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Case Study: RTU on the Way to Participate in Race to Zero Challenge

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Abstract. Race to Zero challenge is a world-wide activity for the universities and colleges to foster the climate goals. This paper analyses the potential of Riga Technical University (RTU) for this action. Different renewable energy sources (PV, wind generators) have been discussed to be installed around the RTU campus. The profiles of electric power consumption are analysed for one faculty and sport centre. The consumption profiles show the amount of power demanded during the working hours, weekends and at night. Energy yield assessment on the roofs is made for two buildings where the configuration of PV panel placement and orientation are analysed that in turn is reflected in the energy generation profile. SCADA system is considered as a monitoring and control tool to visualize power generation and control of the power flow within the system elements.

Keywords—Race to Zero, renewable energy sources, distributed power generation, SCADA

I. Introduction

Riga Technical University (RTU) is a modern internationally recognized and prestigious university, the only multidisciplinary technical university in Latvia. There are more than 14,000 students including 3,000 international students and more than 500 doctoral students. Total number of employees is 2218 including 1379 academic personal. Studies and research at RTU are implemented by 9 faculties, including 33 institutes.

Values - Riga Technical University has set the values that not only contribute to the successful implementation of the objectives and tasks of the university, but are also respected when planning the development and day-to-day activities of the university, and are important for every employee and student of the university. The values of Riga Technical University are sustainable development, quality, openness and cooperation, creativity, academic freedom, motivation to learn and discover.

Mission – to build a competitive, educated, innovative and creative future.

Vision - Riga Technical University is an internationally competitive, dynamic and modern university of research and technology.

Objectives - RTU sets 4 main objectives for the next planning period. Three of them are related to the development of the main RTU's activity – in the study, research and valorisation areas, but the fourth is an improvement of the university support function and the development of internal governance – building institutional excellence.

As one of the *objectives in the RTU strategy* is sustainable development that includes infrastructure and resource management, e.g. to promote sustainable development and efficient use of RTU infrastructure, to create and popularize Kipsala (island where RTU main campus is located) as a smart city of the future, creation of green technologies, demonstrations and a place of testing, to involve RTU staff and students into the improvement of RTU environment and infrastructure. The resource management per one representative of RTU is presented in Table I [2].

TABLE I. RESOURCE MANAGEMENT [2].

Indicators	2020 data	Planned growth in 2025 compared to 2020	Planned growth in 2027 versus 2020
"Carbon content" of electricity use per 1 RTU representative (students and employees), kWh	**638**	**- 17% (530)**	**- 22% (498)**
"Carbon content" of heat use per 1 RTU representative (students and employees), kWh	**1 094**	**- 15% (930)**	**- 17,7% (900)**
Water consumption per 1 RTU representative (students and staff), m^3	**9,3**	**- 8% (8,6)**	**- 14% (8)**

This paper presents a case study of RTU potential in Race to Zero campaign [3] that is organized among the universities and colleges. The aim of the action is to find out what are the potential directions for electric power production and management among the RTU campus buildings, with the focus on use of renewable energy sources.

II. RTU in Race to Zero

The RTU campus (demarcated area) is located on Kipsala island (see Fig.1.) nearby the city center of Riga and it is surrounded by the Daugava River to the right and the Zunda channel to the left.

The campus contains 6 department buildings, library, student dormitories, parking lots, exhibition center as well as a swimming pool building equipped also for other sporting activities. The general development plan of Riga requires the presence of such social infrastructure like open-green-space for open-air activities, trees, pedestrian walks and low-speed e-mobility roads.

There are various scenarios for renewable energy sources (RES) installations that will be discussed below by analysing each type of installations separately.

Fig. 1. Kipsala Island and RTU campus (marked in red)

RTU participation in the initiative will be a stimulus for other universities, education facilities as well as society (including households [4]) to become CO_2 neutral.

A. *RES Usage Examples*

1) Roofs

Roof areas of RTU buildings have a great potential for PV systems and wind turbines installation. Despite that the whole roof surface cannot be used for PVs due to the ventilation and air conditioning equipment installed on the roof, there is still enough free space for power generation equipment.

2) Facades

Facade coverage with PV panels could be also considered because many external walls of RTU buildings are oriented directly to the south. Moreover, Latvia being a Nordic country has a low angle of the Sun light especially in autumn, winter and spring. In this case the vertical placement of PV panels on the facades could be beneficial.

