

FINAL REPORT

PROJEKT 2015-1-12314

EConGrid

February 2015 – January 2017



(Rønne, Bornholm. Eget foto)

Final report

1.1 Project details

Project title	EConGrid – Energy Cool ApS on GRID
Project identification (program abbrev. and file)	Energinet.dk project no. 2015-1-12314
Name of the programme which has funded the project	EnergiNet / ForskEL
Project managing company/institution (name and address)	Henrik R. Thorsen Energy Cool ApS Navervej 10 DK-7000 Fredericia
Project partners	Orogenic ApS, KPR Consult A/S
CVR (central business register)	DK 33067135
Date for submission	24.3.2017

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1.2 Short description of project objective and results

The main objective of the project was to collect data and information necessary to build a business case viable for the market; data on batteries such as stability, life-time and utilization for balancing the grid, management of power data and settlement forms for this type of services. The project also researched what types of communication channels are needed to prepare the unique concept of Energy Cool's for the market.

Data collected shall be precise and secure enough to build a business case on, in order to sell a 1 MW demonstration installation to one of the telecom operators in Denmark.

The project also aimed to clarify how all user requirements from the TSO, balance responsible parties (BRP) and from telecom operators can be accommodated to provide a viable and commercially attractive market solution.

Energy Cool's battery tests confirmed the thesis that batteries at tele sites benefit from ongoing control, exercise and monitoring. This prolongs the life-time of batteries and thus enables economical as well as environmental savings.

Results collected during the project confirmed that utilization of tele sites for balancing the grid is technically and practically feasible, although the original business model needs to be changed and adapted in order to be commercially profitable. The collected data enabled Energy Cool to prove to the customers, that communication with a site is possible and fully under control. The project's success in data collection and analysis therefore enabled Energy Cool to sell the 1 MW demonstration project to a customer – telecom operator with a deep interest in the developed solution.

1.3 Executive summary

The purpose of the project Energy Cool was to investigate and clarify a business case for activation of emergency power batteries in tele sites, owned by telecom operators, and its utilization for the quick balancing of the power grid while at the same time securing undisturbed power necessary for basic operation of the tele sites.

The project focused on testing batteries, data communication through customer's network, evaluation of tests and interpretation of collected data, aggregation of tele sites as well as generating data and information necessary for building a viable business case ready for the market.

Several tele sites were integrated in Energy Cool test environment, called Cool Universe, where multiple tests were performed, giving opportunity to test in an optimal environment.

The project has built on project EcoGrid Bornholm and the former ForskEL supported project No. 12002, Regulating power from tele sites. Tests and collected data as well as telecom operators' response to them have shown that the technical solution is

attractive for the market. The project results however have pointed out that the proposed business model is not viable for the market, but it needs a significant modification in order to be commercially attractive.

1.4 Project objectives

Primary focus and overall purpose of the project has been to conduct research of batteries at tele sites, collect data and practical experience with batteries in order to assess a possibility of using tele sites as energy storage suitable for balancing the grid. The project can be seen as a bridge between the current technical solution and the customers' acceptance of a possible market solution.

The initial project work started in November 2015, according to the agreement and a commitment made to Energinet.dk.

At the EC Group headquarter, Navervej 10, Fredericia, Energy Cool have built its own test environment, Cool Universe, in which accurate copies of tele sites as well as real tele sites have been integrated. The first tele site, Bornholm was returned home from project EcoGrid Bornholm, where tele sites with batteries simulated electric vehicles. At that time, electric vehicles were not yet present at Bornholm. Other 3 sites in Cool Universe were built to simulate tele sites. For the purpose of this project, Cool Universe expanded with in total seven (7) real-life tele sites (Faaborg). Each tele site has 4-8 batteries of 12 V each and consumes approximately 3 kW. Some tele sites contain 12 batteries. There are different types of batteries used around at tele sites in Denmark.



Energy Cool has used Cool Universe for performing tests and collecting the data.

