Business Model Considerations for a Solution to Optimize and Diagnose Solar Panel Installations

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***Abstract* — This paper describes the business model considerations for an Internet of Things (IoT) solution to diagnose and optimize solar panel installations. The solution consists of a sensor platform and a cloud-based service. The sensor platform collects information about the position and orientation of the solar panels, the solar radiation, the ambient temperature and humidity, and the temperature of the solar panels. The cloud-based service receives the collected data together with data from the inverter. An algorithm analyzes the data and makes recommendations about possible adjustments and malfunctions. Users are offered recommendations through a web-based interface. The focus of this paper is the business model considerations. How can the solution create value for the manufacturer and stakeholders in the solar panel business? The solar panel value chain is examined to see where the solution can be bundled with other business activities.**

Keywords-solar panels; photovoltaic energy; testing; business model; IoT; cloud-based service.

I. Introduction

Prosumers are energy consumers that also produce energy. The produced energy can be used, stored for later consumption, or sold to the grid. A smart meter keeps track of the energy flow between the prosumer and the grid. Fig. 1 shows a prosumer connected to the grid through a smart meter. The prosumers have solar panels on their rooftops to produce their own energy.

The most popular technology for small-scale renewable production is solar panels. However, solar panels are only effective during the daytime, with a peak output when the solar radiation is the highest. A solar panel needs to capture as much radiation as possible. Therefore, the characteristics and the orientation/positioning of the solar panel are critical factors for the efficiency of energy production. The output of the solar panels also depends upon the surface temperature of the solar panel. High temperature dramatically decreases photovoltaic output.

To face this challenge, a collaborative effort of teams from three countries with different climatic conditions, ICPE SA from Romania, EPRA Electric Co. from Turkey, and the University of South-Eastern Norway joined their efforts in the project *Cloud-based analysis and diagnosis platform for photovoltaic (PV) prosumers* to develop a solution to optimize and diagnose solar panel installations. The solution was named Dr. Solar since it diagnoses the solar panel installation. The solution, including the algorithms used for optimization, is described in detail in [1]. Section 3 provides an overview of the solution and the sensor platform used.

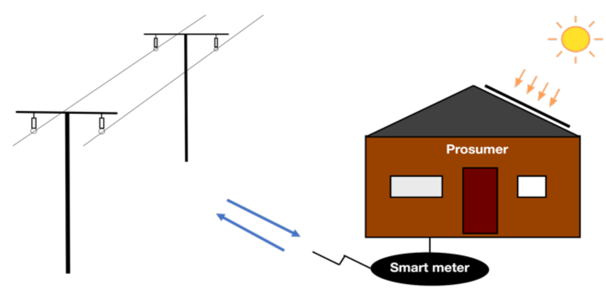

Figure 1. The prosumer

This paper aims to discuss possible business models for the Dr. Solar solution. Section 2 briefly introduces the Internet of Things. Section 3 describes the Dr. Solar solution. Section 3 discusses business models in general, while Section 4 considers business models for the Dr. Solar solution. Section 6 presents the results, while Section 7 provides a conclusion and ideas for future work.

II. Internet of Things

The Internet of Things (IoT) refers to devices connected to the Internet. The connection to the Internet opens new opportunities. IoT devices can collect information from sensors and control the environment through actuators. The network makes it possible to process information at a remote location. Fig. 2 shows a couple of IoT devices connected to an IoT service through the Internet.

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A cloud-based service processing data reduces the need for local processing capacity in the IoT device. The cloud-based service also makes it easier to replace or tune the algorithms used.

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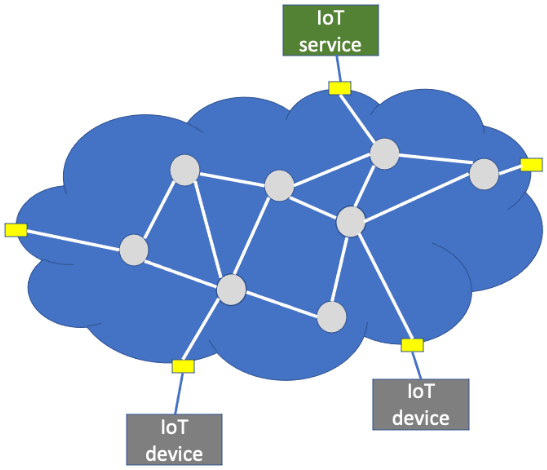

