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Clean energy for EU islands: **Renewable energy for Prangli**

Prangli, Estonia

Clean energy for EU islands

Renewable energy for Prangli

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Introduction

Prangli is an Estonian island in the Gulf of Finland. It has an area of 6.44 km^2 and it is part of the rural Municipality of Viimsi Parish. Prangli is the only island of North-Estonia which managed to maintain its indigenous population during the harsh rules of Soviet-Russian occupation after the second World war until the early 90s. Today the island has a population of approximately 75 inhabitants during all year round and between 200-250 people who live on this island during the summer season. Prangli is connected to the mainland by a ferry that leaves from the port of Kelnase to Leppneeme, which is 30-min drive away from Tallinn city centre.

Figure 1 Prangli is located in the Gulf of Finland, North East of Tallinn

Tourism is the main economic activity on the island: Prangli is more and more popular destination for both Estonians and foreigners who seek an adventure outside of the capital Tallinn.

The island's only energy source is currently a generator fuelled by diesel fuel. Hence, Prangli's energy security is strongly dependant on the ferry connection. In the past, Prangli's electricity grid was connected to the mainland through a submarine cable; however, the cable was damaged, and the connection was never reinstalled.

Two island beneficiaries (Prangli Saarte Külaühing and Energiaühistu) applied in April 2022 to the second round of Technical Assistance from the Clean energy for EU islands secretariat. The goal of this assistance has been to quantify the renewable energy potential on the island, focusing on solar PV and onshore wind. The results of the study are presented in this report, which is structured in two main Tasks: PV and wind resource assessment).

Task 1 Solar PV assessment

After discussions with the island beneficiaries, it was agreed that the PV resource assessment would be limited to rooftop PV on the municipal buildings. The option of a solar carport was initially considered, but the location and development of the possible parking area was unclear and could not be fixed in time for the development of the study.

Four different municipal buildings were considered for rooftop PV: the culture house, the school, a rescue shed and a shop. The details of all four sites are provided in Table 1.

The following subsections present first the equipment recommended for rooftop installations, followed by the preliminary design (including equipment sizing and electrical configuration).

Table 1: Site geographical details

Sites	Cadastral number[1]	Latitude	Longitude	Altitude (m)
Culture House	89001:002:0327	59.629526	25.01004	14
School	89001:002:0290	59.628864	25.010699	15
Rescue Shed	89001:002:0493	59.629883	25.011077	14
Shop	89001:002:0068	59.628006	25.012302	15

Equipment Overview

PV modules[2]

PV modules can be grouped into three categories: thin film modules, mono crystalline modules, and poly crystalline modules.

Although thin film modules are relatively less expensive, they are manufactured using heavy metals such as Cadmium and Telluride, which therefore may require extra precautions for handling and disposal. In addition, they require more roof space for installation.

Poly crystalline and mono crystalline modules are more widely used in solar PV installations and are made of silicon substrate. While mono crystalline modules are more expensive, they offer a higher efficiency than other types of modules. Hence, mono crystalline modules are recommended for this study.

There are several established mono crystalline module manufacturers. Among these, Trina Solar, with headquarters in China and representations in Europe, offers modules which are specifically designed for rooftop installations. The new product Vertex S TSM DE09C.05 – 405W is of a relatively smaller frame size to optimise the use of rooftop space while maximising power output at an efficiency as high as 21.1% and offers a longer product warranty of 25 years. Hence, this module (Trina Solar Vertex S TSM DE09C.05 – 405W) has been selected for the purpose of this study.

[1] Cadastral numbers were converted to geographical coordinates through: https://xgis.maaamet.ee/xgis2/page/app/maainfo.

[2] Evaluation of PV modules is supported by a guide published by Arup for rooftop installations: “Five_min_guide_to_solar_Arup.pdf”

Inverters

For small scale rooftop solar PV installations, string inverters are typically used in the industry due to their small size. Huawei is an established manufacturer of string inverters, which have been selected for the purpose of the current study. The different inverter sizes selected for each site are shown in Table 2. Detailed information on equipment configuration is provided in Section Equipment Sizing.

Table 2: Inverter selection

Sites	Inverter selection	Power rating	Output voltage
Culture House	Huawei SUN2000-8KTL-M1 Huawei SUN2000-10KTL-M1	8 kW and 10 kW	230 V_{AC}
School	Huawei SUN2000-4KTL-M1 Huawei SUN2000-5KTL-M1	4 kW and 5 kW	230 V_{AC}
Rescue Shed	Huawei SUN2000-8KTL-M1	8 kW	230 V_{AC}
Shop	Huawei SUN2000-8KTL-M1	8 kW	230 V_{AC}

Preliminary Design Configuration

General approach and assumptions

Site roof dimensions

For each building (or site), roof dimensions were obtained from drawings provided for each site. Except for the Rescue Shed where all dimensions could be obtained/calculated accurately from the drawings, dimensions for the remaining sites were estimated by applying a scaling factor to physical measurements made on the drawings.

For Culture House, no scaling factor was reported on the drawing, but vertical elevation indices for various building points were available. Therefore, all dimensions were estimated by using a height of 5.1 m as reference (refer to Appendix A).

Roof sections considered for each site are illustrated in Section 0 , and their respective dimensions are provided in Appendix A.

Azimuth

The azimuth angle for each roof section was first estimated qualitatively (South, North, East, West or Northeast etc.) by visual observations of satellite images. This estimate was further refined within the PVsyst simulation software by importing 2-dimensional satellite ground images for each site. Once the PV tables were defined according to the visual azimuth orientation of the ground image, a more accurate azimuth angle was automatically calculated by PVsyst and used in the final simulation.

PV modules inclination/tilt

For the Rescue Shed, exact roof tilts were reported on the drawings. For the remaining sites, tilts were estimated in Microsoft PowerPoint by drawing a horizontal line and rotating it until it was parallel to the roof plane, with the tilt corresponding to the total angle of rotation.

PV modules quantity

The dimensions of the PV module selected for the study are provided below:

- Length: 175.4 cm
- Width: 109.6 cm.

In the absence of editable AutoCAD drawings for each site, the above PV module dimensions were used to estimate the number of PV modules which can fit within the dimensions (along the length, and along the width) of the available roof sections, assuming an arrangement of PV modules in portrait. The final adjusted estimate accounts for roof edge clearance of at least 10 cm, clearance from chimney and window obstructions, and PV module spacing of 2 cm. For large roof sections, as indicated below, allowance for additional spacing for potential O&M activity is made.

Type of usage

This study assumes a residential usage of the power produced from the PV system. As such no transformer system has been considered. Furthermore, an inverter output voltage of 230 V_{AC} has been considered as the applicable residential voltage in Estonia[3].

Inverters quantity

The power rating and the number of inverters for each site was determined in such a way to maximise the AC output of the PV system.

Equipment sizing

Culture House

Table 3: Equipment sizing for Culture House

Roof sections	Dimensions (m)	Azimuth	Tilt	PV modules quantity	Inverters quantity
1	7.21 x 22.95	177° (~ North)	45°	4 x 18 = 72	3 (8 kW)
2	7.21 x 17.00	-4° (~ South)	45°	4 x 14 = 56	2 (10 kW)
3	2 x (7.21 x 7.82)	-93° (~ East)	45°	2 x (4 x 6) = 48	2 (8 kW)
4	2 x (7.21 x 7.82)	86° (~ West)	45°	2 x (4 x 6) = 48	2 (8 kW)
			Total	**224**	**9**
			DC power	**90.720 kWp**	
			AC power		**76 kW$_{AC}$**

School

Table 4: Equipment sizing for School

Roof sections	Dimensions (m)	Azimuth	Tilt	PV modules quantity	Inverters quantity
1	4.63 x 4.38	-101° (~ East)	42°	2 x 3 = 6	1 (4 kW)
2	4.63 x 3.88	-101° (~ East)	42°	2 x 3 = 6 Actual[4] = 5	
3	4.63 x 5.25	81° (~ West)	42°	2 x 4 = 8	1 (5 kW)
4	4.63 x 5.25	81° (~ West)	42°	2 x 4 = 8 Actual[5] = 7	
			Total	**26**	**2**
			DC power	**10.530 kWp**	
			AC power		**9 kW$_{AC}$**

[3] List of Voltages & Frequencies (Hz) Around the World. Available at: https://www.generatorsource.com/Voltages_and_Hz_by_Country.aspx .

[4] Adjusted for clearance from glass windows and chimney

[5] Adjusted for clearance from chimney

Rescue Shed

Table 5: Equipment sizing for Rescue Shed

Roof sections	Dimensions (m)	Azimuth	Tilt	PV modules quantity	Inverters quantity
1	7.46 x 12.19	38° (~ Southwest)	10°	4 x 10 = 40	2 (8 kW)
2	4.82 x 12.19	-141° (~Northeast)	20°	2 x 10 = 20	1 (8 kW)
Total				**60**	**3**
DC power				**24.300 kWp**	
AC power					**24 kW_{AC}**

Shop

Table 6: Equipment sizing for Shop

Roof sections	Dimensions (m)	Azimuth	Tilt[6]	PV modules quantity	Inverters quantity
1	10.00 x 9.00	Northeast	4°	5 x 8 = 40 Actual[7] = 5 x 7 = 35	2 (8 kW)
2	7.125 x 4.125	Northeast	4°	3 x 3 = 9 Actual[8] = 3 x 2 = 6	
3	3.5 x 1.5	Northeast	4°	1 x 1 = 1	
Total				**42**	**2**
DC power				**17.010 kWp**	
AC power					**16 kW_{AC}**

Electrical configuration

Table 7: Electrical configuration for all four sites

Sites	Electrical configuration[9]
Culture House	3 INV X 2 STR X 12 MOD (North)
	2 INV X 2 STR X 14 MOD (South)
	2 INV X 2 STR X 12 MOD (East)
	2 INV X 2 STR X 12 MOD (West)
School	1 INV X 1 STR X 11 MOD (East)
	1 INV X 1 STR X 15 MOD (West)
Rescue Shed	2 INV X 1 STR X 20 MOD (Southwest)
	1 INV X 1 STR X 20 MOD (Northeast)
Shop	2 INV X 1 STR X 21 MOD

[6] Actual roof inclination is 4°, which is too flat for the project location. It was therefore assumed that a special mounting structure can be mounted on the relatively flat roof to raise the tilt to 42° as this is the optimum tilt in Estonia according to PVGIS.

[7] Adjusted for clearance from chimney, the width of one PV module (approx. 1 m).

[8] Adjusted for clearance from chimney, the width of one PV module (approx. 1 m).

[9] INV: Inverters; STR: Strings in parallel per inverter; MOD: Modules in series per string.

Yield Assessment

Meteorological data

The authors considered different meteorological data sources for calculating the yield of the rooftop PV installations presented in this study. These sources are listed in Table 8, which provides a comparison of horizontal irradiation results. Given the proximity of all four sites to each other, it is considered that the horizontal irradiation will be the virtually the same for all sites; hence, this was derived by using the coordinates of Culture House as reference.

Table 8: Global irradiation on the horizontal plane (kWh/m²/year)

Source	Number of years	Average irradiation
Meteonorm	20	979
Soda-HelioClim	17	1 073
3E Solar Data	17	994
PVGIS-SARAH2	16	953
SolarGIS	26	1,004

The horizontal irradiation source was used to calculate the yield before combining the results by using a statistical weighting function. This function considers the specific characteristics of the data, such as the number of years available and the uncertainty of resource quantification according to the authors' own experience. Table 9 shows the weighted horizontal irradiation as well as the in-plane irradiation. These weighted values are given as an indication only, as they are not directly used in the calculations. The transposition factor is obtained from the irradiation data of SolarGIS and the Perez transposition model within the PVsyst simulation software. The transposition factor is the ratio of in-plane irradiation to the horizontal irradiation and gives an indication of the effective solar irradiation based on the PV system's orientation and inclination. The ambient temperature used in the simulations is also presented. It comes from the SolarGIS database.

Table 9: Weighted irradiation, transposition factor and temperature

Parameter	Culture House	School	Rescue Shed	Shop
Weighted horizontal irradiation (kWh/m²/yr)	1 004	1 004	1 004	1 004
Transposition factor (%)	-12.4	-5.0	-0.9	-18.5
In-plane irradiation (kWh/m²/yr)	880	955	995	818
Ambient temperature (°C)	6.4	6.4	6.4	6.4

The monthly breakdown of meteorological data for each site is presented in Table 10, Table 11, Table 12 and Table 13.

