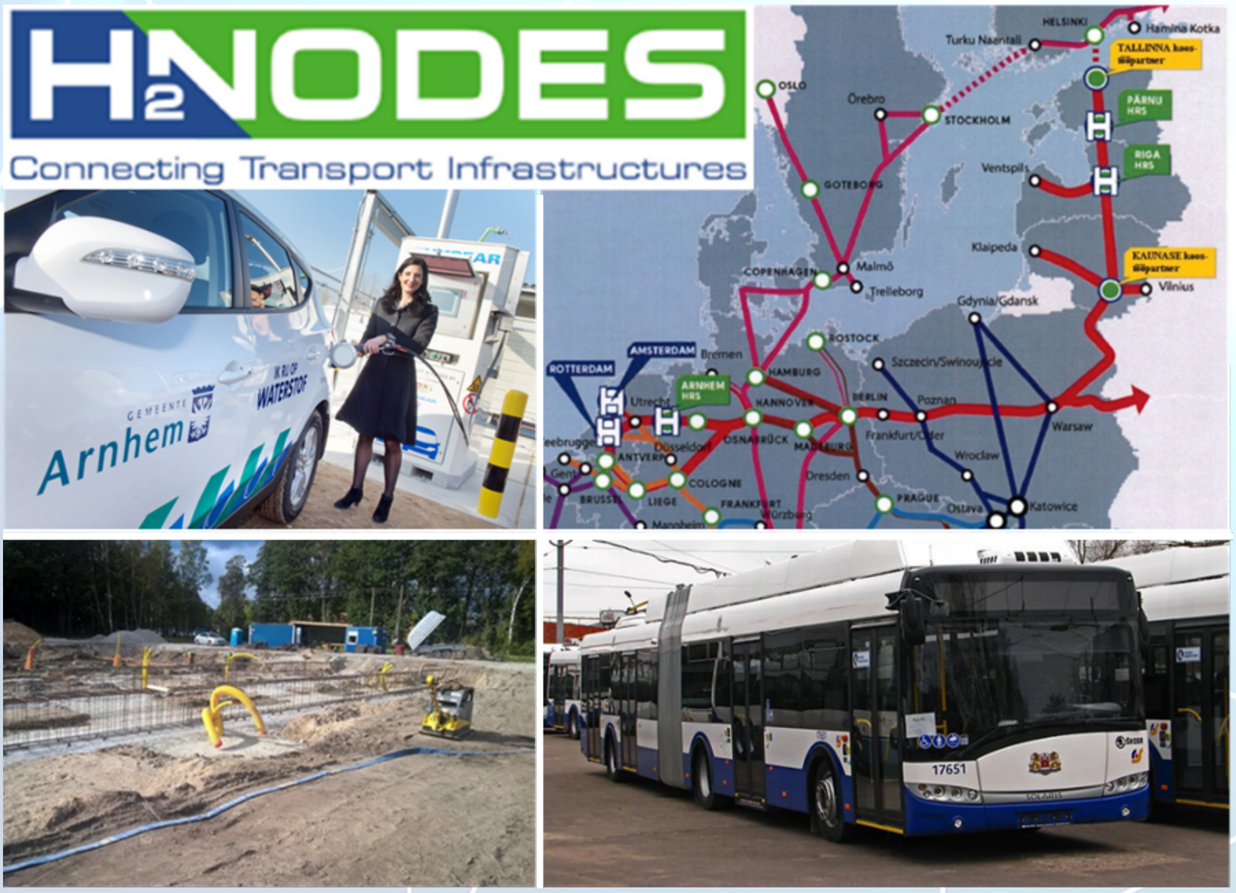
Milestones H2NODES

Milestone 2

Sustainable hydrogen production pathways in Pärnu



Co-financed by the Connecting Europe
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Milestone 2 Report

Date: June 2021 (Final)

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1. Introduction

This report describes the evaluation of potential hydrogen production pathways in Pärnu count by considering the available renewable energy resources. The Milestone 2 "Sustainable hydrogen production pathways in Pärnu " corresponds to Action H2NODES Sub-activity 1.1. whereas the local studies of the possible pathways for sustainable hydrogen production for the longer term are conducted and involve potential producers of hydrogen in the wider region around each Hydrogen refuelling station (HRS).

Note that the HRS in Pärnu will not be deployed within the Action H2NODES due to the lack of potential hydrogen demand. Although the station will not be deployed, this study will address the potential of hydrogen production.

Milestone 2 "Sustainable hydrogen production in Pärnu" report consists of Estonia energy production overview and specific evaluation of potential hydrogen production sources in Pärnu county.

Additionally, the potential CO_2 reduction rates are calculated by assuming that the hydrogen would be used in FCE-buses that would substitute the existing conventional fuelled units.

2. Potential green energy resources for hydrogen production in Estonia

2.1 Total energy supply

In order to assess the potential energy sources that would be available for hydrogen production the overall energy supply of Estonia must be evaluated. The total energy supply (excluding for non-energy uses) in 2019 was 194.4 PJ. During last decade, in 2010-2018 the total energy supply had varied in the range 221 – 248 PJ and had significantly decreased in 2019 down to 194 PJ. This decrease was caused by the significant reduction of oil shale consumption. Namely, oil shale contribution in total energy supply during 2010-2018 had varied in the range 153-190 TJ (average annual 171 PJ) and had decreased down to 123 PJ in 2019.

Due to decrease of electricity production by utilising oil shale, Estonia has become electricity net importer. In 2010-2018 Estonia was electricity net exporter (net export varied in range 3.3-12.9 PJ, average annual 9.2 PJ). In turn, in 2019 and in 2020 Estonia had net import of electricity of 7.8 PJ (2.16 TWh) and of around 13 PJ (3.65 TWh) respectively[1].

