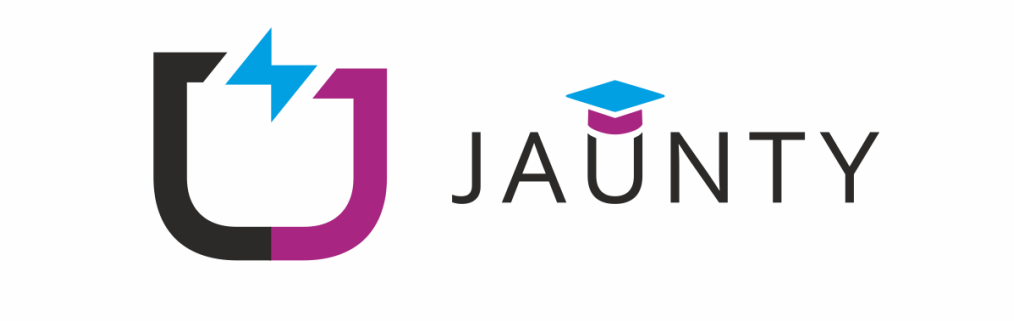
L3. Information Flow for Energy Consumption Monitoring

(Use of Information from the Measurements to Increase Energy Efficiency)



Author: Technical University of Sofia

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1. Abbreviations

API	Application Programming Interface
CSV	Comma Separated Values
ESS	Energy Storage System
EV	Electric Vehicle
GUI	Graphical User Interface
HTTP	HyperText Transfer Protocol
HTML	HyperText Markup Language
JSON	JavaScript Object Notation
PEV	Plug-in electric vehicle
PV	Photovoltaic
RES	Renewable Energies
RTP	Real-Time Pricing
SA	Schedulable Appliances
UTC	Universal Time Clock
V2G	Vehicle-To-Grid
XML	eXtensible Markup Language

2. Scope

The aim of the laboratory module is to provide students with knowledge and skills about the information flow for the energy consumption monitoring (including devices with communication interfaces, protocols, standards/formats for data description and use of the information from the measurements to increase the energy efficiency).

2.1 Specific outcomes

Upon completion of this lab, individuals will be able to:

- Understand concepts of information processing for energy consumption monitoring.
- Know the characteristics of contemporary communication protocols and be able to determine their implementation in specific situations.
- Receive additional information about devices with communication interfaces and know their applicability.
- Know, work and integrate data by using XML, JSON and CSV formats.
- Work with original Web-based VR application named “Smart Home Energy Monitoring, Analysis and Optimisation”, analyse the monitoring data and propose optimized schedule.

2.2 General description

The students are introduced to the communication protocols, their advantages and disadvantages and gain knowledge and skills to determine their use in specific cases.

The students acquire information about the contemporary devices with communication interfaces for monitoring the energy consumption (for local energy consumption devices and those providing aggregate information on electricity consumption).

The students will be able to understand and use standards/formats for data delivery by using XML, JSON and CSV formats.
Via original Web-based VR application named “Smart Home Energy Monitoring, Analysis and Optimisation” to the students will be provided a tool for to receive knowledge and skills about how to use the information from the measurements for to increase the energy efficiency.

2.3 Lab configuration

The following information is provided by the lab instructor:

- Additional information about the communication protocols, devices with communication interfaces, data formats/standards and smart home energy monitoring.
- Formulated tasks, based on lectures and additional information.
- Links to: a) original Web-based application for verification, validation and visualization of XML monitoring document and b) Web-based VR application named “Smart Home

Energy Monitoring, Analysis and Optimisation" (** Web-based applications will be developed as a part of O4 work on Output 4 - Online Platform for Remote Labs*).

3. Exercise 1: Communication Protocols

The first exercise is privy to the communication protocols and their role in the process of energy consumption monitoring.

Step 1: Additional Information (Provided via Web Links)

The lab instructor provides, to the students, additional information about following communication protocols:

Table 1: Communication protocols - additional information

Names & References	
Infrared [1]	
Ethernet [2]	
WiFi [3]	
Bluetooth [4]	
Thread [5]	

Zigbee [6]	
Z-Wave [7]	
KNX [8]	
6LowPAN [9]	
LoRaWAN [10]	
MQTT [11]	
SIGFOX [12]	
Radio-frequency identification (RFID) [13]	
Near-field communication (NFC) [14]	

General Packet Radio Service (GPRS) [15]	GPRS
Cellular (5G) [16]	5G

Step 2: Task - Comparison between Two Protocols Set Randomly

Personal tasks are given to the students to compare two communication protocols [17] from Table 1. Students have to write and send to the lab instructor their answers, pointing on their differences, advantages, disadvantages and to discuss their applicability.