Table 10: Monthly breakdown of the meteorological data – Culture House

Month	**Global Horizontal Irradiation – GHI (kWh/m²)**	**Global In-plane Irradiation – GII (kWh/m²)**	**Ambient temperature (°C)**
January	9	12	-2.0
February	25	27	-3.2
March	72	68	-0.7
April	116	99	3.9
May	169	142	9.4
June	174	146	14.0
July	174	148	17.4
August	137	115	16.7
September	77	68	12.1
October	36	36	6.8
November	11	12	1.9
December	5	9	-0.8
Year	**1 004**	**880**	**6.4**

Table 11: Monthly breakdown of the meteo data – School

Month	**Horizontal irradiation (kWh/m²)**	**In-plane irradiation (kWh/m²)**	**Ambient temperature (°C)**
January	9	11	-2.0
February	25	26	-3.2
March	72	71	-0.7
April	116	111	3.9
May	169	157	9.4
June	174	159	14.0
July	174	163	17.4
August	137	130	16.7
September	77	74	12.1
October	36	35	6.8
November	11	11	1.9
December	5	7	-0.8
Year	**1 004**	**955**	**6.4**

Table 12: Monthly breakdown of the meteo data – Rescue Shed

Month	**Horizontal irradiation (kWh/m²)**	**In-plane irradiation (kWh/m²)**	**Ambient temperature (°C)**
January	9	10	-2.0
February	25	25	-3.2
March	72	72	-0.7
April	116	114	3.9
May	169	166	9.4
June	174	171	14.0
July	174	171	17.4
August	137	135	16.7
September	77	76	12.1
October	36	36	6.8
November	11	11	1.9
December	5	6	-0.8
Year	**1 004**	**995**	**6.4**

Table 13: Monthly breakdown of the meteo data – Shop

Month	Horizontal irradiation (kWh/m²)	In-plane irradiation (kWh/m²)	Ambient temperature (°C)
January	9	6	-2.0
February	25	18	-3.2
March	72	55	-0.7
April	116	92	3.9
May	169	143	9.4
June	174	150	14.0
July	174	149	17.4
August	137	108	16.7
September	77	59	12.1
October	36	27	6.8
November	11	8	1.9
December	5	3	-0.8
Year	**1 004**	**818**	**6.4**

System modelling

The 3D visually illustrations of the PV systems are presented in Figure 2, Figure 3, Figure 4, and Figure 5. These allow to visualise the roof orientations, and the surrounding obstacles (trees, shown as black structures) which were considered in the modelling of the near shading loss.

