SRC – the societal and economical effectiveness of the consortium project

THE SECOND OBJECTIVE

The name and abbreviation of the project: **Cloud computing as an enabler of large scale variable distributed energy solutions: Bright Clouds – Dark Clouds (BCDC)**

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1. The impact objective

THE POSSIBILITIES OF BCDC CLOUD SERVICES IN IMPROVING ENERGY EFFICIENCY (consortium level impact)

Electricity market transition to smart grids with large shares of renewables is a true technological disruption. Consumers become active prosumers and small scale producers in the market. The grid moves from a one-direction driveway into a two-way highway. At the same time, the market transforms into a two-sided mode of operation. The amount of real-time information flows increases significantly. New types of digital services are necessary to balance and optimize this new type of market. Since the intermittency attribute of wind and solar power is the central uncertainty-creating feature, it is obvious that more accurate weather forecasts as well as weather related energy forecasts are needed.

Through interaction with different communities, we aim at achieving significant efficiency results when succeeding in combining automation and digital services with the possibilities of the intelligent electricity network. One way to ensure successful results is to diminish the uncertainty related to renewable energy by developing better weather forecasts. The development of new services requires changes in regulation and incentive mechanisms (including taxation). The most interactive means for achieving this objective is to enhance *productive interaction* and *co-creation* between all players involved in the development of the services. Interaction between service developers and policy makers is also prerequisite.

The objectives (O) for interaction related to the services are outlined in our Interaction plan as follows: Setting up a forum for industrial partners in the energy sector (O3); Integrating knowledge and knowing of the researchers of all the WPs and the partners involved during six years (O5); and Enhancing changes in regulations and legislation related to energy production and market principles (O7).

2. What program questions (A, B, C, or D) does this objective address?

C. *In what ways can the public sector best support the change process to maintain a controlled change and create the best possible conditions for Finland to utilize disruptive technologies?*

Traditional models of regulation need to change into smart, dynamic and flexible incentive-based regulation. This change necessitates new type of digitalization related expertise. Possible barriers to the spread of new technologies and related market mechanisms should also be removed. The public sector has a central role in disseminating this new knowledge. The results of BCDC can be utilized since BCDC creates both private and social innovations for society. Social innovations relate to partnerships and co-operatives to mitigate climate change. The private innovations, in turn, relate to the scalable and transferable digital services and market places for selling and buying electricity. New possibilities for firms to commercialize the smart meter and numerical weather forecast technologies are studied and developed. This second objective of the BCDC Energy consortium relates to the level of the markets from the viewpoint of the service providers.

3. Means

The BCDC consortium works in the interface between academic research and private markets. Therefore, the companies with the knowledge of the current market situation in the energy sector are a vital partner in developing the service platform. Consequently, our Advisory Board (AB) was formed right from the beginning (see the Interaction plan). The aim is to use active co-creation methods to develop the new services with the key players of the energy markets, and to share knowledge of the recent research with them. Interactive events and workshops organized by BCDC with the AB have been the means to develop models for new types of service platforms. These means allow multidisciplinary, multi-organizational and multi-professional collaboration. Face-to-