4. Exercise 2: Devices with Communication Interfaces

Exercise 2 is related to energy consumption metering devices with communication protocols. Web-based information from contemporary manufacturers about such devices is provided to the students and their research skills and knowledge are tested by working on the task to describe their usability and net connectivity.

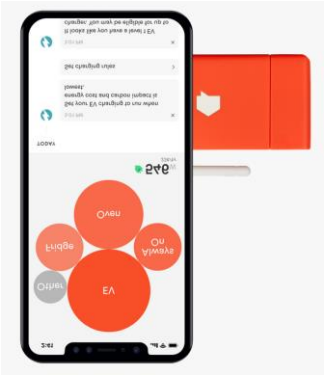
Step 1: Additional Information (Provided via Web Links)

The lab instructor provides, to the students, additional information about following energy consumption meters:

Table 2: Energy consumption meters

Energy Consumption Meters & References
Fludia – Smart Energy Components [18] 

Sense [19]



Efergy [20]

Emporia [21]

Aeotec [22]

Eyedro Home Electricity Monitors [23]

Jiangsu Acrel Electrical Manufacturing Co.,LTD. [24]

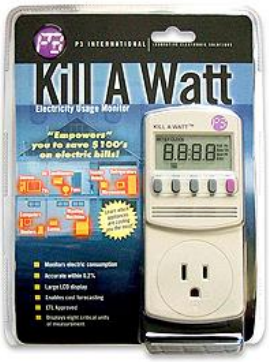
ADW300 IoT Wireless Power Meter

DJSF1352-RN DIN Rail DC Energy Meter

Meross [25]

Works with Apple HomeKit

P3 International [26]



Step 2: Task – Description of Usability and Network Connectivity of a Given Device

Personal tasks are given to every one student. Students have to describe briefly the usability and network connectivity of a given device from the list above. They have to write their answers into Web form text field and submit them to the lab instructor.

5. Exercise 3: Standards Data Delivery

Transferred data can be adequately represented by using different formats/standards.

Step 1: CSV (RFC 4180), XML (W3C) and JSON (RFC 7159, ECMA 404 & 262) Standards/Formats

In the beginning of the Exercise 3 the instructor will explain briefly the main rules and syntax of the following widespread data formats/standards: CSV (RFC 4180), XML (W3C) and JSON (RFC 7159, ECMA 404 & 262) by using example information from practice. The same information will be applied in the explanation of all formats/standards.

Students are requested to use text editor for to be able to read and create standards data files. It is recommended to be downloaded and used “Notepad++” (see Fig. 1) [27].

