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Connectivity between various types of energy measurement systems into single platform for data visualization and energy management

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A comparative analysis between three different energy monitoring platforms used in Slovenia was made and evaluated. All three platforms enable measurement of energy use measured with various types of instruments and enable production of custom visualization of measured parameters that suits customers' needs. Comparison between used smart meters, energy monitors, storage execution, possibilities of data visualization and real time energy monitoring was made. Energy monitoring solution of Petrol was developed and implemented within the project TOGETHER.

The upcoming era of smart meters and cheap, easy-to-install measurement equipment are transforming buildings to contain modern energy monitoring systems. When a new energy system (new heat pump, gas boiler or photovoltaic system) is installed, it usually involves a simple measuring system with display and connection to LAN network. Some of the energy system providers even offer their own cloud monitoring solutions, where user can observe energy use via smart monitoring, analyze statistics and lower the energy use.

The aim of this paper is to analyze different energy monitoring platforms in order to find out, which is the most suitable for the connection with the visualization platform.

Three different companies (PETROL, LEAD and UFRA) with their implemented energy monitoring solutions and used platforms were audited and managers of the companies were interweaved to evaluate best practices and point out their biggest challenges and possible restrictions of the used platform.

Visualization of PETROL (project Together) energy info point dashboard

Energy saving as a results of implementation of all three audited energy monitoring platforms is reported to be around 10% of saved electric energy and saved water. Energy saving measures have been taken with passive instructions such as embracing selective lighting during cleaning of objects, energy saving tips displayed on dashboards and alarms sent to building caretaker in case of large deviations of energy and water use.

All three audited energy monitoring platforms work sufficiently well inside their own domain but they all operate as direct competition to each other and therefore do not share knowledge and resources, which results in lack good customer support. The all exposed a stable power and internet connection as the biggest vulnerability of their system stability and operability.

A smart house/city infrastructure is exposed to several risks such as attacks on the control infrastructure, poisoning of data, and leakage of confidential data. Future platforms such focus on challenges that concern privacy, security and trust of the information available in the smart city. An attacker can simultaneously attack on multiple layers.

Future platforms, which should combine and effectively operate with information, operating parameters, statistics, costs and availability of energy sharing parameters, are presented as platform provided services with description and implementation in Table below.

Provided Service	Description and implementation
Location of equipment	GPS coordination and RFID tags for simplified localization
Specification of equipment	Equipment manuals and links to manufacturer service portal
Operation indication	Current state and history of operation,
Selective maintenance	Improved servicing based on deviation from normal operation
Targeted alarming	For users, operators, owners and maintenance companies
Energy watch	Time and location based trend analysis, high data accuracy
Electric signatures	Remote determination of specific home appliances
Statistics and messaging	Comparison to baseline use and dashboard visualization
Energy share	Local photovoltaics production directly to e-mobility
Cost calculation	Presented costs induce lowering of user consumption
Cryptocurrency payment	open-source distributed ledger cryptocurrency such as IOTA

Across examination of cross platform electronic payment solutions, a unique cryptocurrency for the Internet-of-Things (IoT) industry named IOTA was established as most promising and universal solution. IOTA, based on the tangle algorithm, which describes itself as "next generation blockchain" and says its no-fee system is more suitable for the micropayments needed for the internet of things. A new data economy is developing and it will control data production, secure transportation and utilization. IOTA therefore might become a key player in this process of smart city digitalization.

The future Smart solutions based on Together project will use of measured/recorded data help optimize large interconnected systems such as package delivery, personal transportation and automatic borrowing of equipment within platforms and automatic payment with scalable cryptocurrencies without transaction fees such as IOTA cryptocurrency and multi-layer ecosystem solution implementation.

Connectivity between various types of Energy measurement systems into single platform for data visualization and energy management.

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ABSTRACT

A comparative analysis between three different energy monitoring platforms used in Slovenia was made and evaluated. All three platforms enable measurement of energy use measured with various types of instruments and enable production of custom visualization of measured parameters that suits customers' needs. Comparison between used smart meters, energy monitors, possibilities of data visualization and real time energy monitoring was made.
A potential for development additional end-user dashboards within each platform and connectivity to various mobile platforms was assessed and evaluated to determine integration with third-party analytics frameworks and solutions. The overall improvement of energy efficiency and energy saving in buildings was assessed and approaches to changing behavior of building users and promoting energy efficiency measures were compared.
Other energy management platform solutions were examined to determine most versatile, interconnected holistic solutions for further development and larger interconnected integration of smart buildings into smart city and emerging energy and data economy.

