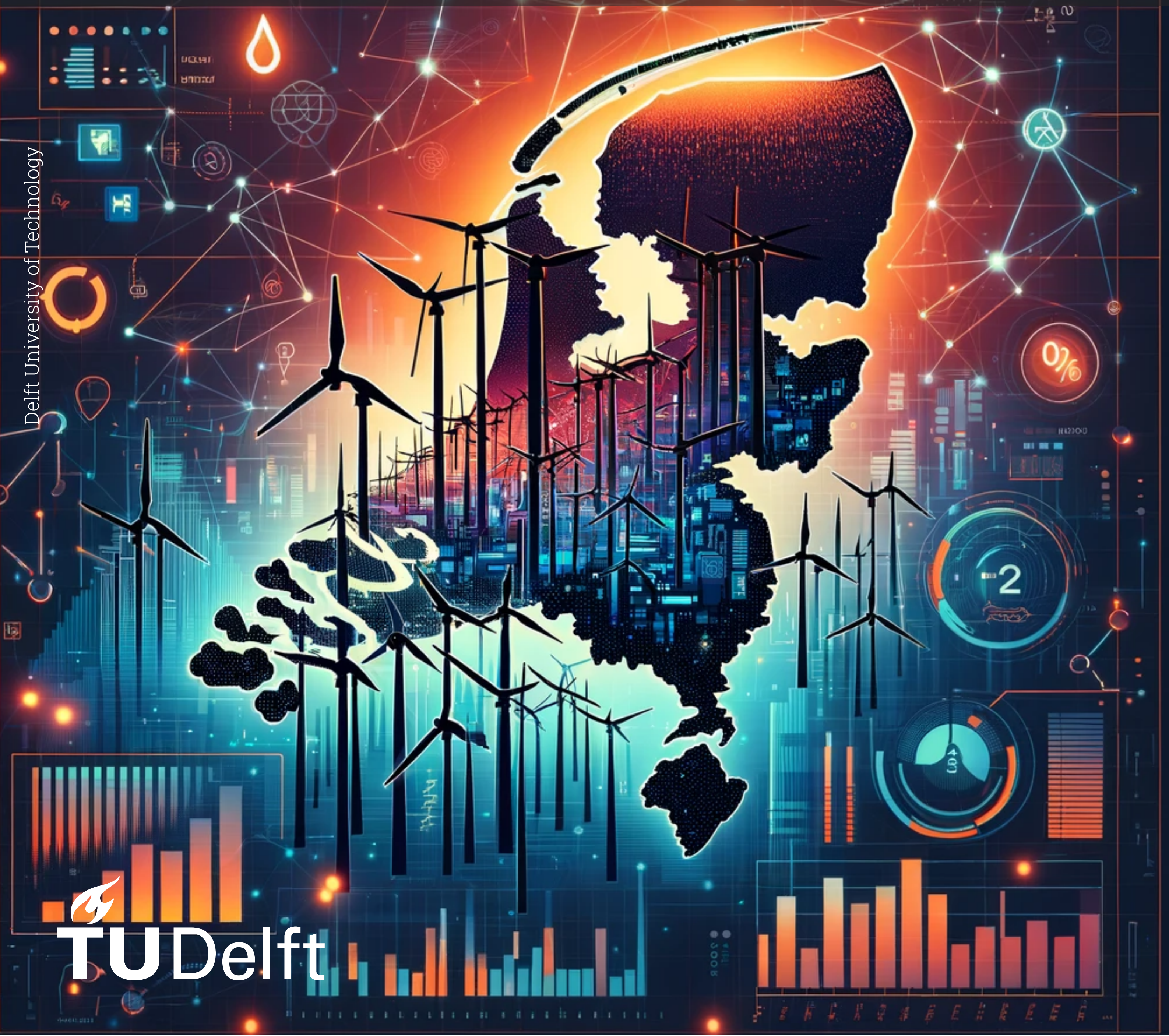
Social Prioritization for the Energy Grid

Energy Justice Evaluation and Impact Analysis

Masters Thesis by
Maxim Pavlov



Delft University of Technology

TU Delft

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Acknowledgements

In my opinion, this master thesis could be the definition of *in the right place at the right time*. The Dutch energy grid is experiencing a lot of challenges and the population feels it. Thankfully, the Netherlands in my experience is the country that always strives for a better solution. That's how social prioritization came to life. From the desire to make sure that despite of the congestion and long waiting times to receive the power transport capacity, the society will still function and population needs will be met. This is an early attempt to better understand these changes, critically assess them, and propose improvements.

For me the journey started by actively seeking a thesis internship where I could combine the social and technical aspects of engineering. I was lucky to be accepted in Alliander as a thesis intern at the Research Center for Digital Technologies (RCDT). The research topic initially was called Decision Intelligence. In the initial research stage, we have identified the waiting list to be a good use case for looking at the Decision Intelligence applications. At the same time, we find out about the social prioritization framework. I was immediately interested and we realized that this is a research topic in itself. I want to thank all of my colleagues at the RCDT for making this research possible and more importantly - enjoyable. Special thanks to Archana Ranganathan and Hans Fugers for supervising me during this project. Your critical thinking, experience, and guidance were not only important for the research itself but also gave me a lot of motivation.

At the same time I started my internship at Alliander, my Graduation Committee at TU Delft was assembled. From the first meetings, our discussions were very challenging and fascinating. Thank you Niek Mouter, Roel Dobbe and Eva de Winkel. I want to thank Eva for actively helping me out even outside of our scheduled meetings. For example for sharing relevant and interesting articles or papers and helping me out with your already gained experience of working with Alliander. Roel provided excellent guidance throughout the project and always made sure that both the big picture and the accuracy of the research were intact. I always knew that after our meeting I would have a better feeling for what the next steps should be. Thank you, Niek for chairing the committee and making sure that the research was both relevant and doable. Your feedback has greatly helped me to structure the project and to think about future directions. Working with you was a great pleasure. Thank you all!

Last but not least, I would like to extend my gratitude to my family and friends. It was a long and hard academic journey but looking back I do not think I was ever really nervous because of the support I had. My family has a great talent for comforting but also for telling me to stop complaining when necessary. My dear friends went through many different life and academic journeys but have always been an inspiration to me despite of whether we were close or lived in separate countries.

Personally, it is hard to remember everything that happened in the past 6,5 years since I started my bachelor's degree but it was definitely the right decision. I like to romanticize the long difficult days spent in the lab or the time spent getting used to a very different science I chose for my master's. I think that is a good sign. Hard to imagine that all of that was just part of the journey and not the whole thing. Looking forward to what's next! Hope to see you then.

