New Energy Solutions Optimised for Islands

NESOI

EUROPEAN ISLANDS FACILITY

Z-052 - Sustainable Estonian Islands

Final Deliverable

Foreword

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The document is compiled by following the Final Deliverable Template and Feasibility Study inputs of the NESOI Platform. The document includes the necessary information to achieve the NESOI objectives. However, minor changes have been made to the template to reduce the redundancy of excess repetition of subheadings in order to deliver more concise information for the reader. In other words, the changes mostly affect opportunities that have the highest technological readiness levels and are easy to put into practice. For instance, the renovation of street lighting, district heating networks and buildings.

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RE = Restricted to a group specified by the consortium (including the Commission Services)
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Table of Contents

Foreword 2
Technical References 3
Introduction 12
Sissejuhatus 14
Executive summary 16
Kokkuvõte 21
1. Overview of energy consumption and carbon dioxide emissions 26
1.1. Overview of the islands 26
1.2. Baseline Emission Inventories 26
2. Strategic objectives 29
2.1. General objectives 29
2.2. Sub-objectives 29
3. Current status 31
3.1. Developments compared to BEI 31
3.2. Decrease in the carbon intensity of electricity 31
3.3. Energy consumption and emissions in 2020 32
3.4. Adjusted sub-objectives 34
4. The Baltic Sea transmission grid across Saaremaa and Hiiumaa 36
4.1. Introduction 36
4.2. Document references 36
4.3. Scope of intervention and general description 37
4.4. Regulatory framework 43
4.5. Technical analysis 46
4.6. Impact analysis 47
4.7. Risk analysis 49
4.8. Implementation guidelines 49
4.9. Technical recommendations 51
5. Energy communities 54
5.1. Introduction 54
5.2. Document references 54
5.3. Scope of intervention and general description 55

This project has received funding from the European Union's Horizon 2020
research and innovation programme under grant agreement N° 864266

5.4. Analysis on possible renewable energy solutions 57
5.5. Identification of suitable technological options 57
5.6. Technical feasibility to set up an energy community 59
5.7. Eco-fin feasibility to set up an energy community 63
5.8. Identification of financing needs and possible funding options 73
5.9. Impact assessment 76
5.10. Risk analysis 77

6. Electricity and hydrogen in public transport 78

6.1. Introduction 78
6.2. Document references 78
6.3. Scope of intervention and general description 78
6.4. Pilot characterization and collection of relevant KPIs 81
6.5. Assumption on the expected impacts 81
6.6. Assumption on the financial needs 84

7. Synergy of offshore wind farms and blue economy 88

7.1. Introduction 88
7.2. Document references 88
7.3. Scope of intervention and general description 89
7.4. Regulatory framework 95
7.5. Expected impacts analysis 96
7.6. Eco-fin feasibility 97
7.7. Risk analysis 98

8. Innovative wind energy solutions 100

8.1. Introduction 100
8.2. Document References 100
8.3. Scope of intervention and general description 100
8.4. Identification of suitable technological options and definition of the advantages and disadvantages of various technologies 108
8.5. Expected impacts analysis 114

9. Offshore wind farm 117

9.1. Project overview 117
9.2. Production of renewable energy 118
9.3. Impact analysis 118
9.4. Green hydrogen 121
9.5. Energy storage 125
9.6. Risk analysis 128

10. Wave energy 130

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

NESOI
EU ISLANDS FACILITY

10.1. Overview 130
10.2. Potential for the Estonian islands 131
10.3. Potential solution for the wind energy innovation area 132

11. Expansion of the renewable energy solution of Ruhnu 134

11.1. Overview 134

12. Installation of PV panels for the ambulance centre of Ruhnu 136

12.1. Overview 136

13. Renovation of street lighting 137

13.1. Overview 137
13.2. Renovation of street lighting in Saaremaa 138
13.3. Renovation of street lighting in Muhu 138
13.4. Renovation of street lighting in Hiiumaa 139
13.5. Consumption of renewable electricity for street lighting 139

14. Electrification in transport 140

14.1. Development of EV charging network 140
14.2. Electrifying local government vehicles 140
14.3. Private electric vehicles 142
14.4. Electric micromobility 143

15. Biomethane production 144

15.1. Overview 144
15.2. Scope of intervention and general description 145
15.3. Description of the preferred option 146
15.4. Technical analysis and KPIs 148
15.5. Economic-financial analysis and KPIs 149
15.6. Sensitivity analysis 149
15.7. Risk analysis 151
15.8. Adoption of gas-powered vehicles 153
15.9. Electricity production from biogas 154

16. Renovation of district heating networks 156

16.1. Kuressaare Soojus district heating network 156
16.2. Suuremõisa district heating network 156

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

17. Käina district heating....158

17.1. Project overview....158
17.2. Impact analysis....160
17.3. Technical analysis and KPIs....160
17.4. Economic-financial analysis and KPIs....160
17.5. Dagöplast AS industrial excess heat....162
17.6. Sensitivity analysis....163
17.7. Risk analysis....164

18. Renovation of buildings....165

18.1. Overview....165
18.2. Grant measures and funding....166
18.3. Impacts....167
18.4. Small buildings and apartment buildings....167
18.5. Local municipality buildings....168

19. Small-scale energy efficiency measures....171

19.1. Overview....171
19.2. Scope of intervention and general description....172
19.3. Description of the measures....173
19.4. Changes in habitual behaviour....175

20. Education....176

20.1. Overview....176
20.2. Current situation....176
20.3. Perspective....177

References....178
Appendix 1 Road maps towards sustainable island communities for the local municipalities....188
Appendix 2 Baseline Emission Inventories....211
Appendix 3 Sub-objectives....213
Appendix 4 2020 Emission Inventories....216
Appendix 5 Adjusted sub-objectives....218
Appendix 6 Economic-financial analysis of biomethane production 221
Appendix 7 Stakeholder feedback....223

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Appendix 8 Comparison of overhead lines and underground cables 229

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Table of Figures

Figure 1.1. Energy consumption and CO_2 emissions by consumer groups (2) (3) (4) (5) .. 28
Figure 3.1. Energy consumption and CO_2 emissions by consumer groups in 2020 34
Figure 4.1. The Baltic Offshore Grid (BOG 2050) concept (11) 38
Figure 4.2. Alternative to the Baltic Offshore Grid concept 38
Figure 4.3. Transmission network around Central Baltic Sea (15) 40
Figure 4.4. Power grid load 47
Figure 4.5. Power grid load forecast 47
Figure 4.6. Life-cycle steps of a transmission project (24) 49
Figure 5.1. Solar energy production in Estonian households 2014–2019 (1) 58
Figure 5.2. Setup for an energy community 64
Figure 5.3. Monthly electricity production for a 15 kWp PV farm in 2021 (40) 66
Figure 5.4. European clean energy finance landscape (41) 74
Figure 7.1. Areas excluding the development of fish farms (73) 92
Figure 8.1. Average wind power density at a height of 200 m (85) 101
Figure 8.2. Areas determined suitable for wind energy development on land by the Ministry of Defence (86) 102
Figure 8.3. Flight information zone of Kuressaare airport 102
Figure 8.4. Flight information zone of Kärdla airport 102
Figure 8.5 Natura 2000 - Birds and Habitats Directives Estonia (51) 104
Figure 9.1. Saare Wind Energy Offshore Wind Farm (planned) 117
Figure 9.2. Global annual hydrogen production in the Sustainable Development Scenario (107) 121
Figure 9.3. Green Hydrogen production price compared to fossil fuel CSS............... 125
Figure 9.4. Operating principle of a Li-ion battery 126
Figure 9.5. Operating principle of a vanadium redox battery 126
Figure 9.6. Operating principle of a fuel cell 127
Figure 10.1. Long-term average energy flux along the coasts of the eastern Baltic (146) 131
Figure 10.2. Combined scatter and energy diagram (146) 132
Figure 18.1 Kredex reconstruction grants on the Estonian islands......................... 167
Figure 18.2. Buildings with at least energy performance label C among municipality buildings (193)... 169

Table of Tables

Table 1.1. Baseline Emission Inventory (2) (3) (4) (5) 27
Table 2.1. Sub-objectives (2) (3) (4) (5) 30
Table 3.1. Emission Inventory 33
Table 3.2. Adjusted sub-objectives 35
Table 4.1. Elering annual production and consumption data (18) 46
Table 4.2. Installed total transfer capability 47
Table 4.3. Risk analysis of establishing the Baltic Sea transmission grid across Saaremaa and Hiiumaa 49
Table 5.1. Electricity cost 66

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 864266

Table 5.2. Investments 66
Table 5.3. HP. 1 Base Scenario 67
Table 5.4. Investment costs for HP. 1 Base Scenario 67
Table 5.5. Electricity production and consumption in HP. 1 Base Scenario 68
Table 5.6. Economic output of HP. 1 Base Scenario 68
Table 5.7. HP. 2 Intermediate Scenario 68
Table 5.8. Investment costs for HP. 2 – Intermediate Scenario 69
Table 5.9. Electricity production and consumption in HP. 2 – Intermediate Scenario 69
Table 5.10. Economic output of HP. 2 – Intermediate Scenario 69
Table 5.11. HP. 3 – High Scenario 70
Table 5.12. Investment costs for HP. 3 – High Scenario 71
Table 5.13. Electricity production and consumption in HP. 3 – High Scenario 71
Table 5.14. Economic output of HP. 3 – High Scenario 71
Table 5.15. HP. 4 – Islands-Level Scenario 72
Table 5.16. Investment costs for HP. 4 – Islands-Level Scenario 72
Table 5.17. Electricity production and consumption in HP. 4 – Islands-Level Scenario 72
Table 5.18. Economic output of HP. 4 – Islands-Level Scenario 73
Table 5.19. Community energy production targets on the islands by 2030 77
Table 5.20. Risk analysis of energy community projects 77
Table 6.1. Potential uses of hydrogen and derived products for transport applications (48) 83
Table 6.2. Comparison of the costs of different bus types 85
Table 7.1. Employment and revenue in the blue economy in 2020 (72) 90
Table 7.2. Risk analysis of the synergy of offshore wind with aquaculture and port activities (83) 99
Table 8.1. Advantages and disadvantages of airborne turbines with generator on the ground 109
Table 8.2. AWE systems with generator on the ground 110
Table 8.3. Advantages and disadvantages of airborne turbines with generator in the air 111
Table 8.4. AWE systems with generator in the air 111
Table 8.5. Advantages and disadvantages of modular small wind turbines 112
Table 8.6. Modular small wind turbines 112
Table 8.7. Advantages and disadvantages of vortex bladeless systems 112
Table 8.8. Vortex bladeless 113
Table 8.9. Advantages and disadvantages of vertical axis wind turbines 113
Table 8.10. Small vertical axis wind turbines 114
Table 8.11. Comparison of two AWE solutions 116
Table 9.1. Estimated indicators of planned offshore wind farms 118
Table 9.2. Overview of different sources reporting construction and operation FTE/MW numbers 118
Table 9.3. Overview of offshore wind farm job creation ranges 119
Table 9.4. Overview of activities and FTE jobs during offshore wind farm lifespan 119
Table 9.5. Overview of human resource and education requirements 120
Table 9.6. Scenarios for converting wind energy to hydrogen 123
Table 9.7. Transport input for hydrogen calculations 123

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Table 9.8. Hydrogen to Power and Hydrogen to Transport effect on CO_2 reduction.... 124
Table 9.9. Wind energy and hydrogen production cost of energy 124
Table 9.10. Comparison of storage technologies 127
Table 9.11. Examples of energy storage projects 128
Table 9.12. Risk analysis of the synergy of offshore wind with aquaculture and port activities 129
Table 10.1. Overview of wave energy technology projects (141).......................... 130
Table 11.1. Upgrade of the renewable energy solution 135
Table 12.1. Installation of 30 kW of solar panels....................................... 136
Table 13.1. Street lighting renovation 137
Table 14.1. Electric cars and public charging points 140
Table 14.2. Electrification of local government vehicles 141
Table 14.3. Private electric vehicle adoption scenarios 142
Table 14.4. Ruhnu communal electric vehicles for private transport 143
Table 15.1. Biomethane production 144
Table 15.2. The impact of the price of biomethane and investment cost on the discounted payback period of the project 150
Table 15.3. The impact of the price of biomethane and the production volume of biomethane on the discounted payback period of the project 150
Table 15.4. The impact of the price of biomethane and investment cost on the net present value of the project 150
Table 15.5. The impact of the price of biomethane and the production volume of biomethane on the net present value of the project.................................. 150
Table 15.6. The impact of the price of biomethane and investment cost on the internal rate of return of the project 151
Table 15.7. The impact of the price of biomethane and the production volume of biomethane on the internal rate of return of the project........................... 151
Table 15.8. Risk analysis of biomethane production (175)................................ 151
Table 15.9. Investment cost of biomethane vehicles 153
Table 16.1. District heating network heat loss targets.................................. 156
Table 17.1. Potential district heating at Käina 158
Table 17.2. Price of thermal energy 161
Table 17.3. Feasibility of central heating system renovation for district heating....... 161
Table 17.4. Potential for using excess heat from Dagöplast to heat greenhouses 163
Table 17.5. Price of district heating network thermal energy 163
Table 17.6. Price of subsidised district heating network thermal energy 163
Table 17.7. Feasibility without renovation subsidy 164
Table 17.8. Feasibility with renovation subsidy 164
Table 17.9. Risk analysis 164
Table 18.1. Renovation of buildings (189) (190)... 165
Table 19.1. Small-scale energy efficiency measures...................................... 171

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Introduction

The NESOI Z-052 – Sustainable Estonian Islands project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266. The report was ordered by Saaremaa Development Center with the public procurement (Public Procurement Register No. 238608) *"Lääne-Eesti saartele energiapõhise säästva arengu potentsiaali analüüsi koostamine"*.

NESOI Z-052 aims to use the grant to fund this analysis to:

- Identify energy-intensive sectors that add value to diversified and sustainable growth;
- Identify opportunities for sustainable energy and material resources;
- Investment proposal schemes to finance regional development – strengthen and change existing economic inputs;
- Describe the knowledge bases and skills required to promote innovation, entrepreneurship, and job opportunities within the given project;
- Strengthen the role, skills, and quality of governance in implementing energy programmes;
- Make the region an international example of sustainable island modernisation.

NESOI Z-052 addresses the following questions:

- *How can the islands become sustainable and environmentally friendly communities and contribute as much as possible to the economic development and diversification of the region?*
- *What are the opportunities for investment projects related to energy use and carbon dioxide reduction? What are the steps towards this?*
- *What other sectors can be developed that contribute to regional diversification and sustainable growth?*
- *What developments around the world can inspire development in the region?*

The data for the preparation of the NESOI Z-052 was sent by the contracting authority and local governments in accordance with a separate agreement, based on the content of the tender and the availability of the data. The research questions were answered based on literature sources and interviews conducted. To involve stakeholders, seminars were held to introduce the study and intermediate results were introduced at interim seminars. The analysis gives recommendations:

- on projects and activities for the public sector to implement energy and climate plans - in terms of infrastructure, planning, educational programs, centres of competence, conservation, efficiency, and co-financing.
- for companies in the region in terms of smart energy production and use.
- on value propositions for investors to fill value chain gaps and develop the region.

The analysis methodology is based on the procurement conditions set out in the terms of reference. The implementation of the project is divided into four stages: preparatory activities, work phase, summary stage and editing and supplementing the analysis.

About Energex Energy Experts

The work was compiled by a team of experts from Energex Energy Experts OÜ. Energex Energy Experts is an engineering and consulting services company specialising in energy, digitisation, production technologies and processes. The mission of Energex is to contribute to the economic, social and environmentally sustainable development of its customers.

Energex Energy Experts project manager Rander Süld confirms that the NESOI Z-052 document was compiled independently and is impartial.

Energex Energy Experts OÜ is grateful and would like say to thank you for the valuable contribution of: Saaremaa Development Center, Hiiumaa Development Center, Saaremaa Municipality, Hiiumaa Municipality, Muhu Municipality, Ruhnu Municipality, E.ON, SINLOC, Energiaühistu, JetGas, Estonian Hydrogen Association, Enefit Green, Enefit Connect, Danpower, Hysto, Kuressaare Soojus, Saare Wind Energy, Transport Administration, Tartu Regional Energy Agency, Empower 4Wind, Utilitas, Toomas Remmelkoor Harju talu, Rexplorer, Kredex, Elering, Elektrilevi, Samsø Energy Academy, Flexens, Estonian Tax and Customs Board, Ministry of Economic Affairs and Communications, Hendrikson & Ko, and the residents of the islands.

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Sissejuhatus

Projekti *NESOI Z-052 – Sustainable Estonian Islands* elluviimist rahastati Euroopa Liidu teadusuuringute ja innovatsiooni raamprogrammist Horisont 2020 toetuslepingu nr 864266 alusel. Töö tellis SA Saare Arenduskeskus riigihankega: *"Lääne-Eesti saartele energiapõhise säästva arengu potentsiaali analüüsi koostamine"* (RHR nr 238608).

NESOI Z-052 eesmärk on kasutada toetust selle analüüsi rahastamiseks, et:

- Teha kindlaks energiakasutusega sektorid, mis pakuvad lisaväärtust mitmekesiseks ja kestlikuks kasvuks;
- Teha kindlaks säästva energia ja materiaalsete ressursside võimalused;
- Investeerimisettepanekute kavad piirkonna arengu rahastamiseks – tugevdada ja muuta majanduse olemasolevaid sisendeid;
- Kirjeldada teadmiste alused ja vajalikud oskused, mis edendavad antud projekti raames innovatsiooni, ettevõtluse arengut ja töövõimalusi;
- Tugevdada valitsemise rolli, oskusi ja kvaliteeti energiaprogrammide rakendamisel;
- Muuta piirkond rahvusvaheliseks näiteks kestlikust saarte kaasajastamisest.

NESOI Z-052 käsitleb järgmisi küsimusi:

- *Kuidas saavad saared muutuda kestlikeks ja keskkonnasõbralikeks kogukondadeks ning aidata maksimaalselt kaasa piirkonna majandusarengule ja mitmekesistamisele?*
- *Millised võimalused on energiakasutuse ja CO_2-heite vähendamisega seotud investeerimisprojektidel? Millised on sammud selle suunas?*
- *Milliseid teisi sektoreid saab arendada, mis aitavad kaasa piirkonna mitmekesistamisele ja jätkusuutlikule kasvule?*
- *Milliseid arenguid kogu maailmas on, mis võivad piirkonna arengut inspireerida?*

Vajaminevad andmed aruande koostamiseks saadi tellijalt ja kohalikelt omavalitsustelt lähtudes hanke sisust ja andmete olemasolust. Küsimustele koostati vastused kirjanduse ja tehtud intervjuude põhjal. Sidusrühmade kaasamiseks korraldati uuringut tutvustavaid seminare ja vahetulemusi tutvustati vaheseminaridel. Koostatud analüüs annab soovitusi:

- avalikule sektorile energia- ja kliimakavade rakendamiseks (ELi) projektid ja tegevused – taristu, planeerimise, haridusprogrammide, kompetentsikeskuste, säästmise, tõhususe ja kaasrahastamine osas;
- piirkonna ettevõtetele nutika energia tootmise ja kasutamisvõimaluste osas;
- väärtuspakkumisteks investoritele, et täita väärtusahelate lüngad ja arendada piirkonda.

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Analüüsi koostamise metoodika lähtub hankes toodud lähteülesandest. Projekti elluviimine on jaotatud nelja etappi: ettevalmistavad tegevused, analüüsi koostamine, kokkuvõttev etapp ning analüüsi toimetamine ja täiendamine.

Ettevõttest Energex Energy Experts

Töö koostas ettevõtte Energex Energy Experts OÜ ekspertidest koosnev meeskond. Energex Energy Experts on inseneri- ja konsultatsiooniteenuste ettevõte, mis on spetsialiseerunud energeetikale, digitaliseerimisele, tootmistehnoloogiatele ja -protsessidele. Energexi missioon on aidata kaasa klientide majanduslikule, sotsiaalsele ja keskkonnasäästlikule arengule.

Energex Energy Experts projektijuht Rander Süld kinnitab, et NESOI Z-052 dokumendi koostanud meeskond on olnud sõltumatu ja erapooletu.

Energex Energy Experts OÜ tänab abi ja koostöö eest sihtasutust Saare Arenduskeskus, sihtasutust Hiiumaa Arenduskeskus, Saaremaa Vallavalitsust, Hiiumaa Vallavalitsust, Muhu Vallavalitsust, Ruhnu Vallavalitsust, E.ON-i, SINLOC-i, Energiaühistut, JetGasi, Eesti Vesinikutehnoloogiate Ühingut, Enefit Greeni, Enefit Connecti, Danpowerit, Hystot, Kuressaare Soojust, Saare Wind Energyt, Transpordiametit, Tartu Regiooni Energiaagentuuri, Empower 4Windi, Utilitast, Toomas Remmelkoori Harju talu, Rexplorerit, Kredexit, Eleringi, Elektrilevi, Samsø Energiaakadeemiat, Flexensit, Maksu- ja Tolliametit, Majandus- ja Kommunikatsiooniministeeriumit, Hendrikson & Ko-d ja saarte elanikke.

Executive summary

The island municipalities of Saaremaa, Hiiumaa, Muhu, and Ruhnu stand to benefit from a jointly organised sustainable development plan. As a follow-up to forming the Sustainable Energy and Climate Action Plans, the Estonian islands would like to develop an investment plan outlining all major assets, and a realistic roadmap in time towards a sustainable island community, that includes an overview of feasible solutions to climate change, economic developments, and ecological issues, and a vision of on-island developments on topics based on local resources.

Thus, within the support of the NESOI project, 5 different proposals were jointly analysed by E.ON, Energex, and SINLOC in high-level detail considering areas of high priority for the Estonian islands such as the production of energy from renewable sources, implementation of sustainable mobility solutions, and the implementation of blue economy solutions. Additional measures were analysed by Energex. With the initiatives analysed in this plan, the Estonian island municipalities of Saaremaa, Hiiumaa, Muhu, and Ruhnu set the starting point for the development of their pathway towards climate neutrality and energy independence.

This document aims to describe the analyses carried out for the five proposals, which are:

- Baltic Sea transmission grid across Saaremaa and Hiiumaa
- Energy communities
- Electricity and hydrogen in public transport
- Synergy of offshore wind farms and blue economy
- Innovative wind energy solutions

In addition to the five proposals presented above, the document aims to describe the analyses carried out for complementary measures.

Furthermore, this document provides information that allows stakeholders to have an overview and understanding of the initiatives. However, a more detailed analysis will be necessary for the development and implementation of the identified solutions.

The total energy consumption on the islands in 2018 was 929 GWh with the consumption of electricity and fuels both for heating and transport. When including the energy consumed by ferries and aeroplanes, the total energy consumption exceeded 1 TWh. The consumption of energy on the islands resulted in 310 $ktCO_2$ emissions, and, when including ferries and aviation, there was a total of nearly 330 $ktCO_2$ emissions.

The overall vision for the islands is to become Smart and Green. Strategic objectives have been set to achieve that vision, which include the reduction of carbon dioxide emissions by 40% by 2030 compared to 2018, achieving a 60% share of renewable energy in final energy consumption by 2030, and switching to 100% renewable energy and low carbon fuels in the municipal sector by 2030. For Ruhnu the share of renewable energy should be 70% and for the municipal sector of Ruhnu the goal is to reach a 75% share. By 2050 the

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islands intend to become energy independent. To reach the strategic objectives, several sub-objectives have been determined. As a result of the changes occurring over the past few years compared to the baseline year, this document presents adjusted sub-objectives for 2030.

The Baltic Sea transmission grid across Saaremaa and Hiiumaa has the potential to improve the security of supply of the islands, contribute to decarbonisation, and increase the share of renewable sources. The implementation of such a project needs to follow the guidelines determined by ENTSO-E and involve all regional TSOs and Member States as shareholders. The grid would improve connections in the whole region and reduce electricity price differences between countries.

Energy communities provide an opportunity to actively engage residents of the islands in achieving the objectives set and thus reduce the dependence on imported electricity. Solar energy has been determined as the solution with the greatest potential for carrying out community energy projects thanks to the ease of implementation, relatively low capital expenditure, few constraints, and scalability, which make the technology accessible for communities. The European Commission estimates that, by 2030, 21% of installed PV could be owned by energy communities. Based on the current growth rate of solar energy, community owned solar PV farms could produce 6.7 GWh of electricity annually by 2030.

Today the public transportation systems of the islands consisting of buses and ferries are mostly dependent on imported fuels. The goal of turning public transport carbon neutral by 2030 has been set. Electrification and the use of hydrogen can significantly contribute to that objective. Both opportunities require additional investments in production facilities and infrastructure. To properly evaluate the feasibility of electric or hydrogen buses, a pilot project should be carried out in Hiiumaa. The local municipalities do not have great impact on developments with ferries as the investments are carried out either by the state or the operators. However, it is important to clearly express the expectations of the islands to the responsible implementers.

In addition to the production of renewable electricity, offshore wind farms also create the possibility for synergies with other areas of the blue economy. The synergy is well expressed through the combination of offshore aquaculture activities and wind farms along with the increased usage of ports and the resulting requirement for additional port services. Overall, cooperative activities can reduce costs, create jobs, and improve the economic position of the islands, which leads to a better society.

Innovative wind energy technologies have a great deal of potential on the islands of Saaremaa, Hiiumaa, and Muhu as they could bring the socio-economic benefits of attracting alternative wind energy developers to the islands as well as show different methods of wind energy production that will help to decrease the opposition of the community towards wind energy developments.

Offshore wind farms not only have the greatest potential impact on the energy consumption for the islands but also for the whole country. Therefore, it is of vital importance to support the development of the projects as the renewable electricity produced far exceeds the annual consumption of the islands. Offshore wind farms also create the possibility for large-scale green hydrogen production. Wave energy as an alternative offshore energy source has a limited potential for a more distant future.

The island of Ruhnu currently receives electricity from the local renewable energy solution that uses wind and solar energy in addition to imported biodiesel. Although the electricity produced is carbon neutral, the share of electricity produced from local resources can be increased with the expansion of the renewable energy solution and with the installation of PV panels for the ambulance centre.

The renovation of street lighting enables the reduction of electricity consumption. Although the savings are relatively low, new street lighting solutions ensure better illumination and a safer environment.

Transport is a sector where CO_2 emissions are hard to abate. Currently, electrification offers a great possibility for the reduction of carbon dioxide emissions. A vital prerequisite for the electrification of transport is the development of charging infrastructure. Although electric vehicles are becoming increasingly popular, based on the speed of adoption, it is not likely that the sub-objective for the reduction of carbon dioxide emissions in transport will be reached by 2030.

Another method of reducing carbon dioxide emissions from the transport sector is by using biomethane. Saaremaa has a large potential to produce biomethane with the assumed quantity sufficient to cover the needs of public road transport, replace fossil fuels used in industry, and provide fuel to municipal and private transport. Digestate, as a valuable by-product, can be used as a fertiliser and reduce environmental impacts.

Renovation of district heating networks reduces losses occurring in the transport of heat and therefore primarily reduces the consumption of wood chips for heat generation, which in turn has a positive impact on the forests of the islands. Establishing new district heating grids can replace the usage of inefficient or carbon-intensive local heat generation, increase comfort, and reduce the amount of harmful gases in the vicinity of residential buildings.

Buildings form a significant share of the total energy consumption of the islands. Therefore, improving energy efficiency has great potential for reducing the use of fuels. The improved living conditions along with extended lifetime and increased value of buildings are of even greater importance to the residents of the islands.

To reach the objectives set, community involvement is of great importance. Therefore, the local municipalities have a role in encouraging the residents to carry out small-scale energy efficiency measures. It is also important to raise overall awareness about energy

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efficiency and sustainable solutions as examples set by others have positive impacts on the whole communities of the islands.

Table 1 gives an overview of the measures to be implemented with their respective implementation periods, the resulting reduction in CO_2 emissions, the total investment cost by 2030, and the cost of investment to be carried by the local municipalities. Detailed road maps for the local municipalities with required actions are provided in Appendix 1.

Table 1. Roadmap towards a sustainable island community

	Measure	Implementation period	Reduction in CO_2 emissions, tCO_2/yr	Total investment cost, €	Investment cost for the local municipalities, €
1.	The Baltic Sea transmission grid across Saaremaa and Hiiumaa	2030+	-	-	-
2.	Energy communities	2022-2030+	3650	6 700 000	-
3.	Electricity and hydrogen in public transport	2025-2030	16 160	70 000 000	600 000
4.	Synergy of offshore wind farms and blue economy	2028-2030+	-	-	-
5.	Innovative wind energy solutions	2022-2030+	330	420 000	25 000
6.	Offshore wind farm	2022-2028	114 380	4 000 000 000	35 000
7.	Adoption of hydrogen vehicles	2030+	90 080	-	-
8.	Wave energy	2030+	-	-	-
9.	Expansion of the renewable energy solution of Ruhnu	2025-2030	-	50 000	-
10.	Installation of PV panels for the ambulance centre of Ruhnu	2022-2023	-	30 000	30 000
11.	Renovation of street lighting	2022-2030	290	3 600 000	3 600 000
12.	Electrification in transport	2022-2030+	5900	126 000 000	5 260 000
13.	Biomethane production	2022-2026	6220	8 000 000	-
14.	Adoption of gas-powered vehicles	2025-2030	-	10 300 000	1 500 000
15.	Renovation of district heating networks	2022-2025	-	2 740 000	70 000
16.	Käina district heating	2022-2025	240	840 000	10 000
17.	Renovation of buildings	2022-2030+	-2780	238 500 000	18 040 000
18.	Small-scale energy efficiency measures	2022-2030+	9620	42 100 000	1 527 500
	Total by 2030		143 000	4 509 280 000	30 697 500

With changes taking place in the energy sector affecting the whole economy of the islands, changes in the education system must also be carried out to adapt to the new needs: increasing volume of renewable energy being produced on the islands or in the waters near the islands, increasing electrification of transport, development of the blue economy

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sector, and other activities lead to a demand for new skills and competencies. The educational institutions on the islands have a major role to play in the energy transition and, with the right decisions, changes can be implemented faster while bringing more benefits to the islands.

The transition towards a sustainable island community is accompanied by benefits in health and wellbeing. Using renewable sources of energy enables the reduction of the amount of air pollutants resulting from the combustion of fossil fuels that are considered harmful to public health. Reducing the amount of pollution can lead to a longer life expectancy with a greater number of healthy years. The greatest direct impact on the islands can be achieved by reducing the use of fossil fuels in transport. In addition to decreasing the amount of pollution, health benefits also stem from the renovation of buildings. Improved living conditions can result in fewer illnesses and disabilities.

Tourism is a sector that is of great significance for the islands. The adoption of renewable energy and the transition towards sustainability is a value that can promote interest towards the islands. To introduce the islands as a sustainable tourism location, the aspirations and achievements in energy transition need to be included as a vital part of the marketing of the islands.

The local municipalities have an important role in guiding the energy transition and setting an example for others to follow. It is important to have the necessary competence for carrying out projects related to improved energy efficiency and reduction in carbon dioxide emissions. To ensure the successful transition towards sustainability and to offer the support needed to the residents, the local governments need to place emphasis on reducing barriers for innovative renewable energy projects, simplifying the process of acquiring permits for carrying out projects that benefit the communities, and raising the awareness of locals to reduce opposition towards projects with a great positive impact.

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research and innovation programme under grant agreement N° 864266

Kokkuvõte

Ühiselt korraldatud jätkusuutliku arengu kava toob kasu Saaremaa, Hiiumaa, Muhu ja Ruhnu saarelistele omavalitsustele. Energia- ja kliimakavade koostamise jätkuna tahavad Lääne-Eesti saared luua investeerimiskava, milles kirjeldatakse kõiki tähtsaid varasid, ja kestliku saarekogukonna loomise tegevuskava, mis sisaldab ülevaadet võimalikest lahendustest kliimamuutuste, majandusarengu ja keskkonnaga seotud probleemidele, ning plaani saarel toimuvate kohalike varadega seotud arengute kohta.

Seega analüüsisid E.ON, Energex ja SINLOC üksikasjalikult NESOI-projektis viit eri ettepanekut, võttes arvesse Eesti saarte jaoks tähtsamaid valdkondi, nagu energiatootmine taastuvatest allikatest, säästvate liikuvuslahenduste ja sinimajanduse lahenduste rakendamine. Lisameetmeid analüüsis Energex. Analüüsitud algatustega panevad Eesti saarelised omavalitsused – Saaremaa, Hiiumaa, Muhu ja Ruhnu – aluse oma teekonnale kliimaneutraalsuse ning energiasõltumatuse suunas.

Käesolevas dokumendis kirjeldatakse analüüse, mis tehti viie alljärgneva ettepaneku kohta:

- Saaremaad ja Hiiumaad hõlmav Läänemere ülekandevõrk;
- energiakogukonnad;
- elekter ja vesinik ühistranspordis;
- avamere tuuleparkide ja sinimajanduse sünergia;
- uuenduslikud tuuleenergialahendused.

Lisaks viiele eelnimetatud ettepanekule kirjeldatakse dokumendis lisameetmete jaoks tehtud analüüse.

Samuti antakse siinses dokumendis teavet, mis annab huvirühmadele algatuste kohta ülevaate ja võimaldab neil algatustest paremini aru saada. Tuvastatud lahenduste arengu ja rakenduse jaoks on siiski vaja põhjalikumat analüüsi.

Saarte energiatarve 2018. aastal, mis sisaldas elektrienergia tarbimist ja kütuste tarbimist nii kütteks kui ka transpordis, oli 929 GWh. Kui lisada parvlaevade ja lennukite tarbitud energia, ületab kogu energiatarve 1 TWh. Energiatarbimise tulemusena paiskus atmosfääri 310 ktCO_2 heitmeid ning kui kaasata parvlaevad ja lennundus, oli CO_2-heite kogus ligi 330 kt.

Saarte üldine eesmärk on olla arukas ja keskkonnahoidlik. Selle saavutamiseks on seatud järgmised strateegilised eesmärgid: vähendada CO_2-heidet 2030. aastaks 40% võrra võrreldes 2018. aastaga, saavutada 2030. aastaks 60% taastuvenergia osakaal energia lõpptarbimises ning 100% üleminek taastuvenergiale ja vähese CO_2-heitega kütustele omavalitsussektoris aastaks 2030. Ruhnu taastuvenergia osakaal peaks olema 70% ja Ruhnu omavalitsussektori eesmärk on saavutada 75% osatähtsus. Aastaks 2050 plaanivad saared olla energiasõltumatud. Strateegiliste eesmärkide saavutamiseks on määratud mitu

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alameesmärki. Kuna viimaste aastate jooksul on võrreldes lähteaastaga toimunud muutused, esitatakse siinses dokumendis 2030. aasta kohandatud alameesmärgid.

Saaremaad ja Hiiumaad hõlmaval Läänemere ülekandevõrgul on potentsiaal parandada saarte varustuskindlust, aidata kaasa CO_2-heite vähendamisele ja suurendada taastuvallikate osakaalu. Sellise projekti rakendamisel tuleb järgida Euroopa elektri põhivõrguettevõtjate võrgustiku (ENTSO-E) määratud suuniseid ning kaasata kõik piirkondlikud põhivõrguettevõtjad ja liikmesriigid. Võrk parandaks kogu piirkonna ühendust ja vähendaks riikide elektrihinna erinevusi.

Energiakogukonnad annavad võimaluse kaasata saarte elanikke eesmärkide saavutamisse ja seeläbi vähendada sõltuvust imporditud elektrienergiast. Otsustati, et tänu lihtsale teostatavusele, suhteliselt väikestele kapitalikulutusele, vähestele piirangutele ja kohandatavusele, mis teevad tehnoloogia kogukondadele kättesaadavaks, on päikeseenergia suurima potentsiaaliga lahendus, et kogukonna energiaprojektid ellu viia. Euroopa Komisjoni hinnangul võib 2030. aastaks kuuluda 21% paigaldatud PV-paneelidest energiakogukondadele. Päikeseenergia praeguse kasvutempo põhjal võiksid kogukonna päikesefarmid toota 2030. aastaks 6,7 GWh elektrit aastas.

Praegu sõltub bussidest ja parvlaevadest koosnev saarte ühistranspordisüsteem enamasti imporditud kütustest. Seatud on eesmärk muuta ühistransport 2030. aastaks CO_2-neutraalseks. Elektrifitseerimine ja vesiniku kasutus võivad selle eesmärgi täitumisele märkimisväärselt kaasa aidata. Mõlema võimaluse jaoks on vaja lisainvesteeringuid tootmisüksustesse ja taristusse. Selleks et elektri- või vesinikubusside tasuvust korralikult hinnata, tuleks Hiiumaal korraldada katseprojekt. Kohalikud omavalitsused ei saa avaldada olulist mõju parvlaevadega seotud arengutele, kuna investeeringuid teevad kas riik või transpordiettevõtjad. Tähtis on siiski selgelt väljendada saarte ootusi vastutavatele asutustele.

Lisaks taastuvenergia tootmisele loovad avamere tuulepargid koostöövõimalusi teiste sinimajanduse valdkondadega. Heaks näiteks võimalikust sünergiast on vesiviljeluse ja tuuleparkide kooslus ning sadamate suurenenud sellest tulenev nõudlus rohkemate sadamateenuste järele. Üldjoones võib koostöö kaudu vähendada kulusid, luua töökohti ja parandada saarte majanduslikku positsiooni, mis loob parema ühiskonna.

Uuenduslikel tuuleenergiatehnoloogiatel on Saaremaal, Hiiumaal ja Muhus suur potentsiaal, kuna nendega võivad kaasneda sotsiaal-majanduslikud hüved nii investorite saartele meelitamise näol kui ka erinevate tuuleenergia tootmisvõimaluste tutvustamise kaudu, mis aitaks vähendada kogukonna vastuseisu tuuleenergia projektidele.

Avamere tuuleparkidel on suur mõju kogu riigi energiakasutusele, mitte ainult saartele. Seetõttu on väga tähtis toetada nende projektide arengut, kuna toodetud taastuvelekter ületab saarte aastast kogutarvet märkimisväärselt. Avamere tuulepargid loovad ka võimaluse toota suures mahus saastevaba vesinikku. Laineenergial alternatiivse avamere energiaallikana on piiratud potentsiaal kaugemas tulevikus.

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Ruhnu saar saab praegu elektrit kohalikust taastuvenergialahendusest, mis kasutab lisaks imporditud biodiislile ka tuule- ja päikeseenergiat. Kuigi toodetud elekter on CO_2-neutraalne, saab kohalikest allikatest toodetud elektri osakaalu suurendada, laiendades taastuvenergialahendust ja paigaldades kiirabikeskusele PV-paneelid.

Tänavavalgustuse renoveerimine võimaldab vähendada elektritarvet. Kuigi sääst on suhteliselt väike, tagab uus tänavavalgustus parema valgustatuse ja turvalisema keskkonna.

Transport on sektor, mille CO_2-heidet on raske vähendada. Praegu pakub elektrifitseerimine suurepärast võimalust vähendada CO_2-heidet. Transpordi elektrifitseerimise tähtis eeldus on laadimistaristu arendamine. Kuigi elektrisõidukid muutuvad üha populaarsemaks, ei ole kasutuselevõtu kiiruse põhjal tõenäoline, et transpordisektori CO_2-heite vähendamise alameesmärk 2030. aastaks saavutatakse.

Kaugküttevõrkude renoveerimine vähendab soojusenergia edastamisel tekkivaid kadusid ja seega vähendab peamiselt soojusenergia tootmiseks kasutatava hakkpuidu tarvet, mille on omakorda positiivne mõju saarte metsadele. Uute keskküttevõrkude loomine võib asendada ebatõhusa või rohket CO_2-heidet põhjustava kohaliku soojusenergia kasutuse, suurendada mugavust ja vähendada kahjulike gaaside kogust elamute ümbruses.

Hooned moodustavad märkimisväärse osa saarte kogu energiatarbest. Seetõttu on energiatõhususe parandamisel suur potentsiaal vähendada kütusetarvet. Paremad elamistingimused ning hoonete pikem eluiga ja suurenenud väärtus on saarte elanikele veelgi tähtsamad.

Kogukonna kaasatus on seatud eesmärkide saavutamiseks äärmiselt tähtis. Seetõttu tuleb kohalikel omavalitsustel innustada elanikke rakendama väikesemahulisi energiatõhususmeetmeid. Samuti on tähtis suurendada üldist teadlikkust energiatõhususest ja kestlikest lahendustest, sest teiste näidete eeskujul avaldab see positiivset mõju kogu saarekogukonnale.

Tabelis 1 antakse ülevaade rakendatavatest meetmetest koos elluviimise perioodiga, investeeringute tulemusena vähenenud CO_2 kogusest, investeeringute kogukulust 2030. aastaks ja kohalike omavalitsuste investeeringukulust. Kohalike omavalitsuste üksikasjalikud tegevuskavad koos vajalike meetmetega on esitatud Lisas 1.

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Tabel 1. Tegevuskava kestliku saarekogukonna loomiseks

	Meede	Elluviimise periood	CO_2 heite vähenemine, tCO_2/a	Investeeringute kogukulu, €	Kohalike omavalitsuste investeeringute kulu, €
1.	Saaremaad ja Hiiumaa hõlmav Läänemere ülekandevõrk	2030+	-	-	-
2.	Energiakogukonnad	2022-2030+	3650	6 700 000	-
3.	Elekter ja vesinik ühistranspordis	2025-2030	16 160	70 000 000	600 000
4.	Avamere tuuleparkide ja sinimajanduse sünergia	2028-2030+	-	-	-
5.	Uuenduslikud tuuleenergialahendused	2022-2030+	330	420 000	25 000
6.	Avamere tuulepark	2022-2028	114 380	4 000 000 000	35 000
7.	Vesinikusõidukite kasutuselevõtt	2030+	90 080	-	-
8.	Laineenergia	2030+	-	-	-
9.	Ruhnu taastuvenergialahenduse laiendamine	2025-2030	-	50 000	-
10.	PV-paneelide paigaldamine Ruhnu kiirabikeskusele	2022-2023	-	30 000	30 000
11.	Tänavavalgustuse renoveerimine	2022-2030	290	3 600 000	3 600 000
12.	Transpordi elektrifitseerimine	2022-2030+	5900	126 000 000	5 260 000
13.	Biometaani tootmine	2022-2026	6220	8 000 000	-
14.	Gaasisõidukite kasutuselevõtt	2025-2030	-	10 300 000	1 500 000
15.	Kaugküttevõrkude renoveerimine	2022-2025	-	2 740 000	70 000
16.	Käina kaugküttevõrk	2022-2025	240	840 000	10 000
17.	Hoonete renoveerimine	2022-2030+	-2780	238 500 000	18 040 000
18.	Väikesemahulised energiatõhususmeetmed	2022-2030+	9620	42 100 000	1 527 500
	Kokku 2030. aastaks		143 000	4 509 280 000	30 697 500

Kuna energiasektoris toimuvad muutused, mis mõjutavad saarte majandust tervikuna, tuleb uute vajadustega kohanemiseks teha muudatusi ka haridussüsteemis: saartel või nende lähedal asuvates vetes toodetava taastuvenergia koguse suurendamine, transpordi elektrifitseerimise suurendamine, sinimajanduse sektori arendamine ning muud tegevused tekitavad nõudluse uute oskuste ja pädevuste järele. Saarte haridusasutustel on suur osa energia üleminekul ja õigete otsuste abil saab muudatusi teha kiiremini, tuues samal ajal saartele rohkem kasu.

Üleminekuga jätkusuutlikule saarekogukonnale kaasneb kasu tervisele ja heaolule. Taastuvate energiaallikate kasutamine võimaldab vähendada õhusaasteaineid, mis tekivad fossiilkütuste põletamisel ja, mis on tervisele kahjulikud. Saaste vähendamine võib pikendada eeldatavat eluiga ja suurendada tervena elatud aastate arvu. Suurimat otsest

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mõju saab saartele avaldada, kui vähendada fossiilkütuste kasutust transpordisektoris. Lisaks saaste vähenemisele on hoonete renoveerimisest kasu ka tervisele. Paremad elamistingimused võivad vähendada haiguste ja puuete teket.

Turismisektor on saartele äärmiselt tähtis. Taastuvenergia kasutuselevõtt ja üleminek kestlikkusele on väärtus, mis võib suurendada huvi saarte vastu. Selleks et esitleda saari kestliku turismipaigana, tuleb energia üleminekuga seotud eesmärgid ja saavutused muuta saarte turunduse oluliseks osaks.

Kohalikel omavalitsustel on tähtis roll energia ülemineku juhtimisel ja eeskuju andmisel. Oluline on vajaliku pädevuse olemasolu, et viia ellu projekte, mis on seotud energiatõhususe parandamise ja CO_2-heite vähendamisega. Selleks et tagada edukas üleminek kestlikkusele ja pakkuda elanikele vajalikku toetust, peavad kohalikud omavalitsused keskenduma uuenduslike taastuvenergiaprojektide tõkete vähendamisele, lihtsustades kogukondadele kasu toovate projektide lubade taotlusprotsessi, ning suurendama kohalike teadlikkust, et vähendada vastuseisu projektidele, millel on suur positiivne mõju.

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1. Overview of energy consumption and carbon dioxide emissions

1.1. Overview of the islands

The island municipalities of Saaremaa, Hiiumaa, Muhu, and Ruhnu are located in the Baltic Sea off the western coast of mainland Estonia. In addition to the four main islands, the municipalities consist of several smaller islands and islets surrounding the main islands with most of them being uninhabited. The islands belong to the West Estonian Archipelago Biosphere Reserve, a part of UNESCO’s Man and the Biosphere Programme. The islands have a total population of 42 471 and a total area of 3972 km^2 which means that the average population density is 10.7 people per km^2 (1).

Saaremaa is the largest of the islands with an area of 2718 km^2 and a population of 31 073 people followed by Hiiumaa with an area of 1032 km^2 and a population of 9381 people. Muhu, which has a connection to Saaremaa via a causeway has an area of 210 km^2 and a population of 1876 people and Ruhnu, which is located in the Gulf of Riga far away from the rest of the islands, has an area of 12 km^2 and a population of 141 people. The largest inhabited centre of Saaremaa is the town of Kuressaare with a population of 12 698 people and the largest inhabited centre of Hiiumaa is the town of Kärdla with a population of 3160 people (1).

1.2. Baseline Emission Inventories

In 2020 Sustainable Energy and Climate Action Plans (SECAPs) were composed for the islands by Tartu Regional Energy Agency. The plans were a prerequisite for joining the Covenant of Mayors. The SECAPs prepared Baseline Emission Inventories (BEI) and mapped the total energy consumption of the islands. The year 2018 was used as the baseline as data for 2019 was not yet available when conducting the reports. An overview of the energy consumption, the resulting carbon dioxide emissions, and share of renewable energy sources used is given in Table 1.1. Baseline Emission Inventories for each municipality are given in Appendix 1.

The Baseline Emission Inventory divided the energy consumed into three main groups, district heating, fuels which includes fuels both for heating and for transport, and electricity. Energy consumption and CO_2 emissions are viewed based on consumer groups. Consumers are divided into local government buildings, street lighting, the business sector, the building sector, private transport, local government vehicles, and public transport. Ferries and aeroplanes used for connecting the islands to the mainland and to each other are viewed as separate consumer groups.

Local government buildings include all buildings owned by the local municipalities such as schools, cultural centres, administrative buildings, care homes etc. Street lighting covers all public lighting points administered by the municipalities. The business sector covers the energy consumption in all buildings belonging to the business sector, industrial

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processes, and buildings of the public sector owned by the state. The building sector covers all residential buildings. Private transport includes all vehicles in private use. Local government vehicles encompass vehicles used for road transport by the local municipalities. Public transport is the road transport organised by the local governments. Ferries cover both the marine transport connecting the islands to the mainland as well as to each other. Aviation covers the fuel consumption of the aeroplanes used for connections to Kuressaare, Kärdla and Ruhnu (2) (3) (4) (5).

In 2018, the total energy consumption on the islands was 929 GWh. When including the energy consumed by ferries and aeroplanes, the total energy consumption exceeded 1 TWh. **The consumption of energy on the islands resulted in 310 ktCO_2 emissions** and when including ferries and aviation, there was a total of nearly 330 ktCO_2 emissions.

Table 1.1. Baseline Emission Inventory (2) (3) (4) (5)

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	13 560	5230	6650	25 440	7640	13 770
Street lighting	-	-	2780	2780	2890	-
Business sector	29 560	225 370	133 000	387 940	144 320	230 880
Building sector	36 350	109 260	78 250	223 850	81 690	141 260
Private transport	-	282 280	-	282 280	71 960	5580
Local govt vehicles	-	1850	30	1880	510	40
Public transport	-	4830	-	4830	1260	110
Total	79 500	628 800	220 700	929 000	310 300	391 600
Ferries	-	67 370	-	67 370	17 920	10
Aviation	-	5010	-	5010	1290	-
Total	79 500	701 200	220 700	1 001 400	329 500	391 600

Figure 1.1 gives an overview of the energy consumption and carbon dioxide emissions by consumer groups. The business sector was responsible for both the largest share of energy consumed and carbon dioxide emissions emitted in 2018. With 144 ktCO_2 emitted, the business sector accounted for 43.8% of the total carbon dioxide emissions when also taking into account the emissions from ferries and aviation. The share of energy consumed by the business sector was 38.7%. The second largest emitter of carbon dioxide emissions was the building sector with a share of 24.8%.

Even though private transport made up a greater share of energy consumption than the building sector, the resulting carbon dioxide emissions were smaller. This is due to the high carbon intensity of the electricity consumed in Estonia in 2018. The emission factor for Hiiumaa, Saaremaa, and Muhu was 1.042 tCO_2/MWh as a great share of electricity consumed in Estonia in 2018 was oil-shale based. This means that electricity consumption was responsible for nearly 70% of the total CO_2 emissions (2) (3) (4) (5).

Other consumer groups with a significant impact on energy consumption and CO_2 emissions were ferries and buildings owned by the local municipalities. The remaining groups - street

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lighting, aviation, public transport and local government vehicles - formed as a whole less than 2% of the total emissions and energy consumption.

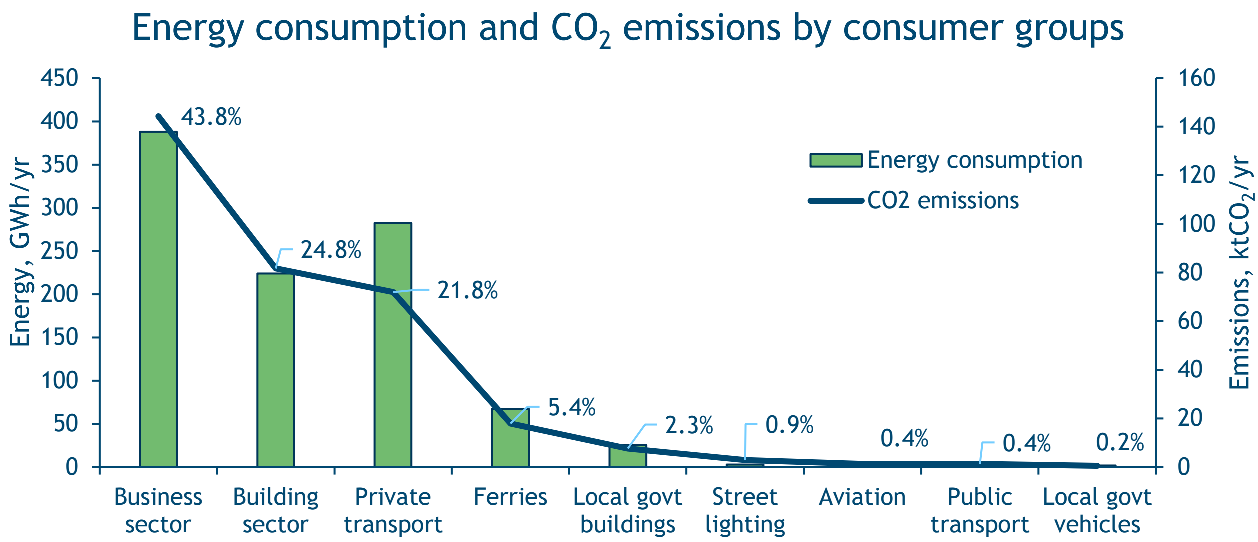

Figure 1.1. Energy consumption and CO_2 emissions by consumer groups (2) (3) (4) (5)

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2. Strategic objectives

2.1. General objectives

The overall vision for the islands is to become Smart and Green by designing, developing, and deploying smart and green solutions through sustainable and intelligent use of resources, economic growth and environmental sustainability, clean energy policies, reuse, being a role model to others, and moving towards minimising the ecological footprint (2) (3) (4) (5).