KEYWORDS

Energy, monitoring, platform, dashboard, data visualization, energy efficiency, energy saving

INTRODUCTION

The upcoming era of smart meters and cheap, easy-to-install measurement equipment are transforming buildings to contain modern energy monitoring systems. When a new energy system (new heat pump, gas boiler or photovoltaic system) is installed, it usually involves a simple measuring system with display and connection to LAN network. Some of the energy system providers even offer their own cloud monitoring solutions, where user can observe energy use via smart monitoring, analyze statistics and lower the energy use.

Connectivity for Home Energy Management applications and Home Energy Management Systems (HEMS) [1], were taken as a base information about Energy Management System (EMS) functionalities. Evolution, trends and frameworks of home energy management systems [2], were studied to implement demand side management (DSM), peak shaving and load shifting which are considered to offer solutions directly to building caretaker.

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With observed platform solution, users and manager of the building can be cognizant with use of energy and resources measured from various instruments. On the basis of recorded measurement and observed statistic, specific building user behavior can be observed and suitable energy saving solutions can be proposed and implemented.

ASSESSMENT OF ENERGY SAVINGS

All three audited energy metering systems providers report annual energy savings around 10%, with only unnecessary energy trimming measures on the basis of measured data. Additional 5-10% energy savings were made with the more intentional saving approaches, such as displaying the current consumption and comparison to mean consumption values with direct alarming to building caretaker.

Other articles on the topic of Internet of Energy (IoE), which represents a novel paradigm where electrical power systems work cooperatively with smart devices to increase the visibility of energy consumption were inspected and assessed. Best combination of electric appliance signatures can be used to identify the type of appliance and classifiers shows a 93.6% accuracy [7].

Some research results show that the potential of flexible demand is only found in the 2 h time frame with 24% and the daily time frame with approx. 7% of the electricity demand. The system benefit at the assessed amount of flexible demand is limited however. Results from the other analysis indicate that in order to have a significant impact on the energy system performance, more than a quarter of the classic electricity demand would need to be flexible within a month, which is highly unlikely to happen. The value of flexible demand in the energy system is thus limited [8].

Three different platforms used in Slovenia were compared in the areas of: types of used monitoring hardware (smart meters, measuring equipment), their communication protocols, security, possible encryption and connectivity to other devices such as mobile devices or even advanced augmented reality devices such as Microsoft Hololens.

METHODS

Three different companies (PETROL, LEAD and UFRA) with their implemented energy monitoring solutions and used platforms were audited and managers of the companies were interweaved to evaluate best practices and point out their biggest challenges and possible restrictions of the used platform.

Energy monitoring solutions

All three companies offer energy service of sensor installation, energy monitoring hardware and software configuration and monitoring of energy use over their platform. They offer similar solutions and promise direct energy saving via energy management strategies and detection of possible abnormalities or unexpected events such as water leaks or alarming or large deviation from the mean energy use. They developed different solutions and their platforms can manage energy metering with various types of hardware equipment with minimal limitations. Comparison between three energy metering systems offered from companies PETROL, LEAD and UFRA is presented in Table 1.

Table 1: Comparison between three energy metering systems

	LEAD	PETROL	UFRA
Type of installed sensors	modular sensors digital output sensors	NI-10000, PT100, PT1000, analogue 0 - 10V, current 4 - 20 mA	digital output sensors, analogue 0 - 10V, current 4 - 20 mA
Interfaces to adjust the signal between sensors and the data capture system	I2C bus directly to the microcontroller.	13-bit analog converter, all analog, reverse and digital signals converted to the controller	RS485 - USB, RS485 - RS232, I to V signal converter, 1 wire, wireless communication.
Communication between sensors and interfaces if the interface for signal adjustment is required	I2C protocol	MBUS communication for direct meter reading.	RS485 - USB, RS485 - RS232. Smart sensors 1-wire
Data capture device (eg controllers)	Self-developed controllers (IAM)	- platform Siemens Climatix POL638.7, POL965, POL907, As regards hardware, the program was developed by PETROL	controllers: Ai Rupar, Siemens, CTC, In-house solution for HVAC controllers, (RS 485 or Modbus)
Performing a local data store	memory card	- SQL Server 2016	Local PC
Execution of remote data storage	MSSQL 2014+	- Apache Hadoop	PC storage of data, sorts them, displays it in the WEB environment and sends them selectively to the portal according to the http protocol,
Communication between devices for data capture and remote data storage; platforms	WiFi, internet TCP/IP, web API	TIS client via MQTT	C-portal energy accounting and the portal Merger monitoring
Security of stored data (failures, unauthorized entries, intrusions, privacy protection)	Remote backup MSSQL server, hosting in Microsoft Azure, API key for writing data, username and password to view data	Servers placed in the VM Ware environment, hardwired redundancy of disk fields, access through authorized certificates x.509	Passwords, backup copies