Testing has focused on the best utilization of existing batteries, aggregation methods, measuring equipment, data acquisition and settlement methods.

The project team has conducted intensive research, practical tests as well as numerous interviews with experts on relevant technology and telecom operators, in order to determinate the best technical solution, limits and success parameters.

The team performed ongoing user evaluation of the project and its idea, evaluation of software, business model and technical solutions.

The project team identified several stakeholders whose interests need to be taken into consideration for the project to succeed on the market terms. Close cooperation between project partners and stakeholders has proven to be essential. Energy Cool have received a lot of valuable input from telecom operators, project partners, suppliers of technologies and from the TSO Energinet.dk.

Energy Cool has initiated preparations for development of an aggregation software that would be able to pool together 100 000 of small and medium-sized tele sites or other units. The goal is to monitor, forecast and control their ability to deliver energy for balancing the grid in an adequate volume.

The project has at large been executed as planned, but Energy Cool has experienced challenges that needed attention, especially regarding the business model and the use of inverter, as described below.

There have been several risks associated with the project. One of them is both economic and structural, related to the future development in energy markets, especially balancing and reserve markets.

- How likely is it that the solution, Energy Cool has been trying to develop in this project, is going to be accepted at all by the TSO Energinet.dk and integrated in future market rules?
- How likely is it that Energy Cool is going to be allowed to participate on same terms as traditional power producers?
- How are prices of ancillary services going to develop in the future? Questions about the prices of batteries and the rules in telecommunication sector?
- Are there any existing policies that may hinder application of this solution in the future?
- Are batteries technically capable of performing for the grid? What is the real approach of telecom operators to their tele sites, are they going to be willing to allow their utilization for energy markets and under what conditions?
- What requirements will be placed on Energy Cool in case telecom operators decide to invest in the solution?
- Will Energy Cool be able to develop the solution and the business model quickly enough as to be first-mover on the market and win a direct advantage?

The work has included tasks as:

- Clarification of user needs and security parameters.
- Ongoing dialog with stakeholders like Energinet.dk, project partners, telecom operators and suppliers of chosen technologies.
- Clarification of market rules and existing -legislation relevant for application of the technical solution in balancing market.
- Clarification of settlement methods in a working group with Energinet.dk.
- Clarification and definition of battery testing methods and testing needs.
- Actual testing of batteries and monitoring charge and discharge cycles.
- Research on battery life-time, handling and use of second-life batteries.
- Collection of data from tele sites implemented in Cool Universe, data interpretation and creation of a communication platform between tele sites and the software solution.

- Clarification of security demands set by telecom operators – limits for battery use and buffer for minimum emergency reserve on a tele site – definition of parameters necessary for no interference with customers’ business operations.
- Dialog with different suppliers of technical solutions as well as a dialogue with specialized experts to get insight, knowledge and experience necessary for the project (batteries, inverter, rectifier, electricity metering, balancing and reserve markets, settlement, IT security, servers, databases, aggregation, monitoring and remote communication).
- Research on user needs regarding hardware, software, installation and business processes involved in implementing the technical solution at a site.
- Business architecture of the software solution as well as programming (coding) itself.
- Economic calculations and evaluations of intended business model.
- Project management / Coordination of all project activities.

1.5 Project results and dissemination of results

In the initial stage of the project, Energy Cool has executed brainstorming meetings with several telecom operators in order to get access to their used batteries, as well as to set up testing of new batteries of one type. The purpose was to build-up basic data and knowledge for further project. Batteries from tele sites have been collected in various different conditions and implemented in Cool Universe.





Energy Cool has collected 10 tons of batteries from locations in Funen and Jutland.

Work package 1 and 2: Research on batteries and battery tests

Batteries in telesites have been tested simultaneously with batteries in EConGrid lab environment, as planned. In order to do so, Energy Cool has improved testing facilities, performed research on batteries, battery types, testing batteries, designed battery tests suitable for the purpose of this project and performed continuous optimization based on the ongoing results.