The SECAPs set strategic objectives for the municipalities to mitigate climate impact. The general objectives set are as follows:

- **Reduce carbon dioxide emissions through energy efficiency and renewable energy usage by 40% by 2030 compared to 2018, or by 124 120 tonnes per year.**
- **Achieve a 60% share of renewable energy in final energy consumption by 2030.**
    - **For Ruhnu, the goal is to reach a 70% share.**
- **Switch to 100% renewable energy and low carbon fuels in the municipal sector by 2030 the latest. When consuming heat energy, give preference to district heating.**
    - **For Ruhnu, the goal is to reach a 75% share.**
- **Become energy-independent by 2050 through security of supply, new renewable energy solutions, connections and storage facilities, flexibility in production and consumption, and the development of micro-grids.**
- **Reduce the effects of climate change on the population and the economy. Increase community preparedness for climate risk** (2) (3) (4) (5).

2.2. Sub-objectives

In order to reach the primary strategic objectives regarding the reduction of carbon dioxide emissions and the increase of the share of renewable energy consumed, sub-objectives have been determined for each municipality. The sum of the CO_2 emission reduction targets of the sub-objectives exceeds the overall goal, which guarantees that the strategic objectives are achieved when the sub-objectives are reached. The strategic objectives can also be reached without fulfilling the expectations of all the sub-objectives.

Table 2.1 provides an overview of the sub-objectives set as a total for all of the municipalities. Municipality-specific sub-objectives are given in Appendix 3. The largest share of emission reductions is expected to be achieved by covering the electricity consumption of the commercial and residential sectors by having at least 40% of the electricity consumed being locally produced or having a green certificate. This aim is expected to reach more than half of the total expected CO_2 emission reduction of the sub-objectives. Other sub-objectives with a significant positive impact on the overall carbon

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dioxide emissions are behavioural change through raising awareness and the reduction of fossil fuels in both private transport and in ferry traffic.

Table 2.1. Sub-objectives (2) (3) (4) (5)

	Sub-objective	Baseline, t/yr	Reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the islands by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity). For Ruhnu, the goal is 70%.	219 890	87 960
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	2890	2890
3.	100% renewable electricity is consumed in municipal buildings of Hiiumaa, Saaremaa, and Muhu.	6850	6850
4.	With raising awareness, changing consumption habits, and using smart solutions it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	220 920	18 990
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	550	550
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development and cost-effectiveness.	1260	1260
7.	A 30% reduction in the use of fossil fuels for private transport, including the transport of goods. For Ruhnu, the goal is to achieve a 70% reduction by reducing the usage of transportation or adopting electric vehicles.	71 960	21 280
	Total		**139 800**
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	17 920	17 920
	Total		**157 720**

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3. Current status

3.1. Developments compared to BEI

As the Baseline Emission Inventory was composed based on 2018 data, a number of changes have occurred that have led to a change in energy consumption and carbon dioxide emissions. The major changes are given below:

- The overall changes in the electricity market have resulted in lower carbon intensity which has a significant impact on CO_2 emissions.
- At the end of 2018 the renewable energy solution of Ruhnu came online which enables the island to use carbon-free electricity.
- The municipalities of Saaremaa and Muhu started using gas powered buses instead of diesel buses in public transport.
- Building renovations have been carried out by the local governments, and the business and private sectors.
- In 2020 one of the ferries servicing the Virtsu-Kuivastu line, Tõll was converted to a hybrid energy solution (6). Due to an accident in 2021, the ferry is currently operated with only diesel power.
- The street lighting of Saaremaa, Hiiumaa, and Ruhnu has been renovated to a large extent, whereas the number of lighting points in Muhu increased significantly with the development of Liiva's centre.
- The restrictions imposed by the Estonian government as a means of handling the COVID-19 pandemic temporarily limited the connections between the islands and the mainland in the spring of 2020. In addition to the restrictions, the pandemic had an impact on economic activities and the resulting energy consumption. Overall, however, the COVID-19 pandemic has not caused a significant change in energy consumption as in general the change from 2018 to 2019 was greater than the change from 2019 to 2020.

3.2. Decrease in the carbon intensity of electricity

In 2018 the yearly average carbon intensity of electricity consumed in Estonia was 1.042 tCO_2/MWh due to the large share of oil-shale based electricity. As a result of the decreasing electricity generation from oil shale and an increase in renewable electricity generation, the average annual carbon intensity dropped to 0.757 tCO_2/MWh in 2019 and to 0.547 tCO_2/MWh in 2020 (7).

The islands themselves have made an important contribution to the reduction of the carbon intensity of electricity supplied. According to data from Elering, the national TSO and Elektrilevi, the DSO operating on Saaremaa, Hiiumaa, and Muhu, a total of more than 15 MW of solar PV generation was added to the grid on the islands in 2019 and 2020. The fast increase in installed PV capacity was driven by the renewable energy subsidy which applied to all renewable energy generators with an installed capacity of less than 50 kW

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that were connected to the grid by the end of 2020. Compared to 2018, 20 additional GWh of renewable electricity was supplied to the grid on the islands and the growth of renewable energy sources has continued at a slower pace in 2021.

In addition to Muhu, Saaremaa, and Hiiumaa that are supplied with electricity by the grid connecting the islands to the mainland, the carbon intensity of electricity supplied in Ruhnu has also decreased. At the end of 2018 the renewable energy solution of Ruhnu was launched (8). The solution consists of solar panels, a wind turbine, batteries, and a diesel generator, which are controlled by an automation system. The diesel generator uses biodiesel for fuel (9). As a result, the electricity generated in Ruhnu is carbon neutral.

The renewable energy solution of Ruhnu consists of 200 kW of solar panels, a 50 kW wind turbine, a battery bank with a peak output of 180 kW and a capacity of 220 kWh, and a biodiesel generator with a nominal power of 160 kW (9). In 2019 the solar panels and the wind turbine supplied 54% of the total electricity demand (10) and in 2020 the corresponding share of electricity from wind and solar energy was 53%.

In the baseline emission inventory, CO_2 emissions resulting from the consumption of electricity formed the greatest share of the total emissions with nearly 230 ktCO_2. In 2020, the CO_2 emissions from electricity consumption decreased to about 114 ktCO_2. The emissions from the consumption of electricity still form the greatest share of the total carbon dioxide emissions, but the share has dropped to about 55%.

3.3. Energy consumption and emissions in 2020

Table 3.1 gives an overview of energy consumption, CO_2 emissions, and the share of renewable energy sources by consumer groups. Data was gathered from the local municipalities and various data sources according to the methodology described in the SECAPs. Appendix 4 gives the overview for all municipalities.

As some of the data such as the consumption of fuels in the building sector is not available in databases due to the information not being gathered, it was necessary to derive it based on existing data. Based on the data available at Statistics Estonia it was concluded that the fuel consumption in the business sector of Saaremaa had been overestimated in the BEI. As a result, the reduction in the consumption of energy in 2020 compared to 2018 appears to be greater than it is. However, as the overestimation primarily covered renewable fuels used for heating such as wood chips, pellets, and firewood which are considered to be carbon neutral, there is no significant impact on the CO_2 emissions resulting from that estimation.

Overall, the energy consumption in 2020 was 163 GWh smaller than in 2018. When excluding the difference stemming from the use of fuels in the business sector in Saaremaa, the difference is 69 GWh or 7.5% of the total energy consumption in 2018 excluding the overestimation of fuels consumed in the business sector in Saaremaa. Energy consumption decreased in all consumer groups except public transport. A reduction in consumption was achieved for all sources of energy.

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As the consumption of energy decreased, the total amount of renewable energy consumed also decreased. However, the amount of renewable energy consumed in buildings owned by the local government increased as a result of switching from fossil fuels to renewable fuels and heat pumps. The amount of renewable energy used in private transport also increased as biofuels are blended in the fuel supplied. The amount of renewable energy consumption also increased for street lighting in Ruhnu and for the fuel consumption of the vehicles of the local municipalities and public transport as a result of biofuel blending.

The total carbon emissions were reduced by 124.3 ktCO_2 with a reduction of 121.4 ktCO_2 achieved on the islands and the remainder coming from the reduction of emissions in ferry and aeroplane transport. Therefore, the target of reducing carbon dioxide emissions by 124.12 ktCO_2 by 2030 has almost been reached. However, as 93.0% of that decrease comes from the reduced consumption and lower carbon intensity of electricity, most of the sub-objectives have not been met.

Table 3.1. Emission Inventory

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	12 680	4750	4800	22 230	3110	15 410
Street lighting	-	-	1400	1400	760	10
Business sector	25 680	131 100	128 220	284 990	75 950	132 780
Building sector	34 850	96 360	74 680	205 900	40 950	131 070
Private transport	-	255 690	-	255 690	66 710	7930
Local govt vehicles	-	1910	-	1910	500	60
Public transport	-	4450	-	4450	1060	140
Total	73 200	494 300	209 100	776 600	189 000	287 400
Ferries	-	56 770	-	56 770	15 100	10
Aviation	-	4820	-	4820	1200	-
Total	73 200	555 900	209 100	838 200	205 300	287 200

Figure 3.1 gives an overview of energy consumption and CO_2 emissions by consumer groups in 2020. The business sector is still the group with the largest energy consumption and greatest carbon dioxide emissions. However, the share of CO_2 emissions for the business sector has dropped from 43.8% to 36.9%. Private transport and the building sector have exchanged places when it comes to CO_2 emissions, with private transport making up a 32.4% share and the building sector forming 19.9% of the total emissions. The importance of emissions resulting from the fuel consumption of ferries has increased while buildings owned by the local municipalities have reduced their environmental impact. The remainder of the consumer groups have an insignificant impact on both energy consumption and CO_2 emissions.

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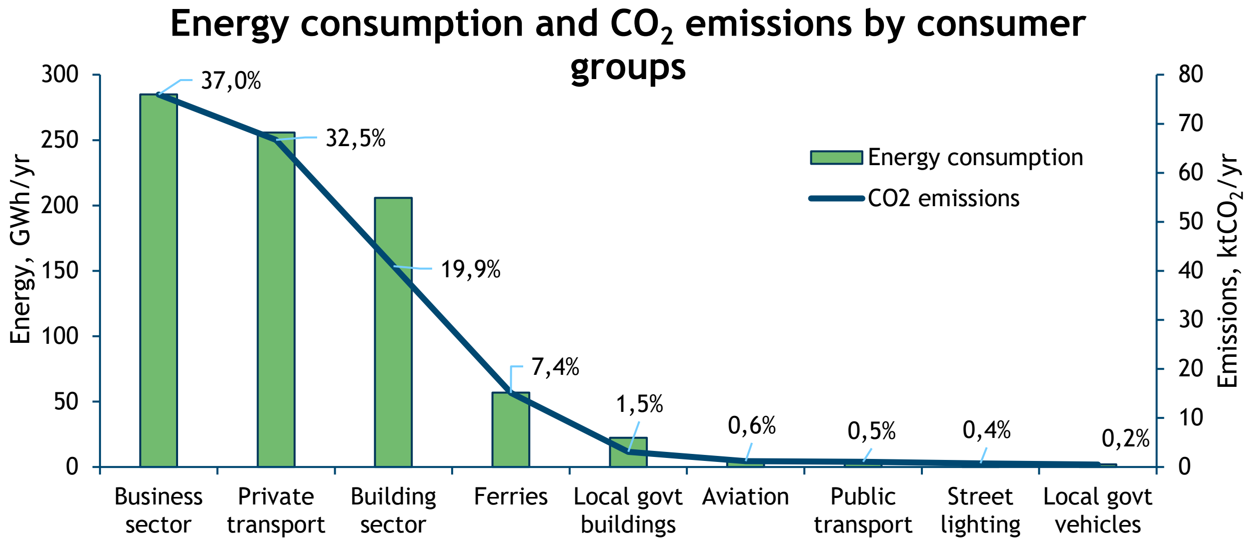

Figure 3.1. Energy consumption and CO_2 emissions by consumer groups in 2020

3.4. Adjusted sub-objectives

As a result of the changes that have taken place in the years following 2018, a large reduction in overall carbon dioxide emissions has occurred and therefore also some of the sub-objectives have already been partially or fully reached. To give an overview of the emission reduction targets for each sub-objective, Table 3.2 gives the adjusted sub-objectives based on the comparison of the emissions in 2018 and 2020. The adjusted sub-objectives for each municipality are given in Appendix 5.

The emissions reduction target for the first sub-objective has already been reached. However, as the reduction has been achieved thanks to external impacts, the aim of having at least 40% of the electricity produced locally or covered by a green certificate is not fulfilled.

The decrease in emissions target for raising awareness, changing consumption habits, and using smart solutions has also been reached. However, there is significant potential for further improvement, which means that the ambition can be elevated.

Sub-objectives seven and eight still require significant attention as they form nearly 85% of the total remaining carbon dioxide emissions reduction target. The emissions resulting from ferries can be reduced with a small number of large-scale investments, whereas in order to reach the target set for private transport, a large number of smaller investments and a better involvement of the local communities are required. The other sub-objectives with remaining carbon dioxide emissions reduction targets are related to sectors administered by the local municipalities. By reaching the set goals, the municipalities can also set an example for others.

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Table 3.2. Adjusted sub-objectives

	Sub-objective	Baseline, t/yr	2020, t/yr	Remaining reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the islands by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity). For Ruhnu, the goal is 70%.	219 890	110 710	-
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	2890	760	760
3.	100% renewable electricity is consumed in municipal buildings of Hiiumaa, Saaremaa, and Muhu.	6850	3110	3110
4.	In raising awareness, changing consumption habits and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	220 920	116 890	-
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	550	500	500
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development and cost-effectiveness.	1260	1060	1060
7.	A 30% reduction in the use of fossil fuels for private transport, including the transport of goods. For Ruhnu, the goal is to achieve a 70% reduction by reducing the usage of transportation or adopting electric vehicles.	71 960	66 710	16 030
	Total			21 500
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	17 920	15 100	15 100
	Total			36 600

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4. The Baltic Sea transmission grid across Saaremaa and Hiiumaa

4.1. Introduction

The Baltic Sea has a great potential for the growth of offshore wind energy, thanks to favourable conditions such as shallow waters, strong winds, and short distances to shore. The development of offshore wind farms and cross-border transmission corridors in the Baltic Sea will be accelerated in the coming decades to increase the use of clean energies and reach the green energy policy goals of the EU.

A cross-border transmission grid corridor that connects the islands of Saaremaa and Hiiumaa with the Baltic grid could bring a solution to the islands in terms of security of energy supply, decarbonisation, and use of renewable sources which correspond to the goals of the EU.

The following sections show an analysis of an alternative cross-border transmission corridor that would connect Ventspils in Latvia and Lieto in Finland across the Estonian islands of Saaremaa and Hiiumaa. The analysis includes the impact and risk analyses as well as a guideline for the implementation of the project.

4.2. Document references

This chapter gives an overview of the documents used to carry out the study. The list of documents is given as follows. As concrete plans regarding the development of the Baltic offshore grid are yet to be developed, there are no specific documents covering the project. The documents available provide an understanding of the opportunities and limitations for developing such infrastructure project.

- Baltic InteGrid: towards a meshed offshore grid in the Baltic Sea, Final report, https://projects.interreg-baltic.eu/fileadmin/user_upload/Library/Outputs/Baltic_InteGrid_HighLevelConcept.pdf
- Baltic Sea offshore wind. Joint declaration of intent, https://ec.europa.eu/energy/sites/ener/files/signature_version_baltic_sea_offshore_wind.pdf
- Study on Baltic offshore wind energy cooperation under BEMIP, https://op.europa.eu/et/publication-detail/-/publication/9590cdee-cd30-11e9-992f-01aa75ed71a1/language-en
- Elering, Security of supply of the Estonian electricity system 2020, https://elering.ee/sites/default/files/public/VKA2020.pdf
- Estonian Maritime Spatial Plan, http://mereala.hendrikson.ee/dokumendid/Eskiis/Estonian_MSP_main-solution_ENG.pdf

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- Estonian Maritime Spatial Plan, Draft Impact Assessment Report, http://mereala.hendrikson.ee/dokumendid/Eskiis/Estonian_MSP_Impact_assessment_ENG.pdf
- United Nations Convention on the Law of the Sea, https://www.un.org/depts/los/convention_agreements/texts/unclos/unclos_e.pdf
- Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention), http://library.arcticportal.org/1870/1/ECE.MP.EIA.21_Convention_on_Environmental_Impact_Assessment.pdf
- Protocol on Strategic Environmental Assessment to the Convention on Environmental Impact Assessment in a Transboundary Context (Kyiv Protocol), https://unece.org/fileadmin/DAM/env/eia/documents/legaltexts/protocolenglish.pdf
- The Convention on Access to Information, Public Participation in Decision-making, and Access to Justice in Environmental Matters (the Aarhus Convention), https://unece.org/DAM/env/pp/documents/cep43e.pdf
- The Convention on the Protection of the Marine Environment of the Baltic Sea Area (the Helsinki Convention), https://helcom.fi/media/publishingimages/Helsinki-Convention_July-2014.pdf
- Regulation on guidelines for trans-European energy infrastructure, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex%3A32013R0347
- Directive (EU) 2019/944 of the European Parliament and of the Council on common rules for the internal market for electricity, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32019L0944
- European Network Codes, https://www.entsoe.eu/network_codes/

4.3. Scope of intervention and general description

4.3.1. Project overview

From 2016–2019 the Baltic InteGrid project was implemented to explore the potential of meshed offshore grids in the Baltic Sea Region (BSR). The findings of the Baltic InteGrid project were extrapolated to the long term and across the whole Baltic Sea to formulate a vision for 2050 tentatively named the Baltic Offshore Grid (BOG). An analysis of the situation is expected on the ground in 2030, followed by study cases of potential meshed grid solutions in the Baltic Sea that could be implemented during the timeframe of 2025-2045. A tentative vision for a realistic meshed grid configuration in 2050 was formulated based on these estimates. This aims to provide a realistic model for a meshed grid in the Baltic Sea in the service of EU priorities. BOG 2050 specifies a combined radial and meshed approach to existing and new offshore wind farms and transmission infrastructure (11).

While the Baltic had an installed capacity of just 2.2 GW in 2018, it is expected to host up to 9.5 GW by 2030 and up to 35 GW by 2050. This new capacity will require a great

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deal of additional transmission infrastructure. This would entail an improvement of the connections between offshore wind farms in the Baltic Sea and a strengthening of cross-border links in the service of EU priorities such as increasing the share of renewables in the regional energy mix, enhancing the security and diversity of the energy supply, reducing the energy isolation of Member States in the BSR, unifying the local markets, and reducing energy costs (11).

Given the current plans for the installation of offshore wind farms and interconnectors, the main component of BOG 2050 would be a combination of the south-western and south-eastern meshed grids. Wind farms close to shore would mainly be expected to be connected radially, while the integrated section of the grid would realistically be deployed for wind farms some distance from the shore. A potential secondary focus could be envisaged in the northern part of the Baltic Sea, between Estonia, Finland, and Sweden. And a third prospect could be considered to link the northern and southern systems through a configuration situated off the coast of the Baltic States. Figure 4.1 shows the proposed development corridors of BOG 2050 together with planned and existing interconnectors and offshore wind farms (11).

The BOG 2050 segments that are executed will depend on the balance of costs and benefits which in turn will largely be determined by the distances involved and the availability of transmission technology. It will also be highly dependent on which offshore wind farms are built and when. While general indications for cable corridors are included in the concept, the concrete planning and implementation of individual cross-border interconnectors will be determined by the TSOs and their coordination within ENTSO-E via the TYNDP (11).

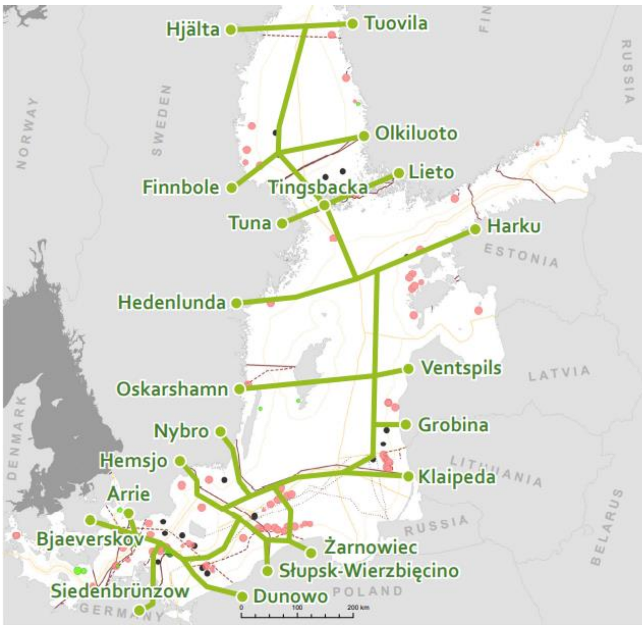

Figure 4.1. The Baltic Offshore Grid (BOG 2050) concept **(11)**

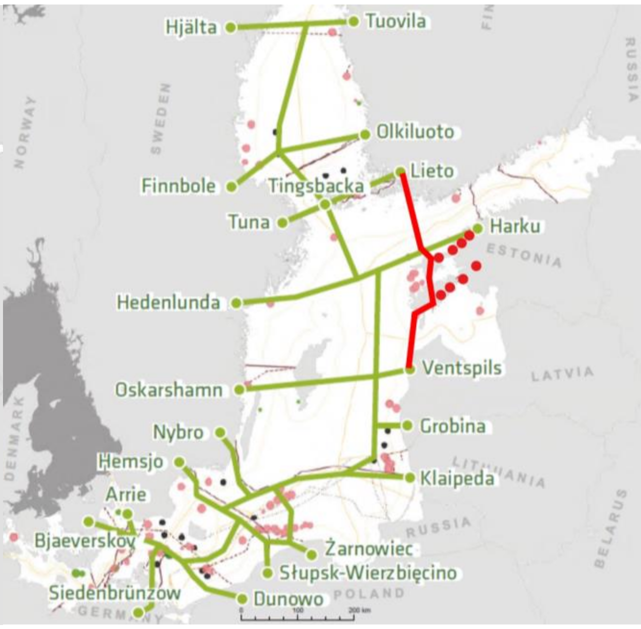

Figure 4.2. Alternative to the Baltic Offshore Grid concept

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Figure 4.2 depicts an alternative development corridor for the Baltic Offshore Grid. The alternative grid corridor is depicted in red. The alternative solution would connect Ventspils in Latvia and Lieto in Finland over the Estonian islands of Saaremaa and Hiiumaa. The main goals of the alternative are to connect the islands to the international transmission grid, promote the development of offshore wind farms off the coast of the islands, and reduce the cost of creating the grid by partially replacing offshore cables with onshore overhead power lines. Radial connections from Saaremaa to Lihula in mainland Estonia and from Hiiumaa via Aulepa to Harku in mainland Estonia are depicted with red dots.

The realisation of cross-border transmission lines is carried out by the TSOs of the respective countries (12). Transmission system operators of the Baltic Sea region have agreed to strengthen their cooperation for the future of the offshore grid in the Baltic Sea. The aim of the Baltic Offshore Grid Initiative is to develop common planning principles for the offshore energy network, enable the consideration of the offshore grid in the ENTSO-E Ten-Year Network Development Plan and perform studies that support the common vision for the grid (13). The TSOs have signed a memorandum of understanding to launch joint network connection studies and feasibility assessments. The joint conception of the grid is expected to be achieved in 2023 and the network and local connections are expected to be built between 2030 and 2050 (14). At the moment there are no preliminary plans in place, which is why different alternatives need to be considered so that they could be used as input for the conceptual plan.

4.3.2. Background

Estonia is located on the shores of the central part of the Baltic Sea. The country is isolated from Finland by the Gulf of Finland and from Sweden by Baltic Proper. When it comes to the power transmission network, the country is connected to Russia and Latvia by land and to Finland by cables in the seabed (Figure 4.3). In 2025, the Baltics will be disconnected from the Russian and Belarussian power grids and will join the synchronous area of Continental Europe. In the following decades the Baltic Sea is expected to have major developments in offshore wind energy, which means that Estonia will also need to upgrade the transmission network of the country and establish new international connections.

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Figure 4.3. Transmission network around Central Baltic Sea (15)

The Baltic Energy Market Interconnection Plan (BEMIP) initiative was signed in 2009 by all eight Baltic Member States and the European Commission with the aim of connecting the BSR to the EU's internal energy market and thereby ending the region's energy isolation. The concrete goals of the BEMIP include setting up an integrated electricity and gas market in the BSR through the development of infrastructure projects for renewable energy and interconnections. The BEMIP was updated and combined with the Energy Policy Area of the EU Strategy for the BSR in 2015. The resulting revised common action plan defined measures to be implemented by 2020 in areas such as energy infrastructure, the electricity market, security of supply, energy efficiency, and renewable energy (11).

Interconnections between Member States in the Baltic region and the strengthening of internal grid infrastructure are needed to end the energy isolation of the Baltic States and to foster market integration, which includes working towards the integration of renewable energy in the region (16).

4.3.3. Project Objectives

The main objectives of the project are to develop cost-effective cross-border connections for the transfer of renewable electricity between Member States in the Central Baltic

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Region, establish the network required to promote offshore wind energy generation projects in the region, and to create connections to the international transmission grid on the islands of Estonia to improve the security of supply and create the environment needed for the development of energy-intensive economic sectors on the islands.

4.3.4. Project Benefits

The implementation of the project would create a beneficial environment for the development of offshore wind energy projects through the existence of nearby connection opportunities which significantly reduce the costs the developers would need to bear for establishing radial connections on their own. The cost of establishing connections can determine the feasibility of an offshore wind farm compared to other offshore wind farms being developed.

The costs of the cross-border transmission can be significantly reduced by building a large part of the connection as an overhead power line instead of a submarine cable that needs to be dredged in the seabed. The cost difference between an overhead power line and a submarine cable of the same capacity can be tenfold (17). Therefore, it would be in the interests of wind energy developers and TSOs to build the construction grid across the islands instead of bypassing them. In addition, building the transmission grid across the island can reduce the need for other network investments on the islands.

Currently the island municipalities of Muhu and Saaremaa are connected to the mainland grid via subsea cables in the Suur Strait. Hiiumaa is connected to the grid of Saaremaa via subsea cables in the Soela Strait. There is no circular connection back to the mainland, which means that in the case of a power outage, alternative connections cannot be used, and the islands can only regain power once the fault has been rectified. Even though the security of supply of the currently existing connections is high, a potential outage can have a major impact on the functioning of the islands. By establishing additional connections and strengthening the networks on the islands, the diversity and security of supply is guaranteed, which makes the islands more attractive to potential investors interested in establishing energy-intensive consumer facilities such as data centres, chemical production plants or renewable energy projects on the supply side.

Better interconnections between the countries can reduce the price differences and the overall electricity price on the market as additional transmission capacity reduces congestion. Currently the market prices in Estonia and Finland can vary by multiple times as there is not enough transmission capacity to allow the free flow of cheaper electricity from Finland, Sweden, and Norway to the Baltic states.

4.3.5. Scope

The scope of the project is to establish a south to north cross-border transmission connection from Latvia to Finland via the Estonian islands of Saaremaa and Hiiumaa. The potential locations for establishing connections in Latvia and Finland are Ventspils and

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Lieto respectively. As an addition to the south-north connection, radial connections from Saaremaa to Lihula and from Hiiumaa to Harku need to be considered.

4.3.6. Project boundaries and constraints

The goals for Saaremaa, Hiiumaa, and Muhu based on their respective SECAPs are to have 60% of the energy consumed supplied from renewable sources by 2030 and achieve energy independence and climate neutrality by 2050. Offshore wind developments currently offer the best opportunity for reaching those targets, which is why it is essential to establish connections to the islands that can support the achievement of the goals.

As the Baltic Offshore Grid Initiative is at the conceptual stage, the detailed planning procedure is yet to begin and therefore no permits have been applied for and no contracts have been signed when it comes to the development of sections of the grid.

4.3.7. Business model and relationship scheme (governance)

The TSOs of the region are responsible for the implementation of the projects. Useful support for cross-border linkages is provided by the introduction of EU interconnection targets and investment in Projects of Common Interest (PCIs); preference is given to projects in priority corridors, as identified in the Trans-European Networks for Energy (TEN-E) strategy. PCIs benefit from accelerated planning and permit granting, improved regulatory conditions, streamlined environmental assessment processes enabling lower administrative costs and increased visibility to investors. They can also apply for funding from the Connecting Europe Facility (11).

The self-financed part of the cost needs to be covered by the TSOs. For the third Estonia–Latvia interconnection, Elering covered the cost with the profits from transmission capacity sold at auction, which means that the transmission services tariffs were not affected (12). As the cost of the project cannot be accurately estimated at such an early stage, it is difficult to say whether the tariffs need to be increased for carrying out the project.

The main stakeholders of the project are as follows:

- Transmission System Operators:
    - Estonia: Elering AS
    - Finland: Fingrid OY
    - Latvia: AS Augstprieguma tīkls
    - Lithuania: Litgrid AB
    - Sweden: Affärsverket Svenska Kraftnät

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- Planning and building:
    - Local Governments for detailed functional zoning plan.
    - Ministry of the Environment for the environmental impact assessment.
    - Consumer Protection and Technical Regulatory Authority for the building permits.
    - Competition Authority for analysis of the project impact on electricity distribution service pricing.
    - ENTSO-E for the planning of the project.
    - Local authorities in Finland and Latvia.
- State-side financing:
    - Ministry of Finance for the state budget strategy.
- Offshore wind farm investors.

4.4. Regulatory framework

4.4.1. United Nations Convention on the Law of the Sea

Customary international law of the sea is largely codified in the **United Nations Convention on the Law of the Sea** (UNCLOS) which sets common rules, establishes limits on sovereignty, and specifies the activities permitted in coastal areas. All eight EU Member States in the Baltic Sea Region (BSR) are parties to the convention (11).

Under UNCLOS, the sea is divided into different zones of activity and competence. In territorial waters which extend up to 12 nautical miles (22.2 km) from the coast, a state has full sovereignty over the surface, seabed, and subsoil, while other states still enjoy a right of innocent passage. In exclusive economic zones (EEZs), which extend 200 nautical miles (370.4 km) beyond the shore, states have sovereign rights to all economic activities involving the water, seabed, and subsoil, but the surface belongs to international waters (11).

The sovereign rights reserved to states in their respective EEZs are enumerated in UNCLOS and comprise economic activities such as the construction of offshore wind farms and laying of export cables. The laying of interconnectors is not considered an economic activity under this definition and is permitted to other states as well as the owner of the EEZ (11).

4.4.2. Environmental protection conventions

The Convention on Environmental Impact Assessment in a Transboundary Context (the Espoo Convention), which entered into force in 1997 and to which all eight EU Member States in the BSR are party, specifies that ‘appropriate and effective measures’ such as environmental impact assessments (EIAs) must be undertaken before projected major

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construction activities 'to prevent, reduce and control significant adverse transboundary environmental impact'. In 2010 the Espoo Convention was supplemented by the **Protocol on Strategic Environmental Assessment** (Kyiv Protocol) which specifies that countries should undertake strategic environmental assessments (SEAs) in the early phases of the development process so potential environmental effects can be evaluated while plans are still at an abstract stage. All eight Baltic Member States are parties to the Espoo Convention and Kyiv Protocol, as is the EU itself (11).

The Convention on Access to Information, Public Participation in Decision-making, and Access to Justice in Environmental Matters (the Aarhus Convention), in force since 2001, establishes a public right of access to environmental information and participation in environmental decision-making as well as access to judicial review on environmental issues (11).

The Convention on the Protection of the Marine Environment of the Baltic Sea Area (the Helsinki Convention) took effect in 2000. Its governing body is the Baltic Marine Environment Protection Commission (HELCOM) whose contracting parties include the eight EU Member States in the BSR as well as the EU and Russia. The Convention designates several Maritime Protection Areas (MPAs) with the goal of protecting marine and coastal flora and fauna specific to the BSR. There are currently 176 MPAs in the Baltic Sea (11).

Other relevant conventions include the **1979 Convention on the Conservation of European Wildlife and Natural Habitats** (Bern Convention), which served as a model for the EU's Habitats Directive, and the 1971 **Convention on Wetlands of International Importance especially as Waterfowl Habitat** (Ramsar Convention) (11).

4.4.3. BEMIP

The Baltic Energy Market Interconnection Plan (BEMIP) initiative was signed in 2009 by all eight Baltic Member States and the European Commission with the aim of connecting the BSR to the EU's internal energy market and thereby end the region's energy isolation. The concrete goals of the BEMIP include setting up an integrated electricity and gas market in the BSR through the development of infrastructure projects for renewable energy and interconnections. The BEMIP was updated and combined with the Energy Policy Area of the EU Strategy for the BSR in 2015. The resulting revised common action plan defined measures to be implemented by 2020 in areas such as energy infrastructure, the electricity market, security of supply, energy efficiency, and renewable energy (11).

Useful support for cross-border linkages is provided by the introduction of EU interconnection targets and investment in Projects of Common Interest (PCIs); preference is given to projects in priority corridors, as identified in the Trans-European Networks for Energy (TEN-E) strategy. PCIs benefit from accelerated planning and permit granting, improved regulatory conditions, streamlined environmental assessment processes enabling lower administrative costs, and increased visibility to investors. They can also apply for funding from the **Connecting Europe Facility** (11).

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Regulation (EU) No 347/2013 on guidelines for trans-European energy infrastructure defines the criteria for projects of common interest. According to Article 4 projects of common interest shall meet the following general criteria:

a) the project is necessary for at least one of the energy infrastructure priority corridors and areas,
b) the potential overall benefits of the project, assessed according to the respective specific criteria in paragraph 2, outweigh its costs, including in the longer term,
c) the project meets any of the following criteria:

   (i) involves at least two Member States by directly crossing the border of two or more Member States,
   (ii) is located on the territory of one Member State and has a significant cross-border impact as set out in Annex IV.1,
   (iii) crosses the border of at least one Member State and a European Economic Area country.

Directive 2009/72/EC concerning common rules for the internal market in electricity (the Electricity Directive) establishes the rules for the organisation and functioning of an integrated and competitive electricity market in the EU and promotes regional cooperation (11).

Other instruments relevant for the development of meshed offshore grids and considered by the Baltic InteGrid project include the Regulation on conditions for access to the network for cross-border exchanges in electricity (Electricity Regulation), which lays out rules for cross-border electricity exchanges, and the EU network codes and guidelines, which are binding legal instruments establishing rules for the EU electricity market (11).

Furthermore, the Regulation on guidelines for trans-European energy infrastructure (the TEN-E Regulation) provides support for the development of priority corridors and aspects of trans-European energy infrastructure, including tasks within the scope of the BEMIP initiative. In particular, this Regulation addresses PCIs and rules for the cross-border allocation of costs and risk-related incentives for those (11).

4.4.4. European Network Codes

Network codes are a set of rules drafted by ENTSO-E, with guidance from the Agency for the Cooperation of Energy Regulators, to facilitate the harmonisation, integration and efficiency of the European electricity market. Each network code is an integral part of the drive towards completion of the internal energy market, and achieving the European Union’s energy objectives of:

- at least a 40% cut in greenhouse gas emissions compared to 1990 levels;
- at least a 32% share of renewable energy consumption;
- at least 32.5% energy savings compared with the business-as-usual scenario.

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4.4.5. EU Environmental law

The Strategic Environmental Assessment Directive (SEA Directive) of 2001 obligates Member States to ensure that environmental assessments are carried out when designing 'plans and programmes which are likely to have significant effects on the environment'. It applies to a wider range of public plans and programmes adopted by public authorities at national, regional, or local levels, such as those concerning land use and the development of power plants. As a result, strategic environmental assessments (SEA) need to be carried out in an early, abstract phase of planning to assess the environmental impact not of just a concrete plant project but of development in general. The SEA Directive was adopted to implement the Kyiv Protocol of the Espoo Convention into EU legislation (11).

The EU also implemented the provisions of the Aarhus Convention through the adoption of the Public Participation Directive and the Freedom of access to information Directive. The Habitats Directive and the Birds Directive set standards for nature conservation in the EU and called for the creation of the Natura 2000 network of protected sites (11).

4.5. Technical analysis

Table 4.1 presents the Estonian power grid consumption and production peaks, lows, and average baseline demand.

Table 4.1. Elering annual production and consumption data (18)

Year	2019		2020	
	Consumption	Production	Consumption	Production
Maximum, MW	1540	2043	1409	1158
Average, MW	939	697	905	501
Minimum, MW	499	151	495	171
Total, GWh	8223	6102	7954	4398

Figure 4.4 presents the annual continuous load curve. Electrical grid operator Elering has forecast increasing peak power consumption and annual consumption until 2035. In 2035 the estimated consumption peak is 1717 MW (Figure 4.5) (19) (18).

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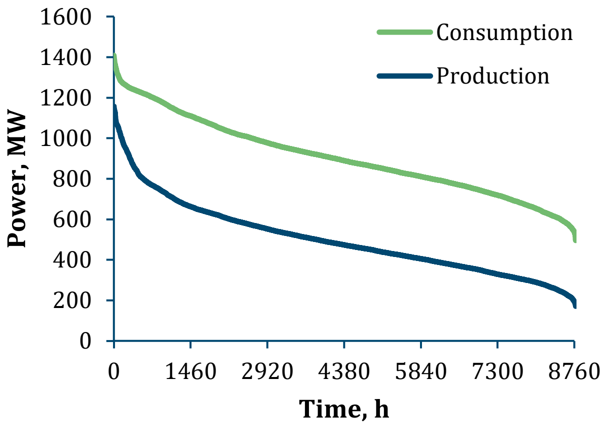

Figure 4.4. Power grid load

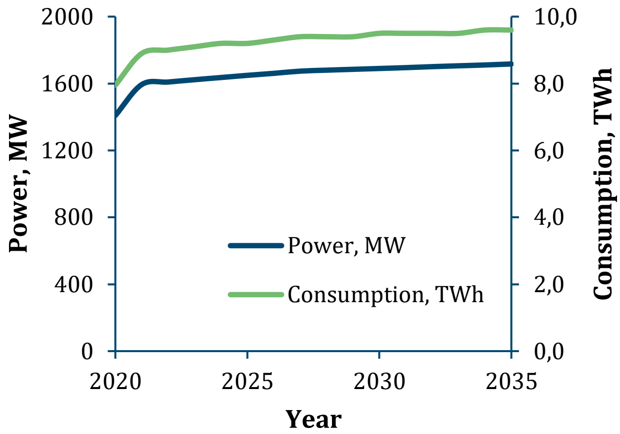

Figure 4.5. Power grid load forecast

Through three external connections it is possible to export up to 3166 MW of electric power during winter and 2266 MW during summer. Meanwhile, during winter it is possible to import up to 3016 MW and 2166 MW during summer (Table 4.2) (20). In 2020, Estonia imported 7296 GWh and exported 3564 GWh of power through HVDC links. Around 94% of imported electricity was transmitted via Estlinks 1 and 2 (EE ↔ FI) and 6% through Latvian transmission. Estonia's exports to Latvia account for up to 95% of all exported electricity. The remaining 5% was exported to Finland. In 2020 Estonia's imports exceeded export by more than 3.7 TWh which makes up to 47% of annual electricity consumption (18).

Table 4.2. Installed total transfer capability

Grid total transfer capability	EE → LV	LV → EE	EE ↔ FI	EE → RU	RU → EE
Winter 0°C, MW	1150	1150	1016	1000	850
Summer 25°C, MW	700	750	1016	550	400

The analysis conducted by Elering and the Estonian Competition Authority concluded that Estonia's electrical grid resource adequacy will be in good shape until at least 2030. It is important to ensure that Estonia has a 1000 MW capacity for system operation purposes. As of 1 January 2020, the total installed net generating capacity is 3041 MW, of which the capacity used during peak periods accounts for 1779 MW. However, installed capacity will be reduced to 800 MW by the end of 2029 due to oil shale power phase-out (20) (21).

4.6. Impact analysis

Estonian transmission system operator Elering AS has an online 330/110 kV electrical substation's overview and investment budget calculator (https://vla.elering.ee/). It is possible to check the production and consumption capacity (MVA) of each substation and the estimated cost of establishing a connection point or the cost of strengthening the power grid.

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Regarding the possible offshore wind farms in the Gulf of Riga and the Baltic Sea, Elering suggested possible onshore connection points to either Lihula, Sindi or Kilingi-Nõmme 330/110 kV substations. However, as those connection points are far away from the offshore wind farm planned west of Saaremaa and establishing connections at those locations would require significant improvements in the transmission grid of Estonia, an alternative of establishing a connection between Latvia and Finland over the Estonian islands of Saaremaa and Hiiumaa is analysed in this report.

The power system of the Baltic States is currently technically part of the Integrated Power System / Unified Power System (IPS/UPS) of Russia. The strategic goal is to disconnect power systems from the IPS/UPS and join the Continental European power grid and frequency area. Elering discusses it further on their webpage and maps the transmission line that will be constructed as part of Baltic synchronisation project (22). Most of the grid improvement investments are planned in Eastern Estonia.

The establishment of the grid would create employment opportunities on the islands both for the construction of the transmission lines and substations and over the lifetime of the project as operation and maintenance technicians are needed.

Improved connections and an ample supply of renewable electricity make the islands an attractive environment for investors interested in establishing energy-intensive facilities such as data centres and the production of chemicals. There might be negative impacts for companies whose activities are limited by the construction of the grid, however the overall negative impact is expected to be relatively small.

The social impacts of creating the transmission grid are related to the potential change of land use and the visual pollution created by the pylons and overhead power lines. As a side-benefit to the construction of the transmission grid, the local systems are likely to be upgraded to some extent, which further increases the security of supply and parts of the existing power lines can be decommissioned.

The primary onshore environmental impact of the transmission grid is the protection zone of the grid that requires open corridors to be created. The protection zone for 330 kV transmission grid lines extends 40 metres in both directions from the line (23). As a large share of the islands is covered in forests, the construction of new power lines can require deforestation and maintaining corridors without woodland. With land use change those areas could also be taken to use as farmland.

Additional environmental impact stems from the power lines presenting an electrocution hazard to birds, as the islands are an important migration corridor. To reduce the threat to birds, reflectors were installed on the 110 kV transmission grid over the Väike Strait causeway between Muhu and Saaremaa.

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4.7. Risk analysis

Table 4.3 gives an overview of the major potential risks associated with the establishment of the Baltic Sea transmission grid across Saaremaa and Hiiumaa. The risks with a high probability of occurrence are related to the overall development of the Baltic Offshore Grid 2050 concept as it is a long-term outlook with numerous variables that can impact the implementation of the concept, inclusion in the ENTSO-E Ten Year Network Development Plan due to the high competition of projects across Europe, and permitting which needs to be thoroughly investigated with all the necessary stakeholders.

Table 4.3. Risk analysis of establishing the Baltic Sea transmission grid across Saaremaa and Hiiumaa

Description of risk	Probability	Impact	Mitigation measures
High dependence on the development of the BOG 2050 concept	High	High	Considering the TYNDP and the different scenarios for 2030 and 2050
Inclusion of the project in the TYNDP	High	High	Engaging the Estonian TSO from an early stage of the project
Environmental impact	Medium	High	Taking into account the MSP and Natura 2000 to avoid environmental protected areas
Permitting	High	High	Identification of the permitting process at an early stage
Social acceptance	Medium	Medium	Transparent communication of the project to the community

4.8. Implementation guidelines

For the implementation of the project, ENTSO-E has determined the life-cycle steps of a transmission project shown in Figure 4.6 that shall be considered when building or renewing electricity transmission assets.

Figure 4.6. Life-cycle steps of a transmission project (24)

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Each step is briefly described below (24):

- ***Step 1 – Identifying the needs:***
  The first step, before developing a project, is to identify the needs for reinforcement of the transmission network. TSOs assess needs at national level on a regular basis. This assessment is completed by studies of needs at regional and pan-European levels carried out by ENTSO-E in the bi-yearly System Needs Study and regional investment plans.

- ***Step 2 - Identifying solutions to address the need:***
  Addressing tomorrow's challenges will require the parallel development of all possible solutions, not only including different transmission technologies or connections and routes but also electricity storage, the role of prosumers and generation in addition to reinforcing the transmission grid.

- ***Step 3 - Preliminary design of a project & cost-benefit -analysis:***
  Performing the cost-benefit analysis of a project consists of assessing its benefits for society considering its impacts in terms of reduction of generation costs and CO_2 emissions, improved security of supply, etc. These benefits are then compared to the expected costs of the project. The cost-benefit analysis is monitored through the lifecycle of the project development.

- ***Step 4 - Inclusion of the project in the National Development Plan and in the TYNDP:***
  Most European countries release on a regular basis a National Development Plan (NDP) describing the planned investments in the national transmission network including building new infrastructure and replacing existing infrastructure.

- ***Step 5 - Applying for European "Project of Common Interest" status:***
  European Projects of Common Interest (PCI) are key cross-border infrastructure projects that link the energy systems of EU countries. They are intended to help the EU achieve its energy policy and climate objectives. PCIs must have a significant impact on energy markets and market integration in at least two EU countries, boost competition on energy markets, and help the EU's energy security by diversifying sources as well as contribute to the EU's climate and energy goals by integrating renewables.

- ***Step 6 - Engineering design and permitting process:***
  After the preliminary design of the project comes the definition of its concrete technical characteristics. What route should the line follow considering constraints such as the presence of protected areas or of densely populated areas? How to minimise the environmental and social impact of the project?

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- ***Step 7 - Financing and final investment decision:***
  Funding may come from public or private investors. Organisations such as the European Investment Bank provide grants. Projects that are granted PCI status are eligible to receive funding from the Connecting Europe Facility - an EU fund worth € 30 billion supporting energy, transport, and digital infrastructure.

- ***Step 8 - Construction and commissioning:***
  Construction and commissioning covers the civil works, cable laying, and once the construction is over, the testing phase. The building of transmission infrastructure generates economic activity for the promoter's contractors and subcontractors, and for the local community.

- ***Step 9 - Operation of the new infrastructure:***
  Once the infrastructure is in operation, analysing its impact on system operations and markets makes it possible to tell whether the benefits anticipated during the planning phase have been delivered. Promoters look at indicators such as – for a cross-border project – the price difference on the border before and after the commissioning of the project, the congestion, etc.

As a cross-border transmission corridor will involve local and external stakeholders, it is necessary from a very early stage to get the engagement and support of the local authorities and TSO for the promotion of the project and its consideration into the NDP.

4.9. Technical recommendations

The cross-border transmission corridor proposed would connect Ventspils in Latvia and Lieto in Finland over the Estonian islands of Saaremaa and Hiiumaa, with the goal of connecting the islands to the international transmission grid and promoting the development of offshore wind farms off the coast of the islands. For this interconnection a HVDC cable shall be used; cable losses above a certain distance are lower than with the AC equivalent. Two main types of HVDC cable technologies are available commercially: mass-impregnated (MI) cables and XLPE cables.

To transport electricity in HVDC transmission lines special facilities have to be built. DC cables require a converter station at both ends of the link, at the starting point and the end point that transform direct current into alternating current and vice versa. Costs are lower for the cable but higher for the DC converter.

Preliminary analyses of the cross-border transmission corridor are recommended, e.g.:

- Impact assessment (political, economic, technological, legal, environmental)
- Preliminary investigation of the potential connection points in Ventspils and Lieto as well as on the islands; evaluation of different scenarios could be considered.
- Preliminary investigation of the high voltage installations at the landing points of the submarine cable as well as the islands.

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- Preliminary investigation of the transmission capacity of the corridor.

4.9.1. Technical Considerations with HVDC systems

Components of an HVDC System
The main components of an HVDC system are the transmission line and the converter stations at either end of the interconnection. The heart of the converter station is the converters themselves, which are composed of high-voltage solid-state "valves" that perform the AC to DC and DC to AC conversions. Converter stations also include transformers to convert to and from the AC transmission voltage to which the DC link is attached. Finally, converter stations include filters on both the AC and DC sides.

Choice of Converter Technology
An important issue in HVDC systems is the choice of converter technology. There now follows an overview of the converter technologies:

- **LCC-based HVDC technology:**

  Line-Commutated Converter (LCC) is a mature technology with the highest power and efficiency rating used for more than 50 years for bulk power transfer. LCC-HVDC technology employs line-commutated thyristor valve converters which rely on a stable AC system voltage for a reliable commutation. LCC-HVDC technical capabilities combined with its economic advantages and low operating losses make it a widely used solution for enlarging or enhancing power system interconnections.

- **VSC-based HVDC technology**
  A voltage source converter (VSC) is composed of high-voltage transistors called IGBTs. The VSC performs conversion at very high frequencies using a method called pulse-width modulation. This gives the VSC-HVDC technology a very high degree of control over the incoming and outgoing waveform allowing it to change power angles, control both real and reactive power, and maintain high power quality. In case of blackouts, the system can be restored if the grid at the other end of the HVDC system is still active and the VSC link is equipped with black start capability.

Reactive Power Consumption
Natural commutated converters consume a substantial amount of reactive power in the conversion process and may require reactive power compensation on the AC side. VSCs by their nature do not consume reactive power.

Harmonics
The process of converting AC to DC power, and vice versa, involves rapid switching which generates various harmonics that can reduce AC power quality and interfere with telecommunications facilities. AC filters are needed especially to eliminate harmonics of orders 11, 13, 23, and 25. The amount of filtering necessary depends on the kind of converter technology employed.

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Operation and Maintenance

HVDC systems are designed for remote operation because of the high voltage environment associated with them. A relatively small number of people can operate HVDC links from a central location. The maintenance requirements for HVDC transmission lines are comparable to those for high voltage AC lines. Turnkey systems, where a supplier builds an HVDC system then turns it over to a line operator, are common and the supplier should provide the necessary training and support to utility personnel. One week of maintenance per year is the typical anticipated outage time for HVDC systems.

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5. Energy communities

5.1. Introduction

With the adoption of the Green Deal and the Clean Energy for All package, the EU put a focus on citizens with the intent of fostering their active and coordinated participation in energy communities. An enabling framework and stable policies are the most important factors in establishing energy communities. Estonia is still on the transposition of the new directives (EU) 2019/944 and (EU) 2018/2001.

The following sections show the assessment of the feasibility and the possibilities of community energy projects on the islands of Saaremaa and Hiiumaa including the identification of the need for investment grant measures to increase the number of community energy projects.

5.2. Document references

This chapter gives an overview of the documents used to carry out the analysis. The list of documents is given as follows. Estonia is currently working on the transposition of the European directives and has compiled draft documents that are yet to be approved.