Figure 2. Internet of Things

One of the typical IoT applications in the energy sector is monitoring power output and related parameters, such as voltage, current, and consumption. Such monitoring can support short- and long-term planning of operations as well as the future development of the power grid. Monitoring may require real-time or close to real-time data transmissions. Real-time requirements may influence the design of the IoT architecture. The value of IoT lies in the data the sensors provide and how the data is interpreted. A cloud-based service can analyze sensor data and provide decision-making information

III. THE DR. SOLAR SOLUTION

This section describes the solution and the sensor platform.

A. *The Solution*

Dr. Solar is an IoT solution developed to assess the performance and operation of photovoltaic systems. The solution consists of three main subsystems, shown in Fig. 3.

The first subsystem is the Dr. Solar sensor platform containing sensors and data loggers. The Dr. Solar sensor platform acts as the data acquisition system for the Dr. Solar solution. The sensor platform collects and uploads data to the cloud-based service using a GSM-based mobile router. A router is necessary since the solar panels are usually not placed within the range of an existing Wi-Fi network. The sensor platform is configured to collect data every 5 minutes for three consecutive days, ideally when solar radiation exceeds 600 W/m2. The sensor platform and the inverter provide data at five-minute intervals polled by the cloud-based analytics service for the time interval between 10:00 am to 2:00 pm. More details on the sensor platform will be discussed later.

The second subsystem is the inverter which converts the generated DC power by the solar panels into AC power. Within this process, the inverter collects and provides data concerning energy production. The prototype of the Dr. Solar solution uses a Huawei inverter SUN2000L-3KTL model to demonstrate the functionality.

The third subsystem is a cloud-based analytic service that contains assessment algorithms and engines. The engines within the cloud-based service acquire inputs from the Dr. Solar sensor platform and the inverter to perform two main tasks:

1. Performance evaluation which is called asset management service in Dr. Solar solution. The main objective of the asset management service is to evaluate the performance of the solar panels and perform a health check. The solution provides information about the problem and possible reasons to the customer if any malfunction is observed.

2. Performance enhancement which is called optimum decision support in the Dr. Solar solution. The optimum decision support service's main objective is to evaluate the solar system's operating conditions and develop an optimal operation schedule to reduce the customer's electricity bill. The optimum decision support considers user preferences and uses these together with the data from the inverter. The optimum decision support does not rely on the Dr. Solar sensor platform and can be done after the unit is removed from the installation.

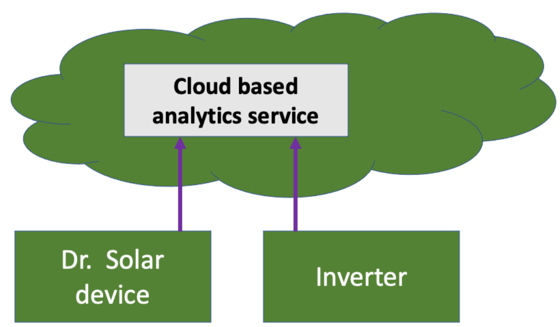

Figure 3. The Dr. Solar solution

The Dr. Solar solution provides a user-friendly web interface to investigate monitoring results for asset management and optimum decision support.

B. *The Sensor Platform*

The Dr. Solar sensor platform is the hardware component of the solution, including sensors for data acquisition and submission to a dedicated cloud-based analysis and diagnosis platform. The sensor platform is compact, autonomous, and collects data regarding:

- Direct solar radiation level in the plane of the photovoltaic generator (solar panel).

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- Ambient temperature and humidity, as well as solar panel temperature.
- Geographical location and specific installation angles (the inclination and the azimuthal deviation of the solar panel from the southern direction).

The sensor platform is easy to mount onto the solar panel installation, and a prosumer can install the unit without expert help.

The architecture of the IoT sensor platform is shown in Fig. 4. The different parts communicate through signals and protocols to collect sensor information.

