# CLEAN RESOURCES FINAL PUBLIC REPORT

## 1. PROJECT INFORMATION:

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| **Project Title:** | Improved Electrical Demand Forecasting Techniques in Presence of Behind the Meter Distributed Solar Generation |
| **Alberta Innovates Project Number:** | 201910762 |
| **Submission Date:** | April 30, 2022 |
| **Total Project Cost:** | $331,793 |
| **Alberta Innovates Funding:** | $158,557 |
| **AI Project Advisor:** | Sheila Schindel |

## 2. APPLICANT INFORMATION:

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| **Applicant (Organization):** | **Arcus Power** |
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## 3. PROJECT PARTNERS

This project was made possible through the support of Alberta Innovates, the University of Calgary and the City of Medicine Hat.

## A. EXECUTIVE SUMMARY

With the democratization of energy, growth of distributed energy resources and the implementation smart grid technologies, small-scale solar energy generation units, known as Behind the Meter Solar (BTMS), are increasingly being installed and used to support on-site electricity needs. BTMS generation offsets consumers' electricity demand from the grid, and thereby impacts the grid's total electrical load. Since BTMS generation is not continuously measured or reported to grid operators, a technology gap exists in accurately forecasting the aggregated BTMS generation and the net-electrical demand of the grid.

This project was focused on developing a scalable and accurate real-time estimate of the small-scale solar energy generation within a region, collecting weather data relevant to regions with electrical load, and with this data as input, developing an improved electricity demand forecasting tool to accurately predict the net-load on the region's electricity grid.

The project was successful in its objectives, with the primary success being the development of a net-load forecasting model that can handle large volatile loads in a small region. This model improved the net-load forecast accuracy by more than 2% compared to benchmark models, which met our expectations. This improvement in accuracy was supported by the successful deployment of proprietary weather stations for more accurate weather data collection, and the development of a stable model for estimating BTMS. With the iterative nature of training machine learning models with live data, we expect further improvements in the future.

An important learning from this project was the that it is beneficial to decouple different parts of the project so there is less interdependence between tasks, and instead integrate results from the tasks in the final steps. There were several tasks in this project that followed the waterfall approach to project management where a task couldn't begin without the output from the previous task. A faster approach would be to decouple the model development from other models and from real-time data, only connecting all components together at the end of the project.

To the best of our knowledge, this is the first live net-demand forecast to addresses a region with small load, highly volatile load influences, and behind the meter solar generation components. Given that the penetration of solar is increasing, the importance of a net-load forecasting model that is capable of accounting for renewable energy injections is going to become more prominent and necessary. With enhanced accuracy of net-load forecasting, grid operators will have more confidence in optimizing the grid operations with presence of distributed renewable energy resources, thus we believe the outcomes of this project will play an important role in decarbonizing the grid.

## B. INTRODUCTION

This project contributes to the innovation of the smart grid technology sector. Smart grids are recognized as the digital transformation of the electrical grid system that allows for two-way communication between power generation and power consumers to support improved grid reliability, efficiency, flexibility, sustainability, and optimization. Smart grid technologies such as smart meters, automated controls, and real-time and forecasted information, enable the effective adoption of distributed energy resources, including renewables and battery storage, while also empowering demand side behaviors such as adjusting electrical consumption based on market conditions. Arcus Power is a smart grid company that develops AI-driven electrical demand forecasting software for energy grid participants. Arcus's accurate demand forecasts and notification of upcoming periods of peak electricity demand supports commercial and industrial facilities with their demand response strategies and asset optimization to reduce electricity costs.

With the democratization of energy and the implementation smart grid technologies, small-scale solar energy generation units, known as Behind the Meter Solar (BTMS), are increasingly being installed and used to support on-site electricity needs. BTMS generation offsets consumers' electricity demand from the grid, and thereby impacts the grid's total electrical load. Since BTMS generation is not continuously measured, a technology gap exists in accurately forecasting the aggregated BTMS generation and the net-electrical demand of the grid.

## C. PROJECT DESCRIPTION

This project developed an innovative electricity demand forecasting tool to accurately predict the load on the electricity grid. The tool incorporated weather data relevant to electrical load and an estimate of the real-time Behind the Meter Solar (BTMS) generation into machine learning algorithms that produce a net-demand forecast. The electrical demand forecasting tool developed in this project will have improved accuracy compared to the current industry standards and will be incorporated into Arcus Power's existing commercial platform.

The project's specific objectives included developing a scalable and accurate real-time estimate of the small-scale solar energy generation within a region. The real-time estimate is necessary as an input into the machine learning algorithm that calculates the forecasted net-demand of the region. The project also quantified the improvements in accuracy achieved by incorporating weather data relevant to regions with electrical load into the electricity demand forecast. This objective was important for determining how sensitive the net-demand forecast is to weather data and if improved weather data relevant to regional loads impacts the forecast. The final objective of this project was to develop an improved electricity demand forecast which incorporates weather data relevant to high load regions and estimates of solar panel generation. With the growth of behind the meter solar generation in many jurisdictions, this objective aligns with Arcus's business goals of improving Arcus Power's existing demand forecast to support expanding its customers segments to include municipalities, utilities, and independent system operators. The objective also aligns with Arcus's environmental values of improving the efficient operation of small-scale solar energy generation within the smart grid electricity system.