- Community Energy: A practical guide to reclaiming power, https://www.rescoop.eu/toolbox/community-energy-a-practical-guide-to-reclaiming-power
- Energy communities: an overview of energy and social innovation, https://publications.jrc.ec.europa.eu/repository/handle/JRC119433
- Community Energy – Broadening the Ownership of Renewables, https://euislands.eu/document/community-energy-ownership
- Handbook. Renewable energy communities, https://www.trea.ee/wp-content/uploads/2020/06/Co2mmunity_k%C3%A4siraamat.pdf
- Directive (EU) 2019/944 of the European Parliament and of the Council on common rules for the internal market for electricity, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L0944
- Directive (EU) 2018/2001 of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG
- Electricity Market Act, https://www.riigiteataja.ee/en/eli/ee/528082014005/consolide/current

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5.3. Scope of intervention and general description

5.3.1. Project overview

The islands' SECAPs set a target that the net energy consumption of the islands should be covered by renewable energy. Community energy projects increase local renewable energy production and increase the involvement of locals. **A 2020 European Commission report about community energy estimated that by 2030 energy communities could own some 17% of installed wind capacity and 21% of solar capacity and by 2050 almost half of the European population could be producing energy** (25).

5.3.2. Background

Community energy enables locals to manage and generate electricity. Community energy projects have an emphasis on engaging the locals. In order to promote sustainable power generation on the islands there is a need to increase the involvement of local communities in energy production. According to the sustainable energy and climate action plans composed for the islands, the annual electricity demand of the islands needs to be covered by local output of renewable energy and one of the indicators for the progress is the number of community-owned power plants. The electricity consumption figures of the islands in 2018 were as follows: Saaremaa municipality 161.5 GWh, Hiiumaa municipality 50 GWh, and Muhu municipality 8704 MWh.

A report about the state of community energy development in the Baltic Sea region published in 2019 states that Estonia is making initial steps towards community energy and that opportunities for the expansion of community energy projects exist.

An Estonian non-profit organisation Energiaühistu (The Estonian Energy Co-op) has been in contact with locals to find local activists willing to participate in community energy projects. Currently solar energy is stated as the main opportunity for community energy projects on the islands. Several projects were assessed during the community energy workshops in autumn 2021 in Hiiumaa and Saaremaa by Energiaühistu and Rexplorer OÜ. The potential installed solar PV capacity of assessed projects in Saaremaa is approximately 556.2 kW, in Hiiumaa 1667.1 kW, and in Muhu 40.5 kW (26).

5.3.3. Project Objectives

The aim of the project is to increase renewable energy production on the islands to meet both SECAP targets and European Commission estimates about the energy communities. Moreover, community energy projects could help increase the involvement and awareness of locals and thus increase the willingness to support renewable energy related projects, increase the islands' energy security, and support distribution system operation.

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5.3.4. Project Benefits

Increasing renewable energy generation on the islands is of crucial importance for meeting the targets set in the sustainable energy and climate action plans. So far, the local populations on the islands have shown opposition towards large-scale renewable energy projects. Community energy projects could help increase the involvement and awareness of locals and thus increase the willingness to support renewable-energy-related projects.

In addition, community energy projects would increase the islands energy security and support distribution system operation. The local communities could also benefit from lower energy prices associated with community energy production.

5.3.5. Scope

The scope of the project is to establish community energy power generation projects on the islands. These projects increase the islands' energy security and the locals' involvement and awareness in renewable energy production.

5.3.6. Project boundaries and constraints

The two main challenges that arise with the deployment of community energy are regulatory and financial. Examples show that smaller-scale investment is not necessarily enhanced by separate incentives and specific definitions for community energy investors. Additionally, community energy projects are likely to suffer more from regulatory changes such as changes in tariff structure because they cannot compensate for losses in one project, and they are more vulnerable to regulatory risks (27) (28) (29).

The 2020 community energy handbook listed the main difficulties regarding community energy – low level of awareness in energetics, lack of positive examples, knowledge, initiators, capital, and willingness to cooperate. Another important factor is the lack of motivation. The current supply of energy is reliable and it is easier for people not to initiate community energy projects that need building permits, cooperation among participants, and initial investments. A hindering factor for projects in co-operative housing associations is the incompatibility of electricity meters. Apartments have direct contracts with electricity sellers who own the electricity meters in apartments, meaning that the electricity generated locally would be sold to the grid and the residents would buy it from an electricity provider, resulting in additional expenses for the consumer. To get the maximum benefits on electricity production it would be necessary to renew the ownership contracts (30).

5.3.7. Business model and relationship scheme (governance)

For community energy projects locals could form a legal entity. The formed entities initial investment costs could be funded for example by the contribution of the members of the project or a loan. After implementation the assets would then belong to the entity and

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the energy produced that is not consumed by the community members could be sold to the power grid.

Another option is to co-operate with an organisation promoting community energy. Some organisations offer the possibility to rent out equipment, and aid with permitting and assessing the techno-economic feasibility of projects.

5.4. Analysis on possible renewable energy solutions

Community renewable energy projects raise locals' awareness and involvement in power generation. This is necessary to meet the set renewable energy targets. There are several different solutions for community energy projects some of which are wind and solar for electricity production and wood-fuel boilers for heating. These solutions vary both in the difficulty of implementation and regulatory aspects.

5.5. Identification of suitable technological options

The project "Best Practices, Business Models and Incentives for Launching Small-scale Electricity and Heat Cooperatives" identified that in Estonia the most popular solutions for energy communities are solar power stations for electricity generation and designing wood-fuel boilers for heating.

The potential to generate wind energy does not correspond to the communal generation potential in Estonia, i.e. the location of apartment and social buildings. Even on small islands and on the coast, the buildings are mostly not located close to the places open to the winds in order to use wind by means of small wind turbines for the self-consumption of the buildings. Based on the effect of scale, it is more profitable to produce electricity in big wind parks for sale into the power network (31).

The solar energy production in Estonian households has increased considerably in recent years as shown in Figure 5.1. Still, only 1% of the electricity consumed by Estonian households is produced from solar energy. If the same growth rate continues, Statistics Estonia estimates that by 2024 households will be able to generate nearly 7% of their electricity needs from solar energy (1).

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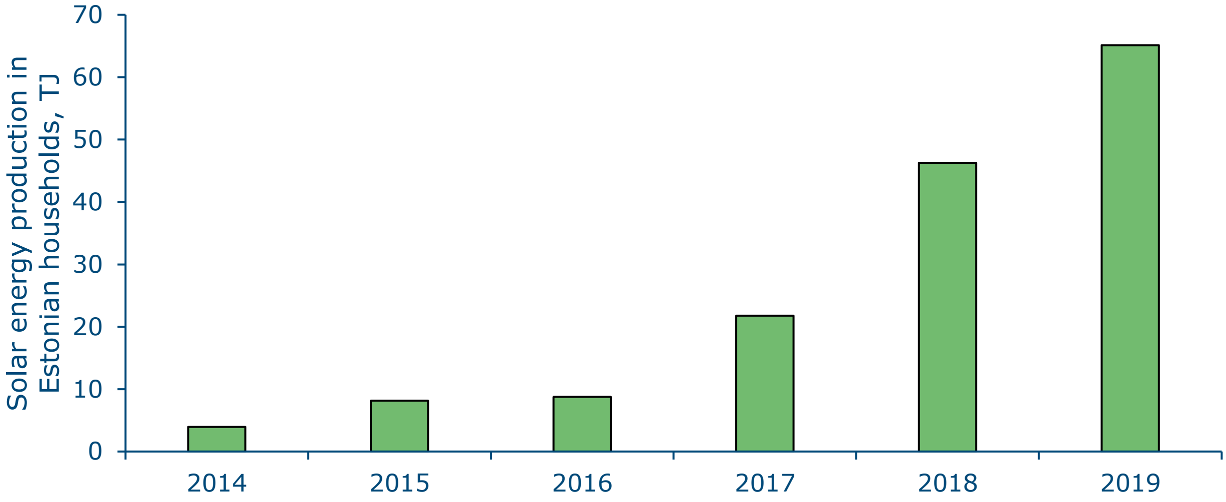

Figure 5.1. Solar energy production in Estonian households 2014-2019 (1)

Solar energy has been stated as the preferred option for electricity generation on community energy projects on the islands meaning that photovoltaic (PV) systems are the suitable technological option to be implemented.

A PV system employs solar panels, each comprising a number of solar cells which generate electrical power. PV installations may be ground-mounted, rooftop-mounted, wall-mounted, or floating. These systems are generally fixed but can be mounted on structures that tilt toward the sun on a seasonal basis or on structures that roll east to west over the course of a day.

The array of the PV system produces direct current (DC) power which fluctuates with the sunlight's intensity. For practical use this usually requires conversion to certain desired voltages or alternating current (AC) through the use of inverters (32). There are different types of inverters including centralised and string inverters. Centralised inverters have higher capacity in the order of 1 MW while string inverters are significantly lower in capacity, normally in the order of 10 kW (33). Many residential PV systems are connected to the grid. In these grid-connected PV systems the use of energy storage is optional.

There are typically three scales of solar installations: utility-scale, commercial, and residential.

- Residential-scale PV systems produce power for use on a single property.
- Commercial systems are medium-sized to large and may provide power for multiple or single commercial or municipal buildings on campuses, in complexes, neighbourhoods, or other special districts.
- Utility-scale installations are very large arrays located on open lands and provide power for hundreds or even thousands of homes and businesses.

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Many residential-scale PV and commercial systems use rooftop-mounted panels as these systems are small and designed to serve the needs of a single building. Usually the panels do not provide 100% of a building's electricity consumption but they can dramatically reduce dependence on the grid which translates into lower electric bills for homeowners.

The suitability of a roof for a PV system depends on several factors such as:

- Overall energy efficiency of the home/building
- Age and pitch of the roof
- Roof slope and aspect
- Orientation of the sun in relation to the home/building
- Tree coverage near the home/building
- Weather patterns for the region

In utility-scale PV systems the electricity is shared by more than a single property. It is not necessary to have a suitable rooftop, meaning it is a great option for renters and people who live in shared housing. The power generated is cheaper due to the scale of the projects and the location of the system in prime solar locations to maximise generation with better reliability.

5.6. Technical feasibility to set up an energy community

In order to an energy community project to be feasible two key aspects are necessary:

- Engagement of the community - the promoter of the project needs to approach the population and encourage interest in the participation of an energy community.
- Legal framework - the legal structure in which the energy community is organised is crucial for the decision-making process as it determines the voting rights of the participants.

Energy communities can be formed more easily if a potential group of participants is already organised in some form, for example as a housing association. The available equity is also strongly dependent on the respective members of a community. Only when the target group and the target area are determined, can the specific needs and wishes be identified and suitable technical solutions be found.

In general, the widespread installation of smart meters is a requirement for the technical implementation of energy communities since only with their help can the collective self-consumption in a community be measured and the resulting financial benefits be realised.

The following preconditions to establish energy communities are considered common in BSR countries:

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- Need for reconstruction of buildings to improve energy efficiency.
- Sufficient building density in a community to find common energy solutions.
- Sufficient potential of fuel-free and renewable energy sources.
- Freely available technology for the generation of heat and electricity.
- Previous experience with joint action in a community.
- Existence of smart system elements (e.g. smart meters).
- Possibility to sell the energy produced from renewable energy sources to the network.

It is expected that the implementation of the EU regulations will bring further benefits for Energy Communities in the future. For example, fees for the use of the distribution network could be eliminated. A precise examination of the prerequisite and a clear agreement between the communities and the distribution network operator on the new conditions are therefore necessary.

5.6.1. Regulatory framework for Energy Communities

EU Regulations

In June 2018, the EU through the **Clean Energy for All Europeans Package** (CEP) introduced the concept of energy communities in its legislation, notably as citizen energy communities and renewable energy communities.

The Directive (EU) 2019/944 (EMD II) (34) article 2(11) defines citizen energy community as a legal entity that:

a) *is based on voluntary and open participation and is effectively controlled by members or shareholders that are natural persons, local authorities, including municipalities, or small enterprises;*
b) *has for its primary purpose to provide environmental, economic or social community benefits to its members or shareholders or to the local areas where it operates rather than to generate financial profits; and*
c) *may engage in generation, including from renewable sources, distribution, supply, consumption, aggregation, energy storage, energy efficiency services or charging services for electric vehicles or provide other energy services to its members or shareholders.*

In addition, the revised Directive (EU) 2018/2001 (REDII) (35) article 2(16) defines renewable energy community as a legal entity:

a) *which, in accordance with the applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects that are owned and developed by that legal entity;*

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b) *the shareholders or members of which are natural persons, SMEs or local authorities, including municipalities;*
c) *the primary purpose of which is to provide environmental, economic or social community benefits for its shareholders or members or for the local areas where it operates, rather than financial profits;*

The EU member states are obliged to transpose the implemented directives into their national legislation to ensure they are consistent with the new EU legislation.

Estonian Regulations

Estonia is currently working on the transposition of the directives and has drafted legislation that is expected to be approved in 2021. However, the definition of Citizen Energy Community (CEC) or Renewable Energy Community (REC) has not yet been specified in the national law (the Electricity Market Act and the Energy Sector Organisation Act, respectively).

The Bill on Amendments to the Energy Sector Organisation Act and Amendments to Other Associated Acts (382 SE), initiated by the Estonian Government, will transpose the EU Renewable Energy Directive which aims to increase the production and consumption of renewable energy both in households and at the level of large producers and consumers (36).

The amendments made with the transposition of the **Renewable Energy Directive** can be divided into three groups according to their content and scope: the national renewable energy targets and the principles for the calculation thereof together with the issues of guarantees of origin; the boosting and facilitation of the consumption of renewable-source energy generated for own use, which includes spatial plans and administrative and authorisation procedures; and the sustainability criteria for biofuels (36).

The Act 382 SE, currently in draft, includes the following related to renewable energy communities:

§ 32 Renewable energy community (37)

(1) *Unreasonable or discriminatory conditions shall not be imposed on the participation of a consumer in a renewable energy community.*
(2) *A renewable energy community shall be a legal entity controlled by shareholders, partners or members of a natural person, an SME or a local authority, whose residence or registered office is close to the renewable energy projects owned and developed by that legal entity and whose main objective is to provide environmental, economic or social community benefits to its shareholders, partners or members or to the regions in which it operates, instead of financial profits.*

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(3) *The main business or professional activity of an undertaking participating in a renewable energy community shall not participate in a renewable energy community.*

(4) *A renewable energy community may:*

   a. *produce, consume, store and sell renewable energy;*
   b. *to distribute within the community the renewable energy produced by generating units owned by the community, while maintaining the rights and obligations of the members as consumers;*
   c. *have access to all appropriate energy markets, either directly or in aggregated form.*

(5) *At the energy metering points of the renewable energy community, the energy used shall be measured by means of a telemetering device intended for that purpose.*

At the moment the Estonian law recognises ‘small consumers’ as “household consumers, apartment associations, building associations and such commercial consumers whose electrical installation is connected to the network at low voltage and through a main circuit breaker of up to 63A” (38), which allows certain models of collective energy actions. Apartment associations are allowed to act as an electricity supplier within their association as they are “a non-profit organisation who sells and conveys electricity to its members solely for the purpose of supplying electricity to the apartments, cottages, garages or private dwelling houses which the members own or occupy.”

Up to now it was possible but rather uncommon to have only one electricity contract per apartment association. However, this solution has recently become more popular as new buildings can connect with the DSO with one meter and organise their own metering and billing by the building association (39).

If an apartment association plans to apply this model, it can be implemented technically during a deep building retrofit. The national renovation grant for innovation, which is funded by the state, can cover about 30-40% of deep renovation costs (39).

The disadvantage of such a business model is that it does not motivate occupants towards energy saving behaviour. As electricity prices are rather low in Estonia and a potential reduction does not weigh substantially on it, energy communities concepts are not that popular. As a result, Estonians are not showing significant interest in additional services such as energy management (39).

5.6.2. Main barriers for developing Energy Communities

In the development of energy communities there are some socio-economic factors that limit the projects, the most common are:

- Lack of a stable policy framework for CEC and REC investments.
- Lack of long-term and low-interest investment funding schemes.

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- Existing regulatory barriers. In some BSR countries, the current metering regulations prevent many residents of housing associations from benefiting from the solar PV self-consumption in their apartments.
- Lack of understanding of the co-benefits of community energy projects, namely renewable energy acceptance, socio-economic development in rural areas, increased social cohesion, and energy literacy.
- Missing the right conditions for support organisations to operate.
- Cultural barriers and a certain sceptical mindset about collective action preventing the popularisation of energy communities' initiatives.
- Low awareness about energy communities, the opportunities for it, and its benefits among regular citizens and citizen associations.
- Rigid and complicated legal procedures, a large amount of bureaucracy and administrative regulations, and long timeframes.

In addition, a hindering factor for projects in co-operative housing associations is the incompatibility of electricity meters. The apartments have direct contracts with electricity sellers who own the electricity meters in apartments, which means that the electricity generated locally would be sold to the grid and the residents would buy it from an electricity provider meaning additional expenses for the consumer. To get the maximum benefits in regard to electricity production it would be necessary to renew the ownership contracts.

5.7. Eco-fin feasibility to set up an energy community

5.7.1. Overview of the analysis

Energy communities are only recently being implemented all over Europe, therefore they will be subject to innovations and more diverse possibilities. At the time of the study, one of the common setups for an energy community is to involve different actors, usually in both private and public sectors, like residential buildings (houses), private buildings (factories, warehouses, etc.), and public buildings (town hall, offices, schools, public gyms, etc.). The proposed mix of ownership, including public and private buildings, acts as a guarantee mechanism through which citizens will feel more secure in undertaking an innovative and new type of investment.

Figure 5.2 depicts the above presented scenario:

- The RES plant is located on one building or directly linked to one building
- Several buildings are connected to the same MV/LV electric cabin where the PV is connected to
- Energy can be virtually shared among the consumers connected to the same grid

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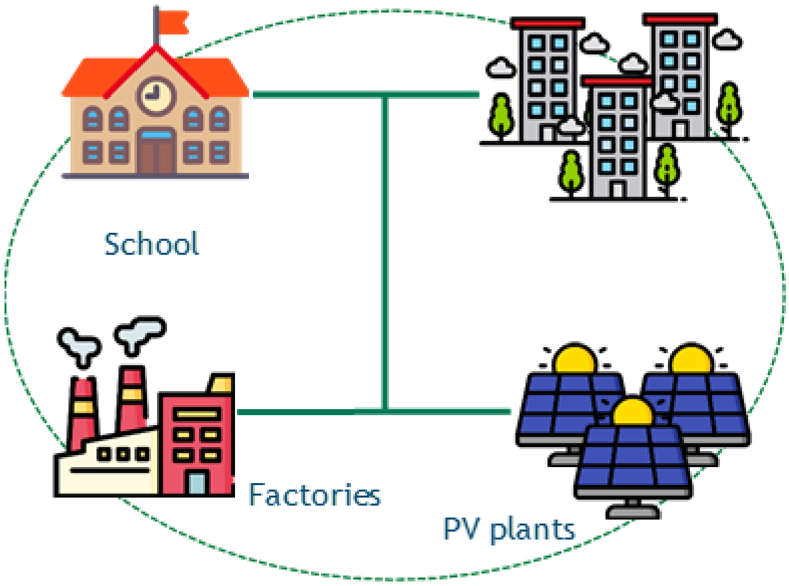

Figure 5.2. Setup for an energy community

The main rationale of the energy community is the sharing of both investments and benefits arising from the production and self-consumption of electricity from a renewable energy source. In such schemes, the community plays a relevant role and citizens turn from consumers into prosumers - producers and consumers at the same time.

The scenario considered for the following economic and financial analysis is however simplified compared to the one presented, excluding the presence of private buildings different from houses.

The business model behind the energy community is based on simple pillars:

- Community members are directly involved in/affected by the structuring, financing, managing and operating of the whole systems
- Not primarily for profit, but must guarantee the return on investment and benefit from cheaper energy supply and sale of surplus energy
- Energy Communities may also establish local micro-grids, allowing for additional services and revenues

The analysis aims to investigate the feasibility of an energy community pilot project on the Estonian islands. Leveraging these results, the pilot will be scaled up at island level.

The proposed scenario analysis will be based on some inputs common to them all, and on other inputs which will vary case by case. The common inputs are the following:

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Community energy project

Energy community projects are rooted in the community which promotes them. The social component is highly relevant in the undertaking and preservation of a project owned by a community. Therefore, this component will be present in all hypotheses analysed.

Membership

Membership to the energy communities is open for all interested parties. Local residents are thought to be the main participators of energy communities with the possibility for local governments and companies and the Estonian Energy Cooperative to participate as well.

The annual electricity consumption of an average community centre building chosen as an example is 34 000 kWh while for the residential building the annual electricity consumption is 3750 kWh.

Self-consumption

The main objective of the initiative is to increase the share of self-consumption of the main building which acts as sort of an “anchor” for the community energy project. In the assumed scenario, the main building is represented by a community centre. In the island-level scenario, energy communities are built around public buildings with an average consumption of 40 700 kWh/yr.

RES Plant

It is assumed that a PV plant is installed as a source of renewable energy for the community. A 15 kWp (kWp – nominal power, peak power of a PV system/panel under standard conditions) plant is assumed as in this case the plant would be considered as a microgenerator and would gain simplified access to the grid. No physical constraints are considered since both land and roofs are available for the installation. The considered PV plant will have an energy production of around 15 000 kWh every year, assuming a unitary average production of 1000 kWh/kWp for an installation with optimal slope and azimuth. Figure 5.3 shows the assumed energy production distribution over the year on the island of Saaremaa.

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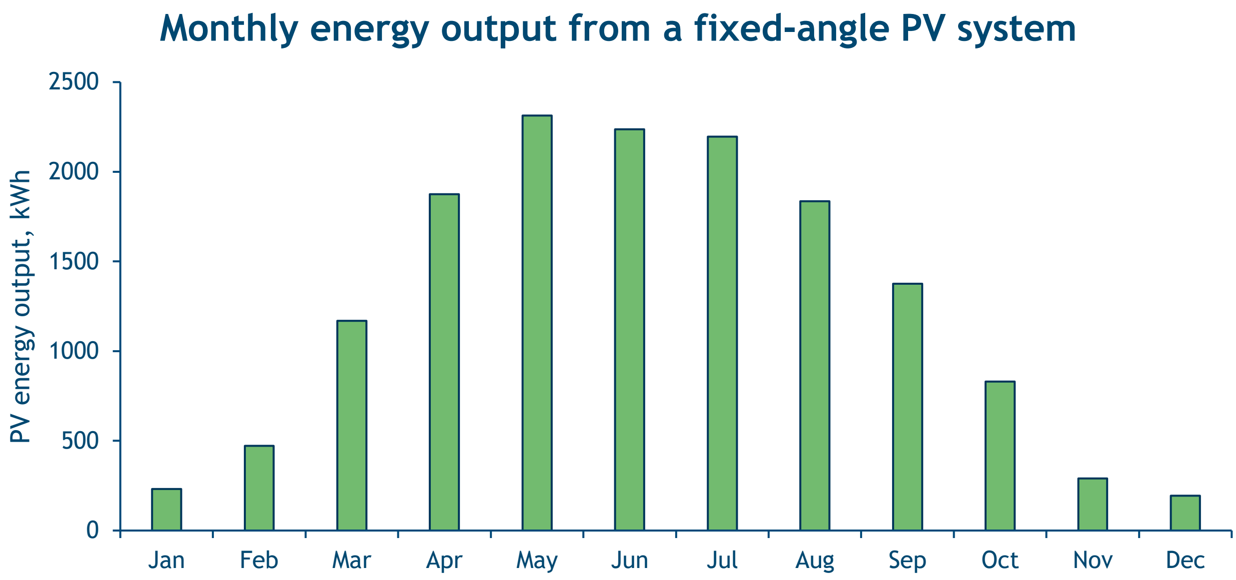

Figure 5.3. Monthly electricity production for a 15 kWp PV farm in 2021 (40)

Table 5.1. Electricity cost

	Price
Buy electricity from the grid	0.12€
Sell electricity to the grid	0.05€

Electricity cost is a common input in all the performed analysis. Based on current market trends, the total cost of electricity that consists of the price of electricity, network fees and taxes was estimated to be around 12 cents per kWh and the average selling price was estimated to be around 5 cents per kWh.

Table 5.2. Investments

	Unitary cost
PV plant	900 €/kWp
Smart meter	300 €/Unit
Platform	700 €
Others	800 €

The main investment costs are related to the cost of the plant itself, the smart meter and the platform for managing this.

The different scenarios have been analysed with the goal of highlighting differences in the potentialities related to production and sharing of renewable energy coming from the PV plant and the resulting benefit for the community.

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5.7.2. HP. 1 – Base Scenario

In the first scenario, analysed members of the community will install a photovoltaic plant at a community centre for which the landlord, the local municipality, grants permission. The electricity produced by the PV plant owned by members of the community will be supplied to the community centre building and the grid. It is assumed as input for the model that the public building has an average annual electricity consumption of 34 000 kWh.

Electricity will be produced by the photovoltaic plant and partially consumed by the public connected building. Considering electricity production and consumption over the day and through the year, it is considered that the building will manage to consume about 50% of the produced energy. The remaining energy will be sold to the grid.

Table 5.3. HP. 1 Base Scenario

Electricity consumption - Public Building	34 000 kWh/year
PV plant capacity	15 kWp
Electricity consumed by the public building	50%
Electricity sold to the grid	50%

In this scenario the local municipality will benefit from the availability of locally produced renewable electricity. The members of the community will benefit from supplying the building owned by the local municipality with electricity at the cost of the savings from the electricity that would have otherwise been consumed from the grid and by selling excess electricity to the grid.

The total investment is broken down into the direct investment for the photovoltaic plant and other costs which refer to the smart meter, general and permission costs. In this scenario, the platform for managing the community is not considered since only one building is involved. This scenario will require an average investment of €14 600 divided up as in Table 5.4.

Table 5.4. Investment costs for HP. 1 Base Scenario

	Investment, €
PV plant	13 500
Smart meter	300
Legal costs	800
Total investment costs	**14 600**

According to these assumptions, the presented scenario would be able to generate benefit for the community promoting it. As stated, the benefit will come in two different forms, as savings from the reduced purchase of electricity from the grid, and as revenue from the sale of energy to the grid. With the considered input the outcome related to energy production, self-consumption, and sale to the grid is going to be as follows:

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Table 5.5. Electricity production and consumption in HP. 1 Base Scenario

	Energy output, kWh/yr
RES energy production	15 000
of which RES electricity-consumed by the public building	7500
of which RES electricity sold to the grid	7500

The energy output is on the basis of the economic benefit which totals €1275 per year. As can be seen from the table below, the majority of the benefit comes from the electricity sold to the municipality at the cost of electricity savings from the grid.

Table 5.6. Economic output of HP. 1 Base Scenario

	Economic output, €/yr
Turnover from sale of electricity to the municipality	900
Turnover from sale of electricity to the grid	375
Overall income	1275
Income per member (n. 30)	42.5
Payback period	11 years

It is assumed that the investment will be carried out by 30 members of the community. Considering the described assumptions, the payback period is 11 years.

5.7.3. HP. 2 – Intermediate Scenario

In the second scenario analysed, in addition to the public building, a number of residential buildings are considered, which vary in accordance with the percentage of electricity allocated to shared self-consumption. Again, the energy community would be constituted with the installation of a photovoltaic plant with a capacity of 15 kWp. As in the previous case, average consumptions are in line with the initial assumptions: the public building has a yearly electricity consumption of 34 000 kWh, while a single residential building has a yearly electricity consumption of 3750 kWh.

Compared to the base scenario, the share of energy sold to the grid is in fact reduced and more energy is shared among the members of the community. Considering electricity production and consumption over the day and through the year, it is considered that the public building will manage to consume about 50% of the produced energy. Of the remaining electricity, 30% of will be used for self-consumption of the residential buildings and the remaining 20% will be sold to the grid (Table 5.7). According to this hypothesis, 1.2 residential buildings could be involved in the initiative.

Table 5.7. HP. 2 Intermediate Scenario

Electricity consumption - Public Building	34 000 kWh/year
Electricity consumption - Residential Building	3750 kWh/year
PV plant capacity	15 kWp
Public building's share of electricity consumptions	50%
Residential buildings' share of electricity consumption	30%
Share of electricity sold to the grid	20%

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In this scenario, not only will the PV plant be needed as investment but also the infrastructure for the functioning of the energy community and a management platform.

The total investment is broken down into three components:

- the direct investment for the photovoltaic plant
- investment for setup and management of the energy community
- other costs which refer to general and permission costs

In this scenario one smart meter for every member and a managing platform are also considered. Overall investment costs are reported in Table 5.8.

Table 5.8. Investment costs for HP. 2 – Intermediate Scenario

	Investment, €
PV plant	13 500
Smart meters	660
Platform	700
Legal costs	800
Total investment costs	**15 660**

The electricity produced by the photovoltaic plant will be partially self-consumed by the public building connected, partially self-consumed by the residential buildings and partially sold to the grid.

By considering a majorly daytime use of the public building, it is reasonable to assume that it will be able to absorb most of the produced energy, while the connected houses will manage to use only 30% of the remaining production. The 20% left will be sold to the grid, as shown in Table 5.9.

Table 5.9. Electricity production and consumption in HP. 2 – Intermediate Scenario

	Energy output, kWh/yr
RES energy production	**15 000**
of which RES electricity-consumed by the public building	7500
of which RES electricity consumed by residential buildings	4500
of which RES electricity sold to the grid	3000

With such output the members of the energy community will be able to generate positive income for €1590 per year (Table 5.10).

Table 5.10. Economic output of HP. 2 – Intermediate Scenario

	Economic output, €/yr
Savings	540
Turnover from sale of electricity to the municipality	900
Turnover from sale of electricity to the grid	150
Overall income	1590
Income per household (n. 1.2)	723
Income per member (n. 30)	53
Payback period	10 years

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The total benefit is higher than in the first scenario, where only the public building was benefitting from the self-consumption of electricity. Such positive economic elements let the investment become affordable with a return period of 10 years.

5.7.4. HP. 3 – High Scenario

In the third scenario analysed, there are still two types of actors considered, a public building and a number of residential buildings which vary in accordance with the percentage of electricity allocated to shared self-consumption. The main assumptions are maintained, considering the installation of a 15 kWp PV plant, and average consumptions.

This scenario is very similar to the previous one, but the major difference is in the percentage of electricity allocated to shared self-consumption. As in the second scenario, different actors make a joint investment for the production and consequent consumption of renewable energy.

The electricity produced by the photovoltaic plant would be partially self-consumed by the public building connected and partially self-consumed by the residential buildings. Considering electricity production and consumption over the day and through the year, it is considered that the public building will manage to consume about 50% of the produced electricity. The remaining electricity will be self-consumed by the residential buildings.

Table 5.11. HP. 3 – High Scenario

Electricity consumption - Public Building	34 000 kWh/year
Electricity consumption - Residential Building	3750 kWh/year
PV plant capacity	15 kWp
Energy for self-consumption - Public building	50%
Energy for self-consumption - Residential building	50%

According to this hypothesis, two residential buildings could be involved in the initiative. In this scenario, as in the second one, not only will the photovoltaic plant be needed as investment but also infrastructure for the energy community functioning and a management platform.

The total investment is broken down into three components:

- the direct investment for the photovoltaic plant
- investment for setup and management of the energy community
- other costs which refer to general and permission costs

In this scenario, one smart meter for every member and a managing platform are also considered. Overall investment costs are reported in Table 5.12.

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Table 5.12. Investment costs for HP. 3 – High Scenario

	Investment, €
PV plant	13 500
Smart meters	900
Platform	700
Legal costs	800
Total investment costs	**15 900**

By considering a majorly daytime use of the public building, it is reasonable to assume that it will be able to absorb about half of the produced electricity, while the connected houses will manage to use all the remaining production. In this case there is no electricity left to be sold to the grid (Table 5.13).

Table 5.13. Electricity production and consumption in HP. 3 – High Scenario

	Energy output, kWh/yr
RES energy production	**15 000**
of which RES electricity-consumed by the public building	7500
of which RES electricity consumed by residential buildings	7500

With such an output the members of the energy community will be able to generate a positive income of €1800 per year. This amount is only composed in this scenario by savings which are therefore maximised.

Table 5.14. Economic output of HP. 3 – High Scenario

	Economic output, €/yr
Savings	900
Turnover from sale of electricity to the municipality	900
Overall income	1800
Income per household (n. 2)	900
Income per member (n. 30)	60
Payback period	9 years

The total benefit is higher than in the first and the second scenario, reflecting the positive effect of reducing the purchasing of electricity from the grid. This phenomenon is due to the price difference between the cost for purchasing electricity and the income from the sale of electricity. Such positive economic elements let the investment become affordable with a return period of 9 years.

5.7.5. HP. 4 – Islands-Level Scenario

This scenario aims at providing an overview on the possibility to scale up the energy community structure to the whole islands level. In this scenario only residential buildings have been considered. The electricity produced by the photovoltaic plant would be partially self-consumed by the residential buildings part of the energy community and partially sold to the grid. Considering electricity production and consumption over the day and through the year, it is considered that the residential buildings will manage to

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consume about 50% of the produced electricity. As a consequence, 50% of the electricity would be sold to the grid.

Based on the number of people in an average Estonian household and the number of residents on the islands, about 20 000 households are present on the islands. To supply their electric needs, assuming a 50% of self-consumption, the needed capacity to be installed is 150 MWp. In this case the widespread nature of the energy community does not imply the installation of a single large PV plant, but several smaller plants. The plants will have an annual production output of about 150 000 MWh.

Table 5.15. HP. 4 – Islands-Level Scenario

Electricity consumption - Households	3750 kWh/year
PV plant capacity	150 MWp
Energy for self-consumption - Households	50%
Energy sold to the grid	50%
Households involved	20 000

Not only will the photovoltaic plant be needed as investment but as in the previous cases, also infrastructure for the energy community, like smart meters, and a management platform. Such costs have been addressed considering:

- €800 for every kWp installed
- €200 for every smart meter, every household of the energy community needs one
- €20 000 for a managing platform
- other costs which refer to general and permission costs

The investment has been computed with the goal of guaranteeing a minimum of 50% of electricity requirements to all 20 000 houses of the islands.

Table 5.16. Investment costs for HP. 4 – Islands-Level Scenario

	Investment, €
PV plant	120 000 000
Smart meters	4 000 000
Platform	20 000
Legal costs	45 000
Total investment costs	**124 650 000**

In the presented model 50% of the electricity produced by the photovoltaic plant will be self-consumed by households, while the remaining 50% will be sold to the grid.

Table 5.17. Electricity production and consumption in HP. 4 – Islands-Level Scenario

	Energy output, kWh/yr
RES energy production	**150 000 000**
of which RES electricity consumed by households	75 000 000
of which RES electricity sold to the grid	75 000 000

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With such output the members of the energy community will be able to generate a positive income for €12 750 000 per year (Table 5.18).

Table 5.18. Economic output of HP. 4 – Islands-Level Scenario

	Economic output, €/yr
Savings	9 000 000
Turnover from sale of electricity	3 750 000
Overall income	12 750 000
Income per household (n. 20 000)	637
Payback period	10 years

The individual benefit has been computed by dividing the total benefit with the number of households in the community. It is lower than in the first two scenarios due to a lower percentage of self-consumed energy. Positive overall income means that the investment has a payback period of 10 years.

5.8. Identification of financing needs and possible funding options

Financing opportunities for the development of energy transition and renewable energy projects are numerous and usually country-specific. Despite their differences they are resembled in two main categories: funds provided in the form of grants and funds provided in the form of loans.

The types of renewable energy finance mechanisms now in use across Europe have been identified and aggregated in one flux diagram for the European Commission. Figure 5.4 represents the connection among the financing sources and how they are conveyed towards different climate action areas within the European Union. In the specific case of energy communities and renewable energy installations, the climate actions to investigate are related to “Supply side intangible” and are Grids & Storage and Renewable Energy Sources. The possibilities for those two items are:

- **Financing sources:**
  - National public administration
  - EU budget
  - National promotional banks
  - Commercial banks
  - Financial markets
- **Investment instruments**
  - Public private partnership
  - Concessional debt
  - Commercial market rate debt
  - Self-financing
  - Equity

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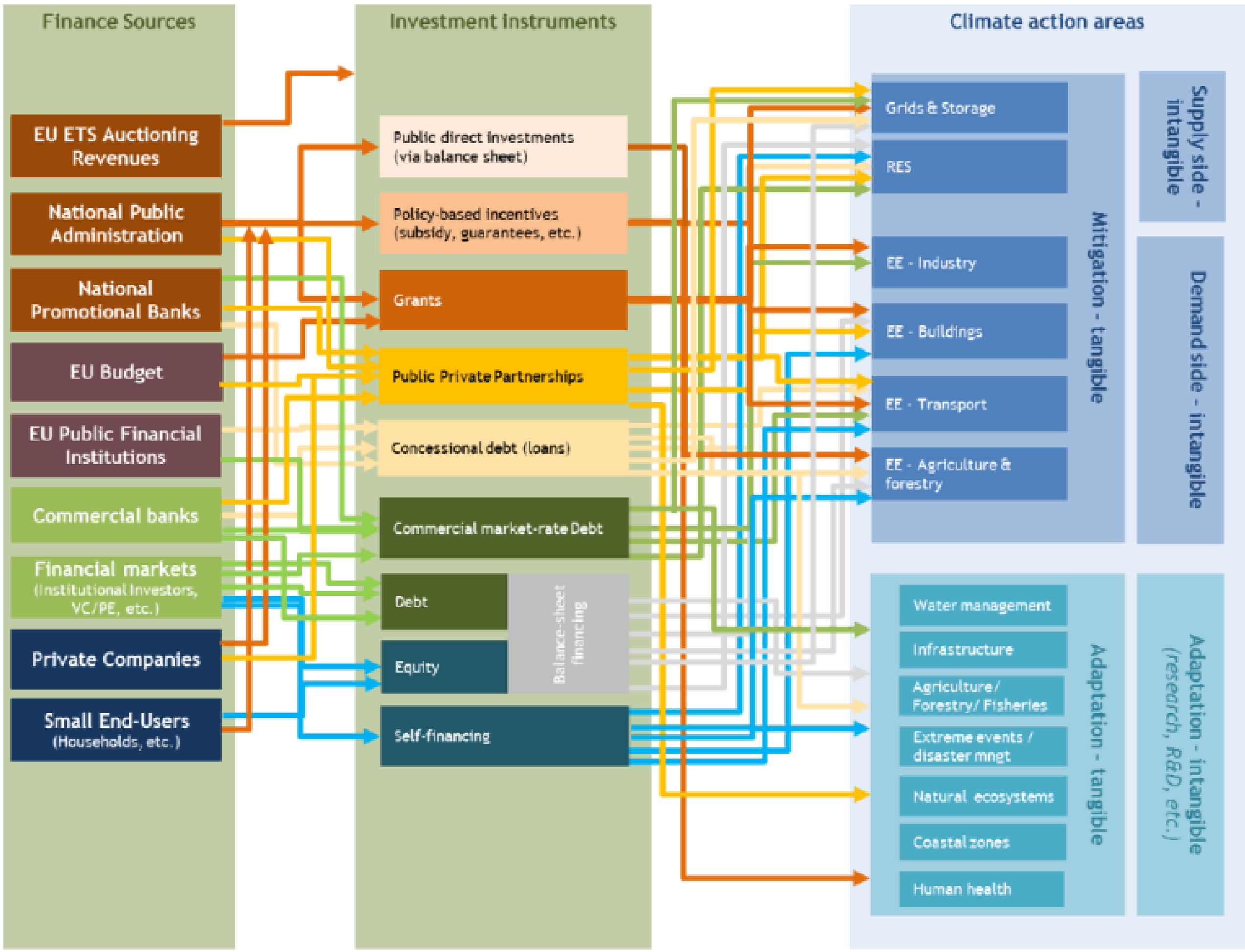

Figure 5.4. European clean energy finance landscape (41)

At EU level, different opportunities are available. The most relevant ones are briefly presented as follows.

European Structural and Investment Funds (ESIF)
The European Commission and EU member states share management of six funds. Their goal is to invest in employment creation as well as a healthy, sustainable European economy and environment. Energy-related initiatives can be financed with some funding.

Projects Development Assistance (PDA)
The European Commission has established facilities to assist ambitious public authorities - regions, cities, municipalities, or groups of them - and public entities in establishing bankable sustainable energy projects.

European Investment Fund (EIF)
EIF is active with two financial instruments, equity and debt, to small and medium enterprises.

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European Bank for Reconstruction and Development (EBRD)
EBRD provides renewable energy developers with equity, loans, and loan guarantees for projects with good commercial prospects of up to 15 years duration.

National support schemes
Electricity from renewable sources has been primarily pushed in Estonia through a premium rate introduced with the Electricity Market Act of 2007. The premium tariff program ensured that for every kWh of renewable energy produced, an additional amount was provided to the producer. Renewable energy system operators can sell the electricity they generate on the open market and receive a bonus on top of the market price under the premium tariff plan. The feed-in premium is paid out for a period of 12 years starting from the commissioning date. The eligible technologies for the scheme were all the renewable sources, limited in terms of capacity.

However, in recent years, considerable amendments to the legislation governing RES support systems have occurred and the premium tariff was abolished and replaced by an auction-based support system. At first, an exception was granted to small producers – subsidies paid to producers with an electrical capacity less than 50 kW, but this exception was valid until the end of 2020.

Thus, in Estonia the main national program currently active is the auction-based support system corresponding to a public reverse auction, through which the government, on the recommendation of the Ministry of Economic Affairs and Communication (MKM), arranges an underbidding to obtain additional production capacity if the capacity of existing production equipment is insufficient to meet the goal of electricity production from the state's renewable energy sources or through CHP plants.

The purpose of the technology neutral tender is to attain the national objective of generating electricity from renewable energy sources and through efficient CHP plants. Tenders are announced and organized as reverse auctions by the Ministry of Economic Affairs and Communication (MKM). As of December 2021, there is an active tender to introduce 450 GWh of renewable electricity to the grid annually that accepts bids until 1st June 2022 (42). In 2023 the next tender for 650 GWh will be carried out.

The eligible technologies under the public tender scheme are solar energy, wind energy, geothermal energy, biogas, hydro-power and biomass energy with a support duration of 12 years starting from commencement of production (38).

Enterprise Estonia (EAS)
EAS provides financial assistance (guarantees and loans) and advice for start-ups using capital from EU structural funds.

Kredex
State-owned credit institute issuing loans and grants. Supports the installation of solar panels as a part of renovating buildings.

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Rural Development Foundation (MES)
MES offers loans and guarantees to projects investing in rural economic development.

Agricultural Registers and Information Board (PRIA)
Amongst other activities, PRIA offers subsidies for diversification of economic activities in rural areas that includes supporting the installation of PV-panels.

EEA Grants
The EEA and Norway Grants are funded by Iceland, Liechtenstein, and Norway. The Grants have two goals: to contribute to a more equal Europe - both socially and economically – and to strengthen the relations between Iceland, Liechtenstein, and Norway along with the 15 Beneficiary States in Europe, including Estonia.

Crowdfunding
Crowdfunding is a widespread scheme for capital collection for a specific purpose or project. One innovative model of crowdfunding is the so-called “energy crowdfunding”. Through energy crowdfunding a promoter can collect capital for its project regarding sustainability, energy efficiency, or energy transition with the goal of reducing dependence on non-renewable sources of energy.

Crowdfunding investments in the energy sector offer a combination of financial products and ethical value that is attracting several investors. Most investors are financial planners, experienced investors focused on the financial return of the product, however a new category of investors is showing up - “ethical investors”. Ethical investors are concerned about the impact of their investment activities and are motivated by the “green value” of the investment.

5.9. Impact assessment

Based on the current growth of solar energy production, by 2030, the share of electricity produced from solar energy could reach 13.7% in Saare County and 21.5% in Hiiu County. The electricity consumption of the islands in 2020 was 208 504 MWh. Assuming similar levels of consumption, if the European Commission target of 21% for community energy is reached, solar energy communities could produce nearly 6700 MWh of electricity by 2030 (Table 5.19). This forms about 9.0% of electricity consumed by the building sector in 2020 (43) (44).

With optimal placement a 1 kW solar panel installation produces approximately 1 MWh of electricity per annum in Estonia. The average unit cost for smaller solar installations is in the range of 1000 €/kW. With larger installations, the unit cost is reduced. The carbon dioxide emissions reduction calculations are based on the 2030 grid electricity emissions rate prognosis of 0.5 CO_{2eq}/MWh (45). Community energy projects have several other costs depending on project parameters, including permitting, changing unsuitable meters, and forming an entity. These costs need to be assessed on a project-by-project basis.

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Table 5.19. Community energy production targets on the islands by 2030

	Electricity consumption, MWh/yr	Community owned solar energy production target, MWh/yr	Investment cost, €	CO_2 reduction, t/yr
Saaremaa	158 107	4549	4 500 000	2274
Hiiumaa	41 666	1881	1 900 000	941
Muhu	8731	251	300 000	126
Total	208 504	6681	6 700 000	3341

5.10. Risk analysis

Table 5.20 gives an overview of the risks associated with energy community projects, their probabilities and impacts, and measures for mitigating the impacts of those risks. Risks with a high impact on the outcome of the project are related to the permit application, disputes amongst members of the community, and lower than expected electricity production.

Table 5.20. Risk analysis of energy community projects

Description of risk	Probability	Impact	Mitigation measures
Project planning			
Permits for the development of projects are not granted	Medium	High	Careful assessment of the planned locations for the development of projects. Communication with permit authorities
Disputes among community energy project members	Medium	High	Defining the responsibilities and benefits of energy community members with contracts to avoid misunderstandings and legal disputes.
Operation			
Projects have lower output than expected	Medium	Medium	Creating conservative estimates for evaluating the project
For apartment community energy projects the electricity meters and contracts do not allow the direct use of the produced energy and the produced energy must be sold to the grid	Medium	Medium	It is important to assess the existing meters and contracts and the possibility to change them for it to be possible to use the produced energy for direct personal use
Finances and the economy			
The investment cost is higher than expected	Medium	Medium	Thoroughly assessing costs related to the project using conservative estimates
Production volumes are lower than expected	Medium	High	Preparing the projects using conservative estimates for the output of production
Energy prices drop extending the project payback period	Low	Medium	Preparing the projects using conservative energy price estimates
Difficulty obtaining financing	Medium	Medium	Exploring possible alternative financing methods and involving external investors

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6. Electricity and hydrogen in public transport

6.1. Introduction

Today the public transportation systems of the islands are mostly dependent on imported fuels. They consist of buses and cars used on the islands and ferries used for connecting the islands to the mainland and to each other. The Sustainable Energy and Climate Action Plans of the islands set out objectives for public transportation on the islands to be 100% fossil fuel free by 2030. All public transportation must use only renewable energy by then.

6.2. Document references

This chapter gives an overview of the documents used to carry out the analysis. The list of documents is given as follows. Due to the nature of the study, a large part of the analysis consists of practical technical assessment based on the public transport data, therefore the number of documents used is limited.

- A hydrogen strategy for a climate-neutral Europe, https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf
- Estonia's 2030 National Energy and Climate Plan, https://ec.europa.eu/energy/sites/ener/files/documents/ee_final_necp_main_en.pdf
- The Future of Hydrogen, Seizing today's opportunities, https://www.iea.org/reports/the-future-of-hydrogen

6.3. Scope of intervention and general description

6.3.1. Project overview

The islands have set a goal of turning public transport that includes road transport by buses and maritime transport by ferries and small vessels carbon neutral by 2030. Aviation is not within the scope of this project. Carbon neutrality and energy independence can be achieved through the usage of locally produced renewable fuels such as biomethane and hydrogen or by electrification when using locally generated renewable electricity.

The local road transport is organised by the municipalities along with the maritime connections of Saaremaa-Abruka and Saaremaa-Vilsandi. The remaining ferry connections are organised by the Transport Administration of Estonia. As of November 2021, there is one road transport operator on the islands and there are two companies operating the ferry connections. In order to reach the goal set by the local governments, close cooperation is needed between the participants and clear communication especially between the local governments and the Transport Administration.

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6.3.2. Background

There are about 40 buses used for public road transport on the islands of Saaremaa, Hiiumaa, and Muhu. The connections from the mainland to Muhu and Hiiumaa are primarily operated by four similar ferries which make up most of the energy consumption of the public transport. In addition, there is a smaller spare vessel used when needed, a ferry operating between Saaremaa and Hiiumaa, a ferry connecting Ruhnu to Saaremaa and the mainland, a ferry connecting Abruka to Saaremaa, and a boat connecting Vilsandi to Saaremaa.

In 2020, public transport of the islands consumed a total of more than 61 GWh of fuels with road transport forming about 7% of the total energy consumed and maritime transport making up the remaining nearly 93% of the energy consumption. The amount of carbon dioxide emissions exceeded 16 ktCO_2.This formed 7.9% of the total carbon dioxide emissions related to energy consumption.

Since 2021, most of the buses used for public transport in Saare County are gas-powered. However, as there is no production of biomethane on the island, the buses use natural gas which is brought to the island in the form of LNG. The buses used in Hiiumaa are diesel-powered. One of the main ferries operating between Muhu and the mainland was converted to hybrid in 2020; however, due to an accident in 2021, the ferry is currently operating as a fully diesel-powered vessel. The remainder of the ferries use diesel, whereas the boat operating the connection to Vilsandi is powered by gasoline.

6.3.3. Project objectives

The goal of the project is to determine the technologically and financially suitable options for the islands to convert their public transport to fully renewable sources. As a first approach, pilot projects need to be carried out prior to 2030 to gather information for long-term developments as the pilot projects can validate the suitability of the technological options chosen or point out problems that need to be addressed before the final solutions are decided upon.

6.3.4. Project benefits

Using innovative technologies in the transportation sector enables the islands to become more sustainable by reducing the energy consumption and the resulting carbon dioxide emissions. A sustainable public transportation system could also benefit the tourism sector of the islands as tourists are becoming increasingly more concerned about sustainability and the environmental impact of travelling. In addition, the research of new possibilities in the transport sector could benefit local charging infrastructure. Increasing the coverage of charging stations would enable the locals to prefer electric or hydrogen vehicles in the future.

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6.3.5. Scope

The scope of the project covers public transport carried out by road and maritime transport. Aviation is not included in the scope of the project. The public road transport of Saare County is not within the main focus of the project as the production of biomethane for covering the needs of the public transport of Saare County is analysed in more detail in Chapter 15.

6.3.6. Project boundaries and constraints

The main boundaries of the project are related to the availability of the required resources. Regardless of whether the suitable option will be the usage of electricity or hydrogen, the infrastructure for supplying the vehicles and vessels with energy needs to be established. In addition to the lack of infrastructure there is currently no hydrogen production which means that additional investments need to be done to start the production of hydrogen from renewable energy sources. Due to sparsely located farms and low availability of biological waste, biomethane production is not considered for Hiiumaa.

When it comes to the adoption of alternative-energy powered buses and ferries, there are no specific limitations besides the fact that the quality of service cannot deteriorate. The ferry lines are operated according to contracts that last until 2025. The existing ferries are not allowed to be replaced prior to the end of the contract.

When retrofitting existing ferries with new solutions, the time away from servicing the line needs to be kept to a minimum or a replacement needs to be found for the period of carrying out the works. The contractual terms between the local governments, the transport service operators, the Transport Administration, and the state need to be followed.

6.3.7. Business model and relationship scheme (governance)

The main source of income for the project comes from the reduced energy costs. As ferries have a larger potential for the reduction of costs, the adoption of alternative energy sources for ferries is more likely to be cost-effective than for buses, which have a relatively low energy consumption.