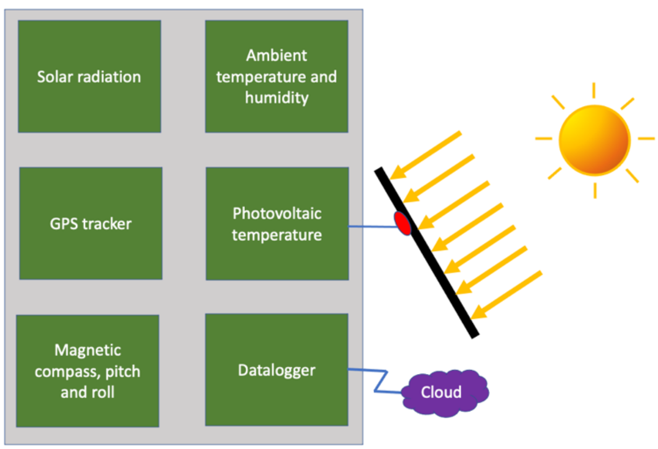

Figure 4. The architecture of the sensor platform

From the sensor platform, the data is transferred through web get-type procedures to the remote subsystem residing in the cloud.

Figure 5. The physical construction of the sensor platform

Fig. 5 shows the physical construction of the sensor platform, while Fig. 6 shows how the sensor platform is mounted on a solar panel.

IV. IoT Business Models

A business model is the underlying knowledge of a venture or the core logic for generating value in a venture [2][3]. Research has tried to establish a more unified business model by using it as a new analytical unit with a system-level, holistic approach to explain how a company creates value through its activities [4]. A holistic approach includes the role of the market, the customer, and the systematic and integrated approach to business model innovation processes [5]. Considering the relationship between explicit needs and extended value chain, a business model is defined as a mechanism to comprise the framework/mode/logic of profit-seeking and business structure to make a profit [6].

Figure 6. The sensor platform mounted on a solar panel

A business can expand its value creation by increasing its activities upstream, downstream, or both. In our case, the industrial partner, ICPE, delivers solar panel installations. Upstream activities would be producing solar panels, while downstream activities may be operating and maintaining the solar panel installations. The Dr. Solar box represents downstream value creation.

IoT opens new opportunities for business models. Gassmann, Frankenberger, and Csik [7] conceptualized the business model by four central dimensions: the *who*, the *what*, the *how*, and the *value*. Who is the target customer or segment? What do we offer to the customer (value proposition)? How do we deliver our goods and services (value chain)? And finally, how do we generate value (revenue model)? The conceptualization is shown in Fig. 7.

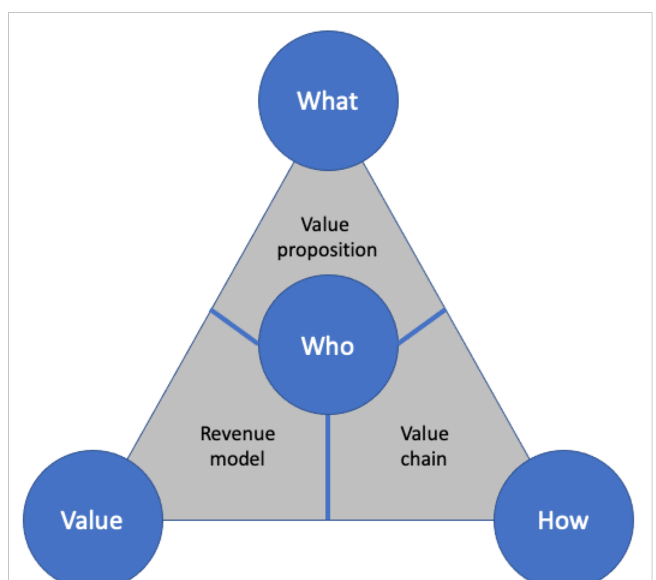

Figure 7. Central dimensions of a business model [7]

Sinclair [8] presents five classes of business models and shows the evolution over time, called the business model continuum. The first class is called the *product* business model, where a product is sold to the customer. IoT can provide added value through new features, better performance, reduced cost, and increased accuracy. The second class is the *product-service* business model. Here, the relationship between the producer and the customer creates added value. The relationship can incorporate training, predictive maintenance, and smart services.

