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Cloud computing as an enabler of large scale variable distributed energy solutions: Bright Clouds – Dark Clouds (BC – DC) 26.4.2015

2 Rationale

The main aim of BC-DC is to provide a research based link between the development of variable distributed production of energy and the recent work of Finland's parliamentary committee on energy and climate issues summarized in an Energy and Climate Road Map for Finland. Finland's long term objective is to become a carbon-neutral society. This objective will be particularly challenging for the energy sector, as approximately 80% of Finland's greenhouse gas emissions originate from energy production and consumption. The Road Map was not intended to produce delineated pathways towards 2050; rather, it considers the cost-efficiency of a series of alternative scenarios for reaching the desired 80–95% reduction in greenhouse gas emissions from the level of 1990, by 2050. Our aim is to contribute by opening the concrete possible pathways for these targets.

Energy markets have gone through a major change because of liberalization of the market. Still bigger changes are to come and these changes will have major economic, environmental and social changes. These changes relate to market penetration of intermittent energy supply through renewable resources, technological developments in smart grids and ICT based digital services. In the last decades, advancements in wind turbines and solar cells allowed these technologies to be reliable enough to be integrated into the grid, as solar and wind "farms". In the same sense, nowadays, due to reduction costs in photo-voltaic (PV) and wind generators, and also due to the growth of environmental awareness, the capability of generation is also becoming available to individual customers.

There are several research subjects and proposed architectures for deploying the smart grid infrastructure. Bera et al. [1] summarizes current research in the area of providing smart meter services via cloud computing, also presenting some future challenges. Rusitscka et al. [2] presents some use cases that could be more easily addressed by means of cloud computing as for example, market liberalization. Hägerling et al. [3] show a hierarchical structure which uses aggregators to gather and process data from a given neighborhood to send to the utility, and, on the other way, gets instructions from the utility and distributes them to the houses. The function of this aggregator could be easily performed in the cloud, instead of in a dedicated equipment installed either at the utilities' center of operations or in the nearest substation/transformer.

The key word of the future energy system thus is *flexibility*. A key problem related to renewable energy sources is that they are producing energy variably (intermittently) – wind generators can only produce when wind is blowing and solar generators when the sun is shining. As the energy available to the system is very much dependent on weather-related variations in the energy production, weather forecasts constitute a critical component in the cost minimization process. Both Numerical Weather Prediction (NWP) models and other techniques of weather forecasting will be utilized in BC-DC, providing data on time scales from hours to days that help minimize the costs.

The uncertain variability of supply creates extra costs to the system. In the literature these costs have been recognized to be related e.g. to increased grid costs, costs of balancing services and increased costs of cycling and ramping of conventional plants and they have been called as "hidden costs", "system-level costs" or integration costs " [4], [5].

Our aim in this project is to find solutions that materialize the full potential of variable energy sources in cost minimizing economically efficient ways. Minimizing integration costs of variable production can have significant effects to the society in transition to the new energy system. Because it is not possible to reduce integration costs through management of intermittent production the management of demand and forecasts related to load and weather conditions becomes into key roles in minimizing integration costs. Efficient management of demand to correspond variable production requires totally new 1) market mechanisms and market participants, 2) efficient transmission of real time information related e.g. to load, production and weather forecasts (wireless ICT) and 3) digital services. The main goal of this project is to build a *cloud computing based market place of electricity trading (CBES)* where all of these above mentioned issues can be combined.

The quality of interaction and communication is critical for creating new knowledge. It is crucial also for effective outcomes of this multidisciplinary research project BC-DC. Effective interaction must be ensured at various levels in society from political decision makers to public and private players in the field, to non-governmental civic organizations and finally to citizens. Besides scientific knowledge and expertise of the domains represented by the research groups (WPs1-5) involved in BC-CD, also other players in the field have critical knowledge and expertise that will be combined in the knowledge creation and production of BC-DC. The point of departure of the BC-DC's interaction plan is to enable integration of these different knowledge domains to a knowledge-base of BC-DC community to be built on and developed further during the six years and beyond (see details from WP5).

The joint consortium project is linked to previous or other concurrent research by the team leaders or their teams as follows. Professors Svento and Kopsakangas-Savolainen lead an active energy economics research group. Recently main emphasis of their research has concerned sustainable energy economics such as the effects of real-time pricing on long run efficient investments, efficient use of renewable energy and promotion market access for renewable intermittent energy. A key current research question concerns the profile costs of large scale variable energy supply. They have done both theoretical and empirical research. In empirical studies the applied methodologies have been based on simulation methods and modern econometrics. They are partners in **P2P-Smart Test H2020** and **FLEXe** projects.

The fundamental research of *The Center of Wireless Communications (CWC)* focuses on signal processing and radio engineering, radio access and network topologies and future wireless internet. In application oriented research new technologies, such as beyond 4G or 5G, disaster prevention and recovery ICT, test environments for cognitive networking and medical ICT are identified as strong future opportunities. New emerging openings include also smart energy grids and mobile clouds. The funding partners include e.g. European Commission, Finnish Funding Agency for Technology and Innovation, Academy of Finland, European Defence Agency, European Space Agency, Finnish Defence Forces, Nokia Siemens Networks, Nokia and Elektrobit. Current major projects include **P2P-SmarTest H2020**, **Smart Grids and Energy Markets (SGEM)**, SUSTAIN and several FP7 projects.

FMI is strongly involved in the development of the NWP models and products in Europe. The development work is done in deep collaboration with the HIRLAM-B and ALADIN consortia, a coalition of 26 European weather services, developing a joint, short-range forecasting system (Harmonie). Furthermore, FMI BC-DC-team is highly skillful on addressing the challenges related to model initial condition problem [22].With respect to renewable power generation, the FMI BC-DC-team has successful record of projects such as producing the Finnish Wind Atlas [23], the Finnish Icing Atlas [24] and the evaluation of solar energy potential in Östersundom, Helsinki [25]. Dr. Niemelä coordinates ongoing sub-project on "Improving the value of variable and uncertain power generation in energy systems (**VaGe**)" and Dr. Lindfors is the co-PI of the ongoing project "Influence of Clouds and Atmospheric Aerosols on Solar Energy in India and Finland (**ICASIF**)". Both projects are funded by the New Energy program of the Academy of Finland.

The special added value of the consortium is to combine technical, economic, meteorological and information science expertise in order to solve the multidisciplinary research problem of digitalization as a driver in the transition to a flexible large scale intermittent energy system. Through effective goal setting and related interaction the consortium enables integration of the knowledge domains of WPs1-5 with the partners involved in development and implementation. This knowledge-base will form the basis for the R&D activities of the BC-DC community.

3 Societal significance and impact

The research of BC-DC addresses programmatic questions A, B and C as follows.

The transition in energy markets is driven by disruptive technological changes but there are also major social and economic reasons necessitating this change. Firstly, primary sources of fossil fuels are diminishing, secondly, in mitigation of climate change energy plays a crucial role and thirdly the global energy demand is increasing (due to growth of population and industrialization of developing countries). These changes show the great social relevance of our project. Mitigation of the climate changes is best reached through renewable energy sources and we aim to show how this is best done in a cost minimizing way. The solutions we develop for distributed energy markets can be transferred and scaled so that we aim to produce exportable solutions. The new energy market related digital services also create new export possibilities.

A. In the case of a concrete disruptive technology, how is it manifested in Finland and what are its potential benefits

Transition of the traditional, inflexible energy system into a two-sided, flexible smart system requires the utilization of cloud computing based smart ICT solutions which we see as the concrete disruptive technology. This transition includes (but is not limited to) increasing share of intermittent production in the system and smart metering and smart housing technologies and new digital services. New export possibilities appear based on scalable solutions related to intermittent and distributed generation related knowledge. Further benefits include reduced CO_2 emissions and increasing competitiveness through cost efficiency.

B. In order to make the best possible use of a particular disruptive technology, what changes are required in human activity, institutions and operational methods

Flexible and changing roles of existing market participants are necessitated. Consumers become active players in the two-sided energy market. New market participants enter and the roles of these and incumbents mix. The traditional energy institutions need to change their roles into flexible and adaptive market participants. A necessary condition is to create a sense of community in order to involve users into the new market contexts. Consumption patterns need to change so that the new market based equilibriums can be reached.

C. In what ways can the public sector best support the change process so as 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 types of digitalization related know-how from the public. The public sector has a central role in disseminating this new knowledge. The results of BC-DC can be made use of in society since BC-DC creates both private and social innovations for the society. The private innovations relate to the scalable and transferable digital market place for selling and buying electricity. We also create new possibilities for firms to commercialize the smart meter and numerical weather forecast technologies. We also create social innovations related to climate change mitigation partnerships and co-operatives.

4 Objectives, expected results

This project investigates and models the smart and flexible ICT based distributed energy system. We study the new market mechanisms, ICT solutions and digital services that the efficient operation of this new system requires. Our multidisciplinary research works through five limited and united work packages.

WP1 Market mechanisms for efficient integration of variable distributed production to the energy system.

Task 1.1 Benchmarking of the Regulatory, Business, and Technological enablers and barriers of the current power system.

In this task key regulatory, business and technological enabler and barriers (or limiting factors) are to be investigated. This will include the investigation of the following 1) control, operation, planning and regulation related to distribution network 2) the role of current market players and the need for new market players, 3) government interventions in tariff setting and green subsidies 4) commercial and regulatory arrangement and mechanisms as enablers/barriers in transition to distributed energy system (e.g. how can the access/role of new market participants (ESCOs, Aggregators, service providers, prosumers) to be efficiently utilized in the perspective of whole society).