Bus operators are awarded contracts through local government tenders. The technical requirements are set out by the tender request documents for the operators, which means that the potential operator is responsible for acquiring either electric or hydrogen buses. The cost of the investment in turn is reflected in the offered price for the tender. For carrying out a pilot project, the cost of renting a bus should be covered by the local municipality with potential support from the state as this cannot be expected from the service provider.

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Except for the connections to Abruka and Vilsandi, the operation of ferries is managed by state institutions. Therefore, to carry out investments, the state needs to make the necessary decisions for the next contractual period.

6.4. Pilot characterization and collection of relevant KPIs

A suitable pilot project is the bus route on Hiiumaa that connects Kärdla to Käina. One option is to introduce an electric bus on the route. Recharging of electric buses would not be an issue in this case as the buses are not driving very often or long distances which means that changing the operating schedule is not necessary. The project is straightforward to carry out as changes in the schedule are not necessary. Charging infrastructure can be placed at the depot to charge the buses out of operation hours. As the bus can be charged over a longer period in the terminus, the lifetime of batteries is increased, and the cost of charging infrastructure is lower due to the fact that a lower charging power is needed. Alternatively, a hydrogen bus could be used on the same route. However, the lack of hydrogen infrastructure needs to be considered.

A possible pilot hydrogen or electric ferry could be placed on the Roomassaare-Abruka or the Sõru-Triigi route. These routes are relatively short and are not operated very often (a few times per day). This places lower requirements on hydrogen storage or battery capacity needs on the ferry which can help keep the costs lower for the pilot project. Due to current lack of availability of hydrogen infrastructure the resulting investment to build this infrastructure is high.

The relevant key performance indicators for transport pilot projects are primarily related to the reliability and the energy efficiency of the projects. Indicators to be monitored are the accuracy of keeping to schedule, the number of departures cancelled, the number and duration of technical errors and the resulting availability, the average amount of energy consumed per service kilometre and the average energy consumption under different climatic conditions.

6.5. Assumption on the expected impacts

The plan for decarbonisation of public transport of the islands considers the following technologies:

- Electric buses powered by 100% renewable energy
- Green hydrogen

The transition to a clean and sustainable transport system will positively impact the islands regarding energy consumption and the environment, e.g. better air quality, reduction of GHG emissions, reduction of fuel imports, etc. However, decarbonising the sector with renewables will require adequations on the infrastructure or building up a new one according to the technology selected. For instance, it will be required to make the

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necessary investments in filling stations, production plants, or distribution networks since on the islands there exists no hydrogen distribution network or filling stations.

Currently, the bus lines of Hiiumaa move in circles around the island. Kärdla and Käina or other frequently approached locations on the existing bus routes could be used as charging/refuelling locations. The bus routes on Saaremaa are structured in an even more suitable way. Most routes start and end in Kuressaare and all lines are arranged in a star form around the city. Therefore, there could be a charging/refuelling station in Kuressaare. Orissaare could be the site for a smaller charging station as some routes only operate around there.

Considering a project pilot on Hiiumaa in the bus route that connects Kärdla to Käina, which is a distance of 20.9 km and takes 25 min to drive (46)**, recharging of electric buses would be no obstacle as the buses are not driving very often or long distances.** Therefore, in terms of adjusting the operating schedule there is no significant difference in decision-making between hydrogen buses and electric buses. However, due to the lack of current availability of hydrogen infrastructure, the resulting investment to build this infrastructure is high.

6.5.1. Electric buses powered by 100% renewable energy

The range of modern E-buses varies around 300 km under normal conditions. This range is increasing steadily because of improvements in battery technology. For example, this would allow the drive from Kärdla to Käina and back again 7 times without recharging. The maximum range is currently 550 km. E-buses are available in all required sizes for typical public transportation. The average lifetime for modern E-buses is around 12 years, which is comparable to normal diesel buses.

Infrastructure for charging

There are two options to organise the charging of electric buses which are often used in combination. The first option is to charge the buses out of operation hours at the depot. This requires planning as the batteries of the buses can reach a longer lifetime when they are charged over a longer period using less power.

The other option is to charge the buses more frequently for a shorter time on the route or at the end point of each route. While this may disrupt the schedule of the buses for charging breaks, overall longer operation hours and further distances can be achieved. These charging breaks can be combined with the normal breaks for the bus drivers.

There are even fast charging technologies that give power to the buses with 600 kW within 15-20 seconds. Globally, the most popular way to charge buses is by using the DC plug in charging technology at 50 kW or above (47).

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6.5.2. Green hydrogen

Globally at least 11 companies currently manufacture fuel cell electric buses. **Because their long range means that there is generally no need to recharge during the day, they are in general well suited to: higher daily mileage (above 200 km per day);** larger bus fleets where refuelling can be simpler than recharging the battery of electric buses; and flexible routing and operations, for example extending a given route at certain periods of the year (48).

Hydrogen can also be converted to hydrogen-based fuels including synthetic methane, methanol and ammonia, and synthetic liquid fuels which have a range of potential transport uses as shown in Table 6.1. An advantage is that there would be no changes necessary in the route plans and times because hydrogen-based buses have similar operation ranges as classical diesel engine vehicles (48).

Table 6.1. Potential uses of hydrogen and derived products for transport applications (48)

Vehicles	Current role	Demand perspectives	Future deployment	
			Opportunities	Challenges
Cars and vans (light-duty vehicles)	11 200 vehicles in operation, mostly in California, Europe and Japan	The global car stock is expected to continue to grow; hydrogen could capture a part of this market	**Hydrogen:** Short refuelling time, less weight added for energy stored and zero tailpipe emissions. Fuel cells could have a lower material footprint than lithium batteries. Captive vehicle fleets can help overcome challenges of low utilisation of refuelling stations; long-distance and heavy-duty are attractive options	**Hydrogen:** Initial low utilisation of refuelling stations raises fuel cost; reductions in fuel cell and storage costs needed; efficiency losses on a well-to-wheels basis **Power-to-liquid:** Large electricity consumption and high production costs **Ammonia:** Caustic and hazardous substance close to end users mean that use is likely to remain limited to professional operators
Trucks and buses (heavy-duty vehicles)	Demonstration and niche markets: ~25 000 forklifts ~500 buses ~400 trucks ~100 vans. Several thousand buses and trucks expected in China by end-2019	Strong growth segment; long-haul and heavy-duty applications are attractive for hydrogen		
Maritime	Limited to demonstration projects for small ships and on-board power supply in larger vessels	Maritime freight activity set to grow by around 45% to 2030. 2020 air pollution targets and 2050 greenhouse gas targets could promote hydrogen-based fuels	**Hydrogen** and **ammonia** are candidates for both national action on domestic shipping decarbonisation, and the IMO Greenhouse Gas Reduction Strategy, given limitations on the use of other fuels	**Hydrogen:** Storage cost higher than other fuels **Hydrogen/ammonia:** Cargo volume lost due to storage (lower density than current liquid fuels)

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6.6. Assumption on the financial needs

To achieve the objective of fully decarbonizing public road transport and ferries by 2030, detailed studies need to be performed. As a starting point, pilot projects should be carried out to gather useful data for further analysis.

6.6.1. Bus transport of Hiiumaa

Given the lack of hydrogen infrastructure, currently the electrification of buses is more feasible than the adoption of hydrogen buses. However, for an overview of both alternatives, a comparative analysis with diesel buses is carried out.

The public transport service is provided by a private operator that owns the vehicles, bears the operational costs, and receives subsidies provided by the state. Public transport is free of charge for users, which means that the public subsidy is the sole revenue flow for the operator. A public procurement is carried out to determine the operator, which ensures efficient use of the subsidy.

From an economic point of view, assumptions have been gathered on the current costs incurred by the operator. As a reference, the operational costs of the transport providers of Saaremaa in 2020 were taken and adapted to Hiiumaa based on the line-kilometre costs of the respective transport operators and the number of buses used. The costs considered are:

- The variable costs related to fuel or electricity consumption, bus drivers' employment costs, and other variable costs,
- The fixed costs related to the amortization of buses, other fixed costs,
- The fixed costs related to the electric charging and hydrogen filling infrastructure
- Administrative costs of the local public transport organizer.

Table 6.2 gives an overview of the annual costs related to the usage of different bus types to cover the needs of Hiiumaa. The volume of annual contractual line kilometres in Hiiumaa is 645 000 km and the line kilometre price of the service provider is 1.023 euros (49), which means that the average annual costs and margin of the service provider are 620 500 euros and with estimated administrative costs of 39 400 euros, the total annual costs are 659 800 euros. The energy costs are estimated based on the equivalent costs for Saaremaa in 2020 when diesel buses were still used. Employment costs, other variable costs, other fixed costs of the service provider, and administrative costs are assumed to be same for diesel, electric, and hydrogen buses as the type of bus does not have a significant impact on those costs.

The fixed costs of the buses represent the amortization of buses over a period of 10 years. The corresponding costs for electric and hydrogen buses were determined based on the average price differences of buses using different technologies (50) (51). Hydrogen buses have currently the highest investment cost. In addition to the costs occurring for diesel buses, electric buses, and hydrogen buses require additional infrastructure for charging and filling. It is assumed that the electric charging infrastructure will be created by external developers and the local municipality will only need to cover the costs related to the preparation of suitable sites for the installation of chargers. For hydrogen buses, the costs for producing, compressing, and transporting hydrogen have been excluded and only the annual amortization of a filling station over a period of 10 years has been taken into account (52).

Table 6.2. Comparison of the costs of different bus types

Costs, €	Diesel	Electric	Hydrogen
TOTAL COSTS	659 800	703 300	765 200
Variable costs	**390 600**	**370 900**	**370 900**
Energy costs	82 100	62 400	62 400
Employment costs	243 300	243 300	243 300
Other variable costs	65 200	65 200	65 200
Fixed costs	**229 900**	**292 500**	**326 100**
Fixed costs of the buses	102 900	165 600	199 200
Other fixed costs of the service provider	126 900	126 900	126 900
Administrative costs	**39 400**	**39 400**	**39 400**
Charging or filling station	-	500	28 800

Potential savings compared to diesel buses stem from the cost of energy. For electric buses, an average electricity consumption of 1.5 kWh/km is assumed based on prior experience with electric buses and the average annual temperature in Estonia (53). **With an average price of electricity of 100 €/MWh excluding VAT, the annual energy costs are in the range of 62 400 €, which is a 19 700 € or 24% reduction in costs compared to diesel buses.** Due to the losses in converting hydrogen to electricity, the expected hydrogen consumption is in the range of 3 kWh/km. It is assumed that the price of green hydrogen can drop to around 50 €/MWh by 2030. With this assumption, the cost of hydrogen would be the same as the cost of electricity and hydrogen buses would also achieve a 19 700 € energy cost reduction as compared to diesel buses.

As electric and hydrogen buses are significantly more expensive than diesel buses and require additional investments in infrastructure, it is not cost effective to replace diesel buses. When the total cost for a line kilometre for diesel buses is 1.023 € then the corresponding values for electric and hydrogen buses are 1.090 € and 1.186 € respectively. However, with the development of battery technology and widespread utilization of hydrogen, the costs related to electric and hydrogen buses are expected to decrease and can become competitive with diesel buses.

As hydrogen buses require more time to become cost-effective and require large investments in infrastructure, **as a first approach a pilot project with one electric bus should be carried out between 2025 and 2028 prior to the next public transport procurement to assess the suitability of the technology.** As the climatic conditions of Hiiumaa vary significantly throughout the year, the duration of the test period should be at least half a year. Based on the expected price of electric buses, it is assumed that the

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rental cost for one bus for six months is about 25 000 euros. The current service provider is not obligated to acquire an electric bus. Therefore, the costs should be carried by the local municipality. Although there are chargers in both Käina and Kärdla, additional chargers should be installed by charging network developers. The expected cost for the local municipality for preparing the locations for charging is assumed to be in the range of 5000 €. Previously the purchase of electric buses and the creation of the charging infrastructure has been supported by the EIC (54) and it is likely that there will be additional support mechanisms in the coming years.

6.6.2. Ferry transport

The islands are connected to the mainland and to each other with a total of nine ferries and boats of different sizes. Leiger and Tiiu service the route between Hiiumaa and mainland, whereas their sister vessels Tõll and Piret connect Muhu to the mainland. Regula is used as a spare vessel for the Kuivastu-Virtsu line and is expected to be replaced by a new environmentally friendly ferry in the following years. The connection between Saaremaa and Hiiumaa is established with Soela. Runö services the island of Ruhnu in the summer season. Abro and Vilsandi are used for connecting Abruka and Vilsandi respectively to Saaremaa. All of the vessels use diesel except Vilsandi, which is powered by gasoline.

Generally, electric ferries are suitable for shorter distances due to the low energy density of batteries as compared to diesel. Larger electric ferries can travel solely on electricity for 10 km and mid-sized electric ferries can travel up to 45 km (55). Based on the limitations, it was assumed that Tõll, Piret, Soela, Abro, and Vilsandi could be converted to electric, whereas Tiiu, Leiger, and Runö could be either retrofitted with hydrogen systems or replaced by new vessels.

For converting Tõll and Piret to electric, the examples of Aurora and Tyche Brahe - the ferries operating between Helsingør and Helsinborg in Denmark and Sweden respectively - were used for reference. The connection distance from Kuivastu to Virtsu is about 7 km with the trip taking less than 30 minutes. Both ferries are 114 metres long and have a capacity of 150 vehicles and 700 passengers (56). The connection between Helsingør and Helsinborg is 4 km (57). Both ferries have a length of 111 metres (58), a capacity of 240 vehicles (59) and 1250 passengers (60). A single trip consumes on average 1175 kWh of electricity (61). Based on the electric retrofit of Tyche Brahe and the differences between the ferries and the route, it was estimated that the required battery capacity for one ferry is about 3120 kWh (62). Although batteries have already been installed on Tõll as a part of converting the vessel to a hybrid (63), it is expected that the batteries will need to be replaced when the ferry is converted to 100% electric due to the end of life of the batteries. Based on prior experience, the investment cost for retrofitting both Tõll and Piret and creating the necessary shore-side infrastructure is estimated to be in the range of €10.5 million.

The cost of electrification of Soela and Abro was estimated based on the same reference project. The required investment for retrofitting Soela is in the range of 7.1 million euros

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due to the longer distance covered and larger battery capacity needed. The investment cost for retrofitting Abro was estimated to be about 600 000 €. As Vilsandi is a small boat, an electric retrofit might be complicated. Therefore, the purchase of a new fully electric boat with an estimated investment cost in the range of 400 000 € (64) was considered. The total estimated cost of converting the vessels to electric and creating the required infrastructure is in the range of 19 million euros.

As Leiger, Tiiu, and Runö travel longer distances, the possibility of retrofitting them with hydrogen solutions or purchasing new hydrogen ferries was considered. The investment costs were estimated based on prior experience and analyses carried out. It was estimated that the retrofit of Tiiu and Leiger would cost about €28.5 million. Instead of retrofitting Runö, the construction of a new hydrogen vessel that would better fit the needs of the island was considered. The investment cost of a new ferry is expected to be in the range of €10.3 million (65) (66).

In addition to retrofitting the existing vessels or purchasing new ones, the usage of hydrogen ferries requires the development of hydrogen infrastructure that includes onsite hydrogen production, compression, storage, and dispensing. For Ruhnu, it was assumed that the hydrogen would not be produced on the island and the ferry would have double the storage capacity to be able to make a return trip as hydrogen production on the island creates a problem with excess electricity or hydrogen when there is no demand due to the ferry being only seasonally used. Therefore, hydrogen production facilities and filling stations are planned in the ports of Rohuküla, Heltermaa, Pärnu, and Roomassaare. Based on a conservative estimate of a hydrogen station cost in the range of €3 million and the need for four filling stations, the total expected costs for hydrogen infrastructure are in the range of €12 million (67). The total investment cost for adopting hydrogen ferries is therefore about €51 million.

Based on prior knowledge and the assumptions made, the decarbonization of ferries and boats with renewable electricity and hydrogen would require an investment in the range of €70 million. Due to lack of knowledge and experience, the investment costs are very preliminary. Each project requires thorough analysis to assess the potential of each alternative. Battery and fuel cell technology is developing fast and large renewable energy projects are carried out which enables cost reduction and thus making electrification and the adoption of hydrogen more cost-competitive as compared to diesel. It is likely that the required investment costs will decrease significantly by 2030 which makes the projects feasible without subsidy.

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7. Synergy of offshore wind farms and blue economy

7.1. Introduction

The islands of Estonia have historically relied on the sea surrounding them. Activities such as fishing, shipbuilding, and seafaring have played an important role in the development of the islands. With the emergence of offshore wind energy and the global development of marine and marine-related activities, new opportunities are unfolding for the islands. Comprehensive development of the blue economy sector in synergy with offshore wind farms can lead to significant overall benefits for the islands.

A sustainable blue economy promotes economic growth, social inclusion, and improved livelihoods while ensuring the environmental sustainability of the natural capital of the oceans and seas. A sustainable blue economy encompasses all sectoral and cross-sectoral economic activities related to the oceans, seas, and coasts. It comprises emerging sectors and economic value based on natural capital and non-market goods and services through the conservation of marine habitats and ecosystem services (68).

The following sections are intended to introduce the potential synergies of offshore wind farms and other sectors of the blue economy and the impacts that they would have on the islands.

7.2. Document references

This chapter gives an overview of the documents used to carry out the analysis. The list of documents is given as follows:

- Offshore Wind and Grid in the Baltic Sea – Status and Outlook until 2050, https://vasab.org/wp-content/uploads/2019/05/Baltic-LINes-Offshore-Wind-and-Grid-in-the-Baltic-Sea-%E2%80%93-Status-and-Outlook-until-2050.pdf
- The EU blue economy report 2021, https://op.europa.eu/et/publication-detail/-/publication/0b0c5bfd-c737-11eb-a925-01aa75ed71a1
- Estonian Maritime Spatial Plan, http://mereala.hendrikson.ee/dokumendid/Eskiis/Estonian_MSP_main-solution_ENG.pdf
- Estonian Maritime Spatial Plan, Draft Impact Assessment Report, http://mereala.hendrikson.ee/dokumendid/Eskiis/Estonian_MSP_Impact_assessment_ENG.pdf
- Fostering a blue economy: Offshore renewable energy, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Fostering_Blue_Economy_2020.pdf

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- Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets, https://www.energy.gov/sites/prod/files/2019/03/f61/73355.pdf
- Study on Baltic offshore wind energy cooperation under BEMIP, https://op.europa.eu/et/publication-detail/-/publication/9590cdee-cd30-11e9-992f-01aa75ed71a1/language-en
- Sustainability criteria for the blue economy, https://op.europa.eu/en/publication-detail/-/publication/893c5ae2-a63a-11eb-9585-01aa75ed71a1
- The Input-Output Analysis of Blue Industries: Comparative Study of Estonia and Finland, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3176955

7.3. Scope of intervention and general description

7.3.1. Project overview

By 2030 offshore wind energy developments are planned to be commissioned in the coastal waters of the islands. The wind farms planned have annual capacities that largely exceed the needs of the islands and therefore directly contribute to achieving the climate objectives set.

In addition to supplying the islands with renewable electricity, the construction and operation of offshore wind farms also has the potential for stimulating the development of other sectors of the blue economy. Offshore wind farms will increase the need for maritime transport which in turn offers possibilities for the ports of the islands. To increase maritime transport, new vessels need to be built which can increase the local shipbuilding and repair sector. Despite the fear of offshore wind turbines ruining the view to the sea, they can attract new tourists interested in renewable energy and create possibilities for new sectors of tourism such as scuba diving as wind turbines create new artificial habitats. A large sector that can benefit from offshore wind farms is marine aquaculture and the related seafood processing. The development of the blue economy is expected to result in the creation of innovative technologies, solutions, and services. A tight connection between the educational facilities and the business sector can promote innovation (69).

The focus in this analysis is set on the synergy of aquaculture with offshore wind farms and port activities supporting the blue economy. In addition to the direct impact on those sectors, the impact imposed on the whole value chain is important. With the developments in the blue economy sector, the islands are to become more self-sustainable and improve their economic position, which overall leads to a better society.

7.3.2. Background

In 2018 the offshore wind capacity in Europe was 18.5 GW of which the majority was in the North Sea (70). The North and the Baltic Sea have similar characteristics. Thus, the

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conditions of relatively shallow waters, smaller waves, weaker tides, and more potential sites close to shore are not only excellent for offshore wind development but also result in lower manufacturing, installation, and servicing costs for generation and grid infrastructure (11).

Currently, the most active offshore wind energy projects are being developed in the Gulf of Riga south of Kihnu island and off the western coast of Saaremaa. The developer of the offshore wind farm located off the western coast of Saaremaa is planning to construct a 1.4 GW wind farm that would start generating electricity around the year 2030.

The Estonian Blue Economy employs over 40 000 people and generates over €1 billion in GVA. The Blue Economy's contribution to the Estonian domestic GVA stands at around 4.4%. The Blue Economy is dominated by coastal tourism, which contributed with 68.8% of the jobs and 49.2% to the overall Blue GVA in 2018, while port activities generate 22.3% of the GVA and 8.9% of the jobs (71).

At the end of 2020, there were more than 800 residents of the islands employed in the blue economy fields, which makes up 6.3% of all people employed. The revenue of the companies from the islands operating in the blue economy formed 12% of the total income (Table 7.1) (72).

Table 7.1. Employment and revenue in the blue economy in 2020 (72)

Field of activity	People employed				Revenue (million euros)			
	Saare County	Hiiu County	Total	Share	Saare County	Hiiu County	Total	Share
Ship and boatbuilding	344	-	344	2.7%	59.4	-	59.4	6.2%
Processing and preserving of fish, crustaceans and molluscs	177	6	183	1.4%	40.0	0.4	40.4	4.2%
Fishing and aquaculture	70	59	129	1.0%	5.1	4.1	9.2	1.0%
Activities serving water transport	110	4	114	0.9%	7.4	0.1	7.5	0.8%
Food production not classified elsewhere*	26	-	26	0.2%	0.8	-	0.8	0.1%
Water transport	9	-	9	0.1%	0.1	-	0.1	0.0%
All blue economy activities	736	69	805	6.3%	112.8	4.6	117.4	12.3%
All activities	10 282	2462	12 744	100%	759	197	957	100%

Production of furcellaran

When it comes to the workforce in the blue economy there is a lack of well-trained professionals and highly skilled personnel to carry out innovation and increase the capacity of the sector. Other concerns are related to the lack of communication and cooperation between education and industry, lack of attractiveness and awareness of career opportunities, and a lack of ocean literacy (69).

Some of the trends regarding skills in the blue economy are as follows:

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- A need to strengthen existing education provision in the marine fields and to develop specialised training adapted to the maritime industry (e.g. shipbuilding needs education/training in the digital domain, green technologies, and soft skills).
- The shipbuilding sector must attract new talent while implementing generational replacement systems.
- Raising the level of ocean literacy would increase the visibility of professional opportunities in the blue economy likely to appeal to younger generations and female applicants
- Skill ecosystems - meeting points for relevant stakeholders will help them obtain reliable data at a time when skill needs are constantly evolving.
- Heightened efforts towards a special Digital Literacy and Data Literacy training in the maritime sector (69).

7.3.3. Project Objectives

The long-term vision of the Estonian marine area is to have good environmental status, diverse and balanced use, and promote the sustainable growth of a blue economy. Blue economy, including blue growth - sustainable maritime economy, covering all areas related to the sea: tourism, renewable energies, aquaculture, fisheries, biotechnology, use of seabed mineral resources, etc. (73).

The main objective of the project is for the islands to develop a strong blue economy sector that can support the growth of the economy and contribute to the development of the society of the islands. The aim of the project is to create the most value with the resources and opportunities available to the islands.

In addition to direct value and employment opportunities created in the blue economy sector, the growth of the sector would also create indirect employment in the value chain and would lead to the creation of new curricula and promote innovation.

7.3.4. Project Benefits

The implementation of blue economy projects in synergy with offshore wind energy projects would decrease costs and accelerate progress. The combination of different activities enables the possibility to carry them out more efficiently and therefore increase the competitiveness of implementing those projects.

The development of the blue economy would create a significant number of employment opportunities with a large share of them being well-remunerated jobs. New jobs would make the islands more attractive to the workforce and help preserve or increase the population. In addition to direct jobs, the blue industry sectors contribute significantly to the national economic growth and employment. On average 1.76 to 2.49 individuals are additionally employed in Estonia for every €100 000 invested in the blue economy (74).

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The blue economy industries produce limited negative externalities on the overall economy and they are not particularly vulnerable to shocks affecting the national economy. This means that blue industries are relatively independent within national economies while having a remarkable role in socio-economic development of maritime regions (74).

7.3.5. Scope

The scope of the project is to determine the potential synergies of offshore wind farms and other sectors of the blue economy and based on that determine the actions for the implementation of those projects and the impacts resulting from the developments.

7.3.6. Project boundaries and constraints

The project boundaries stem largely from environmental constraints. Figure 7.1 gives an overview of the areas covered by Natura 2000 areas defined according to the Birds and Habitats Directives, areas assigned for national defence purposes, international shipping route and other areas with specific limitations. The areas depicted are in general depicted as unsuitable for establishing fish farms. Environmental risks related to the development of offshore activities in Natura 2000 network sites should be examined extensively (73).

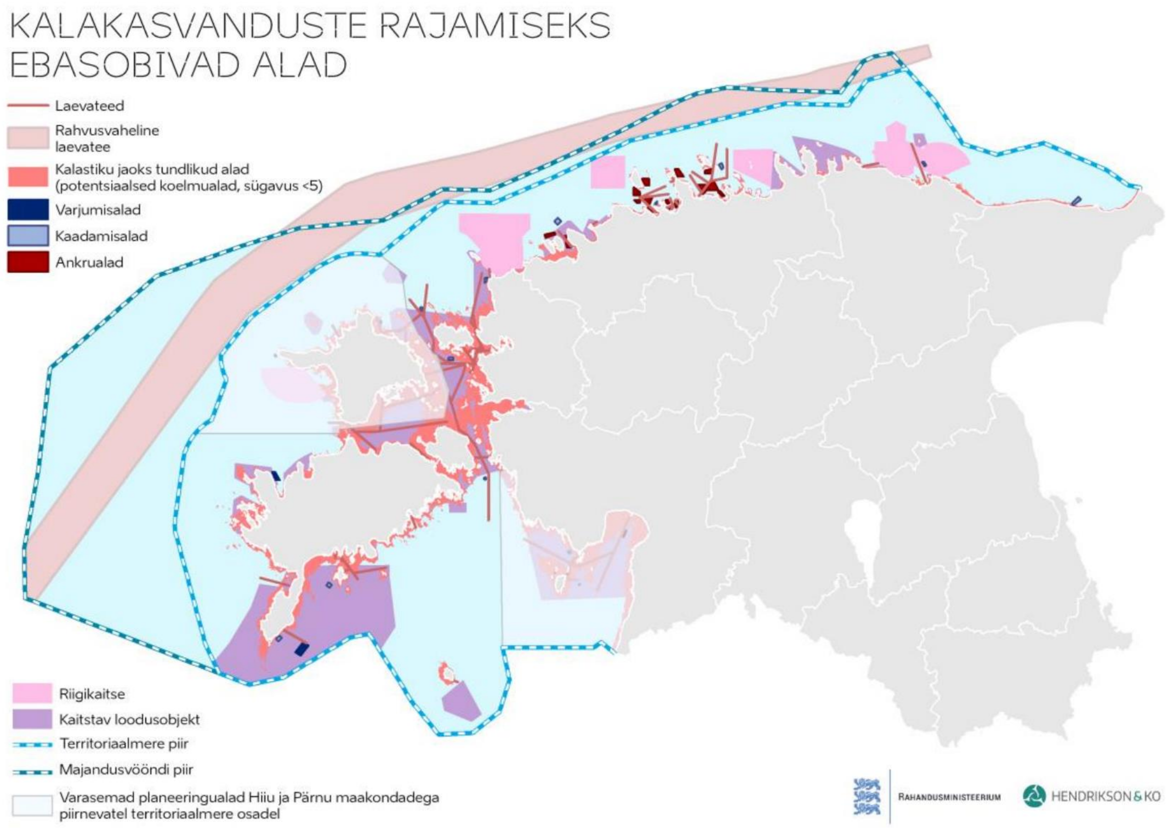

Figure 7.1. Areas excluding the development of fish farms (73)

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Approximately 19% of the entire Estonian marine area including the exclusive economic zone is covered by various types of protected natural objects. All of the existing protected areas are located in the territorial sea. Most protected natural objects of the marine area are also internationally protected within the Natura 2000 network of nature and/or special protection area (75).

Environmental impact of the blue economy

According to the Maritime Spatial Plan, areas suitable for the development of wind energy are envisaged to be somewhat offshore and in deeper areas of the sea. Large-scale fish farming is also conditionally directed to deeper sea areas. Given that the majority of fish spawning grounds and juvenile fish feeding grounds are located in shallow waters and coastal areas or they are passed through by species heading for spawning in freshwater, conservation of these areas is essential for the sake of maintaining and reproducing the good status of fish stocks. Therefore it is recommended that offshore fish farms are established in marine areas with depths of at least 5 m (75).

In terms of environmental impact, aquaculture clearly distinguishes between the environmental impact of the classical fish farming and the innovative farming of algae and shellfish aquaculture sectors. The most important impact of fish farms on the marine environment is the release of nutrients and the favouring of eutrophication, which results in a disturbance of the natural balance, and at worst, in the loss of biota and habitats near the farm. Therefore, the establishment of fish farms is directed outside protected areas, but also into deeper and more open seas, where nutrients are dispersed more efficiently, and the impacts on conservation values and the environment are minimised (75).

All offshore developments have to apply for a building permit. As a part of the application process, an environmental impact assessment needs to be carried out which identifies the potential threats caused by the project and determines whether the project can be implemented or not. The environmental impact assessment takes approximately two to three years to complete. Some of the potential impacts to the environment or by the environment to the development are given as follows.

Impact on fish population

Many traditional uses of the marine area have achieved a balance with fish and fisheries over the years. It has been established by law how the use of the marine area is permitted. Such uses of the marine area include maritime transport with the construction and dredging of ports, dumping and selection of new dumping areas, use of deposits, and other marine area use with a long tradition. For some new and intensifying uses of the marine space, such as energy production, aquaculture, and recreational industries, there is little experience of environmental impact assessment and ex-post evaluation (75).

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Impact on bird population

Bird protection in Estonian marine areas is mainly based on the so-called Birds Directive, which obliges EU Member States to implement special measures to protect regularly occurring migratory species, designating the most suitable areas, both in number and in size, for their protection as bird sanctuaries. To meet the requirements of the Birds directive, Estonia established a network of Natura Bird Areas at the beginning of this century which includes among other things, 26 areas that encompass some marine areas (75).

Impact on mammal population

The uses of the marine area addressed in the Maritime Spatial Plan do not contradict the established patterns of marine use of seals. The key habitats are covered by various nature conservation measures in the plan (75).

There is currently no comprehensive picture of the use of the marine area by bats in Estonia. Only a few studies have been carried out covering very limited marine areas. It is believed that the main migration corridor is between Sõrve peninsula in southern Saaremaa and Courland peninsula in northern Latvia over the Irbe Strait (75).

Impact by ice

In the Estonian marine area, at least in the Gulf of Riga and the Väinameri Sea, ice cover occurs every year. The entire Estonian sea area is covered with ice during harsh winters. Ice drift and its potential damage to offshore and coastal facilities is an important barrier to offshore activities (75).

7.3.7. Business model and relationship scheme (governance)

The development of the blue economy sector is expected to create a cluster of companies sharing the same values and working closely together to achieve the best results. The revenue of the blue economy is expected to come from various sources. There is no central governance. However, a union of companies on the island active in the blue economy field should be formed to better manage the growth and further development of the sector and protect the interests of local companies in the global market by creating a competitive advantage through cooperation.

With regards to aquaculture, the main revenues will come from the production of fish which will obtain additional value during processing on the islands. It is essential that an end product with a well-known brand is created on the islands as it can increase revenues and introduce the islands to the end consumers of the products supplied. Additional income is created from the sale of mussels and algae.

For ports, the main revenue will come from port fees and offering services as required by the vessels and their crews. Depending on the requirement, the ports can increase the

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range of services offered by for example establishing opportunities for onshore maintenance of wind turbine parts and create spaces for the collaboration of different fields of the blue economy.

7.4. Regulatory framework

7.4.1. The European Integrated Maritime Policy

The European Integrated Maritime Policy (IMP) seeks to provide a more coherent approach to maritime issues with increased coordination between different policy areas. It covers several cross-cutting policies, of which 'Blue Growth' and 'Maritime Spatial Planning' are of specific importance with regard to multi-use offshore platforms (76).

The environmental pillar of the IMP is constituted by the Marine Strategy Framework Directive, which intends to achieve the Good Environmental Status of the European marine waters as well as the protection of the resources on which economic and social activities depend (76).

Marine aquaculture is largely regulated by the regulations of the Common Fisheries Policy. However, due to the different fields of interest that multi-use offshore platforms cover, several other European directives are of high significance such as the Habitats Directive and Birds Directive or Water Framework Directive (76). The EU Water Framework Directive provides a coherent framework for action to plan and organise water protection in the European Union (75).

The European Union Strategy for the Baltic Sea Region unites eight EU Member States around the Baltic Sea – Estonia, Lithuania, Latvia, Poland, Sweden, Germany, Finland, and Denmark. The strategy has three general objectives:

- saving the sea,
- connecting the region,
- increasing well-being.

and a wide range of policy and cross-cutting issues stemming from these objectives:

- capacity building,
- climate change,
- cooperation with neighbouring non-member countries,
- spatial planning (75)

The Estonian Marine Strategy includes measures such as the establishment of a network of marine protected areas in the Estonian EEZ, the establishment of regional plans for aquaculture to manage environmental pressures, the enhancement of marine pollution response capacities to respond to environmental emergencies at sea, and other activities (75).

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7.5. Expected impacts analysis

The focus of this analysis is set on the synergy of aquaculture with offshore wind farms. Knut Senstad, Jonne Kotta, and Georg Martin carried out a feasibility study of the West Estonia coastal zone with the aim of identifying the potential of an eco-friendly sustainable strategy, where the marine and coastal zones resources can be exploited with investment in modern technology. The attention of the report was on fish farming with an emphasis on aquaponic farming in combination with mussels and algae. As the Baltic Sea is eutrophicated, the introduction of open-net fish farms would lead to further input of nutrients and the deterioration of the environmental status of the sea. To counterbalance the flux of nutrients from a large open net fish farm, the cultivation dimensions of mussels have to be very large, which makes it unfeasible. Therefore, aquaponic solutions with floating closed fish bags or fish tanks on land and separate floating shellfish bags are proposed. In a closed-loop solution, nutrient- and sediment-rich water from the fish bag is first passed through a mechanical filter and then sent to a bag with mussels and algae (77).

As a result of the study, it was estimated that the potential for open net farming of rainbow trout is 20 000 tonnes per year which would create a total of 270 jobs in the supply chain including farming and lead to an annual income of € 175 million. In addition to creating jobs in fish farming, jobs would also be created in education and other services such as fish health, water chemistry, logistics, harvesting, processing, and maintenance. Land-based fish tanks and floating fish bags each have a production potential of 10 000 tonnes per year and would create a total of 250 jobs. By implementing aquaponic solutions, another 175 jobs are created, and the total revenue of farming fish, mussels, and algae would reach €200 million (77).

Using closed-loop systems with floating bags or land-based fish tanks means that water circulation needs to be provided with pumps. When using floating bags, 1 kWh of electricity is needed per 1 kg of fish produced. The necessary energy can be provided from the offshore wind farm. The wind turbines themselves can be used as structural elements for creating aquaponic systems (77).

The cost of mussel aquaculture includes the deployment, fixation, maintenance, and reeling of aquaculture installations and cultured organisms. Additional costs are composed of the control and regulation of harvesting operations as well as monitoring the health of mussels as part of the management of new farming grounds. Separate processing and distributing sectors may be involved in the cultivators' activities, and thus must be paid for, such as taking care of grow-out seeds until market size, the transfer of seeds to licenced nearby cultivation spots, and onshore processing or marketing (78).

In the MERMAID project, it was concluded that the cost category with the greatest potential for reduction when combining offshore wind energy and aquaculture is the operation and management cost. For example, when a multi-purpose vessel sails out to transport a maintenance crew to and from the wind turbines, its crew can inspect the aquafarm installations, feed the fish, and even harvest fish, mussels, or algae while the

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maintenance crew is busy carrying out the maintenance work. Based on expert consultation, a 10% reduction in operation and maintenance costs can be realised through this multiuse (78).

Developments in the blue economy must be considered from an ESG perspective. The **environmental impact** (E) of the blue economy and its contribution to sustainability encompasses not only the issue of biodiversity, but also its contribution to mitigating the effects of climate change and the rise of the oceans. At the **social level** (S) the impact is just as broad and has effects on levels of direct and indirect employment. A recent study by G. Ashyrov, T. Paas, and M. Tverdostup shows that blue industry sectors contribute significantly to national economic growth and employment. On average 1.76 to 2.49 individuals are additionally employed in Estonia for every 100 000 € invested in the blue economy (74). An area that seems more disconnected is **governance** (G), which includes the issue of the economic resources required and their financing.

7.6. Eco-fin feasibility

Ranking as the world's 7th largest economy with an annual economic value estimated at USD $ 2.5 trillion, the blue economy is attracting increasing investments and raising the interests of insurers, banks, and policymakers alongside traditional investors (79).

7.6.1. Funding opportunities

The relevance of the sector is also confirmed by the numerous initiatives created to finance and support the development of a sustainable blue economy.

Among the main supporting initiatives worldwide, the **Sustainable Blue Economy Finance Initiative** plays a relevant role, developing a global community to focus on the convergence of private finance and ocean health, and assisting with the implementation of the Sustainable Blue Economy Finance Principles, launched in 2018 (79).

The Sustainable Blue Economy Fund Principles is the world's first worldwide guiding framework for banks, insurers, and investors to finance a blue economy that is sustainable, developed by the European Commission, WWF, the World Resources Institute (WRI), and the European Investment Bank (EIB). They encourage the implementation of SDG 14 (Life Below Water) and provide ocean-specific criteria, allowing the finance industry to mainstream ocean-based sector sustainability (80).

Different opportunities are currently available also at the European level, confirming the relevance of the sector in achieving the target set by the European Green Deal. The main opportunities are presented as follows.

The European Maritime, Fisheries and Aquaculture Fund (EMFAF) runs from 2021 to 2027 and supports the EU common fisheries policy, the EU maritime policy, and the EU agenda for international ocean governance. It provides support for developing innovative projects ensuring that aquatic and maritime resources are used sustainably. The EMFAF

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supports innovative projects that contribute to the sustainable exploitation and management of aquatic and maritime resources, which includes amongst others the development of a sustainable and competitive aquaculture contributing to food security, the economic and social vitality of coastal communities, and innovation in sustainable blue economy. The total budget for 2021–2027 is €6.1 billion. The programme management is divided between shared management and direct management. €5.3 billion is provided through national programmes co-financed by the EU budget and EU countries. €797 million is provided directly by the Commission (81).

Through the European Maritime and Fisheries Fund, the Commission also funds an additional €40 million grant scheme to help blue economy SMEs with developing and bringing to market new innovative and sustainable products, technologies, and services (82).

The European Commission is partnering with the European Investment Fund to announce €45 million of **BlueInvest** financing into two funds targeting the blue economy across Europe. The BlueInvest pilot initiative, managed by the European Investment Fund, provides financing to underlying equity funds that strategically target and support the innovative blue economy as this sector can play an important role in the transformation to a carbon-neutral economy by 2050. Two new funds have received funding to-date. These investments will support start-ups developing innovative products, materials, and services that can contribute to enhance ocean conservation and the sustainability of the blue economy. Three additional fund investments into specialised blue economy funds, backed by BlueInvest and **InnovFin Equity** under Horizon 2020 finance, have also already been approved. Through investments into these funds, around €300 million in equity funding will be mobilised for investment in innovative and sustainable ventures active in the blue economy. These funds are: Blue Horizon Ventures, Ocean 14 Capital, Sofinnova Partners, Astanor Ventures, and Sarsia (82).

SMEs and individual business have the chance to submit an application to the BlueInvest Project Pipeline which is a showcase initiative of DG MARE. Starting from this, the European Maritime Forum Platform will feature a select group of innovative projects, start-ups, and SMEs that have a long-term impact on the Blue Economy. Investors will be able to search the pipeline for projects that fit their portfolios and contact them. Potential European investors include X2 Labs – A Startup Factory, Aqua Spark, BroodStock Capital, Portugal Ventures, and INCO.

7.7. Risk analysis

Table 7.2 gives an overview of the risks associated with the development of offshore aquaculture and port activities, their expected impact, the probability of their occurrence, and measures to mitigate the risks.

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Table 7.2. Risk analysis of the synergy of offshore wind with aquaculture and port activities (83)

Description of risk	Probability	Impact	Mitigation measures
Project planning			
Permits for the development of projects are not granted	Medium	High	Careful assessment of the planned locations for the development of blue economy projects
Public opposition	Medium	Medium	Engaging the local community throughout the planning process, implementing suggested changes
Conflicting interests with other developers	Medium	Medium	Determining alternative suitable locations
Operation			
Projects have lower output than expected	Medium	Medium	Creating conservative estimates for evaluating the project
Lack of workforce	Medium	Medium	Training of personnel prior to commencing operation, gaining public traction to the field
Finances and the economy			
The investment cost is higher than expected	Medium	Medium	Thoroughly assessing costs related to the project using conservative estimates
Production volumes are lower than expected	Medium	High	Preparing the projects using conservative estimates for the output of production
Difficulty entering the market	Medium	High	Establishing contracts with customers during the planning stage
Difficulty obtaining financing	Medium	Medium	Exploring possible alternative financing methods and involving external investors
Environment			
Environmental requirements are not met	Medium	Medium	Considering the need for possible additional investments to fulfil environmental requirements
Threat of environmental pollution	Low	Medium	Taking additional measures to avoid contamination and polluting the environment
Ecological effects on biodiversity	Low	Medium	Carrying out thorough environmental impact assessment

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8. Innovative wind energy solutions

8.1. Introduction

Innovative wind energy technologies have a great deal of potential on the islands of Saaremaa, Hiiumaa, and Muhu as they could bring socio-economic benefits of attracting alternative wind energy developers to the islands as well as show different methods of wind energy production that will help to decrease the opposition of the community towards wind energy developments.

This document intends to introduce emerging innovative wind solutions that can be suitable and have a potential development on the islands.

8.2. Document References

This chapter gives an overview of the documents used to carry out the analysis. The list of documents is given as follows. The chapter primarily provides an overview of different technologies under development based on information from the websites of the developers.

- Changing Winds: Emerging Wind Turbine Technologies, https://www.powermag.com/changing-winds-emerging-wind-turbine-technologies/
- Future emerging technologies in the wind power sector: A European perspective, https://www.sciencedirect.com/science/article/pii/S1364032119304782
- Six innovative wind turbine designs, https://www.engadget.com/2016-11-05-six-innovative-wind-turbine-designs.html?guccounter=1&guce_referrer=aHR0cHM6Ly93d3cuZ29vZ2xlLmNvbS8&guce_referrer_sig=AQAAAM-VmOgaVx3FkHH231Fh-HtVZSt8scFCZC1zo_QtS-gwZ51o_PjPQ7CR0CUjbE1Ea-HN20gjhBSD7m0HCbr0H66R6OjereexnTZF5docomByUhe7fHabFDRduF9EVjAB8oQE2dCZbD-jBSbvck778EviNQZTRfISxer-QPkPUHtB
- VIV resonant wind generators, https://www.researchgate.net/publication/331345449_VIV_resonant_wind_generators
- Estonia's 2030 National Energy and Climate Plan, https://ec.europa.eu/energy/sites/ener/files/documents/ee_final_necp_main_en.pdf

8.3. Scope of intervention and general description

8.3.1. Project overview

The largest advantage of alternative wind energy technologies is its response to the limitations of traditional solutions, be it ecological, scale, land use, or cost-related

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concerns. Although the possible benefits are plentiful, most of the technologies are still in the development phase or being tested but are still worth considering due to the islands' great wind energy potential and the current restrictions on large-scale developments. Viable technological alternatives would also decrease the current community opposition towards wind energy projects. Dagöplast, a plastics producer from Hiiumaa, has expressed interest in kite-mounted turbine solutions while small modular solutions could work for households.

8.3.2. Background

As of 2019 there were 15 large-scale wind turbines installed in Saaremaa and one in Hiiumaa that is not functional (84). In spite of the large average wind power available near the islands as shown in Figure 8.1, several onshore wind energy projects have been cancelled over the past few decades due to radars which monitor the airspace of Estonia. The suitable areas are depicted in yellow and areas to become available in 2024 depicted in green (Figure 8.2). Additional radars are planned to be installed in the future which will open most of Estonia to onshore wind farm developments. The flight information zones of the airports near the capitals of Saaremaa and Hiiumaa - Kuressaare and Kärdla respectively (Figures 8.3-8.4) must also be taken into consideration.

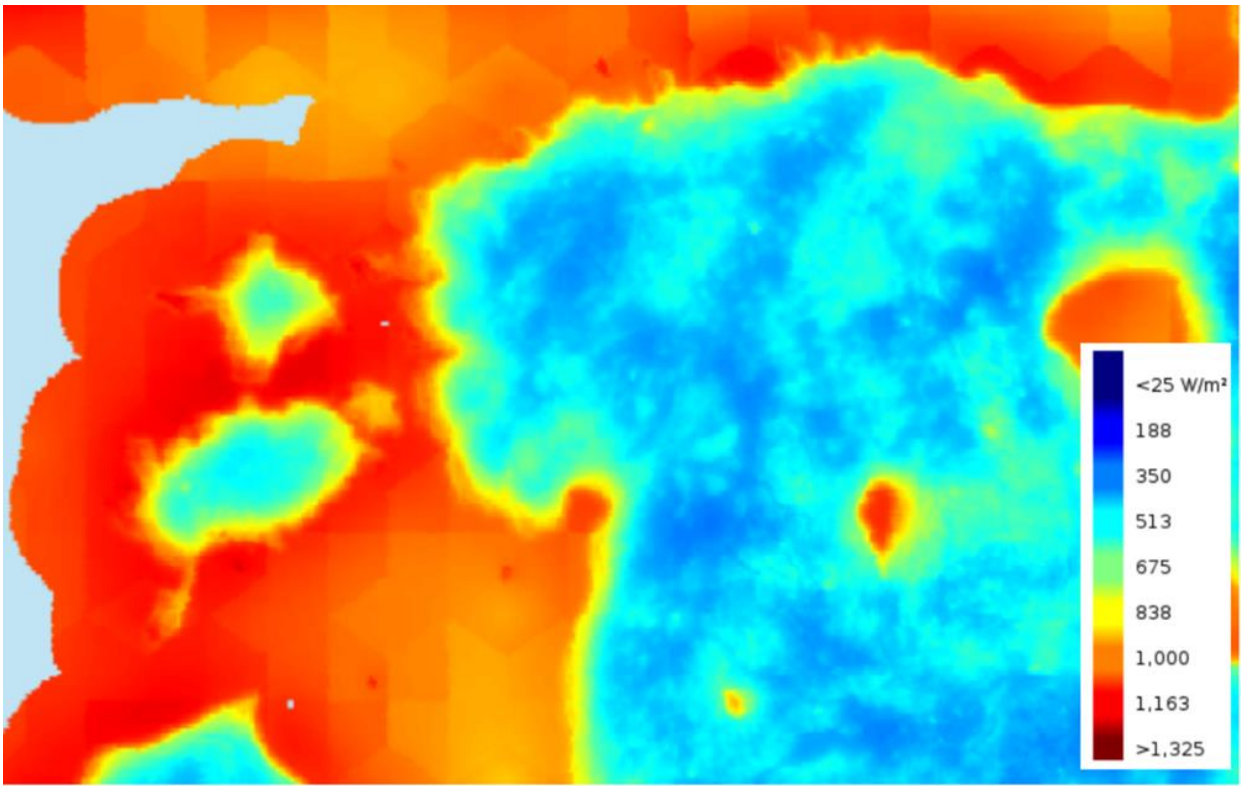

Figure 8.1. Average wind power density at a height of 200 m (85)

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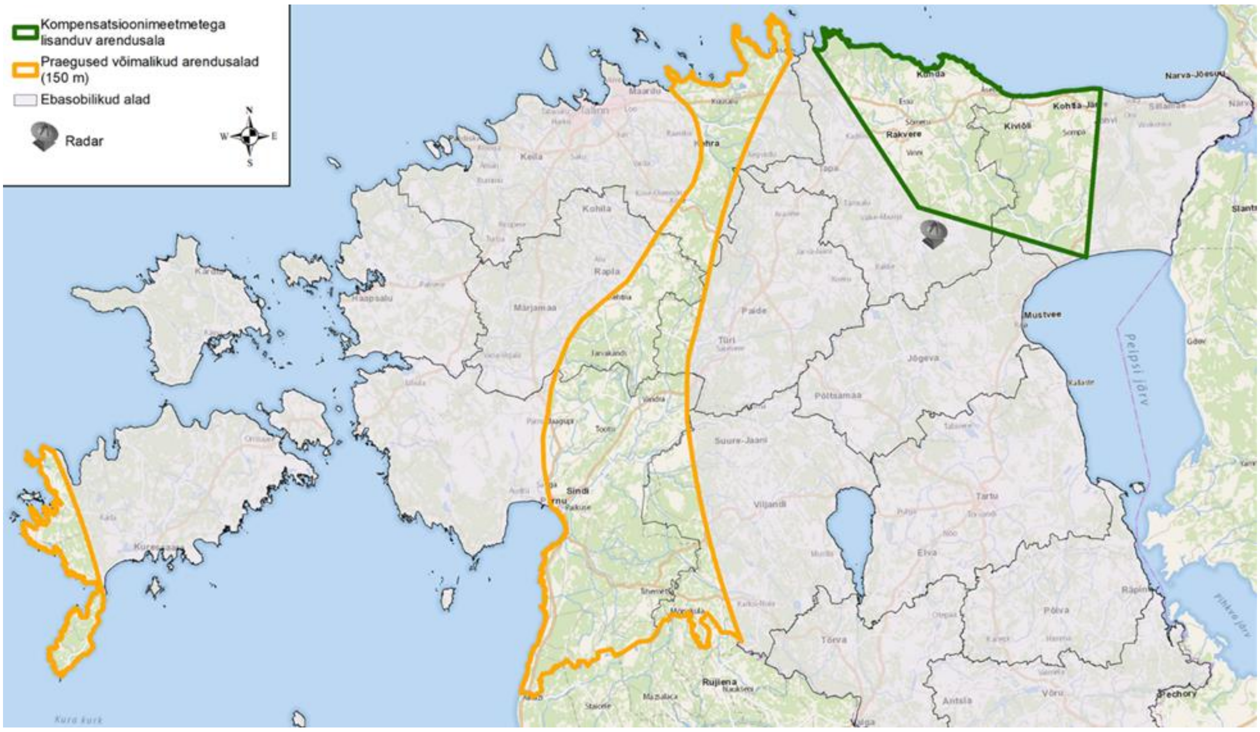

Figure 8.2. Areas determined suitable for wind energy development on land by the Ministry of Defence (86)

Figure 8.3. Flight information zone of Kuressaare airport

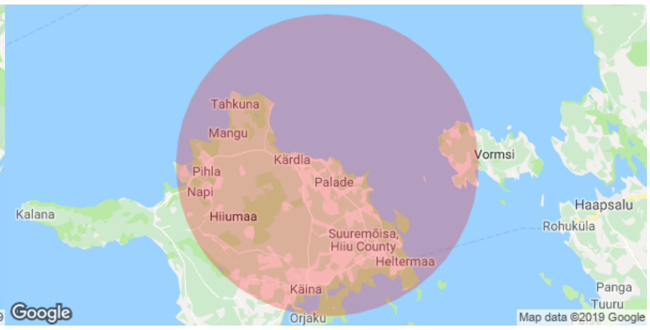

Figure 8.4. Flight information zone of Kärdla airport

The restrictions set offer the possibility of adopting innovative alternative wind energy solutions for harvesting the wind potential of the islands. Solutions such as airborne wind turbines, vertical axis wind turbines, and bladeless wind power might be the answer to bypassing some of the restrictions or for harvesting large quantities of wind energy at a relatively low altitude while minimising the impact on wildlife habitats and birds which has been a large source of opposition to wind energy projects.