From early on, the research focused on possible best utilization of existing battery parks in tele sites and mapping. What condition are these batteries in? The goal was that the data collected should give a representative picture of 60.000-80.000 batteries (equivalent to 60-80 MW) waiting for their full utilization at tele sites and a representative picture of their delivery effect in 1 – 15 min.

Energy Cool performed a test of batteries in a “marathon”, meaning delivery from batteries in a very long time, over couple of months – in order to find out, how much can actually be delivered from a single battery group with 4 batteries connected in series were good with more than 3000 deliveries. In the process, it was necessary to perform continuous adjustment of use and safety parameters for batteries.

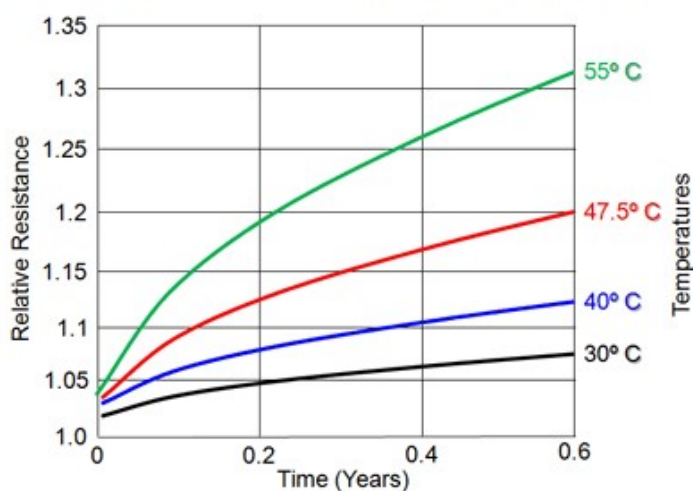
Based on the tests, Energy Cool can prove that active participation of batteries in system services market would not decrease their performance / value. For example, a test ongoing several months, 24/7 from July 2016, with 8 deliveries from a single battery group per day has shown that after several months, battery capacity remains almost unchanged. Energy Cool therefore concludes that batteries from telesites can be used for balancing the grid min. 2 times per day. Tests confirmed that batteries at tele sites benefit from ongoing control, exercise and monitoring, as this prolongs their actual life-time and enables economical as well as environmental savings.

The test results are an essential part of the unique know-how built in this project and an imperative for Energy Cool ability to be able to sell the solution on the market. Further more Energy Cool has developed own battery testing procedure, suitable for the purpose of the project, as well as procedures to prepare batteries before a cycle test, in order to gather results that could be verifiable and widely approved. This extensive testing has naturally caused a great challenge in form of growing electricity

bills, which had to be paid during the project period. These extra costs for electricity were not anticipated before the project.

Another challenge has been that battery producers in their product description guarantee up to 1200 charging and recharging cycles and do not view battery exercise as positive contribution to battery lifetime. This may also be caused by the fact that battery producers do not have a commercial interest in prolonging battery lifetime. To the EC Group's internal knowledge, no battery producer Energy Cool have been in contact with has performed such extensive tests on their batteries as to have enough data for a valid conclusion on that matter. Battery producers focus in their testing on how outside conditions, such as temperature, affects battery lifetime. The direct correlation between the parameters has been proved:

Increasing Internal Resistance with Time and Temperature



Empirical models { $t^{1/2}$ time dependency
Arrhenius (temperature T) relationship

Battery producers so far remain conservative in their view on battery use and battery lifetime.

Work package 3: Research on aggregation methods

For telesites to be able to deliver sufficient effect to the power grid, it is necessary to aggregate a majority of the approximately 10,000 telesites dispersed over Denmark. Aggregation of tele sites can be performed only when telecom operators' requirements for security, reliability and level of control can be implemented. As a result hereof, relevant knowledge and available data from other projects have been collected (EcoGrid Bornholm). Energy Cool has spent many hours on learning about and understanding telecom operators' processes, requirements, needs and demands, in order to implement them in technical and business solutions. The project team performed research on Smart Grid systems and which of them would be applicable to the specific needs.