Maxim Pavlov
March 22, 2024

Executive Summary

This research originates from an issue of electricity grid congestion in the Netherlands. Grid congestion occurs when there is no longer enough capacity to accommodate everyone's electricity consumption or production needs. This subsequently results in the waiting lists of clients that apply for either a new power connection to the grid or a transport capacity request. These waiting lists are becoming very long and some requests are estimated to be granted in a decade. There are various factors contributing to this congestion, such as population growth and the transition to sustainable energy sources, which have overwhelmed the existing infrastructure.

Distribution System Operators (DSOs), like Alliander, are tasked with addressing this challenge. The problem investigated is specifically the waiting list management, which has become more complex in the face of increased demand. Still, the main principle that applies to the waiting list is the First-Come-First-Serve (FCFS), which has been working just fine because the number and size of requests were not that high and the DSOs were able to keep up with the rising demand. The situation is only getting worse, and because of the FCFS principle, some socially important clients are waiting for a long time for their turn. Policymakers, such as the Autoriteit Cunsument & Markt are developing new guidelines to address this problem, proposing a prioritization framework based on societal relevance. This is a significant deviation from how the waiting list has been treated originally. It will allow to prioritize the transport capacity requests from clients that fall under the congestion softener, safety, basic needs and sustainability categories. Congestion softeners category are the clients, whose requests can alleviate the congestion on the grid, for example, battery storage facilities. Under the safety category, are the functions that contribute towards national security such as defense, police, firefighters, water safety and emergency services. The basic needs category includes schools, hospitals, housing needs, water management, public transport and waste management. Lastly, the sustainability category includes producers of sustainable electricity and parties who commit to above-legal sustainability improvements. The social prioritization framework suggests that giving priority to the aforementioned clients will benefit society.

The introduction of this new framework can potentially cause significant implications to the clients on the waiting list and to society as a whole. First of all, it will rearrange the order of existing waiting lists which will create more uncertainty. Secondly, every new priority client request will delay all the other nonpriority clients even further. The social prioritization framework is analyzed with the help of Energy Justice. Energy Justice refers to the concept of finesses in the activities and situations in the energy system context, for instance, ensuring that all individuals and communities have access to affordable, reliable, and clean energy services. This concept can be divided into three main areas, namely the distribution, recognition and procedural justice. The focus is made on distributive justice implications because the proposed framework redistributes the burdens and benefits in terms of the waiting time clients in congested areas experience. To understand the implications the following research question is posed:

How can the distributive justice implications for new energy grid waiting list prioritization framework be structurally identified and deliberated?

To answer this question the Design Science Research methodology is used which is an iterative approach and consists of three cycles: relevance, rigor and design cycles. In the relevance cycle the problem and requirements are investigated and initial testing is done. In the design cycle, the artifact is being built and evaluated. In the rigor cycle the additions to the knowledge base are determined and scientific methods and theories are used. In the design cycle, the artifact is tested and developed. In this specific case, the artifact will be the assessment tool to help aid the decision-making around social prioritization. It will allow to see the effects of different decisions based on the prioritization framework on the clients on the waiting list. To accomplish this, initially, a comprehensive literature review (Chapter 3) was conducted to identify the theoretical knowledge and academic gaps within En-

ergy Justice research. This involved exploring examples of quantitative metrics for measuring Energy Justice implications and consulting relevant research areas. Subsequently, Chapter 4 described the existing waiting list management process and introduced ACM's proposed social prioritization framework. To understand the implications of social prioritization, a qualitative analysis (Chapter 5) was conducted, revealing main themes, suggestions, concerns, and the industry groups represented by stakeholders. Following this, a quantitative analysis (Chapter 6) was performed to estimate potential impacts on waiting times for both priority and non-priority clients, shedding light on necessary components and algorithms for more accurate estimates. Additionally, conceptual Energy Justice metrics were proposed to gauge the distributive effects of social prioritization, aiming to provide insights into the fairness of waiting time distribution. Finally, a conceptual tool was proposed to aid in the design of the social prioritization framework and visualize its direct impact.

The literature review was done in five groups of research: Energy Justice, Metrics in Energy Justice, Waiting List Management, Distributive Justice, Energy Distribution and Prioritization. The Energy Justice and Metrics in Energy Justice literature was reviewed to understand the basic concepts and theories of the Energy Justice research as well as to identify the metrics that have been previously used to measure fairness with respect to Energy Justice. Waiting List Management literature indicates most developments in the healthcare sector when it comes to dealing with waiting lists of patients. It shed light into different approaches to deviation from FCFS principle. The Distributive Justice literature helped to understand the basic ethical principles behind the different ways the distribution of burdens and benefits can be justified and what approach is fair from what perspective. Lastly, examples of Energy Distribution and Prioritization were investigated which showed different approaches to prioritization when it comes to the distribution of energy for specific cases, most of which were low-scale, such as home appliances and local solar networks.

The waiting list management process was then investigated. The current approach to managing it was identified, as well as the important technical and administrative constraints were identified. For example, the fact that FCFS principle can not be always applied from the technical perspective as well as the complex structure of the energy grid was described. The complex structure makes it very difficult to predict the time of the estimated time to solution of each of the client's requests, which also makes it difficult to re-estimate the waiting times when the waiting list is rearranged according tot the social prioritization framework. Then the social prioritization framework is discussed in detail. All the priority groups are introduced, the requirements to be eligible for the prioritization are discussed, as well as the reasoning by the ACM behind their choices for this framework.

The first data analysis is done in the form of a quantitative analysis that focuses on the published opinions of the stakeholders on the social prioritization framework. The published opinions can be split into 9 categories, based on the industry or function of the stakeholder. The categories are the energy sector, educational institutions, municipalities, healthcare, agriculture & food, construction, water management, transport & logistics, and others. Energy sector representatives fear uncertainty and administrative burdens, advocating for the inclusion of gas infrastructure and mobility electrification while cautioning against favoring large polluters. Educational stakeholders criticize vague guidelines and the exclusion of higher education institutions. Municipalities seek decentralized decision-making and suggest including additional sectors like general practitioners and traffic infrastructure. Healthcare stakeholders prioritize GPs and hospitals in the safety category, while agricultural representatives emphasize food supply inclusion and concerned about large players benefiting unfairly. Building and city planning stakeholders stress the link between commercial activities and housing needs, highlighting uncertainties in housing development. Water management stakeholders propose prioritizing drinking water and advocate for mandatory social prioritization, while transport sector stakeholders call for inclusion across all modes and special transport for vulnerable groups. Other stakeholders caution against overlooking digital processes, recommend prioritizing projects based on readiness, and emphasize transparency to avoid errors and delays in framework expansion.