In 2019 renewables contributed 49.4 PJ of total energy supply. The share of renewables in total energy supply (excluding non-energy uses) in 2019 was 25.4%. During last decade renewables utilisation has increased. In 2010 renewables contributed 35.8 PJ of total energy supply that was 24,6%.

The first wind power plants started operation in 2002. In 2015 the total capacity or wind power plants had reached 300 MW. In turn, in 2015-2019 only few new wind power megawatts had been installed (more details below, in the section devoted to wind power). Active solar PV installation has started after 2015 and is particularly active in recent years. In its turn, hydro has only minor role.

Regarding combustible renewables, primary solid biofuels dominate. Utilisation of solid biofuels for energy supply has increased in last 5 years (2015-2019) per around one quarter. It is simultaneously increasing both primary production and net export of solid biomass. In 2019, it was produced in Estonia 73.8 PJ of solid biofuels and net export of them constituted 28.3 PJ. In 2015 it was produced 50.6 PJ of solid biofuels and 15.7 PJ exported, in 2010 – 40.1 PJ and 6.4 PJ respectively).

Biogases utilisation is increasing, however still makes only small share of total renewables. The same relates to liquid biofuels which currently are blended to transport fuels.

[1] Statistics Estonia

Table 1 Renewables in Estonia total energy supply (TJ)[2]

	2010	2015	2019
Hydro	97	96	68
Wind	997	2574	2473
Solar PV	0	0	265
Primary solid biofuels (net)	34192	34557	43685
Biogases	155	550	581
Liquied biofuels	324	107	1147
Renewable municipal waste	0	1212	1148
TOTAL	**35765**	**39096**	**49367**

2.2 Final energy consumption

The final energy consumption in 2019 was 118.4 PJ. During last decade, in 2010-2019, the final energy consumption was rather stable and varied in the range 115 – 121 PJ. In 2019, non-renewable fuels contributed 45.6%, renewable fuels – 15.7%, electricity – 22.3% and heat – 16.4% in final energy consumption.

In 2019, among renewable fuels solid biomass dominate – 91.4%. Other renewable fuels contributed still comparatively low shares: liquid biofuels – 6.2%, biogases' – 1.8%, renewable municipal waste – 0.6%.

Table 2 Final energy and fuel consumption (TJ)

	2010	2015	2019
Non-renewable fuels	49893	52007	54047
Renewable fuels	23371	20464	18542
Electricity	24869	24667	26341
Heat	22254	18029	19446

[2] Statistics Estonia, KE0240

In 2019, the sectorial shares of final energy consumption were: Households – 33.7%, Transport -29.4%, Commercial and public services – 16.5%, Industry – 16.4%, Agriculture, forestry, fishing – 4%.

2.3 Wind parks

Wind power plants (WPPs) had started operation in Estonia from 2002. In 2009 the total (accumulated) capacity of WPPs had exceed 100 MW. Over the years a significant growth in WPPs could be seen in Estonia as In 2014 the total WPPs capacity reached 334 MW. After 2014 only few MW of new WPPs capacities have been put into operation.

In 2019 total capacity of wind parks in Estonia was 316 MW (~ 140 turbines[3]). Dominating number of turbines are deployed in public power plants with power capacity of 315 MW whereas autoproducers capacity is only 1 MW[4]. The average annual full-hours load of on-shore wind parks is around 2200 hours. It can be seen in Table 3, that from 2014 – till 2019 36 wind turbines are dismantled and only 18 new installed. Therefore a small decrease of WPPs capacity can be seen.

As for the deployment of WPPs, currently there is no operating off-shore wind parks in Estonia. Note that seasonal production can be seen in Estonia. From 2015-2020 the WPPs produced 4.2 TWh wind electricity in total (around 0.7 TWh annually). From this amount:

- 32.3% had been produced in winter (December, January, February);
- 23.5% had been produced in spring (March, April, May);
- 17.9% had been produced in summer (June, July, August);
- 26.4% had been produced in autumn (September, October, November)[5] .

Table 3 Development and current state of wind power plants in Estonia: capacity and annual production

	New installed capacity, MW	**Total (accumulated) capacity, MW**	**Total available (accumulated) capacity, MW**	**Production, GWh**
2002	2	2	1	1.4
2003	0.4	2.4	2.4	6.1
2004	20.4	23	7	7.6

[3] single small size capacity turbines are excluded from this number

[4] Statistics Estonia. Database KE032

[5] Statistics Estonia. Database KE21

2005	8.2	31	31	53.9
2006	0	31	31	76.3
2007	27	58	50	91
2008	19	77	77	133
2009	39	116	104	195
2010	16	132	108	277
2011	49	181	180	368
2012	85	266	266	434
2013	0	266	248	529
2014	68	334	334	604
2015	-34	300	300	715
2016	10	310	310	594
2017	1	311	309	723
2018	-2	309	307	636
2019	7	316	316	687

The most Wind power capacity[6] is in 7 Estonian counties (*maakond*). Largest part (around 70%) of the total capacity is sited in four North Estonia counties having sea border with Finnish Gulf.

[6] Estonian Wind Power Association. Tuuleenergia Eestis (List of Estonian Wind Power Parks), https://tuuleenergia.ee/?page_id=1024

Figure 1 Administrative division of Estonia: counties

Table 4 WPPs capacity and annual average power production in different Estonia Counties

County	Total installed capacity, MW	Total average annual production, GWh (full load 2200 hours)
Lääne county	57	125.4
Harju county	63.4	139.5
Lääne -Viru county	56.7	124.7
Ida-Viru county	39	85.8
Pärnu county	77.45	170.4
Saare county	16.11	35.4
Tartu county	0.3	0.7

Taking into account the Table 4 data, the **Pärnu county has the largest wind energy availability compared to other Estonia Counties.**

2.4 Hydro power plants

Hydro power plants (HPPs) provides very minor contribution of electricity production in Estonia. Installed total capacity of HPPs in 2019 had been only 6 MW[7]. More than 40 small scale HPP operates in Estonia. The largest share of capacity is sited in Harju county. There is no HPPs sited in Pärnu county.

