1. Technical Specification Double-side Page

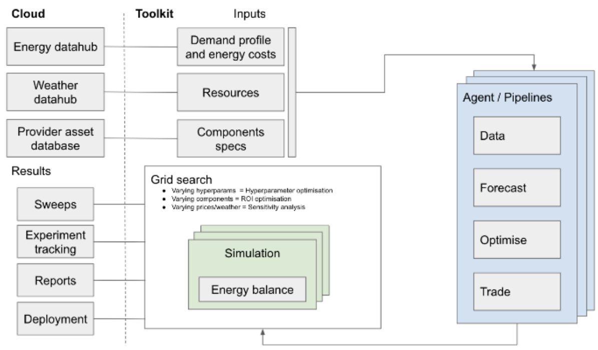
1. **TECHNICAL SCOPE:** Summarize the solution developed during the EXPERIMENT phase: how have you finally addressed the challenge/Theme Challenges and tackled with its requirements and data. Include a diagram.

The Rebase Platform enables users to find optimal dispatch strategies for operation of battery storage systems given the expected PV output and load profile of a building. It is possible to define different preferences for the optimal dispatch strategy, such as maximising revenue, maximising self-consumption or minimising carbon emissions. Potential savings are then presented to the user in an intuitive way. In addition, the Rebase Platform provides tools for calculating the optimal size of storage systems based on techno-economic criteria.

In order to serve the needs of several different users, ranging from experienced data scientists to non-expert end-users, we have adopted a layered approach. The approach consists of three parts:

2. An open source toolkit including algorithms and optimization models. Making the algorithms open source allows the data scientists to easily review, modify or expand them to fit their needs.
3. A cloud-based platform that allows the scalable simulation of thousands of systems based on the same open source algorithms. This allows data scientists and energy engineers to assess permutations and scenarios of the energy systems by leveraging the Rebase cloud computing infrastructure.
4. A widget that allows non-expert end-users to easily estimate the potential energy and peak savings of PV and battery installations in their buildings.

The Rebase Platform is built to seamlessly interact with the Rebase Toolkit to create energy models, such as agent-based simulations. The toolkit loads data from the cloud to build up an agent-based energy model (e.g. for battery dispatch). The model is built up and the simulation setup is specified. Then cloud computing infrastructure can be leveraged to scale up computations and get results quicker. The flow chart below depicts a user flow for an agent-based energy simulation.



2. **ALGORITHMS, TOOLS AND CONCLUSIONS:** Detail the algorithms and tools finally selected to accomplish the challenge/Theme Challenges. Summarize the main results that you have obtained during the EXPERIMENT phase: data, insights, conclusions and the main contributions to solve the challenge/Theme Challenges.

The core of the project is a set of open source optimization models [1] which have been developed in Pyomo [2]. Pyomo is a Python-based open-source mathematical programming language used for formulating, solving, and analyzing optimization models.

The optimization models can be used for calculating the optimal operation of distributed energy resources (load, PV and battery) under the grid tariff structures applied in Sweden and Spain. These include a) fixed tariffs, b) power-based tariffs and c) time of use tariffs. The same models can be applied in other countries with similar grid tariff structures or they can be easily modified / extended to cover different grid tariff structures.

Two different KPIs can be optimized with the models, which are either the minimization of the system total operation cost or the maximization of the system self-sufficiency.

The models can be used in two modes:

a) For simulating the operation of a system, b) As model predictive control (MPC) algorithms

The first mode allows the simulation of the operation of the battery for a period of time and the estimation of savings when compared to the base case when there is no PV generation and/or battery. For this type of simulation, historical load and PV generation data are used provided by the data provider.

In the second mode, the same models can be used as MPC control algorithms which calculate the amount of charging/discharging of the battery. Because this type of MPC controller needs an estimation of the load and PV generation in the near future, a load and PV forecasting algorithm has been developed using LightGBM [3], a popular open-source gradient boosting framework.

Finally, the operation models have also been extended to calculate the optimal size of new PV systems and batteries using techno-economic criteria. This can be used for new PV or battery installations.

The second tool which has been developed is a widget [4] which allows the easy estimation of the potential savings of new PV and battery installations in a specific location. The widget makes use of the optimization algorithms described above. The estimation of the PV generation in the site employs the Rebase Datahub for ERA5 reanalysis data [6] as well as the open source tool pvlib [7] to generate hourly PV generation time series.

The third tool is a cloud-based platform [8] that allows the calculation of savings for multiple sites. The platform makes use of the same open source algorithms as the widget but allows for scalable and parallel computation of many sites. This gives the advantage to easily simulate multiple sites and make an initial screening of the sites that are suitable for PV and/or battery investments.

3. **SCALABILITY AND FLEXIBILITY OF THE SOLUTION:** Explain how the solution copes with the challenge/Theme Challenges requirements and how it can be adapted to other similar problems. What work is still pending to create a real/stable product if any? What TRL level is it in?

The Rebase Toolkit interacts seamlessly with the open source Enerflow library [9] that includes the algorithms described above and was designed with flexibility in mind. Enerflow handles a broad range of different energy flow optimisation problems in addition to optimising solar PV and battery of a building and can easily be adapted. Other possible extensions include problems such as thermal building modelling, optimisation of hybrid power plants e.g. wind, solar and energy storage (including battery, hydrogen and heat storage). Actually, we are already working with a paid pilot on hybrid power plants together with Siemens Energy. In the future, additional energy management strategies such as data predictive control and reinforcement learning could be integrated. Both environments and energy demand strategies can also be used in the platform through additional modular open source components.