3) Carports

There are several parking lots near all the buildings in the campus with the total number of 300 car places (plus 250 parking places at the exhibition centre located in the campus). It could be feasible to create carports with roofs covered with PV systems. Fig. 2 presents an example of carport with integrated PV system.

Fig. 2. Example of carport with integrated PV system.

4) On-ground PV

The PV system installations on the ground are also under consideration. This type of installations is more vulnerable to vandalism, thus the additional precautions measures should be taken into account. Most of the RTU's land is already used for buildings, roads, carports and parks with grass for open-air activities, thus the area for such kind of installations is limited.

5) Floating PV installations

As it can be seen from Fig.1, the RTU campus is gathered round by the Zunda channel on its left, that could lead to some floating PV installations. The Zunda channel is about 2 m deep and has very low flow, as well as it is quite weakly used by small boats sailing for sightseeing. Presently, there are no regulations for floating PV installations in Latvia, thus the additional efforts should be made to rise this issue at the level of Ministry of Regional Development (responsible for territory planning and water resources) and Ministry of Economics (responsible for energy resources).

6) Decorative PV generation elements

RES can be located in the campus central part where large amount of students and workers are passing by. In order to make the environment modern, attractive or even futuristic a decorative RES could be considered. So called Solar trees and wind trees (Fig. 3) are becoming very popular. Small wind turbines (Fig. 3*a*) or Solar panels (Fig. 3*b*) are fixed onto the constructions looking like trees [5]-[9].

(a) (b)

Fig. 3. Wind tree (a) and Solar tree (b)

7) Wind turbines on roofs

Relatively large wind turbine could be hardly located at any place on the roof, as it affects as a point-type loading onto the roof, and without a dedicated roof design procedure, could not be installed. The building of the Faculty of Electrical and Environmental Engineering (FEEE) laid down their demands to the architects to plan two dedicated places for vertical axis wind turbine (VAWT) installation, that had been completed. Thus 500 kg turbine equipment could be placed. Meanwhile, other building has no dedicated place for point-type load, as a result only small wind turbines (< 1 kW) without high tower, could be placed on the northern edge of the roof, minimizing shadowing on potential free surface for the PV installations.

8) On-ground wind turbines

In order to use wind turbines on the ground the specific wind measurements should be made, because there are plenty of obstacles (buildings) splitting the wind flow in the city. This fact can be overcome by increasing the installation height or using wind concentrators. In our case both sides of island are very attractive because they are at the banks of river and channel that could provide smooth air flow or act as a natural wind concentrator. Therefore, there is an effective area of more than one kilometre at both sides of the island. According to the proposals of the companies producing wind turbine installations, it is essential to make wind measurements at each place and height where a wind turbine is planned to be installed in order to make proper assessment on energy yield.

III. Methodology

A. Existing Infrastructure

Primarily heat and electrical energy supply on Kipsala island is ensured by RTU cogeneration station, which operates on the natural gas. Due to the electrical market liberalisation, the electrical energy is being sold based on economic feasibility, primarily depending on the Nord pool prices, while RTU buys the electrical energy from a supplier, who wins a tender, in the form of long-term contracts with fixed prices. Meanwhile, the electrical and heat energy tariffs have been raised several times per year by 20 and 15% respectively due to dramatical price increase of primary energy sources, such as natural gas and bio-resources. Thus, besides the EU goals on reaching CO_2 neutrality, there is an economic feasibility to increase the share of RES in the energy balance.

Fig. 4. RTU campus buildings (Building numbers revieled below).

A1 Faculty of Electronics and Telecommunications (FET)
A2 Faculty of Electrical and Environmental Engineering (FEEE)
A 2.1 (P1) Faculty of Computer Science and Information Technology (FCSIT)
A3 Faculty of Material Science and Applied Chemistry (FMSAC)
A4 Scientific Library
A5 Faculty of Civil Engineering (FCE)
A6 Lab House
A7 Faculty of Architecture (FA)
A8 Sport complex
A9, 9.1, 10 Students Dormitory

There are 10 buildings (Fig. 4.) with different types of roof material, consequently different load capacity. Thus, various RES technologies and mounting systems should be taken into account to evaluate the potential of the buildings' roof space.