2.5 Solar PV

Solar PV has sharp increase of contribution in Estonia total energy supply. In 2019 solar PV contribution in Estonia energy supply was 73.5 GWh. This contribution continues to increase. 112 GWh electricity was fed into the grid total in the first three quarters of 2020.

Solar PV, GWh	0	9.7	14.5	30.8	73.5

Estonian TSO Elering provides the data on grid-connected production modules (contractual rated connected capacity)[8]. **The total contractual connected capacity of solar PVs, provided by these data, in 2020 is around 115 MW.** Based on these data, we have made the split of the solar PVs capacities according to the capacities range of single connections, presented in the figure below.

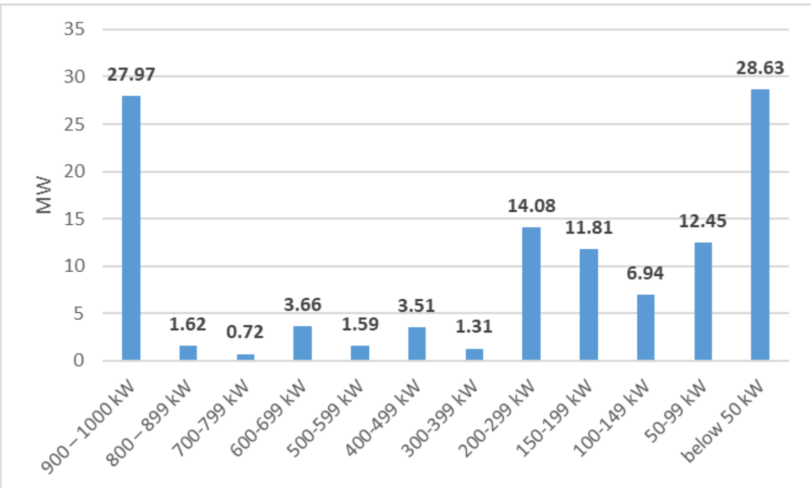

Figure 2 Split of the solar PVs connections to the grid in Estonia

2.6 Combustible Renewables

During last decade electricity production from wood chips and wood waste had been rather stable during 2010-2015 (annual average production of electricity was 737 GWh) and has slight stable tendency to increase after 2015. In 2019 1247 GWh electricity was produced

[7] Statistics Estonia. Database KE032.

[8] Estonian TSO Elering. Võrguga ühendatud tootmismoodulite andmed 2020.

from wood chips and wood waste, of which dominating share (1213 GWh) was produced by public power plants and very minor share (34 GWh) by autoproducers. Most part of electricity is produced in CHP mode. 887 thousand m3 solid volume consumption was allocated to electricity production.

Also renewable municipal waste is used for electricity and heat production. In 2019 around 1 PJ of this waste had provided input in energy transformation sector. However, dominating practice is heat production. In 2019 it was produced, by utilizing renewable municipal waste, 239 GWh heat and only 10 GWh electricity, all this electricity amount was produced by autoproducers. In 2019 43 TJ of renewable municipal waste was allocated to electricity production. Electricity production from renewable municipal waste has decreasing tendency: in 2012 – 48 GWh, in 2016 – 25 GWh electricity was produced. Autoproducers are dominating in the production. From 2013 Estonia statistics does not indicate the electricity production by public power plants utilising renewable municipal waste.

Electricity production from biogas has started in Estonia in 2013 however up to now has minor role. In 2019 39 GWh electricity was produced from biogas, of which dominating share (37 GWh) was produced by public power plants. 9 million m3 of biogas consumption was allocated to electricity production.

Table 5 Electricity production from combustible renewables (GWh)[9]

Combustible renewable	2015	2016	2017	2018	2019
wood chips and wood waste	710	815	940	1192	1247
renewable municipal waste	19	25	21	14	10
biogas	50	45	40	36	39

The Estonia Biogas association states that there are 17 active biogas plants in Estonia[10], of which

- 5 biogas plants utilise agriculture sector raw materials;
- 7 biogas plants operate in municipal and industrial waste water treatment plants;
- 5 biogas plants operate in managed waste landfills.

Biomethane production has started in Estonia in 2018. The total annual biomethane production of two first biomethane plants is 6.5 million m^3 per year[11]. In 2019 Estonia had

[9] Statistics Estonia, KE033
[10] Estonian Biogas Association website, http://eestibiogaas.ee/tootmine-ja-kasutamine/
[11] Energy Policies of IEA countries: Estonia 2019 Review, https://www.iea.org/reports/energy-policies-of-iea-countries-estonia-2019-review

produced 60 GWh of biomethane. In 2020 and 2021 three biogas plants have been equipped to produce biomethane. **In 2021 five biomethane production facilities operate having biomethane total annual production capacity of around 13 million m^3 biomethane.**