The quantitative analysis was then performed to estimate the real impact on the clients on the waiting list. The impact analysis requires various components, including entry dates, client information, transport capacity, and solution estimates. Limitations such as unavailable SBI codes and incomplete solution dates were addressed by manually assigning priorities and estimating solution dates. This data was then used to rearrange waiting lists based on social priority and assess the impact on waiting times, considering technical constraints like available capacity. Despite a lack of applicable metrics in existing literature, distributive justice metrics were proposed, including time equity disparity, change in estimated time to solution ratio, and capacity ratio. These metrics aimed to quantify the fairness of the social prioritization framework by assessing the distribution of benefits and burdens between priority and non-priority clients.

Analysis of five real waiting lists revealed mixed outcomes from the social prioritization framework, with both priority clients experiencing non to high decreases in waiting times, and non-priority clients experiencing non to large delays. While the framework aimed to decrease waiting times for socially important requests, its strict adherence sometimes resulted in extreme delays for other clients. Distributive justice metrics showed a closing gap in waiting times between priority and non-priority clients but highlighted the disproportionate burden on non-priority clients. Additionally, the framework's impacts extended beyond delays to include financial, technical, and psychological effects. Recommendations included improving stakeholder feedback loops and proposing a tool to analyze different priority categories' impacts on waiting lists.

Directions for future research are also recommended:

- Incorporate historical data in the impact analysis to improve the accuracy.
- Obtain SBI codes for all clients to extend the understanding of the impacts and effectiveness of the social prioritization framework.
- Improvements and further research on the policy development tool.
- Participatory Value Evaluation (PVE) research and improved feedback loop analysis
- Analyse other tenets of Energy Justice. It has also been identified in the literature that the majority of research contributes to the distributive justice aspects and neglects the other.
- Connect the quantitative implication results to societal values. The analysis can be taken a step further by creating a link between the waiting time, capacity and the actual benefits to society.

Contents

1
Introduction

1.1. Background

There is one notion that is really hard to grasp for an everyday energy consumer in countries where the access to electricity has never been an issue: electricity is no longer available for everyone at all times. It is no longer the case that you can just flip a switch or add a connection and it will always work. The energy grid in the Netherlands is overloaded frequently and there is not always capacity to accommodate absolutely everyone's needs in certain areas [6, 7]. One of the many examples, two newly built schools in Veldhoven, Netherlands will most likely not get an electricity connection for the next five to ten years [50].

There are multiple reasons behind this problem, such as population growth, political tensions, electrification of the transportation sector, and transition towards more sustainable sources of energy [4]. The list goes on and on. According to Netbeheer Nederland, trade organization for electricity and gas network operators in the Netherlands, the issue also stems from the unexpected growth in the sustainable energy market when solar parks became a very attractive business [37]. Companies started building solar parks in thinly populated areas because of the availability of space at affordable prices. The energy grid in those areas never predicted such a rapid increase in demand and supply for energy capacity. That is why perhaps the areas that are less populated by people have more congestion.

Distribution System Operators (DSOs), such as Alliander, are attempting to solve this or mitigate this problem and accommodate everyone who needs a new connection to the energy grid or transport capacity either for consumption or production purposes. A new connection to the energy grid means an actual physical connection through power lines and transport capacity is the contracted power that client gets for producing or consuming electricity. The goal of alleviating congestion is of course supported by technical advances and investments in the energy distribution grid expansion but also by re-imagining how a DSO should function. Now it is necessary to be more dynamic and adapt to the situations, as well as look far ahead in the future. For instance by implementing new rules and ways of treating congested areas.

1.2. Practical Problem

In the congested area, if there is no more capacity available, new requests for connection or transport capacity are placed on a waiting list. Before the grid became heavily congested, waiting list management was not a very complicated problem. When a client requests more capacity than they already have contracted for production or consumption of energy the first step is to check whether there is enough space or capacity in the infrastructure for this request. If the answer is no, then the client is placed on the waiting list. The list functions on a first-come first-serve basis, which is mandatory and regulated [31]. Depending on the availability of capacity on the line, the client would be connected to the grid when it is the client's turn based on the first-come first-serve principle.

These days however, this system needs adjustments. Although the energy grid operators are not supposed to discriminate clients by law, the first-come first-serve principle comes with certain drawbacks. Because everyone is treated equally, socially important projects or clients are waiting their turn for a very long time because of other, potentially less socially important projects before them. Another difference is in the number of clients requesting an increase in electricity consumption or production and the number of clients that request a new connection. These requests are treated equally and the number of new requests are significantly lower than those of existing clients. Therefore, new businesses are waiting in the same line as many existing ones that require an expansion.

Policymakers are now working on new guidelines for Distribution System Operators (DSOs) that will allow them to prioritize their clients based on their societal relevance and a new framework [11]. The changes have been proposed by the Autoriteit Consument & Markt (ACM) back in March of 2022 and confirmed that they will go forward with developing them in March 2023 [29].This received a positive reaction from Netbeheer Nederland and DSOs because it meant moving towards a solution. After finishing the draft code with the first version of the prioritization framework the ACM asked all the involved parties to respond to it and give feedback [1]. The new prioritization framework includes four categories of clients: congestion relievers, safety, basic needs and sustainability [41]. Congestion relievers are the parties that according to the grid operators can alleviate the congestion on the grid by accepting a new contract. Safety category involves emergency responders, police and defense, water safety and etc. Under the basic needs fall things such as healthcare, education, water access, and public transport. Lastly, the sustainability category represents producers of renewable energy. The responses from Netbeheer Nederland and NVDE (Ducth Sustainable Energy Association) suggest that the overall feeling is positive however there are concerns on how this will actually be implemented and they urge to be very careful with the categories that fall under the prioritization framework and to keep them narrow [39].

To address these changes and to better understand what they mean the goal is to evaluate the potential outcomes of the social prioritization framework from Distributive and Energy Justice perspectives, develop a metric to measure the justice or fairness of the implications and to develop a tool that will help decision makers to better understand the consequences.

1.3. Academic Relevance

The socio-technical concerns need to be addressed when designing a system or framework that clearly needs to correspond to social norms and values. There is a potential for interesting dilemmas when it comes to managing a congested energy grid. The social prioritization framework poses a normative question of fairness and value to society. A certain area of academic research has been dealing with normative questions in relation to the energy grid, namely the Energy Justice. Energy justice looks at topics such as equal access to energy, fair distribution of costs and benefits and the participation right in choosing how the energy system evolves [34]. This is a framework, that in the past 10 years, has been increasingly used to understand and asses the decision-making in the energy sector and the implications of that. Through that framework, the changes to the energy grid management via new policies and technology can be assessed and it gives an insight into the impacts of current development. Energy Justice encompasses the principles of equity, fairness, and inclusivity in the energy sector, aiming to address the inequalities and unfairness that exist in energy access, environmental impacts etc [21]. It recognizes that energy decisions and policies can have significant social, economic, and environmental consequences, and seeks to ensure that these decisions are made in a transparent, participatory, and accountable manner.