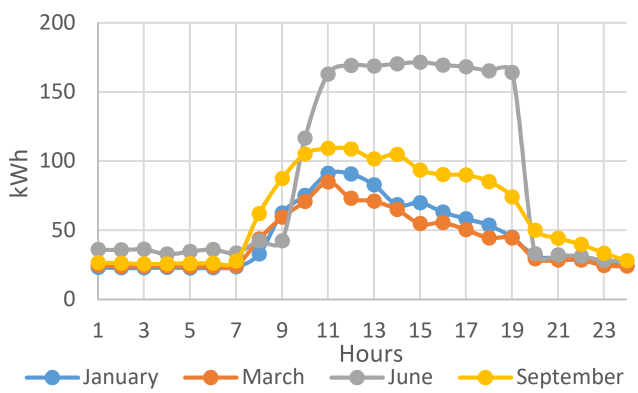
Taking into account the future development plans with the new department houses, as well as new 9-floor dormitory building, the potential places for RES should be revised carefully taking into account shading for PV systems.

B. Electrical Energy Demand

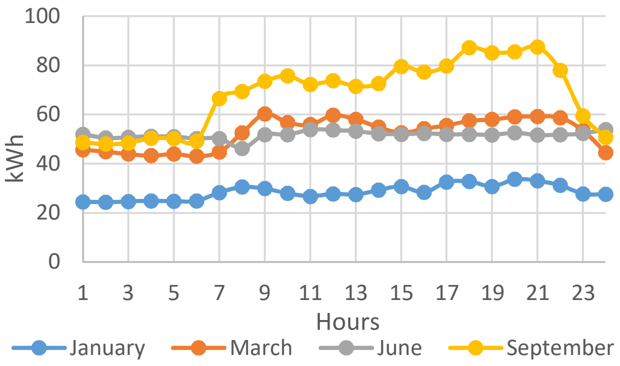
Based on information obtained from infrastructure department the total consumption of university buildings (including administrative buildings, student dormitories, sport complex and student canteen) in year 2021 was 4.9 GWh.

The typical daily electrical energy consumption profiles of FEEE and sport complex are seen in the figure below (Fig. 5.). It has typical peak-loads during morning hours, obviously due to overlapping of research and teaching activities, as the latter is energy demanding due to increased demand from Heat ventilation and air conditioning (HVAC) systems. In the afternoon the consumption profile mostly remains constant till the end of the working hours, when most of the employees leave their workplaces. Additionally, it should be emphasized that in summer the air conditioning unit has high electric power consumption compared to autumn, winter and spring that is reflected in the power consumption curve of June (Fig.5.*a*).

On the contrary to the academic-type load profile, the sport complex with swimming pool has almost constant consumption due to the pump type load used in water purifying process. Some insignificant increasing of the load occurs in the evening hours due to higher number of visitors.



a)



b)

Fig. 5. Typical daily consumption of each quartal: (a) Faculty of Electrical and Environmental Engineering (FEEE Āzenes street 12/1), (b) Sport complex (Kipsalas street 5)

C. *Energy yield assessment*

1) *Building of FEEE*

As an example, the Faculty of Electrical and Environmental Engineering is selected, that is 21 m height 6 floor building. In southern part of the roof it has HVAC system, as well as such research facilities like two wind turbines of vertical exes and two PV strings used for long term monitoring of PV potential in Latvia. The northern part of the roof is mostly free for new RES installations with total area of about 400 m^2. Hereby, the PV installations are taken into account to evaluate different mounting system configurations and PV module orientation. The 450W modules are taken into account with 1100 x 2100 mm dimensions.

(a) Single-row fixed-tilt angle S-orientation (Az160)	(b) EW-orientation (Az160)

Fig. 6. FEEE building with two configuration of PV installations.

Fig. 6. demonstrates two mounting configuration examples possible to realize in the mentioned segment of the roof. The first configuration has a single row 30º fixed-tilt mounting system with 160º azimuth orientation and 1 m spacing between the rows. The second configuration has a mounting system with east-west orientation with rows being placed along the roof (azimuth 160º) and 0.8m spacing between the rows.

Although, the first configuration results in higher kWh/kWp ratio, the second configuration allows installing photovoltaic panels with higher density, that results in even higher annual energy production from the same area under consideration. This case can be useful for other buildings, where the limited free area of the roof is available for PV installations. Moreover, East West (EW)-orientation also ensures wider generation profile especially during summer period. This feature allows covering the instantaneous consumption with higher self-consumption percentage, minimizing energy export to the grid. On the top of that, EW-configuration is better than south (S)-configuration during cloudy condition as it receives higher portion of diffused light.