Table 6 Biomethane producing plants in Estonia

	Location county	Short description
Biometaan OÜ	Viljandi	Year of deployment:2018 Annual input of raw materials: 81,000 tonnes of slurry 5,000 tonnes of solid manure and 5,000 tonnes of silage[12] Annual production capacity of biomethane: 1.2 – 1.5 million Nm3.
Estonian Cell AS	Lääne-Viru: Kunda	Year of deployment: 2018 Raw material: aspen pulp mechanical waste water sludge Start of biomethane production: June 2018. Annual energy value of biomethane production -more than 50 GWh. The plant is capable of injecting of produced biomethane into the Eesti gas distribution grid[13].
Vinni Biogaas OÜ	Lääne-Viru	The main raw materials: 88000 tons of manure and leftovers from food production annually. Vinni plant produced over 4 million m^3 biogas (58,8% methane) annually[14]. Start of biomethane production: July 2020 Biomethane production capacity: rated at 465 Nm^3/h.[15]
Tartu Biogaas OÜ	Tartu	Year of deployment: 2013. Raw materials: milking cow slurry, manure and bio-waste, annually used amount is 80,000 tons in total. Start of biomethane production: July 2020. Biomethane production capacity: 425 Nm^3 /h

[12] https://k-agro.ee/biometaani-tootmine/
[13] https://www.europeanbiogas.eu/malmberg-supply-first-biogas-upgrade-baltic-states/
[14] Risk Assessment of Biogas Production in the Baltic Sea Region from the nutrient management perspective: Final Report, 07.12.2017 (the same source for Tartu biogas plant as well)
[15] https://www.envitec-biogas.com/infocenter/press-releases/delivery-of-two-envithan-biogas-upgrading-plants-to-estonia (the same source for Tartu biogas plant as well).

Oisu Biogaas OÜ	Järva	Year of deployment: 2013 Raw materials: milking cow slurry and manure. Produced annually over 4 million m^3 biogas (52,4% methane)[16]. Biomethane production is planned to be started not later than May 2021[17]. Capacity - 427 Nm^3/h.

Note, that the information on electricity production capacities at Estonia biogas plants is provided based on the referenced information sources or the interactive map of Estonia biogas power plants.

	Location county	Short description	Electric capacity, MW
Agriculture sector raw materials			
Aravete Biogaas OÜ (year of deployment – 2008)[18]	Jarva County		2 MWel (13.5 GWh el)
Municipal solid waste poligons. Heat and electricity production			
Tallinna Prügilagaa (2010)	Harju County		1.05 MWel[19]
Uikala Prügila (2010)	Ida-Viru County, Kukruse		0.3 MWel[20]
Tartu Aardlapalu prügila (2014)	Tartu county		0.4 MWel
Paikre OÜ	Paikuse, Pärnu County		0.15 MWel
Väätsa Prügila	Järva county		0.1 MWel
Municipal waste water treatment facilities. Heat and electricity production			
Tartu Vesi AS (2014)	Tartu county		0.3 MWel

[16] Risk Assessment of Biogas Production in the Baltic Sea Region from the nutrient management perspective: Final Report, 07.12.2017 (authors: Katarina Oja, Margarita Oja, Ahto Oja, Tauno Trink, Estonian Biogas Association), https://johnnurmisensaatio.fi/wp-content/uploads/2019/05/estonia_biogas-risk-assessment_final.pdf // Interactive map of the Estonian Biogas plants,
[17] EnviTec Biogas News, 9th November 2020, https://www.envitec-biogas.com/infocenter/press-releases/third-envithan-in-estonia
[18]. Annual input of raw materials: milking farm manure (33.6 thousand tons liquid and 3.36 tons solid manure (Risk Assessment of Biogas Production …)
[19] https://tjt.ee/jaatmekaitlus/teenused/prygilagaasi-kogumine/
[20] https://www.uikalaprugila.ee/et/p/general-information/development

		Production for own use
Kuressaare Veevärk AS (2014)	Saare county	0.1 MWel

According to the previous data, different energy production facilities are located around Estonia. Due to the fact that the report is mainly based on sustainable hydrogen production in Pärnu, the potential of hydrogen production will be assessed for the specific county.

3. Potential energy resources for hydrogen production in Parnu county

3.1 Overall fuel consumption

Data on counties' energy consumption are provided by Statistics Estonia in the data base KE07 in natural units. Data on electricity and heat consumption are available starting from 2012. By assessing the available data, in 2019, around 7.8 PJ energy was consumed in Pärnu county, of which fuel consumption has constituted around 60% (4.6 PJ), electricity consumption around 17% (1.35 PJ or 374 GWh) and heat consumption around 23% (1.8 PJ or 510 GWh). Dominating renewable fuel is solid biomass which has contributed around 37% in total fuels consumption.

Currently in Pärnu county annual RES electricity production is around 312 GWh, thus Pärnu county is "electricity importer", but electricity consumption and production are very close.

Consumption of transport fuels in Pärnu county in 2019 was around 52 thousand tons, of which diesel oil – 38 thousand tons and motor gasoline around 14 thousand tons.

Table 7 Fuel consumption by type of fuel in Pärnu county (TJ)

	2010	2015	2020
Coal	25	25	25
Peat, including briquettes	987	122	151
Firewood, wood waste and chips	1493	1447	1701
Natural gas	308	342	410
Shall oil heavy fraction	39	39	117
Gas/diesel oil	1435	2574	1604
Motor gasoline	704	616	616
Electricity	1426 (2012)	1235	1346
Heat	1627 (2012)	1519	1836
TOTAL	**8054**	**7920**	**7806**

3.2 Wind energy

In Pärnu county is sited 25% of existing total Estonian wind power capacity. At the moment 77.45 MW of wind power are in operation in Pärnu county, Lääneranna municipality[21]. Esivere, Tooma and Virtsu wind parks initially were sited in Lääne county – Hanila parish – which had joined Pärnu county in 2017.Mäli and Tamba small size wind parks are sited close to each other and creates Tamba-Mäli wind park.