Energy justice is a multidimensional concept, considering also the social, economic, and environmental dimensions of energy grid systems. This concept can be divided in to three main areas, namely the distribution, recognition and procedural justice [21]. Or so-called three tenets of Energy Justice. This framework allows for a structured way of working when analyzing for energy justice. That means first the concerns need to be identified, then the affected parties and lastly - strategies and recommendations for improvements. The recognition justice aspect looks at the importance of considering the different communities with their own values, needs, both historically and currently. The procedural justice is concerned with the fairness in the decision-making processes when it comes to the energy policies and regulations. The distributive justice tenet addresses the fairness in distribution of benefits and burdens when it comes to energy production, consumption and access.

There are some example of applying Energy Justice framework specifically in the Netherlands [33, 38]. In their research, the authors identify other important values that need to be taken into account when designing smart grids. Values such as privacy, security and flexibility. Apart from purely technical issues within the grid, these studies reflect on other failures such as transformational and systematic failures. One of the key reasons behind it is argued to be the lack of infrastructure to stimulate the knowledge diffusion between the actors. A similar concept of collective ownership and commons governance is identified as a potential area for large improvements and research in the Dutch energy grid [25]. These findings suggest the need for better use of information, especially when decisions need be made quickly.

Energy Justice supports its claims via metrics that can be used to evaluate fairness in the processes, distribution and recognition of groups [3]. The social prioritization is a new development and a new problem to investigate, and therefore there is a need to develop new or adapt existing metrics of just or fair decision-making to assist the evaluation of the social prioritization framework and potentially other developments in managing scarce resources. Furthermore, this topic touches the area of research related to waiting list management. Specifically, in the social context when the priority is not obvious or hard to measure. Lastly, this a new case in the area of research related to prioritization of energy distribution. From the perspective of prioritization in energy distribution, to the best of the authors' knowledge, there has been no study focused on waiting list management. Moreover, this is a perfect case to expand on the understanding of the Energy Justice concepts and add to the knowledge base on the metrics used to measure the Energy Justice. Finally, this is an opportunity to evaluate the social prioritization framework as a case for Distributive Justice.

1.4. Societal Relevance

Energy plays a big role in our society, it is the power that allows for development and economic growth, and the other way around [53]. Without electricity we can not power manufacturing plants, transportation and crucial infrastructure such as healthcare, education institutes and law enforcement agencies. One of the United Nations Sustainability Development Goals is the affordable and clean energy [36]. Clean renewable energy is clearly an urgent necessity but to support the transition, the energy grid infrastructure needs to keep up with the developments. This problem specifically resonates with the issue in the Netherlands. According to Netbeheer Nederland, the unforeseen rapid increase in the solar energy development is one of the main reasons behind the current congestion issues in the Netherlands [37].

The goal of the social prioritization framework is to benefit the society [41]. The societal relevance of this research is the early assessment of impacts and the Energy Justice implications this change in regulations brings. It is a step in making sure that the framework is doing what it is intended to do. Due to the large scale congestion issue, the framework can potentially effect all of the congested areas which is a big portion of the Netherlands. It is important to make sure that this effects are fair.

The bottom line is, the sources of energy and its use are dependent on the grid to support those activities. This bottleneck, in the form of the energy distribution system, requires time to be physically expanded to allow for more capacity flow. In the meantime, thousands of clients are placed on the waiting list to wait their turn to be connected or two expand their capacity [19]. This societal issue then spans from accessibility and clean energy production to a problem of fair distribution. Reasons being that it is very geographical dependent and now there is a prospect of a new social prioritization framework. This problem concerns a number of stakeholders. The main groups are the Distribution System Operators, national government, municipalities, energy production sector, consumers and authority for consumers & market.

2
Research Question & Methods

2.1. Goal of the Research

A more general goal of this research is to contribute to the development of a solution that will help to alleviate the current situation with long waiting times for transport capacity requests caused by the congestion on the Dutch energy grid and allow for social prioritization when managing the waiting list of clients. There is now an ongoing discussion on how the decision-making framework should look like and be implemented by the DSOs such as Alliander. More specifically, the goal is to evaluate the potential outcomes of the social prioritization framework from Distributive and Energy Justice perspectives, develop a metric to measure the justice or fairness of the implications and to develop a tool that will help decision makers to better understand the consequences.

2.2. Research Question and Sub-Questions

Main Research Question: How can the distributive justice implications for new energy grid waiting list prioritization framework be structurally identified and deliberated?

The following sub-questions (SQ) are posed to help answer the main research questions in a structured way.

SQ 1: *What is the problem at hand and what is the proposed solution to benefit the society?*

The problem analysed here is not the congestion itself but the current decision-making process in addressing this problem. It is important to truthfully identify the current process, where the issues are and how it is being dealt with at the moment. Under this question also falls an investigation into the draft social prioritization framework proposed by the ACM. Additionally, it is important to understand which of the three pillars of Energy Justice play a role here. Intuitively this is a Distribution Justice case, however, there is always a possibility for the cases of Procedural and Recognition Justice relevance. This question is important to answer in order to better understand what is the problem that the social prioritization framework wants to address. It helps to answer the main research question as this part addresses the current situation, which in turn will help to identify the way to measure the implication social prioritization brings.

SQ 2: *What are the opinions of the stakeholders on the new social prioritization framework?*

The opinions of a large number of stakeholders are currently available open source. This allows to understand what are their concerns, what they support and what would they like to be adjusted. This will also shed light on how well was the public opinion taken into account into the development of the new prioritization framework. Moreover, some expert groups will be able to provide very valuable insight into the things that could be overlooked both from technical and social perspective. By answering this question, it will already help to understand the potential implications of the social prioritization framework, which is a part of the main research questions.

SQ 3: *What is the algorithm and what are the necessary components for the evaluation of social prioritization effects?*

This question is aimed at understanding the data of the waiting list data. It is done to identify the groups of clients and to map them to the newly proposed social prioritization framework. Moreover, the logic needs to be constructed that will allow for calculation of the waiting times, and the relations to other properties on the waiting list. All that and more to understand the bottlenecks, majorities and minorities groups. The insights should help answer the main question on how can the implications be identified, how can the findings be structured and explained.

