara Uusikaupunki would like to select a larger scope that reaches past its physical boundaries, the decision would not be in accordance with the requirements of the standard, as the organization must be able to manage energy performance inside the scope and boundaries of its EnMS. In the case of Yara Uusikaupunki, the potential to have an effect on the activities happening outside the site's physical boundaries was discovered to be fairly minor due to the multi-layered nature of the concern. As discussed earlier in this document, Yara Uusikaupunki, as a part of Yara Suomi Oy, is a subsidiary of Yara and, in several facets, has no exclusive right to make independent decisions without having Yara Suomi Oy or the Yara concern involved in some manner - e.g. through the operational standards guiding the site. This also applies to a number of energy-related purchases, such as the purchase of ammonia or electricity. Therefore, the impact of the site-specific implementation of the EnMS at Yara Uusikaupunki on GHG emission reductions from a fertilizer life cycle perspective can, consequently, be concluded to be minor.

As Yara Uusikaupunki is part of Yara Suomi Oy, it is worth considering whether the impact of an EnMS would be broader from a GHG emissions point of view if a common system for Yara Suomi Oy as a whole were implemented. In any case, Yara Uusikaupunki must cooperate with other sites, as e.g. the activities of procurement extend beyond the boundaries of the site - and this does not necessarily require the creation of a common EnMS between all sites. It is likely that a certain, equal impact on energy-related GHG emissions could also be achieved through a combination of site-specific implementations and close cooperation with other Yara Suomi Oy sites, in the instance of an implementation of an EnMS being Yara Suomi Oy -wide.

Yara has already set a target for its bigger production units to implement the ISO 50001 EnMS. It is viable to consider that this kind of integrated and ambitious requirement by Yara can be assumed to have a wider impact on GHG emissions over the life cycle of the fertilizer if the standardization responsibility covers energy-intensive ammonia production sites that Yara manages. It could also be considered whether energy-saving principles and implementation frameworks provided in a top-down way that follow the guidelines of the standard would contribute to energy-related GHG emissions reductions better than the individual implementation practices of the sites. In this case, the activities in terms of energy management of all the sites would end up having similarities in principle, even when implemented as site-specific. The challenge of the nature of such a coherent framework is probably to create one that meets the strategic goals and resources of each actor. Considering Yara and the fertilizer industry as a whole, it is likely that Yara’s investment alone will not be sufficient to achieve large-scale energy-related GHG reductions throughout the life cycle of fertilizer due to the fragmented nature of the fertilizer industry, meaning also that the input of other industry actors at all levels of the life cycle will be required.

8 CONCLUSIONS

Implementation of the requirements of ISO 50001 is expected to help Yara Uusikaupunki to manage its energy consumption in a systematic manner and thus establish and improve processes related to energy performance and reduce GHG emissions related to energy use to some extent. A systematic approach can also assist the site in recognizing energy performance improvement opportunities, discovering cost savings, increasing overall awareness of the importance of energy management, and creating value by being considered a socially responsible industry actor. Currently, the target of the site is to arrive at readiness for certification by the end of 2021.

In terms of the implementation plan of the ISO 50001 EnMS, it was discovered that the resources for managing the EnMS are currently limited; meaning that an effective cooperation and sharing responsibility between the departments is essential. It is important that top management commits to continuously improving energy performance and the EnMS. To share the workload and improve information flow, it is proposed to establish a cross-functional energy management team, and define clear roles and tasks therein. The establishment of an energy management team is also likely to improve information flow regarding energy matters. A responsibility matrix (Appendix 2) is presented as an example for maintaining the EnMS and to ensure that all the requirements of the standard will be fulfilled and assigned to responsible persons. Cooperation with other Yara Suomi Oy sites is suggested, since it was discovered that at least the procurement of Yara Uusikaupunki keenly operates at the Yara Suomi Oy -level. Cooperation with Yara Siilinjärvi is especially proposed, as both sites aim to implement ISO 50001 in the near future and have similar operations in fairly similar operational environments. The sharing of knowledge and experiences about the meters used for monitoring energy performance - and about the EnMS in general - could aid in facilitating the implementation.