Table 8 Existing WPPs in Parnu county

Wind power park	Total capacity, MW	Number of turbines	commissioned
Mäli windpark	12	4	September 2013
Tamba windpark	6	2	September 2013
Esivere	8	4	2005
Esivere I	12	4	2008
Tooma I	16	8	2009
Tooma II	7.05	3	2016
Virtsu I	1.8	3	2002
Virstsu additional turbine	0.8	1	2008
Virtsu II	6.9	3	2008
Virtsu III	6.9	3	2010

[21] Estonian Wind Power Association. Tuuleenergia Eestis (List of Estonian Wind Power Parks), https://tuuleenergia.ee/?page_id=1024

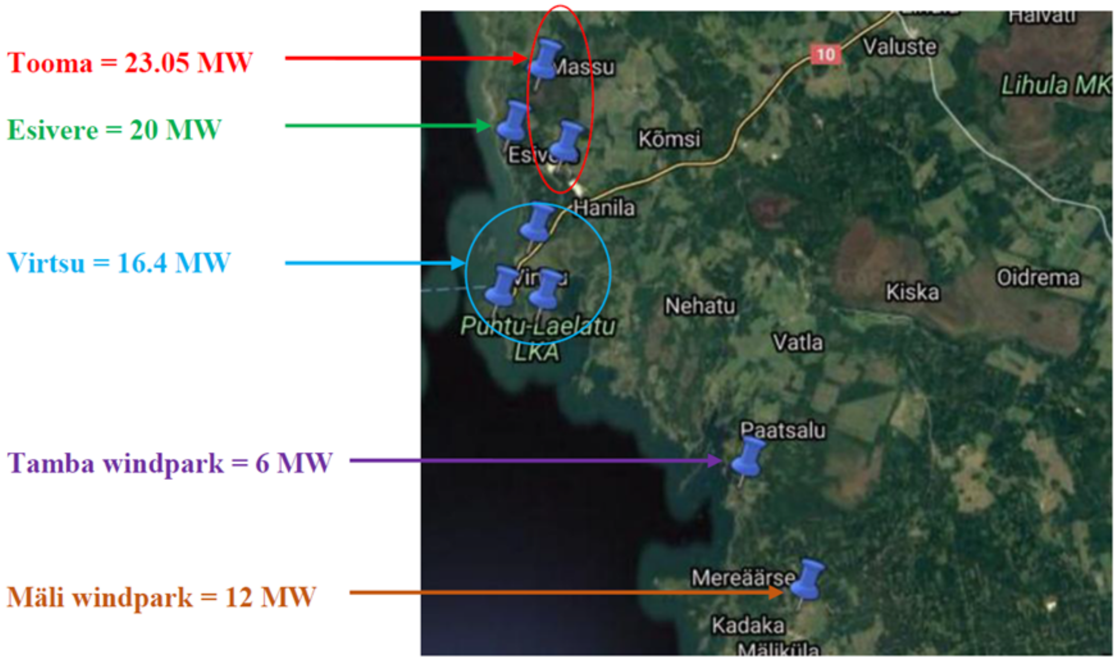

Figure 3 Location of WPPs in Parnu county

The potential hydrogen production capacity in different thresholds is provided in Table 9. Note that the potential amounts are set for 24h cycle. As it is unlikely that a whole wind park would be dedicated to hydrogen production the thresholds of 10%,20% of available energy division to hydrogen production are calculated.

Table 9 Potential green hydrogen production from existing Wind parks (kg/H_2)

Wind power park	Total capacity,MW	10%	20%	100%
Tooma	23,05	267	534	2672
Esivere	20	231	463	2318
Virtsu	16,4	190	380	1900
Tamba	6	69	139	695
Mali	12	139	278	1391
Total		**897**	**1790**	**8978**

The potential hydrogen production from using the already deployed WWPs could allow to achieve the hydrogen availability in the region. By only using 10% of the produced electricity to produce hydrogen, the capacity would reach around 900kg of hydrogen per day.

3.3 Solar PV parks

In July 2019, it has been opened the **large scale solar PV park complex of 3.96 MW in Pärnu county**. The contractor was Pärnu Päikesepargid, a joint company owned by Eesti Gaas AS and Paikre OÜ. In the area of 16 ha it is sited four 990-kilowatt solar parks comprising 13,000 solar panels. The solar parks are located in the territory of the former Rääma landfill, which ceased operation and was recultivated[22].

The contractual connection capacity of other solar PV parks (above 200 kW) are:

- Wendre I Päikesepark (Metsakombinaadi)– 950 kW;
- Voore – 900 kW (Urge village of Tori parish);
- Lageda – 468 kW (Urge village of Tori parish);
- Hansu – 200 kW (Killingi-Nomme).

The *Metsagrupp* has around 50 solar PV parks with a capacity of up to 50 kW. For the most part, the company operates smaller facilities, i.e. no more than 50 kW. Four solar PV parks is rated at 50 kW[23].

Comparing to the WWPs the Solar PV produced hydrogen amounts can reach only up to 233kg of hydrogen per day. Note that this calculation is made on the assumption that the Solar PV is using all produced electricity to produce hydrogen.

3.4 Solid Biofuel

The Pärnu CHP plant uses local biofuels – woodchips to produce electricity and heat. The plant has been commissioned in November 2010 and has electrical capacity 24 MW and heat capacity 48 MW[24].

Regarding the high electrical capacity. The potential to produce hydrogen from Pärnu CHP is evaluated and provided for different thresholds.