	LEAD	PETROL	UFRA
Data management (data analytics, real time and delayed forecasting, forecasting)	last value, values of the sensors in the table, graphic display, export to csv	data analyst, data display in real time, archive display, M & T diagrams, CUSUM, …	Real-time display, delayed by time delay, periodic data sending
Speed of data transfer in individual communications	400 kbps	- TIS allows processing of 250 kbps	56 kbps
Functionality of data platforms (alarms, further activities, feedback loops)	SMS defined events, remote monitoring via android or iOS platform	- SMS defined events, overdrawing errors, - the following changes, - influence on performance through pre-defeated functions,	data collection, processing calculations and comparisons Setting of alert thresholds, limits for alteration and service notifications. Error confirmation priority

During the conducted interview, some information were not disclosed, because the companies are direct competition to each other in local environment and no NDA was signed while conducting the survey.

Project Together (PETROL energy monitoring solution)

In the Project TOGETHER (Interreg CENTRAL EUROPE) a transnational capacity building platform, where partners with different levels of knowledge can strengthen their competences together, thus reducing their disparities and promoting actions on both the supply and demand side, in the context of planning EE in public buildings. The main goal of the project is improving energy efficiency and energy saving in public buildings by changing behavior of building users and promoting energy efficiency measures [3].

Faculty of Energy Technology under University of Maribor as a partner in project TOGETHER audited 7 buildings for evaluation and decided to install smart meters and establish modern energy management system on 4 of audited buildings. Installation of necessary hardware and software equipment in order to provide the feedback about the energy consumption and other optional parameters for the users of buildings (3 student dormitories in Maribor and Faculty of Energy Technology in Krško).

Measured energy use is displayed on large dashboard displays on the entrance into the building. For more explicit comparison, statistics and comparison to previous use of energy is displayed and rate of energy saving is graphically displayed. These approach of energy use display and comparison will influence on building user's behavior with raising awareness on the basis of real-time energy data.

The active role for managers of energy systems have become possible, to allow and determine possible remote control and lower power of some users at peak energy consumption times (lower power of heat pumps between 18:00 and 21:00, when electric energy consumption is highest) and therefore establish peak energy use “shaving” and transferring use of electricity to more suitable time within the reasonable limits.

Small wireless sensors measuring quality of ambient were installed in multiple rooms, measuring temperature, humidity and ambient light. From measured data, sensor can inform if the room is occupied and the lights are turned on [4]. To establish even better

IMPLEMENTATION

Due to size of the investment, a 3 bids method for public procurement in accordance to EU/national rules for public procurement. Petrol was chosen as contractor for hardware installation and provide software and cloud storage of measured data with SCADA system. Installation of smart metering was outsourced to company PETROL, while its operation and costs in relation with these activities during project implementation will be fulfilled by Faculty of Energy Technology which is part of University in Maribor. PETROL energetika provides their software and cloud access of monitored consumptions and is responsible for hardware and software operation.

In 4 chosen buildings, automatic data collection was implemented, and smart meters have been installed. Electric energy and heat consumption are monitored and will be compared to set baseline, which is average measured values of previous three years.

Measured data are collected with measurement equipment and via PLC controllers sent to PETROL cloud storage. For processing and viewing data from SCADA system Technology Information System (TIS) is developed enabling access to registered users. In parallel with automatic data collection the building caretaker do a manual data collection for verification of the automatically gathered data. The manual data collection will be held for the first year of the automatic data collection due to necessity of additional calibration of automatic measurement equipment.

Energy consumption data is measured with automatic regulator for remote heating, where heating programs are set and adjusted on the basis of outside temperature [5]. Implemented modules enable remote control, reading and optimization of energy use with alarming of system caretakers and therefore shortening action times and possible irregularities or outbursts.