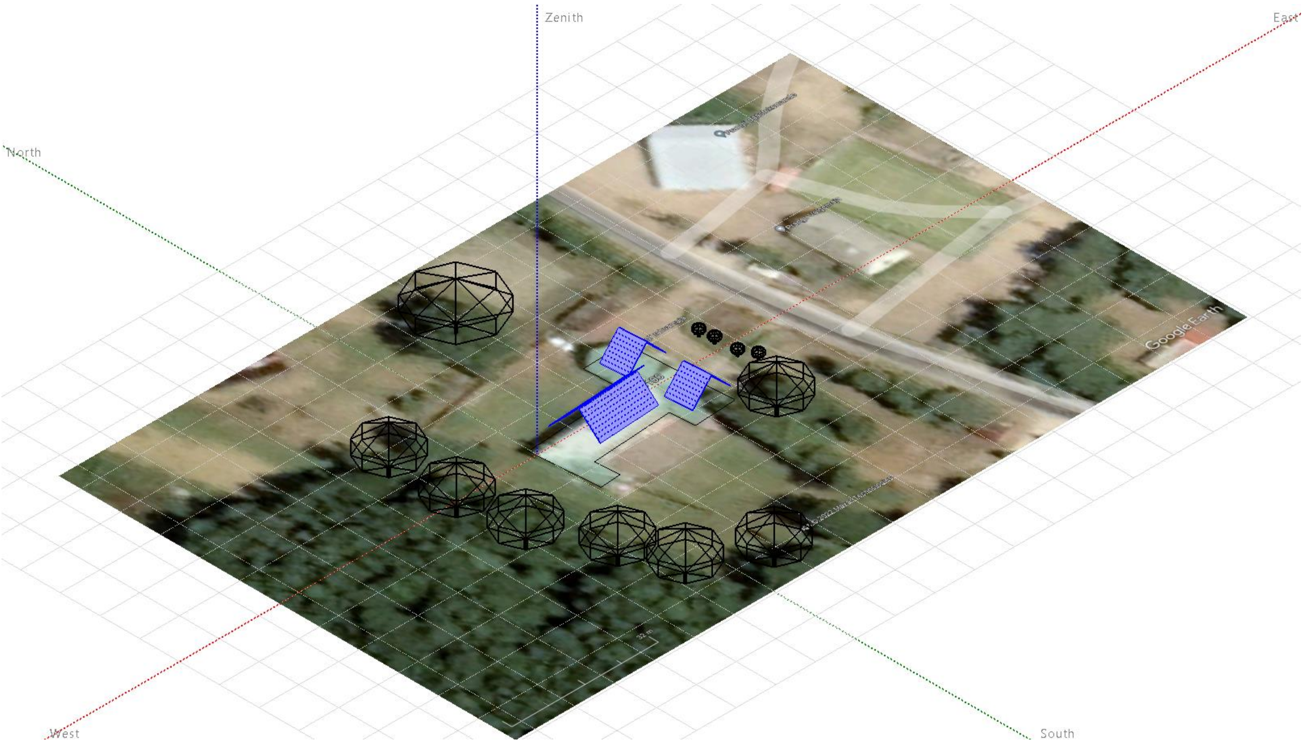


Figure 2: Culture house – PVsyst 3D model for near shading losses

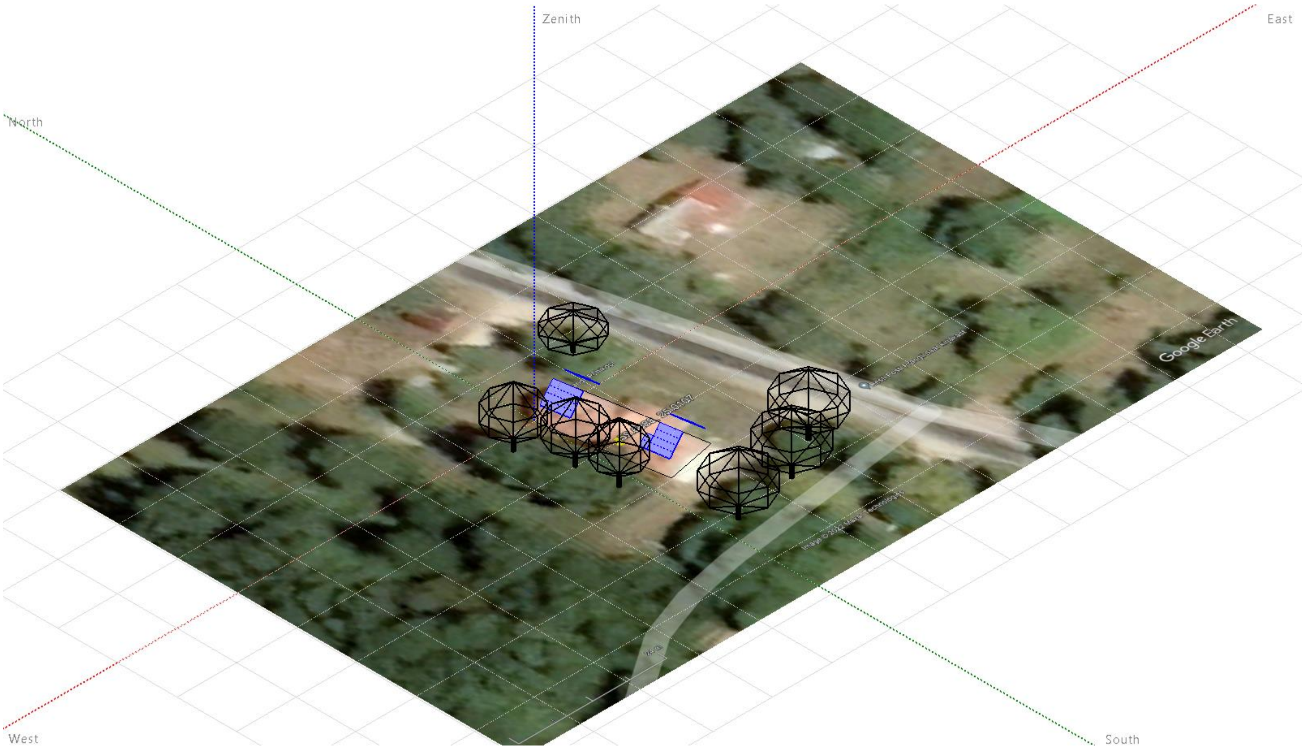


Figure 3: School – PVsyst 3D model for near shading losses

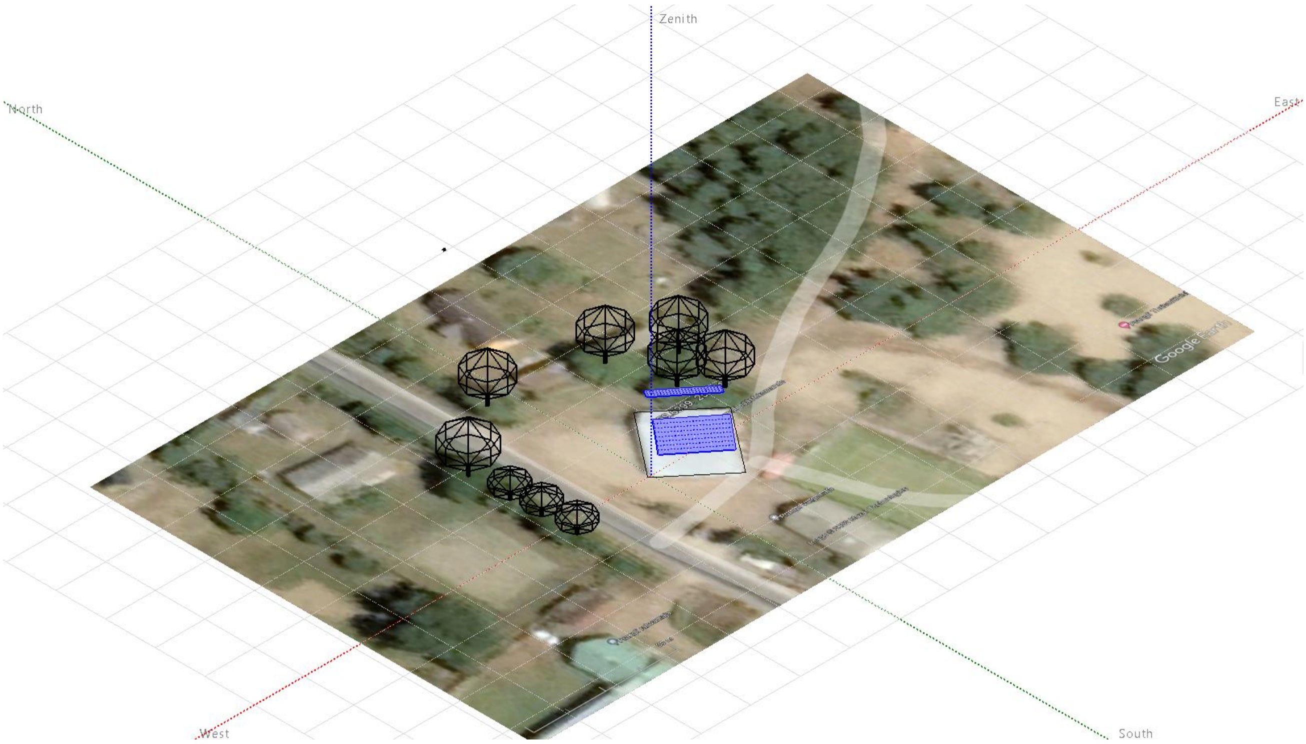


Figure 4: Rescue Shed – PVsyst 3D model for near shading losses

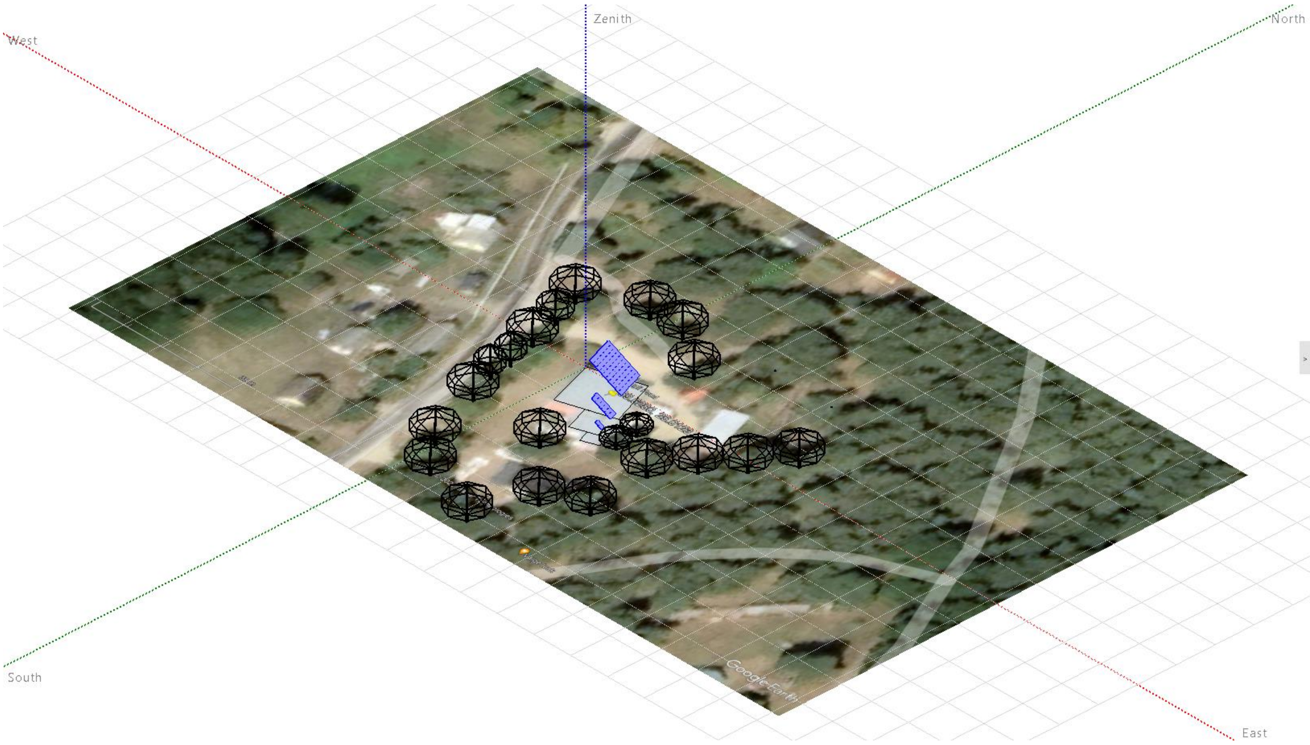


Figure 5: Shop – PVsyst 3D model for near shading losses

Detailed performance losses

The Performance Ratio (PR) presented in Table 14, is equivalent to the PV system's efficiency and allows to compare the actual performance of the system relative to the maximum theoretical performance. It includes all losses occurring in the PV system, from the solar irradiation hitting the PV module to the final energy output at the point of energy delivery.

Table 14: Initial Performance Ratio breakdown

Losses breakdown	Loss/ Gain Culture House	School	Rescue Shed	Shop
In-plane conversion	**-12.4%**	**-5.0%**	**-0.9%**	**-18.5%**
Horizon shading	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Optical	**-18.4%**	**-35.4%**	**-17.1%**	**-14.8%**
- Near shading: irr. loss	-5.4%	-26.4%	-3.9%	-3.1%
- Reflection	-3.3%	-3.1%	-3.9%	-3.3%
- Dirt, soiling and snow	-10.8%	-9.4%	-10.2%	-9.2%
Module	**-7.6%**	**-9.5%**	**-5.3%**	**-3.4%**
- Irradiance dependencies	-2.3%	-2.6%	-2.0%	-2.3%
- Temperature dependencies	-1.4%	-0.9%	-1.4%	1.0%
- Spectral dependencies	0.0%	0.0%	0.0%	0.0%
- Near shading: acc. to strings	-2.6%	-4.8%	-0.6%	-0.6%
- Power tolerance of modules	0.3%	0.3%	0.3%	0.3%
- Light induced degradation (LID)	-1.3%	-1.3%	-1.3%	-1.3%
- Mismatching	-0.5%	-0.5%	-0.5%	-0.5%
Electrical	**-3.7%**	**-6.0%**	**-4.0%**	**-4.4%**
- DC cabling	-0.7%	-0.6%	-0.6%	-0.6%
- Inverter	-3.1%	-5.5%	-3.4%	-3.9%
- Auxiliaries	0.0%	0.0%	0.0%	0.0%
- AC cabling (LV, MV & HV)	0.0%	0.0%	0.0%	0.0%
- Transformer (MV & HV)	0.0%	0.0%	0.0%	0.0%
- Curtailment	0.0%	0.0%	0.0%	0.0%
Total	**-27.4%**	**-45.0%**	**-24.6%**	**-21.3%**
Performance ratio at project start-up	**72.6%**	**55.0%**	**75.4%**	**78.7%**

The Performance Ratio of all sites is relatively good (over 70%), except for the school site which recorded a rather low Performance Rati of 54.3%. Near shading loss due to surrounding trees has a significant effect on performance for all sites, with the largest loss of -26.4% recorded for the school site, which explains its poor performance.

Monthly yield breakdown

The monthly energy yield figures for all fours sites are presented in Table 15, Table 16, Table 17 and Table 18.

Table 15: Monthly PR and system yield at year 1 – Culture House

Month	Performance ratio (PR) year 1	System yield (P50) year 1 (MWh)	System yield (P90 lifetime) year 1 (MWh)
January	20.7%	0.232	0.209
February	28.0%	0.677	0.609
March	31.4%	1.933	1.741
April	72.1%	6.449	5.808
May	81.2%	10.443	9.406
June	80.6%	10.701	9.638
July	78.9%	10.585	9.534
August	78.8%	8.220	7.404
September	78.0%	4.793	4.317
October	73.4%	2.379	2.143
November	58.6%	0.627	0.564
December	29.7%	0.238	0.215
Year	**71.7%**	**57.276**	**51.586**

Table 16: Monthly PR and system yield at year 1 – School

Month	Performance ratio (PR) year 1	System yield (P50) year 1 (MWh)	System yield (P90 lifetime) year 1 (MWh)
January	0.9%	0.001	0.001
February	14.4%	0.039	0.031
March	20.4%	0.152	0.123
April	53.4%	0.625	0.505
May	63.7%	1.056	0.853
June	63.9%	1.068	0.863
July	61.0%	1.045	0.844
August	58.8%	0.807	0.652
September	56.8%	0.442	0.357
October	49.5%	0.184	0.149
November	31.3%	0.035	0.029
December	0.0%	0.000	0.000
Year	**54.3%**	**5.455**	**4.406**

Table 17: Monthly PR and system yield at year 1 – Rescue Shed

Month	Performance ratio (PR) year 1	System yield (P50) year 1 (MWh)	System yield (P90 lifetime) year 1 (MWh)
January	22.5%	0.055	0.050
February	30.6%	0.189	0.171
March	33.7%	0.586	0.531
April	74.1%	2.061	1.867
May	82.4%	3.335	3.021
June	80.8%	3.357	3.041
July	79.4%	3.306	2.995
August	80.9%	2.653	2.403
September	82.3%	1.518	1.375
October	80.7%	0.706	0.640
November	63.7%	0.175	0.158
December	34.0%	0.053	0.048
Year	**74.4%**	**17.993**	**16.300**

Table 18: Monthly PR and system yield at year 1 – Shop

Month	Performance ratio (PR) year 1	System yield (P50) year 1 (MWh)	(P90 lifetime) year 1 (MWh)
January	12.4%	0.013	0.012
February	27.3%	0.083	0.076
March	32.4%	0.302	0.275
April	75.2%	1.180	1.075
May	86.6%	2.112	1.924
June	85.7%	2.187	1.993
July	84.3%	2.135	1.945
August	83.4%	1.533	1.396
September	82.5%	0.826	0.752
October	77.9%	0.358	0.326
November	58.4%	0.083	0.076
December	9.1%	0.004	0.004
Year	**77.7%**	**10.817**	**9.853**

Based on the P50 year-1 annual yields and the system DC capacities, the specific yields can be estimated as 636 kWh/kWp, 518 kWh/kWp, 740 kWh/kWp and 636 kWh/kWp for Culture House, School, Rescue Shed and Shop respectively. These figures fall on the lower end of the spectrum, according to the World Bank's estimates of solar PV power potential for countries globally[10].

Uncertainties affecting yield estimates

The expected yield is affected by several uncertainties of different types. The uncertainty due to the climate variability is stochastic and its effect is levelled out when calculating long-term averages. Most other uncertainties, e.g., those related to the modelling, the site or the system, are systematic and their effect is not levelled out when calculating long-term averages. Stochastic uncertainties vary year by year whereas systematic uncertainties are constant assuming a system properly working as per design.

The uncertainties affecting the yield estimates are summarised in Table 19. All uncertainty values are standard deviations and apply to well-functioning systems. Negative outliers in performance due to bad installation, low-quality components or extreme local conditions (e.g. heavy soiling or unidentified shading) are not taken into account in these uncertainties. The uncertainty values have been determined by 3E based on an extensive literature study and own calculations.

[10] Suri, Marcel; Betak, Juraj; Rosina, Konstantin; Chrkavy, Daniel; Suriova, Nada; Cebecauer, Tomas; Caltik, Marek; Erdelyi, Branislav. Global Photovoltaic Power Potential by Country (English). Energy Sector Management Assistance Program (ESMAP) Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/466331592817725242/Global-Photovoltaic-Power-Potential-by-Country

Table 19: Uncertainties considered for the calculation of the probabilities (P90)

Uncertainty	Variable	Values: Culture House	School	Rescue Shed	Shop
Due to the yearly variation	Climate variability	3.2%	3.2%	3.2%	3.2%
Affecting the resource estimation	Resource quantification	5.0%	5.0%	5.0%	5.0%
	In-plane conversion	2.0%	2.0%	2.0%	2.0%
Affecting the system performance	Optical	6.1%	14.0%	5.5%	4.9%
	Module	1.4%	1.4%	1.4%	1.4%
	Electrical	1.6%	2.8%	1.7%	2.0%
	Degradation	0.3%	0.3%	0.3%	0.3%

Project Cost Estimate

Average country cost information for residential solar PV installations, for the year 2020, was obtained from the International Renewable Energy Agency (IRENA) database and used along with the system installed capacity to estimate the total project Capital Expenditure (CAPEX). The equivalent cost in EUR is based on USD/EUR exchange rate for the year 2020.

Table 20: Project cost estimate

Sites	DC Capacity [kWp]	CAPEX[11] [USD/kWp]	CAPEX [USD]	CAPEX[12] [EUR]
Culture House	90.72	1 609	145 970	100 885
School	10.53	1 609	16 943	11 710
Rescue Shed	24.30	1 609	39 100	27 023
Shop	17.01	1 609	27 370	18 916

[11] As included in: IRENA_Power_Generation_Costs_2020.pdf – Table 3.1.
Cost in the year 2020, with Germany used as reference country.
[12] Based on USD/EUR exchange rate of 0.691143, for the year 2020. Available at: https://www.ofx.com/en-au/forex-news/historical-exchange-rates/yearly-average-rates/

Task 2 Onshore wind

Considering the high local wind resources on Prangli, the focus of this analysis is on the onshore wind resource assessment.

Wind resource potential

For the whole onshore area of Prangli, a wind atlas has been generated using the software WindPro[13]. The Wind Climate from the Global Wind Atlas [1] has been used to calculate a wind resource map. Wind resource maps have been generated at three different heights above ground level: 25.0 m, 50.0 m and 75.0 m. These heights are in the range of potential hub heights for onshore wind exploitation.