TABLE II. ENERGY YIELD ASSESSMENT FOR FEEE BUILDING

	S-orientation	EW-orientation
Tilt angle, row spacing	30º, 1m	15º, 0.8m
Installed power [kW]	33	46.8
Produced energy [MWh]	26.89	35.24
Effective hours [kWh/kW]	807.4	752.9

Fig. 7. demonstrates the average daily irradiance level at different PV module orientations. The yellow curve represents irradiance for on unit area of surface with South-orientation, while blue curve represents East-West-configuration. It is obvious, that South-orientation provides the highest power output per panel.

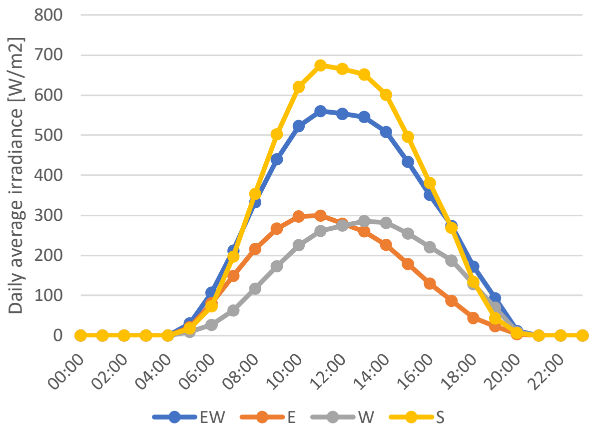


Fig. 7. Daily average irradiance levels at different module orientation in May.

As it was previously mentioned, EW-configuration allows installing larger number of PV modules per unit of area. Due to this fact the generation profile is scaled in respect to the installed capacity. Fig. 8. demonstrates average daily power generation profile for two mentioned configurations of the PV system located on the building under consideration.

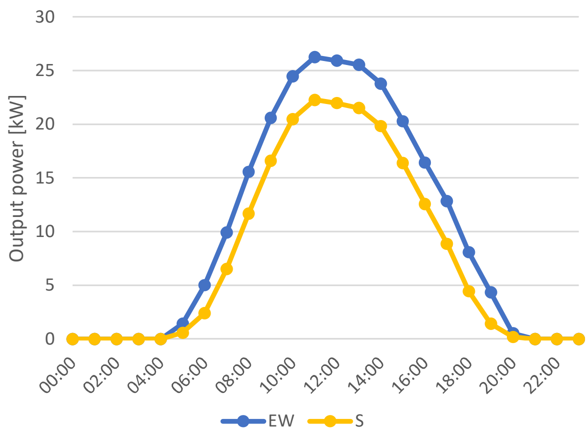


Fig. 8. Average daily power generation profile for S and EW configuration on FEEE building in May.

The final yield of monthly production is demonstrated in Fig. 9.

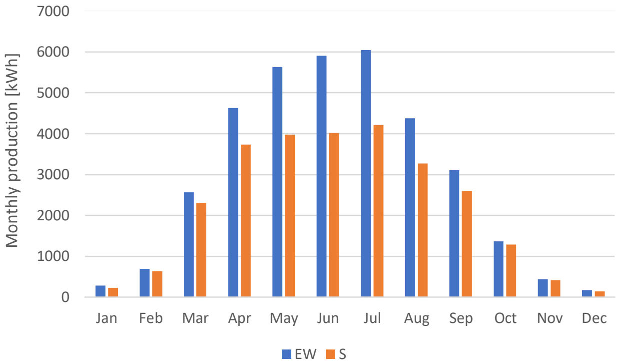


Fig. 9. Monthly energy production for two configurations.

2) Swimming pool

RTU has Olympic-type swimming pool with 50 m long paths used for international championships. The roof has built of long-pass roof trusses covered with insulation and membrane type of hydro isolation material. The roof has limited additional load potential. Thus, PV installations could be located above the external walls, where PV loading does not threaten safety.

The figure below (Fig. 10) represents two configuration of PV installations– EW and S orientation.

(a) Single-row fixed-tilt angle S-orientation (Az160)	(b) EW-orientation (Az160)

Fig. 10. Swimming pool building with two configuration of PV installations.

Like in the previous case, the EW configuration allows installing larger number of PV modules, in comparison to S configuration. Nevertheless, in this case the annual production is almost the same, meaning that payback period will be longer in EW configuration due to higher initial investments.

TABLE III. ENERGY YIELD ASSESSMENT FOR SPORT COMPLEX (SWIMMING POOL) BUILDING

	S-orientation	EW-orientation
Tilt angle, row spacing	30º, 1m	15º, 0.8m
Installed power [kW]	114.3	131.4
Produced energy [MWh]	84.11	89.9
Effective hours kWh/kW	735.9	684.4

Fig. 11. demonstrates generation profile for S and EW configurations assumed for the swimming pool.