The main processes - fertilizer and nitric acid production - consume the majority of energy at Yara Uusikaupunki. It is likely that the most convenient and effective way to improve energy performance at Yara Uusikaupunki is to emphasize the role of design and procurement activities, take energy performance into strong consideration at an early stage, and monitor the actual consequences of the decisions made. Regarding the implementation of a new standard, especially already existing management systems, robust technical knowledge, and a desirable approach toward energy management are all likely to help facilitate the progress of meeting the new requirements. Resource needs for the EnMS are suggested to be reviewed. Identified areas of development - especially in terms of monitoring and reporting energy consumption - should be assessed and, if necessary, updated. Improvements regarding the coverage and operation of automated energy monitoring have been and will be made, which can especially contribute to the selection and monitoring of the SEUs to which the resources are allocated.

The impact of an implementation of an EnMS at Yara Uusikaupunki on GHG emissions at the site and from a fertilizer life cycle perspective was assessed to be insignificant, although the control of energy consumption itself is well-grounded. The reasons behind the assessed minor impact are the nature of the operations at the site and both the freedom and limitations regarding the application of the requirements of the standard.

The potential for reducing energy-related GHG emissions was discovered to be more remarkable at highly energy-intensive ammonia production sites rather than at Yara Uusikaupunki. In addition, it was assessed that the impact on reducing GHG emissions at Yara Uusikaupunki is likely to be more significant through e.g. technical choices and procedures and tools that aim directly at GHG emission reductions, than through energy performance improvements in accordance with the ISO 50001 standard. Neither does Yara Uusikaupunki have wide-reaching authority to control energy consumption, energy use, energy efficiency, and energy-related emissions outside its physical boundaries, and hence, the scope and impact of the future EnMS for the site cannot reach much further. It is likely that the suggested cooperation with the other sites of Yara Suomi Oy not only facilitates the implementation of the EnMS, but also a wider impact on the reduction of energy-related GHG emissions to some extent, although a shared EnMS is not created.

Yara has decided to certify its biggest production sites according to an ISO 50001 EnMS when the more energy-intensive production sites are also likely to be involved, and therefore, a reduction in GHG emissions into the atmosphere from Yara as a whole can be assumed to be larger. Consequently, the further the coverage of the implementation of an ISO 50001 EnMS reaches - also concerning other fertilizer production sites and actors throughout the whole fertilizer life cycle - the wider the impact on energy-related GHG emissions reductions would be. In general, it is good to note that the level of stringency of the actions with regard to the ISO 50001 EnMS may vary greatly between organizations, as the objectives and subsequent actions are largely at the discretion of the organization itself. In other words, implementation of an EnMS does not set any absolute targets for energy performance improvement that the organization-in-question should achieve - meaning the majority of the responsibility and, consequently, the reductions in energy-related emissions are on the shoulders of the organizations themselves.

Although the ISO 50001 EnMS was not assessed to be a superior tool for reducing the GHG emissions of Yara Uusikaupunki or from a fertilizer life cycle perspective, it can be claimed that the standard can still have a notable effect on energy-related GHG emissions amongst fertilizer production actors. The impacts are likely to be more significant especially at ammonia production sites, as well as at sites wherein energy management is new, and the potential for and importance of improving energy performance has not yet been identified. The EnMS and its impact as a tool for GHG mitigation for different types of organizations could, indeed, provide interesting topics for further research as the global potential for energy savings and, thus, reducing GHG emissions exist and is significant.

9 SUMMARY

Companies have a fundamental role in terms of avoiding the worst consequences of climate change. Tools that are expected to support businesses in meeting climate targets have been established. Although the ISO 50001 standard is not directly linked to GHG emission reductions, it pursues - in addition to improving competitiveness through reduced energy costs - directing organizations in meeting the climate targets by reducing their energy-related GHG emissions.

The aim of this Master’s thesis was to plan a site-specific framework for an ISO 50001 EnMS for the Yara Uusikaupunki fertilizer production site, after which the significance of implementing the EnMS for reducing GHG emissions was assessed. To support the planning process and evaluation of possible impacts of the EnMS on GHG emissions at the site and from a fertilizer life cycle perspective, the life cycle of fertilizer, other tools for GHG mitigation, and, finally, the ISO 50001 standard were examined. Furthermore, several interviews were performed regarding operations and energy use, energy consumption, and energy efficiency at the site.

Yara Uusikaupunki is expected to fulfill Yara’s requirement of implementing an ISO 50001 EnMS, and currently, the target of the site is to be at the stage of readiness for certification by the end of 2021. It was discovered that procurement and design activities are likely to have a remarkable role in terms of improving energy performance at the site. Another essential action for Yara Uusikaupunki is to evenly share the workload regarding the EnMS, better ensuring that it becomes established and the implementation and management practices do not become a burden. An energy management team is suggested to be assembled, and top management, along with the suggested energy management team, must take a robust lead in implementing, monitoring, and improving the energy performance of and the EnMS for the site. The establishment of the EnMS is to be carefully planned, and discovered and clear shortcomings in the current and future energy management practices should be addressed at as early a stage as possible. The implementation of the system should be simple and in line with the current existing resources and organizational priorities, and cooperation with the other Yara Suomi Oy sites is suggested. The EnMS can later be refined and improved upon further in accordance with the principles of continuous improvement.