SQ 4: *What are the appropriate metrics for evaluating the fairness of the social prioritization outcomes?*

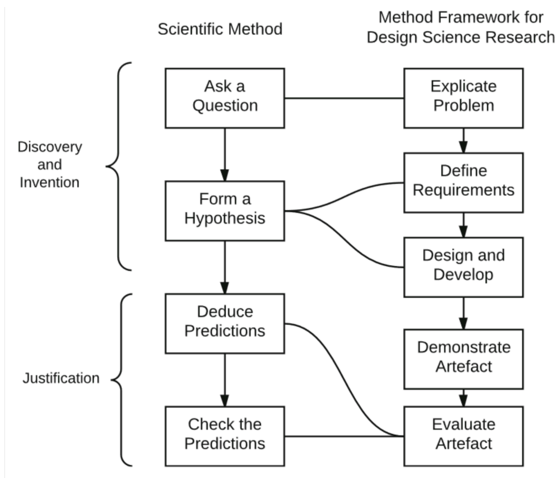
The solution in the end needs to bring meaningful and useful results to society. In order to have meaningful results in this research, the outcomes need to be measurable. To do so, appropriate measurable quantities need to be identified. These quantities should provide an insight into the technical and justice effects of social prioritization. This sub-questions is connected to the previous and the main research questions by helping to understand how the implications can be deliberated.

SQ 5: *What is the impact of the social prioritization on the clients that are within and those outside of this framework?*

The goal of the framework proposed by the ACM is, simply put, to bring more good or benefits to the population. This question will help to understand whether the social prioritization is bringing more good or bad to the public and from which perspective. Answering sub-questions combines all the previous answers to calculate and explain the implications cause by the social prioritisation framework. This question will also focus on the distribution on benefits and burdens.

2.3. Methodology and Methods for Answering the Research Questions

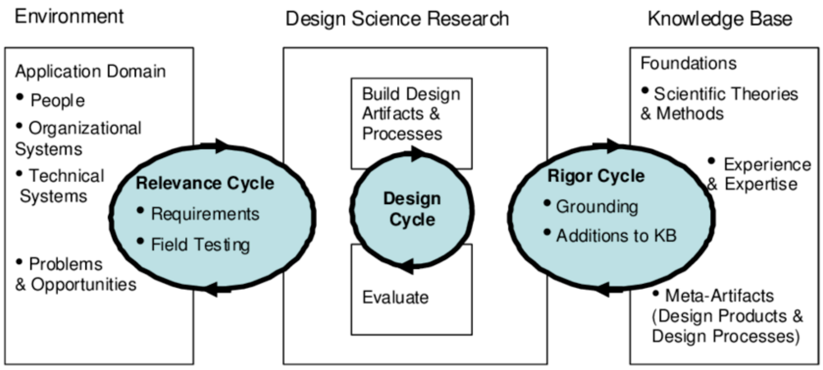
Figure 2.1: Linear representation of the Design Science Research [23]



The methodology chosen to answer the aforementioned research question is the Design Science Research. Design Science Research, like empirical research, describes, explains and predicts the world but also creates an artifact that is aimed to solve a problem and to add knowledge through its evaluation [23]. One of the main reasons for choosing this methodology is exactly because it involves the creation of a concept solution, which will be most valuable in the situation when the problem needs to be solved quickly. Even though, a fully functional prototype is of course not possible under time constraints, the design process and ethical considerations that will arise in this research will aid in better understanding of how to approach the solution. A concept design will be developed and discussed.

The way of executing this method can be looked at from a linear point of view (Figure 2.1) or from a three- cycle point of view (Figure 2.2). That being said, the linear view is still an iterative process as it involves constant evaluation and communication with stakeholders. The three-cycle view consists of the relevance, rigor and design cycles [18]. In the relevance cycle the problem and requirements are investigated and initial testing is done. In the design cycle, the artifact is being built and evaluated. In the rigor cycle the additions to the knowledge base are determined and scientific methods and theories are used. In the design cycle, the artifact is tested and developed. In this specific case, the artifact will be the assessment tool to help aid the decision-making around social prioritization. It will allow to see the effects of different decisions based on the prioritization framework on the clients on the waiting list.

Figure 2.2: Three-cycle view on the Design Science Research [18]



2.3.1. Relevance Cycle

To answer SQ1, or to explicate the problem and solution space, a desk research is performed in addition to semi-structured interviews with experts within Alliander that are working closely with the waiting list or providing solutions. These people include the grid architects that are doing the technical checks, the people responsible for managing congestion in certain geographical areas and the specialists in the regulations department that are investigating the new ACM code. A literature review is also done for an understanding of the Energy Justice implications. First, the basics of the Energy Justice framework are identified, as well as the research directions in this academic area. That is also where the knowledge gap is identified. The goal is to identify the points where the social prioritization fulfills the principles of Energy Justice and where it is lacking, or introduces injustice to the energy grid.

To answer SQ2, and to add to the understanding of the environment, the published responses of involved stakeholders are analyzed. This needs to be done in an organized and systematic manner where the stakeholders are grouped as closely as possible corresponding to the categories within the social prioritization framework. That can be achieved with the help of a qualitative analysis tool such as ATLAS.ti and identifying relevant and prevailing themes in the text. This will help not to only understand opinions and potential effects of the new ACM code but also to identify under-represented groups. The results of this quantitative analysis will then be used to discuss the energy justice implications and also indicate the room for improvement in the framework.

2.3.2. Design Cycle and Rigor Cycle

For answering SQ3, a data analysis is performed, which is also connected the relevance cycle. The data that is used is the internal data of Alliander which combines all information available on the waiting list and the corresponding solutions. This data is necessary to understand the available quantities that can then be further used in calculating the impact of the social prioritization framework. Then the algorithm is developed that uses the data and technical constraints to calculate the change in waiting time for every client. This algorithm is then extended to a concept tool that can be used for analyzing and modifying the environment, the framework and constraints. This toll can help with understanding the impacts and with answering the follow up questions. The algorithm and the tool are then the main artifacts in this research. The data analysis is done using pandas software library as it is very commonly used for data analysis. For the development of the tool Streamlit is used as it is an easy way to build apps.

To answer SQ4, the Energy Justice metrics can be consulted via literature review. This is done to evaluate whether the existing metrics can be applied in this case and to be able to structurally develop new metrics. Additionally, some of the research on the waiting list management in the healthcare sector can also offer some metrics. The healthcare sector has long experience with the waiting list management especially in the with taking into account normative values. Lastly, by analyzing the responses of stakeholders and the data, some metrics can be derived for this specific case.

For answering the last SQ5, the previously gathered information after investigating the preceding sub-questions is used. The impacts can be both discussed from purely ethical perspective, such as in Distributive Justice, and from more quantifiable results, such as Energy Justice metrics. Here, the main quantitative analysis is done, with the goal to predict the implications and interpret the numerical results with the help of previously gathered knowledge. The iterative nature of Design Science Research implies a constant review of the design, knowledge base and the environment.

Lastly, certain considerations need to be taken into account. Specifically, the data protection plan, which will minimise the risk of exposing sensitive information, which can be done for example by data classification and subsequently - anonymization.