Harvesting wind energy as a renewable source of electricity is necessary as the potential of the other main source of renewable electricity - solar power is very limited for a large part of the year due to the location of the islands.

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8.3.3. Project Objectives

This project aims to introduce and analyse the potential use cases for innovative wind energy solutions to better comply with the growing needs and sustainable energy objectives of the islands. The attractiveness of alternative solutions could increase the interest of wind energy developers which would therefore stimulate the sustainable energy sector of Hiiumaa and Saaremaa. This would also decrease the local opposition to wind farms by involvement in the project whether by distributed generation or job creation.

8.3.4. Project Benefits

Innovative wind energy solutions make harvesting larger quantities of wind energy onshore possible. By developing alternative wind energy solutions, the islands can reduce their energy dependency and increase the share of locally generated electricity. Alternative solutions promote distributed electricity generation by encouraging local communities and entrepreneurs to become more self-sufficient and thus reduce the load on the distribution networks of the islands. Smaller functional solutions have potential for reducing public opposition to wind energy and therefore indirectly supporting the development of large offshore wind farms.

Being open to innovative solutions is a good way to attract companies interested in testing their solutions. In combination with suitable wind conditions, the islands have the potential for becoming a location for introducing new technologies to the world.

8.3.5. Scope

The scope of the project involves all companies and private parties who wish to participate and invest in renewable electricity production. Larger concentrated farms could be set up by companies which would work in synergy with a community energy-oriented approach.

8.3.6. Project boundaries and constraints

The boundaries of the project are mainly regulatory, geographic, and ecological. Most constraints have been set regarding large-scale wind turbine installations and small distributed networks might be exempt from a large part of the restrictions.

Without increasing the current capacities of the transmission network 0 – 0.2 MW is available on the low voltage side (6, 10, 15 or 20 kV) of the substations in Hiiumaa and Saaremaa based on Elektrilevi's data (87). At 110kV the free connection capacity of the substations managed by Elering for the customers joining the transmission system is 6.4 MW. (88)

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In addition to the geographic restrictions detailed in Figures 8.2 to 8.4, the multiple Birds Directive sites and Habitats Directive sites on the islands might affect wind energy development in the area (Figure 8.5).

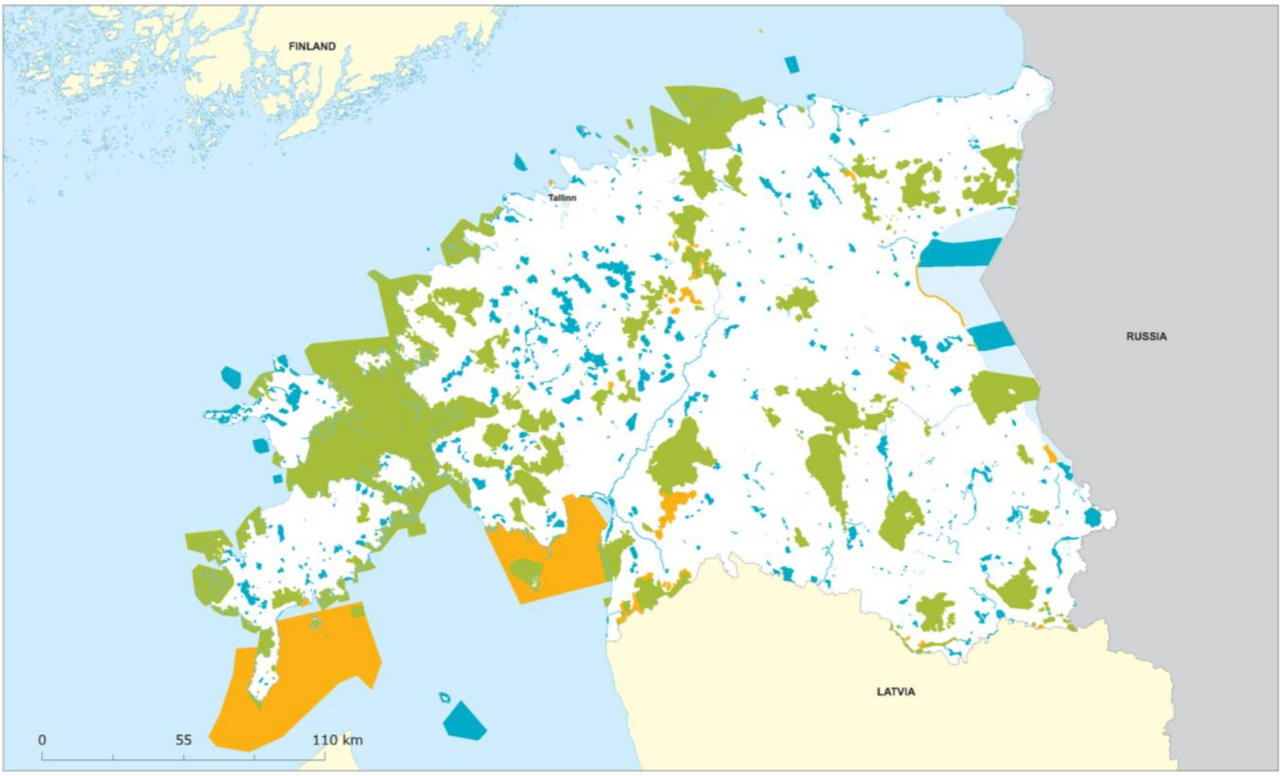

Figure 8.5 Natura 2000 - Birds and Habitats Directives Estonia (51)

Building restrictions

Ministry of Economic Affairs and Communications principles for the planning of wind energy development areas (89).

- The distance between residential and public buildings and wind turbines may not be less than 1000 m, except in densely populated areas (cities, towns) 2000 m.
- With the consent of the landowner, electric wind turbines may be placed closer than 1000 m to the landowner's dwelling if the noise level is compliant to regulations.
- Rest and recreational areas must have a buffer area of 1000 m from wind farms.
- The wind turbine must not be closer than 1.5 x (H + D) m to public roads (regardless of their function, type, class and permitted speed) (H = wind turbine mast height and D = rotor diameter). In the case of the proposed new state roads (Via Baltica etc) the minimum distance from the edge of the route corridor specified in the plan must be taken into account.

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- In the case of low-use (less than 100 cars per day) public roads, in justified cases, based on a risk analysis and with the consent of the road owner, wind turbines may be allowed in the plan closer to the road but not closer than the total wind turbine height (H + 0.5D) m. Due to the long-term validity of the adopted comprehensive plan, it is recommended to use the proposed formula instead of defining a certain distance when preparing the plan. Example: For a wind turbine with a mast height of 200 m and a blade height of 70 m (rotor diameter 140 m), the distance from the public road would be 1.5 x (200 + 140) = 1.5 x 340 = 510 m.
- Water bodies - the extent of the buffer zone must be equalised with the construction prohibition zone of the water body.
- Cemeteries - the buffer area is 500 m.

Regulatory Environment

The Estonian Grid Code sets requirements for wind turbines and wind farms connected to the grid (90):

1. The following requirements apply to connection to the network of wind turbines and wind farms:

   1) the connection to the distribution network of a power plant whose rated active capacity exceeds 200 kW is to be approved by the transmission network operator. The transmission network operator decides on the matter within 30 days from receiving the corresponding application;
   2) a power plant whose rated active capacity exceeds 10 MW is connected to the transmission network.

2. The producer installs wind overspeed protection on wind turbines and wind farms. The producer must install the following relay protection on wind turbines and wind farms:

   1) overload protection;
   2) overcurrent protection;
   3) overvoltage and undervoltage protection;
   4) frequency protection.

3. After the operation of voltage or frequency protection has been triggered, the wind turbine or wind farm may be switched on again when the voltage or frequency in the electricity network has remained within permissible limits for at least 10 minutes.

4. In the case of a wind turbine or wind farm whose rated active power exceeds 1 MW, the network operator must install, network-side from the connection point, backup protective devices, and a backup automatic disconnection device.

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5. The set points of relay protection and automatic equipment must be submitted for approval to the network operator to whose network the wind turbine or wind farm is to be connected.

6. The automatic devices of the wind turbine or wind farm must ensure the switching off of that wind turbine, wind farm or solar power plant when the dead-ended feeder connecting the turbine, farm or plant with the system is switched off by relay protection.

7. In the case of changes in wind speed, it must be possible to control the speed of variation of the power of the wind turbine or wind farm to be connected to the transmission network. Control conditions are to be agreed between the transmission network operator and the producer.

8. The following requirements are applicable in relation to controlling the active power of a wind turbine or wind farm whose rated active power exceeds 200 kW:

1) the deviation of the value of active power must not exceed the setpoint prescribed by the transmission network operator by more than ± 5%;
2) the limit of active power shall be controlled by a single signal. The signal may be relayed by remote control from the control centre of the network operator, or by locally using the frequency of the network, the position of the high-capacity circuit breaker or other relevant means;
3) control algorithms and set points are changed by remote control;
4) in the case of fast reduction in the generation of active power, it must be possible to reduce, within two seconds from the corresponding control signal's reaching the control system of the wind turbine or wind farm, the output of active power from that turbine or farm from their rated active capacity down to 20% of that capacity. In order to achieve a fast reduction of the active power generated by a wind farm, it is permitted to switch off a wind turbine or a group of wind turbines.

9. The following requirements are applicable in relation to controlling the reactive power of a wind turbine or wind farm:

1) the reactive power required for the operation of the wind turbine or wind farm is to be produced on-site. The reactive power supplied to or consumed from the network must be minimal. The permitted deviation of reactive power output is ± 10% of the rated active power of the wind turbine or wind farm;
2) in the case of network disturbances it must be possible for the dispatch operator of the electricity network to control the output of reactive power from the wind turbine or wind farm whose rated active power exceeds 200 kW within the entire range of the reserve of reactive power that is technically possible;

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3) the adjustment of the output of reactive power must take place in accordance with reactive power and voltage on the high-voltage or low-voltage side of the wind turbine or wind farm. In the latter case, current compensation must be used;
4) the output of reactive power is to be controlled by a single signal;
5) control set points and algorithms are to be changed by remote control;
6) if reactive power is controlled by the network operator, that operator is to pay the producer for reactive energy supplied to or consumed from the network on the basis of the applicable price list.

10. If the rated active power of the wind turbine or wind farm exceeds 200 kW, the measurement results of the active and reactive power and of the voltage supplied to the network must be relayed to the control centre of the service area of the network operator in real time. For this, the appropriate measuring devices must be installed on the wind turbine or wind farm in accordance with the connection contract.

11. The following special requirements apply to wind turbines and wind farms:

1) the remote control system must make it possible to switch the power plant on to and off from the transmission network and to relay to the control centre of that network in real time the position and fault signals and the results of measurement of active and reactive power, current and voltage;
2) from the wind turbine or wind farm connected to the transmission network, data on windspeed measurement and data describing the status of the wind farm or wind turbine and the reason for the switching off the wind farm must be relayed to the control centre of the transmission network in real time. For this, the devices specified in the connection contract must be installed on the wind turbine or in the wind farm.

12. If the wind farm is being built stage by stage, its conformity to the requirements may also be verified on a stage-by-stage basis, provided this is technically possible.

13. When setting the start-up time of the generating installations of power plants participating in load control, what must be taken into consideration is that the start-up period from outage to full-load operation should be as short as possible. For wind turbines and wind farms, the start-up period from reception of the corresponding instruction from the system operator is up to 15 minutes provided weather conditions are such as to make it possible to start the installation.

14. The minimum continuous output power shall be as little as possible. For wind turbines and wind farms, it must be less than 10% of the rated power.

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8.3.7. Business model and relationship scheme (governance)

The revenue of the project would come from the sale of electricity into the grid and the cost savings associated with producing one's own electricity for energy communities further detailed in Chapter 5. The investment cost could be reduced by attracting companies interested in testing their solutions in addition to the subsidies offered by Elering for each MWh generated. For example in 2022 the subsidies will be up to 20 € for every MWh generated under the market price of 45 €/MWh with the subsidies cap being 450 GWh generated per year for all new installed renewable sources (91).

8.4. Identification of suitable technological options and definition of the advantages and disadvantages of various technologies

The innovative wind energy designs here presented can be classified into two categories:

- The first category includes products that harvest wind energy at great heights because the wind speeds increase with the distance to the surface of the earth and therefore the potentially generated wind energy increases as well. The main disadvantage is that these technologies can interfere with the air traffic regulations and, in case of large rotors, with the radar of the military defence system.
- In the other category are products that are located close to the ground. The advantage is that products of this category can be located closer to residential areas or even be operated by residents themselves. However, the generated power is lower in this case. Furthermore, there are systems that do not have external blades or blades at all which makes them safe for bats and birds and thereby opens the opportunity to more locations.

However, the innovative wind energy solutions are individually very different in terms of the technological principles and designs, the development status, and scalability. Many projects are still in the early phase of design and prototype testing. Consequently, most of the technical parameters come from early calculations and it is not proven that a particular concept will generate as much energy and function as reliably as predicted. Additionally, the disadvantages of the technologies will be found in a later developing phase of each project and the advantages need to be proven. Innovative wind energy solutions often exit the market within a short period of time after their development.

A list of possible innovative wind energy solutions with their expected advantages and disadvantages is given below and sorted according to their relevance to the project. Although many wind energy solutions are only in the early stages of development, the islands can provide an important location for testing and improving these technologies for small businesses.

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8.4.1. Airborne wind energy (AWE) solutions

In general, AWE systems have the advantage that there is less material needed and structural considerations than with tower-based systems to be able to harness the higher wind speeds further away from the earth's surface. Less material results in lower cost and an easier construction than tower-based systems. However, operating in these great heights interferes with air traffic. Also, the distance to residential areas needs to be substantially increased as the possible impact radius of the tether/cable and the flying object is also increased in comparison with tower-based systems. Therefore, the possible sites on the islands are limited. Challenges are also seen in long autonomous flight times. The ground station can potentially also be located offshore to ensure a safer distance to the people and harness more wind energy. There are primarily two different types of airborne wind energy systems, as shown in Figure 8.6.

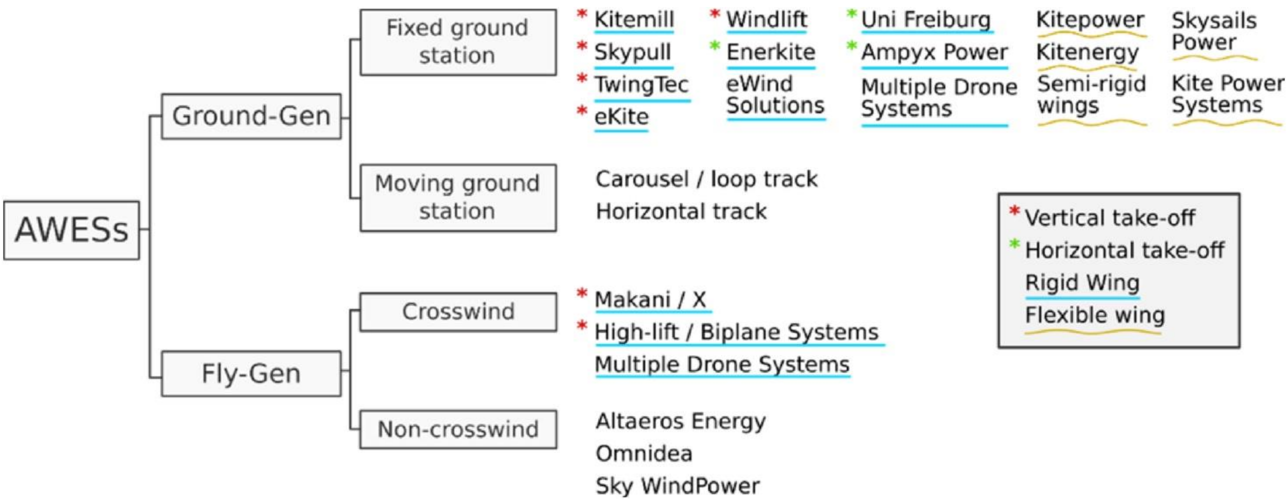

Figure 8.6. Classification of AWE systems (92)

1) Airborne turbine - Generator on the ground

In this case, the flying device (plane, kite, drone) is attached to the ground station through a tether that is wound on a drum. In a yoyo-like motion the flying device first pulls out the tether and energy is generated. Then the tether is wound up again using only a small amount of energy as during descent the flying device is flying in a way that minimises the resistance on the tether. There also exist concepts with multiple flying devices.

Table 8.1. Advantages and disadvantages of airborne turbines with generator on the ground

Advantages	Disadvantages
• Greater wind speeds higher in the air • If the tether breaks, only the cheapest parts are lost while the ground station remains intact	• Limited possible locations due to air traffic

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Examples of AWE systems with generator on the ground are shown in Table 8.2.

Table 8.2. AWE systems with generator on the ground

Technology	EnerKite 	Skysails Power GmbH 
Reference	https://www.enerkite.de/	https://skysails-power.com/
Power	30-500 kW	Prototype Kite of 200 kW will be tested in a height of 400 m
Technology	Ampyx Power 	Kitemill AS 
Reference	https://www.ampyxpower.com	https://www.kitemill.com/
Power	250 kW version being tested (cooperating with E.ON)	Small 30 kW prototype already successful
Other technologies	Kitepower https://thekitepower.com/	Twingtec https://twingtec.ch/
	Skypull https://www.skypull.technology/	Omnidea https://www.omnidea.net/aerial-platforms.html

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2) Airborne turbine - Generator in the air

The small turbine(s) and the generator are up in the air with a floating device (plane, helium, drone). They are connected to the ground station via a cable.

Table 8.3. Advantages and disadvantages of airborne turbines with generator in the air

Advantages	Disadvantages
• Greater wind speeds higher in the air	• Limited possible locations due to air traffic • Generator is heavy to keep in air

Examples of AWE systems with generator in the air are shown in Table 8.4.

Table 8.4. AWE systems with generator in the air

Technology	Windlift 	Sky WindPower 
Reference	https://windlift.com/	https://www.skywindpower.com/
Other technologies	KiteKraft https://www.kitekraft.de/	

8.4.2. Small-scale wind energy solutions

The following wind energy solutions are of a smaller scale and can therefore be located close to residential buildings. The grid connection and distance regulations are presumably no obstacle for this kind of technology.

1) Modular small wind turbines

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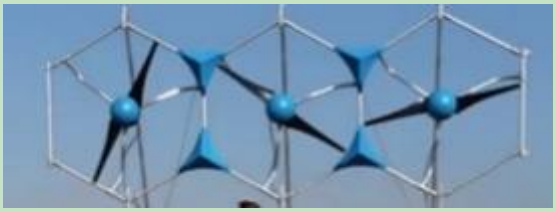
Mowea manufactures small rotators that are modularly assembled and can thus also be gradually expanded.

Table 8.5. Advantages and disadvantages of modular small wind turbines

Advantages	Disadvantages
• Modular • Small rotors can operate at higher wind speeds • Simple construction	• Are easily shadowed by buildings or trees

Table 8.6. Modular small wind turbines

Technology	Mowea 
Reference	https://www.mowea.world/en/
Power	50 kW

2) Vortex Bladeless

The cylinder that is regulated has the same resonance frequency as the resonance frequency of the current wind. Therefore, the cylinder starts to oscillate and an alternator generator turns this vibration into electricity. Prototypes are currently being tested.

The system is 2.75 m in height and is estimated to produce 100 W.

Table 8.7. Advantages and disadvantages of vortex bladeless systems

Advantages	Disadvantages
• No blades • Can be located closely together (minimum distance between two cylinders is half of the height) • Wind from any direction	• Are easily shadowed by buildings or trees

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Table 8.8. Vortex bladeless

Technology	Vortex Bladeless 
Reference	https://vortexbladeless.com/
Power	100 W

3) Small vertical axis wind turbine (VAWT)

VAWTs can produce power regardless of the wind direction. Additionally, the maximum endurable wind speeds are higher as excess energy can outflow easier than on horizontal axis turbines.

Table 8.9. Advantages and disadvantages of vertical axis wind turbines

Advantages	Disadvantages
• Silent • Wind from all directions • Resistant to high wind speeds (60 m/s) • Bird safe • Low maintenance cost	• Not many close together • Are easily shadowed by buildings or trees

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Table 8.10. Small vertical axis wind turbines

Technology	Icewind 	Halcium 
Reference	https://icewind.is/	https://www.halcium.com/
Power	0.1-3 kW	No external blades, not producing yet, plan to start selling in mid-late 2022

8.4.3. Recommendations

The research into innovative wind energy solutions indicates that most of the technologies are still in the development phase by testing a prototype, so technical parameters and actual data do not yet exist. Therefore, it is important to be careful with these innovative solutions as the risk is high since there is not enough information about the implementation of these technologies in large or small-scale projects.

However, airborne energy systems with the generator on the ground (kites or drones) seem to be the most advanced new technology at the time, and it could be implemented on the islands. AWE systems can be used in the southwest and northwest of Saaremaa, as there are great wind speeds, low population density, and the regulations allow greater heights in these areas.

8.5. Expected impacts analysis

Financing innovative technologies could arise more criticalities that traditional ones, mainly linked with the lower level of maturity of the associated projects which is also reflected in lower awareness in terms of risks. For this reason, investment evaluations need to be supported by solid technical analysis.

The Europe Commission provides different opportunities which are generally oriented to support renewable energy sources. Among the most relevant opportunities, ESIF, PDA, and Multi-annual financial framework 2021-2027 including funding instruments such as

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Horizon Europe and Programme for Environment and Climate Action (LIFE) are worth mentioning.

Innovation Fund

When dealing with innovation, the Innovation Fund is a key initiative, being the world's largest funding programme for the demonstration of innovative low-carbon technologies with a budget of €25 billion to invest until 2030 in the EU's climate neutral future (93).

In more detail, the fund can support innovation both on large (capital expenditure above €7.5 million) and small (total capital costs under €7.5 million) scale projects dealing with:

- innovative low-carbon technologies and processes in energy-intensive industries including products substituting carbon-intensive ones
- carbon capture and utilisation (CCU)
- construction and operation of carbon capture and storage (CCS)
- innovative renewable energy generation
- energy storage

The Innovation Fund will support up to 60% of the additional capital and operational costs of large-scale projects and up to 60% of the capital costs of small-scale projects. Grants are awarded through pubic open calls. The second call for small-scale projects is planned to be launched in March 2022 with an expected budget of €100 million and will remain open for five months (93).

Crowdfunding

Crowdfunding in energy typically offers investments in renewable energy projects: solar, wind, and biomass. Most of the active platforms currently offer investing in equity and lending while the remaining platforms propose projects based on rewards in donation or reward mode.

There are two key factors in the use of crowdfunding:

- Access to capital - being an innovative and alternative form to institutional finance for the financing of energy projects. In this sense the first studies on the subject also seem to show that access to capital is faster and easier than other alternative forms of financing.
- The possibility of involving local citizens and stakeholders - this allows to expand the pool of potential investors, to increase the visibility of projects and potentially overcome any local opposition thanks to the implicit redistribution of resources on the territories through the recognition of economic returns to local investors.

Technological analysis

As there has already been interest in Hiiumaa towards kite-based wind turbine systems, two technologies with higher technology readiness levels from aforementioned options are analysed and compared in Table 8.11. The installation of an Enerkite EK200 100 kW energy kite would cost about 420 000 € and produce up to 600 MWh of electricity annually, which can offset 328 tonnes of carbon dioxide emissions. The potentially higher-powered

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SKS PN-14 from SkySails Power could produce more – 1300 MWh of electricity per year, which would be about 1% of Saaremaa's yearly energy consumption or around 3% of the yearly energy consumption of Hiiumaa. The technologies are expected to become cheaper and more productive by 2030.

Although the land used by the generator and power station of the system is low – implying quick & cheap installation, the safety area is quite large due to the height of the kite. This restricts the potential sites for AWE systems to rural areas but offers an opportunity for synergy with land dedicated to agricultural use or PV farms since the moving kite would not impact the PV output (94).

Table 8.11. Comparison of two AWE solutions

	Enerkite EK200 (95)	SkySails Power SKS PN-14 (94) (96)
Rated power	100 kW	80-200 kW (depending on kite size and height)
Annual energy production	600 MWh	520 MWh – 1.3 GWh
Approximate cost	4200 €/kW 70 €/MWh LCOE	40 €/MWh target LCOE (97)
Reduction in CO_2 emissions	328 t/yr	284 – 711 t/yr
Land use	12.2 m long shipping container (30 m^2)	9.2 m long shipping container (22.4 m^2)
Height of the kite	200 - 300 m	200 - 400 m
Manufacturer recommended safety area	500 m from residential areas, high structures and public infrastructure	850 m from residential areas, high structures and public infrastructure, 150 m from trees

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9. Offshore wind farm

9.1. Project overview

Saare Wind Energy is developing an offshore wind farm west of the coast of the island Saaremaa in the Baltic Sea (Figure 9.1) (98). **The aim is to build an offshore wind farm with up to 100 wind turbines with a capacity of up to 1400 MW.**

The Saaremaa offshore wind farm location is unique due to its hybrid nature. The combination of good wind resources, an offshore wind location in line with the Marine Spatial Plan, construction of a transmission system with a connection to the Estonian onshore grid and the opportunity to develop interconnectors across the Baltic Sea to Sweden and Latvia, give Estonia the opportunity to take its first steps in implementing the vision of the Baltic Sea declaration with the first offshore wind park. **Saare Wind Energy has planned to start construction in 2026 and aims to be operational and supply electricity to the grid in 2028.**

Figure 9.1. Saare Wind Energy Offshore Wind Farm (planned)

Simultaneously, another offshore wind farm with a capacity of up to 1000 MW is planned by Eesti Energia in the Gulf of Riga, 10 km from the island of Kihnu. The equipment of the wind farm is interconnected by seabed cables. Cables lead to the mainland in the Häädemeeste area to Kilingi-Nõmme 330 kV substation and in the direction of Latvia when establishing a cross-border connection. Eesti Energia has planned to start construction in 2025 and aims to be operational and supply electricity to the grid in 2028 (99).

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9.2. Production of renewable energy

The aim of the project is to reduce the carbon dioxide emissions shifting from fossil fuels to renewable energy generation.

Table 9.1 summarises estimations of the key indicators for the planned offshore wind parks. Offshore wind park CAPEX is estimated by using a weighted average of total installed costs for offshore wind in 2000-2020 (100). The estimated capital expenditure of the offshore wind farm is in the range of three to four billion euros. As a result, both offshore wind farms would generate more renewable energy than the islands could consume. **Both offshore wind parks combined would statistically generate enough renewable energy for the whole country (1.2 times more).** This will open up opportunities to use excess renewable energy for green hydrogen production and electrification of transport.

Table 9.1. Estimated indicators of planned offshore wind farms

Wind Farm	Saare Wind Energy	Eesti Energia
Generation capacity, MW	1400	1000
Annual energy generation, TWh/yr	5.5	3.9
Capacity Factor	45%	45%
CAPEX, M€	4000	3000
OPEX, M€/yr	18	13
Annual amortisation & OPEX (25 years), M€	314	235
Cost of transmission, €/MWh	57.0	59.7
Consumption		
Estonian electricity consumption, TWh/yr	8.0	
share of the electricity consumption	69%	50%

9.3. Impact analysis

Table 9.2 gives an overview of different case studies about regional impacts of an offshore wind project (101). Each study calculated full-time equivalent (FTE) job creation based on offshore wind farm capacity (MW). While construction job creation statistics range from 1 to 29, operational jobs range from 0.24 to a maximum of 5.5 but the latter seems to be an outlier because most of the case studies stay under 1 job per MW during the operation and maintenance phase.

Table 9.2. Overview of different sources reporting construction and operation FTE/MW numbers

Source	Construction, FTE/MW	Operation, FTE/MW
U.S DE, 2021	1.04	0.45
IRENA, 2020	4.74	2.23
GWEC, 2018	11.72	5.57
Kahouli S., Martin J.C., 2015	6.03	1.02
Sercy et al., 2014	23.97	0.25
US DE, 2013	4.99	1.66
Zammit and Miles, 2013	29.00	1.66
Colbert-Busch, 2012	3.62	0.67
Oxford Economics, 2012	-	0.40
Renewable and Sustainable Energy Reviews, 2011	4.19	0.33

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Source	Construction, FTE/MW	Operation, FTE/MW
Boettcher et al, 2008	-	0.34
Carbon Trust, 2009	1.26	0.27
GWEC, 2008	15.10	0.33

Table 9.3 provides a global overview of job effects per megawatt of wind power installations. The analysed paper reviewed up to 27 articles, papers, and case studies to assess job creation indicators (min and max) (102).

Table 9.3. Overview of offshore wind farm job creation ranges

Journal articles, FTE jobs/MW	Range
Max Direct	0.5 to 15.6
Min Direct	0.9 to 2.7
Indirect	1.22 to 15.7
Total Direct and Indirect	5.2 to 16.55
Max O&M	0.2 to 10.8
Min O&M	0.1 to 3.9
Reports, FTE jobs/MW	**Range**
Max Direct	0 to 11.14
Min Direct	0.71 to 8
Max Indirect	5 to 13.27
Min Indirect	7.42 to 8.66
Max O&M	0.18 to 0.4

Table 9.4 estimates Saaremaa offshore wind farm job creation based on previously analysed parameters. Calculations were made using U.S DE 2021 parameters (Table 9.2). As a result, about 90% of all FTE jobs are created during construction and 10% for operation and maintenance (103) (104). **Given this pessimistic estimation, an offshore wind farm with a capacity of up to 1400 MW will create about 100 FTE jobs located at Saaremaa.**

Table 9.4. Overview of activities and FTE jobs during offshore wind farm lifespan

Segment	Activities	Example jobs	Jobs	% of total
Project planning and development	Site selection Feasibility studies Environmental impact assessments Community engagement Engineering design Project development	Legal. property and tax experts Financial analysts Naval engineers Environmental and geotechnical scientists Ship crew	16.0	1.10%
Procurement	Design specifications Sourcing	Sourcing specialists Engineers	4.4	0.30%
Manufacturing of components and systems	Manufacturing and assembly of nacelles. blades and towers. Manufacturing of monitor and control systems	Factory workers Quality control Marketing and sales Engineers Management	811.0	55.70%
Transport	Transport of components	Drivers Ship crew Technical personnel	1.5	0.10%
Installation	Project site preparation Civil works	Construction workers Technical personnel	152.9	10.50%

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	On-site assembly of components	Naval engineers Ship Crew Health and safety experts Logistics and quality experts		
Grid connection & commissioning	Cabling and grid connection Project commissioning	Construction workers Technical personnel Engineers Health and safety experts	0.4	0.03%
O&M	Ongoing O&M over project lifetime (typically 25 years)	Operators Electrical and naval engineers Construction workers Crane operators Ship crew Helicopter pilots Technical personnel Lawyers Management	97.7	27.90%
Decommissioning (Circular Economy)	Planning or decommissioning or repowering Dismantling the project on-site Disposal and recycling of components Site clearing	Construction workers Technical personnel Drivers Engineers Ship Crew Environmental scientists Health and safety experts	15.1	4.30%
Total FTE jobs			**1099**	**100%**
share of construction jobs			*986*	*90%*
share of operation and maintenance jobs			*113*	*10%*

Table 9.5 gives an overview of job education requirements based on the previously calculated estimation (105). Over half of the jobs created are administrative.

Table 9.5. Overview of human resource and education requirements

Human resource and education requirements	%	FTE
Lower certification	8%	88
STEM professionals	19%	209
NON-STEM professionals	21%	231
Administrative	52%	571
Total	**100%**	**1099**

Job creation is dependent on the choice of perspective towards job creation and which jobs are considered. To ensure consistency when comparing different projects, methods used for data collection, interpretations obtained from employment ratios, territory aspects, speed of technology development, and availability of skilled labour must be considered. Return-to-scale factors, geographical distances, labour-cost differences, and institutional factors are some of the factors that hinder the comparison. Any obtained results are hardly comparable or applicable to contexts outside of wind power and should be interpreted with caution on a country level.

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9.4. Green hydrogen

9.4.1. Hydrogen demand forecast

In 2019, the global hydrogen demand was 75 million tonnes, accounting for 6% of global natural gas consumption and 2% of coal consumption. Demand for hydrogen is expected to increase by 7% per year until 2050 (106). Over 95% of current hydrogen production is fossil-fuel based. Steam-methane reforming is the most common way of producing hydrogen. Figure 9.2 gives an overview of hydrogen production by production method for the following decades (107).

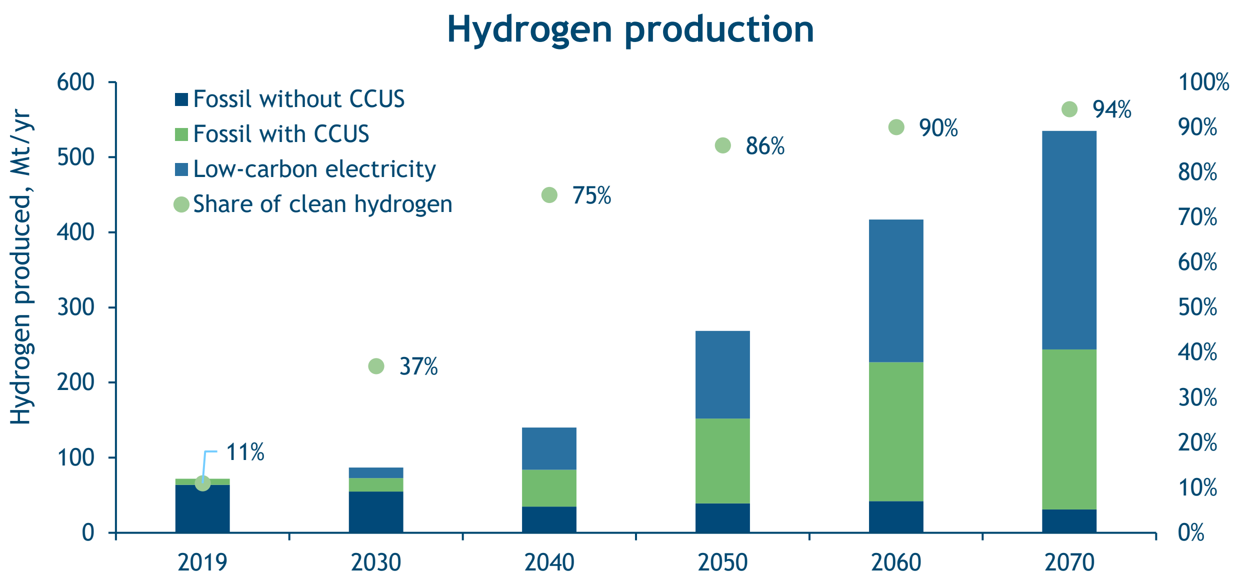

Figure 9.2. Global annual hydrogen production in the Sustainable Development Scenario (107)

Based on the EU hydrogen strategy the plans and the targets to 2030 include:

- Until 2024 installation of at least 6 GW of renewable hydrogen electrolysers will take place in the EU. Hydrogen's production will reach up to 1 million tonnes of renewable hydrogen;
- From 2025 to 2030 installation of at least 40 GW of renewable hydrogen electrolysers and the production of up to 10 million tonnes of renewable hydrogen in the EU;
- From 2030 and after the target is for renewable hydrogen to be deployed at a large scale across all hard-to-decarbonise sectors (108).

Based on projected investment in production capacities, 500 GW is the projected installation of renewable hydrogen electrolysers by 2050 (106). Renewable energy sources, especially offshore wind, will play an important role in this long-term transition for the development of clean and renewable hydrogen.

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From now to 2030, investments in electrolysers could range between €24 and €42 billion. Over the same period, €220-340 billion would be required in addition to scale up and directly connect 80-120 GW of solar and wind energy production capacity to the electrolysers to provide the necessary electricity. From now to 2050, investments in production capacities would amount to €180-470 billion in the EU (108).

9.4.2. Wind to hydrogen projects

REFHYNE project

Attempting to increase the scale of green hydrogen production projects, the largest to date is a 10 MW electrolyser in Rhineland, Germany. The REFHYNE project began in January 2018 and started operation in 2021. The plant cost around 20 million euros, of which half came from EU funds. Powered by renewable electricity using offshore wind, the 10 MW PEM electrolyser will produce up to 1300 tonnes of green hydrogen per year, which will initially be used to produce lower-carbon fuels. The green hydrogen will also be used to contribute to the decarbonisation of other industries (109) (110).

NortH2 project

The Netherlands' national strategy states that a reduction of 65% of the CAPEX for electrolysers can be expected by 2030, from around the current 100 M€ per 100 MW to 35 M€ 100 MW when scaling up to 3-4 GW of electrolysis capacity installed (111).

The objective of the NortH2 project is to achieve large-scale green hydrogen production using offshore wind power. NortH2 wants to produce around 3 to 4 GW of wind energy for hydrogen production before 2030 which will fulfil one of the goals set by the Dutch Climate Agreement as well as to upscale to more than 10 GW by 2040 (111).

Hollandse Kust Wind Farm

Hollandse Kust Noord is one of three offshore wind areas chosen by the Dutch government to be developed by 2023 as part of the country's Energy Agreement for sustainable growth. 69 Siemens Gamesa 11 MW turbines will be erected with a total output of 759 MW. The wind farm will generate around 3.3 TWh annually. The plan is to use power from Hollandse Kust Noord to create a renewable hydrogen hub in the Port of Rotterdam with an electrolyser capacity of around 200 MW (112).

H2RES project

H2RES will have an electrolyser capacity of 2 MW and will be situated in Copenhagen. The project will investigate how to best combine an efficient electrolyser with the fluctuating power supply from offshore wind using Orsted's two 3.6 MW offshore wind turbines at Avedøre Holme. The facility will produce up to around 1000 kg of renewable hydrogen per day which will be used to fuel zero-emission road transport in the Greater Copenhagen

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Area and on Zealand. The project is expected to produce its first hydrogen in late 2021 (113).

9.4.3. Wind to hydrogen potential in Saaremaa

Table 9.6 gives an overview of possible scenarios regarding the Wind to Hydrogen project analysed (114) (115). Based on preliminary calculations, an offshore wind farm with capacity of 1400 MW generates 5.5 TWh of renewable energy. When compared to hourly power consumption in Estonia, 81% of annual wind farm energy generation is consumed and 19% is exported. To produce competitive green hydrogen a low electricity price is essential. Green hydrogen is expected to start becoming competitive with blue hydrogen by 2030 with electricity prices below 30 $/MWh (26 €/MWh) (115). Three scenarios were analysed to estimate hydrogen production by mass:

1. Scenario 1: Instead of exporting electricity, hydrogen is produced with excess electricity.
2. Scenario 2: Hydrogen is produced while the electricity market price is under 20 €/MWh.
3. Scenario 3: Hydrogen is produced when scenarios 1 and 2 apply simultaneously – market price is under <20€/MWh with excess wind energy.

Table 9.6. Scenarios for converting wind energy to hydrogen

Indicator	Value
Consumption	
Annual electricity consumption, TWh/yr	8.0
Annual wind energy	
Generation capacity, MW	1400
Generation, TWh/yr	5.5
Consumption, TWh/yr	4.5
share of generation, TWh/yr	81%
S1: Export, TWh/yr	1.1
share of generation, TWh/yr	19%
S2: Generation while <20 €/MWh, TWh/yr	0.6
S3: Generation while <20 €/MWh and exporting, TWh/yr	0.4
Hydrogen	
Hydrogen conversion, kWh/kg	44
S1: Export to Hydrogen, kg	22 953 940
S2: Generation at 20 €/MWh to Hydrogen, kg	12 818 389
S3: Generation and export at 20 €/MWh to Hydrogen, kg	9 698 458

Table 9.7 gives an overview of total distance travelled annually by all types of road transportation (116). This is later used to estimate the potential of hydrogen in transportation.

Table 9.7. Transport input for hydrogen calculations

Indicator	Value
Total distance travelled, km	11 659 100 000
Distance travelled on the islands, km	600 090 613

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Indicator	Value
Vehicles	702 957
Average distance travelled per vehicle, km/vehicle	16 586
CO_2 emitted by vehicles, $kgCO_2$	2 405 000 000
CO_2 per km, $kgCO_2$/km	0.21

Table 9.8 compares Hydrogen to Power and Hydrogen to Transport carbon dioxide reduction (117). While the results of the analysis show that Hydrogen to Power has better carbon dioxide reduction potential, it is important to note that the Hydrogen to Power calculation uses the current residual mix emission rate of 0.547 tCO_2/MWh. Additionally, the residual mix will decrease as new offshore wind farms are completed and connected to the grid. In conclusion, Hydrogen to Power is an efficient short-term solution for load balancing in the energy grid while fossil fuels are used for power generation. In comparison, Hydrogen to Transport is a long-term project as it is harder to decarbonise transport when alternative fuels are not produced by the renewable power grid. Hydrogen to Transport analysis results show that the islands could decarbonise the transport sector with hydrogen in the range of 73% to 100%.

Table 9.8. Hydrogen to Power and Hydrogen to Transport effect on CO_2 reduction

Scenario logic	S1	S2	S3
Wind to Hydrogen, kg	22 953 940	12 818 389	9 698 458
Hydrogen to Power			
Hydrogen energy, TWh	0.76	0.43	0.32
Electricity, TWh	0.46	0.26	0.19
CO_2 reduction, t*	250 865	140 093	105 995
Hydrogen to Transport			
Hydrogen travel distance, km	1 033 495 727	577 144 917	436 670 799
share of total distance travelled	9%	5%	4%
share of island distance travelled	172%	96%	73%
CO_2 reduction, t	213 186	119 052	90 075

** 0.547 tCO_2/MWh at current grid production*

Table 9.9 estimates wind energy and hydrogen production cost of energy. The estimation is made based on scenario 2. In this case it is suitable to pilot hydrogen production with a capacity of 100 MW with a cost up to 128 million euros. The current CAPEX of hydrogen production ranges from 750 to 1950 €/kW (118). A CAPEX of around 400 €/kW is projected in the future for systems up to 100 MW (119).

Table 9.9. Wind energy and hydrogen production cost of energy

Generation Final product	Electricity Electricity	Electricity & Hydrogen Electricity	Electricity Hydrogen
Generation capacity, MW	1400	1400	1400
Hydrogen capacity, MW	0	100	1400
Annual power generation, TWh/yr	5.5	5.5	5.5
Annual hydrogen generation, TWh/yr	0	0.4	4.2
CAPEX, M€	4000	4128	5785
OPEX, M€/yr	18	20	45
Annual CAPEX+OPEX (25 years), M€	314	326	473
Cost of energy, €/MWh	57	59	113

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Figure 9.3 forecasts the production price of green hydrogen up to 2050 (120). The figure shows that in 2035 the price of green hydrogen produced from wind energy will be competitive with the price of grey hydrogen. In the best-case scenario hydrogen can compete with fossil fuels in three to five years.

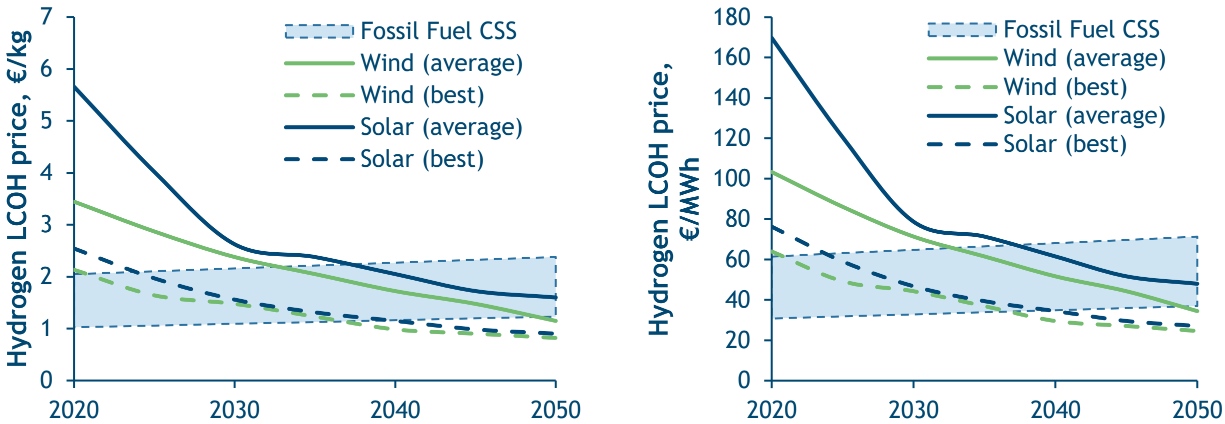

Figure 9.3. Green Hydrogen production price compared to fossil fuel CSS

9.5. Energy storage

9.5.1. Energy storage technologies

There are several storage technologies that are either proven and have been in use for a long time - mature, yet still developing fast and becoming more cost-effective - and immature technologies with great potential of becoming important in the following decades.

When it comes to the islands of Estonia, storage technologies such as pumped hydro and compressed air energy storage can be excluded due to unsuitable geographic conditions and relatively low storage capacity needs. Supercapacitors and flywheels can also be excluded as those technologies are more suitable for frequency regulation. Liquid metal and molten salt technologies are promising, however there is still a lack of experience. Therefore, the three suitable technologies to be considered on the islands are:

- Li-ion batteries
- Flow batteries
- Hydrogen

9.5.2. Operating principles

In Li-ion batteries, the lithium ions carry the charge from one electrode to the other while the electron travels through the outer circuit. While charging, Li^+ ion leaves the cathode through the electrolyte and reduces on the graphite that is used as the anode. The process is reversed during discharging (Figure 9.4).

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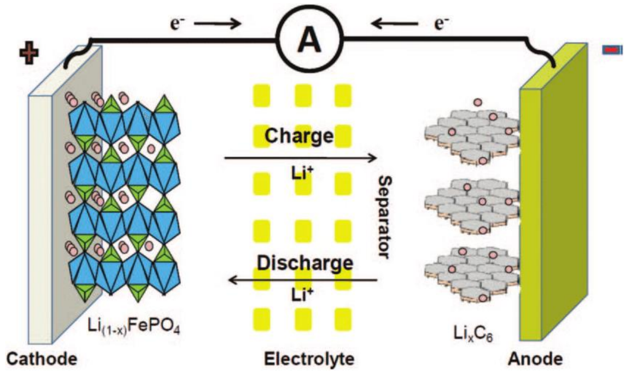

Figure 9.4. Operating principle of a Li-ion battery

The design of the Vanadium Redox Battery (VRB) uses vanadium's ability to exist in four different oxidation states in a solution. The anode and the cathode are in a liquid state. During charging the vanadium ions in the anolyte gain an electron and in the catholyte oxidation occurs. The ion membrane between the electrolytes lets hydrogen pass through to preserve charge neutrality between the two cells. The process is reversed during discharging (Figure 9.5). The battery essentially functions as a two-way fuel cell.

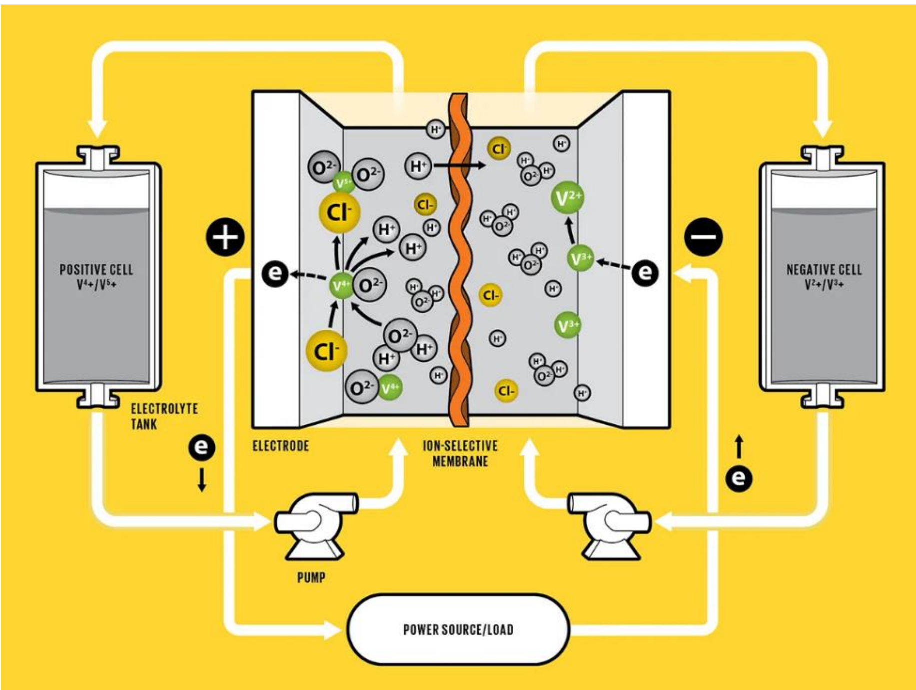

Figure 9.5. Operating principle of a vanadium redox battery

Hydrogen produced via electrolysis is stored in storage tanks and sent to the fuel cell when electricity is needed. In the fuel cell, hydrogen cation is passed through the electrolyte to the cathode where it combines with the oxygen in the air and forms water while at the

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same time electrons are passed through the external circuit - an electric current is generated (Figure 9.6).

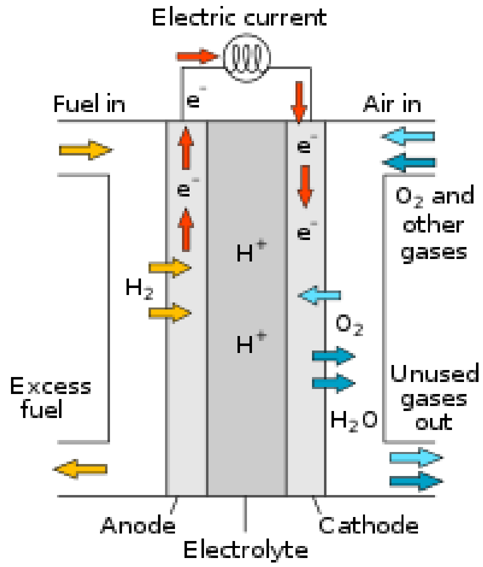

Figure 9.6. Operating principle of a fuel cell

Table 9.10 gives an overview of Li-ion, vanadium redox battery and hydrogen storage technologies, their benefits, and shortcomings.