Task 1.2. Integration costs of variable distributed production

The motivation of this task is to identify and estimate the main cost drivers of integrating the variable production into the energy system. This is crucial in the sense that only after specifically identifying these cost drivers other part of the energy system, such as smart ICT, digital services and demand side management, can be optimized in order to minimize these costs. The estimation of integration costs is done by solving the decisions that maximize total surplus assuming different levels of intermittent energy capacity. Integration costs depend mainly on 1) the variability of intermittent generation and the extent to which this variability correlates with demand, 2) the costs of building (and using) backup capacity in order to maintain system level reliability and 3) the flexibility of demand (see e.g. [4] and [5]). Also the extent to which the generation of intermittent production is forecastable may play an important role (see e.g. [6]).

The model that is constructed includes the possibility for the operator to use demand side management (DSM) tools (e.g. interruptible power contracts or real-time price contracts [4]) to curtail the demand. The decisions on scheduling generators and decisions on demand-side management are done hour by hour Each hour wind output and load are realized, scheduling and DSM decisions are followed and some fossil fuel (or other) generators may fail. As a result of these iterative calculations a welfare maximizing equilibrium can be found i.e. production and demand patterns which minimize integration costs. This information is used as a input in designing efficient market mechanisms as well as the smart ICT-system.

Task 1.3. Market mechanisms for efficient integration of variable distributed production

In this task we develop market mechanisms so that the value of variable distributed production to the energy system can be maximized. The derivation of these efficient market mechanism starts from two preconditions: first, the results of the task 1.2. related to minimizing integration costs is used and second the two-sided feature of the market is efficiently utilized.

The traditional electricity market is not a two-sided market. Users and buyers of electricity are only out takers from the grid. However, technological development is changing this picture as the network is changing from dumb grids to smart grids. This change is already well under way and is going to enable the change of electricity markets to two-sided markets. The big change is that the smart grids allow each participant to be a consumer and producer at the same time.

The literature on two-sided markets has grown steadily since the path breaking papers by Rochet and Tirole [8], [9] and Parker and Van Alstyne [10]. This literature combines network effects to multiproduct pricing behavior. The business model for two-sided markets must be chosen so that “both sides get on board” and this necessitates that the operators must choose a price structure as well as a price level for their services in order to internalize the network effects of both sides (see [8] for a more detailed classification).

In order to design market mechanisms so that the integration costs of variable production are minimized and that the two-sided feature of the market is utilized the new players (such as aggregators, electricity service companies) and platforms (e.g. virtual power plants) are included into the model. Chalkiadakis et al. [11] show that co-operative game theory is a promising method for solving the market equilibrium conditions for these kinds of models. The mechanism proposed in [8] can be seen as an efficient alternative to traditional incentive mechanisms, and so promotes the incorporation of distributed producers in the grid. In this task we utilize and further develop the basic framework proposed in [11] to include two-sided characteristics of energy system including significant amount of variable distributed production. The new elements which should be included to the basic model are the optimizing behavior of prosumers, new incentive mechanisms for flexible demand and a target of maximum value creation throughout the whole business ecosystem.

1.4. Optimal energy mix for energy system with large scale of variable distributed production

The objective of this task is to provide a connection of the analysis of variable distributed production of this study to the recent work of Finland’s parliamentary committee on energy and climate issues summarized in an Energy and Climate Road Map for Finland [12]. This task will complement the Road Map by examining *optimal investment pathways* to the 80-95% reduction target with the assumption of significant share of variable distributed production. The current Road Map relies on a partial equilibrium model that balances the generation of electricity between different power sources so that the total variable generation costs are minimized where the production capacity is specified outside the model, as a scenario parameter. The objective of this task is to fill the gap in knowledge regarding the changes in production capacity that are required to meet the 2050 targets, and do so at least cost to the Finnish society on the whole when both generation costs and investment costs are accounted for. To this end, we construct a dynamic optimization model that determines the optimal energy production capacity mix on the way towards the 2050 greenhouse gas emissions target.

In the first stage of the research we consider the problem of optimal energy mix from the point of view of the society on the whole, assuming implementation of large scale variable distributed capacity that “a social planner” is responsible for decisions about energy production and investment. We build on dynamic optimization literature with a ceiling on pollution, initiated in [13] and determine the optimal energy production and investment path from 2016 until 2050.

Relation of WP1 to other WPs can be summarized as follows. WP2; The key information of economic market drivers to be used as inputs for smart metering and ICT based communication. WP3; The results of the market structures, mechanisms and their time scales give important guidance for weather forecast development. WP4; The business model for CBES.

WP2: Cloud computing as enabler for smart ICT automation in distributed energy solutions. Team leader Professor Matti Latva-Aho

This work-package focuses on the conceptual ICT framework to enable the future electricity grid. In such new scenario, the load and generation control in micro-grids should be designed in a distributed fashion [14]. It should account for new market structures and available ICTs, as well as meteorological predictions, consumptions patterns, types of consumers, intermittent distributed generation, energy storage devices, electric vehicles, among other factors [15-17]. The architecture is built as follows: Consumers or prosumers (houses, industries, hospitals etc.) equipped with smart meters are part of a micro-grid. They then share their state information with the local cloud to decide, for example, when buying/selling energy from/to outside. Different micro-grids may have different control algorithms and the relation between them will define the new market structure and its dynamics. In this case, the communication network topology is important to identify the energy needs and surpluses, which are the key to enable the market.

Our objectives are the following: (1) study the most suitable wireless communication strategy between smart meters and the cloud, (2) design the micro-grid control algorithm that will run in the local cloud, including possible services, (3) analyze the interactions between the algorithms within the cloud looking at how the power grid (generation, transmission and distribution), communication network and market are coupled, and (4) simulate the smart grid system to test our proposals.

Task 1. Smart-metering communication strategy (M1 – M36)

This task deals with two different approaches to proceed with the wireless communication link from the smart meters to the cloud, namely time-based and event-based [18]. In the time-based approach, the smart meters will send the information to the cloud at a per-determined time periods (e.g transmit at every 15 seconds). In the event-based approach, the information from the smart meter is sent whenever a predetermined event happens (e.g. transmit at every 1 kWh consumed). The information to be transmitted could be, for instance, energy consumption, energy generation, local temperature, sun incidence or wind speed. The objective of this task is to compare these strategies and optimize the parameters so that the relevant information can efficiently reach the cloud while respecting privacy (e.g. one cannot reconstruct the house behavior from smart metering data) and quality constraints (e.g. maximum packet error rate or maximum delay). We will also investigate how the feedback (like energy prices and energy consumption or generation) from the cloud to the consumer can be done, for example via smart meter, internet, cellular network etc [15, 16].

Task 2. Cloud computing algorithm to control local power flows (M6 – M54)

The information sent by the smart meters needs to be processed by the cloud together with other relevant external factors such as weather forecast, energy price and period of the day [14]. The cloud algorithm is assumed to control a specific, relatively small, region (e.g. micro-grid composed by a specific neighborhood of hundred houses or an energy-intensive industry plant). This task aims at designing simple, autonomous, algorithms that are able to control the energy flow within the micro-grid and decide when to buy or sell energy. It is important to note that the algorithm should be flexible enough to allow for different applications; a house, a hospital and an industry have different requirements and consumption patterns so the algorithm needs to take this fact into account. Besides, we identify the cloud algorithm as an opportunity for business models and we also plan to evaluate other possible services like remote appliance control.

Task 3. Effects of the interactions within the cloud on the power system as a whole (M12 – M60)

Due to the distributed nature of the new power grid, the micro-grid control algorithms will interact within the cloud [17]. The algorithm designed in Task 2 determines if a micro-grid will buy or sell its energy, but it does not determine from or to whom (e.g. from other micro-grid in a peer-to-peer trading or from the grid in a traditional market structure). In this case, the interactions between the algorithms within the cloud (including algorithms that have different structure from ours) is of key importance [2,3]. For example, what are the effects of algorithms built upon speculative behavior (e.g. buy electricity when it is cheaper, use batteries to store it and sell it later, when the price is higher) on the whole energy system? In this task, we plan to study the smart grid as a complex system composed by interrelated complex subsystems (physical system, communication network and market) which constitutes a multilayer network whose elements interact within the same layer and across different layers [19]. Our objective is to show how different market strategies reflected in the micro-grid control algorithms relate to each other through a communication network [20], and how these interactions will affect the power flows and the system stability in general. Our modeling will include not only the low voltage system, but also the transmission lines and traditional generation. By studying possibly harmful market strategies, this task can provide clear guidelines for regulations of allowed control algorithm behaviors.

Task 4. System-level simulations (M36 – M72)

We plan to test our concept using a system-level simulation including generation (traditional and distributed), transmission and distribution. At this point, we plan to use the open-source software GridLab-D [21].

Relation of WP5 to other WPs can be summarized as follows. WP1; The understanding of the market structures and mechanisms developed in WP1 are of key importance when designing the micro-grid control algorithm ant their relations through, for example, energy prices (Tasks 2, 3). WP2 will also provide inputs to WP1 by assessing how different market strategies may affect the power grid dynamics. WP3; Weather forecast is a fundamental building block in the design of the micro-grid control algorithm since the solar and wind incidence for a given place is determinant to power generation. Besides, evidences show correlation between weather conditions and energy consumption (e.g. need for heating or air conditioning). WP4; Digital services define the quality constraints that need to be taken into account when developing the control algorithm. For example, some applications may require low delays and/or high reliability. In this case, WP2 and WP4 need to work together to assess the feasibility of the proposed solutions.