The wind on Prangli predominantly blows from sectors west-southwest (WSW), south-southwest (SSW) and west (W). The wind energy rose depicts that most of the energy production comes from sector west-southwest (WSW) (Figure 6).

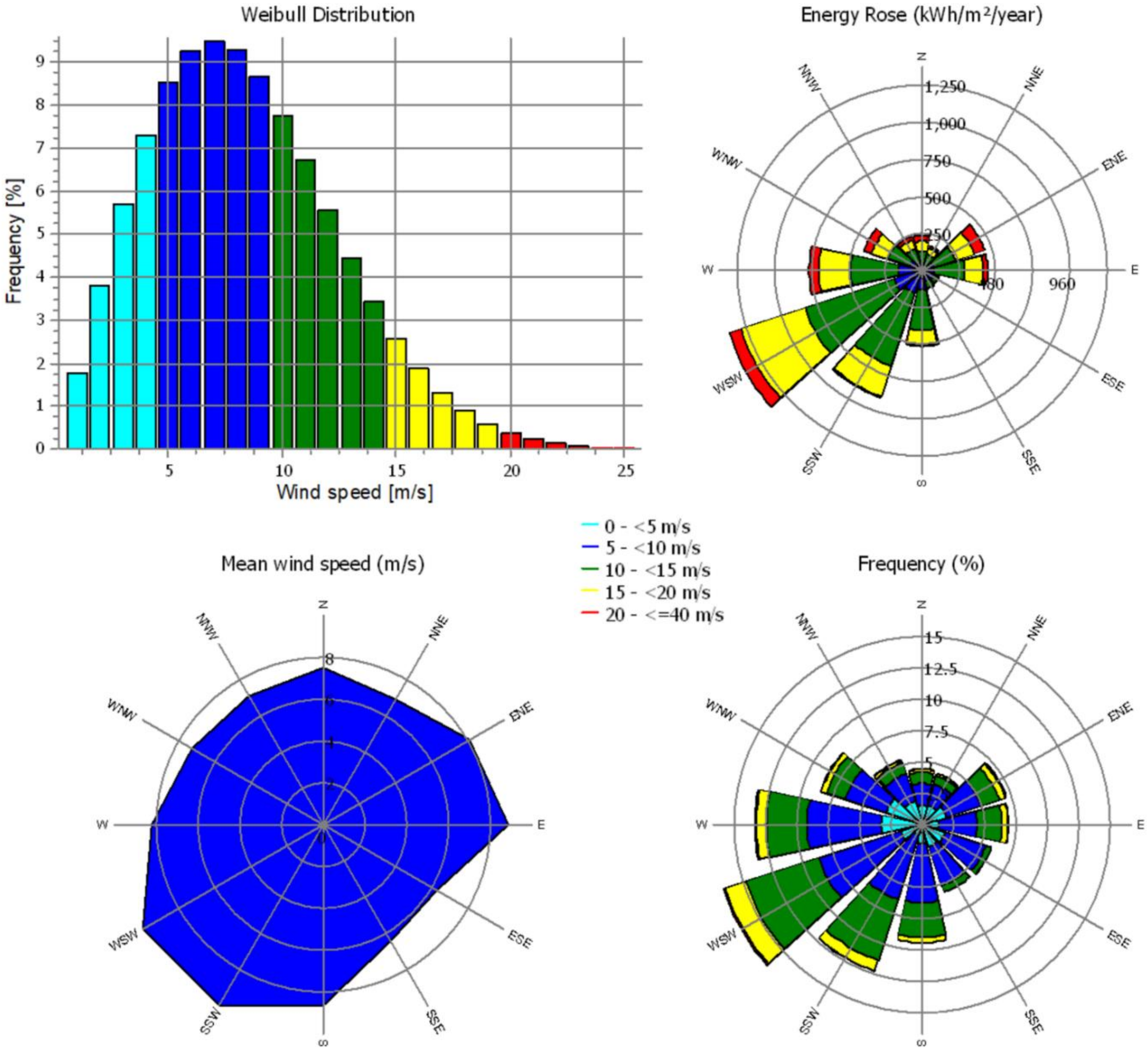


Figure 6: Wind distribution over the area of Prangli

13 WindPRO is a software package for designing and planning wind farm projects. It uses WAsP to simulate wind flows. It is developed and distributed by the Danish energy consultant EMD International A/S. It is trusted by many investment banks to create wind energy assessments used to determine financing for proposed wind farms.

The different wind resource maps are presented in the figures below. The mean wind speed on site ranges between 4.6 m/s and 7.7 m/s at 25.0 m , between 7.2 m/s and 8.3 m/s at 50 m and between 8.2 m/s and 8.8 m/s at 75 m depending on the location on the island, as shown in the resource maps from Figure 7 to Figure 9.

The wind speeds are heterogeneously distributed all over the island, with the highest values located in the central and north-west areas, and the lowest ones in the centre-southern location and along the easter coastline of Prangli. A similar wind speed pattern is observed for all the heights considered in this study.

