Cloud-Based platform for enhancing energy consumption awareness and substantiating the adoption of energy efficiency measures within SMEs

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***Abstract*—Nowadays, in order to be competitive in the context of dynamic market changes, companies concern themselves with the adoption of novel business models for the optimization of resource consumption. The decision to adopt energy efficiency measures within a company is often hard to substantiate, given the multitude of factors that influence the feasibility of the project, such as regional laws and regulations, ambient weather conditions, energy pricing, company's activity profile, building structure and characteristics, consumption infrastructure and availability of funding sources. The combination of these factors is unique for each company, thus the adoption of any energy efficiency measures, especially when the investment costs are high, should be rigorously evaluated. The purpose of this paper is to present the conceptual model of a Cloud-based energy management platform that aims to help SMEs monitor energy consumption and associated costs in real time, analyze consumption patterns, assess the economic efficiency of EPC-based projects, benefit from recommendations, generate energy reports in compliance with international standards and find suitable business partners in the field of energy.**

Keywords—Cloud platform; energy efficiency; resource management; Energy Performance Contracting; SME.

I. INTRODUCTION

Systematically monitoring the energy efficiency became a key success factor for enterprises of all sizes by enhancing medium and long-term sustainability. In the past decades, the compliance to regional laws and regulations became a challenge for companies as the competitiveness of the business environment is significantly determined by the optimization of resource consumption and their impact on the environment [1].

Energy Service Companies (ESCO) are businesses that provide solutions for enhancing energy efficiency within other companies in compliance with the targets defined in the Energy Performance Contract (EPC). ESCOs can provide energy efficient equipment or various services such as energy audit, feasibility studies, project management, equipment installation, commissioning and maintenance, and employee training. According to [2] and [3], the most common business models used by ESCOs are "Shared Savings", "Guaranteed Savings", "Chauffage" and "BOOT".

Consumption and energy pricing data can be used to identify consumption patterns, sources of energy inefficiency and more reliable alternatives when it comes to power supplying. In order to support SMEs efficiently manage their energy consumption and better substantiate the adoption of energy efficiency measures, the Power2SME – "Cloud Platform for Intelligent Energy Use by SMEs" project [4] will provide a Cloud energy management platform with functionalities for (i) measuring energy consumption and costs, (ii) analyzing customer's consumption pattern, (iii) assessing the economic efficiency of ESCO / EPC projects, (iv) providing recommendations based on consumption and economic data, (v) generating energy reports in compliance with ISO 50001 and (vi) matchmaking between customers, equipment / services providers and energy suppliers. The platform will collect data from energy sensors (smart meters), context sensors (temperature, solar radiation etc.), third party sources (websites of energy providers for pricing data) and users.

In the context of the Power2SME project, the paper provides an overview of the energy management, energy modelling and project performance assessment solutions existing on the market, and presents an innovative Cloud-Based platform for enhancing energy consumption awareness and substantiating the adoption of energy efficiency measures within SMEs.

The rest of the paper is organized as follows: Section II presents related work in the field of energy management, modelling and project performance assessment, Section III describes the proposed conceptual Cloud energy management platform, Section IV presents the proposed tool for assessing the performance of EPC-based projects, while Section V concludes the paper.

II. RELATED WORK

A. Energy management and consumption simulation solutions

Nowadays, companies of all sizes and activity fields are looking for new methods for reducing energy consumption while staying competitive [5]. Given the global concerns associated with energy conservation, in the last decade a wide

variety of energy management software has been developed and used by the companies to diminish costs.

Cisco Energy Management Suite [6] is a solution that facilitates the optimization of energy use by providing data regarding energy use, costs, savings and emissions. The data collected from IT and operational technology (OT) devices can be visualized by cost center (device, group, location) and timeframe. Thus, its applicability in substantiating energy efficiency decisions relies on the fact that it provides means to identify energy inefficient devices, infrastructures and practices within the client company. Cisco Energy Management Suite does not require the integration of smart meters.