During the project, Energy Cool have performed comprehensive research on data collection, databases, control and data communication. Getting data on their own battery parks is one of the most interesting aspects of this project for future customers – telecom operators. In order to be able to collect, store, organize and manage large amount of data, Energy Cool will have to work extensively on information architecture and software part of the solution. As a result, work on a software part, in order to define, how to make use of the collected data in the future, has been started.

In order to adapt hardware as well as software to match the requirements of this project, it has been necessary to conduct further optimization of internal work procedures. Existing technical solutions have been consulted and tested with various suppliers. Project discussions and meetings were held with several Danish and international producers (for example inverter producer in China and the access of the inverter on the approved list of producers of Energinet.dk).

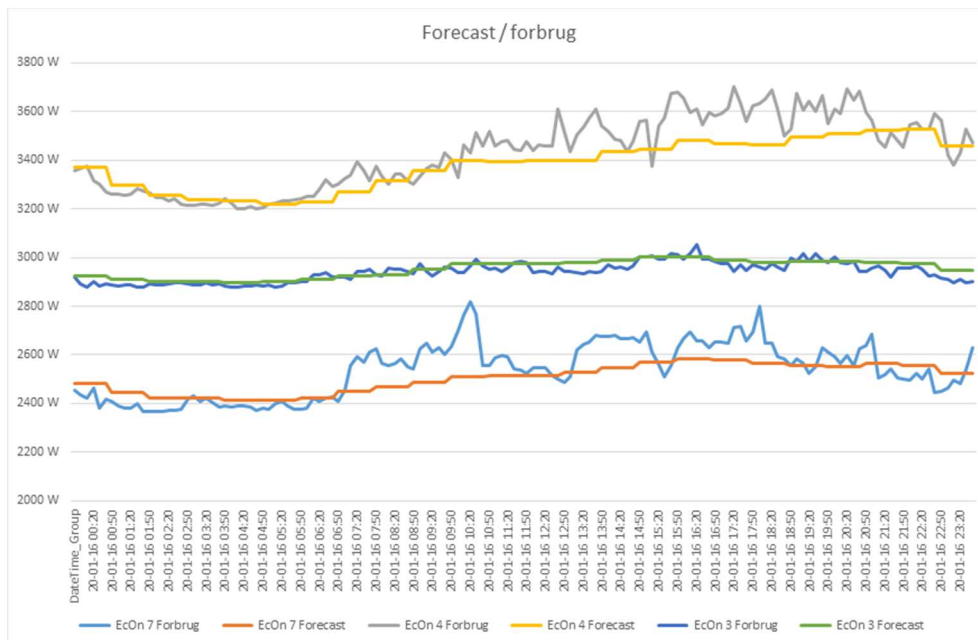
Another vital part of the process has been an ongoing user evaluation of project idea, software, technical solutions and business model, as it has a significant importance for a commercial success of the project idea.



There are various charging systems at tele sites and different types of chargers are used.

Tests have confirmed that it is technically and practically possible to utilize the battery capacity existing at tele sites and include this capacity as well as telecom operators indirectly in the market for system services. Tests have also shown that it is possible to match the requirements of system services for response times. This however needs to be tested further both in lab and in real-life tests.

Energy Cool have been working on learning to forecast consumption at tele sites from the data collected, as seen on the below graph:



Forecast of power consumption.

Based on the tests performed, it is possible to conclude that tele sites could deliver system services frequency reserves, where short regulation time (within 30/150 seconds) is required as well as a full response time, which can be maintained in min. 15 minutes.

The project has therefore redirected its focus on control of batteries where these requirements could be obtained or outperformed. The project has subsequently focused on testing limits for charge and discharge cycles of batteries and their relation to battery lifetime. This mainly due to the fact that the economic advantage is naturally higher when providing frequency reserves to Energinet.dk (compared to providing only automatic and/or manual reserves), since prices for this service on the market are higher.