Other variables and tools - such as optimal operation procedures and technical choices and procedures aimed directly at GHG emission reductions - have been assessed to better contribute to the improvement of the environmental performance of Yara Uusikaupunki in terms of GHG emissions into the atmosphere than just the implementation of the ISO 50001 EnMS. This is due to the nature of the activities at the site, as well as a certain level of both the freedom and limitations regarding the application of the requirements of the standard. Therefore, the implementation of an ISO 50001 EnMS at Yara Uusikaupunki for affecting GHG emission levels at the site and from a fertilizer life cycle perspective is assessed to be insignificant. It is still, in any case, a step forward, also when considering energy-related GHG emissions into the atmosphere, as it is said that many small streams make a big river.

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Appendix 1: Stakeholder Analysis

Stakeholder	Stakeholder's Expectations	Yara Uusikaupunki's Expectations	Communication channel	Relevance to the EnMS
Employees at Yara Uusikaupunki	- Employment - Payment - Comfortable and safe working environment - Social benefits - Progression in career - Open communication and cooperation between departments	- Work input - Motivation - Innovativeness	- Personal interaction - Meetings - Events - Trainings - Surveys - Intranet - Info-TV - Newsletters - Online services	Yes. Employees and their level of awareness, motivation, and working methods have considerable effect on the effectiveness of the EnMS and improving energy performance.
Yara International ASA & Yara Suomi Oy	- Meet targets and strategies - Decision-making power - Continuous improvement	- Resources to operate - Cooperation and open communication - Operational review	- Personal interaction - Events - Meetings - Visits - Reporting - Stock exchange - Online services - Mass media	Yes. The strategy and the targets set by the parent company are relevant to the EnMS. Exchanging know-how between the sites.
Authorities and governmental institutions	- Fulfil legal and other obligations - Investments - Employment - Cooperation - Tax payment - Transparency - Competitiveness - Willingness to do voluntary work beyond obligations	- Legislation and other obligations (the frameworks inside which to operate) - License to operate - Clear communication	- Personal interaction - Cooperation between authorities - Online services - Mass media - Events - Meetings - Visits - Audits - Stock exchange releases - Annual and other reporting	Yes. Legal requirements and voluntary agreements and actions shall be taken into account when constructing the EnMS. May have an effect e.g. on license to operate, public image, and energy targets. Possible economic consequences in the case of an offence against regulations.
Customers	- Reliable production and supply - Quality and safety - Environmental and other responsibility - Customer service - Adequate pricing	- Interest in the products - Interaction	- Personal interaction - Fact sheets - Events and visits - Meetings - Campaigns - Marketing communication - Online services (home page) - Social media - Mass media	Yes/No. Do not directly affect the EnMS or energy consumption but may call for energy efficiency when making a decision to purchase (effect on public image).

External contractors	- Employment - Competitive purchase prices - Comfortable and safe working environment - Social benefits - Cooperation with the site's employees	- Work input - Motivation - Innovativeness - Long-term and reliable cooperation	- Personal interaction - Meetings - Events - Trainings - Surveys - Info-TV	Yes. Contractors working at the site and their level of awareness, motivation, and working methods have considerable effects on the effectiveness of the EnMS. Deviations in services may have a significant effect on the EnMS.
Suppliers	- Competitive purchase prices - Long-term and reliable cooperation	- Long-term and reliable cooperation - Commitment - High-quality raw materials and other products and services	- Personal interaction - Meetings - Visits - Online services - Social media	Yes/no. If the supplier is directly related to energy - e.g. deviations in ammonia supply could have a significant effect on the EnMS.
Energy companies	- Reliable production and supply - Quality and safety - Environmental and other responsibility - Adequate pricing	- Reliable energy distribution network	- Personal interaction - Meetings - Visits - Online services	Yes/no. May have an effect on the EnMS e.g. via malfunction in distribution network.
City of Uusikaupunki	- Cooperation and communication - Participation - Employment - Educational possibilities - Safety - Environmental awareness	- Cooperation and communication - Motivated and skilled employees - Infrastructure	- Personal interaction - Events - Meetings - Visits - Fact sheets - Marketing communication - Homepage / other online service - Social media - Mass media	Yes/No. Does not directly affect the EnMS, but the actions of the company may influence the projects of the city of Uusikaupunki and vice versa (e.g. Hinku-program for GHG reduction).
Competitors	- Fair competition	- Fair competition	- Homepage / other online service - Social media - Events - Meetings	No. No notable relevance to the effectiveness of the EnMS besides being a motivational driver.

