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# MONITORING AND DATA ACQUISITION FOR A CONSUMPTION SYSTEM BASED ON RENEWABLE ENERGIES

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***Abstract:*** Within the HORESEC project, a combined wind-photovoltaic-motogenerator renewable energy system was developed at the Nautical Base of the Maritime University of Constanta (CMU). The system was entirely designed and built at CMU for the purpose of combined testing of on-grid and off-grid operation efficiency. In this paper the following aspects are presented: 1) the need to create a research centre on monitoring and use of solar and wind resources, through the project Holistic impact of renewable energy sources on the environment and climate-HORESEC in the context of supporting smart specialization in energy; 2) the purpose of the work is presentation of the structure of the system designed and built at CMU in order to test its efficiency, as well as the acquisition of data displayed on a portal for all parameters monitored by the system, at intervals of 5 minutes, or daily, or weekly, monthly or annually. The research consisted in: 1) the configuration of the system to be made for the off grid variant, which opted for a Li-Ion battery bank [2], with a nominal voltage of 55.5 VDC and working between 61.5 V and 45 V, with nominal storage capacity of 6.74 kWh and usable of 5.5 kWh; 2) programming of the measurement and data transmission systems on the web, as well as of the mobile measurement system with the possibility of data transmission to the PC with the sampling rate of minimum 1 month / sec and measurement time of maximum 30 days (Janitza system, SMA Energy meter, Fluke ammeter-voltmeter group + PC + adapter ). The obtained results consist in displaying on a portal all the parameters monitored by the created system, on intervals lasting 5 minutes, or daily, or weekly, monthly or annually (data reports), as well as the existing events in time. The created system has the advantage of increasing energy efficiency by using unconventional methods of storage and consumption management.
***Key words:*** data acquisition, monitoring, renewable energy, wind turbine, efficiency, consumption.

## 1. INTRODUCTION

The selectivity of a measuring system is the property of a measuring system, using a specified measurement procedure, in which the system provides measured values of the size for one or more measurements, so that the values of each measurement are independent of other measurements or other matters related to the phenomenon, body or substance under investigation [1]. Specialized software packages for data acquisition, such as Lab VIEW, NI-DAQ (National Instruments), MATLAB / DAQ (Math Works) have libraries and functions for linearzing and converting signals from various standardized transducers - thermocouples, thermo-resistors, resistive brands [1]. The architecture of a measurement and data acquisition system can be of several types, depending on the requirements of the application and the hardware used. Such process computer architectures are currently used in industrial applications, in technological or processing lines, in power plants, etc. When the measurement system is designed and engineered to monitor a particular process, it is implemented and implemented at the same time and is optimized according to its technical requirements. A possible structure of a data measurement and acquisition system is typical of the use of microprocessors. The progress in research and development activities resulting in creation numerous innovative solutions. The renewable energy sources are the basis for sustainable development, [8]. The construction sector in Europe accounts for 40% of energy consumption and 36% of $CO_2$ emissions [9]. Due to the estimated, high energy saving potential of the housing construction sector, the European Union has established a policy framework focused on reducing energy consumption in buildings, consisting of different policy actions, i.e., Energy Performance of Buildings Directive (EPBD) [10], Energy Efficiency Directive (EED) [11], Ecodesign Directive [12], Energy Labelling Regulation [13] and the mentioned Renewable Energy Directive (RED) [14].” Such a structure is also implemented at the Nautical base of the Maritime University of Constanta [2].
The Maritime University of Constanta has a wide base for data acquisitions in the field of renewable energies. At the Nautical Base of the university, a

research centre was created regarding the monitoring and use of solar and wind resources, through the Holistic project of the impact of renewable energy sources on the environment and climate-HORESEC [1]. This centre was equipped with modern monitoring equipment and data acquisition that support smart specialization in energy, through holistic analysis of the impact of energy sources on climate change, achieving evolution, progress of knowledge, for a sustainable development of Romania [2]. The system was entirely designed and built at CMU for the purpose of combined testing of on-grid and off-grid operation efficiency.