Table 9.10. Comparison of storage technologies

Indicator	Li-ion	VRB	Hydrogen
Sensible application range (121)	<10 MW	25 kW - 10 MW	100 kW – 100 MW
Useful life (121)	10 years	15 – 20 years	30 years
Specific capacity per mass	100 – 400 Wh/kg (122)	15 - 70 Wh/kg (123)	33.6 kWh/kg (124)
Specific capacity per volume (121)	250 – 693 Wh/l	15 - 25 Wh/l	2.2 kWh/l (in liquid form) (124)
No. of cycles (122) (125)	1000 - 2500	12 000 - 14 000	10 400
Depth of discharge (122)	80%	100%	100%
Round trip efficiency (125)	80%	68%	35%
Reaction time (122) (126)	10 ms	10 ms	<1 s
Work temperature (122)	10-50 °C	10-40 °C	N/A
Suitable function (126)	Short-term storage Frequency regulation Peak shaving	Short-term storage Frequency regulation Peak shaving	Seasonal storage Ensuring fault tolerance
Required ancillary systems (127)	Air conditioning	Pumps, air conditioning	Electrolyser, storage tanks, fuel cell
Other (125) (127)	Explosive Promising developments in new formulations	Capacity does not decrease over time Power and capacity separately changeable	Can also be used in vehicles Complicated/expensive

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Indicator	Li-ion	VRB	Hydrogen
Main benefits		Resilient to short-term overload Inherent temperature control	Waste heat from fuel cells can be utilised
	High energy density and specific energy Existing infrastructure	Power and capacity unrelated Long lifetime Safety Stability	Seasonal storage Usable as transport fuel
Main shortcomings	Overheating Lack of lithium and polluting production Short lifetime	Immature technology Ancillary systems needed Low round-trip efficiency	Low round-trip efficiency Lack of infrastructure
Investment cost (128) (125)	1500 €/kW 360 €/kWh	2000 €/kW 490 €/kWh	2800 €/kW 280 €/kWh

9.5.3. Energy storage projects

An overview of energy storage projects implemented in the past years is provided in Table 9.11. Storage technologies are primarily used for load shifting.

Table 9.11. Examples of energy storage projects

Project	Technology	Peak power	Objective
Hornsdale, Australia (129)	Li-ion	100 MW	Wind farm load balancing, load regulation
Saticoy, California, USA (130)	Li-ion	100 MW	Solar farm load balancing
Viinamäki, Finland (131)	Li-ion	6 MW	Wind farm load balancing
Forshuvud, Sweden (132)	Li-ion	5 MW	Hydropower load balancing
Minami Hayakita, Japan (133)	VRB	15 MW	Solar farm load balancing, frequency regulation
Pfinztal, Germany (134)	VRB	2 MW	Wind farm load balancing
Yadamalka, Australia (135)	VRB	2 MW	Solar farm load balancing
Bella Coola, Canada (136)	VRB + Hydrogen	125 kW + 100 kW	Hydropower load balancing
Ramea Island, Canada (137)	Hydrogen	250 kW	Wind farm load balancing
Lolland, Denmark (138)	Hydrogen	8.5 kW	Part of Europe’s largest hydrogen co-generation project, converting excess wind power to hydrogen

9.6. Risk analysis

Table 9.12 gives an overview of the risks associated with the development of offshore wind farms, hydrogen, and energy storage, the expected impact they would have, the probability of their occurrence and measures to mitigate the risks.

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Table 9.12. Risk analysis of the synergy of offshore wind with aquaculture and port activities

Description of risk	Probability	Impact	Mitigation measures
Project planning			
The terms of the joint undertaking are not agreed upon	Medium	High	The positive impacts for all stakeholders need to be clearly defined at an early stage
Public opposition	Medium	Medium	Engaging the local community throughout the planning process, implementing suggested changes
Finances and the economy			
The capital expenditure is greater than expected	Medium	Medium	Thoroughly assessing costs related to the project using conservative estimates
Difficulty obtaining financing	Medium	Medium	Exploring possible alternative financing methods and involving external investors
Production volumes are lower than expected	Medium	High	Preparing the projects using conservative estimates for the output of production
Energy prices drop extending the project payback period	Low	Medium	Preparing the projects using conservative energy price estimates
Permits			
The plant does not receive a permit for operation	Low	High	Learning from the experience of other plants and creating a compelling project plan
Environmental requirements are not met	Low	Medium	Consider the need for possible additional investments to fulfil environmental requirements
Operation and maintenance			
Lack of qualified workforce	Medium	Medium	Training of personnel prior to commencing operation, gaining public traction to the field

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10. Wave energy

10.1. Overview

Wave energy is an emerging industry with most technologies currently at an immature stage (Table 10.1). The technology development faces challenges from the fact that the marine environment is uncertain to work in. Policy frameworks and economic incentives from governmental bodies are other decelerative factors for the growth of wave energy. Comparing wave power to wind power, the latter harvests a much lower energy density in the range of 1 kW/m^2 while wave power generates up to 24-70 kW per metre of wave, with peak near-shore power ranging from 40-50 kW per metre (139) (140).

Table 10.1. Overview of wave energy technology projects (141)

Category	Device	Dimensions	Capacity (kW)	Projects to Date
Point absorber	Pontoon Power Converter (PPC)	80 m	3619	R&D Phase
	Ocean Energy buoy (OE)	50 m	2880	R&D Phase (1:4 scale model)
	Wavebob	20 m	1000	R&D Phase (1:4 scale model)
	CETO	7 m	260	Garden Island, Western Australia Wave Hub, Cornwall, UK Pre-consented (3 MW each project)
	Seabased AB	3 m	15	Sotenäs, Sweden Pre-consented, 10-MW demonstration plant
Attenuator	Sea Power	16.75 m	3587	Galway Bay, Ireland, test site
	Wave Star	70 m	2709	Hanstholm, Denmark (1:2 scale model, 600-kW machine
	Pelamis	150 m	750	Aguaçdoura, Portugal (2.25 MW project) Company - Financial problems
	Oceantec	52 m	500	Sea trials - 1:4 scale model
Terminator	Wave Dragon	-	5900	Nissum Bredning, Denmark, prototype testing

The Ocean Energy Systems (OES) assessments based on technical potential criteria predict the worldwide wave energy installation capacity of 337 GW by 2050 whereas the International Energy Agency (IEA) estimates a 63 GW installation capacity by considering technical potential and policy frameworks criteria for the same year (142) (143).

The uncertainty of the capital expenditure (CAPEX) is high due to the dependence on technology and deployment depths (144). Cost targets for ocean energy were established in the SET Plan Declaration of Intent on Ocean Energy and specifically for wave energy the target is 200 EUR/MWh for 2025 and 150 EUR/MWh for 2030 (145). Due to the immature stage of the technologies and cost-related uncertainty, wave power can be seen as a potentially prospective long-term solution.

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10.2. Potential for the Estonian islands

The theoretical available wave power in Western Estonia is 391 MW. **Considering the areas that do not have any kind of restrictions the potential falls to 297 MW** (146). By comparison, the estimated offshore wind power potential of Estonia is 7 GW or about 23 times greater (147).

The average wave energy flux (up to 2.55 kW/m) is largest near the shore of Saaremaa as can be seen in Figure 10.1. From 1970 to 2007 the average annual duration of onshore energy flux not being available due to the seasonal conditions was 102.7 days/year or about 28% of the year near the shore of Saaremaa (147).

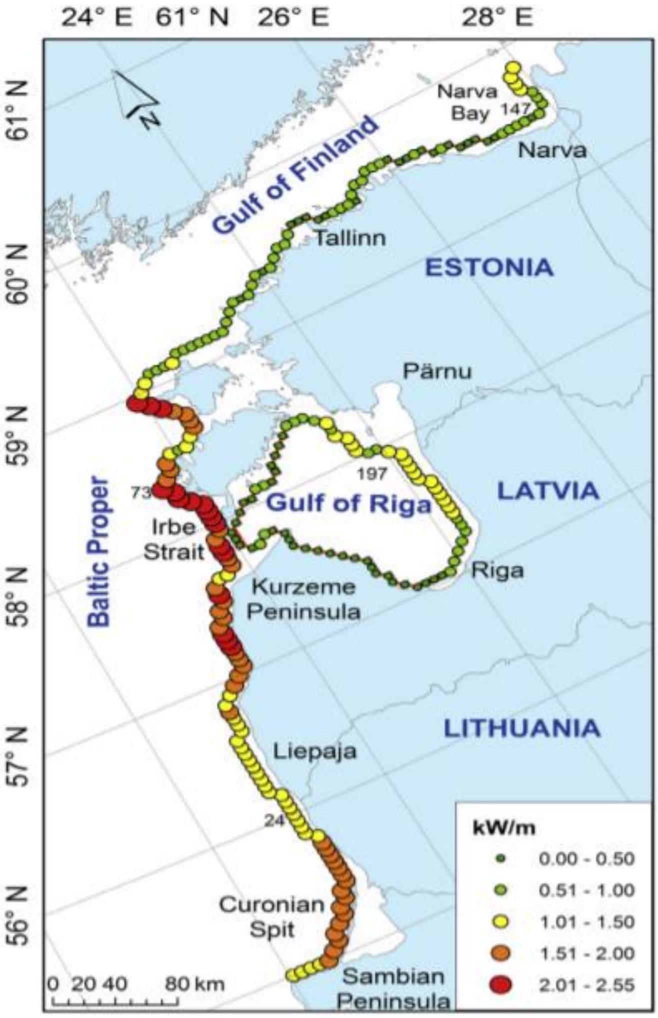

Figure 10.1. Long-term average energy flux along the coasts of the eastern Baltic (146)

The peak wave power value reached 680 kW/m during a furious storm in the north-eastern Baltic Proper near the Western Estonian archipelago. The wave energy flux exceeded 100 kW/m on very few occasions. This frequency was about 15 h/year near Saaremaa. The numbers in each cell show the annual average of hours with the relevant wave conditions

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for a specific area near Saaremaa in 1970-2007. The colour scale shows the annual bulk energy resource in kWh/m (146).

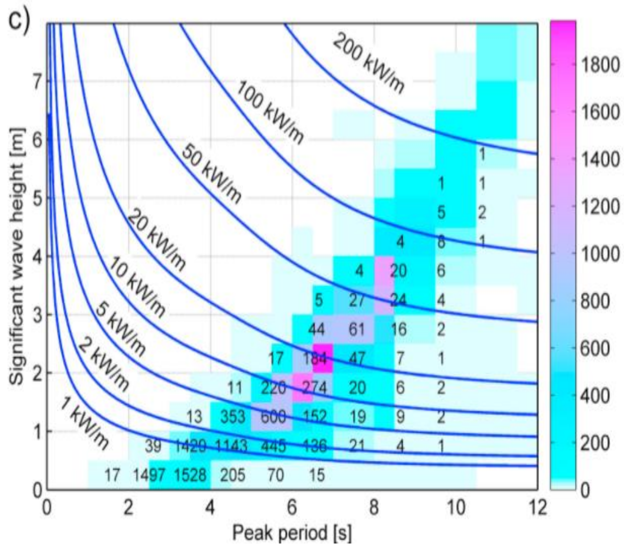

Figure 10.2. Combined scatter and energy diagram (146)

10.3. Potential solution for the wind energy innovation area

The Maritime Spatial Plan defines an area further west of Saaremaa as an innovation area for floating offshore energy solutions. The area could be used for testing and developing new solutions such as wave energy applications.

The H2OCEAN project created an innovative design for an economically and environmentally sustainable multi-use open-sea platform to harvest offshore renewable power. The H2OCEAN platform has harvested wind and wave power, using part of the energy on-site for multiple applications – including a multi-trophic aquaculture farm, and converting the excess energy on-site into hydrogen that can be stored and shipped to the shore as a green energy carrier or supplied to ships as a transport fuel (148).

The basis for the offshore energy harvesting units is a wind and wave hybrid floating modular structure which is based on the coupling of an existing design of large stable floating wave energy converter with a vertical axis wind turbine. The energy is used to directly supply nanomembrane reverse osmosis units at elevated pressures to provide fresh water to electrolytic generators for hydrogen production. The produced hydrogen is compressed and stored in modular vessels on the service platform for collection by ship (148).

The oxygen derived from hydrogen electrolysis can be stored or used directly to boost fish weight gain and prevent algal blooms and Biochemical Oxygen Demand contamination caused by high-density fish farming. To reduce the risk of handling these sensitive processes in a harsh environment, they have been gathered in a single service module

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which is a stable floating structure unlike other energy harvesting units. In addition, the service platform will be equipped with both autonomous remote weather and deep ocean marine monitoring systems including physical, chemical, and biological oceanographic measurements. The latter will measure the effect of the platform on the local environment and allow comparison with other nearby ocean stations (148).

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11. Expansion of the renewable energy solution of Ruhnu

11.1. Overview

At the end of 2020 Enefit Green, the renewable energy system operator of Ruhnu increased the capacity of their solar farm by 50 kW, which increased the total installed capacity to 200 kW (149). In total, the solar PV capacity was increased to 200 kW while the wind turbine capacity remained at 50 kW, the battery capacity remained at 222 kWh or 180 kW and two 160 kW diesel generators using biodiesel remain in use (150).

Based on the installed solar and wind power capacity and prior annual production levels, it is estimated that solar and wind power at the current configuration can supply about 357 MWh of electricity per year, which forms 59% of the electricity consumption. In addition to the renewable energy solution of Ruhnu, it is estimated that the municipality will install 30 kW of solar panels for the ambulance centre, which will generate an additional 5% of the electricity produced on the island.

The target for Ruhnu is to reach 70% of renewable sources for electricity production by 2030. Although the goal has been reached by combining solar and wind energy with diesel generator that run on biodiesel, the estimated capacity for additional solar PV generation was assessed for reaching the target of 70% with only wind and solar power. It was estimated that an additional 34 kW of solar panels need to be added to the renewable energy solution to reach a solar and wind penetration of 70%. As solar and wind are fluctuating energy sources, additional storage capacity is required to compensate for the overproduction coming from the additional PV panels installed by both the municipality and the energy system operator.

The total cost of expansion is in the range of 50 000 euros. The cost of the added solar panels is about 34 000 euros and the cost of additional batteries is about 16 000 euros. The investment will not reduce carbon dioxide emissions as the currently used biodiesel is carbon neutral. With the expansion, the solar and wind energy generation at the renewable energy solution will become responsible for 65% of the electricity generated on the island with 5% of electricity generated by the local municipality. As a result, 70% of the electricity generated in Ruhnu will be generated from locally available wind and solar resources. An overview of the current situation and the upgraded solution is given in Table 11.1.

The cost of the upgrade is expected to be carried by the operator of the renewable energy system. As the increase in storage capacity is partially due to the planned PV panels to be installed by the municipality, the municipality should cover a part of the costs related to the expansion of the storage capacity as it is also necessary for the efficient functioning of the municipality-owned system. As an alternative, the municipality of Ruhnu can install separate batteries for storing electricity on site at the ambulance centre.

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Table 11.1. Upgrade of the renewable energy solution

Indicator	Value
Current situation	
Installed solar PV capacity, kW	200
Installed battery capacity, kWh	222
Forecasted annual solar and wind electricity production, MWh	357
Share of electricity produced	59%
Upgraded solution	
CAPEX, €	50 000
Installed solar PV capacity, kW	234
Installed battery capacity, kWh	350
Forecasted annual solar and wind electricity production, MWh	421
Share of electricity produced on the island	65.0%
Total share of electricity produced from solar and wind	70.0%

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12. Installation of PV panels for the ambulance centre of Ruhnu

12.1. Overview

The municipality of Ruhnu is planning to renovate the ambulance centre of the island and include the installation of 30 kW of solar panels as a part of the project. Based on the solar conditions, a 30 kW PV farm with optimal placement would produce about 30 MWh of electricity per year, which forms about 5% of the total electricity consumed on the island and about 36% of the electricity consumed by the buildings of the local municipality. The cost of the investment is estimated based on the average special cost of 1000 €/kW for small-scale PV installations. The estimated investment cost of the solution is 30 000 euros. Table 12.1 gives an overview of the installation of 30 kW of solar panels. As the electricity consumed on the island is produced from wind and solar energy and biodiesel, the electricity is carbon-neutral and the investment does not result in the reduction of carbon dioxide emissions.

Table 12.1. Installation of 30 kW of solar panels

Indicator	Value
CAPEX, €	30 000
Annual electricity production, MWh	30
Reduction of CO_2 emissions, tCO_2/yr	-
Share of electricity produced on the island	5.0%
Share of electricity consumed by the municipality	36.1%

The investment is to be carried out by the municipality. A partial subsidy can be applied as part of the full reconstruction project. As the annual electricity production exceeds the needs of the building, a contract with the local electricity supplier needs to be signed to sell the excess electricity. Due to the increase of solar power on the island and its inconsistent supply, it is likely that the energy system operator needs to increase the storage capacity with additional batteries.

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13. Renovation of street lighting

13.1. Overview

Over the past few years, the municipalities have renovated a large share of their street lighting infrastructure with support from the Environmental Investment Centre (151) with some of the projects currently still ongoing. Street lighting on the island of Ruhnu has been fully replaced by efficient LED lights. The municipalities of Saaremaa, Muhu, and Hiiumaa still have a large amount of street lighting infrastructure to be replaced to reach the determined sub-objective.

Table 13.1 gives an overview of the investments to be carried out by 2030 and the resulting reduction of electricity consumption and carbon dioxide emissions based on the information provided by the municipalities. **Street lighting renovation on the islands can lead to a 540 MWh/yr decrease in electricity consumption and a reduction of 290 tCO_2/yr. The total required investment is 3.6 million euros.** Although there will be no further funding for the projects from the European Union (152), the amount of subsidy required for the projects to pay off the investment cost by the end of the expected lifetime of 20 years has been estimated. Without a subsidy the projects are not financially viable and increase the costs of municipalities.

Table 13.1. Street lighting renovation

Indicator	Value
Investment and subsidy requirement	
Total CAPEX, M€	3.60
CAPEX for Saaremaa, M€	2.07
CAPEX for Muhu, M€	0.10
CAPEX for Hiiumaa, M€	1.43
Total subsidy required, M€	2.00
Required subsidy for Saaremaa, M€	1.26
Required subsidy for Muhu, M€	0.02
Required subsidy for Hiiumaa, M€	0.70
Reduction of electricity consumption	
Total reduction of electricity consumption, MWh/yr	540
Reduction of electricity consumption in Saaremaa, MWh/yr	270
Reduction of electricity consumption in Muhu, MWh/yr	30
Reduction of electricity consumption in Hiiumaa, MWh/yr	240
Contribution to objectives	
Total reduction of CO_2 emissions, tCO_2/yr	290
share of the total objective	0.2%
share of total street lighting sub-objective	38.6%
share of street lighting sub-objective in Saaremaa	28.8%
share of street lighting sub-objective in Muhu	54.8%
share of street lighting sub-objective in Hiiumaa	58.2%

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13.2. Renovation of street lighting in Saaremaa

Saaremaa currently has about 5200 lighting points, of which nearly 3700 or approximately 70% have been renovated and use efficient LED lights as source of lighting. The remainder mostly consistsy of depreciated sodium-vapour lamps. The municipality itself has set a goal of 90% of LED lights for street illumination for 2030 while the sub-objective defined in the SECAP set the target at 100%.

Based on average working hours and an estimated reduction in power when switching from sodium-vapour lamps to LED lights, nearly 270 MWh of electricity can be saved annually by upgrading the remainder of the street lighting infrastructure. That would lead to an annual reduction of 147 tCO_2 emissions based on the carbon intensity of electricity consumed in 2020.

The estimated investment cost based on other street lighting renovation projects is 2.07 million euros. The cost of the investment is primarily driven by the need to renew the whole infrastructure as in addition to the lights, new masts, cables, and control panels are needed and the installation is a time-consuming procedure. Due to large capital expenditure and relatively small energy savings, the reduction in the cost of electricity cannot cover the cost of investment over the expected lifetime of 20 years without a subsidy. The required subsidy needed for the project to be able to pay off the investment cost was estimated to be 1.26 million euros or 61% of the investment cost.

13.3. Renovation of street lighting in Muhu

The street lighting of Muhu is currently primarily based on sodium-vapor lamps with about 100 sodium-vapour lamps and 15 LED lights. The main change that has taken place in the past years is the expansion of the centre square of the island, which significantly increased the number of lights and energy consumption of street lighting.

Based on average working hours and an estimated reduction in power when switching from sodium-vapour lamps to LED lights, about 26 MWh of electricity can be saved annually. That would lead to an annual reduction of 14 tCO_2 emissions based on the carbon intensity of electricity consumed in 2020.

As a large part of the street lighting infrastructure is relatively new, the required investment per lighting point is lower as in most cases only the light needs to be exchanged. The estimated investment cost of renewing the street lighting solution of Muhu is approximately 100 000 euros. The required subsidy needed for the project to be able to pay off the investment cost was estimated to be around 21 000 euros or 21% of the investment cost. The lighting points where only the light needs to be exchanged can be renovated cost-efficiently without a subsidy.

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13.4. Renovation of street lighting in Hiiumaa

Hiiumaa currently has about 730 sodium-lamp lighting points that need to be renovated by 2030. Based on average working hours and an estimated reduction in power when switching from sodium-vapour lamps to LED lights, approximately 240 MWh of electricity can be saved annually by upgrading the remainder of the street lighting infrastructure. That would lead to an annual reduction of 132 tCO_2 emissions based on the carbon intensity of electricity consumed in 2020.

The estimated investment cost based on other street lighting renovation projects is 1.43 million euros. The cost of the investment is primarily driven by the need to renew the whole infrastructure as in addition to the lights, new masts, cables, and control panels are needed and the installation is a time-consuming procedure. Due to large capital expenditure and relatively small energy savings, the reduction in the cost of electricity cannot cover the cost of investment over the expected lifetime of 20 years without a subsidy. The required subsidy needed for the project to be able to pay off the investment cost was estimated to be around 700 000 euros or 49% of the investment cost.

13.5. Consumption of renewable electricity for street lighting

The renovation of street lighting to 100% share of energy efficient luminaires can reduce the electricity consumption of street lighting by 536 MWh/yr and the resulting carbon dioxide emissions by 293 tCO_2/yr based on the carbon intensity of electricity consumed in 2020. To reach the target reduction of 760 tCO_2/yr set by the sub-objective, the remainder of the emissions, 467 tCO_2/yr, needs to be reduced by using electricity with a green certificate and therefore making street lighting fully renewable.

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14. Electrification in transport

14.1. Development of EV charging network

For widespread adoption of electric vehicles, the development of an electric vehicle charging network is essential. Lack of sufficient public charging infrastructure can be a barrier to the adoption of electric vehicles. However, according to research, 50–80% of charging events take place at home, 15-25% of charging occurs at work, and less than 10% of charging events take place at other locations – public charging stations (153). The lower the number of garages available for regular daily charging, the higher the needs for public charging infrastructure (154). In addition, fast charging infrastructure near major travel corridors is necessary to complement a denser slow charger network (154).

One way to analyse future electric vehicle charging infrastructure needs is to consider the ratio of electric vehicles per established public charging points. Although the electric vehicle market is still in its relatively early stages across the entire world, the most well-developed electric vehicle market is Norway where the ratio of electric vehicles per public charging points is 19. Using Norway as an example, the number of necessary public charging points is and the investment necessary is estimated in Table 14.1 (155).

Table 14.1. Electric cars and public charging points

Indicator	Value
Number of electric cars in 2021	
Hiiu county	14
Saare county	67
Estimated number of electric cars in 2030	
Hiiu county	800
Saare county	2 500
Number of public charging points in 2021	
Hiiu county	10
Saare county	16
Number of public charging points in 2030	
Hiiu county	42
Saaremaa	126
Muhu	8
Investment, €	
Hiiu county	94 000
Saaremaa	277 000
Muhu	18 000

14.2. Electrifying local government vehicles

One part of the reduction of CO_2 emissions in the transport sector on the islands is for the local governments to invest in electric vehicles. An overview of the necessary investments and possible savings is given in Table 14.2. It is assumed the local governments can apply

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for grants to purchase electric vehicles as the Ministry of Environment has said that in order to reach national objectives of reducing CO_2 emissions in transport, supporting the purchasing of electric vehicles including vans is necessary (156). Similar grants have previously been given in the amount of €5000 per vehicle (157). Since in Saaremaa there is great potential for biomethane use in transport, only around 60% of vehicles must be replaced with electric vehicles. In Hiiumaa and Ruhnu it is possible to eliminate all CO_2 emitted by local government vehicles.

Local governments can encourage the electrification of the transport sector by installing charging infrastructure at local government buildings. The main purpose of the charger would be to charge local governments' fleets. However, these could also be used for charging by the local population while using the local governments' services. It is possible for the local governments to install chargers using entirely their own funds or to collaborate with a public charger network service provider. The optimal investment in chargers is estimated according to the number of electric vehicles that it is required to be purchased according to this paragraph. It is assumed that 22 kW smart chargers would be installed, which have an approximate cost of €1200 per charger if no substantial electrical works need to be performed.

Table 14.2. Electrification of local government vehicles

Indicator	Value
Investment and subsidy	
Total investment, €	6 105 400
Total investment in vehicles, €	5 577 000
Investment for Saaremaa, €	4 200 000
Investment for Hiiumaa, €	990 000
Investment for Muhu, €	280 000
Investment for Ruhnu, €	107 000
Total subsidy for vehicles, €	460 000
Subsidy for Saaremaa, €	350 000
Subsidy for Hiiumaa, €	85 000
Subsidy for Muhu, €	20 000
Subsidy for Ruhnu, €	5000
Total investment in chargers, €	68 400
Investment for Saaremaa, €	42 000
Investment for Hiiumaa, €	20 400
Investment for Muhu, €	4800
Investment for Ruhnu, €	1200
Total reduction of CO_2 emissions, t	360
share of local government vehicles' sub-objective in Saaremaa	55%
share of local government vehicles' sub-objective in Hiiumaa	100%
share of local government vehicles' sub-objective in Muhu	30%
share of local government vehicles' sub-objective in Ruhnu	100%

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14.3. Private electric vehicles

To meet the islands' sub-objectives of reducing CO_2 emissions in the transport sector, changes to the fleet of private vehicles are also necessary. The estimated number of electric vehicles in Hiiu County by the year 2030 is around 800. However, in order to reach the previously mentioned sub-objective, the amount of internal combustion vehicles powered by fossil fuels replaced by electric vehicles needs to be around 2600. The situation is similar in Saaremaa. Current estimations show that Saaremaa might be home to around 2400 electric vehicles by 2030. To meet the sub-objective, the number of electric vehicles needed is about 5900 units. The estimated number of electric vehicles in Muhu by the year 2030 is 150, to reach the sub-objective it would need to be around 490. **To reach the estimated amount of electric cars on the islands, an investment of around 122 M€ is required, to reach the sub-objectives of the regions, an investment of 328 M€ would be needed.**

The reduction in energy consumption and respective CO_2 emissions along the necessary investments into electric vehicles is shown in Table 14.3. Estimations are based on current new electric vehicle prices. It is assumed that an average new electric vehicle costs around €36 500 based on a selection of new electric vehicles.

Table 14.3. Private electric vehicle adoption scenarios

Indicator	Value	
	Projected	Objective
Total reduction of energy consumption, MWh/yr	26 096	70 303
in Saaremaa, MWh/yr	18 541	45 772
in Muhu, MWh/yr	900	2939
in Hiiu county, MWh/yr	6655	21 592
Total reduction of CO_2 emissions, t/yr	6652	17 925
in Saaremaa, t/yr	4721	11 655
in Muhu, t/yr	227	740
in Hiiu county, t/yr	1704	5530
Total investment in vehicles, M€	122	328
in Saaremaa, M€	87	215
in Muhu, M€	5	18
in Hiiu county, M€	29	95

14.3.1. Ruhnu communal electric vehicles

Due to Ruhnu's size, low number of vehicles, and limited mileage there is an opportunity to invest in communal electric vehicles which could help achieve the subobjective of reducing emissions from local private vehicles. An overview of the project's main parameters is presented in Table 14.4. As a result of the project, by investing in three communal electric vehicles, half of the island's fossil fuel powered trips could instead be taken by using the communal electric vehicles. In addition to the vehicles, a communal charging point (2 x 22 kW) needs to be installed.

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An investment in communal electric vehicles could also be a steppingstone in improving the island's electrical system by increasing the available battery storage capacity of the grid. Communal EVs could provide an additional 120 kWh of battery storage. Furthermore, as per chapter 14 by electrifying Ruhnu's government transport, an additional 70 kWh can be added. The current battery storage capacity of the island could be nearly doubled if necessary, which can lead to a higher proportion of the island's electricity produced from locally available renewable sources instead of imported biodiesel.

Table 14.4. Ruhnu communal electric vehicles for private transport

Indicator	Value
Investment, €	95 000
including subsidy, €	15 000
Reduction of CO_2 emissions, t	16
Share of subobjective in Ruhnu	100%

14.4. Electric micromobility

In addition to large electric vehicles, electric micromobility will play an increasing role in the following years. In the summer of 2021, electric scooters were first introduced to the streets of Kuressaare by Bolt and they were quickly accepted by the locals. The local government of Hiiumaa is supporting an electrical bicycle rental project that has already started renting bicycles in Kärdla and plans to establish three locally designed solar powered stations. Renting out electric bicycles is also done by local hotels and guest houses. Tartu Smart Bike Share is a good example of a municipality-supported electric bicycle sharing system that has attracted many users and can also be used as a guideline on the islands.

Using the opportunities presented by electric micromobility has the potential of changing habits, reducing carbon dioxide emissions by reducing the usage of cars and enabling the use of locally produced renewable electricity. Even though electric micromobility solutions are potentially not going to be very profitable on the islands and are largely impacted by seasonality, it is important to support such initiatives as they have the potential of leading to an overall change in the mindset. In addition to reducing the usage of cars, the usage of electric bicycles can also make people look for overall more sustainable modes of transport as a result of raising awareness. Electric micromobility can also expand what the islands have to offer. For example, renting electric fatbikes in Ruhnu can make it easier to reach the locations otherwise only accessible on foot. That solution can also help tourists be more in contact with nature on the other islands.

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15. Biomethane production

15.1. Overview

The production of biomethane can provide value in the form of a carbon-neutral fuel for industrial processes, heating and transport, and as a way to reduce the strain on farmland by processing manure to a more efficient fertiliser as digestate. **As a result of the analysis, it was determined that Saaremaa has the potential for establishing a biomethane plant with an annual production capacity of nearly 35 GWh, which is sufficient to cover the needs of the public transport in Saaremaa and Muhu, exchange fossil fuels being used in the industrial sector, and provide carbon-neutral fuel for local government vehicles and private transport. The estimated capital expenditure of the plant is in the range of eight million euros. Biomethane production is expected to be cost-effective without financial support.** An overview of biomethane production is given in Table 15.1.

Table 15.1. Biomethane production

Indicator	Value
Biomethane production	
Biomethane production capacity, Mm^3/yr	3.7
Biomethane energy content, GWh/yr	34.6
CAPEX, M€	8.0
NPV, M€	12.9
IRR	30.0%
Biomethane consumption	
Business sector, GWh/yr	22.7
Public transport, GWh/yr	3.3
Local government vehicles, GWh/yr	0.4
Private transport, GWh/yr	8.1
Additional consumption	
Increased consumption of heat, GWh/yr	6.5
Increased consumption of electricity, GWh/yr	3.3
Contribution to objectives	
Total reduction of CO_2 emissions, tCO_2/yr	6220
share of the total objective	6.9%
Reduction of CO_2 emissions in the business sector, tCO_2/yr	4850
Reduction of CO_2 emissions in public transport, tCO_2/yr	770
share of the total objective in Saaremaa	5.4%
share of the total objective in Muhu	1.3%
share of public transport sub-objective in Saaremaa	100%
share of public transport sub-objective in Muhu	100%
Reduction of CO_2 emissions of local government vehicles, tCO_2/yr	118
share of the total objective in Saaremaa	0.1%
share of local government vehicles' sub-objective in Saaremaa	30.7%
Reduction of CO_2 emissions of private transport, tCO_2/yr	2110
share of the total objective in Saaremaa	2.3%
share of private transport sub-objective in Saaremaa	14.1%

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15.2. Scope of intervention and general description

15.2.1. Project overview

The farmers of Saaremaa have been looking for ways to put the manure produced in their farms to better use and reduce the impact on the environment from using fresh manure as a fertilizer. Biomethane production can offer a solution to the farmers and provide locally produced biofuel to potential consumers. The establishment of a biomethane production plant on the island is a joint undertaking by the farmers, the gas supplier interested in selling biomethane to their customers, and the project developer with technical expertise. The project is in line with the objectives set in the SECAP of Saaremaa.

15.2.2. Background

There are seven pigsties with more than 1000 pigs and 10 cattle and dairy farms with more than 300 bovines in Saaremaa (158). All of those farms produce large quantities of manure that at the moment is sent to fields as fertiliser but that could instead be used for the production of biomethane. In the production process, digestate is formed which is a better fertiliser than fresh manure. Therefore, the production of biomethane would benefit both the climate ambitions and the interests of the farmers. In addition to manure, biological waste from the food processing industry could be used in methane production (159).

15.2.3. Project objectives

The aim of the project is to utilise manure and biological waste from the food processing industry to produce biomethane. The aim is to produce biomethane in the quantity required for covering the needs of the public transport of Saaremaa and Muhu, the fuel consumption of larger industrial companies to replace currently used fossil fuels, and provide locally produced renewable fuel to vehicles to reduce the carbon dioxide emissions resulting from the consumption of fossil fuels.

15.2.4. Project benefits

The main benefits of the project are related to the production of biomethane which can be used to reduce the dependency on biofuels. Additionally, the project has a positive impact on the environmental conditions of the fields currently fertilised with fresh manure. The project has a relatively low impact on employment opportunities.

15.2.5. Scope

The production of biomethane includes all larger farmers of the island within 30 road kilometres from the planned location of the plant. The scope of the plant is directly related to the capacity of manure available from the farms which sets a limitation to the production of biomethane. Additional sources for the production such as grass can be considered.

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15.2.6. Project boundaries and constraints

Currently, the biomethane production plant is in a preliminary planning stage and no permits have been granted and contracts have not been concluded. To establish the plant, a building permit needs to be acquired from the local municipality in accordance with the functional zoning of the municipality which limits the potential locations of the plant. Due to the expected environmental impact of the plant, environmental impact assessment likely needs to be carried out (160). Carrying out environmental impact assessment is also recommended to better understand all of the potential risks and effects and provide the public with a clear overview of the planned activities.

15.2.7. Business model and relationship scheme (governance)

The main revenue of the plant comes from the sale of biomethane either to the end consumers or to the energy company interested in selling biomethane to their customers. It is assumed that farmers and food processing companies can provide the plant with biological waste without a fee. However, it is also possible to either charge them a gate fee or pay for the waste to potentially increase the amount of biological waste available. The plant is established as a joint venture by the farmers, the gas supplier, and the project developer. After acceptance, the facility can be run by the farmers or external investors.

15.3. Description of the preferred option

15.3.1. Project overview

The preferred option for increasing the value of locally produced biological waste is the production of biomethane generated by anaerobic decomposition. Production of biomethane is chosen as it can be used both as a fuel for heat production and as a replacement for fossil fuels in transport (161).

According to the information from the developers of the project, a <30 km radius on road from the planned site of the plant was assumed as the range for including farms. All the major food processing facilities, five pigsties, and eight cattle farms fall within that range. The quantity of manure produced in the range exceeds 130 kt/yr. Based on the biomethane potential of biological waste from the food industry and manure, it was estimated that about 3.7 Mm^3 of biomethane can be produced annually (162). This quantity of biomethane has an energy content of 34.6 GWh.

Based on the specific investment costs of various projects and analyses (163) (164) (165) (166) (167) (168) (169), it was determined that the capital expenditure for the biomethane plant is in the range of eight million euros. The cost of the investment consists of the costs related to the production of biogas, the upgrading of biogas to biomethane, the establishment of the necessary grid connections, and the construction of a wood chip powered boiler house to provide heat to the anaerobic decomposition process. The

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expected revenues come from the sale of biomethane. Potential additional revenues from the sale of digestate are not considered.

Based on the preliminary state of the project and the time required to carry out planning procedures and reach financial close, it is expected that the investment will be carried out in 2025 and production of biomethane will begin in 2026. According to the cost-benefit analysis based on current and expected market prices, operating income and costs, the project is financially viable with a net present value (NPV) of 12.9 million euros over the lifetime of 15 years and with an internal rate of return (IRR) of 30.0%.

15.3.2. Impact analysis

The establishment of a biomethane production facility has primarily positive socio-economic and environmental impacts. The main impacts are related to the direct displacement of fossil fuels. However, there are also a number of positive impacts on non-energy sectors. The production of biomethane turns waste into a valuable resource which is the core principle of an efficient circular economy (170).

In addition to the energetic potential, the production of biomethane enables the reduction of the use of commercial fertiliser as in fermented digestate nitrogen is mainly found in the form of ammonium which is more suitable for the development of plants. Fermented animal waste increases agricultural productivity by around 10–30% compared to the usage of fresh manure (171).

The sources of odour in manure are usually nitrogen and sulphur compounds. According to a study, 94% of the odour can be removed in anaerobic fixed film reactor in three days, whereas open storage of waste increases the odour by 77% in three days (171).

The establishment of a biomethane plant causes an overall increase of savings and income. It reduces dependency on fossil fuel imports and for the need of foreign fertiliser. The transport of fermented waste is easier than transporting fresh manure (171). Based on the experience of other biogas facilities, the biomethane plant would create two full-time equivalent operator jobs with the remainder of the employment capacity already existing in the agricultural sector.

The production of biomethane can prevent emissions. The emission of N_2O and NH_3 mainly occur during the storage of animal waste. Fermented fertiliser causes less N_2O emissions than synthetic fertilisers. Ammonia emissions which create health, environmental, and odour problems are decreased by the anaerobic processes. The direct use of raw manure also leads to nitrate pollution in the soil and groundwater (171).

In addition to using the digestate as a more valuable alternative to fresh manure for fertilising the fields, it also creates an opportunity to reduce the negative impacts of local greenhouses. Synthetic fertilisers are currently used to promote the growth of plants in large greenhouses. With the availability of locally produced digestate, the dependence on imported fertilisers with a large environmental footprint can be reduced. This enables

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greenhouses to follow bio-based organic farming principles and produce ecologically sustainable products using locally available resources. As organic products are more valuable and digestate is cheaper than imported fertilisers, the greenhouse sector can increase their profitability.

15.4. Technical analysis and KPIs

The biomethane production facility is planned to be constructed in Sikassaare, north of Kuressaare in the vicinity of large food processing industries and a compressed natural gas filling station. This creates the possibility for establishing grid connections to existing large consumers of natural gas and the potential for expansion to other facilities in the region that use fuel oil for heating.

The production of biomethane can cover the needs of all potential business sector customers that currently use fossil fuels for heating and industrial processes, the public transport of Saaremaa and Hiiumaa, and supply energy to private transport. The annual biomethane production capacity is 34.6 GWh. The annual demand for the largest consumer, Saaremaa Dairy Ltd., is 11.2 GWh and for all potential business sector customers the amount required is 22.7 GWh (172), whereas the public transport of Saaremaa and Muhu requires 3.3 GWh of fuels annually. The remaining 8.6 GWh can be utilised by private and local government transport.

There are no incentives currently available to finance a biomethane production facility. The previous support mechanism ended in 2020. However, as the production and consumption of biomethane is seen as a prospective way to primarily reduce carbon dioxide emissions in the transport sector, it is expected that there will be new support mechanisms during the support period that started in 2021. In the previous support mechanism, up to 100 euros per MWh of biomethane supplied minus the market price of natural gas was awarded for supplying biomethane to the transport sector. The corresponding value for supplying biomethane to end consumers via the natural gas grid was 93 euros (173). However, as the project is financially feasible without a subsidy, there is no need for additional support unless the price of biomethane decreases by more than 40%.

The necessary electricity grid connection requirements are to be established in the planning process. As the planned site is located in an industrial area close to a major power substation, connections can easily be established. To create a power connection, an application needs to be sent to Elektrilevi who will prepare a quote. After signing the contract, construction of the connection will begin. The electrical installation needs to be audited before it can be taken into use (174). The estimated annual consumption of electricity is 3.3 GWh.

The gas grid from the plant to the consumers must be built keeping in mind potential expansion possibilities. In addition to the gas grid, a wood chip boiler plant with an annual heat production capacity of about 6.5 GWh needs to be built to supply the anaerobic digestion with heat.

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After commissioning, the plant needs to undergo annual maintenance which causes stoppages in the production of biomethane. Daily maintenance needs are covered by the plant operators.

The key performance indicators for biomethane production are the yield of biomethane, the amount of biological waste used and the amount of digestate produced.

15.5. Economic-financial analysis and KPIs

The expected capital expenditure of the biomethane plant is around eight million euros based on experience with similar plants and financial estimates created in scientific work. The investment is expected to be carried out in 2025 after the planning process has been finalised. It is assumed that 80% of the investment will be covered by a loan from a financial institution and 20% of the total investment or 1.6 million euros will be covered by the project partners, the farmers, the gas supplier, and the developer. Based on market conditions, the estimated payback period of the loan is six years with an interest rate of 5.0%.

The operating income of the biomethane plant comes from the sale of produced biomethane. The operating costs are formed by the costs of electricity, wood chips, labour, maintenance and repair, process additives and analysis, logistics, and other costs, which includes taxes related to economic activity. The EBITDA of the project for the first full year of operation is 2.3 million euros. The project has a discounted payback period of four years. The net present value of the project is 12.9 M€ and the internal rate of return is 30.0%. An overview of the economic-financial analysis of the project is given in of biomethane production.

The key economic-financial indicators for biomethane production are the annual production costs, the revenue earned from selling biomethane, and the profit margin.

15.6. Sensitivity analysis

Sensitivity analysis was carried out to evaluate the impacts of the price of biomethane, the investment cost, and the production capacity of biomethane on the performance of the project. It was determined as a result of the analysis that the project is financially viable even in significantly more conservative scenarios compared to the project scenario (Tables 15.2–15.7).

If the price of biomethane decreases by 20% and the capital expenditure is 10% greater than expected, the discounted payback period is extended by two years. If the price of biomethane increases by 10% and the capital expenditure is 20% smaller than expected, the discounted payback period is three years (Table 15.2).

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Table 15.2. The impact of the price of biomethane and investment cost on the discounted payback period of the project

Discounted payback period, yr.	Price of biomethane, €/Nm^3			
Investment cost, €	0.64 (-20%)	0.72 (-10%)	**0.80 (project)**	0.88 (+10%)
6 400 000 (-20%)	5	4	3	3
7 200 000 (-10%)	5	4	4	3
8 000 000 (project)	6	5	**4**	4
8 800 000 (+10%)	6	5	5	4

Increased production capacity has a positive impact on the discounted payback period. However, if the production volumes of biomethane are 20% smaller than expected and the price of biomethane decreases by 20%, the discounted payback period extends to seven years (Table 15.3).

Table 15.3. The impact of the price of biomethane and the production volume of biomethane on the discounted payback period of the project

Discounted payback period, yr.	Price of biomethane, €/Nm^3			
Biomethane production, Nm^3/yr	0.64 (-20%)	0.72 (-10%)	**0.80 (project)**	0.88 (+10%)
2 970 000 (-20%)	7	6	5	5
3 340 000 (-10%)	6	5	5	4
3 710 000 (project)	6	5	**4**	4
4 080 000 (+10%)	5	4	4	3

A positive NPV is achieved even when the price of biomethane decreases by 20% and the investment cost increases by 10% or the production volume is 20% smaller than expected. The combination of a higher production volume and a higher price significantly increases the net present value whereas the investment cost does not have a large impact on NPV (Tables 15.4–15.5).

Table 15.4. The impact of the price of biomethane and investment cost on the net present value of the project

NPV, €	Price of biomethane, €/Nm^3			
Investment cost, €	0.64 (-20%)	0.72 (-10%)	**0.80 (project)**	0.88 (+10%)
6 400 000 (-20%)	8 476 400	11 512 930	14 549 459	17 585 989
7 200 000 (-10%)	7 676 400	10 712 930	13 749 459	16 785 989
8 000 000 (project)	6 876 400	9 912 930	**12 949 459**	15 985 989
8 800 000 (+10%)	6 076 400	9 112 930	12 149 459	15 185 989

Table 15.5. The impact of the price of biomethane and the production volume of biomethane on the net present value of the project

NPV, €	Price of biomethane, €/Nm^3			
Biomethane production, Nm^3/yr	0.64 (-20%)	0.72 (-10%)	**0.80 (project)**	0.88 (+10%)
2 970 000 (-20%)	3 776 278	6 205 502	8 634 726	11 063 949
3 340 000 (-10%)	5 326 339	8 059 216	10 792 092	13 524 969
3 710 000 (project)	6 876 400	9 912 930	**12 949 459**	15 985 989
4 080 000 (+10%)	8 426 461	11 766 643	15 106 826	18 447 009

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The internal rate of return increases from 30% to nearly 43% if the investment cost is 20% lower than expected and the price of biomethane is 10% higher than expected (Table 15.6) If both the price and production volume of biomethane are 20% lower than expected, the IRR drops below 16% which is still greater than the WACC (Table 15.7).

Table 15.6. The impact of the price of biomethane and investment cost on the internal rate of return of the project

IRR	Price of biomethane, €/Nm³			
Investment cost, €	0.64 (-20%)	0.72 (-10%)	**0.80 (project)**	0.88 (+10%)
6 400 000 (-20%)	26.5%	32.1%	37.6%	42.9%
7 200 000 (-10%)	23.4%	28.5%	33.4%	38.2%
8 000 000 (project)	20.8%	25.5%	**30.0%**	34.4%
8 800 000 (+10%)	18.6%	23.0%	27.2%	31.3%

Table 15.7. The impact of the price of biomethane and the production volume of biomethane on the internal rate of return of the project

IRR	Price of biomethane, €/Nm³			
Biomethane production, Nm³/yr	0.64 (-20%)	0.72 (-10%)	**0.80 (project)**	0.88 (+10%)
2 970 000 (-20%)	15.7%	19.7%	23.6%	27.2%
3 340 000 (-10%)	18.3%	22.7%	26.8%	30.9%
3 710 000 (project)	20.8%	25.5%	**30.0%**	34.4%
4 080 000 (+10%)	23.2%	28.3%	33.1%	37.9%

15.7. Risk analysis

The establishment of a biomethane production facility has a number of risks that can affect the outcome of the project. Table 15.8 provides an overview of the risks associated with the project, the expected impact they would have, and the probability of their occurrence. Risks with the highest impact are risks that could prevent the implementation of the project or would significantly change the characteristics of the project.

Table 15.8. Risk analysis of biomethane production (175)

Description of risk	Probability	Impact	Mitigation measures
Project planning			
The terms of the joint undertaking are not agreed upon	Medium	High	The positive impacts for all stakeholders need to be clearly defined at an early stage
Public opposition	Medium	Medium	Engaging the local community throughout the planning process, implementing suggested changes
Planned location being determined unsuitable	Medium	Medium	Determine alternative suitable locations
Feedstock supply and characteristics			
Smaller quantity of feedstock available	Medium	Medium	Establishing long-term supply contracts
Feedstock has lower solids content than presumed	Low	Medium	Creating the potential for adding additional amount of grass as a feedstock
Biomethane production potential			

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Description of risk	Probability	Impact	Mitigation measures
The optimal transportation distance is overestimated	Low	Medium	Thoroughly assessing the logistics of manure considering all variables
Biomethane output is lower than expected	Low	High	Preparing the project using conservative estimates for the output of biomethane
The size of the farms is significantly reduced	Low	High	Considering alternative sources of feedstock such as grass or biological waste from the HoReCa sector
Biomethane consumption			
Business sector consumers decide not to use biomethane	Medium	Medium	Establishing contracts for the sale of biomethane prior to the implementation of the project
The adoption of gas vehicles is slower than expected	Medium	Medium	Actively engaging in the promotion of gas-powered vehicles
The consumption of biomethane fluctuates significantly	Medium	Medium	Establishing larger storage facilities
Facilities and equipment			
The completion of the plant is prolonged	Medium	Medium	Creating a conservative estimate for the project's timeline
The equipment has significant malfunctions	Medium	Medium	Thoroughly considering the technical requirements with the help of experienced advisors and choosing contractors with proven references
There is a lack of qualification and experience	Low	Medium	Involving external consultants with prior experience
Project cost estimate			
The capital expenditure is greater than expected	Medium	Medium	Estimating the cost of the plant conservatively taking into account potential price increases
Financing plan			
Financial institutions are not willing to hand out a loan	Low	Medium	Exploring the possible alternative financing opportunities
The share of equity needs to be greater	Medium	Medium	Involving external investors as shareholders
Permits			
The plant does not receive a permit for operation	Low	High	Learning from the experience of other plants and creating a compelling project plan
Environmental requirements are not met	Low	Medium	Consider the need for possible additional investments to fulfil environmental requirements
Permit for selling biomethane is not obtained	Low	High	Establish a good connection with the gas market regulators at an early stage
Operation, maintenance, and monitoring			
Qualified operators cannot be found	Low	Medium	Training of personnel prior to commissioning at an existing plant
Safety of the plant is not assured	Low	High	Following safety standards throughout the process
Downtime due to maintenance is longer than expected	Medium	Medium	Choosing maintenance service providers based on their experience
Financial feasibility assessment			

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Description of risk	Probability	Impact	Mitigation measures
Biomethane market price is smaller than expected	Medium	Medium	Actively promoting the use of biomethane to increase market penetration
Expenditures are greater than expected	Medium	Medium	Estimating the costs conservatively

15.8. Adoption of gas-powered vehicles

Based on the analysis, nearly 12 GWh of biomethane per year can be used for transportation needs, which include public transport, vehicles of the local municipality of Saaremaa, and private transport. To reach the penetration of such an amount of biomethane in transport, investments for new vehicles need to be carried out. As the public transport already uses primarily gas-powered buses, no additional investments to regular replacement of vehicles need to be carried out. Table 15.9 gives an overview of the investment costs for the local municipality and the private sector. It is assumed that additional investments in infrastructure will not be necessary as there is a compressed natural gas station in Kuressaare and the gas-powered vehicles are expected to be used in that area.

Table 15.9. Investment cost of biomethane vehicles

Investment cost	Value
Total CAPEX, M€	10.3
Local government vehicles CAPEX, M€	1.5
Private transport CAPEX, M€	8.8
of which passenger cars CAPEX, M€	5.6
of which heavy-duty vehicles CAPEX, M€	3.2

15.8.1. Local government vehicles

It was assumed that most local government vehicles would be electrified by 2030 instead of acquiring gas-powered vehicles. However, heavy-duty vehicles such as tractors, trucks and buses, and some passenger cars are expected to be replaced by gas-powered alternatives. It is assumed that special vehicles such as graders will not be replaced and therefore the vehicles of the local government will not use fully renewable energy by 2030. A total of 24 vehicles will be replaced. The total expected investment cost is in the range of 1.5 million euros based on market information (176) (177) (178).

15.8.2. Private transport

Based on the expected biomethane consumption of the business sector, the public transport, and the municipality of Saaremaa, the amount of biomethane available for private transport is about 8 GWh per year. It was assumed that heavy-duty vehicles would form about 80% of the consumption and passenger cars the remaining 20%. When considering the average annual fuel consumptions of passenger cars and heavy-duty

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vehicles (179) and the respective average fuel economies (180), the number of passenger vehicles to be replaced by 2030 with vehicles consuming biomethane was estimated to be 225 and the number of heavy-duty vehicles to be replaced was estimated to be 21. The expected cost of investment is 5.6 million euros for passenger cars (176) and 3.2 million euros for heavy-duty vehicles (181).

As an alternative to buying new vehicles, existing vehicles can be retrofitted with devices that enable them to use 35-50% of biomethane in addition to diesel (182). Although the investment cost for retrofitted solutions would be significantly lower, this alternative was not considered as it would not enable the possibility to fully replace the consumption of fossil fuels and the timeline of the project is relatively long which means that new vehicles need to be bought regardless of the fuel consumed. Replacing an existing vehicle with a gas-powered variant would not incur relevant additional costs as the cost of gas-powered vehicles is in the same range as the cost of diesel and petrol alternatives.

15.9. Electricity production from biogas

As some of the larger farms particularly in eastern Saaremaa, fall outside of the 30 km range from the planned location of the biomethane plant, the potential of establishing a biogas plant to produce electricity based on those farms was assessed. Due to the location in the sparsely populated countryside without any major industrial facilities as potential consumers nearby, the production of biomethane was not assessed. Jööri was chosen as the location for the biogas plant as there has previously been a functioning biogas plant at that site.