DEXCell Energy Manager [7] [8] is a Cloud energy management and analytics software platform. Its key features include energy consumption monitoring, analysis and reporting, utility bill tracking, budgeting and forecasting, analysis of energy prices, KPIs (Key Performance Indicators) calculation and tracking, and monitoring consumption patterns. By the means of this instrument, users can manage contracts and cost allocation. DEXCell Energy Manager allows the integration of the hardware already owned by the customer, thus the solution can provide data in real time. Through an API, the customer can create tools with customized dashboards, analysis, reports and smart alerts. DEXCell is compliant with the International Performance Measurement and Verification Protocol (IPMVP).

Engage [9] [10] is an energy management solution that provides real time energy consumption data, consumption history data and energy pricing data in order to help users understand energy consumption habits. By using Engage, users can set a budget and track their performance against it. For collecting consumption data, this solution relies on smart meters deployed within the customer entity.

In order to predict energy consumption given certain circumstances, building energy simulation (modelling) software uses inputs for climate conditions, equipment individual consumption and operation hours, occupation, building isolation, activity schedule, etc. Energy modelling software generates predictions for energy consumption and associated costs in typical end-use scenarios.

EnergyPlus [11] [12] is a program used for simulation of energy consumption within buildings. It simulates the consumption used for illumination, ventilation, cooling and heating in buildings and also the consumption generated by other equipment. The solution mainly relies on the thermal balance and convective effects of the building. The IDF (Input Data Files) editor allows users to modify input data.

DesignBuilder [13] [14] is a solution that relies on EnergyPlus to simulate energy consumption within buildings. It provides various design and simulation scenarios for heating, ventilation, and air conditioning (HVAC) systems and controls, lightning, renewable technologies and facades. Typical uses of DesignBuilder are calculating building energy consumption, visualization of site layouts and solar shading, modelling lighting control systems, thermal simulation of buildings and calculating savings. The simulation results are based on the weather data and geographical location of the building.

IDA Indoor Climate and Energy (IDA ICE) [15] [16] is a modelling tool for studying thermal indoor climate and energy consumption within building. The solution provides means for calculating and reporting energy, cooling, heating and air demand. Modelling capabilities can be expanded by equation-based modelling using the Modelica-like Neutral Model Format (NMF). Weather data is supplied by default weather data files or can be supplied by the user using a custom model.

B. *Project performance assessment solutions*

Merak Project Economics and Risk [17] is a software tool that facilitates economic and risk analysis for various investment scenarios. It allows budgeting, resource planning and the management of complex business processes. Merak FML (Fiscal Model Library) is a collection of standardized fiscal models used by this software for economic modelling. The Merak Decision Toolkit allows decision analysis and risk management by evaluating economic uncertainties associated with each particular project.

Scoreboard [18] is a Cloud project performance management solution that allows users to set goals and keep track of KPIs during the project. By using customized dashboards, users can compare different regions, identify trends, point out potential risks, generate reports and set various notifications. The solution provides functionalities for budget tracking and schedule tracking.

SimpleKPI [19] is a KPI analysis and reporting tool meant to help companies evaluate the economic performance of projects for various scenarios. This tool allows users to customize the dashboard by adding business metrics and KPIs, integrate third party data sources, automate data feeds, generate performance reports, identify trends and compare KPIs by timeframes, activities and locations.

III. PROPOSED CLOUD ENERGY MANAGEMENT PLATFORM

This section presents authors' conceptual model of a Cloud Energy Management platform that is designed to help enterprises manage energy consumption and substantiate their strategy to invest in energy efficiency measures.

The Power2SME architecture is presented in Fig. 1.