Table 10 Pärnu CHP potential H_2 production amounts (kg/H_2)

Parnu CHP	10%	20%	100%
Tooma	1031	2062	10314

[22] Elenger website, News, 18 July 2019, https://elenger.lv/en/elenger-opened-the-biggest-solar-power-park/

[23] https://news.err.ee/1222231/parnu-solar-power-developer-awaiting-state-subsidy

[24] https://www.fortum.com/about-us/our-company/our-energy-production/our-power-plants/parnu-chp-plant

Due to higher working hours of CHP plants, the potential hydrogen production rates are significantly higher compared to the WPPs.

3.5 Landfill gas

The Paikre landfill in Paikuse (Paikre OÜ) produces heat and electricity from the landfill gas. The electrical capacity is 0.15 MWel [25] Althought the electrical capacity for Paikre Landfill gas facility is small, it is not viable to deploy a hydrogen production equipment due to available alternatives (Solar, Wind parks) in the nearby county.

3.6 Foreseen on-shore projects

Four new WPP projects are currently initiated in the Pärnu county. The total capacity of all projects might reach around 300 MW producing 660 GWh electricity per year. Currently Environmental Impact Assessment (EIA) procedures are on-going or are initiated. Before the Statements of EIA elaboration, it is hard to project the real size (total capacity) of future wind parks. For example, on-going EIA for Tootsi wind park has already shown that compromise between wind park and nature (birds) protection interests shall be found. The length of the procedures also might delay the preliminary year of start of operation.

To promote local acceptance, the new projects would provide (as possible) direct electricity connection lines to increase a competitive advantage to those industrial companies that are setting up their production near the wind parks.

Thus, to be cautious we assume 50% of the total initiated capacity of new wind power parks – 150 MW – as projection for 2030.

Table 11 Initiated on-shore wind power parks in Parnu county

Wind power parks	Location	Developer	Total capacity, MW	Number of turbines	Preliminary year of commissiong
Tootsi wind park	Metsaküla, Vändra rural municipality	Eesti Energia	140	38	2025.
wind park in Ristiküla	Saarde parish	Enefit Green (Eesti Energia)	70	Up to 10	2025
second wind park in Ristiküla	Saarde parish	Metsamaahalduse AS	35	7	

[25] Interactive map of Estonia Biogas plants

wind park in Põlendmaa	Paikuse rural municipality	Enefit Green (Eesti Energia)	25-35	up to 7	
Extending wind park in Põlendmaa	Tori municipality	Enefit Green (Eesti Energia)	11-15	up to 3	

Development of **Tootsi wind park** is particularly stated by the "Pärnu county Development Strategy 2035+"[26]. The wind park area is 160 ha forest land plot[27], about 30 km northeast of Pärnu. However, the plan to build a wind park had been held up in October 2020 after the discovery of a rare Black Stork's nest in the vicinity. While the site of the proposed wind park is outside the storks' nesting area, it is close enough to be of concern, meaning a compromise is likely to be needed[28]. While an environmental inspection of the plot was conducted in 2016, no sign of any black stork nests were found at the time.

Wind parks in Saarde parish. Wind park in Ristiküla, initiated by Enefit Green (Eesti Energia) in 2020, also would be located inside the forest, at least one kilometre from residential buildings[29]. 2nd wind park project at Saarde municipality also had been initiated in 2020 by the developer - Metsamaahalduse AS. The push to act was given by the statement made by Enefit Green, as the latter's plan would encompass registered immovables of Metsamaahalduse AS[30].

Wind park in Põlendmaa would be sited in an area of swampland within 20 kilometres from the city of Pärnu. In June 2020 Pärnu City Council had approved Enefit Green's application to initiate a designated spatial plan for the construction of a wind farm[31] . In May 2020, Enefit Green had submitted a request to the Tori municipality as well to initiate a corresponding designated special plan procedure which would potentially allow to extend the wind park by up to 3 more wind turbines.

If the previous assumption that 150MW of Wind power is achieved by 2030 from the new on-shore WPPs, the potential hydrogen production capacity reaches 17 388 kg per day. If i.e. 10%

[26] Arengustrateegia Pärnumaa 2035+, https://pol.parnumaa.ee/content/editor/files/P%C3%A4rnumaa%20arengustrateegia%2001.01.2019.pdf
[27] Power Technology com, News, 20 February 2020, https://www.power-technology.com/news/deal-news/eesti-energia-wins-auction-for-160-hectare-tootsi-wind-farm/
[28] National Wind Watch news, 23 October 2020, https://www.wind-watch.org/news/2020/10/23/black-stork-nest-hampers-windfarm-development-progress/
[29] Enefit Green website, news, 23 January 2020, https://www.enefitgreen.ee/en/uudised/avaleht/-/newsv2/2020/01/23/enefit-green-uurib-voimalust-rajada-parnumaale-saarde-valda-tuulepark
[30] https://news.err.ee/1059568/second-company-seeking-to-build-wind-farm-in-parnu-county, 04 March 2020
[31] **ERR news, 20 March 2020,**

of the produced electricity is dedicated to hydrogen production, the production rates fall at 1,7 tons of hydrogen per day.

3.7 Initiated off-shore projects in Gulf of Baltic Sea

According to a BEMIP (Baltic Energy Market Interconnection Plan) study (2019) [32] on the potential of Baltic offshore wind farm, the potential total capacity of the Gulf of Riga is around 3000 MW. This is an initial indication.

Estonian wind energy association presents that 2 large scale off-shore wind parks are initiated in the Gulf of Riga: (1) by Eesti Energia (up to 1000 MW, 40-160 turbines depending on their capacity) and (2) by Tuuletraal (up to 380 MW, up to 76 turbines)[33].

The Latvian marine area planning solution also includes potential location of off-shore wind park near Latvia-Estonia marine border, which provides possibility for joint projects with Estonia.