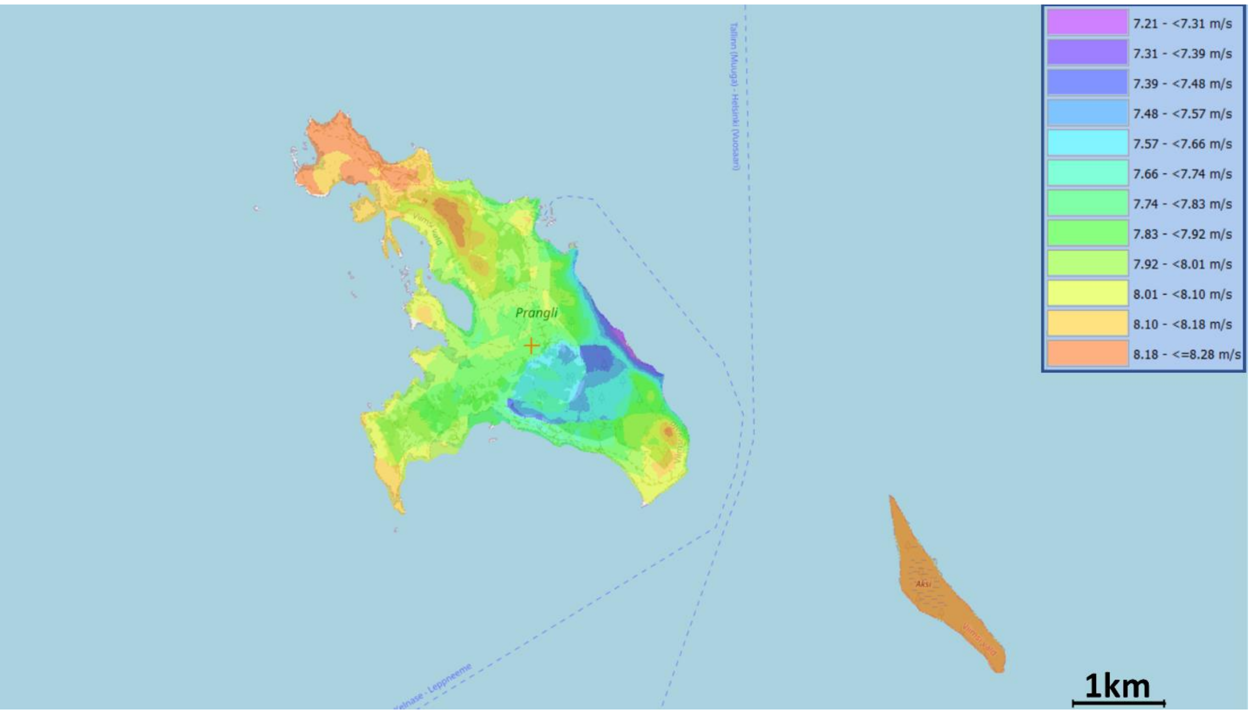


Figure 7: Mean wind speed at 25.0m AGL

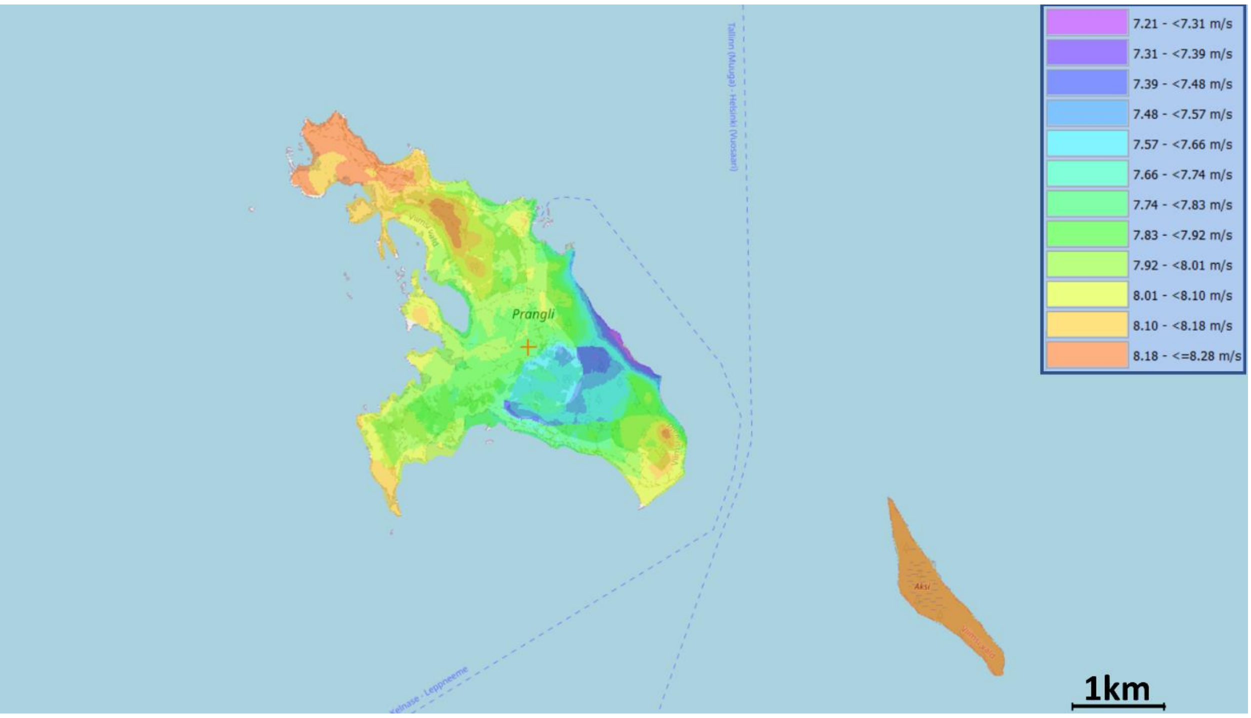


Figure 8: Mean wind speed at 50.0m AGL

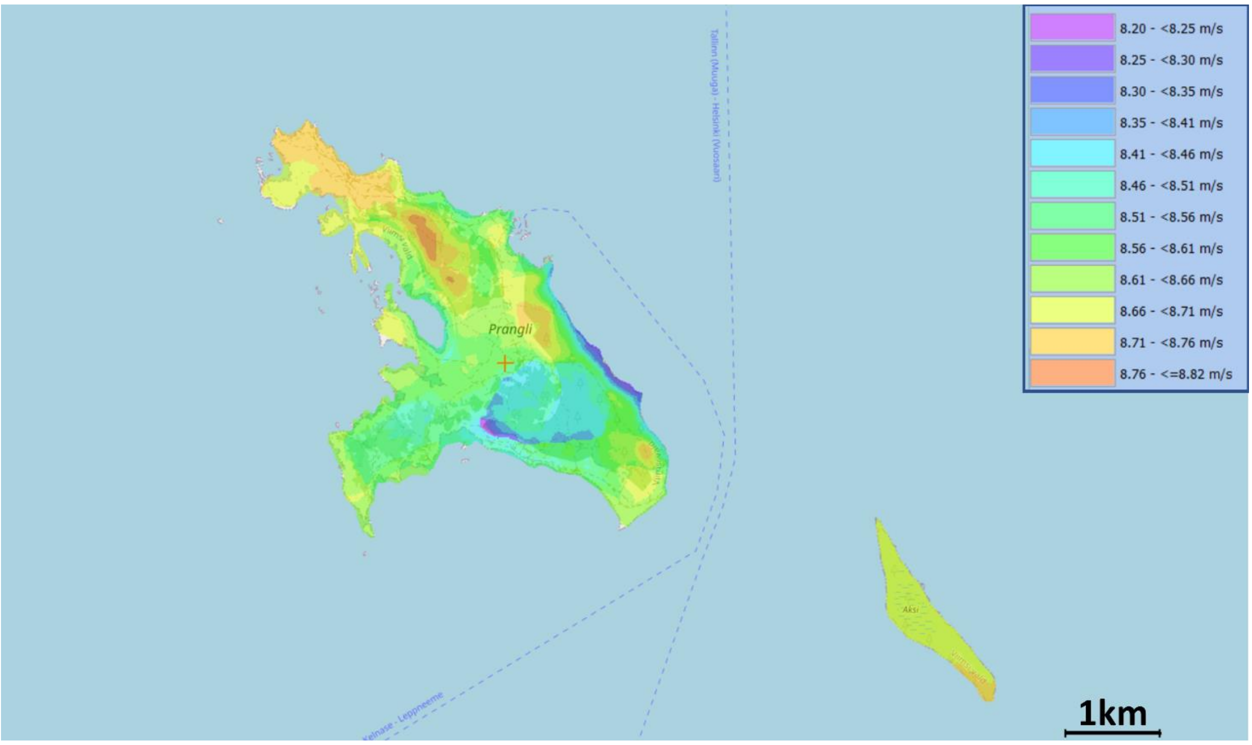


Figure 9: Mean wind speed at 75.0m AGL

A wind resource map in terms of annual production MWh/year has been generated at 25.0 m, 50.0m and 75.0 m above sea level based on the wind turbine Vergnet GEV MP R 275 with a nominal power of 275 kW. This wind turbine model has been selected as an indicative choice for the present study, based on the local wind resources, its reduced size (32 m of rotor diameter) and energy need of the island. Other turbine models are available on the market for this class of wind turbines and can be considered for this project. In total, the configurations considered for the present study are 3:

- Vergnet GEV MP R 275 with 275 kW and 55 m of hub height (tubular)
- WES250 with 250 kW and 48 m of hub height (tubular)
- WES250 with 250 kW and 36 m of hub height (lattice)

The results show that the average wind potential over the Prangli area at 25.0 m ranges between 282 MWh/year and 927 MWh/year for the Vergnet GEV MP R 275 with a nominal power of 275 kW. (Figure 10). At 50.0 m it ranges between 829 MWh/year and 1,056 MWh/year (Figure 11) and, finally, at 75.0 m it ranges between 1 046 MWh/year and 1 173 MWh/year (Figure 12). These results demonstrate that Prangli has an extremely high wind potential in terms of wind speed and related energy already at 25 m of height. Higher values are typically found at higher altitudes. However, additional criteria should be fulfilled before suggesting feasible areas for wind energy exploitation. In this regard, this solution needs to be investigated also in terms of the constrains related to the presence of protected areas/nature reserves, nautical routes, and distance from the main grid. Based on these considerations, a layout with three wind turbines is proposed in the following section.

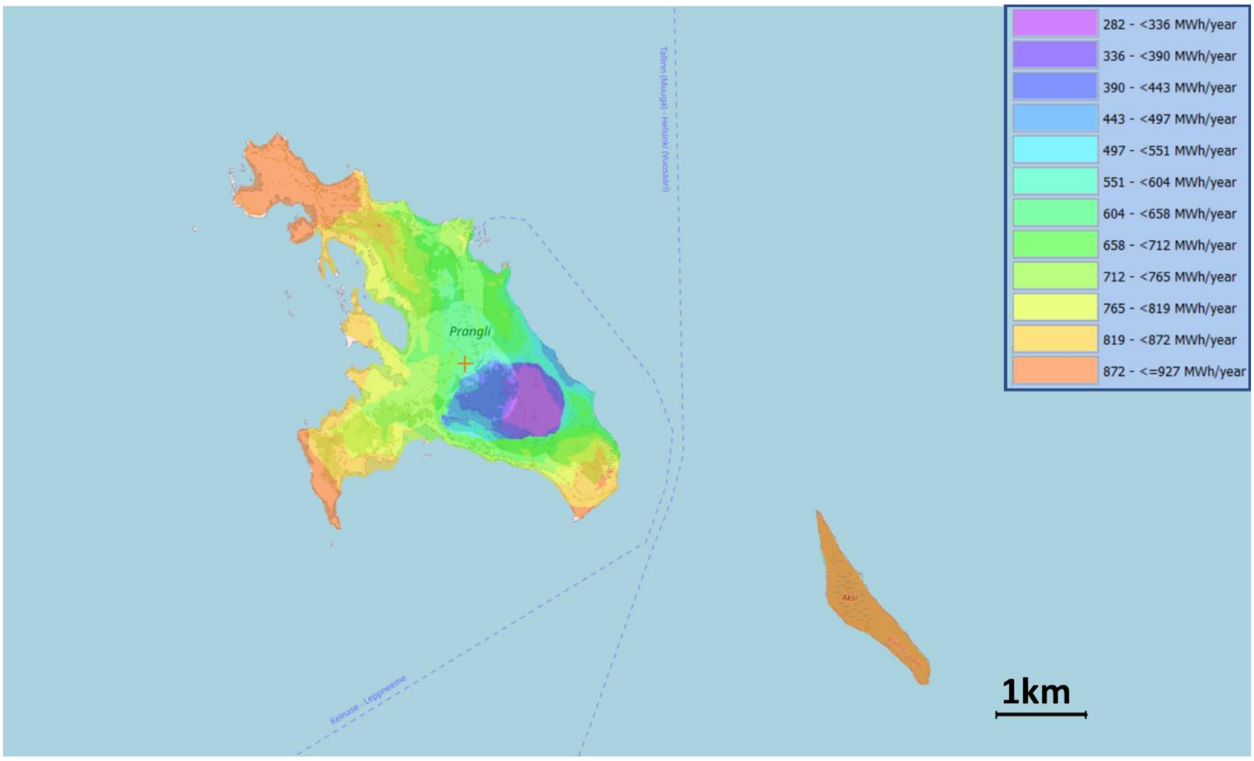


Figure 10: Annual wind production at 25.0m AGL based on the Vergnet GEV MP R 275 wind turbine [MWh/an]

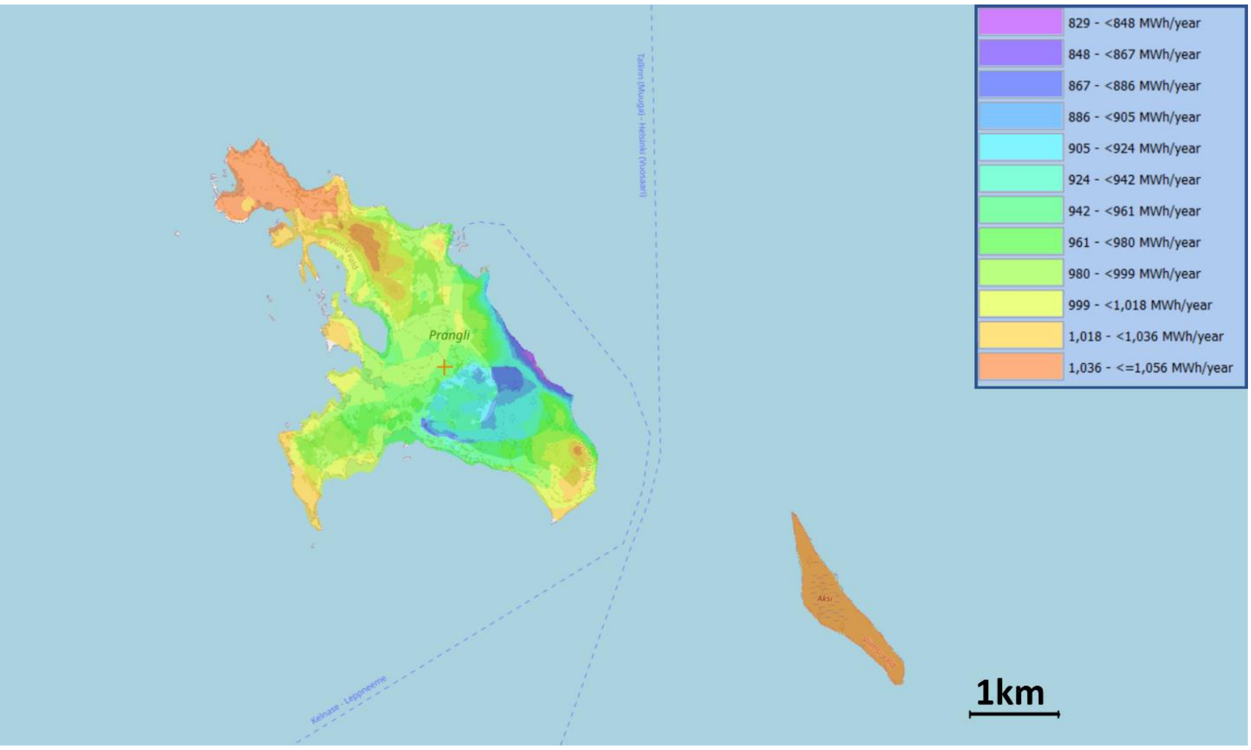


Figure 11: Annual wind production at 50.0m AGL based on the Vergnet GEV MP R 275 wind turbine [MWh/an]

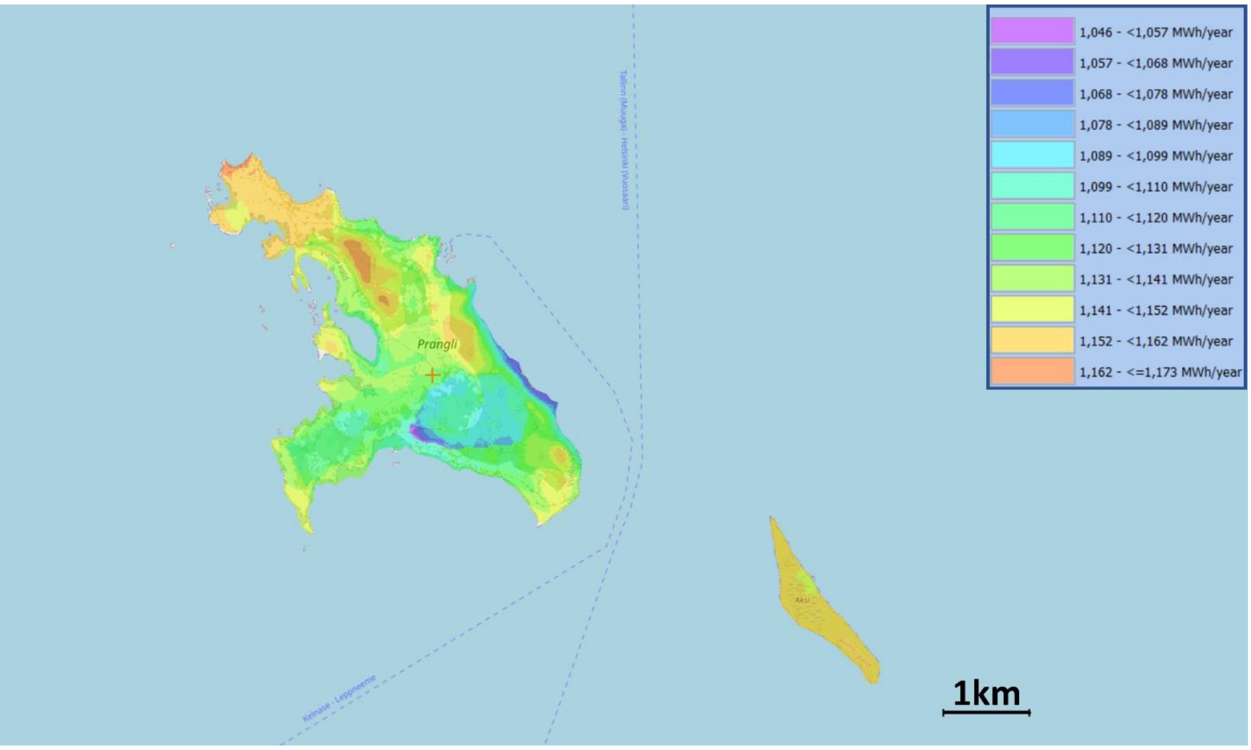


Figure 12: Annual wind production at 75.0m AGL based on the Vergnet GEV MP R 275 wind turbine [MWh/an]

Potential offshore wind farm layout

The three following configurations of wind turbines are indicatively proposed:

- Vergnet GEV MP R 275 with 275 kW and 55 m of hub height (tubular)
- WES250 with 250 kW and 48m of hub height (tubular)
- WES250 with 250 kW and 36m of hub height (lattice)

The proposed layout, based on the wind resource map, includes three wind turbines, in the central northwest area, at a safe distance from nature reserves. A proper intra-spacing is adopted for all the turbines, based also on the main wind direction, in order to reduce the mutual wake impact. The layout is displayed in Figure 13. The coordinates in Geo [deg]-WGS84 are provided in Table 21.