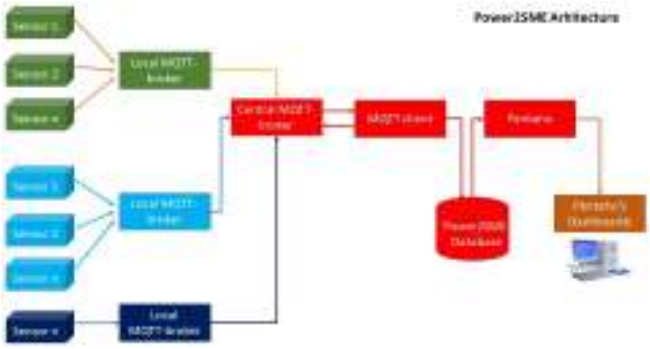

Fig. 1. Power2SME architecture

MQTT (Message Queuing Telemetry Transport) is a protocol which is used in IoT (Internet of Things) and for M2M (Machine-to-Machine) communication. When using this protocol, the publisher sends data to a MQTT message broker. The broker forwards data to clients which have previously subscribed to certain topics. For the system implementation, it is necessary that the publisher connects to a Cloud broker. It will gather data and will send them to the MQTT broker. Within the Power2SME platform, environmental and energy consumption data is sent from Local MQTT brokers to the Central broker. The MQTT client, developed in Java Spring, requests the data from the Central broker and stores it in a POSTGRESQL database. Stored data is used by Pentaho to generate various data representations for the user. Sensors are sending environmental data to the ADCON [20] platform and the data can be retrieved using a Java application. In order to get the response in XML (eXtensible Markup Language) format, a Java application was created using Eclipse IDE. Because a token is required at every login, a function for obtaining the authentication token was created. The second function is used for getting the XML via the HTTP (Hypertext Transfer Protocol) request using the token. The third main function is for parsing the XML. Current implementation efforts focus on the integration of the presented API (Application Programming Interface) solutions and further software developments as data probes (PoS - Pieces of Software) which will allow feeding the data into Graphite. The Graphite web interface reads this data back out, either from cache or straight off from disk. Thus, the Java application collects numeric values and sends them to Graphite's backend, Carbon. Carbon is highly scalable, due to a large community supporting the development of Graphite.

By *collecting energy consumption data*, the platform will provide the customer with information based on the demand of real-time power consumption. This ranges from basic voltage / current / power factor measurement data to a most advanced analyzes (disaggregation) of the actual electrical appliances, which are in operation in a power network by recognizing their individual low / high frequency pattern, embedded in the voltage / current data (time/frequency domain). For collecting energy data, the experimental model of the Power2SME solution supports OWL smart meters [21], but the platform will be continuously updated to support a wide range of energy sensors from different providers. The *acquisition of environmental data* can be achieved through ADCON addUPI which is a communication protocol used for the communication between different TCP/IP components of the ADCON telemetry system. Data exchange can be made with ASCII files. The user can configure these files to a large extent, defining his own headers, averaging methods, export intervals, file extensions (.csv or .txt), etc. The Generic Export Extension facilitates the export of sensor data in the form of .txt or .csv files that can be automatically saved in specific locations to be accessed by third party applications. This allows the integration of the ADCON Telemetry System with other applications extending functionalities and facilitating integration into more complex systems. This protocol is made available to third party software developers upon request in order to retrieve data. For collecting environmental data, such as the solar irradiance and temperature, the experimental model of the Power2SME solution supports high-precision ADCON sensors.

The Recommendation and Comparison feature consists in the automatized analysis of collected and integrated data, in order to: (i) facilitate the analysis of the data collected, by comparing related parameters (energy consumption, outdoor temperature, etc.) in selected time windows, (ii) benchmark user's behavior among past data or data from different offices of the same company, (iii) benchmark user's behavior among others user's behaviors in similar conditions (localization, size of building, type of business, working hours, etc.) and (iv) offer suggestions and recommendations that go beyond of displaying data and assists with a first step in energy efficiency actuation. The Recommendation and Comparison option must be configurable by each user preferences and adapted to its needs and provide the results on the go. The user would be able to enable/disable which parameters can be put together and to select the subsystem/monitored area and time window. The user will also be able of configure its own filters when benchmarking its consumption among other users'. The measures displayed will be the last ones collected or previous ones (stored).