WP3: Short-range local weather forecasts as enablers of distributed energy production.

Team leader Dr. Sami Niemelä

The work in WP3 is focusing on aspects of weather forecast development that are most useful for new market mechanisms (WP1) and digital services (WP4) of distributed energy production. Moreover, the tasks are designed to provide the highest added value when combined with the expected results from the existing projects (VaGe/ICASIF)). The first half (3yrs) of the project (3.1 and 3.2) is planned in more details. The plan for the second half is more general and the details will updated during mid-term review of the project. The development work within these fields will be applied in the mesoscale NWP model Harmonie, which is used operationally at FMI (on a 2.5 km x 2.5 km grid).

Task 3.1. Initial conditions (M0-M36)

A successful weather forecast requires that initial conditions provided to the forecast model are accurate and consistent with available observations. The rapid increase in computational resources has enabled the operational use of high-resolution mesoscale NWP-models. However, the resolution of in-situ observation network is too coarse for providing detailed information for the model initial state. Therefore, the use of remote sensing observations (radar, satellite) becomes very important. From the point of view of short-term (from hour to days) energy production forecasts, high-resolution remote sensing data are currently not used in an optimal way. This task will focus on developing methods for using wind and cloud information from weather radars and satellites in order to improve the forecasting of wind and solar energy production.

FMI's radar network provides data on both precipitation areas and their movement with high spatial and temporal accuracy. In addition, radial wind information can be obtained as well due to Doppler feature of the radars. Methods for assimilating such information exist [22], however, the use of the methods has been only experimental due to small impact in large scale models. The resolution of mesoscale model is more suitable for using radar wind information. Therefore, we will assimilate the radial wind data from FMI radar network into the Harmonie model. In the non-precipitating cases satellite information can be used for extracting wind information. Atmospheric Motion Vectors (AMV) are derived by tracking subsequent features from satellite imagery. AMVs from geostationary satellites are widely used [26]; however, their quality in the high-latitudes is poor. The second aim of the task is to assimilate the new and more accurate AMV-data from polar orbiting satellites (Metop-A/B) into Harmonie. The most critical component for prediction of solar energy production is the cloud forecasting. Although the current models are using satellite derived temperature and humidity profile information in the data assimilation process, the actual cloud information is not widely used. We will assimilate cloud mask data from polar orbiting satellites into Harmonie model by initializing model moisture field in thermodynamically consistent way.

Task 3.2. Physical parameterizations (M0-M36)
The successful wind and solar energy forecasting requires the usage of high-resolution (km-scale) mesoscale NWP model in order to capture the variability of land-sea contrast and elevation. Furthermore, wind and solar energy forecasting has special characteristics that require further development of the physical parameterization of the NWP model.
The first aim of the task is to develop automatic conversion tools for casting the wind and shortwave radiation forecasts to energy terms. Moreover, the forecast will be localized to be used by individual small region cloud algorithms developed in WP2.

In northern latitudes the production loss due to ice formation should be taken into account in the wind energy production forecast. We will assess the icing risk on wind turbines by further developing the model for in-cloud icing, successfully applied in the Finnish Icing Atlas [24]. The main task is to integrate the icing methodology to the Harmonie model and develop methods for short term forecasting of wind energy production loss.

The second most important component in the solar energy production forecasting is the effect of the atmospheric aerosols. Current operational NWP models do not directly take into account the aerosol related attenuation of solar radiation (up to 15% [27]). The aim in this task is to evaluate the direct radiative effect of aerosols on solar energy production forecasts in computationally efficient way. We will use the aerosol optical depth data from MACC reanalysis [28] in the Harmonie radiation parameterization scheme. The purpose is to assess the significance of aerosols to solar energy production in Finland. This task links strongly to the ICASIF project, where MACC aerosol data will be tested as regards their solar forecast skill in India.

Task 3.3. Forecast uncertainty estimation (M36-M72)
The estimate of forecast uncertainty is as important as the forecast itself. Energy system models use energy production forecasts by giving them weight according to statistical uncertainty estimates. The ongoing VaGe-project is developing methods for estimating flow dependent forecast uncertainty estimates. BC-DC will utilize the methods and expands the uncertainty estimation ideas to the local forecasts of wind and solar energy production. Furthermore, this task explores with WP2 the best practices to use uncertainty estimates in cloud computing algorithm to control local power flow in the most efficient way.

Task 3.4. Integration of advanced assimilation and modeling techniques (M36-M72)
It is uncertain how the science and computational capacity will evolve during the life time of the proposed project. Therefore, the decision of further research actions will be based on the available results and partner feedback via WP5. The following themes will be considered. New cloud-based computing environment and smart metering (WP2) enable new source of information for weather forecasting models. Power production information can be collected from the micro-grids in real-time manner. This task will study the usage of this data for i) local forecast calibration and ii) very short-range (0-6h) forecasting by combining the real-time production statistics from nearby micro-grids. Furthermore, aerosol modelling and its data assimilation methods will be further developed, if their role turns out to be significant for solar energy production in Finland (3.2). Otherwise, research actions will be directed in developing cloud microphysics towards prognostic treatment of number concentration of cloud condensation nuclei. This is expected to benefit both solar energy and icing forecasts.

WP4. Digital systems and services for intermittent energy system
Team Leader Professor Jussi Kangasharju
Main goal of work package 4 is to produce a Cloud Energy Broker Service for flexible and large scale intermittent energy system. The developed solution integrates research results of all work packages and this way also validates multidisciplinary research problems of the project.
Starting point for the WP4 activities are the latest research results and developments in cloud computing and services e.g., (32), digital systems and services e.g (33), and Internet of Things (IoT) e.g. (34). The WP4 studies will also cover recent DataHub activities in North America and in Europe (e.g. in Estonia and Denmark). For example, Danish DataHub can facilitate new products and possibilities, such as combined billing, clearinghouse for the public charging of electric vehicles, providing nationwide electricity consumers a simple overview of electricity consumption at all locations (across all grid companies) and creation of new market products using the sophisticated data infrastructure, including hourly measurements of power consumption enabling consumers to respond flexibly with their electricity consumption (35).

In WP4, based on the recent research results and technology benchmarking a Proof of Concept (PoC) solution will be planned and implemented in tight co-operation with the consortium and all stakeholders involved the project. The solution will be further developed via several iterations in order to produce a new Cloud Energy Broker Service serving all parties in future energy ecosystems such as electricity sellers, buyers, consumers or energy plants. In addition, the aim of the WP4 is to identify and trial some new (special) services in the digital ecosystem of the project. Finally, the research of the WP4 contains validation activities of the produced Cloud Energy Broker Service and impact analysis of the achieved results.

Task 4.1. Technology benchmarking (M1–M6)

The task includes state-of-the-arts and practices as well as literature studies of existing technologies, applications, platforms, and digital systems and services that should be taken into consideration while planning and developing an IT solution for intermittent energy system. For example we will analyse the opportunities from automation, such as controlling electricity consumption automatically (e.g., as a service in Cloud). The new remote readable smart meters enable monitoring consumption in real-time. This gives opportunities to develop service that enables controlling electricity consumption according to the daily or hourly price of electricity. This is related to the complete energy markets, including energy production (e.g., solar, wind, geothermal), controlling energy consumption (e.g., heating, air conditioning) and charging (e.g., electric cars). This task will examine the current research literature and existing technologies in order to identify the most promising concepts for the digital service solution of the project.

Task 4.2. Proof of the digital service concept (M4-M24)

This task covers activities that are needed to develop a proof of concept solution of the proposed digital service. The task will start by identifying and expressing the requirements for the core elements of the new service. It will rely also on input from other WPs, in particular on aspects like business modelling and scenarios (WP1), technological feasibility of the envisaged cloud solutions (WP2), and meteorological aspect (as needed; WP3). Specifying the requirements of the core elements allows us to identify the key information and control flows in the service and enable the development of a proof of concept prototype that will later be used as a basis for experimenting and further development in the project. This specification work includes also aspects related to service design and we will follow a user-centred development model, for example using the Owela-tool (www.owela.fi), or other appropriate methods.

In this task we will develop a concrete proof of concept service solution that allows us to validate the basic models from other WPs and serve as a basis for continued development in Task 4.3. Our goal is to make the prototype usable on multiple platforms, including desktop and mobile, to provide the maximum flexibility for all the users of the service. The first prototype is planned to leverage web technologies to allow for easy development and high portability across platforms on the user-facing side. The backend implementation of the service in this stage will rely on standard solutions and components, with the minimal number of modifications needed to interface with the computing elements in WP2.

Task 4.3. Cloud Energy Broker Service (M20-M54)

This task is the main task in WP4 and its goal is to develop the Cloud Energy Broker Service. We will do the development and implantation work in two separate iterations. This follows smoothly from Task 4.2 since we consider the work done in Task 4.2 to have been the “zeroth” iteration, which gives us in essence three iterations for the complete Cloud Energy Broker Service development. Each of the iterations in Task 4.3 follows the same model as in Task 4.2. First iteration is planned to span M20-M40 and it starts with identifying a set of requirements, based on input from other WPs and from the experiences learned in Task 4.2. After the implementation work we will test and pilot the developed service extensively in order to gain understanding on how the features should be adapted and which new features should be added in the second iteration.

The second iteration spans M40-M54 and follows the same model as the first iteration, i.e., define the requirements based on the lessons learned from the testing of the first iteration and then implement the required modifications or additions. The testing and validation of the service developed in the second iteration will be continued in Task 4.5.