3

Literature Review

This chapter is aiming to answer the *SQ1* and*SQ4* of this research:

SQ 1: *What is the problem at hand and what is the proposed solution to benefit the society?*

SQ 4: *What are the appropriate metrics for evaluating the fairness of the social prioritization outcomes?*

First, the Energy Justice literature is consulted with an additional focus on metrics that have been used or proposed for evaluating Energy Justice. Moreover, specifically the Distributive Justice literature is investigated because there might be more similarities to this research due to the distributive nature of the problem. Lastly, the cases of where topic of prioritization was investigated in the energy distribution context were also consulted. The literature can help explicate the problem from distributive justice perspective to help answer SQ1 and to begin the process of

The literature was searched with the help of Scopus, Google Scholar, Semantic Scholar, Connected Papers and Cosensus. The terms that were used in the literature search were: *Energy Justice, Distributive Justice, Energy Justice Metrics, Ethics and Energy Grid, Energy Grid and Prioritization, Waiting List management and Prioritization, Queuing and Ethics, Social Prioritization.* The main criteria for the literature were the relevance to the research, number of citations, publishing journal.

3.1. Metrics in Energy Justice

Energy Justice is a very established area of academic research. However, it is still lacking the evidences needed for it to have an effect on policy making [32]. To achieve that, quantification of Energy Justice is needed.

A large sample of equity metrics for Energy Justice has been assembled and described [3]. Metrics included in this review are the Existing Environmental Justice Metrics, Energy Justice Vulnerability Indices, Consumer Energy Metrics, Wealth Creation, Ownership, Autonomy, Multi-scalar Supply Chain Inequities, Comparative Country-Level Metrics. Additionally, a valuable contribution of this work was a discussion on the criteria for decision-focused energy equity metrics.

According to the authors, metrics should be: decision-relevant, grounded in the preferences of vulnerable and marginalized communities, understandable and measurable, comprehensive enough and yet manageable for implementation. It is important to expand on the comprehensiveness of the metrics, as it can be classified in different categories. First, it needs to be defined which of the three tenets of Energy Justice will the metric address. Secondly, the scale of the metric depends on whether it measures things on local, national or global scale. Then, the sectoral dimension tells which sector is affected. The impact on people can defined as financial, technical, cultural or psychological. Lastly, the life cycle category shows where in the energy life cycle the Energy Justice is addressed.

In case of the waiting list management and social prioritization, some early assumptions can be made on what the metrics will look like according to the comprehensiveness:

- Tenets: distributional
- Spatial: local and national
- Sectoral: all sectors that are present on the waiting list
- Impact on people: technical, psychological
- Life cycle: distribution and end use

Since Energy Justice has its origins in the Environmental Justice, a valuable example of Environmental Justice metric is the EJScreen made by the United States Environmental Protection Agency [12]. This tool is used to support decision-making by using demographic indicators and environmental justice indexes such as climate risks, health disparities and critical service gaps. This helps to identify vulnerable communities and related problems to which they are exposed.

There are also ways to measure the vulnerability of such communities with vulnerability scores based on exposure, sensitivity and adaptive capacity [8, 44]. The variables that were used in these calculations are energy price increases, sociodemographics and low-income bill assistance programs. On a larger scale, international context, similar measures have been done via Global Energy Vulnerability Index, that included variables such as carbon emissions, degree of reliance on energy resources, energy intensity [14]. That allowed for better identification of vulnerable geographical regions.

Another concept, important to the Energy Justice metrics, is the concept of energy poverty. Energy poverty is related to the energy access and involves five dimensions: supply, reliability, quantity, quality, and affordability [26]. The inability to meet the desired situation in one of those five dimensions, therefore results in energy poverty.

The list of metrics used to asses the Energy Justice goes on from number of protests related to energy, to percentage of the ownership of resources by local community members [3]. It is fair to say that there is no solution that would fit all cases. Every case requires a careful consideration of different measurable metrics depending of the question to be answered.

3.2. Waiting List Management

From the literature search, it showed that the most developed waiting list management research is in the medical sector. It makes sense that in a lot of places, access to healthcare is very scarce and healthcare practitioners need a fair and effective way of managing the waiting lists of patients.

Numerous studies have investigated and proposed different strategies to improve and optimize waiting list related processes. For instance, a study carried out at Centro Hospitalar e Universitário do Porto in Portugal developed hill climbing and simulated annealing models [13]. As a result, it improved the scheduling of medical exams. In Chile, a methodology was introduced to forecast the prioritization of patients on surgical waiting lists through the implementation of a machine learning scheme, resulting in improved patient selection and reduced waiting times [47]. A systematic approach was formulated to diminish medical appointment waiting lists, incorporating prescriptive decision-making models and ongoing improvement initiatives [17]. The optimization model resulted in a 90% reduction in waiting time. This was achieved thanks to an innovative approach of proposing prescriptive decision-making models followed by continuous improvement and people engagement. Additionally, the Social Return on Investment (SROI) model was recommended as a decision-making tool for the clinical and healthcare management of waiting lists, assessing the gained quality of life and the social return on investment from interventions [35].

The later research on SROI illustrates a valuable framework for measuring value. The phases in SROI are:

1. Establish the scope of the assessment and the stakeholders involved
2. Create the impact matrix
3. Develop indicators (evidences) and give them economic value
4. Establish impact
5. The report

This results in a decision-making tool that shows the depth of effects caused by delays in the patient's diagnosis or surgical procedures. Findings and methods from this and similar papers could be applied to research focused on waiting lists from other sectors.

3.3. Distributive Justice

Before diving deeper in prioritization within energy distribution grids, it is important to first understand some basic concepts and philosophies about Distributive Justice. Distributive Justice concerns itself with what is fair when it comes to distribution, be it wealth, opportunities, utility or energy [10]. For simplification reasons, the distributive justice principles can be put in broad seven categories. These relevant to the energy distribution categories are the Strict Egalitarianism, The Difference Principle, Equality of Opportunity and Luck Egalitarianism, Welfare-Based Principles, Desert-Based Principles, Libertarian Principles.

The first category, strict egalitarianism, states that simply every person should have the same level of material goods, burdens and services. This comes from the belief that all people are morally equal. One of the key issues of strict egalitarianism is measuring the levels of goods and services distributed. From the energy distribution system perspective, then all should have either the same capacity level or all have the same access opportunities, depending on what is questioned.

The Difference Principle is a theory proposed by John Rawls. According to the Difference Principle, each person has an equal claim to a fully adequate scheme of equal basic rights and liberties. Furthermore, social and economic inequalities are permissible as long as they meet two conditions: they are attached to positions and offices that are open to all under fair equality of opportunity, and they benefit the least advantaged members of society. Therefore, it prioritizes the welfare of the least advantaged and aims to improve their position in society. It allows for some inequalities if they lead to a greater overall benefit for the least advantaged. This principle is very relevant in the social prioritization framework as it is the same as allowing for an inequality (distribution of energy) for the greater benefit of vulnerable or disadvantaged categories of clients. However, the concept of disadvantage is here clearly up for debate.