face interaction in the workshops enables finding alternative solutions for key problems related to two-sided platforms. We have shared the results of these workshops actively in our websites and by using twitter (see Impact Narrative 3). The AB members have their own forum in Basecamp, which has been used to share, store, produce and manage information about BCDC. In addition to facilitating these crucial means, interaction taking place and emerging when collaborating in the workshops has been observed and video-taped. The data are used in a postdoc study in developing a model of interaction for R&D, and the first research articles, based on these data, have been publiseh. Finally, a selected part of these data is anonymised for storage and access in the Finnish Social Science Data Archive (FSD) (https://www.fsd.uta.fi/en/).
The process of developing the ideas of a virtual utility and Energy weather started already in the BCDC's Kick-off meeting in Oulu on Dec 2015, where also the members of the AB and the strategic partners were present (such as Cleworks Ltd. and the Finnish Clean Energy Association). The idea to the Energy weather application was created in this meeting, as a result of a discussion between the researchers and some members of the AB. The researchers of WP3 developed the concept together with WP1 and WP4, an advertising agency and WP5. It was launched on June 2016, and it started spreading fast in public (see Impact Narrative 3). Since then, Energy weather has been further developed in WP3 and also in the meetings and workshops of BCDC in connection with the development of the BCDC Cloud Energy weather as a concept, which is further used in new research projects of FMI, such as EE-VaGe This interaction between BCDC consortium and other FMI projects have further produced new ideas how to develop Energy Weather application. WP3 together with other WPs has started this work.
Discussions concerning Virtual Utility (VU) started in Jan 2016 in the AB's Kick-off meeting. In the workshop on May 2016 some results concerning the VU from the pilot 'Vuokatinmaa' were presented, and the idea was further elaborated, in relation with the Energy weather and the system model (see Impact Narrative 1). To develop the ideas further with the researchers and the AB, a workshop was organized on Jan 2017. It was facilitated by a think tank Demos Helsinki, following a method of co-design. This resulted in four concepts of a VU, which now form a basis for the future development towards a working solution of the model for the service. To test the ideas and research results and to gain further understanding of how to develop the service, we have started to work with practical pilots simultaneously with the concepts of the VU. Different communities are significant energy consumers and thus have potential to be important promoters of efficiency. Thus, we have worked with different types of pilots, which relate to a holiday resort (pilot 'Vuokatinmaa'), a larger living area (pilot 'Mälardalen'), and smart city concepts and different communities (pilot 'Porvoo'). The idea of these pilots was developed in the interactive events of the BCDC community, as well as in the meetings organized with the strategic partners and some members of the AB. In the Kick-off meeting for the AB on Jan2016 in Helsinki, the planning of the pilot 'Vuokatinmaa' was started with the company Cleworks Ltd. The planning continued in the workshops with Cleworks. The pilot 'Mälardalen' was developed in collaboration between the researchers. First the researchers of WP2 were able to get valuable Swedish Energy Agency data from the Mälardalen area in Sweden through their contacts, and then WP1 started a collaboration with our colleagues from the Center of Environmental and Resource Economics (CERE: http://www.cere.se/en/) at the University of Umeå, Sweden, to put the pilot into practise. Research results related to these pilots are well on they way (see below). A VU model balancing the forecast errors of an assumed solar power station with household hot water heater has been created. The results show that this kind of virtual utility can be both economically and environmentally beneficial. The Mälardalen data have been used to show that combined use of real-time pricing contracts and own solar power production can lead to noticeable savings in household's electricity bills. In collaboration between WP3 and WP1 we have developed a simulation based Virtual Power Plant model where we have shown that VPP can reduce the costs related to the solar power forecast errors compared to the current practice to correct the errors in the balancing market.
In co-creation workshop October 2019 BCDC consortium decided to move on to the demonstration phase of the VPP and VU studies. We have started to build one demonstration which concentrate on the efficient management of information flows. In this demo, we utilize solar panel production data from the roof of the University of Oulu combined to the 5G network established within the