As with the proof of concept prototype in Task 4.2, our plan is to make the Cloud Energy Broker Service usable across multiple platforms on the human side. One key point we will consider in the requirements analysis is whether to develop separate clients for different platforms (desktop, mobile, different operating systems, etc.) to allow for careful tailoring to each platform or to leverage web-based technologies for easy portability and accessibility across multiple platforms, at the possible expense of a slightly reduced feature set of the client.

On the backend side of the service, which connects to the cloud components from WP2, we will investigate the use of other communication abstractions (e.g., information-centric networking or publish/subscribe) and compare their advantages to more traditional web-like backends and web-like communication. These will be experimented in the first iteration and according to the results we obtain; we will select one or the other for the second iteration and final version.

Task 4.4. New services in the digital service ecosystem (M40-M72)

As a starting point of this task are, e.g., identified needs and value proposition as well as research results of other work packages for new (special) services in the digital ecosystem of the project. At this point in time we cannot say which kinds of services these would entail, but the design and implementation work in Task 4.3 will explicitly consider the ability to develop new services flexibly and on-the-fly, ideally with minimal actual programming required. In this task we investigate and develop mechanisms that support this kind of dynamic service creation, and also perform initial validation of the mechanisms and new services.

Task 4.5. Validation and impact analysis (M40-M72)

This task includes an impact survey of gathered experiences and validation of achieved research results. The first phase of this task M40-M54 focuses on validation of the Cloud Energy Broker Service from Task 4.3 and collection of usage data from the tests performed. The second part of the task focuses on impact analysis (M55-M72) and includes activities such as defining metrics for service performance, how to measure performance and adapt system execution, as well as identifying key elements of transformation paths to the new system and their impact on other all of the system stakeholders (and other WPs).

WP5: Knowledge Management and interaction for R&D

Team Leader: Prof. Maija-Leena Huotari

The aim of Work Package 5 (WP5) *is to establishing a BC-DC Community and along with this present a theoretically and methodologically consistent model of interaction involving the aspects of knowledge creation, sharing, use and management within a R&D community* (see 11 Interaction Plan).

Background. Knowledge management (KM) including knowledge creation (KC) are the essence for R&D in communities. Research on KM has gained attention in the fields of computer sciences, educational sciences, information studies, and organization theory and management studies, and the Japanese models of KC by Nonaka and his colleagues [36,37] are most well-known. Besides computer sciences, research on information management (IM) belongs to information studies, which is also interested in human information behavior in everyday-life and work settings concerned with information needs and uses of different professions, tasks, and recently the effects of information. Of these studies model of organizational information use by Choo highlights phenomena related to KC [see 38].

In research interaction has be seen as a place where the KC happens [e.g. 36,39]. Successful, knowledge-creating interaction has been regarded as an open, critical, and self-conscious process, where past experiences provide a basis for creating something new [e.g. 39,40]. New knowledge is based on the previous knowledge of individuals and communities, and it is created in communicative acts between individuals, either face-to-face or by using ICT [39,40,41]. In these studies and models KC is a social phenomenon, but theoretical research of this phenomenon is quite limited. [42]

In WP5 interaction is examined, enhanced and implemented in relation to information and knowledge sharing, use and creation in the empirical setting provided by the BC-DC Community. Interaction is essential for KC, and success with interaction requires relevant means for establishing positive circumstances for it. Moreover, research indicates that knowledge is created in the events of interaction between two or more parties, but thus far the event has not been focused on empirically, although the atmosphere and form of this event is crucial. Research on KC [43] shows, that the conception of interaction reflects hermeneutic ideas such as a shared state. Despite of this, often these conceptualizations emphasize the individual as a separate object and knowledge as a separate asset inside that individual's mind. [42,43]

The purpose of WP5 is fourfold, and the objectives for these Tasks (1 to 4) are set as follows:

Task 1: To establish a knowledge-base for the BC-DC Community (M1-M12).

A pre-requisite for effective interaction is setting-up, developing and maintaining the knowledge base of the Community. It will integrate the knowledge and knowing of all WPs' researchers with the partners' information needs, and allow sharing knowledge, knowing and experiences and also social contacts and networks to co-created new products, services, processes or practices during the six years. Mapping the expertise of the partners along with the critical information needs of the entire community will be conducted and a relevant ICT-based application selected for organizing, storing, disseminating and sharing information within the Community. Vital knowledge will be organized by applying participatory methods to ensure the users' ability to access information. This is necessary for effective interaction and communication at the core of KC, which will ensure well-informed political decision on renewable energy systems and related regulations and legislation even beyond the time span of six years. (See also 11 Interaction Plan/11.1 Objectives of Interaction.)

Task 2) To develop a comprehensive interaction plan including a communication agenda with means and practices for a R&D project of this kind (M1-M72)

Activity Theory (AT) [44,45] is utilized to gain understanding of the BC-DC Community as an actor network system simultaneously when implementing the interaction plan and developing the means and practices of interaction and communication further. It is shown that diversity supports innovativeness and different backgrounds, knowledge and experiences form a nursery for novel ideas and outcomes, and vice versa, that major differences in backgrounds may enhance anxiety and insecurity. Emphasis is placed on a detailed examination of emerging discrepancies between the WPs and the partners and other players in the field, through the theoretical lens of AT-based developmental work research [46]. This allows getting hold of potential sources of innovations at boundary activities of the WPs, partners' organizations and other actors involved in the BC-DC Community, where both discrepancies occur and innovations emerge. Related problems will be solved through means of interaction and communication in practice (see 11 Interaction Plan). A shared vision allows utilizing the diverse knowledge of the Community members. Social relations and trust between the researchers, the partners and wider audiences is a pre-requisite for success in interaction. For trust building the Consortium is ideal with shared values on environmental issues and renewable energy systems. Besides IM, the ICT-based formal and informal interaction relates to a variety of features of human behavior. The lack of nonverbal clues, as well as identity, turn taking in conversation, group-decision making, equality, status, goal orientation, feedback, etc. are examples of phenomena to be examined and utilized in relation to KC besides monitoring them.

Task 3: Further development of theoretical and methodological understanding of interaction related to KC at the community level in R&D projects of this type by integrating the phenomenological viewpoint with ideas of activity theory as applied in Task 2. (M17-M53)

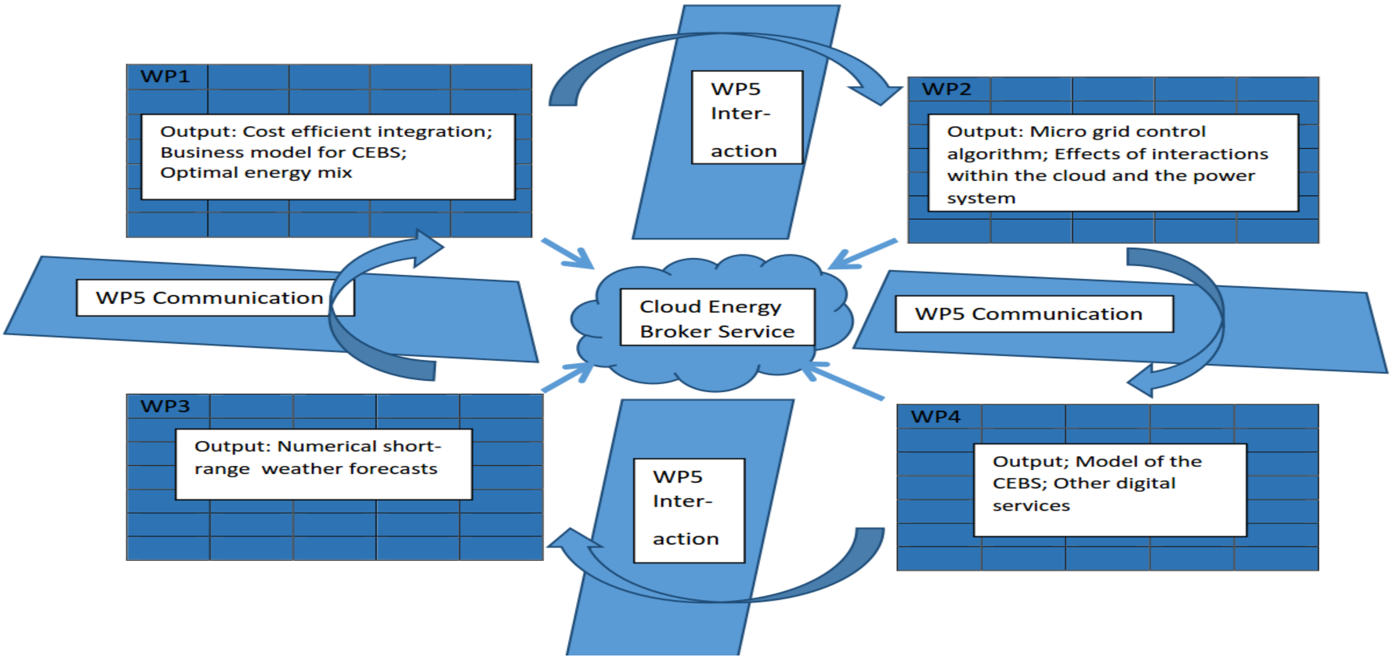
A novel, empirically piloted framework by Suorsa [40,41] consisting of the levels of the actual event of interaction and of the organizational circumstances of this event, allows a conceptually consistent examination of KC and information use. In Suorsa's framework interaction is understood as a communal and shared experience, a human being as a historical being connected inseparably with his context [47, see 41], and communication as a historical, experience-based event, that is understood as play formed by rules and presence in the course of actions [48,49]. According to Gadamer, the notion of play is both an event and an experience, which allows an examination of interaction on three dimensions: the structural dimension of the event, the temporal dimension of the experience, and the dimension of being in play. They also cause concern with the organization as a place of KC. Research combing the theoretical and methodological viewpoint of hermeneutical phenomenology with AT based developmental work related to interaction and communication in practice is a novel approach for increasing understanding of the complexity of KC in communities both in theory and practice.