The main idea behind Equality of Opportunity and Luck Egalitarianism is to 'level the playing field', while luck egalitarianism allows for a role of luck in the distribution of benefits and burdens. Therefore the slight difference is that in equality of opportunity the idea is rooted in the belief that individuals should not be unfairly disadvantaged or advantaged by factors beyond their control, while luck egalitarianism states people should not be held responsible for factors beyond their control.

The Welfare-Based Principle, similar to Utilitarianism, is focused on maximizing the overall welfare or the greater good for the greatest number of people. This principle prioritizes the level of welfare of individuals as the primary moral concern. Therefore, in this view, theories such as material equality, resources are valuable only as long as they affect welfare.

The Desert-based principles state that individuals deserve certain economic benefits based on their actions and contributions to society. Therefore it is a matter of defining what is considered as deserving. This concept can divided in three primary groups: the contribution and the effort put into something and the compensation, where the reward is proportionate to costs endured.

Shortly, the Libertarian principles advocate for minimal government intervention in both economic and social affairs, emphasizing individual liberty and self-ownership. This means that the distribution can not be governed to achieve justice. But rather, justice is achieved through voluntary exchanges and individual actions.

In the end, Distributive Justice provides very useful perspectives to evaluate the effects of the social prioritization framework. It can not provide a definitive answer on whether a decision is good or bad but it will allow for a very useful discussion.

3.4. Energy Distribution and Prioritization

The term priority has appeared in the energy grid and energy distribution research previously. It is common to look at priorities from the perspective of regulations and optimization problems [49, 28, 5, 52, 20]. From a regulatory perspective, priorities are usually related to the priorities when it comes to energy transition, safety and basic rights. While optimization problems become more prominent as the bi-directional flow on the energy grid becomes more common, transport electrification is booming and smart grids are being implemented.

Various methods of optimization and prioritization have been used for numerous specific cases. A dynamic priority listing model was proposed for restoring loads in microgrids based on their importance [2]. The optimization technique in this research was the intelligent fuzzy decision-making technique. Another study showed the use of a priority-based energy distribution scheme for an off-grid solar power systems, considering the importance of home appliances in order to improve overall operating hours [48]. This study provided an example of decision-making by a system when resources are scarce applied to the very basic household appliances. Furthermore, a paper focused on energy optimal management in smart grid infrastructure, where the closest smart grid allocates optimal energy to users to maximize satisfaction [51].

One of the attempts to connect the optimization problem with the social aspect of the distribution of power was done in a case study from Mexico [16]. A multi-objective model was used, considering economics, environmental and social factors. There it was shown that the technical objectives can be met while adhering to the objective of all stakeholder while minimizing the dissatisfaction of involved systems. Although the case is very geographically and resource specific, it provides an example of where stakeholder needs were met while taking into account their priorities.

Game theory also comes to mind when approaching prioritization problems, as well as in the case of distributing resources. A cooperative game theory was used in a peer-to-peer energy trading case in a local energy community [30]. In such case, the objective is to maximize the coalition's social welfare. Similar principle could be applied to the waiting list social prioritization, if considering the nation-wide scale and maximizing the social welfare.

3.5. Conclusion Chapter 3

The literature review so far has shown developments in the areas of Energy Justice and its metrics, Distributive Justice, waiting list management, and prioritization in the context of energy distribution.

The literature related to the metrics in Energy Justice presented examples of how quantitative measurements can be used to assess the distributive, procedural, or recognition of Energy Justice implications. Most of the results use quantities on a large scale, such as health disparities, affordability of energy, quality and so on. Moreover, this literature showed how to define the metrics to structure the analysis. This can be used in this research as inspiration to identify relevant quantities and the way to define the metrics. However, no example has been seen that would fit the analysis of the impacts of social prioritization, which indicates a knowledge gap. Specifically the gap of combining the waiting list analysis and Energy Justice.

The waiting list management in healthcare literature gave examples of how individual value can be used in assigning priority. However, it is difficult to translate those principles to the waiting list in the energy grid scenario. Despite that, the commonality is that the costs to the individuals on the waiting list are considered. Therefore, the metrics and the Energy Justice evaluation can be focused on what are the costs that will be distributed due to the social prioritization framework. That also resonates with the distributive nature of the problem at hand.

The literature related to the topic of prioritization in the distribution of energy has also given valuable examples. For instance, it has been shown how different stakeholder preferences and values have been taken into account and used either in an optimization problem or with a game theory approach. This gives valuable insight into how the social prioritization framework could be improved or evaluated. To achieve that, the stakeholder and societal values need to be taken into account in a quantifiable manner.

The next chapter is going to introduce and describe the waiting list's technical and procedural aspects, as well as a detailed description of the social prioritization framework. The knowledge from Chapter 3 will help to start identifying the data, grouped and technical aspects that could be used for the impact analysis.

4

Waiting List & Social Prioritization Framework

This chapter is intended to provide a basic understanding of the current functioning of the waiting list and to answer *SQ1*.

SQ 1: *What is the problem at hand and what is the proposed solution to benefit the society?*

That includes the waiting list management, what kind of current solution exist in congestion management and what are some important technical constraints. Then the chapter introduced the social prioritization framework developed by the ACM in detail. In this part the priority categories are described, details of the new process and application requirements are introduced and additional information is provided on the reasoning of the ACM for construction of the framework. Lastly, an alternative approach to social prioritization is given that is going to be implemented in the United Kingdom.

4.1. Current State

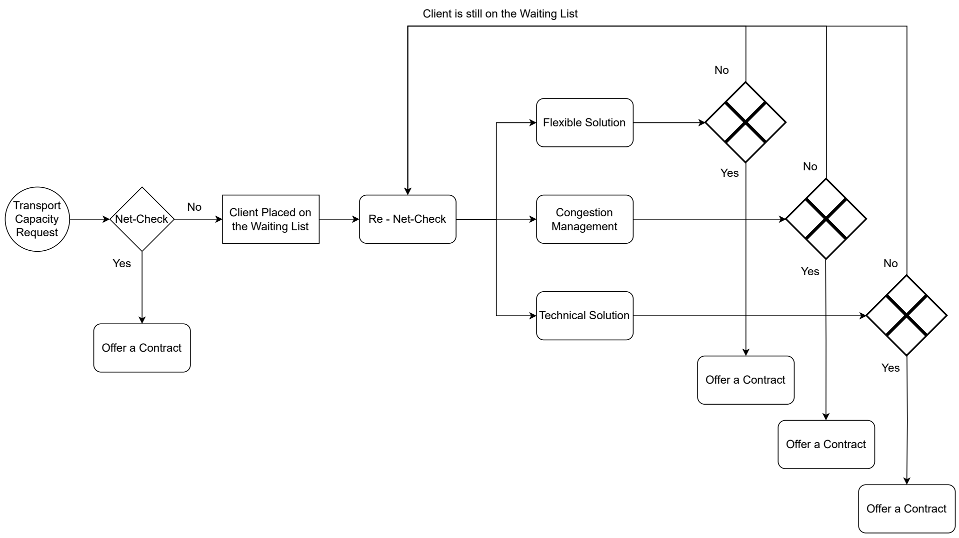


Figure 4.1: Diagram of the current Waiting List management process.