## 2. EXPERIMENTAL METHODS AND RESEARCH

The purpose of the paper is to present the structure of the system designed and built at CMU to test its efficiency, as well as the acquisition of data displayed on a portal for all parameters monitored by the system, at 5 minute intervals, or daily, or weekly, monthly or annually.

### 2.1 The configuration of the system

The research consisted of:

1) the configuration of the system to be performed for the off grid variant, which has opted for a Li-Ion battery bank (Figure 1) [2], with a nominal voltage of 55.5 VDC and operating between 61.5 V and 45 V, with a nominal storage capacity of 6.74 kWh and usable of 5.5 kWh;


Fig. 1. BMZ Li-Ion battery pack, [2]

2) programming of measurement and data transmission systems on the web, as well as of the mobile measurement system with the possibility of data transmission to PC with a sampling rate of minimum 1 month/s and measurement time of maximum 30 days (Janitza system (Figure 2) [1], meter SMA power supply (Figure 3) [1], Fluke ammeter-voltmeter group + PC + adapter).

The photovoltaic generator is composed of 21 polycrystalline photovoltaic panels totaling 5000W (Figure 4) [2], which directly supplies a 5.5kW Sunny Tripower on grid inverter type STP 500TL-20 produced by SMA (Figure 5) [5], and normally supplies power to the three-phase network of the CMU.


Fig. 2. Janitza system for real-time data retrieval and storage, [1]


Fig. 3. SMA Energy meter sensor, [1]

Fig. 4. The photovoltaic generator, [2]

Fig. 5. The three Sunny Island 4.4M-12 off-grid inverters of 3.5kW each, [5]

This on-grid inverter works together with a system of three Sunny Island 4.4M-12 off-grid inverters of 3.5kW each, thus allowing operation in three-phase system in on-grid and off-grid mode (Figure 5) [2]. The first Sunny Island is the system Master and manages the energy to and from the battery (Figure 1).

The wind generator is a 3 kW / 220 V wind turbine from Bornay (Spain) [3] (Figure 6), which can work with either a battery controller for BMZ battery bank (Figure 7) [5] or with a three-phase on-grid inverter, in which case it can supply power to the three-phase grid.

The wind turbine is located on a 12m high pole and is located near a professional meteorological station executed by Logotronic (Figure 8) [3] and which provides the value of wind speed and direction with high precision, for the purpose of turbine efficiency analysis wind. In the absence of the network, an 8.8kW Diesel DeWerk generator (Figure 9) [2] located outside and which is the backup source in case of grid-failure can work.


Fig. 6. The wind generator, [3]

Fig. 7. BMZ battery bank, [5]


Fig. 8. Logotronic station, [3]

Fig. 9. Diesel DeWerk generator, [2]

A novelty element introduced in the design is the wind simulation group (Figure 10) [4] which allows the replacement of the wind turbine system, at which the energy produced it is random, with a stable, laboratory system.

An engine was used for this three-phase asynchronous 3 kW / 900 rpm whose speed can be adjusted by using a frequency inverter (Figure 11) [5].


Fig. 10. The wind simulation group, [4]

Fig.11. The frequency inverter, [5]

## 2.2 Programming of measurement and data transmission systems

The measurement systems used are:

-a Janitza system (Figure 2) that takes the data in real time (20 measurements / s) and them stores in **.csv format** on the SD card of the Schneider PLC which manages the entire renewable energy system. The data can also be downloaded via the Internet. The role of the same PLC is to ensure the transmission of data in the WEB network and makes possible its remote control. The programming of this PLC was done in Schneider's SoMachine 4.1 [4].

Its website is: *185.132.173.34:4001/webvisu.html*.

-the second system for measuring and transmitting data on the web is provided by the SMA, and provided by the Sunny Island Master via an SMA Energy meter sensor (Figure 3) [1, 5].