Task 4. Contribution to the development of a potential ICT-based application/service for interaction of R&D projects of this kind (M1-M72)

The outcomes of Tasks 1, 2 and 3 will be integrated. First, a systemic literature review of research on KM tools and applications will be conducted (M1-M12). Both the discrepancies and solutions to them identified in Task 2 and human and organizational issues related to interactive events identifies in Task 3 could be taken into account in the requirements' analysis of a novel ICT-application for multidisciplinary and multiprofessional interaction also with citizens during a R&D project. All in all, the outcomes of Task 4 could be utilized in WP4 when developing the new cloud computing service.

The combination and deliverables of BC-DC are seen in the solar panels and wind mill of Figure 1.

Figure 1. The BC-DC research ecosystem



The core hypotheses of the project are:

H1. An efficient way of integrating large scale variable distributed energy supply can be created.

H2. Cloud computing based digital services play a central role in this solution.

H3. Short-range local weather forecasts play a central role in this solution.

H4. Export possibilities are created for private and social innovations.

These shall naturally be specified into more detailed sub hypothesis while work in progress.

The potential scientific breakthroughs are:

The modeling of two-sided distributed local energy market and cost minimizing solutions for integration costs (WP1). The micro-grid control algorithm that will run in the local cloud, including possible services (WP2). The development of production forecasts and integration into CBES (WP3). The development of the cloud computing based market place of electricity trading (CBES) (WP4). Contributing to the requirements' analysis of an ICT-application for interaction for R&D that is based on a theoretical, conceptually and methodologically consistent model of knowledge creation is a novel approach to KM research and applications. (WP5).

The core effects on the regeneration of science and research of BC-DC relate to achieving genuine multidisciplinary results from combining economic, engineering, meteorological and information science methods so that they will create concrete efficiency results in economically, socially and environmentally sustainable ways. The model of knowledge creation based on a phenomenological approach in relation to activity theory will provide new theoretical and methodological understanding of interaction and related factors in building, developing and maintaining R&D communities.

Applicability and utilisation potential of the research results builds on the fact that Finland is behind of many countries in this important development of integrating variable energy sources into the energy system. However, using the knowledge created elsewhere and combining it into our high quality scientific understanding of proper and efficient ways of proceeding in this important area creates great possibilities for scalable and exportable solutions. The developed ICT application can be used as a part of an interactive ICT-based service. A set of methods is provided for enhancing and developing interaction and creation of new knowledge in R&D. A "user-guide" in different formats to be delivered through a variety of channels will be provided for consumers as producers and other players at different levels of renewable energy systems. The Finnish Library

Association may be involved in environmental education of citizens (to be confirmed later on). The communal activities of BC-DC will finally lead to social innovations.

Critical points for success relate to genuine collaboration between the highly multidisciplinary team. To avoid possible clashes we put a high weight in our interaction plan where one part relates to creating common understanding and values between the research groups. Using the Activity Theory we can pinpoint contradicting avenues between different WPs. In studying the interaction and communication of the project especially Task 3 of WP5 concentrates on solving these possible contradictions. **Alternative implementation strategies** are based on our broad research network and good international relations.

Publication plan is strongly based on open access policy. We aim at publishing in top quality scientific journals and our dissemination and communication to the scientific community follows traditional routes. For dissemination and interaction with users and beneficiaries, and the general public see our interaction plan in chapter 11.

5 Research methods and material, support from research environment

Research methods

Co-operative game theory and social welfare calculations shall be used to develop the new market models and incentives for cost efficient large scale VER. Simple, autonomous, algorithms that are able to control the energy flow within the micro-grid and decide when to buy or sell energy shall be developed. Numerical short-range weather forecast methods will be developed. In order to evaluate the benefits we will perform model runs using new methods both individually and combined. We will explore the added value that the data yields especially on wind and solar energy production forecasts. The independent observation data from FMI network will be used in verification. Cloud computing methods shall be used in developing the Energy Broker Service and other digital services. Related to WP5 in Tasks 1, 2 and 3 ethnographic research methods applied include observations, video recordings, interviews, surveys, field diaries, and other material produced within the BC-DC Community. Task 1: Mapping of information needs through an ethnographic approach. Task 2 & 3:

Research material of BC-DC is mostly based on publicly available statistical and other data. New weather model data will be created during the project and existing weather observations from FMI and EUMETSAT will be used. We shall also, especially related to interaction conduct interviews, observation, surveys, video recordings.

Data management plan shall basically be based on open data principles. We shall obey informed consent processes when needed. In all data management questions we consult the Data Protector Officer of the University of Oulu. BC-DC receives all possible tangible support from the host universities and organizations. The research communities of INSPIRES and CoACT at the University of Oulu provide excellent support for the analysis of knowledge creation and interaction. Weather observations used in BC-DC include 9 radars and weather station measurement from FMI. All this data is routinely collected and archived. FMI has open data policy and a data portal, where the weather observations and operational numerical forecast can be downloaded without cost. Furthermore, FMI has a full access to EUMETSAT satellite data archive. Results from the new short-term modelling experiments will be stored in FMI central computers. New model results will be freely available upon request. All weather data is secured by rigorous archival and data back-up systems. We shall use LeaFORUM of the University of Oulu, which allows also the use of the observation technology MORE in ethnographic field research. We shall make the consortium agreement once the project starts and data management and intellectual property rights issues shall be settled there.

6 Ethical issues

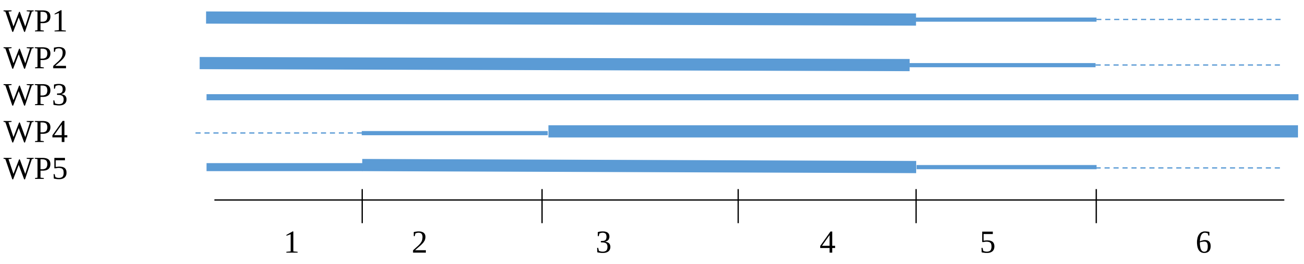
There are no special ethical research issues related to project methods or data. Related to ethical questions we use services of the Ethical Processes Officer of the University of Oulu. Ethical questions shall formally be settled in the consortium agreement.

7 Implementation: schedule, budget, distribution of work

Economic (WP1) and technical (WP2) modelling start with full steam from the beginning since they produce the necessary ingredients for the digital market place (WP4). Also weather forecasting (WP3) and interaction start strongly from the beginning. Especially interaction has its strongest face in years two, three and four. The digital services (WP4) has the greatest work load in the years three, four and five since the digital services are the taken from proof of concepts to actual markets.

The work schedule of different WP's is presented in Figure 2.

Figure 2. The schedule of the BC-DC project



8 Research teams, collaboration

WP1. Professor Svento has a long track of publishing in best environmental and energy economics journals. He has been leader of large Academy of Finland and TEKES funded projects (VRFlow, BWEBS). He has broad experience in academic management (Dean, University Vice President). Professor Maria Kopsakangas-Savolainen has in a short time become one of the leading energy economists in Finland. Doctoral student Juha Teirilä is finalizing his PhD thesis on photo voltaic development with professor Gowrisankaran. PhD student Hannu Huuki is finalizing his thesis on hydro power optimization in the Nordic energy market. PhD student Enni Ruokamo is doing her thesis on consumer attitudes towards hybrid heating systems using renewable energy sources.