Work package 4: Electricity measuring and settlement methods

The purpose of this work package has been to conduct an extensive research in equipment for measuring electricity and in related settlement methods. Settlement of aggregation is a relevant topic for several market actors, and focus have been in a dialogue with a balance responsible party, Energinet.dk, along with a consulting company as well as shared knowledge with other sparring partners working on other ForskEL projects. Discussions about electricity meters, metering as such and settlement with Energinet.dk on a regular basis, both individually as well as in a working group, where a representative of Energy Cool is a part of.

However, the working group on settlement has not yet reached a conclusion on final rules for settlement and how one measures own power consumption in case of running on a supply from batteries. Energy Cool has therefore not succeeded yet in defining a clear strategy for managing settlement methods, but succeeded in describing the equipment, that can be verified by Energinet.dk for the purpose of aggregation.

Work package 5: Telecom operators - conduct and requirements

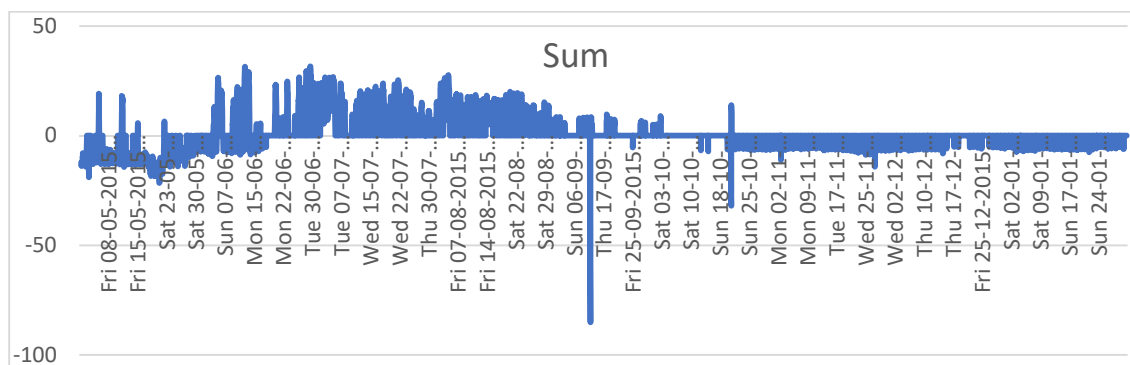
The activities included in this work package have been part of all other work packages, since Energy Cool depended in every step of the way on cooperation with and

input from telecom operators. Therefore, its closer description is included under description of other work packages, where it is relevant in order to explain better progress and challenges of work included in individual package.

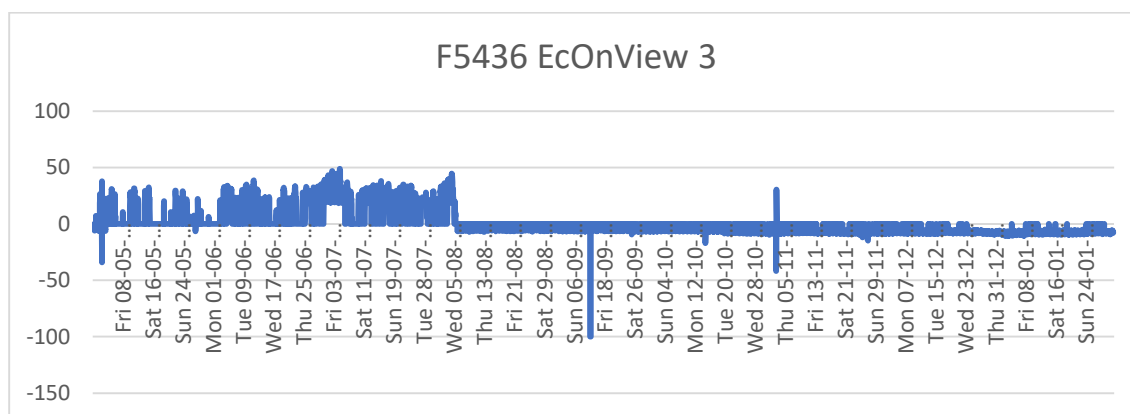
Work package 6: Collection and processing of data for 1 MW demonstration