Organizations and associations	- Active participation - Achieving common goals - Compliance with possible obligations - Continuous improvement	- Promoting interests of the industry - Cooperation forums - Development towards common goals - Expert work	- Personal interaction - Meetings - Visits - Online services - Reporting - Fact sheets	Yes. The actions of organizations/ associations do not directly affect the effectiveness of the EnMS, but, for instance, their promotion of development ideas or program participation may have indirect effects (e.g. Responsible Care program). Also, negotiate collective agreements for chemical industry and expert services.
Media	- Cooperation	- Truthful reporting	- Personal interaction - Meetings - Visits - Online services	No. Does not affect the effectiveness of the EnMS.
Educational/ science actors	- Educational possibilities (e.g. internships) - Research and development opportunities - Cooperation	- Research and development activities - Expertise - Active and curious trainees - Reliable cooperation	- Personal interaction - Meetings/ seminars - Visits - Research and development projects	Yes/no. Do not directly affect the EnMS or energy consumption, but may have an effect later through e.g. advances in technology or working methods of trainees.

Appendix 2: Responsibility Matrix – EnMS/Yara Uusikaupunki

Responsibility Matrix - EnMS/Yara Uusikaupunki					**Energy management team**				
R: responsible **S: supportive** **I: informed** (Add as many energy management team members as needed →)				**Top management**	**Energy management team coordinator**	**Department**	**Department**	**Department**	**Employees**
Area of responsibility	**Requirements**	**Frequency**	**Related documents**	(Name)	Name	Name	Name	Name	All
Resources	Designate resources for the EnMS.								
Energy management team	Gather and assign persons of the energy management team, and designate the tasks of the energy management team members.								
Control	Schedule meetings, schedule dates for internal audits, prepare data for management reviews, analyze results of internal audits and management reviews, and report on EnMS and energy performance.								

Energy policy	Establish energy policy that includes the requirements of the ISO 50001 standard.								
Scope and boundaries of the EnMS	Define which facilities, operations, and activities are included in the EnMS. Define the limits and limitations, as well as the reasoning for the exclusions.								
Energy objectives and targets	Set objectives and targets that are in accordance with the requirements of the EnMS.								
Legal and other requirements	Identify and review compliance with legal and other requirements.								
Energy review	Define the methodology for an energy review and update it, if necessary.								
Data collection plan	Create a plan for energy data collection and update it, if necessary. Ensure that the collected data is accurate.								
Energy data collection	Collect and analyze energy data.								
SEUs	Identify and name SEUs, define the current energy performance and variables related to the SEUs, and find person(s) whose responsibilities have an effect on the SEUs.								
Energy performance improvement opportunities	Discover and prioritize energy performance improvement opportunities.								

Action plans	Create action plans to meet the established energy targets, and utilize the discovered opportunities for energy performance improvement.								
EnB(s) and EnPI(s)	Define EnPI(s) and the correspondent EnB(s) (e.g. for each energy source and for selected SEUs).								
Checking	Define when expected and current energy values are compared with each other, and the necessary actions for when significant deviations occur.								
SEUs and operation	Ensure adequate operation and maintenance of processes related to SEUs in order to avoid significant deviations.								
Design and projects	Create criteria for when energy performance must be considered, and update it if necessary.								
Procurement	Inform suppliers that energy performance is one of the evaluation criteria when purchasing products related to SEUs. Create criteria for assessing energy performance, and update it if necessary.								

Competence	Monitor competence and the need for training - especially of the person(s) who were found to have an effect on SEUs.								
Communication and awareness	Ensure awareness and communicate the energy policy and information related to the EnMS to the organization. Decide and document the needs for external communication.								
Continuous improvement	Maintain the continuation of the process that allows everyone to provide comments or suggest improvements. Ensure that energy performance and the EnMS are continuously improving.								
Documentation	Establish, review, and update the relevant documents. Define where the relevant documentation can be found.								
Internal audit	Plan and carry out internal audit(s), and report the results to the relevant person(s).								
Management review	Carry out a management review.								