Performance Metrics:

The project specific performance metrics include the following:

- Successfully deploying proprietary weather stations for more accurate weather data collection.
- Building and deploying stable live data streams with our municipal partner to support continuous model improvements.
- Building and deploying stable models for estimating BTMS.
- Building and deploying net-load forecasting models that can address large volatile loads in small regions with high fluctuating load components.
- Achieving net-load forecast accuracy of more than 2% below benchmark models.

## D. METHODOLOGY

This project required the collection of real-time data, and the development of several machine learning models, including a BTMS estimation and net-load forecast model. The real-time data collected for this project included publicly available data, data provided to us by our municipal partner, and weather data collected from weather stations strategically placed for this project. The project team developed web scrapers and algorithms to retrieve data from their respective sources, which was then stored in a cloud database and available for input into the different machine learning models. For the machine learning models we built state of the art artificial intelligence models that are capable of adapting to the variations of small regional loads.

## E. PROJECT RESULTS

This project led to the development of a fully functional energy forecasting system that is geared towards the challenges imposed by the growing penetration of solar energy in distribution networks. The models are able to account for the solar energy that is injected into the electrical grid while predicting the energy demand by the energy consumer. Considering that the behind the meter solar energy production is invisible to grid operators, missing it would significantly deteriorate the accuracy of net-load forecasting models. The developed models rely primarily on publicly available data, as well as some locally generated customer data that are measured and otherwise readily available.

Considering that the share of behind the meter solar and other distributed energy resources is growing, the developed models provide a future ready platform for grid operation as we move towards 100% renewable electrical grid.

The numerical results and verifications at this stage indicate that the models improved net-load forecast accuracy by a significant percentage compared to benchmark models, which met our expectations. However, by integrating live data from a network of proprietary weather stations, over time we expect further improvements.

Specific projects success metrics include the following:

- At the end of the project, we have successfully deployed proprietary weather stations for more accurate weather data collection.
- We built and deployed live data streams with our municipal partner, and we now have a stable data stream to support continuous model improvements.
- We built and deployed stable models for forecasting BTMS for up to 6 days ahead, achieving commercial readiness for the first hours of forecast horizon.
- We built and deployed net-load forecasting models that can address large volatile loads in small regions with high fluctuating load components.
- We achieved net-load forecast accuracy of more than 2% below benchmark models.

## F. KEY LEARNINGS

An important take away from this project is that it is beneficial to decouple different parts of the project so there is less interdependence, and instead integrate tasks in the final steps. Initially the Milestones and tasks of this project were ordered with the waterfall project methodology, which required all real-time data collection to occur at the start of the project. As it turned out, the collection of real-time data was the slowest and most challenging task of this project, due to the reliance on external parties. It would have been beneficial to initially plan the model development with offline or historical data, and integrate with real-time data at the very end, allowing for more time to work out the logistics required by external parties. In the end, Arcus decoupled its tasks, enabling the modeling tasks to proceed with offline data sources.

## G. OUTCOMES AND IMPACTS

To the best of our knowledge, this is the first live net-demand forecast to addresses a region with small load, highly volatile load influences, and behind the meter solar generation components. Given that the penetration of solar is increasing, the importance of a net-load forecasting model that is capable of accounting for renewable energy injections is going to become more prominent and necessary. With enhanced accuracy of net-load forecasting, grid operators will have more confidence in optimizing the grid operations with presence of intermittent renewable energy resources, thus we believe the outcomes of this project will play an important role in decarbonizing the grid.

Clean Energy Metrics

The Clean Resources Metrics for this project remained constant through the entirety of the project. The total spend of this project was distributed equally across the three clean resources metrics of Data-Enabled Innovation, Digital Transformation for Business Innovation and Clean Technology. This project supported Data-Enabled Innovation because it incorporated novel methods for estimating behind the meter solar data and weather data pertinent to electrical load, incorporating big data analytics and machine learning algorithms to improve demand forecasts. This project supported the Digital Transformation for Business Innovation because the final product, a highly accurate load forecasting tool, enables businesses to effectively cost manage their electrical load utilizing API and digital controls- an essential component of deploying smart grid technologies. Finally, this project supports clean technology as the improved demand forecasting achieved in this project incorporates behind the meter solar generation, and thereby optimizes power system operations and planning. This in turn maximizes the environmental and economic benefits of having renewables and clean energy in the electric system, ensuring renewable resources are used when they are available. Additionally, by accurately estimating the BTMS generation, regions using Arcus' net-demand forecasts can monitor incremental increases in BTMS generation and the corresponding reductions in $CO_2$ emissions.