Figure 13: Location of the two proposed onshore layout for Pranglu, highlighted in red.

Table 21: Wind turbine coordinates for the proposed layout

Coordinates	Longitude [E]	Latitude [N]
WT1	24.99619°	59.63670°
WT2	24.99675°	59.63567°
WT3	24.99731°	59.63468°

Net energy production

The expected annual energy production and other energy production figures are presented in Table 22 for the three proposed configurations. These results are preliminary, as it must be specified that they do not include additional losses related to potential curtailments (in favour of birds, e.g.). From these preliminary results, it is possible to deduce that the wind potential over the whole area of Prangli is extremely good and suitable for wind exploitation already at relatively low hub heights, 36m e.g.

Table 22: Expected wind farm energy production figures

Configuration	GEV MPR 275 @55m	WES250 @48m	WES250 @36m
Mean wind speed [m/s]	8.3	8.2	7.8
Gross energy production [MWh/y]	3,264	2,654	2,457
Annual net energy production [MWh/y]	2,950	2,377	2,203

Project Cost Estimate

The price estimations for the wind turbine configurations under study are based on the information provided by the turbine manufacturers and their approximative values are provided in the following table.

Table 23: Project cost estimate

Sites	Unit price [EUR]	Total price (x3) [EUR]
GEV MPR 275 @55m	900,000	2,700,000
WES250 @48m	600,000	1,800,000
WES250 @36m	550,000	1,650,000

Conclusions

The present study was carried out as part of the Technical Assistance from the Clean energy for EU islands secretariat for the island of Prangli in Estonia. Prangli is not interconnected to the mainland and benefits from favourable renewable energy conditions; hence, in this report the solar rooftop PV and onshore wind resources are assessed.

In terms of solar PV, this preliminary study showed that a total solar PV capacity of 125 kW_{AC} can be installed on the four sites proposed. The performance ratio (PR) of all sites is relatively good (over 70%), except for the school site which recorded a rather low PR of 54.3%. Near shading loss due to surrounding trees has a significant effect on performance for all sites, with the largest loss of -26.4% recorded for the school site, which explains its poor performance. For this site, it is recommended to reduce the height of threes on the Western side of the building to a level which is below the building height. Furthermore, based on the P50 year-1 annual yields and the system DC capacities, the specific yields were estimated as 636 kWh/kWp, 518 kWh/kWp, 740 kWh/kWp and 636 kWh/kWp for Culture House, School, Rescue Shed and Shop respectively. These figures fall on the lower end of the spectrum, according to The World Bank's estimates of solar PV power potential for countries globally.

Regarding the wind potential over the Prangli island, the mean wind speed ranges between 4.6 m/s and 7.7 m/s at 25.0 m, between 7.2 m/s and 8.3 m/s at 50 m and between 8.2 m/s and 8.8 m/s at 75 m which represent extremely favourable conditions for wind exploitation, already at low altitudes.

The proposed horizontal axis wind turbine configurations should be considered as an indicative model used for the purposes of this study.

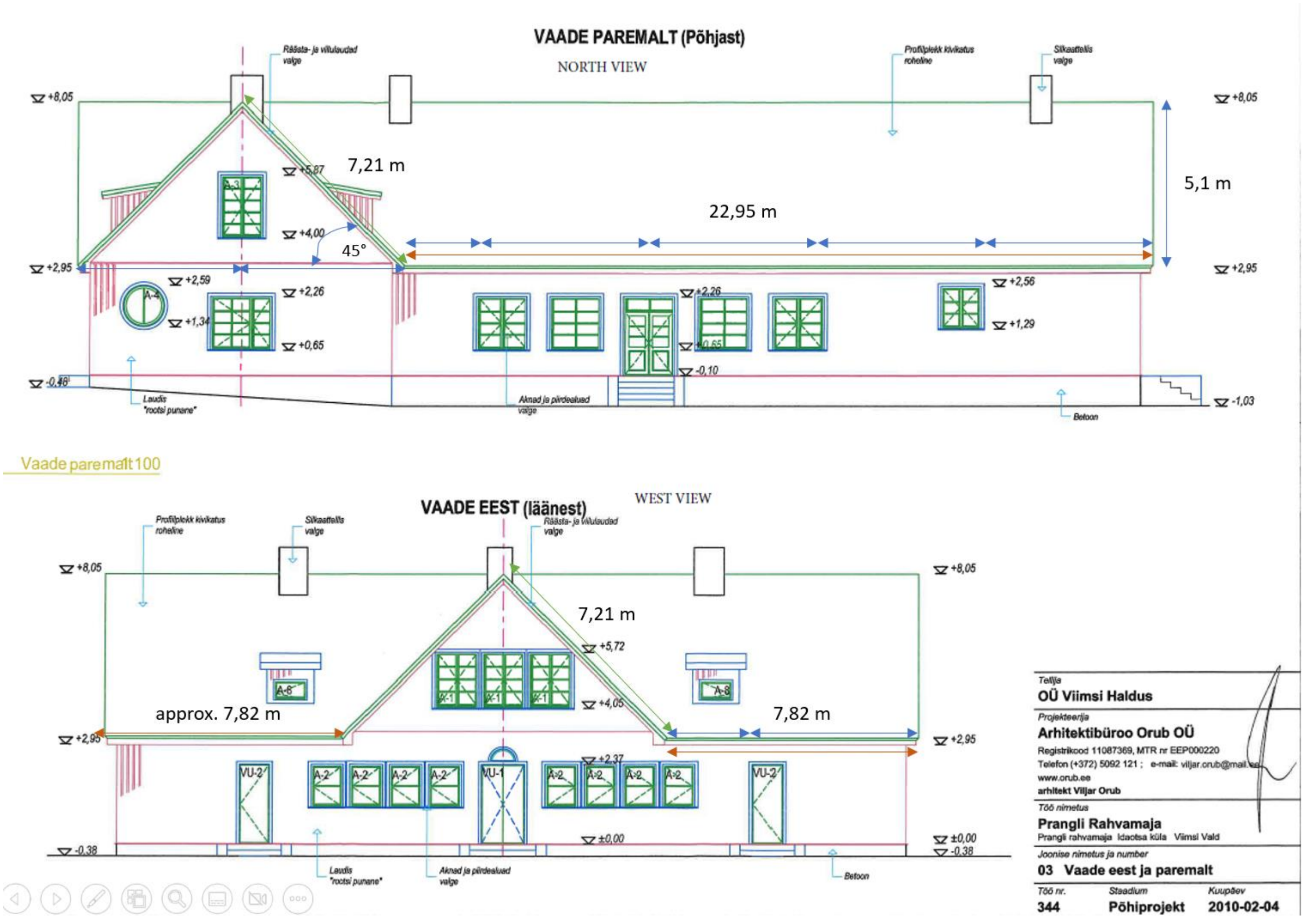
The proposed layouts lead, indicatively, to the following annual production: 2,950 MWh/y for the Vergnet GEV MPR 275 @55m, 2,377 MWh/y for the WES250 @48m and 2,203 MWh/y for the WES250 @36m. These results strongly suggest that this site is suitable for wind exploitation. The annual production will be used in Task 3 regarding the power system modelling.

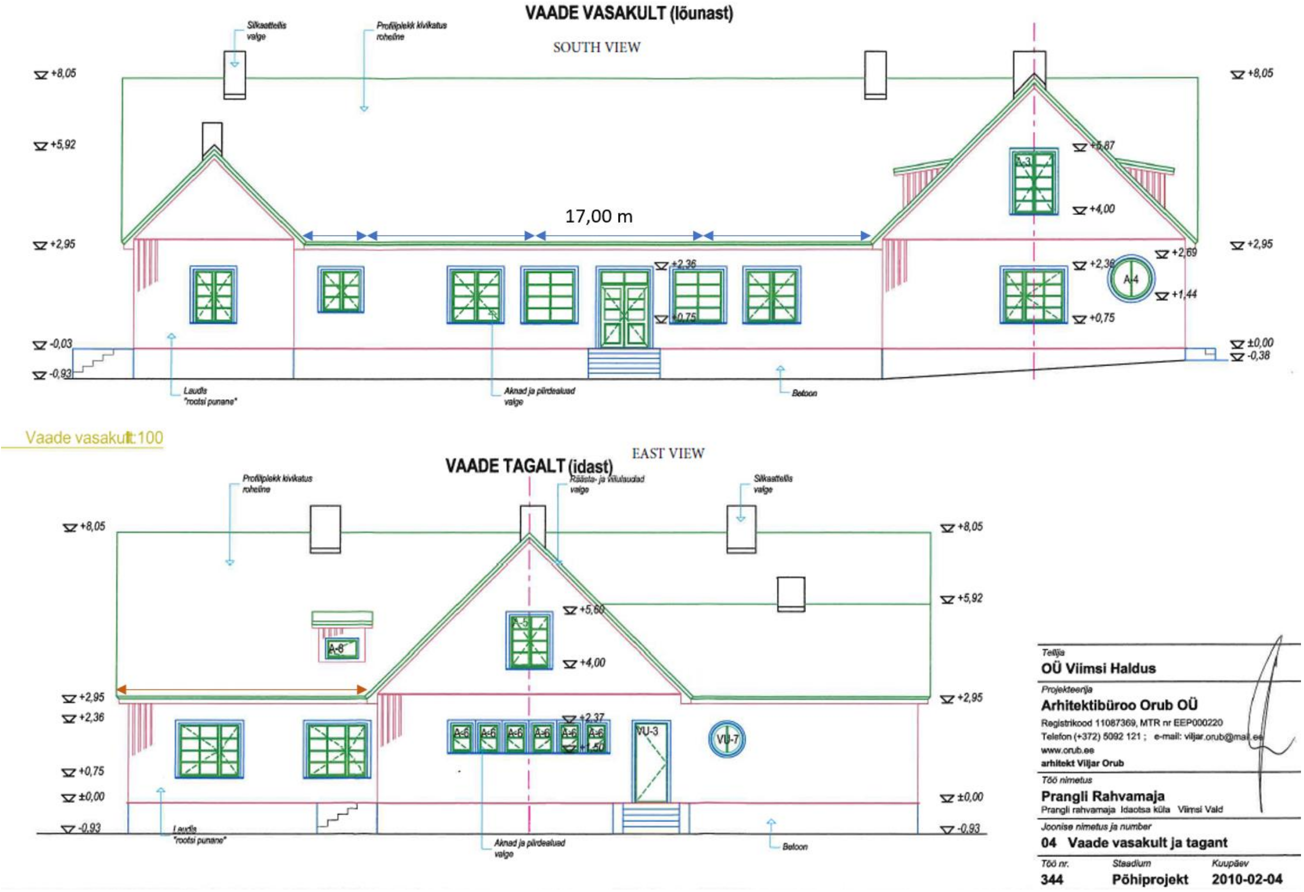
References

[1] Global wind Atlas. Consulted on 01/10/2021, https://globalwindatlas.info/
[2] Fairwind, Produits Small Vertical Axes Wind Turbines (VAWT), F100-F180
[3] The WAsP team, "WAsP best practices and checklist", DTU, June 2013.
[4] Y. Cabooter, K. De Ridder, J.P. Van Ypersele, C. Tricot. Improved prediction of wind power in Belgium, Part 1. SPSD II, Belgian Science Policy, October 2006.
[5] Suri, Marcel; Betak, Juraj; Rosina, Konstantin; Chrkavy, Daniel; Suriova, Nada; Cebecauer, Tomas; Caltik, Marek; Erdelyi, Branislav. Global Photovoltaic Power Potential by Country (English). Energy Sector Management Assistance Program (ESMAP) Washington, D.C.: World Bank Group. http://documents.worldbank.org/curated/en/466331592817725242/Global-Photovoltaic-Power-Potential-by-Country