university area. Another demonstration is built around our data resulted from Caruna collaboration. This data includes four years of hourly household level consumption and PV production data. Through this data, our aim is to show the benefits (economic and environmental) of coordinated management of consumption and PV production instead of individual targets.
Our experience ofthe previous pilots have enabled ***real nudging experiments*** to start. The Energy Authority (Energiavirasto) has agreed with Motiva Ltd. and BCDC that an experiment related to household's electricity consumption among the customers of Porvoon Energia shall be arranged during the winter 2018 - 2019. The nudging has started in November 2018 with the first new letters send to the participating households. New types of nudging techniques shall be developed and analysed. A key point in this nudging is to find out the effects of an own consumption related on-line service. The results can potentially be used is developing the Fingrid data hub and the services related to it. One result of this experiment has proceeded already such that in co-creation workshop October 2019 we agreed to develop a consumer oriented application that allow consumer to tract their own consumption and compare it to the similar consumer. Another interesting experiment concerns the customers of Caruna Ltd. This experiment originated with discussions in the AB. A survey asking incentives and obstacles of own PV production has been carried out to Caruna customers. A permission to use individual household's electricity consumption data has also been received from over 1300 customers. This data enable the construction of different types of VUs for these households.
We have also set up a study to examine energy information literacy and home energy behaviour and user interaction with home energy management systems in the project 'Iisisti Energinen Ii' together with SITRA, Ii municipality, Iin Energia and Micropolis Ltd. Two surveys have been performed to test energy information literacy in this context, one related to inhabitants of the Ii municipality and one for the whole population of Finland. Both are based on randomized samples. Households are a critical node in the smart energy grid and homes are encouraged to acquire energy technologies which increase energy efficiency and demand flexibility. In the project 'Iisisti Energinen Ii', we study what are the goals and motivations of the users of the home energy management systems, and what kind of user experience they have with a newly installed system. We show some reults of newly installed home energy management systems in our newest *Keep on talking Featurette III*: https://www.youtube.com/watch?v=i0aFLW-N0is&t=578s.

4. Observations on concrete effects
As a result of the work described above, the concepts of Energy weather and Virtual Utility have been developed. Moreover, in our pilots, several experiments have been launched, and prototypes are being developed.

Energy weather. The power of *productive face-to-face interaction* was evident since the first joint meeting, as the basic idea for the first novel, interdisciplinary innovation; namely, our Energy Weather Forecast (EWF) was created in the Kick-off. The birth of this application is a good example of the power of interaction (see http://www.bcdcenergia.fi/tarina/osa-5/). The EWF converts sunshine and wind into kilowatt hours for each of the 200 locations in Finland over the next 24 hours. The EWF assumes a peak power of 2.5 kWp for solar panels and wind turbines. Therefore, the wind and solar power production figures of the forecast are comparable with one another.
The forecast is based on the HIRLAM weather forecast model of the Finnish Meteorological Institute (FMI). HIRLAM includes all weather-related details significant for both wind and solar power. More information about weather forecast models is available in FMI's Youtube stream: Mitä säämallit ovat (https://www.youtube.com/watch?v=Z0_Zgk908nQ) and FMI's websites: Säämallit ennusteen apuna (http://ilmatieteenlaitos.fi/saamallit-ennusteen-apuna).
Energy weather forecast was introduced first to the Finnish Government in their strategy session on May 2016, and we got valuable feedback concerning the forecast's further development. Energy weather was launched in the workshop organized to the members of the AB on June 2016. The concept of Energy weather is now been further developed to Energy weather 2.0, which takes into account the uncertainties of the circumstances. This development has also been reported and

discussed in the news and blogs of the website and the tweets of the BCDC consortium.

Virtual Utility (VU). The concepts to the VU were developed, based on the research conducted in the BCDC community and the understanding of the context by the AB. These VUs, or platforms or virtual power plants as they also often are called, can naturally have different organizational structures. They can, but need not be, for-profit organizations. They can be co-operatives or simple aggregators with remote controlling through automated devices. In our research, we study all these different types of VUs. The VU aggregates loads and production from small scale agents and having reached a large enough volume becomes an active market player with bidding and pricing rules. We model the load in this market with two types of consumers. One type of consumers are active spot price followers and they make real-time-price based contracts. Other consumers choose traditional flat price contracts. We solve the production structure using must run constraints for basic power and zero profit constraints for freely allocated generators. VUs can become active players both in the day-ahead market and balancing market. Since the members of the VU are owners of renewable resources the role of the VU materializes more naturally in the balancing market. Based on these earlier results we have now moved to the demonstration phase of the Virtual Utilities.