The data can be viewed with any web browser at *185.132.173.34:4000.*

-the third mobile measuring system, consists of the group of ammeters-voltmeters Fluke a3000Fc + PC3000 FC adapter (2 pieces) and Fluke F375FC (2 pieces) that allow the transmission of data to the PC, with the sampling rate of at least 1 measurements/ s and measurement time of maximum 30 days. The data can be viewed using MsExcel being in **.csv format** with time base [6, 7].

All measuring and control systems, together with relays and power contactors are located in the main control panel (Figure 12) [5].

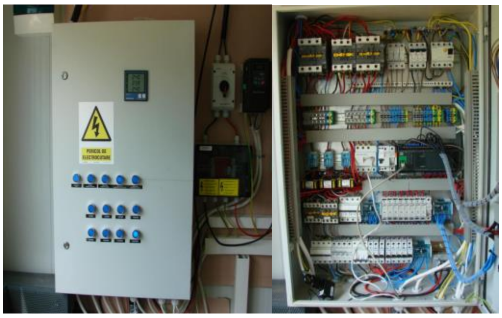


Fig. 12. Main control panel, [5]

#### 2.2.1. Programming of measurements

The data obtained from the monitoring of the combined renewable energy system are displayed on a portal for all parameters, at intervals lasting 5 minutes, or daily, or weekly, monthly or annually (Figure 13) [4].

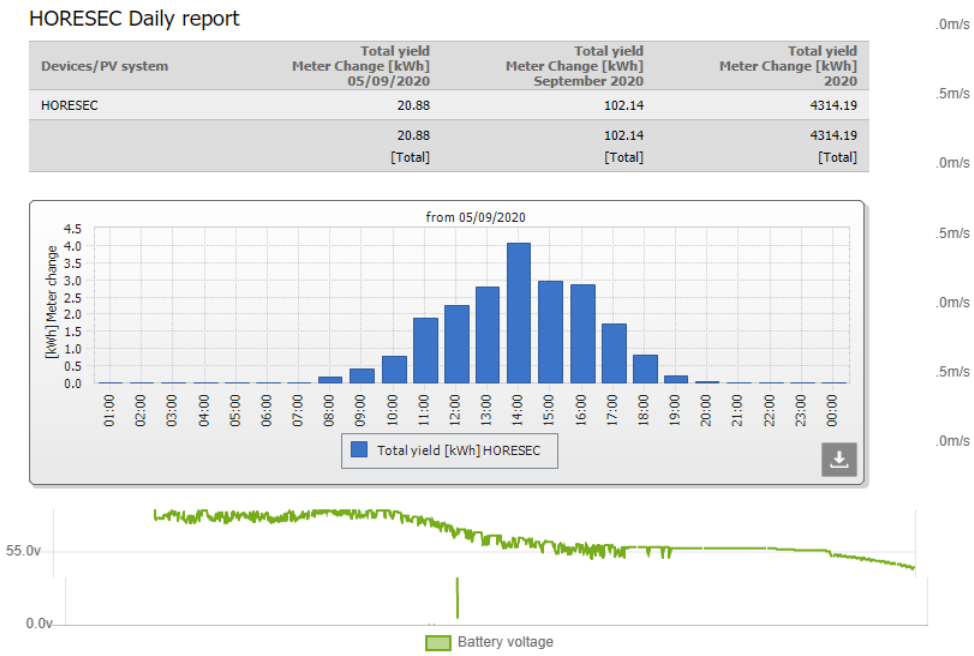
#### 2.2.2. Data storage. Data and events are stored for system components

The measurement system offers also daily, weekly, monthly, annually data and events for wind turbine, like: installations picture, wind speed, energy generated (Figure 14) [4].

## 3. RESULTS AND DISCUSSIONS

The data that is recorded and can be viewed are:

- events existing in time (per minute, at 5 minute intervals, per day, per week, per month, per year);
- the parameters of the components of the combined system.