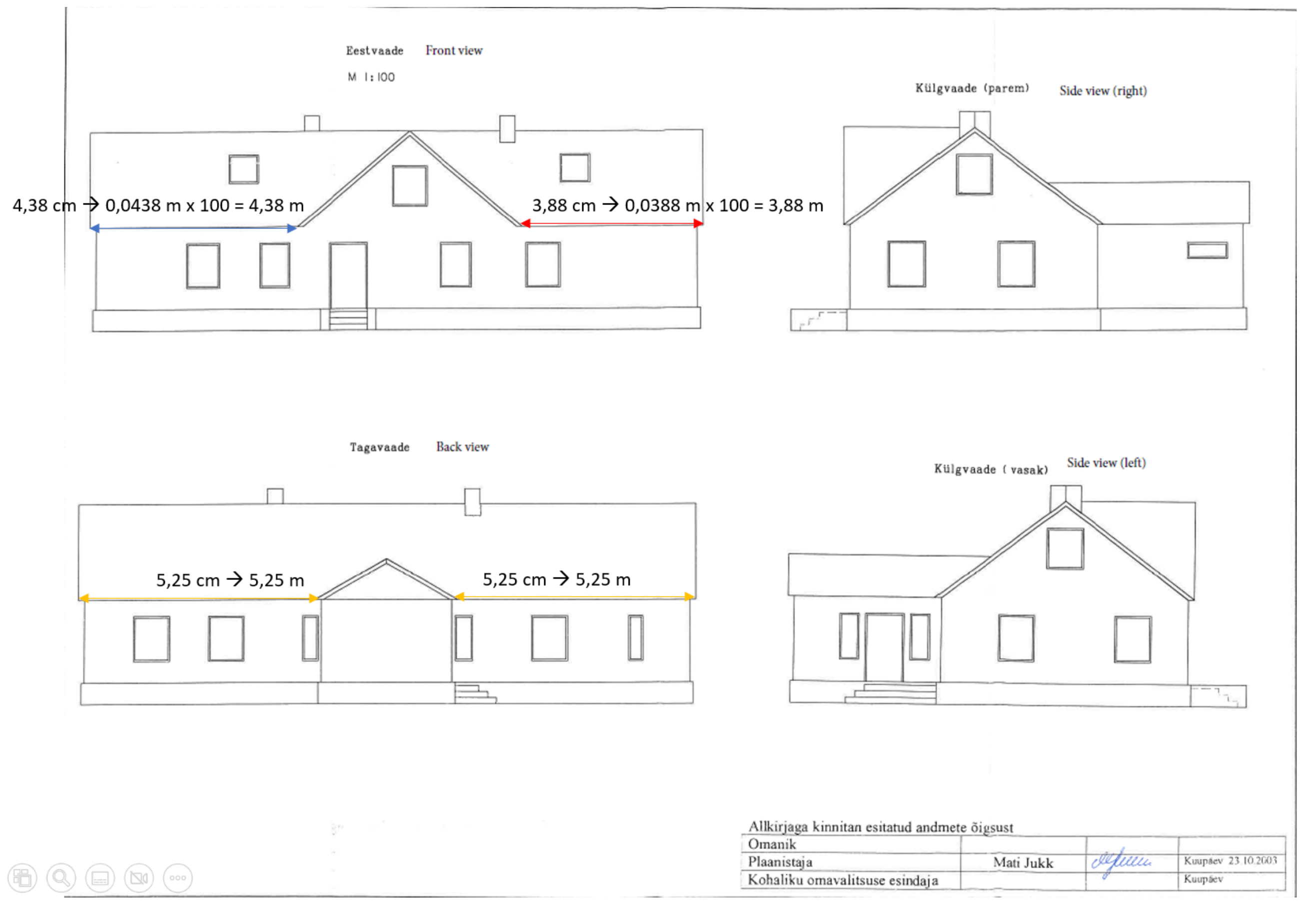
Appendix A – Illustration of roof dimensions for each site

Culture House

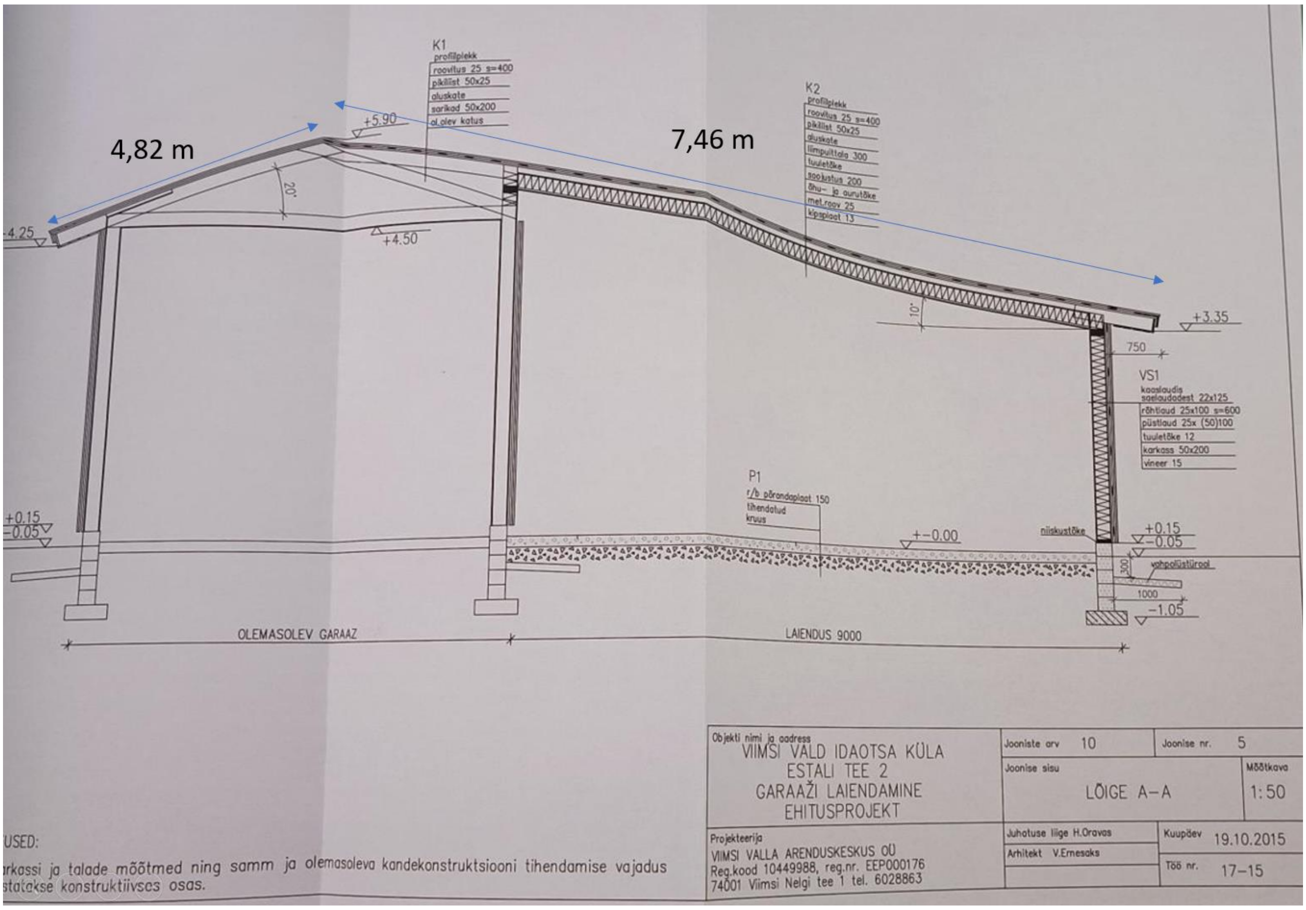


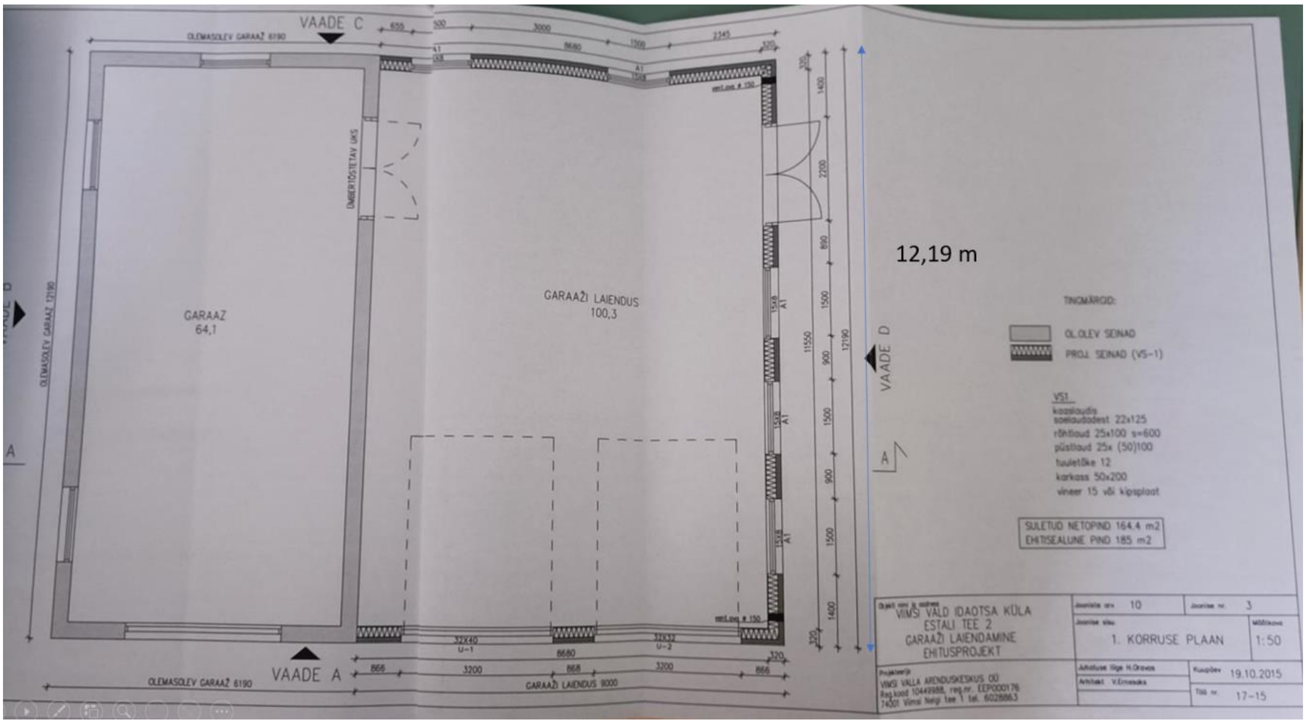

VAADE VASAKULT (lõunast)
SOUTH VIEW
17,00 m
Vaade vasakult 1:100
VAADE TAGALT (idast)
EAST VIEW
Tellija
OÜ Viimsi Haldus
Projekteerija
Arhitektibüroo Orub OÜ
Registrikood 11087369, MTR nr EEP000220
www.orub.ee
arhitekt Viljar Orub
Töö nimetus
Prangli Rahvamaja
Joonise nimetus ja number
04 Vaade vasakult ja tagant
Töö nr.
344
Staadium
Põhiprojekt
Kuupäev
2010-02-04