Through the *Matchmaking feature*, the SMEs can decide whether they want to contact suggested partners (based on localization, service offered, recognized saving potential) themselves (left-handed match) or if they want to be contacted by all partners who were identified as possible service providers (right handed match) or just compile a cross-reference matching-table for both sides (SME and partners) for contacting each other with the help of the Power2SME platform. Every successful match which leads in a business contact counts as a value within a points-rationing scheme. Partners will be billed on the basis of these points. The different service levels supported by Power2SME through this feature are depicted in Fig. 2.

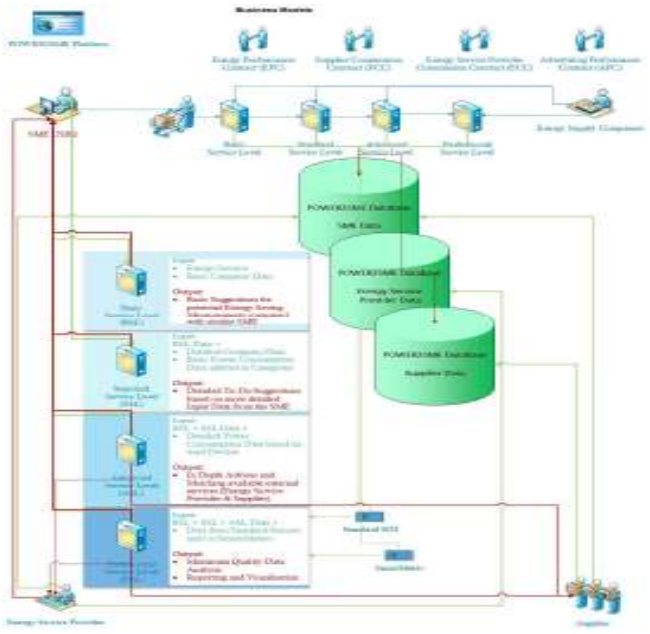

Fig. 2. Service levels supported by Power2SME through matchmaking

The Basic Service Level model allows target groups to participate in matchmaking without having any obligation, such as an initial investment. The user will provide data such as the name of the company, location, domain of activity, surface, headquarter and/or subsidiaries logic, energy consumption estimations etc., while external databases will provide data such as temperature, daily sunshine hours, energy price etc. Based on the collected data, the matchmaking feature provides high quality suggestions for potential energy saving activities compared to other subsidiaries within the multi-location company or to other companies within the domain of interest / area. When sharing data, the user can decide if company data should be anonymized or not.

The Standard Service Level is more complex than the Basic Service by providing a better perspective regarding the energy consumption of the SME. In addition to the input presented for the Basic Service Level, this bundle requires detailed building/construction data (e.g. count and size of windows, insulation of the building, age, location within the building (ground floor, upper floors, top floor), categories of used energy-consuming equipment (light, machines, heating, cooling etc.) and age of used equipment. The matchmaking recommendations are based on the consumption data for different cost centers (equipment groups, departments, floors, buildings etc.). When compared to the previous level, the Standard Service Level relies on the input data to identify strengths, weaknesses, opportunities and threats, and to substantiate matchmaking recommendations.

The Advanced Service Level focuses on the energy consuming devices and requires device and technology data from specification plates, data-sheets and smart meters (equipment's energy consumption). When compared to the previous levels, the Advanced Service Level allows the matching of equipment suppliers to customers based on the consumption and the calculation of Return of Investment (ROI) for different investment scenarios.

The feature for generating energy (ISO 50001) certification reports relies on a central data aggregator (Power2SME server) where the data from the customer is stored after being collected by smart meters. The output of the Power2SME EnMS (Energy Management System) would be an ISO 50001 report, based on templates provided by the SMEs or the consulted external certified engineering company. The generic energy data structure varies from SME to SME, so a setup-process defining a particular customer (SME) has to be achieved before collecting data. Both manual data input as well as automatic data input will be supported. In most SMEs with manufacturing infrastructure, a 'Supervisory control and data acquisition' (SCADA) Software Solution might be implemented and the data should be exported from there.