The Rebase Platform cloud architecture provides a way to manage time series data (commonly present in energy management) which come at different frequencies and grow naturally with time. We have designed the Rebase Platform considering the current and future data growth. There are several layers where the data is compressed and shaped for fast on-demand querying for future use-cases. We also implemented a very flexible way where users can take advantage of our data structures and combine with their own proprietary Python code and quickly iterate and solve energy flow optimization problems. Scaling depends on the user's application so we have designed our platform to automatically react and adapt the necessary computing power depending on the actual requests from user provided code. The platform scales seamlessly from small size optimization problems that fit in one developer's machine to truly distributed petabyte scale problems.

Our platform offers scalability at each layer: Bare-metal -> Azure -> Kubernetes -> Dask -> Rebase Toolkit -> Users. The base layers are managed by our cloud provider and the upper layers by our platform. Data interoperability is handled differently depending on the layer. The top most layer where external data integration is handled communicates using open data formats such as JSON, CSV, XML, GRIB, NetCDF and FIWARE smart data models.

4. **DATA GOVERNANCE AND LEGAL COMPLIANCE:** Describe the security level of the solution, i.e. how authentication, authorization policies, encryption or other approaches are used to keep data secure. Explain how the solution is compliant with the current data legislations concerning security and privacy (e.g. GDPR).

The datasets processed by the Rebase Platform are energy related weather, market, asset and emission data. Most of the weather datasets we process are open datasets without any legal restrictions and some require value added services (VAS) for redistribution. The market and emission datasets are partly open and private, where we tend to focus on the open datasets. Even though weather, market and emission data is not regarded as sensitive data it is of importance to take precautions against data leakage from a contractual perspective. The energy asset datasets are of a more sensitive nature since they include electricity consumption profiles and performance data from assets which could be sensitive from a business perspective.

Data governance is handled through "need-to-know" principles and two-factor authentication for important entries (like cloud login). Keys are shared through 1Password (encrypted key management). We sign NDAs with all employees. We are not handling any personal data that goes under GDPR except login details on the platform. This data is handled in compliance with GDPR according to our privacy policy.

All data traffic is encrypted over HTTPS. Every user-facing service is protected by an authentication gateway, where each user can access their own resources using a personal API key. This API key can be deleted and regenerated by the user at any time. All data is encrypted with customer specific keys and the access is managed within the Rebase Platform. The user owns their data and may at any time contact us to extract or delete all the data associated with them in our system.

5. **QUALITY ASSURANCE AND RISK MANAGEMENT:** Describe the quality process followed for the final product. Technologically, which problems have you encountered and how you have solved them, and any processes followed that guarantee that the solution fulfills the challenge/Theme Challenges and data provider requirements.

We work in small iteration and follow the agile and KPI-driven development method, which ensures both a good project design and regular iterations with stakeholders. We employ best practices for DevOps and we encourage code reviews, continuous testing and continuous deployment as well as fast rollback procedures for disaster recovery. Risk analysis:

#	Risk	Probability	Impact	Risk analysis	Mitigation
1	DATA SENSITIVITY RISK: Handling sensitive data leading to privacy data issues or slow approval limiting access to data (e.g. load profile).	Low	Medium	**Low-Medium**	Have data owners involved from the beginning. Making it easy and transparent to upload data to the platform. Choice to deploy the solution on-premise.
2	DATA ACCESS RISK: Not getting access to the necessary data in order to provide our service.	Low	High	**Medium**	The trend is definitively in the direction of more and more open data as opposed to the contrary. It will be difficult to get access to data from all countries so data access must be one decision factor when decided to expand into a new country.
3	IOT RISK: Risk with IoT connection and integration work.	Low	Low	**Low**	We have taken the strategic decision to not work with the IoT layer ourselves. Instead, we work with partners and experts in this field FIWARE Startup Accelerator, Volttron and RealEstateCore. In case we would use Volttron we have partnered with a company that are Volttron experts (www.aceiotsolutions.com/).
5	RESOURCES RISK: Company resources leaving the company resulting in a loss of knowledge.	Medium	Medium	**Medium**	Knowledge management with always several people involved. Shared knowledge spaces and product documentation.
6	DEVELOPMENT RISK: Development issues due to unforeseen bugs.	Low	High	**Medium**	Eliminate the most difficult challenges first. Have a dedicated team with the right skills as early as possible.
8	OPEN SOURCE RISK: Since the enerflow project is open source there is a risk someone would take the code and develop it themselves.	Medium	Medium	**Medium**	This is a risk we need to take if we want it to be truly open. We believe that the core developer of a library will always have an advantage over replicating products (e.g. www.databricks.com). Also, we will develop hard-to-replicate closed sourced components.
9	TRYING TO DO EVERYTHING OURSELVES RISK: Most startups don't starve, they drown. Trying to do too many things is a significant risk that we should try to avoid to any cost.	Medium	High	**High**	We have created a product roadmap and a value proposition matrix (VP vs customers) where we clearly define what is inside and what is outside of our scope. There is a list of things that we will absolutely not work on e.g. IoT communication. There is also a list of things that we might work on in the future. We always have team discussions when deciding to take on a new challenge.

5. Annex 1. Means for accessing the MVP

Please, indicate in 1 page indicating the means for accessing the MVP for a potential customer (login information, website address, link to a demo video or whatever means are needed to check that the MVP exists and works).

1. Source code
   https://github.com/rebaseenergy/microgrid-opt-example.git

2. Widget
   https://widget.rebase.energy/simulate?api_key=OxjUDKeJU04FaD7aNyWcK17jdrNvfuGSk24vXbZzCls

3. Platform
   https://drive.google.com/drive/u/0/search?q=reach_final_demo