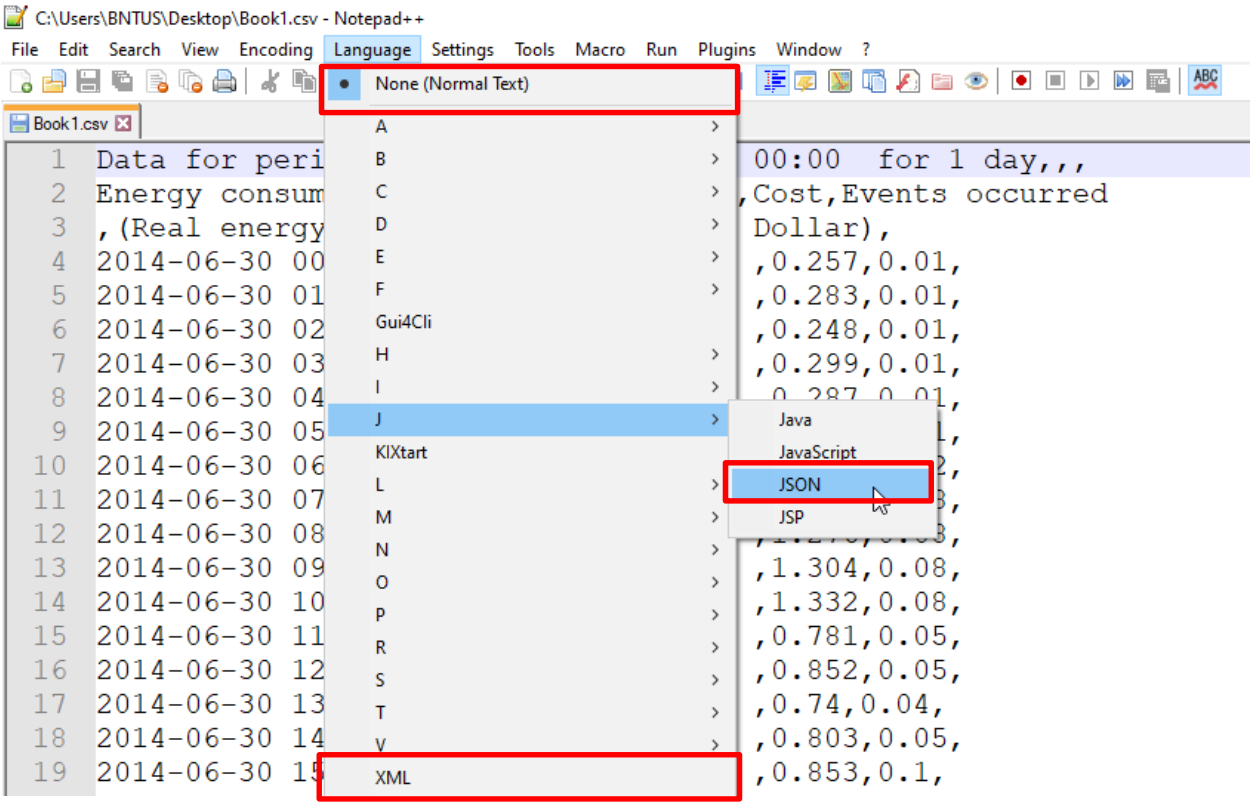


Figure 1: Notepad ++ Languages/Formats: CSV (Normal Text), JSON, XML

As example is used one day energy consumption description from the XML document presented on https://s3-us-west-2.amazonaws.com/technical.greenbuttonalliance.org/library/sample-data/TestGBDataThirteenMonthsBinnedDailyWCost.xml (given on Fig. 2 and Fig. 4) [28].

Data for period starting: 2014-06-30 00:00 for 1 day

Energy consumption time period	Usage (Real energy in kilowatt-hours)	Cost (US Dollar)	Events occurred
2014-06-30 00:00 to 2014-06-30 01:00	0.257	0.01	
2014-06-30 01:00 to 2014-06-30 02:00	0.283	0.01	
2014-06-30 02:00 to 2014-06-30 03:00	0.248	0.01	
2014-06-30 03:00 to 2014-06-30 04:00	0.299	0.01	
2014-06-30 04:00 to 2014-06-30 05:00	0.287	0.01	
2014-06-30 05:00 to 2014-06-30 06:00	0.283	0.01	
2014-06-30 06:00 to 2014-06-30 07:00	0.796	0.02	
2014-06-30 07:00 to 2014-06-30 08:00	1.322	0.08	
2014-06-30 08:00 to 2014-06-30 09:00	1.276	0.08	
2014-06-30 09:00 to 2014-06-30 10:00	1.304	0.08	
2014-06-30 10:00 to 2014-06-30 11:00	1.332	0.08	
2014-06-30 11:00 to 2014-06-30 12:00	0.781	0.05	
2014-06-30 12:00 to 2014-06-30 13:00	0.852	0.05	
2014-06-30 13:00 to 2014-06-30 14:00	0.740	0.04	
2014-06-30 14:00 to 2014-06-30 15:00	0.803	0.05	
2014-06-30 15:00 to 2014-06-30 16:00	0.853	0.10	
2014-06-30 16:00 to 2014-06-30 17:00	0.751	0.14	
2014-06-30 17:00 to 2014-06-30 18:00	0.742	0.18	
2014-06-30 18:00 to 2014-06-30 19:00	1.019	0.31	
2014-06-30 19:00 to 2014-06-30 20:00	1.308	0.39	
2014-06-30 20:00 to 2014-06-30 21:00	1.500	0.36	
2014-06-30 21:00 to 2014-06-30 22:00	1.388	0.25	
2014-06-30 22:00 to 2014-06-30 23:00	1.476	0.18	
2014-06-30 23:00 to 2014-07-01 00:00	0.752	0.05	

Figure 2: GBData One Day Period Contents

The information given on Fig. 2 present hourly information about power consumption within a day period.