The EPC / ESCO project performance assessment feature facilitates the evaluation of energy performance measures implemented through ESCO / EPC projects. This component can act as a project management tool both for the ESCO and its customer. Other parties as investors or financing institutions can see this Power2SME feature as a viable decision-making tool. The tool provides data regarding energy consumption and savings both in monetary and energy units, sharing of savings between ESCO and the customer, Key Performance Indicators (KPI) such as the Internal Rate of Return (IRR), Net Present Value (NPV), Return of Investment (ROI) and various notifications regarding energy prices, budget tracking records, budget allocations and important deadlines.

The main feature of Data Visualization is the possibility of knowing the energy consumption of the company in near real time and other parameters related to it. Likewise, this ability facilitates knowledge and control to the person in charge and provides the possibility to actuate for correcting and avoiding certain behaviors, by establishing smarter (and greener) energy efficiency policies in the company. Measurements can include many kinds of parameters, from lights to the heating/cooling system, even parameters not directly gathered with the sensor network deployed, but data taken from Open Data sources, like outside temperature, sunshine hours, geographic coordinates etc. The user would be able to enable or disable which parameters can be seen on the Dashboard and to select the subsystem or monitored area. Energy Management Cloud platforms are currently designed to be accessed from a personal computer and, although many of them can be access through a mobile application, mobile access often deprive customers of some functionalities or make the utilization less intuitive. A fully functional and easy to use mobile application (or content accessible through a mobile device) would allow to have a complete and agile maintenance tool in a mobile device.

IV. Proposed Tool for Assessing the Performance of EPC-based Projects

This section presents the project performance assessment tool integrated in the Power2SME platform. This tool is designed for assessing the economic performance of EPC-based projects using KPIs such as the Internal Rate of Return (IRR), Net Present Value (NPV), Return of Investment (ROI) and payback period.

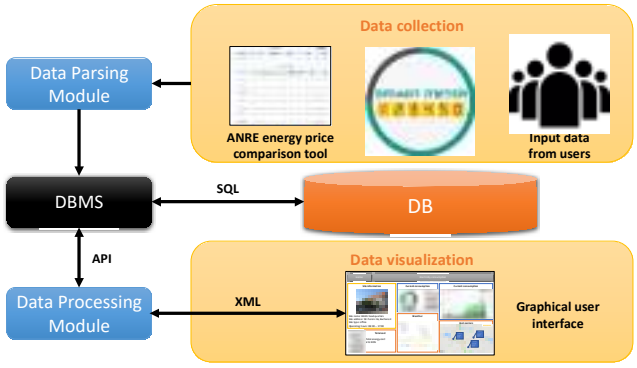

Fig. 3. Architecture of the project performance assessment solution

Fig. 3. depicts the architecture of the proposed project performance assessment solution. Data Collection Layer consists of smart meters that provide consumption data, platform users that provide EPC data and other data sources, such as the ANRE (National Authority for Energy Regulation)

energy price comparison online tool [22] that provides energy pricing data. The data parsing module transforms different types of data into a predefined format and sends the information further to the DBMS (Database Management System) providing guidelines and requests to store collected data into the DB (Database). The data processing module provides calculations of KPIs, statistics, savings, notifications etc. and makes use of the data from the DB through an API that allows communication with the DBMS.

Output data is being updated when data is made available by the sensors (based on users' preferences). Data visualization interface should allow: (i) representation in tabular form; (ii) representation using diagrams and graphs; (iii) representation using maps; (iv) parallel visualization for data associated with different periods or cost centers; (v) graphical representation of the difference between various periods; (vi) customization of notifications (what message the notification needs to display, what events should trigger a notification, what users should receive the notification, what communication channel shall be used etc.); (vii) KPI forecasting based on identified trends (for longer projects, higher accuracy); (viii) event management though a project calendar; (ix) budget tracking for a certain period; (x) dynamic budget allocation (based on the remaining budget for current period, based on the trend of consumption distribution within a month, season or year etc.); (xi) differentiation of budget / KPI / savings sharing on cost centers; (xii) to export data in .xls, .xlsx and .pdf format; (xiii) to generate customized reports (compliance with international standards).