TABLE I. REVENUE MODELS

Business Model Class	**Description**	**Revenue Model**
Product	The customer buys the hardware unit and gets access to the service for free.	Revenues come from the sale of the hardware unit.
Product/ service	The customer buys the hardware unit and subscribes to a service.	Revenues come from the sale of the hardware unit and the subscription fee.
Service	The customer rents the hardware unit or subscribes to a service, and the service provider owns the hardware. The model facilitates long-term relationships with the customer.	Revenues come from the rent or subscription fee only.
Loan	The customer loans the hardware unit and uses the service for free. It is used to add value to other sales	Revenues come from other sources, e.g., increased sales of solar panels and associated hardware or advertisements on the web platform.
Freemium	The product is installed for free. Functionality is unlocked by subscription.	Revenues come from subscriptions. However, the freemium model has become popular in many segments, but in our case, the unit cost may be too high to gamble on whether customers are subscribing or not.
Service/ outcome	A partnership is created between the manufacturer and a stakeholder in the solar panel value chain	Revenues come from profit sharing, where the manufacturer receives its part from the profits generated by the partnership.
Outcome	The product is installed as part of a total system of solar panels and the inverter	Revenues come from a close partnership with stakeholders responsible for the whole power generation process.

The third class is the *service* business model, where the customer pays per hour of use, per time used, or volume collected. The producer owns the product. The customer subscribes to a service. The last two classes focus on the outcome. The outcome is about solving the customer's problem. The fourth class is the *service-outcome* business model. In this case, the producer installs the necessary products to solve a problem. The monetization can be a share of the value generated by the producer's systems. The *outcome* business model is when the producer and customer establish a close partnership that solves the problem for the customer.

In addition to the five classes proposed by Sinclar [8], we added *loan* and *freemium*. Lending out the hardware unit makes it possible for customers to increase the value of their installations and incentivizes them to choose the manufacturer offering such a service. Freemium [9] implies that essential services are free, while more advanced functionality requires the customer to pay.

A review of business model literature by Osterwalder, Pigneur, and Tucci [10] showed broad diversity of understandings, usages, and places in the firm. Creating value is an important factor. However, Chesbrough [11] and Spencer [12] discuss open business models where many partners participate in the innovation process. Additionally, some marketing researchers are studying co-creation and co-production, in which the client participates in developing the primary offering.

The approach used by Gassmann, Frankenberger, and Csik [7] will now be combined with the classes of business models offered by Sinclar [8] to discuss viable business models for the Dr. Solar solution.

V. DR. SOLAR BUSINESS MODEL CONSIDERATIONS

The value proposition for the Dr. Solar solution is optimizing and diagnosing the solar panel installation. By using Dr. Solar, the user can improve energy production and be alerted about possible malfunctions in the installation.

The revenue model is about creating value for the different stakeholders. Building on the classes proposed by Sinclar [7], we present seven alternatives for creating revenues. The revenue models are shown in Table I.

As to the selling behavior, there are two options. The Dr. Solar solution can be sold separately or bundled with other products, as shown in Table II.

TABLE II. STAND-ALONE OR BUNDLING

Stand-alone	Dr. Solar is offered to customers with existing solar panels
Bundle	Dr. Solar is bundled with other products, e.g., inverter and/or solar panels.

The installation of solar panels involves different stakeholders, as shown in Fig. 8. These stakeholders may bundle the Dr. Solar solution with their own products or activities.

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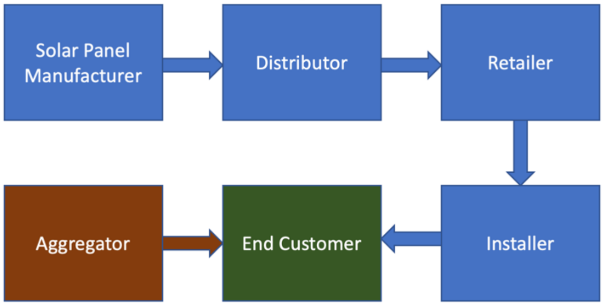