D. Summary of PV potential for RTU buildings

The summary on RES potential (Table IV) is presented below, where each building is separately analysed by several criteria: total installed PV power, orientation, efficiency ratio and annual yield.

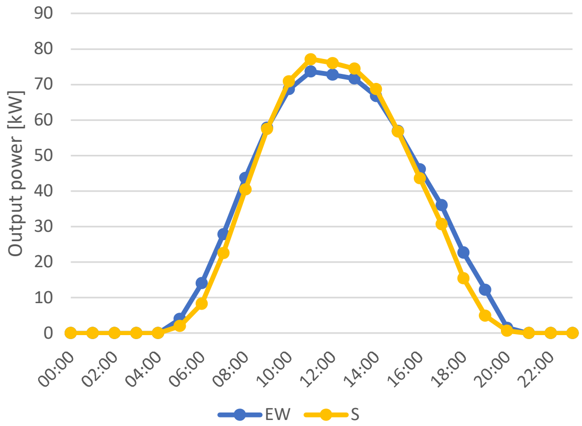


Fig. 11. Average daily power generation profile for S and EW configuration on the swimming pool in May.

TABLE IV. SUMMARY ON RES POTENTIAL OF RTU BUILDINGS

	Installed power [kWp]	Orientation	kWh/kWp	Yield [MWh]
FET (A1)	87	EW	805.7	70.1
FEEE (A2)	46.8	EW	752.9	35.2
FCSIT(A2.1)	43.5	S	826.1	35.9
FMSAC(A3)	159	EW	801.7	127.5
FCE (A5)	85.1	S	838.6	71.4
FA (A7)	106.9	S	807.7	86.3
Sport complex (A8)	114.3	S	735.9	84.11
Dormitory (A9,9.1,10)	40.5	EW	801.6	32.5
Total	596.1		Avg = 795	472.9

As can be seen from the table, there is a high potential for installed PV power on the buildings' roof, that can be used to compensate self-consumption by about 0.5 GWh that constitutes 10% of total consumption of RTU campus buildings.

E. National Policy of RES Usage

Recently Latvia has introduced the net electrical energy calculation methodology, which allows "storing" of the excess of electrical energy in the public grid if produced from RES. End-user pays only the transportation component while consuming previously exported electrical energy. This applies only to microgeneration RES system, that is up to 3.6 or 11.1 kW in one-phase or three-phase connection case respectively.

Of course, it is allowed to connect more powerful RES generation systems than it is considered in the net energy exchange programme. In this case the RES system should be registered as electrical generation plant, which will sell all excess energy to transmission system operator (TSO). Previously (before 2021), when the electrical energy price was comparable with energy transportation cost, it was reasonably to use PV system only to compensate the self-consumption. Nowadays, when the price per electrical energy varies from 0.01 till 1.00 EUR/kWh (December 2021) and most of the time it has double or triple price in comparison with the transportation cost, it is reasonable to use any free space on ground and roof suitable for PV or wind installations to rise generation power and sell energy to TSO.

The last fact arises the necessity to coordinate the output power of all string inverters, introducing generation power control and/or, on the other hand, the demand response. Most of the manufacturers of PV inverters do support Modbus

SunSpec communication protocol, where the output power is being controlled by modifying single holding register in Modbus register map. Thus, power can be adjusted, so does the demand. By now there are 12 e-vehicles owned by RTU, that are regularly connected to charging point, that has communication capability to control the charging current. That leads to a conclusion, that centralised control of production power and demand should be introduced.

F. SCADA system

RTU has received the academic license for full-functional YOKOGAWA FAST/TOOLS SCADA system, that includes Digital-Twin module. It is a new feature in the industrial automation software systems, as it allows automatically to find mathematical correlations between parameters and make predictions of some parameter in the future. For instance, it is expected that electrical energy demand of RTU buildings could be predicted with relatively high level of precision based on statistical data and meteorological forecast. General structure of the SCADA system adapted for RTU infrastructure is presented in Fig.12.

The SCADA system is necessary to control output power of central string inverters, as it was mentioned before, as well as coordinate charging power of EV charging stations.