School

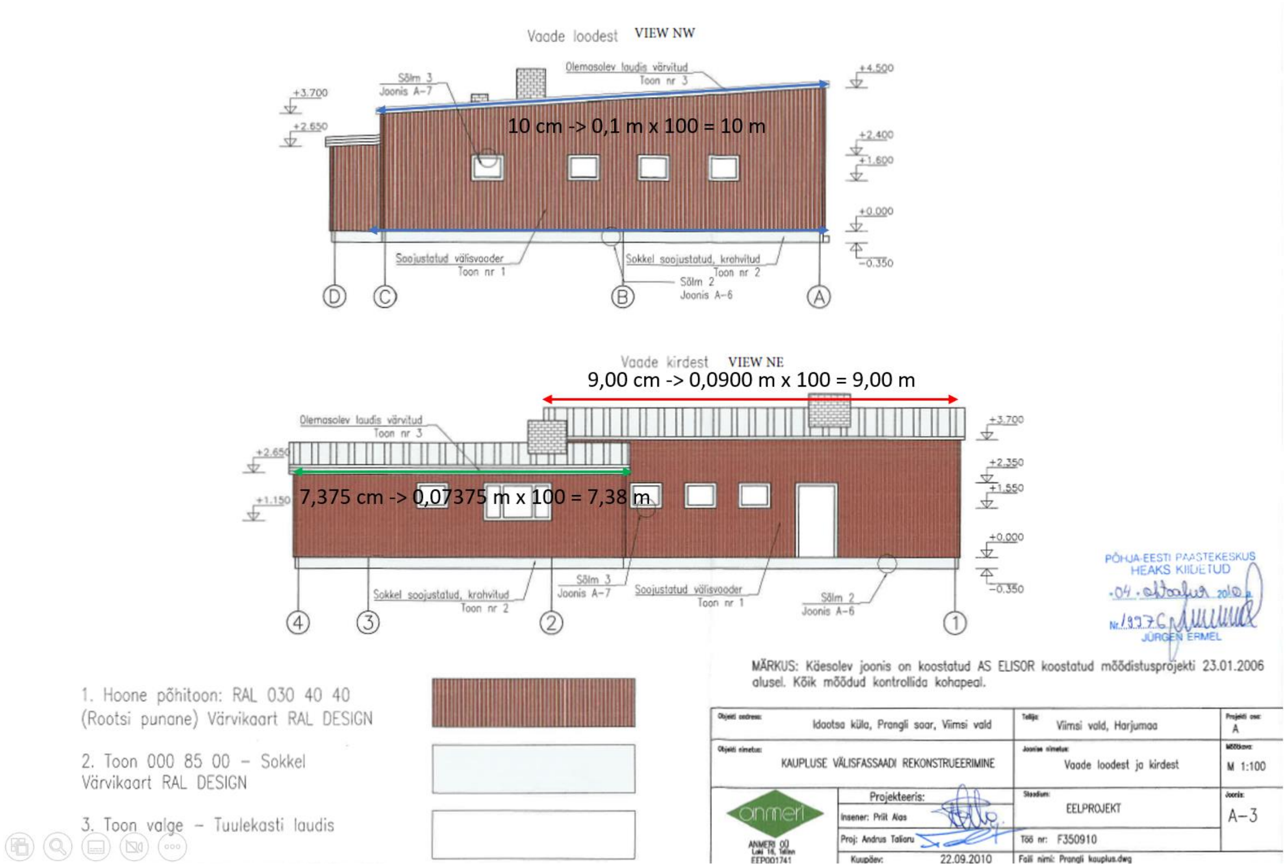

Eestvaade Front view
M 1:100
4,38 cm → 0,0438 m x 100 = 4,38 m
3,88 cm → 0,0388 m x 100 = 3,88 m
Külgvaade (parem) Side view (right)
Tagavaade Back view
5,25 cm → 5,25 m
5,25 cm → 5,25 m
Külgvaade (vasak) Side view (left)
Allkirjaga kinnitan esitatud andmete õigsust
Omanik
Plaanistaja
Mati Jukk
Kohaliku omavalitsuse esindaja
Kuupäev 23.10.2003
Kuupäev

Rescue Shed

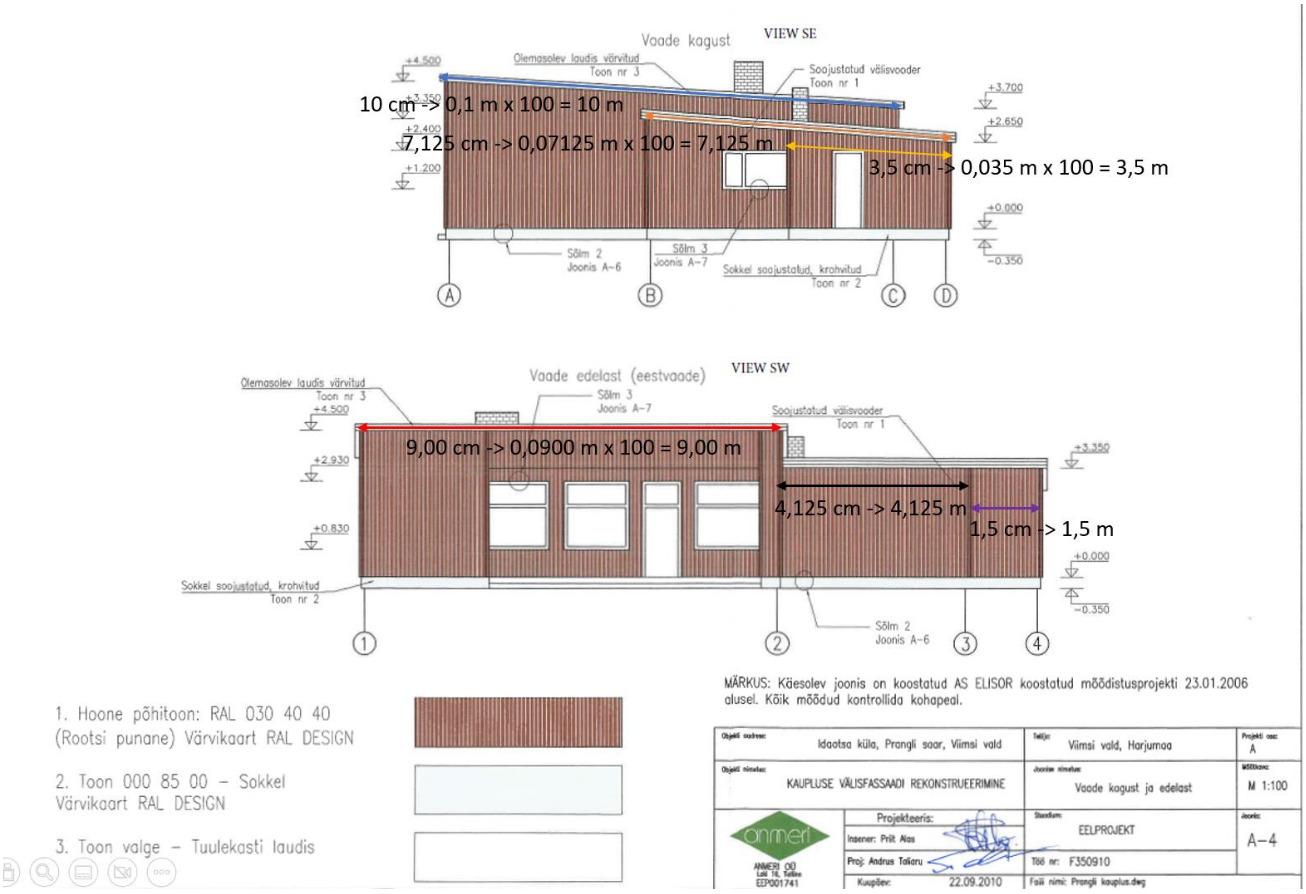

4,82 m
7,46 m
K1
K2
+5.90
+4.50
+4.25
+3.35
20°
10°
750
VS1
P1
+-0.00
+0.15
-0.05
-1.05
1000
OLEMASOLEV GARAAŽ
LAIENDUS 9000
Objekti nimi ja aadress
VIIMSI VALD IDAOTSA KÜLA
ESTALI TEE 2
GARAAŽI LAIENDAMINE
EHITUSPROJEKT
Jooniste arv 10
Joonise nr. 5
Joonise sisu
LÕIGE A–A
Mõõtkava
1:50
Projekteerija
VIIMSI VALLA ARENDUSKESKUS OÜ
Reg.kood 10449988, reg.nr. EEP000176
74001 Viimsi Nelgi tee 1 tel. 6028863
Juhatuse liige H.Oravas
Arhitekt V.Ernesaks
Kuupäev 19.10.2015
Töö nr. 17–15


VAADE C
12,19 m
GARAAŽ
64,1
GARAAŽI LAIENDUS
100,3
VAADE D
VAADE A
OLEMASOLEV GARAAŽ 6190
GARAAŽI LAIENDUS 9000
VIIMSI VALD IDAOTSA KÜLA
ESTALI TEE 2
GARAAŽI LAIENDAMINE
EHITUSPROJEKT
1. KORRUSE PLAAN
1:50
19.10.2015
17–15

Shop



Vaade loodest VIEW NW
10 cm -> 0,1 m x 100 = 10 m
Olemasolev laudis värvitud
Toon nr 3
Sõlm 3
Joonis A-7
+4.500
+3.700
+2.650
+2.400
+1.600
+0.000
−0.350
Soojustatud välisvooder
Toon nr 1
Sokkel soojustatud, krohvitud
Toon nr 2
Sõlm 2
Joonis A-6
D
C
B
A
Vaade kirdest VIEW NE
9,00 cm -> 0,0900 m x 100 = 9,00 m
7,375 cm -> 0,07375 m x 100 = 7,38 m
+3.700
+2.350
+1.550
+1.150
4
3
2
1
PÕHJA-EESTI PÄÄSTEKESKUS
HEAKS KIIDETUD
JÜRGEN ERMEL
MÄRKUS: Käesolev joonis on koostatud AS ELISOR koostatud mõõdistusprojekti 23.01.2006 alusel. Kõik mõõdud kontrollida kohapeal.
1. Hoone põhitoon: RAL 030 40 40 (Rootsi punane) Värvikaart RAL DESIGN
2. Toon 000 85 00 – Sokkel Värvikaart RAL DESIGN
3. Toon valge – Tuulekasti laudis
Idaotsa küla, Prangli saar, Viimsi vald
Viimsi vald, Harjumaa
A
KAUPLUSE VÄLISFASSAADI REKONSTRUEERIMINE
Vaade loodest ja kirdest
M 1:100
Projekteeris:
Insener: Priit Alas
Proj: Andrus Taliaru
Kuupäev: 22.09.2010
EELPROJEKT
A–3
Töö nr: F350910
Faili nimi: Prangli kauplus.dwg


Vaade kagust
VIEW SE
Olemasolev laudis värvitud
Toon nr 3
Soojustatud välisvooder
Toon nr 1
+4.500
+3.350
+2.400
+1.200
+3.700
+2.650
+0.000
−0.350
10 cm -> 0,1 m x 100 = 10 m
7,125 cm -> 0,07125 m x 100 = 7,125 m
3,5 cm -> 0,035 m x 100 = 3,5 m
Sõlm 2
Joonis A-6
Sõlm 3
Joonis A-7
Sokkel soojustatud, krohvitud
Toon nr 2
A
B
C
D
Vaade edelast (eestvaade)
VIEW SW
Olemasolev laudis värvitud
Toon nr 3
Sõlm 3
Joonis A-7
Soojustatud välisvooder
Toon nr 1
+4.500
+2.930
+0.830
+3.350
+0.000
−0.350
9,00 cm -> 0,0900 m x 100 = 9,00 m
4,125 cm -> 4,125 m
1,5 cm -> 1,5 m
Sokkel soojustatud, krohvitud
Toon nr 2
Sõlm 2
Joonis A-6
1
2
3
4
MÄRKUS: Käesolev joonis on koostatud AS ELISOR koostatud mõõdistusprojekti 23.01.2006 alusel. Kõik mõõdud kontrollida kohapeal.
1. Hoone põhitoon: RAL 030 40 40 (Rootsi punane) Värvikaart RAL DESIGN
2. Toon 000 85 00 – Sokkel Värvikaart RAL DESIGN
3. Toon valge – Tuulekasti laudis
Idaotsa küla, Prangli saar, Viimsi vald
Viimsi vald, Harjumaa
A
KAUPLUSE VÄLISFASSAADI REKONSTRUEERIMINE
Vaade kagust ja edelast
M 1:100
Projekteeris:
Insener: Priit Alas
Proj: Andrus Tolkaru
Kuupäev: 22.09.2010
EELPROJEKT
A–4
Töö nr: F350910
Faili nimi: Prangli kauplus.dwg
ANMERI OÜ
EEP001741