WP2. Prof Matti Latva-aho, a graduate of and a professor in University of Oulu, has provided active leadership in broadband communications for 20+ years. He has managed to combine widely-cited research and academic credentials with highly relevant practical systems development which have led to global mobile phone standards. His pioneering work in multiuser CDMA for mobile radio systems and development of a large and well known research group to Oulu region, has had significant impact to global 3G and 4G standards development. He is currently heading the 5G research at CWC. His full credentials (CV and publications) as one of the CO-PI's are attached to this proposal. **Dr. Ari Pouttu** has his M.Sc. and Dr. Tech degrees from University of Oulu. The projects under his command have resulted waveforms and system designs for military radio communication, radar systems, embedded device networks, future wireless radio communications including cellular systems, cognitive networks and navigation applications. He has also been involved with architecture design for Finnish Software Radio including adaptive antennas and related algorithms. He has published more than 40 conference or journal papers in the field of wireless communications and he holds two patents. He was the Director of Centre for Wireless Communications in the University of Oulu from 2006 to 2012. Currently he is heading a research group targeting dependable wireless solutions for critical infrastructures including solutions for 5G. He is the coordinator of P2P-SmarTest H2020 project targeting a smarter electricity distribution system integrated with advanced ICT, regional markets and innovative business models employing Peer-to-Peer (P2P) approaches to ensure the integration of demand side flexibility and the optimum operation of DER and other resources within the network while maintaining second-to-second power balance and the quality and security of the supply. **Dr. Pedro Nardelli** received his doctoral double degree in Electrical and Communications Engineering from University of Campinas, Brazil, and University of Oulu in 2013. During his thesis, Dr. Nardelli evaluates the performance of several communication strategies of peer-to-peer wireless networks. Nowadays, Dr. Nardelli acts as a post-doctoral researcher in a project SUSTAIN whose goal is to build a new theory of modern power grids based on complexity science, jointly funded by Finnish Academy and CNPq-Brazil. **Mr. Florian Kühnlenz** received his M.Sc. in Technical Physics from the University of Ilmenau in 2013. In his thesis he worked on the influence of network topologies in Kuramoto oscillator models for power gird applications. His PhD work is focused on the complexity in multilayer engineering systems. He provides a strong background in numerical simulations and software development

for the team. **Mr. Maurício Tomé** received his M.Sc. in Power Systems from the University of Campinas in 2014. His work was about the impact of residential water heating in the formation of the "peak hour" in the Brazilian power grid. His main interests in his PhD are power and energy measurements and demand response.
WP3. Dr. Sami Niemelä is head of NWP-group and has 15 years experience on mesoscale NWP-models. Niemelä's expertise on physical parameterizations covers the key areas from the renewable energy point of view such as radiation [29], cloud [30] and wind related [31] processes. Niemelä was responsible for designing the modelling strategy for the Finnish Wind Atlas. Dr. Ander Lindfors has 14 years of experience on observing (both in-situ and remote sensing instruments) solar radiation. Lindfors was in charge of assessment of solar energy potential in Östersundom, Helsinki. Dr. Kirsti Salonen has 15 years of experience on data assimilation methods and use of observations. Salonen has been working as data assimilation expert in the world leading medium range weather forecasting center (ECMWF). Salonen was the person in charge in validating the Finnish Wind Atlas by using wind information from Doppler weather radar network. MSc Karoliina Hämäläinen (née Ljungberg) is a PhD student focusing on meteorological applications for supporting wind energy production in Finland.
WP4: Prof. Jussi Kangasharju received his MSc from Helsinki University of Technology in 1998. He received his Diplome d'Etudes Approfondies (DEA) from the Ecole Superieure des Sciences Informatiques (ESSI) in Sophia Antipolis in 1998. In 2002 he received his PhD from University of Nice Sophia Antipolis/Institut Eurecom. In 2002 he joined Darmstadt University of Technology (TUD), first as post-doctoral researcher, and from 2004 onwards as assistant professor. Since June 2007 Kangasharju is a professor at the department of computer science at University of Helsinki. Between 2009 and 2012 he was the director of the Future Internet research program at Helsinki Institute for Information Technology (HIIT). His research interests are information-centric networks, content distribution, opportunistic networks, and green ICT. He is a member of IEEE and ACM. Dr. Suzan Bayhan received her PhD from Bogazici University, Computer Engineering Department, Turkey in 2012. Since August 2012 she has been a postdoctoral researcher at University of Helsinki working on mobile opportunistic networks and information-centric networks. She has over 20 publications, almost 300 citations and h-index of 8 (Google Scholar).
WP5. *Prof. Maija-Leena Huotari's* research focuses on information and knowledge management, and on human information behavior and practices in different contexts including everyday life, work, and health. She was Leader of project Health Information Practice and its Impact, and of a sub-project of SALVE Programme's PrevMetSyn Consortia on the use of new ICT to prevent diseases related to lifestyle, both funded by the Academy of Finland in 2008-2012. She was involved in multidisciplinary MOPO-studies coordinated by Oulu Deaconess Institute and funded e.g. by TEKES and EU/EAKR. Prof. Huotari is PI of Institutions and Practices of New Literacies (INSPIRES) Research Community and a member of the Steering Committee of the Joy of Reading (Lukuinto) program funded by the Ministry of Education and Culture and conducted at the University of Oulu in 2013-2015. She has published widely in international journals and is a member of the editorial board of *Information Research*, UK. *Post doc Researcher Anna Suorsa* is a doctoral student of the national doctoral program in Communications Studies since 2012 and working on her doctoral thesis "*Hans-Georg Gadamer's concept of play in understanding the interaction in knowledge creation situations*" to be defended in 2016. *Communications Specialist (50%) and doctoral student (50%) Kaisu Innanen* is the communication's professional of the Ministry of Education and Culture funded Joy of Reading program from 2014 to 2015 with impressive outcomes:400 articles published in the Finnish press within a year and tight collaboration with partners, such as, Finnish schools and libraries, Communications' Units of the Ministry of Education and Culture, The Finnish Library Assocation, MLL Mannerheim League for Child Welfare, Finnish Parents' League, Veikkaus, and National Audiovisual Institute. She received her MA on speech communication from the University of Jyväskylä in 2003 and received MA on literature from the University of Oulu in 2011. *Research Assistant Kaisa Ikonen* received her MA in Information Studies in 2014. She was Planning Officer in MOPO-Tuning project in 2014 and is currently in the Joy of Reading Program from 2014 to 2015.

National and international collaboration and its significance for project implementation.

The project has large and active international collaboration. Project partners coordinate and participate in the H2020 project P2P. The economic group (WP1) collaborates with one of the leading current energy economics researcher professor Gautam Gowrisankaran from the Arizona State University. We also have active collaboration with the Center of Environmental and Resource Economics in Umeå. For WP2 collaboration involves: Prof. Luiz C. Pereira da Silva's group from Department of Energy Systems in the School of Electrical and Computer Engineering at University of Campinas, Brazil; Dr. Murilo S. Baptista (Reader), Institute for Complex Systems and Mathematical Biology, Scottish Universities Physics Alliance, University of Aberdeen, Scotland and visiting researcher in the Physics Institute at University of São Paulo, Brazil; Dr. Bernardo Alves Furtado, Department of Regional, Urban and Environmental Studies and Policy, Institute for Applied Economic Research, Secretariat of Strategic Affairs of the Presidency of the Republic Brazil. For WP3 the collaboration is sought within the HIRLAM-B and ALADIN consortia members. DA: KNMI,SMHI, SOLAR/WIND/PARAM: SMHI,MetNo. This project will also cooperate with other national projects and research programs, such as VaGe and New Energy program (Academy of Finland. Potential collaborating scholars abroad for WP5 are: Assoc.Prof. Ronald Day, University of Indiana, USA, who has deep expertise in hermeneutical phenomenology and Prof. David Allen, University of Leeds, Business School, UK, who is the most prominent scholar of Information Sciences on Activity Theory and information systems development within organizational settings. Prof. Marianne Ryghaug, Dept. of Interdisciplinary Studies of Culture, Centre for Sustainable Energy Studies – CenSES, Norwegian University of Science and Technology, Norway, whose research interests include energy and everyday life, the cultural dynamics of new renewable energy technologies, environmental communication, science and innovation policy.

9 Mobility plan

BC-DC has current deals of co-operation and mobility with the Center of Resource and Environmental Economics (CERE), University of Austin Tucson, University of StAndrews, University of Bath. FMI’s BC-DC-team will utilize the working visit practices between modeling consortium members. Detailed mobility arrangements shall be made during the project.

10 Key literature or bibliography

[1] S. Bera et al., “Cloud Computing Applications for Smart Grid: A Survey.” IEEE Transactions on Parallel and Distributed Systems, Vol. 26, May 2015.
[2] S. Rusitschka et al., “Smart Grid Data Cloud: A Model for Utilizing Cloud Computing in the Smart Grid Domain.”
[3] C. Hägerling et al., “Communication Architecture for Monitoring and Control of Power Distribution Grids over Heterogeneous.” IEEE International Energy Conference ICT Networks (ENERGYCON), 2014
[4] Hirth, L., Ueckerdt, F., Edenhofer, O. (2015). Integration Costs Revisited – An Economic Framework for Wind and Solar Variability. Renewable Energy 74: 925-939.
[5] Kopsakangas-Savolainen, M. and Svento, R. (2013) Economic Value Approach to Intermittent Power Generation in the Nordic Power Markets, *Energy and Environment research,* Vol. 3 (2), 139-155.
[6] Gowrisankaran. G., Reynolds, S., Samano M., (2014). Intermittency and the Value of Renewable Energy. NBER Workin Paper No. 17086
[7] Kopsakangas-Savolainen, M., Svento, R. (2012). Real-Time Pricing in the Nordic Power Markets. *Energy Economics*, Vol 34, Issue 4. pp. 1131-1142
[8] Rochet, J.-C. and Tirole, J. (2003). Platform competition in two-sided markets. Journal of the European Economic Association June 1(4), 990-1029.
[9] Rochet, J.-C., Tirole, J. (2006). Two-sided markets: a progress report. The Rand Journal of Economics, Autumn, 37, 3, 645-667.
[10] Parker, G. and Van Alstyne, M. (2005). ``Two-Sided Network Effects: A Theory of Information Product Design.” Management Science, Vol. 51, No. 10.
[11] Chalkiadakis, G., Robu, V., Kota, R., Rogers, A and Jennings, N. R. (2011). Cooperatives of distributed resources for efficient virtual power plants. Proc. of 10th Int. Conf. on Autonomous Agents and Multiagent Systems – Innovative Applications Track (AAMAS 2011), Tuner, Yolum, Sonenberg and Stone (eds.).
[12] Energy and Climate Roadmap 2050. Report on the Parliamentary Committee on Energy and Climate Issues on 16 October 2014. Publications of the Ministry of Employment and the Economy Energy and the climate 50/2014.
[13] Chakravorty, U., D. Krulce, and J. Roumasset. 2005. “Specialization and non-renewable resources: Ricardo meets Ricardo.” *Journal of Economic Dynamics and Control* 29:1517-1545.
[14] Y. Simmhan et al., “An Analysis of Security and Privacy Issues in Smart Grid Software Architectures on Clouds.” IEEE International Conference on Cloud Computing (CLOUD), 2011.
[15] B. Genge et al., “A survey on cloud-based software platforms to implement secure smart grids”, 49th International Universities Power Engineering Conference (UPEC), 2014.
[16] P. H. J. Nardelli et al., “Models for the modern power grid.” The European Physical Journal Special Topics 223.12 (2014) 2423-2437.