HORESEC Daily report

| Devices/PV system | Total yield Meter Change [kWh] 05/09/2020 | Total yield Meter Change [kWh] September 2020 | Total yield Meter Change [kWh] 2020 |
|---|---|---|---|
| HORESEC | 20.88 | 102.14 | 4314.19 |
| | 20.88 [Total] | 102.14 [Total] | 4314.19 [Total] |



Fig. 13. Daily report for photovoltaic system, [4]

### 3.1 Data recorded at 5 minute intervals

Table 1 shows data recorded at 5 minute intervals.

The system of three Sunny Island 4.4M-12 off-grid inverters of 3.5kW each, thus allowing operation in three-phase system in on-grid and off-grid mode offer data recorded for Sunny Island 4.4M at 5 minute intervals (Table 1) [4]:

- first column is total energy which is produced, Wh analog;
- the second column is total energy for the battery charging, Wh analog;
- the third column is total energy delivered by the battery, Wh analog;
- the fourth column is total energy which is received from the grid, Wh analog;
- the five column is the total energy delivered to the grid, Wh analog;
- the six to nine column refer to the temperature and state of charge (SOC), voltage and current of the battery;
- from the ten to the thirteen column the values refer to the voltage and power of each phase of the three phase system;
- in the fourteen and fifteen column the values refer to the grid frequency and power received from grid from phase A.

Table 1. Data recorded at 5 minute intervals, [4]

| Data | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4 12 452 | SI4.4 M- 12 452 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 | Sunny Island 4.4M 3E+09 |
| | Metering. Tot WhOut | BatChrg. BatChrg | BatDsch. BatDsch | Metering. GridMs. TotWhIn | Metering. GridM TotWhOut | Bat. Tmp Val (Avg) | Bat.ChaStt (Avg) | Bat. Vol (Avg) | Bat. Amp (Avg) | GridMs. PhV.phsA (Avg) | GridMs. PhV. phsC (Avg) | GridMs .W. phs A (Avg) | GridMs. W. Phs B (Avg) | ExtGrid Ms. Hz (Max) | ExtGrid Ms. W. phsA (Avg) |
| | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog |
| hh:mm:ss | [Wh] | [Wh] | [Wh] | [Wh] | [Wh] | [Â°C] | [%] | [V] | [A] | [V] | [V] | [W] | [W] | [Hz] | [W] |
| 01.09.21 00:00:00 | 255823 | 1100262 | 255823 | 1149080 | 8258600 | 28.7 | 80 | 58.81 | 4.968 | 240.46 | 241.72 | 77 | 76 | 50.04 | -66 |
| 01.09.21 00:05:00 | 255828 | 1100262 | 255828 | 1149090 | 8258600 | 28.7 | 80 | 58.83 | 2.12 | 240.4 | 241.65 | 21 | 21 | 50 | -13 |
| 01.09.21 00:10:00 | 255828 | 1100262 | 255828 | 1149130 | 8258600 | 28.7 | 80 | 58.86 | 1.002 | 240.64 | 241.78 | 0 | 0 | 50.02 | 6 |
| 01.09.21 00:15:00 | 255828 | 1100262 | 255828 | 1149140 | 8258600 | 28.7 | 80 | 58.85 | 1.002 | 240.55 | 241.65 | 0 | 0 | 50.03 | 6 |

Table 2. Data recorded daily, [4]