Program Specific Metrics

The project successfully developed one grid modernization technology: an enhanced demand forecast that incorporates load specific weather data and BTMS generation. Lack of visibility of large fleets of BTMS is a key contributor to large errors in demand forecasts for electricity. Demand forecast errors contribute suboptimal power system operations, which often result in power being supplied by large conventional non-renewable generators. Arcus' improved demand forecasts will support efficient balancing of the electrical system, providing electricity consumers with the foresight to respond to market conditions with demand side behaviours and enabling a greater adoption distributed energy resource, including renewable assets tied to batteries.

Project Outputs

Arcus successful applied for a provisional US patent based on the work of this project. Each graduate student who contributed to this project will also complete a thesis paper and produce a journal publication in the coming year.

## H. BENEFITS

*Economic*

This project directly supported the recent $11 million dollar investment in Arcus by a Canadian private equity firm. Funds from this investment will, in part, support integrating the models developed in this project with Arcus' existing commercial product and scaling the product into international markets. This project indirectly supported several MOUs with global corporations which will help with Arcus's growth into new markets, particularly the US.

*Environmental*

The adoption of the technology developed in this project continues to enable reductions in GHG emissions by creating efficiencies in integrating photovoltaic (PV) and BTMS electricity generation into the grid. As a reference, in Canada every 698 kWh of PV electricity generation reduces 1 tonne of GHG emissions. (Source: https://www.irena.org/climatechange/Avoided-Emissions-Calculator) Over the course of this project, Arcus noticed a distinct increase in customers' awareness and interested in being able to quantify, report and promote how "green" their consumed electricity is, which has supported evaluating the development of other products with the research from this project.

*Social*

This project directly contributed Arcus' growth from a small Alberta based start-up to a tech company that is scaling to global markets. This project enabled Arcus to secure its first customer in a new segment, supporting its growth into new markets. It also cemented the Arcus' roots in Alberta, maintaining Calgary as its global head office.

*Building Innovation Capacity*

This projected made a notable contribution to training, retraining and attracting highly qualified and skilled personnel in Alberta. The three graduate students who supported this project with their research gained skills that support their future employment in the clean tech and smart grid industry. Arcus hired two of the graduate students from this project into part time positions immediately at the end of this project, transferring to full time positions once they have completed their studies. In addition to these new positions, Arcus hired the lead consultant software developer working on this project into a full-time leadership role. Overall, with the support of this project and the successful private equity investment, Arcus' team has grown its team of HQSP four-fold during the duration of this project.

## I. RECOMMENDATIONS AND NEXT STEPS

The next steps for the technology developed in this project is to scale the net-load forecasting model from the region to the entire province of Alberta, to support implementing this technology in Arcus existing commercial product. This will require scaling the stable and reliable real-time data sources identified in this project to areas across the province, which will likely require formalizing additional data partnerships with weather station and BTMS owners. Work will also be done on the existing regional forecasting model to improve its accuracy by extending the outlook of the BTMS estimate and the periods of real-time data used as inputs for training the machine learning models. Arcus has extended its relationship with the University of Calgary to support this work being done in the next two years.

## J. KNOWLEDGE DISSEMINATION

In the coming months, the MSc and PhD students who worked on this project will each publish research papers based on the research developed in this project. These papers will be published once each student has defended their thesis. Arcus may also publish a white paper on the improvements to its forecast achieved through this project, which will not only identify the impact of BTMS on demand forecasts, and highlight the need for accurate demand forecasts, but will support customer acquisition in key segments such as utilities, independent system operators and municipalities, all of which will have growing BTMS assets within their jurisdictions.

## K. CONCLUSIONS

Arcus's project of developing improved electrical demand forecasting techniques in presence of behind the meter distributed solar (BTMS) generation was successful in its objectives. The project built and deployed a net-load forecasting model that addresses BTMS generation and can handle large volatile loads in a small region. This model improved the net-load forecast accuracy by more than 2% compared to benchmark models. This improvement in accuracy was supported by the successful deployment of proprietary weather stations for more accurate weather data collection, and the development of a stable model for estimating BTMS. Over time, and with the iterative nature of training machine learning models, we expect further improvements to the forecasts. The next steps for the technology developed in this project is to scale the net-load forecasting model from the region to the entire province of Alberta, which will support implementing this technology in Arcus existing commercial product. Once commercialized, the improved net-load forecasts will enable GHG reductions by accounting for the incremental increases in BTMS generation that displaces non-renewable generation, and the corresponding reductions in GHG emissions.

Arcus Power would like to acknowledge that this project would not have been possible without the support of Alberta Innovates, the University of Calgary and the City of Medicine Hat. This project made significant contributions to the research and development of Arcus's technology. It supported the company's growth into new markets, and directly influenced an $11 million private equity investment during the course of this project. The project also supported hiring, training, and retraining a significant number of HSQP.