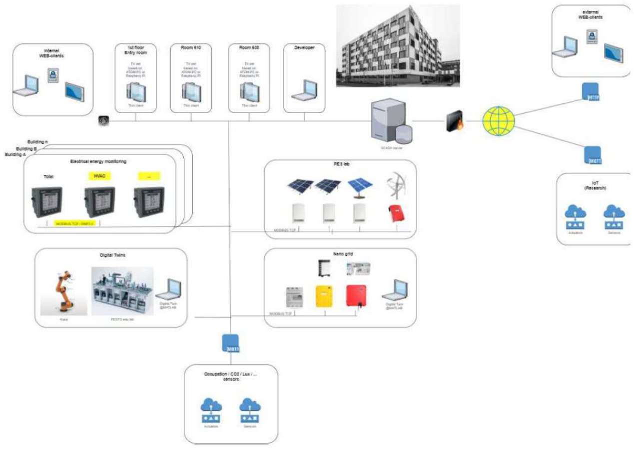


Fig. 12. General structure of the SCADA system.

Besides, the Digital-Twin module is planned to be used for energy-demand and production forecasts, that later will be used for commercial-scale battery energy storage system (BESS) control.

IV. Conclusions

The proposed case study reveals power consumption of several RTU campus buildings with different consumption scenarios. Also, possible potential of the RTU campus buildings in power production was analysed. Despite the fact that the roofs of the buildings are already occupied by HVAC infrastructure there is still a relatively high potential for power generation from renewables. Moreover, there are several places in campus, that could be equipped with additional energy sources (parking lots, costal area, green area). The assessment of campus buildings roof area shows that it is possible to harvest roughly 0.5 GWh that is approximately 10% of the whole year consumption of campus buildings.

Geographical analysis shows that both PV panels and wind generators can be installed around the campus and on the buildings.

When using many energy sources, loads, storage elements together the observation of the production, consumption and power flow among all the elements is becoming very essential. SCADA system was selected as a tool to follow the processes in the RTU campus, that later could be used for energy demand forecasts and BESS control.

In future each building which is a consumer and producer (prosumer) and other energy production objects should be analysed in more details in order to understand its role in the whole picture. The role of other energy sources different from PV also could be studied in more detailed. For example, to understand the wind energy potential additional wind measurements at different places of the campus should be performed in order to choose the type and power of wind energy system.

Acknowledgment

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References

[1] https://lv.wikipedia.org/wiki/R%C4%ABgas_Tehnisk%C4%81_universit%C4%81te

[2] Riga Technical University strategy for 2021-2025 (https://www.rtu.lv/writable/public_files/RTU_strategy_for_2121_2025_eng.pdf)

[3] https://www.educationracetozero.org/

[4] J. Zakis, A. Suzdalenko, O. Krievs and L. Ribickis, "Feasibility Study of Renewable Energy Systems in Households," 2019 IEEE 60th International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON), 2019, pp. 1-6, doi: 10.1109/RTUCON48111.2019.8982297.

[5] S. Watson, A. Moro, V. Reis, C. Baniotopoulos, S. Barth, G. Bartoli, F. Bauer, E. Boelman, D. Bosse, A. Cherubini, A. Croce, L. Fagiano, M. Fontana, A. Gambier, K. Gkoumas, C. Golightly, M. Iribas Latour, P. Jamieson, J. Kaldellis, A. Macdonald, J. Murphy, M. Muskulus, F. Petrini, L. Pigolotti, F. Rasmussen, P. Schild, R. Schmehl, N. Stavridou, J. Tande, N.Taylor, T. Telsnig, R. Wiser. "Future emerging technologies in the wind power sector: A European perspective" Renewable and Sustainable Energy Reviews, Volume 113, 2019, 109270, ISSN 1364-0321.

[6] S. Sawant, S. Bane, S. Bhokare, P. Bute, K. Gosavi and A. Gawade, "Highly Efficient Constant Power Generation Using Solar Tree," 2018 2nd International Conference on Trends in Electronics and Informatics (ICOEI), 2018, pp.1-6.

[7] F. Hyder, P. Baredar and K. Sudhakar, "A novel Sun tracking technique through a Solar PV Tree and a smart controller," 2018 4th International Conference on Electrical Energy Systems (ICEES), 2018, pp. 407-411.

[8] K. Kishore, B. Pesala, M. Santosh, S. C. Bose and S. A. Akbar, "IoT Platform to augment Solar Tree as Smart Highway Street Light with Ambient Monitoring Capability," 2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT), 2019, pp. 1-6.

[9] Bakhshandeh Rostami, Ali. (2015). Energy harvesting by hydro/aero elastic phenomena in small scale