Eesti Energia and offshore wind energy developer Ørsted already has signed a cooperation agreement on the vision to build the first offshore wind farm in the Gulf of Riga region before 2030. The cooperation includes an existing wind park project in the Estonian part of the Gulf of Riga. Simultaneously cross-border Latvia-Estonia hybrid wind park could be developed. Regarding cross-border hybrid wind park, at the end of April 2021, the Ørsted had applied to the Latvia's Ministry of Economics with a proposal to determine the Latvia's marine area for the construction of an off-shore wind park and connection to the onshore electricity transmission infrastructure.

In April 2021, the EIA programme for the Eesti Energia off-shore wind park had been approved. Being as Estonian project, when creating a cross-border connection, the cables will go to the mainland in the **Häädemeeste area in Pärnu county and in the direction of Latvia** The offshore wind park is planned to be located 10 kilometres from Kihnu island. The development area is 183 km2, located in a shallow sea area, where the maximum depth is 36.4 meters[34].

Estonian and Latvian memorandum of understanding, signed by responsible ministries in September 2020, plans a joint offshore wind farm ELWIND (Estonian - Latvian Wind). The next step is to develop detailed project time and work plans and to attract co-financing from the Connecting Europe Facility (CEF) Renewable Energy Fund. During 2021, it is planned to select the area of the wind park as well as to start the EIA. In 2025 - 2026, an

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[32] Study on Baltic offshore wind energy cooperation under BEMIP: Final Report (ENER/C1/2018-456), June 2019, https://op.europa.eu/en/publication-detail/-/publication/9590cdee-cd30-11e9-992f-01aa75ed71a1/language-en

[33] Estonian Wind Energy Association. Off-shore wind development projects, https://tuuleenergia.ee/?page_id=1041

[34] Estonian Wind Energy Association, news, 23 April 2021, https://tuuleenergia.ee/?p=1802

auction of the ELWIND offshore wind park area is planned. The Latvian-Estonian high-capacity offshore wind farm (at least 700-1000 MW) is planned to be commissioned in 2030. It would produce approximately 3.5 TWh of electricity per year.

The significant amount of electricity production in off-shore WPP could allow to achieve the hydrogen availability in Estonia. The total capacity of hydrogen production would reach up to 191,7 tons per day. Therefore, if only a fraction of produced electricity (i.e.) 1% could be dedicated for hydrogen production the amounts would reach 1,9 tons of hydrogen per day.

4. Comparison of CO2 reduction of conventional fuel substitution with FCEVs

The assessment calculates how much CO_2 emissions are being avoided by replacing a conventional fuel vehicle (EURO VI city diesel bus) with FCEVs under different hydrogen production scenarios in Pärnu county.

Based on the estimated available RES electricity potential in Pärnu county, the potential amount of hydrogen produced with its further use for hydrogen electric vehicles in Pärnu county public transport has been calculated for three scenarios. In the first scenario, only 10% of the available RES electricity is used for hydrogen production, in the second and third scenarios 50% and 100%, respectively.

In its turn, based on the estimated hydrogen production in these scenarios, the next step calculates the potential annual bus mileage in each of the scenarios and the CO_2 savings in the road transport sector due to replacing fossil diesel buses with hydrogen electric vehicles.

Table 12 The main assumptions for calculations of avoided CO2 emissions by substitution of conventional fuel vehicles

Parameter	Unit	Value
Available total RES-E (wind and solar PV) for H_2 production in Pärnu county	GWh/year	176.9
Average electricity consumption for H_2 production in water electrolysis process[35]	kWh/kg H_2	52.05
CO_2 emission factor of RES electricity in Pärnu county	kg/MWh	0
Average mileage of bus[36]	km	65 000
Daily mileage of bus	Km	178

[35] The electrolyser efficiency is assumed to be 75%.

[36] Average mileage of Tallinna Linnatranspordi Aktsiaselts (TLT) city bus is 50 000 – 60 000km per year. Due to possibility that city buses also provide regional transportation, an assumption of yearly range of 65 000 kg is made.

Average consumption per 100km[37]	kg/H_2	7

In order to evaluate the potential FCE-bus deployment impact, an assumption of conventional fuel buses is made. For the calculations it is taken into account that 100 conventional fuelled diesel buses would produce:

Table 13 Calculated impact of 100 conventional fuel buses

Parameter	Unit	Amount
Conventional diesel buses	units	100
CO2 emissions	t CO_2/year	6559.4
NOx emissions	t NOx/year	3.51
$PM_{2.5}$ emissions	t PM $_{2.5}$/year	0,067

The calculated avoided CO_2 emissions and other key results characterizing the above H_2 production scenarios are shown in the table below. Considering that diesel buses also have a negative impact on air quality, avoided NOx and PM2.5 emissions have also been calculated.

As can be seen from the summarized results in the table, even if only 10% of the electricity generated by RES in Pärnu county is used for H_2 production by electrolysis and further used to replace diesel buses with FCEVs, this has a significant potential impact to reduce CO_2 and air pollution emissions from road transport.