The feedstock of the biogas plant would consist of manure from four pigsties and four cattle farms. Based on the manure available, an average 40% efficiency of gas engines, and an 8% own consumption of a biogas plant (183), it was determined that the potential for electricity sales is about 3000 MWh per year. Based on the average electricity price of the past three years, the plant has a potential revenue of more than 150 000 euros per year.

The capital expenditure of the plant was expected to be in the range of 1.25 million euros based on prior experience in the field (168) (184). It might be possible to reduce the investment cost as there has been a previously functioning biogas plant on-site. However, in the analyses it was assumed that the investment needs to be carried out as a whole as the previously established facilities will reach the end of their lifetime.

In addition to the market price of electricity, it is also possible to take part in renewable energy auctions and obtain a subsidy for electricity produced. If the market price is below 45.0 €/MWh, a maximum subsidy of 20 €/MWh can fully or partially cover the difference between the actual hourly market price and the price of 45 €/MWh (42). However, as the recipients of subsidies are determined based on an auction system it is unlikely that the maximum subsidy can be acquired and it is difficult to get a subsidy overall.

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To evaluate the financial performance of the project, it was assumed that the project would be successful in the renewable energy auction. However, no subsidy would actually be acquired as the forecasted electricity price exceeds 45.0 €/MWh. **Based on the analysis, it was determined that the project is not financially viable. Both the NPV of the project and the IRR are negative.** The project would be financially viable if the average market price of electricity from 2026 to 2040 exceeded 105 €/MWh.

As an alternative to electricity production, the potential for expanding the radius from within which manure is gathered for the biomethane plant needs to be further assessed. The production of biomethane can increase from 34.5 to 42.3 GWh per year by increasing the range of transportation from 30 to 45 kilometres.

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16. Renovation of district heating networks

16.1. Kuressaare Soojus district heating network

Table 16.1 summarises the renovation effects of district heating networks owned by Kuressaare Soojus AS. The company has set itself relative heat loss targets for 2030. Table 17.1 also provides the reduction of primary energy consumption, the CAPEX of the investment, and the effect on the price of thermal energy for the consumers. 400 €/m renovation cost was chosen for the analysis.

Analysis shows that for the consumer it is best to renovate with a subsidy as it increases the price the least. **Preliminary analysis shows that renovating the Kuressaare district heating network would reduce primary energy consumption by 3249 MWh per annum.** Compared to other district heating networks it is best to focus on reducing Kuressaare's heat loss first as it has the greatest potential to reduce primary energy consumption.

Table 16.1. District heating network heat loss targets

District heating			
District heating network	Kuressaare	Orissaare	Leisi
Annual heat consumption, MWh/yr	67 696	2652	733
Annual heat loss, MWh/yr	10 019	496	154
Relative heat loss	14.8%	18.7%	21.0%
Unrenovated transmission pipes, m	5705	560	575
Share of unrenovated transmission pipes	16%	21%	100%
District heat target goals			
Target relative heat loss, %	10%	14%	8%
Target heat loss, MWh/yr	6770	371	61
Reduction of primary energy consumption, MWh/yr	3249	125	93
Renovation economics			
CAPEX, €	2 300 000	224 000	230 000
Price increase of thermal energy, €/MWh	2.5	6.3	23.2
CAPEX with subsidy, €	1 150 000	112 000	115 000
Price increase of thermal energy, €/MWh	1.2	3.1	11.6
Current price of the thermal energy, €/MWh	44.49	50.50	68.07
Price increase without subsidy	5.6%	12.4%	34.1%
Price increase with subsidy	2.8%	6.2%	17.1%

16.2. Suuremõisa district heating network

Hiiumaa municipality confirmed the heat development plan "Hiiumaa municipality Suuremõisa village heat development plan for 2020-2030" in 2020 (185). The main conclusion of the heat development plan is as follows: "The district heating network of Suuremõisa village is sustainable and it is possible to continue so with it if the boiler house is renovated and the apartment buildings that have disconnected from the network are reconnected to the district heating network."

Current district heating network is operated by the sole proprietor. To improve Suuremõisa district heating, the necessary investments need to be made using the

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Environmental Investment Centre support. The district heating network needs a district heating company with necessary capital and experience.

The development plan foresees two possible scenarios for the district heating. **Both scenarios require a subsidy to achieve the best solution**. It is possible to apply for up to 50% support of the investment. The first scenario requires 257 500 euros worth of investments to maintain the current district heating network and keep the price competitive compared to local solutions. The second scenario requires 396 500 euros worth of investments to connect new buildings to the district heating network and renovate the old boiler house and transmission pipes. Following the first scenario would result in 61.8 €/MWh as the price of thermal energy for the consumers and the second scenario would result in 48.6 €/MWh. Without a subsidy the prices would be 70.9 €/MWh for the first and 56.2 €/MWh for the second scenario. In comparison, the cost of the local heating solution is 68.6 €/MWh. With transmission pipe renovations it is possible to reduce the primary energy consumption up to 137 MWh per annum. Additionally, up to 6% higher efficiency could be achieved with a new boiler house (87 MWh per annum).

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17. Käina district heating

17.1. Project overview

District heating is the best method for supplying carbon-neutral thermal energy to multiple households. District heating centralises heat generation and distribution, reducing local emissions and improving overall life quality. The preferred option for district heating will be determined and validated in the district heating development. Historically, the best solution for cost-effective district heating is to use local wood chips for heat generation.

As a result of the analysis, establishing a district heating network at Käina has the potential to offer low carbon heating options to 119 households and other buildings at a very competitive price, beating all local heating solutions.

The estimated capital expenditure of the district heating network is in the range of 840 000 euros. The Environmental Investment Centre has supported effective production and transmission of thermal energy reducing the total cost to 420 000 euros. The district heating network becomes very cost-effective with financial support. The estimated capital expenditure for the consumers with non-renovated buildings that do not have central heating systems within a building is in the range of 100 000 euros. Buildings that already use local heating boilers with a central heating system within a building are required to connect their system with district heating via a substation which costs roughly around 4000 euros. An overview of Käina's potential district heating is given in Table 17.1.

Table 17.1. Potential district heating at Käina

Indicator	Value
District heating consumption	
Consumption of wood chips, MWh/yr	2185
District heating	
CAPEX, €	840 000
CAPEX with 50% subsidy, €	420 000
WACC	5.55%
Price of thermal (wood chips) energy, €/MWh	**69.6**
Price of thermal (wood chips) energy with subsidy, €/MWh	**51.5**
Average cost of similar Estonian district heating, €/MWh	*60.4*
Local heating	
Price of thermal (pellet) energy, €/MWh	**70.8**
Electricity consumption	
Decreased electricity use for space heating, MWh/yr	225
Decreased electricity use for domestic hot water, MWh/yr	222
Contribution to the objectives	
Total reduction of CO_2 emissions, tCO_2/yr	244
share of the total objective	0.8%
share of the building sector objective in Hiiumaa	9.0%

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17.1.1. Background

It is estimated that 25% of potential consumers of the district heating network use electric heating for space heating and the rest use small-scale solid fuel stoves, fireplaces, and boilers in combination with electric heating and/or air source heat pump. Moreover, an electric boiler is the most popular method for domestic hot water.

17.1.2. Project objectives

The aim of the project is to reduce the carbon dioxide emissions that result from the consumption of electricity for space heating and domestic hot water. Moreover, reducing the number of local boilers will result in fewer local emissions (CO_2, NOx, PM) which results in better air quality.

17.1.3. Project benefits

District heating will be a cost-effective and convenient solution for the consumer. The project has a positive impact on the environmental conditions near Käina and will increase the value of property connected to district heating. The project has a relatively low impact on employment opportunities.

17.1.4. Scope

The scope of the project is to establish district heating to connect 12 potential apartment buildings with 119 apartments. To maintain cost-effective district heating, it is required to maintain high linear heat density. A district heating network will open opportunities to use industrial excess heat for district heating.

17.1.5. Project boundaries and constraints

To establish district heating with subsidies, a local government must have a validated development plan for heat management. The compilation of such a development plan is also subsidised. The purpose of district heating development plans is to make a document with a plan of action that would increase the district heating efficiency and assure its sustainability for consumers by reduction of the final consumption of energy on the account of more efficient production and transmission of heat energy. The development plan for heat management must be compiled by a *Chartered Thermal Energy Engineer, EstQF Level 8.*

17.1.6. Business model and relationship scheme

Local governments in Estonia are responsible for the organisation of the heat sector. Local governments have the right to establish, within their territory, district heating areas and the procedure of provision of services. The district heating act regulates the heating sector. The heat undertaking is required to coordinate the price of heat with the Competition Authority.

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The costs incurred for the production and transmission of heating energy must be justified when coordinating the price. The changes in the price of heating are mainly influenced by the changes in fuel prices and investments in improving the technical condition of the district heating network. Ensuring the most efficient, secure, reliable heat supply with a reasonable price, and making sure that it meets the environmental requirements and consumer needs is the task of the heating undertaking.

Since the maximum production price of heat is set by the Competition Authority, the heat producer can only have a justified return and allowed revenue for the heat production (WACC=5.55%).

17.2. Impact analysis

The analysis estimated that district heating would annually replace 447 MWh of electricity use with wood chips for space heating and domestic hot water. That would result in 244 tonnes of carbon dioxide emission reduction a year.

17.3. Technical analysis and KPIs

The district heating network support application requires consumers and producers to sign a network connection contract before the actual construction of the district heating network. Therefore, it is important to reach a common understanding with potential consumers before committing to establish the district heating network. It also requires consumers to renovate or build necessary central heating systems in a building so it would be possible to connect the building to the district heating network via a substation.

After establishing the district heating network, the boiler house and the district heating network needs to undergo annual maintenance during summer which will be covered by the boiler house operators. Therefore, it opens an employment opportunity for the locals.

The technical key performance indicators of the district heating system are the number of consumers, the amount of heat supplied, the efficiency of the boiler, and the share of losses in the grid.

17.4. Economic-financial analysis and KPIs

Based on the preliminary calculations (Table 17.2), the Käina district heating price would be 69.6 €/MWh without subsidies. It is the cheapest option even without a subsidy because the cheapest local heating solution is using wood pellets at 70.8 €/MWh. **However, the district heating increases the price gap due to subsidies (50%) lowering the price to 51.5 €/MWh. Moreover, in Estonia the average cost of similar district heating (below 3000 MWh annually) is in the range of 60.4 €/MWh.**

The economic key performance indicators of the project are the capital expenditure, the fixed and variable operational expenditure, and the resulting heat price.

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Table 17.2. Price of thermal energy

Heating method	DH*	DH*	Local	Local	Local	Local
Fuel	Wood Chips	Wood Chips	Pellet	Firewood	GSHP	Electricity
CAPEX						
Heat generation, €	520 000	260 000	16 500	16 500	37 950	5280
Heat transmission, €	260 000	160 000	0	0	0	0
Variable and Capital costs						
Variable cost, €/MWh	**33.5**	**33.5**	**58.8**	**60.6**	**50.7**	**140.0**
Electricity, €/MWh	18.2	18.2	0.7	0.0	46.7	140.0
Fuel, €/MWh	2.8	2.8	50.0	44.4	0.0	0.0
Emissions tax, €/MWh	0.6	0.6	0.0	0.0	0.0	0.0
Operating costs, €/MWh	11.9	11.9	8.1	16.1	4.0	0.0
Capital cost, €/MWh	**36.1**	**18.0**	**12.1**	**12.0**	**26.3**	**3.5**
Total price of thermal energy						
Price of thermal energy, €/MWh	**69.6**	**51.5**	**70.8**	**72.6**	**77.0**	**143.5**

** DH – district heating*

There are currently no incentives available to finance a district heating network or compensate for the renovation of a central heating system within a building. The previous support mechanism ended in 2020. However, it is expected that there will be new support mechanisms in 2022. In the previous support mechanism, up to 300 000 euros were given for 1 MW of heat generation and 200 000 euros for 1 km of transmission pipes. The analysis illustrated that the project is also financially feasible without a subsidy but it is reasonable to apply for subsidy to keep district heating network price low for a longer period.

The purpose of the atmosphere air protection programme is to support the improvement of ambient air quality, reduction of transportation pollution, reduction of the threat posed by radiation, reduction of pollution resulting from physical sources of contamination of the environment, reduction of the negative environmental impact of energetics, and fulfilment of the requirements arising from the European Union and Estonian environmental and chemicals policy. Households can apply for support to reduce the capital expenditure of their central heating system renovation and the connecting costs of district heating (186). The feasibility of central heating system renovation for district heating is analysed in Table 17.3.

Table 17.3. Feasibility of central heating system renovation for district heating

Indicator	Value
Heat consumption	
Average surface, m^2/building	1241
Heat consumption, kWh/(m^2yr)	140
Heat consumption, MWh/yr	174
Price of thermal energy	
District heating price (VAT included), €/MWh	62
Electricity price (VAT included), €/MWh	199
Savings on heating per annum, €	23 866
Cost of building renovation to connect with district heating	
Renovation price per surface, €/m^2	65
Total renovation cost, €	80 669
with 50% subsidy	40 335

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Indicator	Value
Feasibility, year	3.4
with 50% subsidy	1.7

17.5. Dagöplast AS industrial excess heat

Dagöplast AS is a film manufacturer based in Käina, Hiiumaa. It is estimated that about 60 kW of heat is generated as a by-product of industrial processes. If exploited, 525 MWh of excess heat could be utilised for heating. Low-temperature heat could be used effectively to heat Käina Spordikeskus' 10x25 metre pool.

This excess heat utilisation would reduce the consumption of thermal energy from the district heating network. As thermal energy consumption decreases, the price of district heating thermal energy increases. Analysis shows that the price of district heating thermal energy would increase 10.9 €/MWh (80.5 €/MWh total) and 6.8 €/MWh (58.4 €/MWh total) when the district heating network is built with a subsidy. Importantly, the thermal energy of district heating with a subsidy is still cheaper than the local heating option. Therefore, the utilisation of excess heat is recommended as it would reduce the island primary energy consumption by 525 MWh per annum.

17.5.1. Heat for greenhouses

As one possible alternative to using the waste heat from Dagöplast in district heating, it could be used to cover the heating needs of greenhouses. Due to the climatic conditions, greenhouses in Estonia require heating for a large part of the year. With the availability of excess heat, it is estimated that there would be no need to pay for heating, which enables the possibility to lower the costs.

The heat demand for greenhouses in the climatic conditions of Hiiumaa was determined based on annual air temperatures, relative humidity, solar irradiance and wind speed (187). Based on the climatic conditions throughout the year, it was estimated that the excess heat would be sufficient to heat 193 m^2 of greenhouses.

In order to assess the financial perspective of building the greenhouse in Käina, the production of tomatoes was assessed. Based on a study carried out at the Estonian University of Life Sciences, the yield of tomatoes with the right conditions should be around 25 kg/m^2 in Estonia (188). Based on the yield of tomatoes per square metre and the area determined, the greenhouse could produce about 4800 kg of tomatoes annually. With a wholesale price of 6.5 €/kg, the production of tomatoes would earn a revenue of 31 300 €/yr. As excess heat is used, there are no additional costs for heating. The annual cost for electricity consumption, primarily for lighting, and for electricity consumption were estimated to be 14 900 euros and 600 euros respectively. The greenhouse would require one employee, with annual labour costs of 14 000 euros. When considering the costs and earnings, the project would make an annual profit of about 2000 euros. Table 17.4 gives a better overview of the potential size of the greenhouse and the potential costs and earning. However, this estimate does not include the initial investment costs or auxiliary costs related to transportation, fertilisers and marketing for example.

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Table 17.4. Potential for using excess heat from Dagöplast to heat greenhouses

Indicator	Value
Greenhouse dimensioning	
Greenhouse annual heat consumption, kWh/m^2	367
Available heat, MWh/yr	525
Potential greenhouse area, m^2	193
Greenhouse cost-benefit analysis	
Heating cost, €/yr	0
Electricity cost, €/yr	14 900
Water cost, €/yr	600
Labour cost, €/yr	14 000
Tomatoes produced, kg/yr	4800
Revenue, €/yr	31 300
Profit, €/yr	2000

17.6. Sensitivity analysis

A sensitivity analysis was carried out to evaluate the impacts of the transmission pipe investment cost and the linear heat density on the heating cost of the district heating network. Transmission pipe investment cost was chosen because in recent years the price of the transmission pipes has almost doubled. Moreover, the length of the transmission pipes is in direct correlation with the linear heat density. The more compact the district heating network, the better linear heat density can be achieved. The data in Table 17.5 and Table 17.6 show the result when a district heating network is subsidised by the Environmental Investment Centre.

Table 17.5. Price of district heating network thermal energy

Price of thermal energy, €/MWh	Transmission pipe price, €/m		
Linear heat density, MWh/m	300 (-25%)	350 (-12.5%)	400 (project)
1.5 (-32%)	71.4	74.7	78.1
2.0 (-9%)	66.4	68.9	71.4
2.2 (project)	65.0	67.3	69.6

Table 17.6. Price of subsidised district heating network thermal energy

Price of thermal energy, €/MWh	Transmission pipe price, €/m		
Linear heat density, MWh/m	300 (-25%)	350 (-12.5%)	400 (project)
1.5 (-32%)	50.2	53.5	56.8
2.0 (-9%)	47.6	50.2	52.7
2.2 (project)	47.0	49.2	51.5

A sensitivity analysis was also carried out to evaluate the feasibility for the consumers who must renovate the central heating system within a building to connect with a district heating network. Analysis evaluated the impacts of the renovation price and the price of thermal energy on the feasibility and return of the investment (Tables 17.7 and 17.8).

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Table 17.7. Feasibility without renovation subsidy

Investment feasibility, years Price of thermal energy (VAT included), €/MWh	Renovation cost, €/m² 65 (project)	100 (54%)	150 (131%)
61.8	3.4	5.2	7.8
83.5	4.0	6.2	9.3

Table 17.8 gives an overview of the feasibility of district heating when using a subsidy.

Table 17.8. Feasibility with renovation subsidy

Investment feasibility, years Price of thermal energy (VAT included), €/MWh	Renovation cost, €/m² 65 (project)	100 (54%)	150 (131%)
61.8	1.7	2.6	3.9
83.5	2.0	3.1	4.6

17.7. Risk analysis

Table 17.9 provides an overview of the risks associated with the project, the expected impact they would have and the probability of their occurrence. Risks with the highest impact are risks that could prevent the implementation of the project or would significantly change the characteristics of the project.

Table 17.9. Risk analysis

Description of risk	Probability	Impact	Mitigation measures
Environmental impact	Low	Medium	Avoiding environmental protected areas.
Social acceptance	Medium	High	Transparent communication of the project to the participants.
Financial institutions are not willing to give a loan or support.	Medium	High	Finding alternative financing solutions – crowdfunding or a long-term investor (fund).
The capital expenditure is greater than expected.	Medium	High	Creating a tender for multiple buyers to submit an offer.
Consumers are not willing to renovate the buildings.	High	High	Certified engineer compiles building energy audits to determine the accurate savings and project feasibility to help the consumer to decide.

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18. Renovation of buildings

18.1. Overview

Improving the energy efficiency of buildings is an important area for reducing energy consumption and achieving the goals set in the climate and energy plan. The climate and energy plan sets targets for the reduction of energy via raising awareness, using smart solutions, and improving energy efficiency by renovating. In Saaremaa, Hiiumaa, and Muhu the target is to renovate 30% of apartments and small buildings. In Ruhnu the target is 30% of small buildings. All new local municipality buildings and apartments should correspond to energy class A or to energy class B if not economically justified and technically feasible. (2) (3) (4) (5)

Table 18.1 gives an overview of the investment needs for renovation and the impact on thermal energy and electricity consumption. The consumption of electricity is expected to increase with renovations which increases carbon dioxide emissions and therefore counteracts the overall objective. The growth of electricity consumption mainly comes from the adoption of heat pumps as a heating source for small buildings instead of heating with firewood.

The target scenario objective is that 30% of all small and apartment buildings are renovated. The minimal scenario focuses only on the renovation of apartment buildings and small buildings with energy performance label G or H. There are 13 apartment buildings and 11 small buildings that have been issued such energy performance labels. The scenarios are based on the data available from the national buildings register, as some buildings do not have an energy performance label the actual number of buildings that need renovation is higher. For local government buildings, 30% of buildings with the highest energy consumption are viewed and the investment estimate is based on the renovation of buildings with an energy performance label below class D or not defined for both scenarios. The investment cost is based on unit costs 400 €/m^2 for small buildings, 300 €/m^2 for apartments and 600 €/m^2 for municipality buildings. And the resulting carbon dioxide emissions are based on the carbon intensity of electricity consumed in 2020. The municipality buildings and energy usage was provided by the local municipalities (189).

In order to achieve the objectives of the target scenarios the overall investment cost exceeds 250 M€. Although, there are subsidies promoting the renovation a substantial part of the investment comes from the building owners. Thus, the investment and loan capabilities of the owners is a hindering factor towards achieving the goals.

Table 18.1. Renovation of buildings (189) (190)

Indicator Investment	Minimal	Target
Total CAPEX, M€	21.5	256.7
Small building CAPEX, M€	0.6	179.0
Apartment buildings CAPEX, M€	2.7	59.5
Local government buildings CAPEX, M€	18.2	18.2
Thermal energy savings		
Total thermal energy savings, GWh/yr	3.7	70.6

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Indicator	Minimal	Target
Small buildings thermal energy savings, GWh/yr	0.2	48.2
Apartment buildings thermal energy savings, GWh/yr	0.9	19.8
Local government buildings thermal energy savings, GWh/yr	2.6	2.6
Increase in electric energy consumption		
Total increase in electric energy consumption, GWh/yr	0.34	5.4
Small buildings electric energy consumption increase, GWh/yr	0.02	4.5
Apartment buildings electric energy consumption increase, GWh/yr	0.03	0.6
Local government buildings electric energy consumption increase, GWh/yr	0.3	0.3
Counteraction to objectives		
Total increase of CO_2 emissions, tCO_2/yr	194	2950
share of the total objective	-0.16%	-2.2%
Small buildings' share of the total objective	-0.007%	-2.0%
Apartment buildings' share of the total objective	-0.012%	-0.3%

18.2. Grant measures and funding

Comprehensive reconstruction of buildings is investment intensive - building owners often lack the financial capacity to renovate buildings to the energy performance class C. There are several funding options offered related to the reconstruction of buildings. The building renovation grants for municipality and private buildings are distributed by the State Shared Service Center, Environmental Investment Centre, and Kredex (189).

For the next funding period, Kredex offers renovation grants worth over 366 M€. The distribution of support depends on the applications but the support rate will remain higher in areas further away from the centres. In 2020 the reconstruction grant amounted to 40% of the total cost of the renovation works in Kuressaare. In other areas on the islands the grant amounts to 50% of the total cost of renovation (191).

From 2015 to 2021 Kredex issued 27 apartment renovation grants in the island municipalities in the total amount of 5.7 M€ for apartment buildings with a net area of 57 247 m^2. In the same period Kredex issued 93 small building renovation grants in the total amount of over 850 000 euros with the net area of the buildings being 12 899 m^2 (191). Figure 18.1 depicts the amount of grant applications in Hiiu and Saare County and in Estonia as a whole for comparison.

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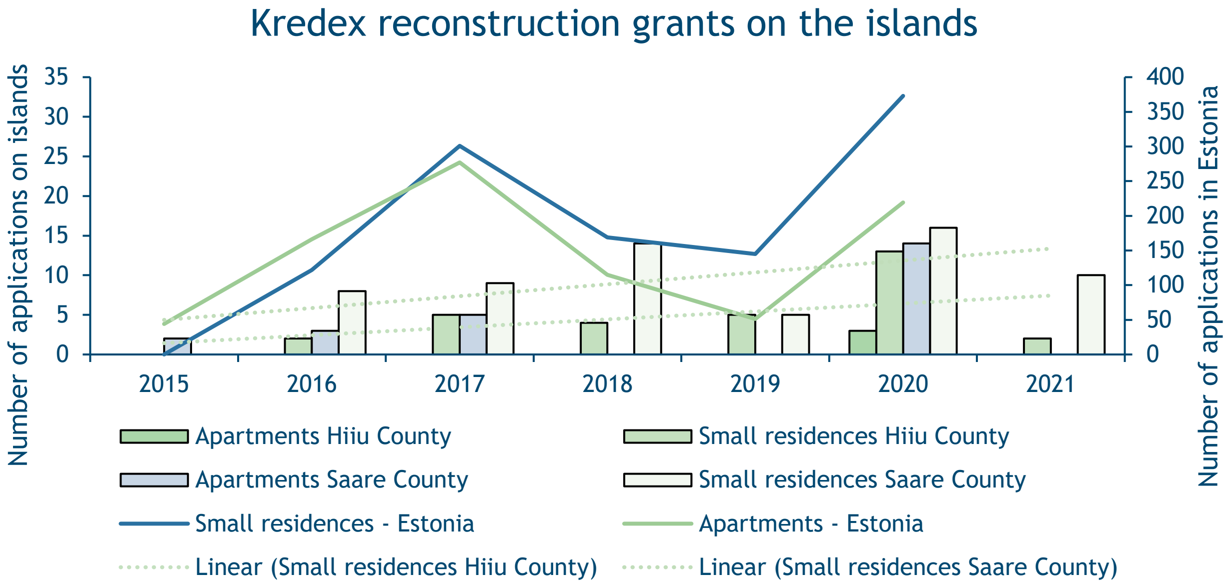

Figure 18.1 Kredex reconstruction grants on the Estonian islands

18.3. Impacts

The renovation of buildings has a wide-ranging impact. **In addition to reducing energy consumption and thus also carbon dioxide emissions, it has a significant effect on the living quality and wellbeing of locals.** It is possible to improve the accessibility of buildings to suit different population groups including the elderly and people with disabilities. Renovations could result in the increase of local renewable energy solutions such as solar panels. Renovation is also crucial from the viewpoint of building safety, older electrical systems, load-bearing structures, and sewage pipelines which might need immediate repairs to meet modern standards. Furthermore, renovations have an impact on the workforce. It is estimated that per 1 M€ investment 17 jobs will be created. (189)

18.4. Small buildings and apartment buildings

The major share of the investment need and energy savings comes from the renovation of residential single-family dwellings and apartment buildings. There are a total of more than 14 600 residential buildings on the islands with nearly 13 700 of them single-family dwellings and about 930 of them apartment buildings which include terraced houses and semi-detached houses. The closed net area of the buildings is 2.15 million square metres, for single-family dwellings the corresponding value is 1.5 million square metres, and for apartment buildings the closed net area is 0.66 million square metres. Based on net area, nearly 92% of the buildings have been built before the 21st century (192). Overall, the building stock needs to be renovated to ensure the durability of the buildings, achieve better living conditions, and reduce energy consumption.

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18.4.1. Small buildings and apartments of Saaremaa

Saaremaa is the largest of the islands and the number of residential buildings exceeds 10 000. The closed net area of the buildings is about 1.5 million square metres. With the target renovation capacity of 30%, the total expected investment cost is 168.8 million euros. Carrying out the renovations would create 2870 construction-related jobs. As a result of the renovations, the thermal energy consumption is reduced by 48.3 GWh per year while the electricity consumption increases by 3.5 GWh per year. Carbon dioxide emissions would increase by 1920 tCO_2 per year.

18.4.2. Small buildings and apartments of Hiiumaa

Hiiumaa is the second largest of the islands and the number of residential buildings exceeds 3700. The closed net area of the buildings is about 0.5 million square metres. With the target renovation capacity of 30%, the total expected investment cost is 56.8 million euros. Carrying out the renovations would create 966 construction-related jobs. As a result of the renovations, the thermal energy consumption is reduced by 16.0 GWh per year while the electricity consumption increases by 1.2 GWh per year. Carbon dioxide emissions would increase by 680 tCO_2 per year.

18.4.3. Small buildings and apartments of Muhu

The municipality of Muhu has 815 residential buildings. The closed net area of the buildings is about 111 000 square metres. With the target renovation capacity of 30%, the total expected investment cost is 13.0 million euros. Carrying out the renovations would create 221 construction-related jobs. As a result of the renovations, the thermal energy consumption is reduced by 3.6 GWh per year while the electricity consumption increases by 310 MWh per year. Carbon dioxide emissions would increase by 170 tCO_2 per year.

18.4.4. Small buildings and apartments of Ruhnu

The island of Ruhnu has 62 single-family dwellings, with a large share of them being heritage protected. Therefore, it is difficult to achieve the targets for reducing energy consumption. The closed net area of the buildings is about 4400 square metres. With the target renovation capacity of 30%, the total expected investment cost is 530 000 euros. Carrying out the renovations would create 9 construction-related jobs. As a result of the renovations, the thermal energy consumption is reduced by 140 MWh per year while the electricity consumption increases by 10 MWh per year. As the island is supplied by fully renewable electricity, there is no impact on carbon dioxide emissions.

18.5. Local municipality buildings

Comprehensive renovations target at least energy performance label C. In Muhu Parish at least 50% of the municipality buildings have at least an energy performance label of C - this is the highest percentage among other island municipalities. While in Saaremaa it is least 35% and in Hiiumaa at least 20% of municipal buildings meet the criteria.

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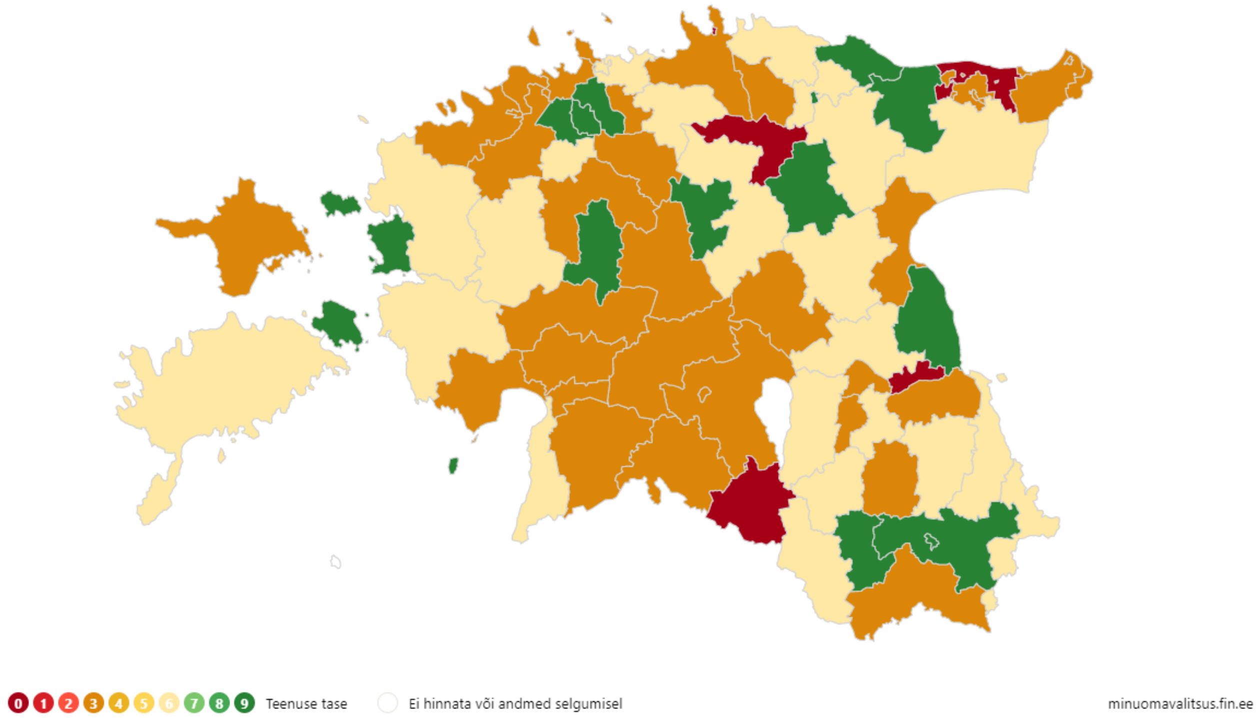

Figure 18.2. Buildings with at least energy performance label C among municipality buildings (193)

The islands climate and energy plans state that by 2030 municipality buildings should use 100% renewable energy, setting an example for other consumers. During the renovation of municipality buildings electricity consumption often increases as older facilities lack cooling and ventilation systems. As the municipalities have set a target to consume only renewable energy the increase in consumption will not increase the carbon dioxide emissions. Municipality buildings, e.g. schools and kindergartens often have large roofs suitable for PV panels increasing the production of renewable energy. Most of the municipality buildings have energy performance labels mapping the energy usage of buildings. The local municipalities estimates are based on the data provided from the municipalities and data acquired from the Estonian building register. Overall, the island municipalities have made significant investments to renovate municipality buildings and improve energy efficiency.

18.5.1. Saaremaa

Saaremaa is the largest municipality and has more than 180 municipal buildings with an energy consumption of more than 2,5 GWh in 2020. The buildings with the largest energy consumption are mainly educational establishments. The largest electricity consumer is Leisi school which was renovated in 2010 and has an electricity performance label class D. It is estimated that the renovation capacity is more than 20 000 m^2 by 2030. The total expected investment cost is 12.1 million euros. Carrying out the renovations would create approximately 206 construction-related jobs. As a result of the renovations, the thermal

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energy consumption is reduced by 1700 MWh per year while the electricity consumption increases by 200 MWh per year.

18.5.2. Hiiumaa

In Hiiumaa there are 44 municipal buildings. The largest consumers of electrical energy are Käina sports hall, which has an energy performance label of class C, Käina school building which has class D and Kärdla school building of which the renovated part of the building has a performance label of class C and the building extension has an energy performance of class A. It is estimated that the renovation capacity is approximately 89 000 m^2 by 2030. The total expected investment cost is more than 5 million €. Carrying out the renovations would create approximately 90 construction-related jobs. As a result of the renovations, the thermal energy consumption is reduced by 800 MWh per year while the electricity consumption increases by 100 MWh per year.

18.5.3. Muhu

In the municipality of Muhu there are 10 municipality buildings. The closed net area of the buildings is 10 197 m^2. The electricity consumption in 2020 was approximately 270 000 kWh. Muhu's school, kindergarten, and sports hall are the three largest consumers of electrical energy. Their consumption is approximately 60% of the total electricity consumption. Muhu's sports hall and school have energy performance certificates of class C and the kindergarten of class F. It is estimated that the renovation capacity is approximately 1400 m^2 by 2030. The total expected investment cost is more than 800 000 euros. Carrying out the renovations would create approximately 14 construction-related jobs. As a result of the renovations, the thermal energy consumption is reduced by 100 MWh per year while the electricity consumption increases by 10 MWh per year.

18.5.4. Ruhnu

In the municipality of Ruhnu there are 10 municipality buildings with a total closed net area of 1400 m^2 and electrical energy consumption of 82 kWh in 2020. Ruhnu's town hall, school, and fire station garage are the three largest electricity consumers from the municipality buildings. The municipality has started a project to reconstruct the Ruhnu fire station garage to improve energy efficiency. The reconstructed building will have LED lights, ventilation with heat recovery, and heating automation. Due to heritage protection rules, the renovation of buildings in Ruhnu is difficult. Thus, Ruhnu's municipality buildings were excluded from the renovation estimate.

18.5.5. Energy management

The municipal sector should set an example in reaching the energy savings potential. To decrease energy consumption and map the main energy saving opportunities it is necessary to monitor energy consumption. The island municipalities could implement an energy management system to monitor their progress and thus decrease the energy consumption in municipality buildings.

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19. Small-scale energy efficiency measures

19.1. Overview

The amount of energy consumed and the carbon dioxide emissions resulting from it can easily be reduced by applying simple energy efficiency measures. In order to implement energy efficiency measures, the local community needs to be involved as every resident of the islands can contribute to energy savings. Raising awareness is of key importance in changing consumption habits, using smart solutions, and investing in energy efficiency.

Table 19.1 gives an overview of the application of simple to implement energy efficiency measures in water consumption, heating, lighting, and insulation. The measures analysed are the mounting of efficient aerators on faucets that reduces the consumption of water and thereby also the consumption of electricity for heating water without cognitive difference in the flow of water, the replacement of fluorescent lights with energy efficient LED lights, the installation of thermostatic radiator valves to reduce excessive heat consumption, and the replacement of windows with more energy efficient windows to reduce heat losses.

Table 19.1. Small-scale energy efficiency measures

Indicator	Value
Energy savings	
Total energy savings, GWh/yr	47.1
Electricity savings, GWh/yr	17.6
Heat and fuels savings, GWh/yr	29.5
Investment	
Total CAPEX, M€	42.1
CAPEX for Saaremaa, M€	30.7
CAPEX for Muhu, M€	1.9
CAPEX for Ruhnu, M€	0.137
CAPEX for Hiiumaa, M€	9.3
Payback period, years	10
Total CAPEX without replacing windows, M€	2.1
Payback period, years	0.75
Contribution to objectives	
Total reduction of CO_2 emissions, tCO_2/yr	9620
share of the total objective	7.8%
share of the total objective in Saaremaa	7.4%
share of the total objective in Muhu	10.4%
share of the total objective in Ruhnu	-
share of the total objective in Hiiumaa	8.4%
share of the total original consumer awareness sub-objective	50.6%
share of the original consumer awareness sub-objective in Saaremaa	54.7%
share of the original consumer awareness sub-objective in Muhu	73.6%
share of the original consumer awareness sub-objective in Ruhnu	-
share of the original consumer awareness sub-objective in Hiiumaa	39.5%

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19.2. Scope of intervention and general description

19.2.1. Project overview

Although large energy savings can be achieved with costly investments, there are also several ways of reducing energy consumption with small investments. This project analyses the impact of some measures that have individual costs of less than 500 euros. The measures analysed are the installation of efficient aerators on faucets, the replacement of fluorescent lights with efficient LED lights, the installation of thermostatic valves on radiators, and the replacement of inefficient windows.

19.2.2. Background

The energy consumption of the business and building sector makes up more than 60% of the total energy consumed on the islands which means that there is great potential for the reduction of energy demand and carbon dioxide emissions. As these sectors consist of numerous shareholders in the form of the local residents and businesses, community involvement and interaction are of vital importance to achieve a large overall impact.

19.2.3. Project objectives

The aim of the project is to involve the community in reducing energy consumption and in adopting more efficient solutions. With the involvement of members of the community, traction can be created, which leads to further investments carried out by other members of the community - resulting in a large overall effect. The realisation of small-scale energy efficiency measures by a large group of participants intends to reach great overall energy and carbon dioxide savings.

19.2.4. Project benefits

The benefits of the project are related to the reduction of energy consumption and the decrease of demand peaks, the decrease in carbon dioxide emissions as well as creating better living and working environments for the residents of the islands through the use of energy efficient solutions.

19.2.5. Scope

The scope of the project includes all residents and businesses of the islands. The overall aim is to achieve the greatest overall savings which means that all members of the community are expected to make their contribution.

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19.2.6. Project boundaries and constraints

The boundaries of the project are mainly related to acquiring a construction permit or a licence from the respective authority for carrying out some of the investments and the low financial capacity of the residents, which makes it difficult to carry out some of the investments. The heritage protection of some of the buildings on the islands sets limitations on the replacement of windows, which can make it more difficult to achieve the expected reduction in heat consumption. The installation of thermostatic radiator valves in district heating areas needs to be agreed upon amongst the apartment association and coordinated with the heat supplier as the investment can alter the heating regime and cause disturbances within the building. In addition, the investment should be carried out during the summer when there is no heating.

19.2.7. Business model and relationship scheme (governance)

The investments are to be carried out by members of the community either by themselves or as part of a smaller community such as the apartment association. There is no clear structure on how the investments should be implemented as everyone can choose the optimal way for themselves. The investments will start earning back the investment cost from the first day they are taken into use in the form of energy savings. Due to the low financial capacity of some members of the communities, the possibility of introducing support mechanisms by the local municipalities for covering a part of the investments should be considered. This can reduce the entry barrier especially for smaller investments with a high return such as aerators for faucets and LED lights, whereas due to the high cost of investment, it cannot be expected that the local governments offer significant support for the replacement of windows.

Offering such support mechanisms is familiar to the municipalities as for example the municipality of Hiiumaa has annual campaigns for residents to buy paint for painting their houses at a lower cost. In cooperation with a local hardware store and the producers of paint, a total discount of 30% is offered with each party covering 10% of the costs (194).

19.3. Description of the measures

19.3.1. Project overview

The replacement of faucet aerators, fluorescent lights, inefficient thermostatic valves, and windows were chosen as the measures analysed within this project, as mentioned previously. As there is no data available regarding the usage of aerators, LED lights, thermostatic radiator valves or the condition of windows, the analysis is largely based upon assumptions based on from the overall characteristics of the housing stock of Estonia.

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The installation of aerators on faucets was analysed for residents living outside of district heating areas where domestic hot water is prepared with district heating, as in that case water is primarily heated using electric boilers.

The amount of fluorescent lights to be exchanged was estimated based on the average share of lighting in the electricity consumption of a household (195), the estimated share of energy efficient lighting solutions in Estonia based on prior overview about the lighting sources used in Estonia (196), and the average number of lightbulbs per household (197).

For the installation of thermostatic valves, the focus was put on buildings in district heating areas. Based on data about the performance of thermostatic valves (198) and the estimated number of radiators in primarily apartment buildings (199), the need for thermostatic valves and the resulting impact was estimated.

For the replacement of windows, it was assumed that on average 15% heat losses occur through windows. The energy saving achieved with new windows is estimated based on the thermal conductivity of windows with low and high efficiency. The number of windows to be replaced was estimated based on the size of the average household.

19.3.2. Impact analysis

As a result of adding efficient aerators to faucets, it was estimated that the total **electricity consumption for heating water can be reduced by more than 13 GWh per year** which results in a **reduction of carbon dioxide emissions of nearly 7200 tonnes per year** based on the carbon intensity of electricity consumed in Estonia in 2020. The cost of one aerator for a faucet is 10 euros and for a shower 20 euros. For an average household, the estimated investment cost is 40 euros and the total investment cost is 670 000 euros. With annual savings in the range of 1.8 million euros, the aerators will have paid off their cost in five months. The analysis does not take into account further cost savings resulting from the reduction of cold-water consumption.

With the renewal of lighting solutions, a **nearly 4.5 GWh reduction in electricity consumption** can be reached which leads to **2450 tonnes of carbon dioxide saved**. The estimated investment cost per household is 125 euros and the total investment is in the range of 1.25 million euros. With annual savings of nearly 630 000 euros, the project will reach its payback period in less than two years. The individual payback period largely depends on the usage of lighting.

Thermostatic radiator valves have the potential to **reduce heat consumption by nearly 6.6 GWh per year**. The cost of investment per household is in the range of 30 euros and the total investment cost is nearly 190 000 euros. With annual savings of nearly 400 000 euros, the payback period is less than half a year.

The replacement of windows is the investment with the highest costs as in addition to the purchase of the window, costly construction work also needs to be carried out. However, the measure also offers the greatest energy savings with **nearly 23 GWh of heat saved**

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annually. The estimated cost per window is 500 euros with a total investment cost of 40 million euros. Due to a high investment cost, the payback period is nearly 30 years. In addition to the energy savings, the improvement in thermal comfort is an important benefit.

19.4. Changes in habitual behaviour

A more cost-efficient way of achieving energy savings compared to small-scale investments is to implement changes in habits that can lead to the conservation of energy. Some of the possible changes in habitual behaviour that can lead to increased energy efficiency without causing discomfort are given as follows (200):

- Increasing the set-point temperature of the refrigerator.
- Regularly cleaning or replacing air filters in air conditioners, ventilation, and heaters.
- Running the washing machine or dishwasher with full loads.
- Air-drying clothes and towel-drying dishes.
- Using the right-sized burner for cooking.
- Letting the rooms be a bit warmer in the summer and a bit colder in the winter.
- Washing clothes in cold water.
- Using window shades to block excessive sunlight in the summer.
- Turning off all lights, appliances, and electronics when they are not in use.
- Setting the water heater to the lowest comfortable setting.
- Shutting doors and cooling or heating only the rooms that are being actively used.
- Using microwave or toaster ovens to cook or warm leftovers instead of the conventional oven.
- Taking shorter showers.
- Turning off the water heater when leaving home for a longer period of time.
- Unplugging battery chargers.

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20. Education

20.1. Overview

With changes taking place in the energy sector affecting the whole economy of the islands, changes in the education system must also be carried out to adapt to new needs. Increasing the volume of renewable energy being produced on the islands or in the waters near the islands, increasing electrification of transport, development of the blue economy sector, and other activities lead to the demand for new skills and competencies. The educational institutions on the islands have a major role to play in the energy transition and with the right decisions changes can be implemented faster while bringing more benefits to the islands.

20.2. Current situation

The islands have three higher education or vocational training facilities: Kuressaare College, Kuressaare Regional Training Centre, and Hiiumaa Vocational School.

Kuressaare College is a regional college of Tallinn University of Technology. Kuressaare College contributes to Saaremaa-specific sectors of the blue economy by providing engineering and entrepreneurship education along with R&D services. Marine technology and hydrodynamics research is conducted by the Small Craft Competence Centre (201).

Kuressaare Regional Training Centre (KTRC) is an educational institute that provides initial and additional vocational training in addition to retraining in a wide selection of specialties both for young people and adults. Located on the island of Saaremaa with strong seamanship traditions and small craft building companies, it is the only vocational school in Estonia that trains ship builders. KRTC is a partner at the Small Craft Competence Centre at Saaremaa, hosting the SCC's technology lab that provides various services to the small craft sector. Other specialties are car repairing, business management, social work, information technology, accounting, and spa therapy. There are about 800 regular students on upper and post-secondary level along with about 800 adult students during a year on different adult training courses (202).

Hiiumaa Vocational School (HVS) provides initial and further vocational training, complementary training, and re-qualification programmes for all age groups. HVS offers a variety of training courses: sustainable agriculture, animal health care, tourism, services, labour welfare (safety), computer skills, restoration, etc. There are 120-250 students in the school every year including participants of complementary training, with 60% of them coming from the mainland of Estonia (203).

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20.3. Perspective

All these educational facilities are already contributing to the energy transition. However, in order to reach the objectives set, adjustments in the curricula and the volume of students trained need to be carried out in the following years. As the blue economy encompasses a wide range of activities, Kuressaare College has the possibility to expand their scope and attract additional talent from outside of Saaremaa. In addition to the fields that the college is currently focused upon, an emphasis on energy technologies - specifically offshore wind and hydrogen - is required to prepare qualified experts and offer support for large renewable energy projects.

With the electrification of transport, KTRC has the role of training technicians capable of servicing both electric vehicles and electric charging infrastructure. In addition to electric transport, there will be a generally large need for electricians which gives an opportunity for creating new curricula. The development of offshore wind energy requires training maintenance technicians and crew members for service vessels. The same applies for offshore aquaculture which in addition needs qualified aquaculture workers in the whole value chain. The increasing pace in the renovation of buildings leads to a greater demand of construction workers.

Hiiumaa Vocational School has mostly the same opportunities as Kuressaare Regional Training Centre to a lower volume, however with their existing competence in training small-craft harbour specialists, their expertise should be further developed to train people that can manage the increased and diversified usage of ports with the development of offshore energy and the blue economy.

Whereas vocational schools and the local college can prepare the workforce needed and offer technical and scientific support, general education has an important role in making the directions developed more attractive and providing required basic knowledge. **It is important to increase the level of teaching when it comes to the sciences and mathematics.** Extracurricular activities such as robotics courses need to be continuously carried out to engage children with the opportunities that technology offers from a young age so that they would choose the development paths needed for carrying out the energy transition and become the leaders of the change.

Overall, it is important that the developments in energy, economy, and education go hand in hand with each sector adapting to changes in other sectors. In order to achieve a smooth transition, close collaboration is needed between the developers and education. **Kuressaare College as the regional higher education centre has the possibility and also the responsibility of becoming the local competence centre for all developments related to the blue economy** which includes developments in offshore energy and the energy sector as a whole.