Other effects

To increase awareness of the issues related to the development of these types of new services our Research Director Marita Laukkanen was interviewed in Finnish Broadcasting company's A-studio in April 2017 concerning subsidising companies. We have collaborated with the other energy related SRC consortia, namely SET and El-Tran to provide a joint comment to the Fingrid Working paper and to release a Policy Brief in June 2018.

To increase the awareness of the questions concerning the development of the VU, the course 'Smart grids 2' was organized (http://www.oulu.fi/energy/node/44602) at the University of Oulu. This has then followed the course "Smart grids 3" which has concentrated on the market mechanisms related to the VU and intelligent networks.

To study knowledge creation and co-creation, all the meetings and workshops have been recorded and stored for further research. A research article on these data related to the development of VU is under revision.

5. Intentional impacts

We have clearly achieved our objective 'The setting up a forum for industrial partners in the energy sector' (O3), as we have been able to form an AB whose members are core players in the Finnish energy markets. By arranging joint workshops and developing communication channels such as the websites, a newsletter, utilizing ICT-based tools (Basecamp, Slack, blogs) and social media (Twitter), to share our knowledge and research developments (see Narrative 3) we have created a solid forum for the industrial partners and researchers to interact.

This is connected with the objective 'To integrate knowledge and knowing of the researchers of WPs 1 to 5 and the partners involved during six years' (O5). The collaboration and co-creation with the AB and our strategic partners have been fruitful and functional, as reported in the sections above. The research conducted in BCDC has gained valuable information concerning the markets and the possibilities to develop new solutions, and the companies have been interested in the development of the research on renewable energy and our solutions. Our core solutions Energy Weather Forecast and Virtual Utility were developed in this kind of collaboration and interaction. Moreover, interaction with our research partners and colleagues abroad has been crucial to gain data to develop our models.

In practise, it is still quite demanding for a VU to become an active market player at least in Finland since Fingrid requires at least 5MW as the minimum tradable size for the offers in balancing market. To gain 5MW the VU needs to have at least 1 000 households with 5KW photovoltaic panels assembled. Fingrid is planning to change this constraint.

The Caruna data has now been implemented into our server and the analysis and development of the VU based on this data has started. First results were presented at BCDC Energy Workshop in

Oulanka research Station in May 2019 and further discussed and developed based on our Workshop in Oulu in October 2019.

6. Nonintentional impacts

We have aimed at collaborating with the AB and our partners, and this collaboration has created some nonintentional impacts concerning the development of the pilots. Especially the pilot 'Porvoo' was of this kind. Collaboration with Porvoo started surprisingly nicely. We had no exact knowledge of renewable resources usage and data collection that had been going on in Porvoo. In the meeting on Nov 2016 in Porvoo we explained our ideas and their answer was: "You are exactly what we need and have been looking for". It turned out that the city had for some time been collecting user data from certain districts in the city and we went home with these data in our 'pockets' to be inserted in the BCDC cloud service prototype. This collaboration has then enabled a large nudging experiment to get started.

Collaboration with Micropolis Ltd. and municipality Ii in the SITRA funded project 'Iisisti Energinen' has produced interesting results on home automation, energy communities and energy related literacy.

7. Background research

Our research related to VUs has proceeded in two lines with two models. In the first model, the hot water heaters of households are combined to formulate an aggregator. It is assumed that each boiler is optimized based on spot prices and under the restriction, that enough hot water is always in the boilers. This optimized electricity usage is aggregated and supplied to the market. The market price effect is calculated, and the optimization is re-run. It turns out that this aggregator can bring benefits both to the member household's and to the environment with reduced CO_2 emissions (Huuki et al. 2017). In the other model, we formulate a VU using the results of FMI solar panel measurements from Kumpula. We compare the real production from these panels to the Energy Weather Forecasts and calculate the difference. Then we scale these differences up to one megawatt and assume that this VU needs to go to balancing markets with these forecasted errors. We assume that a certain number of households would give their hot water heaters to balance these forecast errors. We again manage to show that this virtual utility makes profit by working together with the households who also benefit. The CO_2 diminish also here.

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