[17] V. Gungor et al., “A survey on smart grid potential applications and communication requirements.” IEEE Transactions on Industrial Informatics 9.1 (2013) 28-42.
[18]. W. Saad et al., “Game-theoretic methods for the smart grid: an overview of microgrid systems, demand-side management, and smart grid communications.” IEEE Signal Processing Magazine 29.5(2012) 86-105.
[19] L. Qian et al., “Demand response management via real-time electricity price control in smart grids.” IEEE Journal on Selected Areas in Communications 31.7 (2013) 1268-1280.
[20] M. Simonov, et al, “Gathering Process Data in Low-Voltage Systems by Enhanced Event-Driven Metering.” IEEE Systems Journal (to appear, 2015).
[21] David P. Chassin et al., “GridLAB-D: An agent-based simulation framework for smart grids.” Journal of Applied Mathematics (in press, 2014)
[22] Salonen K., Järvinen H., Haase G., Niemelä S. and Eresmaa R. (2009): Doppler radar radial winds in HIRLAM. Part II: optimizing the super-observation processing. Tellus, 61A, 288-295.
[23] Tammelin, B., and 13 co-authors (2013), Production of the Finnish Wind Atlas. Wind Energy, 16: 19–35. doi: 10.1002/we.517
[24] Ljunberg K., Niemelä S. (2011): Finnish Icing Atlas, Proc. European Wind Energy Event EWEA, Brussels, Belgium, 11-17 March 2011, 6 pp.
[25] Lindfors, A., Riihelä, A., Aarva A., Latikka J., Kotro J. (2014): Auringonsäteily Helsingin Östersundomissa, Ilmatieteen laitos Raportteja 2014:5.
[26] Salonen K., Cotton J., Bormann N., and Forsythe M., (2015): Characterizing AMV Height-Assignment Error by Comparing Best-Fit Pressure Statistics from the Met Office and ECMWF Data Assimilation Systems. J. Appl. Meteor. Climatol., 54, 225–242.
[27] Arola A., Lindfors A., Natunen A., and Lehtinen K. (2007): A case study on biomass burning aerosols: effects on aerosol optical properties and surface radiation levels. Atmospheric Chemistry & Physics, 7:4257–4266.
[28] Inness A. and 30 co-authors (2013): The MACC reanalysis: an 8 yr data set of atmospheric composition. Atmos. Chem. Phys., 13, 4073–4109.
[29] Niemelä S., Räisänen P. and Savijärvi H. (2001): Comparison of surface radiative flux parameterizations Part II: Shortwave radiation. Atmos. Res., 58, 141-154.
[30] Niemelä S,, Fortelius C. (2005): Applicability of large scale convection and condensation parameterization to meso-gamma-scale HIRLAM: a case study of a convective event, Mon.Wea.Rev, 133, No. 8, 2422-2435.
[31] Savijärvi H., Niemelä S. and Tisler P. (2005): Coastal winds and low level jets: Simulations for sea gulfs. Q. J. R. Meteorol. Soc., 131, No. 606, 625-637.
[32] J. Markkula and J. Haapola, “LTE and Hybrid Sensor-LTE Network performances in Smart Grid Demand Response Scenarios,” the 4th IEEE International Conference on Smart Grid Communications (SmartGridComm 2013 Symposium - Demand Side Management, Demand Response, Dynamic Pricing), Vancouver, Canada, 21-24 October 2013.
[33] J. Markkula and J. Haapola, “Impact of Smart Grid Traffic Peak Loads on Shared LTE Network Performance, ”IEEE International Conference on Communications (ICC) - Selected Areas in Communications Symposium, pp. 2639-2644, Budapest, Hungary, 9-13 June 2013.
[34] L. Goratti, J. Haapola and S. Kato, “Highly Reliable Star and Sub-Mesh Hybrid Sensor Network for Smart Grid Monitoring”, IEEE Global Communications Conference 2012 Work- shop on Smart Grid Communications: Design for Performance (SGComm’12), pp. 1480- 1485, Anaheim, CA, USA, December 3, 2012.
[35] H. Karvonen · J. Suhonen · J. Petäjäjärvi ·M. Hämäläinen · M. Hännikäinen · A. Pouttu, “Hierarchical Architecture for Multi-Technology Wireless Sensor Networks for Critical Infrastructure Protection”, WirelessPersonalCommunications:Volume76, Issue 2 (2014), Page 209-229.
[36] Nonaka, I. (1994) A dynamic theory of organizational knowledge creation’, *Organization Science*, vol 5, no 1, pp 14-37.
[37] Nonaka, I., Toyama, R. & Konno, N. (2000) SECI, ba and leadership: a unified model of dynamic knowledge creation, *Long Range Planning*, vol 30, pp 5-34.
[38] Huotari, M.-L. (2010) Knowledge creation and use in organizations. In M. Bates & M.N. Maack (Eds.) *Encyclopedia of Library and Information Sciences*, 3rd ed., New York, NY: Taylor & Francis Group.
[39] Tsoukas, H. (2009) A dialogical approach to the creation of new knowledge in organizations’, *Organization Science,* vol 20, no 6, pp 941-957.
[40] Suorsa, A. & Huotari, M.-L. (2014a) Knowledge creation and the concept of human being: A phenomenological approach, *Journal of the Association for Information Science and Technology*, vol 65, no 5, pp 1042-1057.
[41] Suorsa, A. (2015, in press) Knowledge creation and play – a phenomenological approach, *Journal of Documentation*, vol 71, no 3. (Available on early view http://www.emeraldinsight.com/doi/abs/10.1108/JD-11-2013-0152)[April 19, 2015]
[42] Day, R.E. (2005) “Clearing up "implicit knowledge": implications for knowledge management, information science, psychology and social epistemology. *Journal of American Society for Information Science and Technology,* vol 56, no 6, pp 630-635.
[43] Suorsa, A. & Huotari, M.-L. (2014b) Knowledge creation in interactive events. A pilot study in the Joy of Reading Program. *Information Research.* [Open access, available at http://www.informationr.net/ir/19-4/isic/isic02.html#.VTd0t02KCUk] [April 22, 2015]
[44] Vygotsky, L.S. (1978) *Mind in society: The development of higher psychological processes*. Cambridge MA: Harvard University Press.
[45]Wilson, T.D. (2008) Activity theory and information seeking. In Blaise Cronin (Ed.) *Annual Review of Information Science and Technology, ARSIST*, vol 42, pp 119-161.
[46]Engeström, Y. (1999) Innovative learning in work teams: analyzing cycles of knowledge creation in practice. In: Y. Engström, R. Miettinen & R.-L. Punamäki (Eds.) *Perspectives on activity theory*. Cambridge: Cambridge University Press, pp 377–404.

[47] Heidegger, M. (1985) *Being and time*, Oxford, UK: Blackwell.
[48] Gadamer, H.-G. (2004) *Truth and method*, London, UK & New York, NY: Continuum.
[49] Gadamer, H.-G. (1999) Die Aktualität des Schönen. Kunst als Spiel, Symbol und Fest, in *Gesammelte Werke 8: Ästhetik und Poetik 1: Kunst als Aussage*, Tübingen: J.C.B. Mohr, pp. 34-143.

11 Interaction plan

'*All we need to do is make sure we keep on talking*'
Pink Floyd The Endless River (2014)

The BC-DC Consortium engages its partners throughout the project's life cycle effectively by co-creating and interacting with them as citizens and consumers, civic organizations, firms including their wider networks of stakeholders and clients, municipalities, and governmental decision makers. Interaction and communications with them are professionally managed involving also the partners' communications' units.