Table 14 Calculated impact of conventional fuel vehicle substitution with FCEVs in selected scenarios in Pärnu county

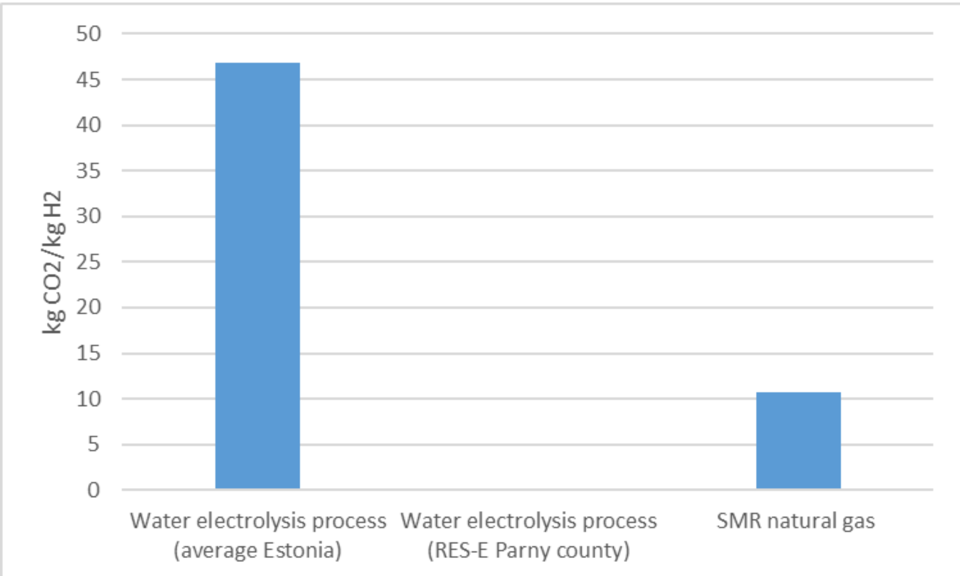
Parameter	Unit	Scenario (RES-E consumption for H_2 production)		
		10%	**50%**	**100%**
Hydrogen production	t/year	339.8	1699.0	3398.1
Number of substituted	number	74	373	746

[37] Report "Hydrogen buses on the Veluwe" includes that "*Consumption by the Solbus is 6.1kg hydrogen/100km, irrespective of the season*." Taking into account different weather conditions in Estonia, the assumption that FCE-bus average consumption per 100km is 7kg/H2 is used for calculations. https://www.h2nodes.eu/images/docs/20200416_status_verslag_2BP_Hydrogen_buses_on_the_Veluwe_Eng_.pdf

conventional fuel buses				
Avoided CO_2 emissions	t CO_2/year	4854	24272	48544
Avoided NOx emissions	t NOx/year	2.6	13.2	26.4
Avoided $PM_{2.5}$ emissions	t PM $_{2.5}$/year	0.05	0.24	0.49

According to the previous table, the current available RES energy sources could allow to produce up to 3398 tons of hydrogen per year (9.3 tons per day), that would result as a substitution of 746 conventional buses with FCE-buses. The significant amount of buses could result in 48544 t of CO_2 emissions avoided and would reduce the environmental impact of conventional fuelled vehicles. In 2020 in Estonia the M2 and M3 fleet consists of 231 CNG and 26 BEV buses.[38] Currently the total number of 5221 motor coaches, buses and trolleybuses are deployed in Estonia.[39] Therefore the 10% scenario would allow to replace 14,2% of the existing fleet in Estonia with zero emission vehicles.

Table 15 Calculated CO2 emissions for different H_2 production processes and conditions in Pärnu county



In order to achieve the significant GHG emission reduction renewable energy share must be increased. As the main fuel utilised in Estonian electricity production until 2019 was oil shale, the average CO_2 emission factor of the electricity production system was very high. Consequently, the CO_2 emissions per kg of hydrogen produced in the electrolysis process are even higher than in the SMR process utilising natural gas. In the case of Pärnu county,

[38] https://www.eafo.eu/countries/estonia/1731/vehicles-and-fleet

[39] https://ec.europa.eu/eurostat/databrowser/view/road_eqs_busveh/default/table?lang=en

the production of hydrogen by electrolysis process using available RES (wind and solar) electricity produces almost zero CO_2 emissions.

5. Conclusion

For hydrogen production in Estonia and Parnu county it is possible to use wind, solar and CHP plants. The potential hydrogen production from using the already deployed WWPs could allow to achieve the hydrogen availability in the region. By only using 10% of the produced electricity to produce hydrogen, the capacity would reach around 900kg of hydrogen per day.

Table 16 Potential green hydrogen production from existing Wind parks (kg/H_2)

Wind power park	Total capacity, MW	10%	20%	100%
Tooma	23,05	267	534	2672
Esivere	20	231	463	2318
Virtsu	16,4	190	380	1900
Tamba	6	69	139	695
Mali	12	139	278	1391
Total		**897**	**1790**	**8978**

Comparing to the WWPs the Solar PV produced hydrogen amounts can reach only up to 233kg of hydrogen per day that would serve as the starting point for hydrogen availability if the hydrogen demand would be achieved. Note that this calculation is made on the assumption that the Solar PV is using all produced electricity to produce hydrogen.

A great option would be to produce the hydrogen at Pärnu CHP whereas if only 10% of energy would be dedicated to hydrogen production it would result as a 1 ton of hydrogen per day.

For the intended on-shore WPPs, the potential hydrogen production capacity reaches 17 388 kg per day. If i.e. 10% of the produced electricity is dedicated to hydrogen production, the production rates fall at 1,7 tons of hydrogen per day. Additionally if only 10% of all RES would be dedicated for hydrogen production, it would allow to replace 14,2% of the existing bus, coach and trolleybus fleet in Estonia with zero emission vehicles.

The future aims to deploy off-shore WPP establishes provides a opportunity to produce a significant amounts of hydrogen that could be also exported to other parts in Europe. The significant amount of electricity production in off-shore WPP could allow to achieve the hydrogen availability in Estonia. The total capacity of hydrogen production would reach up to 191,7 tons per day. Therefore, if only a fraction of produced electricity (i.e.) 1% could be dedicated for hydrogen production the amounts would reach 1,9 tons of hydrogen per day. The calculated amount would allow to refuel and operate up to 151 FCE-buses per day.