CSV files are easily consumed by Google Spreadsheet, Microsoft Excel, and countless other applications. A CSV (Comma-Separated Values) file is a text file that has a specific format which allows data to be saved in a table structured format. CSV uses commas as a delimiter between values.

On Fig. 3 the information given on Fig. 2 is presented via CSV format – a text file with extension ".csv".

```
Data for period starting: 2014-06-30 00:00  for 1 day,,,
Energy consumption time period,Usage,Cost,Events occurred
,(Real energy in kilowatt-hours),(US Dollar),
2014-06-30 00:00 to 2014-06-30 01:00 ,0.257,0.01,
2014-06-30 01:00 to 2014-06-30 02:00 ,0.283,0.01,
2014-06-30 02:00 to 2014-06-30 03:00 ,0.248,0.01,
2014-06-30 03:00 to 2014-06-30 04:00 ,0.299,0.01,
2014-06-30 04:00 to 2014-06-30 05:00 ,0.287,0.01,
2014-06-30 05:00 to 2014-06-30 06:00 ,0.283,0.01,
2014-06-30 06:00 to 2014-06-30 07:00 ,0.796,0.02,
2014-06-30 07:00 to 2014-06-30 08:00 ,1.322,0.08,
2014-06-30 08:00 to 2014-06-30 09:00 ,1.276,0.08,
2014-06-30 09:00 to 2014-06-30 10:00 ,1.304,0.08,
2014-06-30 10:00 to 2014-06-30 11:00 ,1.332,0.08,
2014-06-30 11:00 to 2014-06-30 12:00 ,0.781,0.05,
2014-06-30 12:00 to 2014-06-30 13:00 ,0.852,0.05,
2014-06-30 13:00 to 2014-06-30 14:00 ,0.74,0.04,
2014-06-30 14:00 to 2014-06-30 15:00 ,0.803,0.05,
2014-06-30 15:00 to 2014-06-30 16:00 ,0.853,0.1,
2014-06-30 16:00 to 2014-06-30 17:00 ,0.751,0.14,
2014-06-30 17:00 to 2014-06-30 18:00 ,0.742,0.18,
2014-06-30 18:00 to 2014-06-30 19:00 ,1.019,0.31,
2014-06-30 19:00 to 2014-06-30 20:00 ,1.308,0.39,
2014-06-30 20:00 to 2014-06-30 21:00 ,1.5,0.36,
2014-06-30 21:00 to 2014-06-30 22:00 ,1.388,0.25,
2014-06-30 22:00 to 2014-06-30 23:00 ,1.476,0.18,
2014-06-30 23:00 to 2014-07-01 00:00 ,0.752,0.05,
```

Figure 3: GBData One Day Period Contents presented as CSV file

XML (eXtensible Markup Language) [29], [30] revolutionized the IT industry and has become a necessary skill for professionals in developing a new generation of Web applications.

XML is widely described on the web. Some useful Web pages to look at for a beginners are:

XML Tutorial **https://www.w3schools.com/xml/** [31];

XML Quiz **https://www.w3schools.com/quiztest/quiztest.asp?qtest=XML** [32]

Usage Information

For location: Green Button Sample Data File

Summary of Usage Information*

* Note: Quality of this summary and information is "raw: data that has not gone through the validation, editing and estimation process"

Current billing period as of: 2014-07-01 00:00
Currency: US Dollar (note: all costs presented are rounded to the nearest penny)
Cost of usage(US Dollar): 5.04
Consumption(Real energy in kilowatt-hours) :46.618

Last billing period: 2014-06-01 00:00 to 2014-06-29 00:00
Bill last period(US Dollar): 68.01
Cost of usage last billing period (US Dollar): 68.01
Cost additional last period (taxes and other fixed charges) (US Dollar): 0.00
Consumption last period(Real energy in kilowatt-hours) :628.009

Meter Reading Information

Type of readings: Electricity, Monthly Electricity Consumption, Real energy in kilowatt-hours ,Two-Phase Residential Service

Detailed Usage

Start date: 2013-06-01 00:00 for 395 days

Data for period starting: 2013-06-01 00:00 for 1 day

Energy consumption time period	Usage (Real energy in kilowatt-hours)	Cost (US Dollar)	Events occurred
2013-06-01 00:00 to 2013-06-01 01:00	0.852	0.03	
2013-06-01 01:00 to 2013-06-01 02:00	0.274	0.01	

...