| Date | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4M- 12 452 | SI4.4 M- 12 452 | SI4.4 M- 12 452 | SI4.4 M-12 452 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M | Sunny Island 4.4M |
| | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 | 3E+09 |
| | Metering. Tot WhOut | Metering. Tot WhIn | Bat Dsch. BatDsch | BatChrg . BatChrg | Metering. GridMs. TotWhOut | Metering. GridMs. TotWhIn | Bat. Bat ChaDif | Bat Eq Cha RmgTm | Bat. Ful Cha RmgTm | Bat.Diag. Tot AhOut | GnMs Tot Wh OutCalc | Bat. Diag. Actl CapacNom | Bat. Diag. Stat Tm | Bat. Diag. Ocv PtCnt | Bat. Diag. Vol Max |
| | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog | Analog |
| hh:mm:ss | [Wh] | [Wh] | [Wh] | [Wh] | [Wh] | [Wh] | [%] | [s] | [s] | [Ah] | [Wh] | [%] | [s] | | [V] |
| **01.09.21** 00:00:00 | 255823 | 1100262 | 255823 | 1100262 | 8258600 | 1149080 | NaN | NaN | NaN | 10566 | 0 | 82 | 46723288 | 0 | 61.68 |
| **02.09.21** 00:00:00 | 256148 | 1102341 | 256148 | 1102341 | 8281570 | 1151020 | NaN | NaN | NaN | 10580 | 0 | 82 | 46809688 | 0 | 61.66 |
| **03.09.21** 00:00:00 | 256616 | 1104220 | 256616 | 1104220 | 8304720 | 1152680 | NaN | NaN | NaN | 10598 | 0 | 82 | 46896088 | 0 | 61.62 |
| **04.09.21** 00:00:00 | 257040 | 1106456 | 257040 | 1106456 | 8320750 | 1154060 | NaN | NaN | | 10616 | 0 | 82 | 46982488 | 0 | 61.66 |

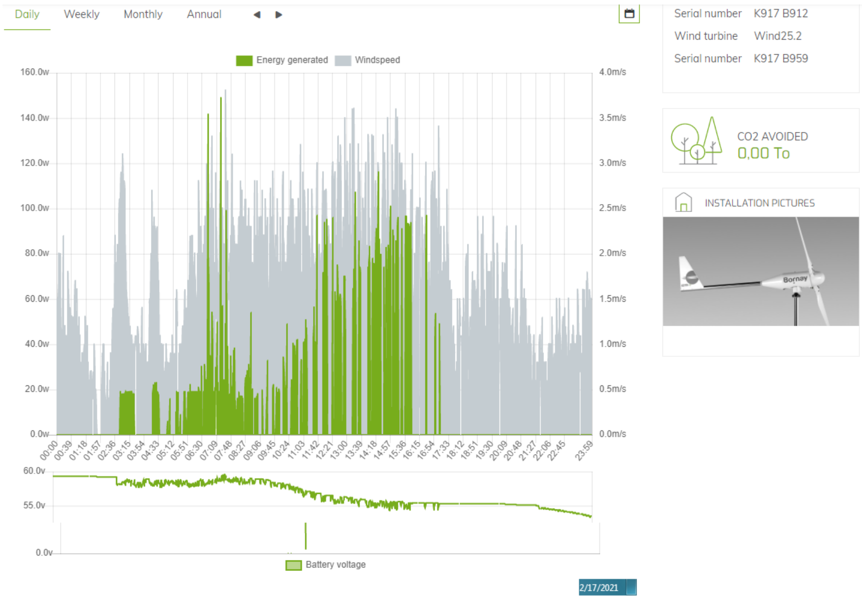



Fig.14. Data storage for wind turbine, [4]

### 3.2 Data recorded daily

Table 2 shows data recorded daily with same values.

### 3.3 The parameters of the system components

Table 3 shows the parameters of the inverter which is a component of the system:

-*Device name*- is the short name of the inverter SI4.4M-12 452;

-*Device class*-battery invertor (of grid inverter);

-*Device type*- Sunny Island 4.4M;

-Next values represent transfer protocol (*WLAN-MAC* network).

Table 3. The parameters of the inverter, [4]

| Device name | SI4.4M-12 452 |
|---|---|
| Device class | Battery inverter |
| Device type | Sunny Island 4.4M |
| Software package | 1.2.10.R |
| Serial number | 3004081452 |
| MAC adress | 00:40:AD:A4:C8:16 |
| WLAN-MAC adress | DC:EF:CA:BF:B7:1E |
| Communication version | 1.1.1.1. |

## 4. CONCLUSIONS

The system created has the advantage of increasing energy efficiency by using unconventional methods of storage and consumption management.