Figure 8. Stakeholders

TABLE III. STAKEHOLDERS

End customer	The end customer would typically use Dr. Solar to diagnose and optimize its photovoltaic installation. The end customer would typically loan the Dr. Solar.
Installer	The installer can use the Dr. Solar unit to improve the installation and achieve a competitive advantage. The installer typically buys and uses the hardware unit for all installation products.
Retailer	The retailer of solar panels and other photovoltaic equipment can offer Dr. Solar on loan or as a service. The retailer could get a competitive advantage from bundling with other products.
Distributor	The distributor could offer Dr. Solar as a product or service to downstream retailers and installers.
Manufacturer	The manufacturer of solar panels and other photovoltaic equipment could offer Dr. Solar as an added value to distributors, retailers, and installers.
Aggregator	The aggregator organizes a group of prosumers. The aggregator could buy Dr. Solar and lend it out to its prosumers.

The stakeholders' use of the solutions is described in Table III, and the bundling opportunities are shown in Fig. 9.

VI. RESULTS

After considering different potential business models, the chosen alternative was to regard Dr. Solar as an added value to photovoltaic installations. The sensors unit, equipped with high performances sensors, is too expensive to be permanently installed on the photovoltaic systems on-site. It is enough to stay installed for only a few days to collect relevant data in one site and then send it to a new installation where the photovoltaic system needs to be assessed. Therefore, the intention is to lend the sensor platform to customers installing photovoltaic systems to diagnose and optimize their installation. Providing this technical solution as a service will obtain a competitive advantage in the market. Bundling with other services may be viable to help create business relationships with other solar panel value chain actors.

The data collected may also be used for value creation. Collecting data from many solar panel installations may be used for analysis on a larger scale. The results can be used to gain further insight into optimizing photovoltaic energy production.

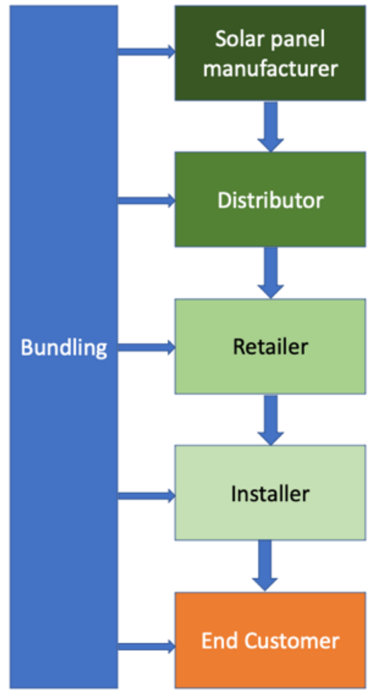

Figure 9. Bundling

VII. CONCLUSION AND FUTURE WORK

The Internet of Things creates new opportunities for innovative business solutions. Dr. Solar is a solution consisting of an IoT sensor platform and a cloud-based service that analyzes sensor data and data from the inverter to optimize and diagnose photovoltaic energy production. This paper focuses on presenting possible business models for deploying the solution in the marketplace. The cost of the sensor platform prohibits permanent mounting to smaller solar panel installations. Therefore, moving the sensor platform from one installation to another is necessary. The solution creates value for the customers by optimizing and diagnosing the installation. However, it is also essential to generate revenues. Several revenue models have been considered. The solar panel installation ecosystem consists of many actors. Bundling is one way of generating revenues.

Dr. Solar is not the final solution; further developments can be done. The application of the solution developed within the PVADIP-C project can be customized to answer further different needs of photovoltaic systems users.

The project did not try to minimize the costs. The components used are all considered high quality. The sensor platform price can be reduced by selecting cheaper components. Selecting other materials for the casing could also bring down the cost.

With lower sensor platform costs, a permanent Dr. Solar unit may be considered for larger photovoltaic installations.

The project has only considered solar panels with a fixed position. The solution provides recommendations on optimal positioning and orientation of the solar panels. However, dynamic positioning can increase energy production. Dynamic positioning is relatively expensive, but enhancing the solution to support the solar panels' real-time positioning would be straightforward. The sensor platform must then be a permanent part of the solar panel installation.

Some of the ideas from Dr. Solar could be used for other types of renewable energy. The sensors would differ, but the overall architecture with a sensor platform and a cloud-based service for diagnosis and optimization could also be used for wind or geothermal energy.

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