Data for period starting: 2014-06-30 00:00 for 1 day

Energy consumption time period	Usage (Real energy in kilowatt-hours)	Cost (US Dollar)	Events occurred
2014-06-30 00:00 to 2014-06-30 01:00	0.257	0.01	
2014-06-30 01:00 to 2014-06-30 02:00	0.283	0.01	
2014-06-30 02:00 to 2014-06-30 03:00	0.248	0.01	

...

2014-06-30 21:00 to 2014-06-30 22:00	1.388	0.25	
2014-06-30 22:00 to 2014-06-30 23:00	1.476	0.18	
2014-06-30 23:00 to 2014-07-01 00:00	0.752	0.05	

Figure 4: GBData – Full document for 395 days Period

The sample Green Button Data File (Licensed by EnergyOS.org) [33] shown on Fig. 2 is presented on Fig. 5 as a XML document model.

```
<IntervalBlock xmlns="http://naesb.org/espi">
    <interval>
        <duration>86400</duration>
        <start>1404100800</start>
        <!-- start date: 6/30/2014 4:00:00 AM -->
    </interval>
    <IntervalReading>
        <cost>772</cost>
        <timePeriod>
            <duration>3600</duration>
            <start>1404100800</start>
            <!-- 6/30/2014 4:00:00 AM  -->
        </timePeriod>
        <value>257</value>
    </IntervalReading>
...
    <IntervalReading>
        <cost>4517</cost>
        <timePeriod>
            <duration>3600</duration>
            <start>1404183600</start>
            <!-- 7/1/2014 3:00:00 AM  -->
        </timePeriod>
        <value>752</value>
    </IntervalReading>
</IntervalBlock>
```

Figure 5: GBData – XML format

JSON (JavaScript Object Notation) is explained on **https://www.json.org/json-en.html** [34] and its usage with MySQL Database is given in [35].

```
{
  "IntervalBlock": {
    "-xmlns": "http://naesb.org/espi",
    "interval": {
      "duration": "86400",
      "start": "1404100800",
      "#comment": " start date: 6/30/2014 4:00:00 AM "
    },
    "IntervalReading": [
      {
        "cost": "772",
        "timePeriod": {
          "duration": "3600",
          "start": "1404100800",
          "#comment": " 6/30/2014 4:00:00 AM  "
        },
        "value": "257"
      },
      {
        "cost": "850",
        "timePeriod": {
          "duration": "3600",
          "start": "1404104400",
          "#comment": " 6/30/2014 5:00:00 AM  "
        },
        "value": "283"
      },
…
      {
        "cost": "4517",
        "timePeriod": {
          "duration": "3600",
          "start": "1404183600",
          "#comment": " 7/1/2014 3:00:00 AM  "
        },
        "value": "752"
      }
    ]
  },
  "#omit-xml-declaration": "yes"
}
```


Figure 6: GBData – JSON format

Step 2: Task – Description, Verification and Validation of a Specific Information Model in XML (W3C)

Students receive personal tasks to describe within a day hourly the energy consumption by using XML file with similar to example above structure. XML file will be developed by the use of text editor and saved to a file with extension ".xml". XML document will be sent to server for check and SVG/CANVAS 2D visualization. (** Web-based application for verification, validation and visualization will be developed as a part of O4 work on Output 4 - Online Platform for Remote Labs*).

6. Exercise 4: Smart Home Energy Monitoring, Analysis and Optimisation

By the use of HTML, XML, JavaScript, PHP, SVG/CANVAS and X3D technologies a Web-based VR lab application is expected to be developed as a O4 work on Output 4 - Online Platform for Remote Labs. The application will simulate energy behavior of a one family smart home based on the smart home and schedule model XML document and will provide to the student XML report with graphical presentation of the energy monitoring results from simulation. The preference of students when scheduling the involved physical equipment of different natures have to be based on an analysis of given monitoring results. The student will try to edit initial model on such a way to improve energy efficiency. Aim is to reach a better economic results and also to prolong the life of batteries and to assure the PEV capacity requirement when traveling.

The common domestic appliances will be classified into different categories [36] and modelled by various dimensions, i.e. the operating nature (e.g. consumption limits, time limits, relativity to different factors as: temperature, family member availability and etc.), controllability and so on [37].