RESULTS AND DISCUSSION

Project TOGETHER

Energy use data and statistics are displayed in school premises and in student dormitories doorways to aware building users and stimulate energy savings. Example of dashboard, displaying energy use in student dormitory is presented. The current consumption data is displayed and various (daily, weekly, monthly and yearly), and statistics of previous energy use are compared to yearly baseline average of last three years of energy use. Visualization of i-Together energy info point dashboard installed in the hallway of measured building is presented on
Figure **1**.

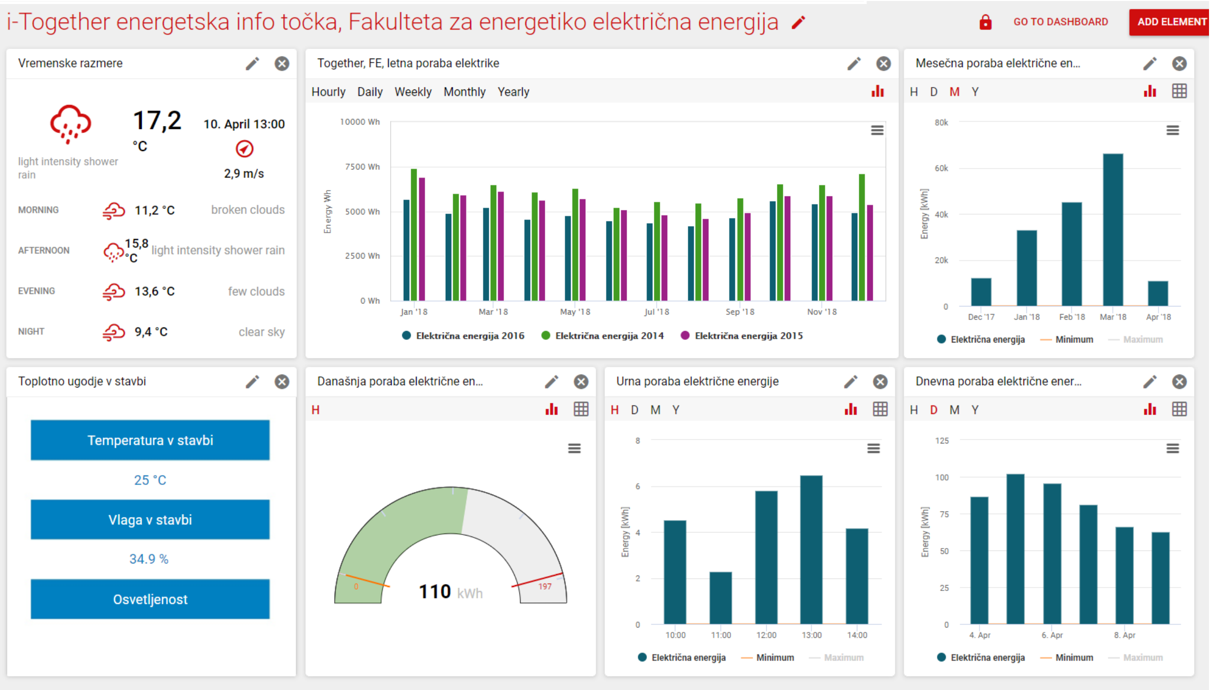

Figure 1: Visualization of PETROL (project Together) energy info point dashboard

Dashboard on
Figure **1** presents local weather conditions and forecast alongside of measured temperature, humidity and lighting in various rooms. Live energy consumption is compared to reference (hourly, daily, weekly and monthly) energy consumption as well as consumption comparison to last three reference years of electric energy consumption based on energy bills.

Monthly challenges and monthly saving goals between student dormitories are planned for practical awards such as board games, gadgets and cheap awareness raising equipment such as large sticker thermometers displaying (lower) temperature levels.

In final implementation, deployed solution enables building consumption to be presented with cost of energy and remind users that large sums of money are spent for energy use of this building. A large list of energy saving tips will be also displayed on dashboard and in online newsletters [6].

All three audited energy monitoring platforms work sufficiently well inside their own domain but they all operate as direct competition to each other and therefore do not share knowledge and resources which results in lack good customer support. The all exposed a stable power and internet connection as the biggest vulnerability of their system stability and operability.

Modern energy monitoring system should be enable smart object user interface containing all information and operating states of the installed equipment is available. Smart object energy monitoring platform is already used for modern industry building such as power plants and can be implemented to existing residential and public buildings constituting a smart city and smart communities.