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Appendix 1 Road maps towards sustainable island communities for the local municipalities

Saaremaa

Sub-objective No. 1

At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity)

Course of action No. 1: Infrastructure development

Activity No. 1: Offer political support to the development of energy infrastructure, provide inputs to the responsible ministries along with the TSO and DSO; raise awareness about the need for infrastructure development projects amongst the residents and provide an overview of the benefits and disadvantages of carrying out such projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	50 000 €	Own resources	Saaremaa Municipality Council, Saare Development Center

Course of action No. 2: Development of energy communities

Activity No. 1: Promote the concept of energy communities; support the creation of community energy solutions by providing the conditions for establishing such initiatives on land or public buildings owned by the local government free of charge; establish contracts for buying the electricity generated

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	50 000 €	Own resources	Saaremaa Municipality Council, Energiaühistu

Course of action No. 3: Introduction of innovative wind energy solutions

Activity No. 1: Promote the development of alternative wind energy solutions to raise awareness about the possibilities and reduce opposition towards renewable energy projects; actively engage with potential investors

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	10 000 €	Own resources	Saaremaa Municipality Council, Saare Development Center

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Course of action No. 4: Offshore wind farm development

Activity No. 1: Provide political support and a stable environment to the offshore wind farm developers; assist in the determination of the suitable connection corridor; involve members of the community and raise awareness about the projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	25 000 €	Own resources	Saaremaa Municipality Council, offshore wind farm developers

Course of action No. 5: Wave energy development

Activity No. 1: Actively engage with potential investors interested in testing wave energy solutions in the determined innovation area

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	10 000 €	Own resources	Saaremaa Municipality Council, Saare Development Center

Sub-objective No. 2

In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed

Course of action No. 1: Renovation of street lighting

Activity No. 1: Carry out street lighting renovation projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	2 070 000 €	Own resources, EIC support for one project carried out in 2022	Saaremaa Municipality Council, Kuressaare Soojus

Course of action No. 2: Consumption of renewable electricity for street lighting

Activity No. 1: Purchase electricity with a green certificate for street lighting

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	No additional costs expected	Own resources	Saaremaa Municipality Council

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Sub-objective No. 3

100% renewable electricity is consumed in municipal buildings

Course of action No. 1: Consumption of renewable electricity for municipal buildings

Activity No. 1: Purchase electricity with a green certificate for municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Saaremaa Municipality Council

Sub-objective No. 4

In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat

Course of action No. 1: Raise public awareness

Activity No. 1: Carry out events aimed at informing residents about energy efficiency and renewable energy technologies; write informative articles; include energy efficiency, sustainability, and renewable technologies as a part of the island's marketing information

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	100 000 €	Own resources	Saaremaa Municipality Council, Saare Development Center

Activity No. 2: Develop support mechanisms for residents to carry out small-scale energy efficiency measures such as installing efficient aerators on faucets, replacing fluorescent lights with efficient LED lights, installing thermostatic valves on radiators, and replacing inefficient windows

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	1 000 000 €	Own resources	Saaremaa Municipality Council

Course of action No. 2: Renovation of district heating networks

Activity No. 1: Support the renovation of district heating networks; conduct heat development plans

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	50 000 €	Own resources, Kuressaare Soojus, EIC support	Saaremaa Municipality Council, Kuressaare Soojus

Course of action No. 3: Renovation of buildings

Activity No. 1: Compile energy audits for municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	100 000 €	Own resources, State Shared Service Centre	Saaremaa Municipality Council

Activity No. 2: Carry out renovations of municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	12 100 000 €	Own resources, State Shared Service Centre	Saaremaa Municipality Council

Sub-objective No. 5

Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources)

Course of action No. 1: Biomethane production

Activity No. 1: Support the development of a biomethane production plant; assist the developers in acquiring the necessary permits; involve residents to raise awareness about the biomethane production plant

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2026	No additional costs expected	Own resources	Saaremaa Municipality Council, biomethane plant developers

Course of action No. 2: Adoption of gas-powered vehicles

Activity No. 1: Partially replace vehicles using fossil fuels with gas-powered vehicles to use locally produced biomethane

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	1 500 000 €	Own resources	Saaremaa Municipality Council

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Course of action No. 3: Electrification of local government vehicles

Activity No. 1: Improve the charging infrastructure

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2025	42 000 €	Own resources	Saaremaa Municipality Council

Activity No. 2: Partially replace vehicles using fossil fuels with electric vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	4 200 000 €	Own resources, EIC support	Saaremaa Municipality Council

Sub-objective No. 6

Public transport to deploy buses using renewable energy sources, taking infrastructure development and cost-effectiveness into account

Course of action No. 1: Use gas-powered buses

Activity No. 1: Replace the remainder of the diesel-powered buses with gas-powered buses; support the development of the biomethane production plant

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	No additional costs expected	State support	Saaremaa Municipality Council, Muhu Municipality Council transport service provider

Sub-objective No. 7

A 30% reduction in the use of fossil fuels for private transport including the transport of goods

Course of action No. 1: Use gas-powered vehicles

Activity No. 1: Support the development of the biomethane production plant; promote the usage of gas-powered vehicles that can use locally produced fuel

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	10 000 €	Own resources	Saaremaa Municipality Council, biomethane plant developers

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Course of action No. 2: Electrification of vehicles

Activity No. 1: Support the development of the charging network

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Saaremaa Municipality Council, electric charging network developers

Activity No. 2: Promote the use of electric vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	10 000 €	Own resources	Saaremaa Municipality Council

Course of action No. 3: Use hydrogen as a transportation fuel

Activity No. 1: Support the creation of a hydrogen value chain; actively engage with companies interested in developing hydrogen solutions on the island; establish agreements with project developers

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	No additional costs expected	Own resources	Saaremaa Municipality Council, hydrogen project developers

Activity No. 2: Support the establishment of hydrogen filling stations

Implementation period	Expected cost	Sources of funding	Responsible implementer
2025-2030+	To be determined	To be determined	Saaremaa Municipality Council, hydrogen project developers

Activity No. 3: Promote the use of hydrogen vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2025-2030+	To be determined	To be determined	Saaremaa Municipality Council, hydrogen project developers

Sub-objective No. 8

Ferry traffic between islands and mainland uses 100% renewable fuels or electricity

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Course of action No. 1: Create electric fast-charging opportunities in ports

Activity No. 1: Promote the electrification of ferries; support the development of charging infrastructure; create charging infrastructure in the ports of Roomassaare, Abruka, Papissaare, and Vikati

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	200 000 €	Own resources, Saarte Kalandus	Saaremaa Municipality Council, Transport Administration, ferry operators, port managers

Course of action No. 2: Electrification of ferries

Activity No. 1: Support the electrification of ferries; acquire an electric boat for Vilsandi

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	400 000 €	Own resources, state financing	Saaremaa Municipality Council, Transport Administration, ferry operators

Course of action No. 3: Develop hydrogen infrastructure in ports

Activity No. 1: Support the creation of hydrogen infrastructure in ports

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030+	No additional costs expected	Own resources	Saaremaa Municipality Council, Transport Administration, ferry operators, port managers

Course of action No. 4: Use hydrogen as a fuel for ferries

Activity No. 1: Support the reconstruction of ferries or the purchase of new ferries

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030+	No additional costs expected	Own resources	Saaremaa Municipality Council, Transport Administration, ferry operators

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Hiiumaa

Sub-objective No. 1

At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity)

Course of action No. 1: Infrastructure development

Activity No. 1: Offer political support to the development of energy infrastructure, provide inputs to the responsible ministries along with the TSO and DSO; raise awareness about the need for infrastructure development projects amongst the residents and provide an overview of the benefits and disadvantages of carrying out such projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	50 000 €	Own resources	Hiiumaa Municipality Council, Hiiumaa Development Center

Course of action No. 2: Development of energy communities

Activity No. 1: Promote the concept of energy communities; support the creation of community energy solutions by providing the conditions for establishing such initiatives on land or public buildings owned by the local government free of charge; establish contracts for buying the electricity generated

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	20 000 €	Own resources	Hiiumaa Municipality Council, Energiaühistu

Course of action No. 3: Introduction of innovative wind energy solutions

Activity No. 1: Promote the development of alternative wind energy solutions to raise awareness about the possibilities and reduce opposition towards renewable energy projects; actively engage with potential investors

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	10 000 €	Own resources	Hiiumaa Municipality Council, Hiiumaa Development Center

Course of action No. 4: Offshore wind farm development

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Activity No. 1: Provide political support and a stable environment to potential offshore wind farm developers; assist in the determination of the suitable connection corridor; involve members of the community and raise awareness about the projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	10 000 €	Own resources	Hiiumaa Municipality Council, offshore wind farm developers

Course of action No. 5: Wave energy development

Activity No. 1: Engage with potential investors interested in testing wave energy solutions near the shore or in the ports of Hiiumaa

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	10 000 €	Own resources	Hiiumaa Municipality Council, Hiiumaa Development Center

Sub-objective No. 2

In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed

Course of action No. 1: Renovation of street lighting

Activity No. 1: Carry out street lighting renovation projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	1 430 000 €	Own resources	Hiiumaa Municipality Council

Course of action No. 2: Consumption of renewable electricity for street lighting

Activity No. 1: Purchase electricity with a green certificate for street lighting

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	No additional costs expected	Own resources	Hiiumaa Municipality Council

Sub-objective No. 3

100% renewable electricity is consumed in municipal buildings

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Course of action No. 1: Consumption of renewable electricity for municipal buildings

Activity No. 1: Purchase electricity with a green certificate for municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Hiiumaa Municipality Council

Sub-objective No. 4

In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat

Course of action No. 1: Raise public awareness

Activity No. 1: Carry out events aimed at informing residents about energy efficiency and renewable energy technologies; write informative articles; include energy efficiency, sustainability, and renewable technologies as a part of the island's marketing information

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	50 000 €	Own resources	Hiiumaa Municipality Council, Hiiumaa Development Center

Activity No. 2: Develop support mechanisms for residents to carry out small-scale energy efficiency measures such as installing efficient aerators on faucets, replacing fluorescent lights with efficient LED lights, installing thermostatic valves on radiators, and replacing inefficient windows

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	300 000 €	Own resources	Hiiumaa Municipality Council

Course of action No. 2: Establish district heating networks

Activity No. 1: Conduct heat development plans

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	20 000 €	Own resources, EIC support	Hiiumaa Municipality Council

Activity No. 2: Support the establishment of district heating areas; present the results of the heat development plans to the local residents, provide information about the benefits and downsides of district heating

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	10 000 €	Own resources	Hiiumaa Municipality Council, heat undertaking

Course of action No. 3: Renovation of buildings

Activity No. 1: Compile energy audits for municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	30 000 €	Own resources, State Shared Service Centre	Hiiumaa Municipality Council

Activity No. 2: Carry out renovations of municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	5 000 000 €	Own resources, State Shared Service Centre	Hiiumaa Municipality Council

Sub-objective No. 5

Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources)

Course of action No. 1: Electrification of local government vehicles

Activity No. 1: Improve the charging infrastructure

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2025	20 400 €	Own resources	Hiiumaa Municipality Council

Activity No. 2: Replace vehicles using fossil fuels with electric vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	990 000 €	Own resources, EIC support	Hiiumaa Municipality Council

Sub-objective No. 6

Public transport to deploy buses using renewable energy sources, taking infrastructure development and cost-effectiveness into account

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Course of action No. 1: Use electric buses

Activity No. 1: Carry out a pilot project with the duration of 6 months to test the suitability of electric buses for Hiiumaa prior to compiling the next public transport procurement; create possibilities for additional chargers in Kärdla, Käina, and Emmaste; attract charging infrastructure developers to invest in chargers

Implementation period	Expected cost	Sources of funding	Responsible implementer
2025-2028	30 000 €	Own resources, EIC support	Hiiumaa Municipality Council, transport service provider

Activity No. 2: Carry out a procurement to organize public transport with best-suited electric buses in the next service period

Implementation period	Expected cost	Sources of funding	Responsible implementer
2028-2030+	No additional costs expected	State support	Hiiumaa Municipality Council, transport service provider

Sub-objective No. 7

A 30% reduction in the use of fossil fuels for private transport including the transport of goods

Course of action No. 1: Electrification of vehicles

Activity No. 1: Support the development of the charging network

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Hiiumaa Municipality Council, electric charging network developers

Activity No. 2: promote the use of electric vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	5000 €	Own resources	Hiiumaa Municipality Council

Course of action No. 2: Use hydrogen as a transportation fuel

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Activity No. 1: Support the creation of a hydrogen value chain; actively engage with companies interested in developing hydrogen solutions on the island; establish agreements with project developers

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	No additional costs expected	Own resources	Hiiumaa Municipality Council, hydrogen project developers

Activity No. 2: Support the establishment of hydrogen filling stations

Implementation period	Expected cost	Sources of funding	Responsible implementer
2025-2030+	To be determined	To be determined	Hiiumaa Municipality Council, hydrogen project developers

Activity No. 3: promote the use of hydrogen vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2025-2030+	To be determined	To be determined	Hiiumaa Municipality Council, hydrogen project developers

Sub-objective No. 8

Ferry traffic between islands and mainland uses 100% renewable fuels or electricity

Course of action No. 1: Create electric fast-charging opportunities in ports

Activity No. 1: Promote the electrification of ferries; support the development of charging infrastructure

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	No additional costs expected	Own resources	Hiiumaa Municipality Council, Transport Administration, ferry operators, port managers

Course of action No. 2: Electrification of ferries

Activity No. 1: Support the electrification of ferries

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	No additional costs expected	Own resources	Hiiumaa Municipality Council, Transport Administration, ferry operators

Course of action No. 3: Develop hydrogen infrastructure in ports

Activity No. 1: Support the creation of hydrogen infrastructure in ports

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030+	No additional costs expected	Own resources	Hiiumaa Municipality Council, Transport Administration, ferry operators, port managers

Course of action No. 4: Use hydrogen as a fuel for ferries

Activity No. 1: Support the reconstruction of ferries or the purchase of new ferries

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030+	No additional costs expected	Own resources	Saaremaa Municipality Council, Transport Administration, ferry operators

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Muhu

Sub-objective No. 1

At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity)

Course of action No. 1: Infrastructure development

Activity No. 1: Offer political support to the development of energy infrastructure, provide inputs to the responsible ministries along with the TSO and DSO; raise awareness about the need for infrastructure development projects amongst the residents and provide an overview of the benefits and disadvantages of carrying out such projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	5000 €	Own resources	Muhu Municipality Council

Course of action No. 2: Development of energy communities

Activity No. 1: Promote the concept of energy communities; support the creation of community energy solutions by providing the conditions for establishing such initiatives on land or public buildings owned by the local government free of charge; establish contracts for buying the electricity generated

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	20 000 €	Own resources	Muhu Municipality Council, Energiaühistu

Course of action No. 3: Introduction of innovative wind energy solutions

Activity No. 1: Promote the development of alternative wind energy solutions to raise awareness about the possibilities and reduce opposition towards renewable energy projects; actively engage with potential investors

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	5000 €	Own resources	Muhu Municipality Council, Saare Development Center

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Sub-objective No. 2

In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed

Course of action No. 1: Renovation of street lighting

Activity No. 1: Carry out street lighting renovation projects

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	100 000 €	Own resources	Muhu Municipality Council

Course of action No. 2: Consumption of renewable electricity for street lighting

Activity No. 1: Purchase electricity with a green certificate for street lighting

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	No additional costs expected	Own resources	Muhu Municipality Council

Sub-objective No. 3

100% renewable electricity is consumed in municipal buildings

Course of action No. 1: Consumption of renewable electricity for municipal buildings

Activity No. 1: Purchase electricity with a green certificate for municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Muhu Municipality Council

Sub-objective No. 4

In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat

Course of action No. 1: Raise public awareness

Activity No. 1: Carry out events aimed at informing residents about energy efficiency and renewable energy technologies; write informative articles; include energy efficiency, sustainability and renewable technologies as a part of the island’s marketing information

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Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	10 000 €	Own resources	Muhu Municipality Council

Activity No. 2: Develop support mechanisms for residents to carry out small-scale energy efficiency measures such as installing efficient aerators on faucets, replacing fluorescent lights with efficient LED lights, installing thermostatic valves on radiators, and replacing inefficient windows

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	60 000 €	Own resources	Muhu Municipality Council

Course of action No. 2: Renovation of buildings

Activity No. 1: Compile energy audits for municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	10 000 €	Own resources, State Shared Service Centre	Muhu Municipality Council

Activity No. 2: Carry out renovations of municipal buildings

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	800 000 €	Own resources, State Shared Service Centre	Muhu Municipality Council

Sub-objective No. 5

Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources)

Course of action No. 1: Electrification of local government vehicles

Activity No. 1: Improve the charging infrastructure

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2025	4800 €	Own resources	Muhu Municipality Council

Activity No. 2: Partially replace vehicles using fossil fuels with electric vehicles

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Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	280 000 €	Own resources, EIC support	Muhu Municipality Council

Sub-objective No. 6

Public transport to deploy buses using renewable energy sources, taking infrastructure development and cost-effectiveness into account

Course of action No. 1: Use gas-powered buses

Activity No. 1: Replace the remainder of the diesel-powered buses with gas-powered buses, support the development of the biomethane production plant

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	No additional costs expected	State support	Saaremaa Municipality Council, Muhu Municipality Council transport service provider

Sub-objective No. 7

30% reduction in the use of fossil fuels for private transport including the transport of goods

Course of action No. 1: Electrification of vehicles

Activity No. 1: Support the development of the charging network

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Muhu Municipality Council, electric charging network developers

Activity No. 2: Promote the use of electric vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	5000 €	Own resources	Muhu Municipality Council

Course of action No. 2: Use hydrogen as a transportation fuel

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Activity No. 1: Support the creation of a hydrogen value chain; actively engage with companies interested in developing hydrogen solutions on the island; establish agreements with project developers

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	No additional costs expected	Own resources	Muhu Municipality Council, hydrogen project developers

Activity No. 2: Support the establishment of hydrogen filling stations

Implementation period	Expected cost	Sources of funding	Responsible implementer
2025-2030+	To be determined	To be determined	Muhu Municipality Council, hydrogen project developers

Activity No. 3: Promote the use of hydrogen vehicles

Implementation period	Expected cost	Sources of funding	Responsible implementer
2025-2030+	To be determined	To be determined	Muhu Municipality Council, hydrogen project developers

Sub-objective No. 8

Ferry traffic between islands and mainland uses 100% renewable fuels or electricity

Course of action No. 1: Create electric fast-charging opportunities in ports

Activity No. 1: Promote the electrification of ferries; support the development of charging infrastructure

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	No additional costs expected	Own resources	Muhu Municipality Council, Transport Administration, ferry operators, port managers

Course of action No. 2: Electrification of ferries

Activity No. 1: Support the electrification of ferries

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Implementation period	Expected cost	Sources of funding	Responsible implementer
2026-2030	No additional costs expected	Own resources	Muhu Municipality Council, Transport Administration, ferry operators

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Ruhnu

Sub-objective No. 1

At least 70% of the electricity consumed on the island is covered by locally produced renewable electricity.

Course of action No. 1: Increase renewable energy generation and storage capacity

Activity No. 1: Offer support to the expansion of the renewable energy solution of Ruhnu

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Ruhnu Municipality Council, Enefit Green

Activity No. 2: Install PV panels for the ambulance centre

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2023	30 000 €	Own resources	Ruhnu Municipality Council, Enefit Green

Sub-objective No. 2

In street lighting, the share of energy-efficient luminaires is 100%

The sub-objective has been fulfilled

Sub-objective No. 3

In raising awareness, changing consumption habits, and using smart solutions, energy consumption is decreased

Course of action No. 1: Public awareness raising

Activity No. 1: Carry out events aimed at informing residents about energy efficiency and renewable energy technologies; write informative articles; include energy efficiency, sustainability, and renewable technologies as a part of the island's marketing information

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	2500 €	Own resources	Ruhnu Municipality Council

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Activity No. 2: Develop support mechanisms for residents to carry out small-scale energy efficiency measures such as installing efficient aerators on faucets, replacing fluorescent lights with efficient LED lights, and replacing inefficient windows

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030+	5000 €	Own resources	Ruhnu Municipality Council

Sub-objective No. 4

Local municipality cars using fossil fuels to be exchanged for electric vehicles

Course of action No. 1: Electrification of local government vehicles

Activity No. 1: Install a public charger

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2025	1200 €	Own resources	Ruhnu Municipality Council

Activity No. 2: Purchase an electric minibus

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	107 000 €	Own resources, EIC support	Ruhnu Municipality Council

Sub-objective No. 5

50% reduction in the use of fossil fuels for private transport by limiting use of transport or adopting electric vehicles

Course of action No. 1: Electrification of vehicles

Activity No. 1: Promote the use of electric vehicles and the idea of sharing the vehicles within the community

Implementation period	Expected cost	Sources of funding	Responsible implementer
2022-2030	No additional costs expected	Own resources	Ruhnu Municipality Council, members of the local community

Sub-objective No. 6

Ferry traffic between islands and mainland uses 100% renewable fuels or electricity

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Course of action No. 1: Use hydrogen as a fuel for ferries

Activity No. 1: Determine the needs related to the ferry for Ruhnu and support purchasing a new, better-suited hydrogen-powered ferry

Implementation period	Expected cost	Sources of funding	Responsible implementer
2028-2030	No additional costs expected	Own resources	Ruhnu Municipality Council, Transport Administration, ferry operators

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Appendix 2 Baseline Emission Inventories

Table A 1. Saaremaa Baseline Emission Inventory (2)

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	9880	3140	4320	17 340	4790	12 460
Street lighting	-	-	1030	1030	1070	-
Business sector	27 960	196 880	100 520	325 360	109 640	205 960
Building sector	31 620	79 310	55 690	166 620	58 210	110 930
Private transport	-	200 480	-	200 480	51 050	3910
Local govt vehicles	-	1620	30	1650	450	30
Public transport	-	3870	-	3870	1010	80
Total	69 460	485 300	161 590	716 350	226 220	333 370
Ferries	-	30 570	-	30 570	8130	5
Aviation	-	2950	-	2950	760	-
Total	69 460	518 820	161 590	749 870	235 110	333 375

Table A 2. Hiiumaa Baseline Emission Inventory (3)

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	2880	2020	1950	6850	2470	430
Street lighting	-	-	1710	1710	1780	-
Business sector	1600	28 050	27 670	57 320	29 760	24 580
Building sector	4350	24 990	18 550	47 890	19 340	24 990
Private transport	-	71 960	-	71 960	18 430	1460
Local govt vehicles	-	199	-	199	52	4
Public transport	-	730	-	730	190	20
Total	8830	127 950	49 880	186 660	72 020	51 480
Ferries	-	33 650	-	33 650	8950	-
Aviation	-	1870	-	1870	480	-
Total	8830	163 450	49 880	222 180	81 450	51 480

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Table A 3. Muhu Baseline Emission Inventory (4)

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	800	10	300	1110	320	810
Street lighting	-	-	30	30	34	-
Business sector	-	280	4460	4740	4650	280
Building sector	380	4430	3900	8710	4070	4810
Private transport	-	9730	-	9730	2450	210
Local govt vehicles	-	230	-	230	61	5
Public transport	-	730	-	730	190	20
Total	1180	15 410	8690	25 280	11 780	6140
Ferries	-	1720	-	1720	460	-
Total	1180	17 130	8690	27 000	12 240	6140

Table A 4. Ruhnu Baseline Emission Inventory (5)

Consumer group	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	63	82	145	57	70
Street lighting	-	7	7	5	1
Business sector	155	280	435	227	50
Building sector	525	107	632	74	534
Private transport	110	-	110	28	2
Local govt vehicles	-	-	-	-	-
Public transport	4	-	4	1	-
Special consumers (lighthouse, radar, mobile communication mast)	-	65	65	45	5
Total	857	541	1398	437	662
Ferries	1434	-	1434	381	-
Aviation	187	-	187	48	-
Total	2478	541	3019	866	662

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Appendix 3 Sub-objectives

Table A 5. Sub-objectives of Saaremaa (2)

	Sub-objective	Baseline, t/yr	Reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity).	162 800	65 000
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	1070	1070
3.	100% renewable electricity is consumed in municipal buildings.	4500	4500
4.	In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	162 800	12 200
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	460	460
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development, and cost-effectiveness.	1010	1010
7.	A 30% reduction in the use of fossil fuels for private transport including the transport of goods.	51 050	15 000
	Total		**99 240**
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	8130	8130
	Total		**107 370**

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Table A 6. Sub-objectives of Hiiumaa (3)

	Sub-objective	Baseline, t/yr	Reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity).	48 000	19 200
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	1780	1780
3.	100% renewable electricity is consumed in municipal buildings.	2030	2030
4.	In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	49 100	6140
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	29	29
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development, and cost-effectiveness.	190	162
7.	A 30% reduction in the use of fossil fuels for private transport including the transport of goods.	18 430	5530
	Total		34 869
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	8950	8950
	Total		43 820

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Table A 7. Sub-objectives of Muhu (4)

	Sub-objective	Baseline, t/yr	Reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity).	8720	3500
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	34	34
3.	100% renewable electricity is consumed in municipal buildings.	320	320
4.	In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	8720	650
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	58	58
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development, and cost-effectiveness.	61	61
7.	A 30% reduction in the use of fossil fuels for private transport including the transport of goods.	2450	740
	Total		5360
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	460	460
	Total		5820

Table A 8. Sub-objectives of Ruhnu (5)

	Sub-objective	Baseline, t/yr	Reduction in CO_2 emissions by 2030, t/yr
1.	At least 70% of the electricity consumed on the island is covered by locally produced renewable electricity.	374	262
2.	In street lighting, the share of energy-efficient luminaires is 100%.	5	0.5
3.	In raising awareness, changing consumption habits, and using smart solutions, energy consumption is decreased.	301	6
4.	Local municipality cars using fossil fuels to be exchanged for electric vehicles.	1	1
5.	A 50% reduction in the use of fossil fuels for private transport by limiting use of transport or adopting electric vehicles.	28	14
	Total		283
6.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	381	381
	Total		664

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Appendix 4 2020 Emission Inventories

Table A 9. Saaremaa 2020 Emission Inventory

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	9640	3270	2700	15 600	1830	11 500
Street lighting	-	-	930	930	510	-
Business sector	24 330	116 230	99 910	240 470	59 720	116 940
Building sector	29 640	66 760	54 580	150 970	29 950	96 130
Private transport	-	184 740	-	184 740	48 200	5730
Local govt vehicles	-	1480	-	1480	390	50
Public transport	-	3110	-	3110	710	100
Total	63 610	375 590	158 110	597 310	141 300	230 430
Ferries	-	22 830	-	22 830	6070	7
Aviation	-	2730	-	2730	680	-
Total	63 610	401 150	158 110	622 870	148 060	230 440

Table A 10. Hiiumaa 2020 Emission Inventory

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	2470	1410	1760	5630	1130	3240
Street lighting	-	-	420	420	230	-
Business sector	1350	14 450	23 490	39 290	13 770	15 170
Building sector	4610	24 990	16 002	45 600	8750	29 600
Private transport	-	59 240	-	59 240	15 450	1840
Local govt vehicles	-	330	-	330	90	10
Public transport	-	1140	-	1140	300	40
Total	8420	1010 550	41 670	151 630	39 720	49 880
Ferries	-	31 000	-	31 000	8250	-
Aviation	-	1920	-	1920	480	-
Total	8420	134 460	41 670	184 550	48 450	49 880

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Table A 11. Muhu 2020 Emission Inventory

Consumer group	District heating, MWh/yr	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	572	9	270	851	147	572
Street lighting	-	-	48	48	26	-
Business sector	-	259	4433	4692	2425	259
Building sector	608	4095	3980	8683	2240	4703
Private transport	-	11 595	-	11 595	3027	359
Local govt vehicles	-	103	-	103	27	3
Public transport	-	193	-	193	44	6
Total	1180	16 250	8730	26 160	7940	5900
Ferries	-	1304	-	1304	347	-
Total	1180	17 560	8730	27 470	8280	5900

Table A 12. Ruhnu 2020 Emission Inventory

Consumer group	Fuels, MWh/yr	Electricity, MWh/yr	Total energy consumption, MWh/yr	CO_2 emissions, tCO_2	Renewable energy sources, MWh/yr
Local govt buildings	64	83	147	-	107
Street lighting	-	7	7	-	7
Business sector	155	322	477	34	350
Building sector	525	123	648	-	648
Private transport	122	-	122	32	4
Local govt vehicles	-	-	-	-	-
Public transport	5	-	5	1	0.2
Special consumers (lighthouse, radar, mobile communication mast)	-	65	65	-	65
Total	871	601	1472	67	1182
Ferries	1640	-	1640	436	-
Aviation	172	-	172	43	-
Total	2683	601	3284	546	1182

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Appendix 5 Adjusted sub-objectives

Table A 13. Adjusted sub-objectives of Saaremaa

	Sub-objective	Baseline, t/yr	2020, t/yr	Remaining reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity).	162 800	84 500	-
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	1070	510	510
3.	100% renewable electricity is consumed in municipal buildings.	4500	1470	1470
4.	In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	162 800	89 670	6700
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	460	390	390
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development and cost-effectiveness.	1010	710	710
7.	A 30% reduction in the use of fossil fuels for private transport including the transport of goods.	51 050	48 200	14 000
	Total			**23 780**
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	8130	6070	6070
	Total			**29 850**

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Table A 14. Adjusted sub-objectives of Hiiumaa

	Sub-objective	Baseline, t/yr	2020, t/yr	Remaining reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity).	48 000	21 600	-
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	1780	230	230
3.	100% renewable electricity is consumed in municipal buildings.	2030	960	960
4.	In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	49 100	22 530	2820
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	29	90	90
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development and cost-effectiveness.	190	300	300
7.	A 30% reduction in the use of fossil fuels for private transport including the transport of goods.	18 430	15 450	4640
	Total			9030
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	8950	8250	8250
	Total			17 280

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Table A 15. Adjusted sub-objectives of Muhu

	Sub-objective	Baseline, t/yr	2020, t/yr	Remaining reduction in CO_2 emissions by 2030, t/yr
1.	At least 40% of the electricity consumed on the island by the commercial and residential sectors is covered by locally produced or green certificate electricity (of which at least 50% is locally generated electricity).	8720	4600	-
2.	In street lighting, the share of energy-efficient luminaires is 100% and 100% renewable energy is consumed.	34	30	30
3.	100% renewable electricity is consumed in municipal buildings.	320	150	150
4.	In raising awareness, changing consumption habits, and using smart solutions, it is possible to achieve 5-10% energy savings from the use of both electricity and heat.	8720	4670	350
5.	Local municipality cars using fossil fuels to be exchanged for fuels with the lowest possible carbon emissions (e.g. biomethane or electricity from renewable sources).	58	30	30
6.	Public transport to deploy buses using renewable energy sources, taking into account infrastructure development and cost-effectiveness.	61	40	40
7.	A 30% reduction in the use of fossil fuels for private transport including the transport of goods.	2450	3030	910
	Total			1500
8.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	460	350	350
	Total			1850

Table A 16. Adjusted sub-objectives of Ruhnu

	Sub-objective	Baseline, t/yr	2020, t/yr	Remaining reduction in CO_2 emissions by 2030, t/yr
1.	At least 70% of the electricity consumed on the island is covered by locally produced renewable electricity	374	-	-
2.	In street lighting, the share of energy-efficient luminaires is 100%.	5	-	-
3.	In raising awareness, changing consumption habits, and using smart solutions, energy consumption is decreased.	301	34	1
4.	Local municipality cars using fossil fuels to be exchanged for electric vehicles.	1	1	1
5.	A 50% reduction in the use of fossil fuels for private transport by limiting use of transport or adopting electric vehicles.	28	32	16
	Total			18
6.	Ferry traffic between islands and mainland uses 100% renewable fuels or electricity.	381	436	436
	Total			454

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 864266

Appendix 6 Economic-financial analysis of biomethane production

Table A 17. Operating income, costs and EBITDA of biomethane production in thousands of euros

Operating income	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Biomethane sales		3329	3396	3464	3533	3604	3676	3749	3824	3901	3979	4058	4140	4222	4307	4393
Total operating income		**3329**	**3396**	**3464**	**3533**	**3604**	**3676**	**3749**	**3824**	**3901**	**3979**	**4058**	**4140**	**4222**	**4307**	**4393**
Operating costs	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Electricity		440	448	457	467	476	485	495	505	515	525	536	547	558	569	580
Wood chips		146	149	152	155	158	161	164	167	171	174	178	181	185	188	192
Labour		59	62	65	68	71	74	78	81	84	88	92	96	99	103	107
Maintenance and repair		124	126	129	132	134	137	140	142	145	148	151	154	157	160	164
Process additives and analysis		54	55	56	57	58	60	61	62	63	64	66	67	68	70	71
Other costs		67	69	70	72	73	74	76	77	79	81	82	84	85	87	89
Logistics		133	136	139	142	144	147	150	153	156	159	163	166	169	173	176
Total operating costs		**1023**	**1045**	**1068**	**1091**	**1114**	**1138**	**1163**	**1188**	**1214**	**1240**	**1267**	**1294**	**1322**	**1350**	**1379**
EBITDA		**2307**	**2351**	**2396**	**2442**	**2489**	**2537**	**2586**	**2636**	**2687**	**2739**	**2792**	**2846**	**2901**	**2957**	**3014**

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Table A 18. Project cash flow and profitability in thousands of euros

Project cash flow	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Loan, €	6400															
Equity, €	1600															
Operating income, €		3329	3396	3464	3533	3604	3676	3749	3824	3901	3979	4058	4140	4222	4307	4393
Total income, €	8000	3818	3829	3840	3852	3864	3876	3889	3902	3932	4001	4071	4143	4222	4307	4393
Investment cost, €	-8000															
Loan payments, €		-1067	-1067	-1067	-1067	-1067	-1067									
Loan interest, €		-170	-170	-170	-170	-170	-170									
Operating costs, €		-1023	-1045	-1068	-1091	-1114	-1138	-1163	-1188	-1214	-1240	-1267	-1294	-1322	-1350	-1379
Total costs, €	-8000	-2260	-2282	-2305	-2328	-2351	-2375	-1163	-1188	-1214	-1240	-1267	-1294	-1322	-1350	-1379
Cash flow, €		1558	1547	1536	1525	1513	1501	2726	2713	2718	2761	2804	2849	2901	2957	3014
Cumulative cash flow, €		1558	3105	4641	6165	7678	9179	11 905	14 619	17 336	20 097	22 901	25 750	28 651	31 608	34 621
Profitability	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Operating income, €		3329	3396	3464	3533	3604	3676	3749	3824	3901	3979	4058	4140	4222	4307	4393
Incoming cash flow, €		3329	3396	3464	3533	3604	3676	3749	3824	3901	3979	4058	4140	4222	4307	4393
Operating costs, €		-1023	-1045	-1068	-1091	-1114	-1138	-1163	-1188	-1214	-1240	-1267	-1294	-1322	-1350	-1379
Investment cost, €	-8000															
Outgoing cash flow, €	-8000	-1023	-1045	-1068	-1091	-1114	-1138	-1163	-1188	-1214	-1240	-1267	-1294	-1322	-1350	-1379
Cash flow, €	-8000	2307	2351	2396	2442	2489	2537	2586	2636	2687	2739	2792	2846	2901	2957	3014
Cumulative cash flow, €	-8000	-5693	-3343	-946	1496	3986	6523	9109	11 745	14 432	17 171	19 963	22 808	25 709	28 666	31 679

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Appendix 7 Stakeholder feedback

Table A 19. Inputs from stakeholders

Energy production, consumption and networks	
The Baltic Sea transmission grid across Saaremaa and Hiiumaa	**Saaremaa Municipality:** There could be a cable that connects Saaremaa and Sweden via Ventspils in Latvia. A consensus is needed between the countries surrounding the Baltic Sea. **Hiiumaa Municipality:** In case an international offshore grid is established, Hiiumaa would like to benefit from it. **Ruhnu Municipality:** The local government supports the establishment of a transmission grid across Saaremaa.
Energy communities	**Saaremaa Municipality:** The local Energy Cooperative has been in contact with the local government and carries out workshops for the residents to increase interest in community energy solutions. There are issues related to the state of the grid and a lack of connection possibilities. Awareness raising is planned to be carried out at events with a large amount of participants. **Hiiumaa Municipality:** Solar PV developments have a lot of potential and there is not much public opposition for this unlike wind energy projects. Currently the local government has taken the role of raising awareness. **Muhu Municipality:** Wind turbines including small turbines are problematic due to the radar, PV has greater potential. The local government has recently installed three 15 kW PV parks and therefore given an example to the residents. Community involvement and increasing awareness are important. **Ruhnu Municipality:** Since the island receives electricity from the local renewable energy solution, there is no need for developing energy communities. **Energy Cooperative:** Estonian communities are small and the capability of establishing solar parks on their own is low. This is where the Energy Cooperative can help with their competencies. In cooperation with Rexplorer, modelling was carried out for interested community representatives for assessing their PV potential. PV has the greatest potential as wind energy is more difficult to reach. The aim is to find active members of the communities that can help carry the community energy projects forward. Positive examples can encourage others. With wind energy the Energy Cooperative wants to get the best deals for communities nearby wind farm developments. There are no specific support mechanisms for energy communities, participating in renewable energy auctions is possible. The European Commission estimates that by 2030 17% of the PV panels installed and 21% of the wind turbines installed could be owned by energy communities. As of now no energy communities have been established in Estonia and therefore, there is no specific model developed for an energy community. The local governments can support energy communities by offering the rooftops of public buildings and buying the electricity generated. The first solutions could be running in the spring of 2022. **Tartu Regional Energy Agency:** Energy communities have potential, but they are at a very early stage. Hopefully the concept will gain traction. The local governments should assume the role of the leader.
Synergy of offshore wind farms and blue economy	**Saare Wind Energy:** Would like to achieve a win-win situation for the islands and Estonia. The wind farm requires ports which can share infrastructure with aquaculture and fishing companies. The goal is to find cooperation possibilities rather than competitors. Currently fish farmers do not want to be near the wind turbines. The wind turbines create new living environments, which increase flora and fauna. The maintenance port could be in Roomassaare, which would be ideal. That would also create about 100 jobs. Training should also be carried out locally. If national welfare is created with wind farms, it should also benefit the local governments.

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Innovative wind energy solutions	**Hendrikson & Ko:** Offshore fish farmers have to go through the same planning procedures as offshore wind developers.
	Hiiumaa Municipality: Dagöplast has considered wind kites, but they would interfere with the flight information zone of Kärdla airport This could be remedied by transponders or remote control to lower the kites. **Danpower:** Alternative solutions have not proven themselves.
Offshore wind farms	**Saaremaa Municipality:** Currently offshore wind farms offer the only possibility for large-scale renewable energy development. Developments onshore are limited due to the radar. There is opposition from the locals, who think that wind farms ruin their surrounding environment. **Hiiumaa Municipality:** The development of Hiiumaa Offshore Wind Farm has stalled and other wind farms will likely be erected before that. The development of the offshore wind farm should also create a network connection from Hiiumaa to the mainland. **Ruhnu Municipality:** It is unclear, where wind turbines will be erected, which causes insecurity. The local government does not see any benefits from offshore wind farms besides potential tolerance fees. Fishermen do not welcome wind farms. Transport corridors need to planned so that the travel times to Ruhnu do not become longer. **Estonian Hydrogen Association:** Wind farms offer the only feasible solution for producing hydrogen. Possible to use hydrogen as energy storage. However, hydrogen should be used in the chemical industry, for example for producing methanol. Selling hydrogen for short-range maritime traffic in the Baltic Sea is a good idea. **Saare Wind Energy:** The application for the building permit was submitted in 2015 and resumed in 2020. Environmental Impact Assessment has been started and it could be finalized in 2023. By the end of 2023 conditions for grid connections could be set and then an operator can be involved. Contracts could be signed in 2025 and the construction could be carried out in 2026 and 2027 with first electricity supplied to the grid in 2028. It is an optimistic, yet realistically achievable approach. Planning might take longer. Lihula seems to be the most feasible connection point in Estonia, however it would be beneficial for the project if Elering was willing to meet them halfway. There is also contact with the Latvian TSO with the aim of establishing a connection from Latvia over Saaremaa to mainland Estonia. The largest power substation of Estonia should be in Saaremaa. The local municipality is supportive. The planned wind farm has 100 turbines with a power of 14 MW, giving a total capacity of 1400 MW. Less than 1 GW is not feasible. Would like to cover at least half of Estonia's demand. There is public opposition, but society has evolved compared to about ten years ago and the attitude is mostly favourable. Financing is not an issue; however Saare Wind Energy would also like to see locals as shareholders. **Empower 4Wind:** As offshore wind farms are far away from the centres in mainland Estonia, operation and support personnel should be located on the islands or possibly in Pärnu. For the wind farm planned by Saare Wind Energy, about 100 employees would be needed in the operation phase. In addition to the people working directly with the wind turbines, jobs are also created in the value chain, such as port activities, ship crews, logistics, accommodation, catering, equipment repair, security, training, and other fields.
Expansion of the renewable energy solution for Ruhnu	**Ruhnu Municipality:** At the moment, the renewable energy solution of Ruhnu is relatively optimised, however to increase the share of locally produced electricity, the battery capacity should be increased. In addition, another 50 kW wind turbine and more PV panels would be needed to reduce the usage of the diesel generator powered by imported biodiesel. Overall, the current system and the electricity network are reliable and there are no major issues. **Estonian Hydrogen Association:** There is an idea of carrying out a pilot project in Ruhnu to turn the island fully renewable with hydrogen. **Enefit Green:** Peak consumption, 160 kW occurs during large events in the summer when there are a lot of yachts in the harbour. Spring and autumn have lower

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	consumption. The batteries can supply the island for four hours with average consumption. The wind turbine and the solar panels have a good balance with more wind power in the winter and more solar power in the summer and more wind when it is cloudy. Realistically, the island could be converted to 90% local renewable sources. It is very expensive to achieve the last 5-10%. Enefit Green assesses the solution annually and added an additional 50 kW of solar panels at the end of 2020. Hydrogen has been left aside due to the low volumes.
Renovation of street lighting	**Hiiumaa Municipality:** In 2018, there were practically no LEDs in use. A large share of street lighting has been renewed from 2019 to 2021. The remainder of streetlights are planned to be exchanged in the following years. **Muhu Municipality:** A large share of streetlights were installed less than ten years ago and there is no point in replacing them yet. **Kuressaare Soojus:** In 2018 about 65% of the lights had been replaced with LEDs. One of the planned projects was put on hold due to the subsidy from EIC being postponed. Without subsidy, the whole infrastructure is not renewed, only the lights themselves are replaced which has a short payback period. Thorough reconstruction is expensive.
Network	**Saaremaa Municipality:** The existing network is old and needs to be renewed. When building new lines or reconstructing old lines, it should be considered whether underground lines are more reasonable as there are a lot of outages with overhead power lines. **Hiiumaa Municipality:** Hiiumaa is interested in having a circular connection as currently the island is only connected to Saaremaa and there is no connection to the mainland. The current network on the island has prevented investments to Hiiumaa as there is a lack of power and a high risk for failures. **Muhu Municipality:** The security of supply has increased significantly with network developments and underground cables. A new transmission line will be built across the island. **Ruhnu Municipality:** Underground power lines would be visually more pleasing but the current overhead lines have been made weatherproof. **Elering:** RRF-supported investments will increase the security of supply in Saaremaa by 2026. Overhead power lines are about 10 times cheaper than underground or submarine cables. Connection fees are paid in full by the developer, which means that Saare Wind Energy would have to cover all the costs related to establishing a connection to Lihula. To transmit the power generated by a 1400 MW offshore wind farm, four parallel transmission lines are needed, which cover an area of 160 metres in width. That is because a greater loss than 350 MW is not allowed to occur in the Estonian power system at the same time.
	Energy consumption in buildings
Biomethane production	**Saaremaa Municipality:** There is support to the production of biomethane, however the suggested location is not favoured. There is economic interest from multiple stakeholders. The local government can support the project with favourable attitude. **JetGas:** Today the biomethane plant is at an early planning stage. Planning takes two years; construction takes one year. 2025 could be earliest time for biomethane production. The first initiative came from the local farmers that want to put manure to better use. Waste from the food production industry could also be used. HoReCa waste would be rather unexpected as other solutions might be more reasonable. There are no estimates about production capacities or the farms that could supply manure. It is likely that the production capacity could exceed the need of the local public transport. The financial model has not yet been discussed, either gate fees might be applied or it might be necessary to pay for the manure. The resulting digestate is a valuable fertilizer that can replace mineral fertilizers to a great extent. In mainland Estonia, biogas plants have been built near large farms. Saaremaa does not have such large farms and therefore a single central location has been chosen within a 30 km radius from about 80% of the manure. In that location a gas pipeline can be built to the existing LNG station which reduces costs for compression and transportation of gas tanks. JetGas does not see any alternative locations. The role of JetGas is to be one of

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	the developers and gas purchaser - there is no interest in operating the plant. The project would be handed over at some stage. Biomethane could also be transported to other locations on the island to replace the fuels currently used. The problem for biomethane is the high price compared to shale oil or wood chips. In order to expand the network of gas stations on the islands, there needs to be an interest from the local governments. A critical mass of clients is expected before the construction of a gas station. **Danpower:** At a preliminary planning stage, no actions have been taken, have cooperation with JetGas.
District heating	**Saaremaa Municipality:** Kuressaare Soojus, the local heat producer and supplier, is trying to find new customers but there are not too many developments taking place. The district heating network is being constantly gradually renewed and a large part has already been replaced. Some of the district heating areas are being converted to ground source heat pump heating, such as the school and kindergarten of Valjala. **Hiiumaa Municipality:** The central boiler house of Käina currently supplies the sports centre, the swimming pool, and some other buildings but there is no capacity for expanding the network. There is interest from apartment buildings to connect to the district heating network. The settlement is compact and the establishment of a larger district heating grid has potential. Waste heat from Dagöplast could also be used. Hot water production during the summer period in the existing Kärdla district heating grid is probably not reasonable. **Muhu Municipality:** The boiler house using wood chips was recently renovated. New consumers are welcome to join. **Danpower:** Danpower is interested in acquiring new district heating networks and boiler houses if offered. Kuressaare Soojus could be of interest, whereas the district heating areas of Hiiumaa are too small and far away. Solar heating is not a rational solution for district heating. Overall, probably too many investments have been done in Kuressaare and therefore it is questionable why additional investments should be made. **Kuressaare Soojus:** There are plans for reconstruction of networks for the following years. All district heating networks of Saaremaa besides Sõmera are operated by Kuressaare Soojus. With the closure of the Sõmera Home for people with special needs, the boiler house will also be closed. Investments are also carried out in smaller district heating areas. Overall, everything is in good condition and functional, better than the Estonian average. The CHP produces as much electricity as possible, there are longer downtimes in the summer. Alternative solutions such as solar collectors have not been thoroughly considered as they cannot reduce costs. The main aim is to increase security of supply, although there have not been any outages and reduce losses. There are no major issues. Kuressaare Soojus could offer support in Muhu if needed but there is no interest towards Hiiumaa.
Renovation of buildings	**Saaremaa Municipality:** The conditions set by Kredex and difficulty getting loans to cover the own share of investments prohibits carrying out renovations. The local municipality also does not have the capacity to support residents financially as there is a lack of funds for renovating public buildings. **Hiiumaa Municipality:** The local government is focused on increasing the energy efficiency of their buildings. The last remaining oil-fired boilers in public buildings will be replaced. The local government has advised apartment associations on applying for renovation subsidies. The local government renovates buildings according to their financial capability. Some of the buildings will be demolished as it does not make sense for them to be renovated and new energy-efficient buildings are built instead. **Muhu Municipality:** The renovation of buildings has a large potential for energy savings. The municipality has advised one apartment association in applying for a subsidy. The municipality renovated an apartment building to an energy efficient rental building and is planning to expand the sports centre and build a swimming pool. The local government itself will move to a more energy efficient building and sell the building currently used.

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	Ruhnu Municipality: Buildings mostly use local firewood or air source heat pumps for heating. The renovated schoolhouse has a ground source heating system. The renovation of buildings is prohibited for a lot of them by heritage protection rules.
	Energy consumption in transport
Electricity and hydrogen in public transport	**Saaremaa Municipality:** Most of the buses run on natural gas. It would be good if the gas was produced locally from waste products. The local government does not have much influence on ferry transport. Hydrogen is a topic for a more distant future. Some of the public transport lines are demand based. **Hiiumaa Municipality:** For the next public transport tender at the end of the decade CNG and hydrogen have been considered, but there is no clear plan at the moment. A pilot project should be carried out to gather information for compiling the next tender. Hysto Ltd has shown interest in producing hydrogen on the island. Hiiumaa does not have much say when it comes to ferries. **Muhu Municipality:** Sustainable mobility is of great importance, especially light traffic roads for safe cycling and the optimisation of public transport. **Ruhnu Municipality:** The main concern that the island has is related to the reliability and suitability of catamaran Runö as the vessel connecting Ruhnu to the mainland and to Saaremaa. There have been plenty of issues with the vessel. A new ship is needed, however there is no interest towards electric or hydrogen ships as that might reduce the reliability. Partial electrification has been considered so that the ship could use electric motors in harbours. That would reduce the need for cooling the engines and mud would not be sucked into the filters, which currently causes mechanical issues. **Estonian Hydrogen Association:** Aviation and ferry connection to Ruhnu could be hydrogen based as a pilot project. Solar PV is the last thing to use for producing hydrogen. Having hydrogen buses in Hiiumaa is complicated, however it is a good idea to skip the step of using CNG buses. There is insecurity about the ferries. Currently pilot projects are ongoing in the world. Hydrogen filling station network should at first be developed in larger centres. **Hysto:** Everybody is talking about hydrogen but nobody is doing anything. Nothing is likely to happen before 2030. Modelling needs to be carried out before investments can be done. The municipality of Hiiumaa has to show will and interest. Transport is not primary as it requires the development of infrastructure. Hydrogen should be used for stability in energetics. Hysto wishes to make Hiiumaa 100% renewable with hydrogen and make it an example for the world. **Transport Administration:** Contracts with ferry operators last until 2026. New tenders will be published before that and requirements for greener ferries will be set. What exactly will be asked, is unclear as suitable technologies have not been defined. Electricity, hydrogen, and LNG are considered. LNG seems the most feasible option at the moment. The focus is on the ferries connecting the mainland to the larger islands. Hiiumaa will not have gas buses as there is no infrastructure. Green electricity might be an alternative. No major changes are planned in aviation. **Tartu Regional Energy Agency:** The islands do not have many opportunities for impacting ferry transport.
Electrification in transport	**Saaremaa Municipality:** In 2021 electric scooters were introduced in Kuressaare by Bolt. The local government is not considering electric vehicles at the moment; however, gas-powered vehicles might be bought. **Hiiumaa Municipality:** Changes in transportation are problematic as it requires the contribution of many residents. Currently only social workers and some residents have electric vehicles. Currently it is a lot more comfortable to use gasoline or diesel-powered cars which are also much cheaper. Raising awareness is an important measure to increase the penetration of electric vehicles. The existing charging infrastructure is meant for cars but there is also a developer interested in creating a charging network for bicycles. The first stage would involve a few dozen bicycles. **Muhu Municipality:** Sharing electric vehicles is rather a long-term goal and not realistic in the near future. Electric vehicles are expensive.

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	Ruhnu Municipality: There has been thought of having, for example, five communal electric vehicles but it does not seem realistic right now. People can repair internal combustion engine cars but not EVs which makes it riskier to use EVs. Renting out electric bicycles offers an opportunity to reduce the usage of cars. **Enefit Connect:** There is a fast growth rate in the adoption of electric vehicles but a low overall volume. For the current needs there is a sufficient network of chargers, it is more a question of convenience and speed. Enefit Connect plans their chargers based on either profitability or coverage to attract additional EVs. All the electricity supplied is certified renewable electricity. The local governments should enable electric connections and rental spaces for developers. Other possible locations for chargers include supermarket parking lots and gas stations.

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Appendix 8 Comparison of overhead lines and underground cables

Table A 20. Comparison of overhead lines and underground cables (204) (205)

Indicator	Overhead line	Underground cable
Fault location	As an overhead line is visible, it is easy to find the location of the fault.	As an underground cable is invisible, it is very difficult to find the location of the fault.
Construction	Overhead power lines are simple to construct and do not require insulation and sheathing. Overhead cables have less requirements and are cheaper to construct.	Underground cables are more expensive to construct since they have to be electrically insulated and have protection against moisture, corrosion, mechanical damage, and other environmental impacts from the soil.
Installation cost	There is no requirement of digging, manholes, and a trench. Thus, an overhead line system is cheaper than an underground system.	The initial cost of an underground transmission system is larger compared to an overhead line because it needs digging, trenching, etc.
Chance of fault	As an overhead line is exposed to the environment, there are more chances of faults occurring.	The cables are not exposed to the environment – a fault is not very likely.
Safety	The system is less safe as conductors are placed on pylons. Overhead cables can be brought down by human, animal intervention, weather, and vegetation such as trees.	The system is safer as the cables are placed underground and are not affected by trees, animals, accidents, wind, storms and other physical interference that may lead to broken poles and short circuits or cable breakages.
Useful life	20-25 years	40-50 years
Maintenance cost	The maintenance cost is lower for the same number of faults as no digging needs to be done	The maintenance cost is higher, as digging is needed to find the fault.
Flexibility	This system is flexible. Because the expansion of the system is simple.	The system is not flexible. The expansion cost is nearly equal to a new system construction.
Heat dissipation	Most of the heat is released to the surroundings, natural cooling is provided by the air.	Heat dissipation in underground cables is limited by the layers of insulation and protection such as armouring and sheaths. Most of the heat is therefore retained near the cable.
Conductor size	The conductors are placed in the atmosphere. Therefore, the size of the conductor is small compared to the underground system.	The cables are larger because of poor heat dissipation.
Interference with the communication line	The communication lines are run along the transmission line. In this case, it is possible to cause electromagnetic interference.	There is no interference with communication lines
Proximity effect	The distance between the conductors is great. Therefore, there is no proximity effect.	As the distance between cables is small, there is very high proximity effect.

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Indicator	Overhead line	Underground cable
Voltage carrying capacity	Overhead lines are better suited to carry higher voltages compared to underground cables.	Underground cables are limited by the expensive construction and limited heat dissipation. For these reasons, underground cables are mostly used for transmitting up to 33KV.
Voltage drop	There is more voltage drop in the overhead power lines due to the small diameter of the cables.	Underground cables have a much larger diameter and a lower voltage drop.
Application	The cost of the system is low. Therefore, overhead lines are used in the long-distance transmission systems and in rural areas for the distribution system.	Because of the high cost, underground cables are used for short distances and in densely populated areas, where space is a major problem for the overhead transmission line.
Environmental impact	Overhead power lines can produce noise, wildlife electrocutions and require the management of vegetation. In addition, there is a great visual impact.	Underground cables have more environmental and health benefits due to reduced noise and better vegetation management. In addition, they have less transmission losses, reduced damage, and accidents such as wildlife electrocutions.
Land use	The pylons and cables of overhead power lines require a lot space that needs to be managed to avoid the occurrence of faults.	Underground cables allow better use of land which leads to improved property values.

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