Step 1: Direct linking to interactive Web-based VR lab application

The lab instructor will provide the link to the Web-based VR lab application (** Web-based VR application named "Smart Home Energy Monitoring, Analysis and Optimisation" will be developed as a part of O4 work on Output 4 - Online Platform for Remote Labs*).

Step 2: One Year Period Smart Home Energy Monitoring Results are Provided and Schedule for Home Energy Consumption Devices and Humans Behaviour is Given

Every one student receives personal model of smart house and schedule (described in XML) and after starting simulation the energy monitoring results are provided to him.

Step 3: Task – Analysis, Optimisation, Setting New Information, Simulation and Conclusions

The flow chart of Web-based VR application for smart home energy monitoring, analysis and optimization is given on Fig. 7.

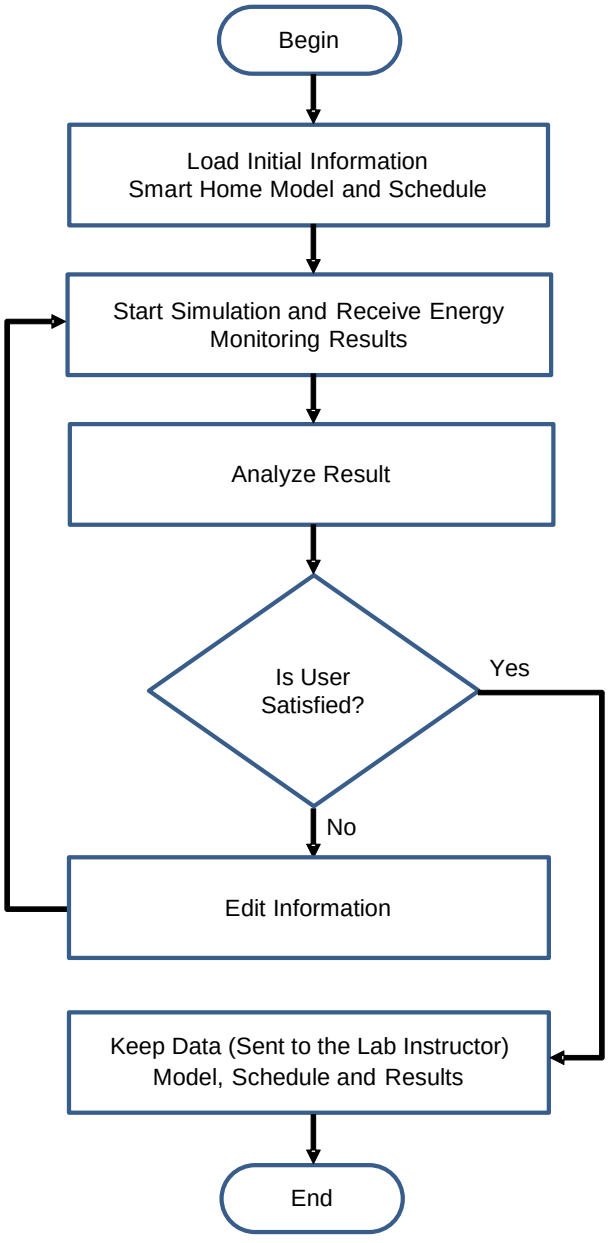


Figure 7: The flow chart of Web-based VR application

7. Exam Questions

1. By using given references to specifications of devices in Table 1 make a comparison of the main characteristics of two randomly given communication protocols: data rate, range, power usage, cost and reliability?
2. How (via which communication protocols/technologies) one randomly selected device, from those presented in the Table 2, can be connected?
3. List the building blocks of eXtensible Markup Language (XML) and describe the syntax rules for every block type?
4. What is the difference between Electric Vehicle (EV) and Plug-in Electric Vehicle (PEV)?

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8. Contacts

Project Coordinator:

- Name: Technical University of Sofia
- Address:
    - Technical University of Sofia,
      Kliment Ohridsky Bd 8
      1000, Sofia, Bulgaria
- Phone: +3592623073

Output 2 Leader:

- Name: FOSS Research Centre for Sustainable Energy, University of Cyprus
- Address:
    - University of Cyprus,
      Panepistimiou 1 Avenue
      P.O. Box 20537
      1678, Nicosia, Cyprus
- Email: foss@ucy.ac.cy
- Phone: +357 22 894288