Such a Smart Object is a bi-directional communicating object which observes its environment and is able to make decisions depending on the application and based on the information extracted from the physical world [9]. Other reliable and scalable solution to address some of the challenges municipalities face and holistic energy management of their cities such as SmartKYE platform [10] were taken into consideration.

A smart city infrastructure, as pictured above, is exposed to several risks such as attacks on the control infrastructure, poisoning of data, and leakage of confidential data. Future platforms such focus on challenges that concern privacy, security and trust of the information available in the smart city. An attacker can simultaneously attack on multiple layers. Standard network security tools such as firewalls, monitoring or typically access control will not suffice to prevent such sophisticated attacks due to the distributed nature of the IoT and the problem of defining/finding trusted parties [9].

Future platforms should combine and effectively operate with information, operating parameters, statistics, costs and availability of energy sharing parameters are presented as platform provided services with description and implementation in Table 2.

Table 2: Expected future platform provided services

Provided Service	**Description and implementation**
Location of equipment	GPS coordination and RFID tags for simplified localization
Specification of equipment	Equipment manuals and links to manufacturer service portal
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Targeted alarming	For users, operators, owners and maintenance companies
Energy watch	Time and location based trend analysis, high data accuracy
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Cost calculation	Presented costs induce lowering of user consumption
Cryptocurrency payment	open-source distributed ledger cryptocurrency such as IOTA

Report from World Energy Council [11] conclude that blockchain cryptocurrency will be able to disrupt the functioning of the industry and contribute toward accelerating the speed of the changes taking place in the energy system. And they are fairly bullish about the likely timescales with 87% anticipating that the most disruptive impact is less than five years away.

The main feature of IOTA cryptocurrency is the tangle, a directed acyclic graph (DAG) for storing transactions which is different from other blokchain technologies. The tangle naturally succeeds the blockchain as its next evolutionary step, and offers features that are required to establish a machine-to-machine micropayment system [12].

Across examination of cross platform electronic payment solutions, a unique cryptocurrency for the Internet-of-Things (IoT) industry named IOTA was established as most promising and universal solution. IOTA, based on the tangle algorithm, which describes itself as “next generation blockchain” and says its no-fee system is more suitable for the micropayments needed for the internet of things. A new data economy is developing and it will control data production, secure transportation and utilization. IOTA therefore might become a key player in this process [13].

Current data infrastructure is coarse: data is either hoarded and valuable, or shared with limited commercial viability. IoT marketplaces begin to offer new business models for the monetization of machine data. The IOTA data marketplace is a good example of the new types of marketplace that are emerging to enable the sharing of sensor and machine data.

CONCLUSION

The main objective was to asses various energy monitoring platforms and evaluate good practices and possible weaknesses. With the implementation of energy use monitoring, raise awareness of building users with presentation of live use and statistics and save energy by behavioral change in the building with the help of energy management methods. It is very applicable to expose energy use monitoring together with energy saving tips and a change to learn or get involved into a project study group of building users.

A general doubt of various issues such as expensive measurement equipment, lack of technological knowledge and problems with interconnectivity of systems have been expressed during the implementation of Interreg Project TOGETHER. With additional research and comparison of various energy monitoring systems, a comprehensive list of existing systems and evaluation of usability was composed. Monitoring systems data protocols were evaluated and a cross connectivity platform solution were assessed. As it turns out, internet connectivity reliability of plays significant role in all three platforms. Loss of internet connectivity and incorrect settings of alarms and boot-up sequence has caused loss of recorded data, false visualization and insufficient alarming to system caretakers.

These platforms represent first real-time energy measurements solution and further use, education and optimization will be needed to achieve totally reliable and well working solutions. With energy meters recording data use, significant savings are already taking place, but it is difficult to determine all optimization solutions without substantial case studies.

There is a rise of open-source communities and use of cheap single-board microcontrollers (Arduino) with cheap measuring modules, tiny and affordable computers (raspberry Pi) for data storage, local display and control are used. This solutions in combination with PC or cloud storage and connectivity to smart phone or tablet for multiple measured data visualization and in-depth statistic analyses is possible. This approach is also applicable to current trend of automation and data exchange in manufacturing technologies and upcoming revolution of data monitoring and exchange that is coming with 5G wireless telecommunication standard.

The future Smart solutions will use of measured/recorded data help optimize large interconnected systems such as package delivery, personal transportation and automatic borrowing of equipment within platforms and automatic payment with scalable cryptocurrencies without transaction fees such as IOTA cryptocurrency and multi-layer ecosystem solution implementation.

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