Energy Cool has achieved the goal of this work package, which was to prepare a business case on 1 MW demonstration project with one of the telecom operators. It is one of the new projects on which Energy Cool works now with a signed contract with one of the telecom operators that sees the benefit in the solution. The process however has been very challenging, as telecom operators from the start were very reluctant to allow access to their sites without any previous proof of the concept available.

Energy Cool therefore had to use a lot of time to obtain the access to the sites in the first place in order to obtain access to collect the data necessary for the success of the project. The access was finally granted by one of the telecom operators to seven (7) of their sites, and collection of data could begin. Energy Cool has focused on logging all available data about the sites, including temperature inside and outside a tele site, data on power consumption of a tele site etc. The data have been logged for several months to be able to recognize trends in different seasons. After several months, the first interpretation of the data has been performed, with very interesting results. Data have for example shown, that there is a high stability of power consumption in 24-hour cycles in all sites, which provides a good basis for forecast and understanding the trends. Data has shown that variation of power consumption in a 24-hour cycle is about 10%, and the variation is further depending on several other factors, such as private or business traffic on a tele site, cooling equipment used, weather conditions, possibly including other special factors.



Total consumption on 6 of the sites, logging period 1.5.2015 to 31.1.2016.



Total consumption on site no. 3, logging period 1.5.2015 to 31.1.2016. Lower consumption from beginning of August is due to change of the cooling equipment on a site.

Cool Universe has played an increasingly important role in the execution of the project and especially in the sale of 1 MW demonstration project to one of our customers. Cool Universe not only enabled collection and processing of data, which convinced the customer that Energy Cool is able and equipped to establish a reliable communication with sites and control them. It also gives value to the customer to come on site at Energy Cool's headquarters, to get a tour around Cool Universe, see the actual hardware and software, which is a part of the solution and see the strict conditions under which Energy Cool has been testing the solution. Cool Universe is a part of the success with the sale of 1 MW demonstration project, because it is the evidence of the high standards for testing, data collection and the devotion, with which Energy Cool is pursuing its vision.

Energy Cool has therefore invested work in improving Cool Universe, meticulous registration of all hardware and software on each and every site and their technical characteristics, test scenarios, data series, description of manuals, guidelines etc.



Graphic overview over Cool Universe sites.

Dissemination of project results

The Project team could not publish and openly disseminate project information, due to the fact that most information is strategically and commercially sensitive for project partners and especially for telecom operators.

Some of the project results have been shared at workshops, working groups and seminars organized by Energinet.dk, Dansk Energi and other industry organizations, both in Denmark and abroad, where Energy Cool has been invited to discuss Markedsmodel 2.0 or role of aggregation in reserve markets.

Project results have also been used to develop several other research and commercial projects, the purpose of which was to take the business model and proposed solution to completion, mature it and offer it on the market to telecom operators, who wish to utilize their existing battery parks.

During the project period, there has been no change in project group or project partners. Energy Cool has mainly used project partners as sparring partners to gain specific technical knowledge and technical input about batteries (Orogenic, EnerSys),

business processes (KPR Consult A/S), energy markets (Houmøller Consulting) and other key issues.

Inside Energy Cool, it has been necessary to adapt project resources. Including hiring of new employees with new competences necessary for the project.

The challenge with an inverter

The greatest challenge experienced during this project has been related to the use of inverter in the technical solution. To establish communication with and to control tele sites a hardware control box is developed, based on the equipment developed in the EcoGrid Bornholm project. This control box initially included an inverter solution. A lot of time and resources have been used to develop the inverter and implement it as a part of the control box system. The inverter was a part of the control system designed to provide battery reserves to the grid. The inverter was installed for test purpose in the seven (7) sites in the Energy Cool test facility. The inverter solution has performed a full-scale test during the last year.