This system for the off grid version allows the programming of measurement and data transmission systems on the web, as well as the mobile measurement system with the possibility of transmitting data to PC with a sampling rate of at least 1 month / s and a maximum measurement time of 30 days.

The system allows the visualization of the main data in real time and the verification through a high level of management based on files generated in ASCI code.

The verification of the data which are presented in the Table 1 and Table 2 allows the subsequent troubleshooting of the system and the establishment of the precise time at which the event took place in order to identify the causes that generated the event.

## 5. ACKNOWLEDGMENTS

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## 6. REFERENCES

1. Lazaroiu, G., Ciupageanu, G.A., Panaitescu, F.V., Panaitescu, M.., Stan, A.N., Vatuiu, T., (2020). *HORESEC Holistic impact of renewable energy sources on the environment and climate- Data acquisition and processing 4*, Polytechnic Publishing Press (Bucharest), 412.

2. Panaitescu, F.-V., Panaitescu, M., Panait, C., (2019). Proc. of 2019 IEEE PES Innovative Smart Grid Technologies Europe (ISGT-Europe), 978-1-5386-8218-06 415.

3. Bornay Company, Available from: www.bornay.com, Accessed on: 10/01/2022.

4. SoMachine Software V4.1 SP1, Available from: https://www.se.com/ww/en/product/SOMNACS41/somachine-software-v4.1-sp1-dvd-format/, Accessed on:

10/01/2022.
5. SMA Energy Meter, Available from: https://www.sma.de/en/products/monitoring-control/sma-energy-meter.html, Accessed on: 10/01/2022.
6. Vătuiu, T., Udrică, M., Tarcă, N., (2013). *Cloud Computing technology - optimal solution for efficient use of Business Intelligence and Enterprise Resource Planning Applications*, Titu Maiorescu Publishing House, Bucharest, 72.
7. Frawley, W., G. Piatetsky-Shapiro, C.M., (1992). *Knowledge Discovery in Databases: An Overview*, AI Magazine, 13(3), 213-228.
8. Piekut, M., (2021). *The Consumption of Renewable Energy Sources (RES) by the European Union Households between 2004 and 2019*, Energies, 14, 5560.
9. Prek, M., (2019). *Primary Energy Factor for Electricity Mix: The Case of Slovenia*, In Energy Policy; IntechOpen: London, UK. Available from: https://www.intechopen.com/books/energy-policy/primary-energy-factor-for-electricity-mix-the-case-of-slovenia, Accessed on: 14/04/2022.
10. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the Energy Performance of Buildings. Available from: https://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex%3A32010L0031, Accessed on: 14/04/2022.
11. Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on Energy Efficiency, Amending Directives 2009/125/EC and 2010/30/EU and Repealing Directives 2004/8/EC and 2006/32/EC. Available from: https: //eur-lex.europa.eu/legal-content/EN/TXT/?uri =CELEX:32012L0027, Accessed on: 14/04/2022.
12. Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 Establishing a Framework for the Setting of Eco-design Requirements for Energy-Related Products (Recast). Available from: https://eur-lex.europa.eu/legalcontent/EN/ALL/? Uri = celex%3A32009L0125, Accessed on: 14/04/2022.
13. Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 Setting a Framework for Energy Labelling and Repealing Directive 2010/30/EU, Available from: https://eur-lex.europa.eu/eli/reg/2017/1369/oj, Accessed on: 14/04/2022.
14. Directive 2009/28/Ec of the European Parliament and of the Council of 23 April 2009 on the Promotion of the Use of Energy from Renewable Sources and Amending and Subsequently Repealing Directives 2001/77/EC and 2003/30/EC, Available from: https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32009L0028, Accessed on: 14/04/2022.

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