The ANRE energy price comparison online tool provides data regarding the price of energy, contribution for cogeneration, value of green certificates, excise and final price per unit of energy for each national energy provider. The price of energy can influence consumers to find the best offer and switch from one provider to another. The Power2SME platform will provide energy pricing data to the user and will formulate recommendations to minimize energy costs. Energy pricing data will also be used for calculating the consumption in monetary units in real time, thus the consumer will have access to project KPIs updated in real time based on their power consumption measured by smart meters.

The EPC-based project performance assessment tool provides resulted performance information to a web-based GUI application through XML, from which users can then access it and visualize data from within an Internet Browser using HTML. A dashboard model is illustrated in Fig. 4.

Fig. 4. Interface for visualizing energy consumption

The initial user input consists of EPC data such as the value of the investment, duration of the contract and the rules associated with it. After the baseline billing value is agreed upon both by the ESCO and its customer, the baseline values are then submitted to the platform. The baseline consumption in monetary units is compared to the actual consumption measured by the smart meter, and, based on the contract rules, the savings are split between the ESCO and the customer. Users from ESCO and customer entities will have access to data regarding the savings achieved and project KPIs and will receive notifications when new data is available (mainly useful for the ESCO members who get notified that new billing data was being submitted by the customer).

Smart meters should provide real time or near real time consumption data in energy units. Energy pricing data should be provided by energy producers / transporters / providers or energy regulation entities. Fig. 5. presents an interface for smart meter data visualization and configuration.

Fig. 5. Interface for smart meters management

For the management of cost centers (different locations of the same company, different consumption areas within the same location etc.), an interface similar to the one presented in Fig. 6. will be implemented.

Fig. 6. Cost centers management interface

Previsions of key performance indicators, such as ROI (Return of Investment), IRR (Internal Rate of Return), NPV (Net Present Value) and energy savings, will allow companies to predict the economic efficiency for various investment scenarios. The platform will allow scenario analysis for different assumptions about specific technical and economic conditions. Through machine learning, the platform will be able to provide its users with increasingly better investment recommendations based on company's activity profile, energy demand, consumption trends, energy price variations, geographical location, weather conditions and stakeholders (energy providers, national regulation entities etc.). The Power2SME experimental model was used to simulate the economic efficiency of investing in a photovoltaic (PV) solution. For a solution that relies on 27 polycrystalline solar panels (255 Watt), a full return of investment could be expected in the last quarter of the 5th year of exploitation. After implementing the PV solution, the energy saved in the 1st year accounts for 21,32% of the investment.

V. CONCLUSIONS

This paper presents the concept of a Cloud-based energy management platform being developed within the Power2SME - "Cloud Platform for Intelligent Energy Use by SMEs" project, that will be available as a prototype by the end of 2018. By providing this solution to the market, we aim to help SMEs reduce energy costs, gain environmental certifications, increase the success rate of EPC-based projects and provide ethical product for the consumers.

As future work, we intend to extend the support for a wide range of data acquisition devices such as smart meters, smart plugs and environmental sensors, and adopt machine learning as an instrument for providing increasingly better investment recommendations based on company's activity profile and various external data. In addition, further developments will include a framework for simulating the output of various investment and consumption scenarios based on customer's profile. The Power2SME platform differentiates from the energy management software existing on the market, as the ones briefly presented in section II, by not only generating awareness regarding energy consumption, but also identifying energy production and consumption patterns, assessing the economic efficiency of investments, comparing consumption behaviour among different cost centers of the company or other entities, generating recommendations based on real time conditions, generating energy reports, and connecting with other entities for trading energy products and services. A key competitive point is that it combines consumption data with economic data associated with it, thus facilitating actuation.

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