During the project, it became clear to Energy Cool that there was a growing problem with the business case. The project cannot be built on the same ideas planned from the beginning of the project. Economic calculations based on test results have shown that the use of inverter will lead to negative impact on the business case and therefore it is not feasible to follow the idea of using inverters to solve the project goal. Energy Cool had to realize in the central part of the project that related technical installations in the tele sites for an inverter solution are too expensive in practice for the business case to be viable. This is due to the fact that although Energy Cool has used many resources to develop an inexpensive inverter, which has been approved by Energinet.dk, and further precisely designed to fit to the basic idea and the physical construction of a tele site, the business case cannot include an inverter solution in a full-scale roll-out of the solution.

Therefore, Energy Cool, in the middle of the project had to accept that the use of inverter was not the right technical solution and that the final goal of the project had to be changed to another economic secure solution. Instead of utilizing the inverter, the focus was shifted to online control of already installed rectifiers in the tele sites. Online control is used to manage the free energy as the new overall goal for the project and the ongoing internal development.

The project has thus changed its focus significantly during the period. It has been a long process to find out, what and how should be delivered to the grid in order for the technical solution to be not only technically but also commercially viable.

1.6 Utilization of project results

One of the success stories of this project is that Energy Cool has gained a unique knowledge and insights into battery lifetime, number of charge and recharge cycles and battery response, supported by data provided by numerous tests performed on several types of batteries. This collected knowledge and data underpin the original theory that it can be technically, practically and commercially possible to utilize existing battery parks at tele sites to balance the grid and thus not only provide a green alternative for integration of renewables and grid balancing, but also to benefit telecom operators by providing an extra revenue stream and prolonging their batteries lifetime.

The project has helped clarify Energy Cool's vision and our business direction for the future and has given a basis for the work focused on today. Energy Cool has built a separate department and invested in a new line of business together with hiring of new employees to support development of this new line of business. Energy Cool sees this new business opportunity as complementing the main business, which is the provision of the most energy-efficient solution for cooling of server and technical rooms on the market. The new line of business can solve Energy Cool customer's need for reduction of the energy consumption and at the same time make a difference to the environment one step further. Energy Cool is excited about this new business opportunity that perfectly fits with company's mission:

"In cooperation with our customers we develop and manufacture energy optimized green solutions and business models which release resources, create significant environmental benefits and thereby result in an overall green business concept."

Another great success story is that Energy Cool has signed an agreement with a large customer in Denmark, who had approved and accepted further development of the technical solution in cooperation with Energy Cool. Software development, practical work and installing of the Energy Cool solution is already running on maximum and will be installation of the Energy Cool's solution in about 70 tele sites as the preliminary target. The first part of the signed project is divided in 5 phases with the first phase accepted by the customer.

The new Energy Cool solution consists of a control box with electricity meter, PLC system, temperature sensor and all needed hardware cables for full data access. The control box is installed into existing racks in a tele site.



EC TeleConnector: Control box developed by Energy Cool for utilizing power from tele sites.

The customer mentioned above has discovered the possibility in data from their battery parks and specially in optimization of the use of the batteries. Before engaging this project and getting data communication to each site, the customer has seen their battery parks only as a liability, as a necessary investment and not as an asset that can provide an extra revenue stream. Let alone, the batteries as an energy asset that can become a source of green energy. The idea of using their existing battery parks for balancing the grid and even earn money on it has been a completely ground breaking discovery for the customer. There are of course concerns of safety of operations, security of the solution and many other questions unsolved. This is why one of the conditions Energy Cool works on is that batteries have to have a minimum capacity of providing 30 min. backup power to a tele site (their primary function) and only the surplus capacity remaining after that, can be used for eventual delivery to

the grid. Yet, the business case is interesting enough for the customer to roll-out a testing project on the first 70 tele sites.