11.1 Objectives of interaction

The aim of interaction is to enable effective co-creation and co-production of the outcomes of the BC-DC Consortium as a whole. The objectives of interaction are outlined as follows: *Establishing a BC-DC Community; Engaging citizens as active partners in the activities of the BC-DC Community; Setting up a forum for industrial partners in the energy sector; Integrating knowledge and knowing of the researchers of WPs 1 to 5 and the partners involved during six years; Setting up, developing and maintaining a knowledge base of the BC-DC Community; Informing political decision makers about the outcomes of the BC-DC Consortium; Enhancing changes in regulations and legislation related to energy production and market principles.*

11.2 Partners

The interaction partners are among the key players in the field of ICT and the renewable energy system in Finland and together constitute a wide forum for mobilization of research results as well as a notable target audience for the communications' efforts (e.g communicating the results of WPs in an attractive way to the forum of the industrial partners to be organizes later on). Finnish Local Renewable Energy Association (Suomen Lähienergialiitto ry)[1], has a key role from 2015 onwards, since their members include approx. 40 communities (firms and associations), which through their networks provide contacts with consumers and citizens. Thus, this partnership enables informing other potential partners to join the new market places and services. This applies also for the Carbon Neutral Municipality Forum[2] consisting of 21 municipalities in Finland. The Finnish ICT firms, involved through Finnish Federation for Communications and Teleinformatics (FiCom)[3] are very active players in the new market. FiCom is a co-operation organization, whose members are companies and other players in the ICT sector in Finland. The total turnover from Finland of FiCom's members is about EUR 6 billion, and approx. 40 000 people work in their different locations. Cleworks[4] in turn, is the firm that will be involved in developing the technical device to be used by the consumers of renewable energy. The role of these two organizations, including the wide network of contacts they provide, will be the strongest in 2018, 2019 and 2020. Energy Authority in Finland (Energiavirasto)[5] is responsible for the new regulation and the legal changes needed; its role is critical in 2019, 2020 and 2021.

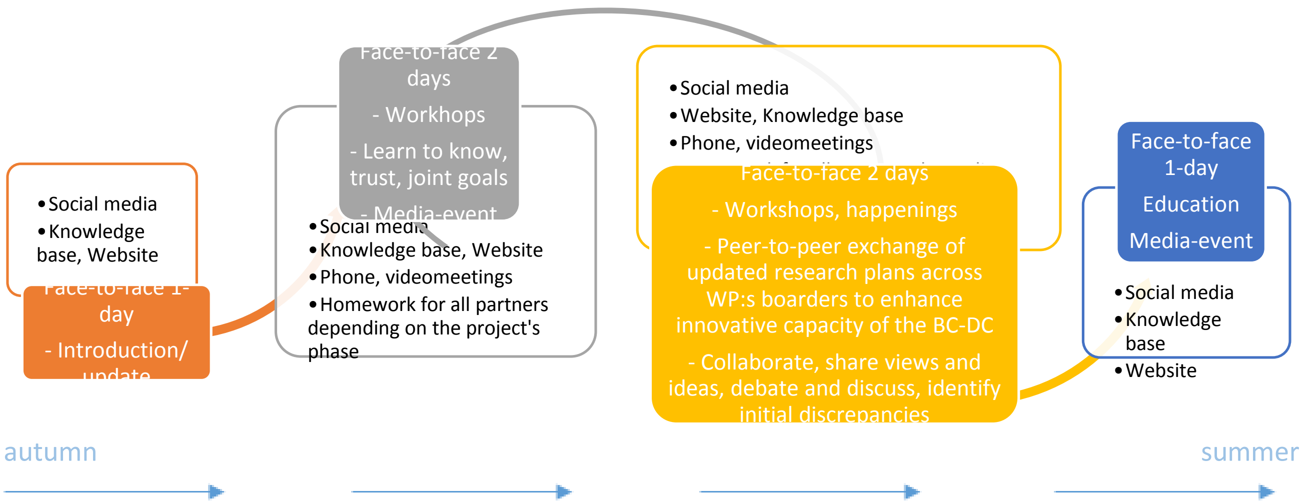
The partners' knowledge and knowing of the fields they represent is pre-mapped. Their information needs will be further investigated and the crucial information organized and constantly developed to form the knowledge-base of the BC-DC Community through research on Information Sciences. The aim is to enhance fulfilling the partners' information needs to establish new everyday practices in their fields of activity and the WPs' needs for information from the partners through tight interaction. Active involvement will ensure the partners' ability to utilize the Community's knowledge base. (See WP5.) The partners present a variety of fields of interests and discourses. Thereby the Consortium's communicative competence is assured within a variety of interaction and communications conventions. The changes will occur in at least the following fields of activity in society: *consumers' behavior, financial energy markets including the role of ICT firms and larger enterprises, technology used in the production and delivery of energy, products and services provided, regulation and legislation, environmental issues and environmental and science education.*

11.3 Means of interaction

Mutual sharing of the aims of the BC-DC Community is essential for the interaction to succeed. The aims will be defined within the Community. The most relevant forums and means needed for tight interaction will be designed in close collaboration with the partners on the basis of participative discussions in workshops to enable true interaction. Shared understanding and decisions made of the partners' roles at different stages of the project will ensure their involvement in and commitment to joint activities from 2015 to 2021.

Relevant forums and means will be selected and used depending on the stage of the project and the purpose of the co-creating or/and co-producing event (see WP5/Tasks2&3). A website and a closed social networking site/sites on different fields of interest for the BC-DC Community as well as for the public will be set up first in the beginning of the project. In 2015 and 2016 the importance of face-to-face interaction is evident to enhance sharing views and ideas, debating and discussing within the Community for defining the joint goals and objectives, learning to know and trust each other and to collaborate and enhance motivation. The means include workshops, events and happenings for all Community members, and also "homework" for deepening the understanding of the other WPs' research. The number of these gatherings needs to be sufficient especially in 2015 and 2016: four events a year, of which two events should take for two days. The other means of interaction utilizing existing ICT applications and services, social media apps as well as establishing active media relations become relevant towards the end of the project. Besides researchers of the WPs and the partners, engaging citizens as consumers to enlarge the Community towards wider public will be crucial in 2018, 2019, 2020 and 2021. A detailed outline of the themes and means for interaction during the first ten months is presented in Fig. 3. Later these will depend on, alter and comply with the WPs' progress.

Figure 3. Themes and means for interaction and related dynamics for first ten months.



Media and journalists will be proactively contacted and good media relations utilized during the project. The variety of target groups will be addressed through different channels and media including newspapers, magazines, radio and tv, e-journals, and a wide set of scientific and professional journals, online communities and social networking sites of the partners' different fields of expertise as well as social media applications for the public including emerging applications for interaction. Moreover, nation-wide media events with press releases (with e.g. Epressi.com) will be organized along with the events provided for the Community to interact (see Fig. 3). The progress of the WPs' research work constitutes the frame for focusing the different communications' activities (see Fig. 3). The Consortium will organize/co-organize an international conferences especially aimed for the forum of the industrial partners and decision makers.

Partners benefit of holding the BC-DC project as a part of their reputation and image, and distinctly visible in their internal and external communications. Moreover, the partners will be encouraged to continuously utilize and promote their involvement in the BC-DC Community in their communications and with media contacts from their own perspective. By spreading the benefits of belonging to the Community from the partners' different viewpoints a wider network of citizens, groups of interest, stakeholders and clients

(1) http://www.lahienergia.org/ | (2) (http://www.hinku-foorumi.fi/en-US | (3) http://www.ficom.fi | year an
(4) www.cleworks.fi | (5) https://www.energiavirasto.fi/en/web/energy-authority/ ced and

shared to the partners' organizations, addressed to their members and clients.

The key messages, visual identity, media kits, etc. materials are produced by the Communications Specialist together with the partners' communications' units. Communications Specialist also joins the Consortiums' management team meetings. Communication actions and mediamonitoring related to the members' fields of interests are shared within the Community by e.g. Webnewsmonitor-service. If successful, proactivity with media and communication may span the national boundaries of Finland.

11.4 Responsibilities and implementation

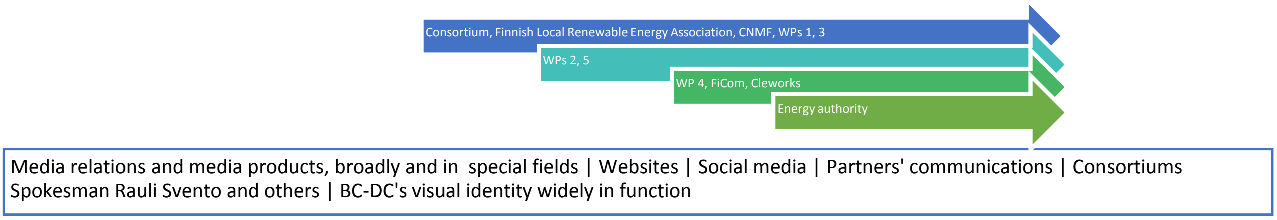
The strength of this interaction plan is that it is based on a scientific approach which enables examination of its operational efficiency and effectives during the six years and beyond (see WP5). The objectives for interaction are further developed on the basis of the key findings of the disciplines and fields of activity within the BC-DC Community. Prof. Huotari is responsible for this part of the plan. Communications Specialist (part-time 50%) is MA Kaisu Innanen (see CV).

PI of the BC-DC Consortium, Prof. Svento is the figurehead and the team leaders and researchers of all WPs will be communicating in scientific and public forums about their projects. The Consortium's partners have routines with societal influence and also have highly professional communications' staff. The Consortium's Communications Specialist will manage the communication's team involving the partners' communications' units also for developing further the partners' Public Affairs (Lobbying).

11.5 Schedule

Types of interaction with the partners are outlined in Figure 4. Schedule for communications is outlined in Sub-Chapter 11.3.

Figure 4. Focus of external communications in 2015 – 2021.



The purpose of setting up the BC-DC Community is to support the partners' abilities to utilize the new knowledge and innovations created through their active involvement in co-creation and co-production. The research data created in the project will be organized and stored by utilizing appropriate technology that will be selected by the end of 2015. The relevant part of the data will be transferred to the Finnish Social Science Data Archive (Yhteiskuntatieteellinen tietoarkisto, http://www.fsd.uta.fi/en/) and possibly to other open infrastructures for scientific research.