The customer appreciates the discovery that batteries benefit from being used and that their lifetime is not negatively affected by the use. Currently, their batteries are changed by their battery supplier on a regular basis without knowledge about and regardless of what their condition is – whether it is necessary or not.

Energy Cool is therefore, thanks to this project, engaged in an intensive user-driven innovation processes with the customer to ensure that the concept, product and solution will become one which the telecommunication industry genuinely demands.

In this process, Energy Cool combines knowledge and competences of the customer, partners/experts and from its own organization.

Energy Cool is exploring pursuing the possibility of taking out patents and other applicable intellectual property rights together with a consultant experienced in the area. The outcome depends on the final architecture of the product, which is not yet fully developed. Energy Cool has already registered the name Energy Cool for marketing of the project on a national as well as international level.

It is a great and positive effect on the environment, if batteries from tele sites are to be used to support balancing the grid and integration of renewable energy in the system. It is a different solution than to build some large grid-scale batteries, since the tele site batteries are already dispersed around the country anyway and can be used for several purposes. This can significantly decrease need for investment in transmission infrastructure, and the project results confirm that implementation of the solution will have the desired effect on environment.

Batteries could be controlled to be charged with renewable energy – in periods, of excess wind- or solar power – and then they could provide a source of green energy to balance the grid in the times of peak power consumption. Energy Cool would thus be able to provide a real green alternative to the thermal power plants, fed mostly by coal and gas today, that pollute environment but are necessary for balancing the grid today. Energy Cool has a similar project currently running in Romania, where batteries from tele sites are combined with solar energy.

Regular use of batteries would also mean that they do not need to be replaced so often for new batteries. This will decrease the number of batteries that need to be produced and hence a less environmental impact.

The potential is expected to increase/ become especially interesting based on size and trends in the telecommunication industry – with the growing need for mobile coverage, digitalization and 4G internet, the number of tele sites in Denmark and around Europe is steadily growing. This means that number of batteries placed around at tele sites is also growing. When the solution is able to utilize all these batteries for grid balancing and thus prolong their lifetime, the overall effect on the environment and support of energy policy objectives will be enormous. Furthermore, telecom operators are multinational companies that operate in several countries around the world, so Energy Cool believe that once the solution is verified and accepted by a telecom operator in Denmark, it will be easily scalable to other countries and other telecom operators. Telecom operators from other countries (Finland, United Kingdom) has also shown interest in the solution and Energy Cool has in late 2016 begun cooperation on implementing solution on the UK market.

Energy Cool therefore concludes that the project findings provide a significant contribution to the energy policy – especially in the following areas:

- All electricity supply green by 2050
- Out phasing coal-fired power plants and oil-fired boilers by 2035
- Integration of 50% wind energy by 2020
- 20 % reduction of CO2 by 2020
- 20% increase in energy efficiency by 2020

Ph.D. has not been a part of this project.

1.7 Project conclusion and perspective

The final conclusion of the project is not yet clear. Energy Cool are working with a very complex business area which is completely new in Denmark and neither our economic nor technical solution are yet final. It needs a bit of fine-tuning.

The project has nevertheless shown that Energy Cool needs to change the business model and change the final objectives of the project – utilize the batteries placed at tele sites and close for the consumption of tele sites to help balancing the grid. Using batteries at reserves gives better meaning to the business case than the original idea. Charging the batteries in times of cheap and green electricity available and turn off the sites' own power consumption in times of the high demand provides a good ground for the further development of a final business model.

Annex

<http://www.energy-cool.com/home/>

<https://markedsmodningsfonden.dk/energy-cloud-tele-connector-optimering-af-handel-med-vedvarende-energi>

<http://www.nordicenergyregulators.org/wp-content/uploads/2016/12/NordREG-Status-report-on-regulatory-aspects-of-demand-side-flexibility.pdf>

<http://energinet.dk/DA/EI/Nyheder/Sider/For-foerste-gang-skal-elbiler-vaere-reserve-for-elnettet.aspx>