The current functioning of the waiting list management is relatively straightforward. The process flow diagram can be referred to on Figure 4.1. This process is only concerning the transport capacity requests and not new connection requests. Transport capacity request is when a client already has a physical connection to the energy grid and potentially already has some amount of contracted capacity

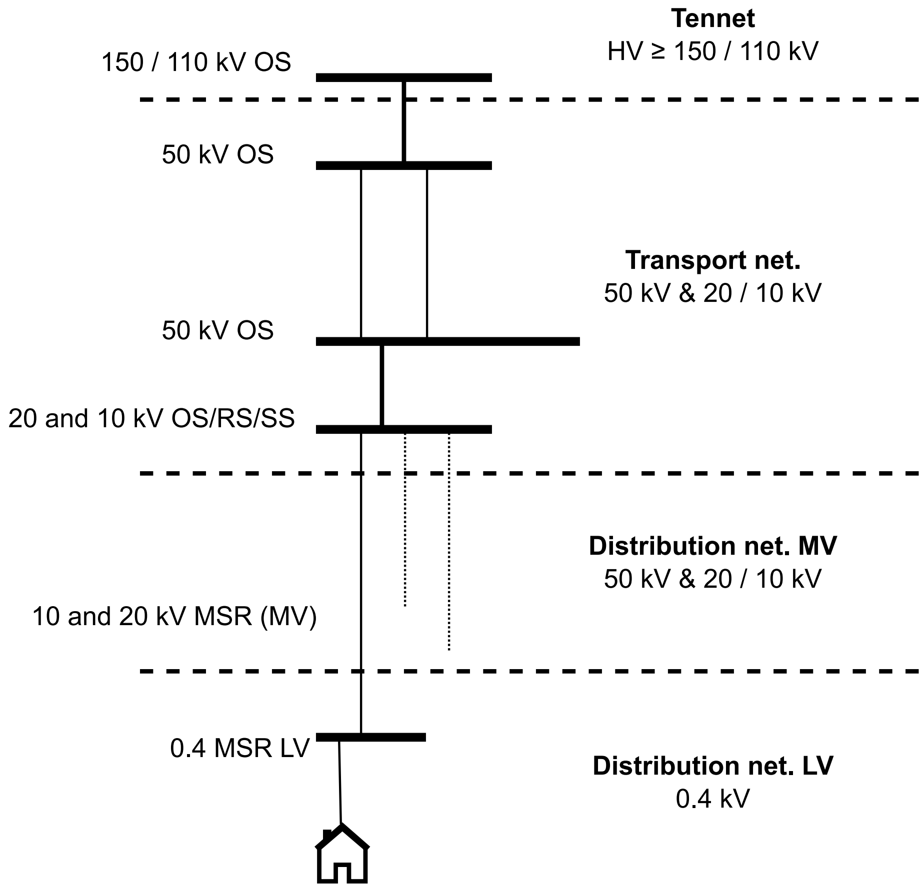


Figure 4.2: Illustration of different voltage levels, substations and technical structure that determines the constraints for the waiting list management.

for either consumption or/and production. As established earlier, the first step after receiving a request for transport capacity is to check whether this request can be fitted on the grid. Calculations are done to check whether a certain additional capacity can be handled by the infrastructure (tet-check) that is required to accommodate it. This infrastructure can include the transmission lines and different kinds of sub-station. The limit is therefore technical, but also administrative since no specific load profile is considered. Is is based on lump-sum and simple calculations of available capacity at the infrastructure and customer demands. If the infrastructure is already at its limit, the request is placed on the waiting list, where the clients are being arranged in the order of their entry and treated on a First-Come-First-Serve basis. Then the re net-check can be performed where a solution for a client on the waiting list can be offered either via, congestion management, flexible or a technical solution.

Congestion management refers to avoiding or relieving congestion and can be classified in two categories: cost-free and non cost-free [43]. The cost-free methods entail the constant operational costs or in other words, the economy of the system is not affected [15]. These methods are technical solution methods. Non cost-free methods are those that affect the economy of the system and are considered to be non-technical methods. For example, flexible contracts. Together with the clients, DSO can agree on the most beneficial power consumption or production profiles that will not put critical loads on the system and at the same time provide the necessary capacity for the client. If one of those solutions can be used to offer a client a certain capacity, they are removed from the waiting list. If not, then the client has to wait until the situation is improved, in most cases by technical solution such as grid expansion.

The waiting list itself is not being managed on a national level but on a much smaller, regional scale. It is logically and technically separated into four different levels as can be seen on Figure 4.2. The four levels are the TenneT operated High Voltage level, then the Transport Network, and finally the Distribution Network on Medium and High Voltage levels. The latter three are managed by a DSO.

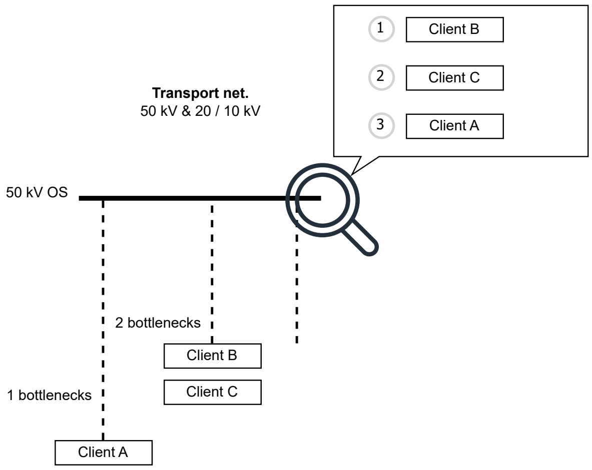


Figure 4.3: Technical exception to FCFS.

The highest order on which the waiting lists are separated is the 50kV Transport Network. At this level the main node is the sub-station. Therefore, the waiting lists are sorted by sub-stations. As can be seen from Figure 4.2, there are several lines that lead from the Transport Network sub-station (OS) level. This creates extra complexity when the waiting list is managed because even though clients are on the same queue of the sub-station, they can be treated differently depending on which line they are connected to. Therefore, the FCFS principle is not applied for 100% of the cases. A hypothetical example of exceptions to FCFS principle is illustrated on Figure 4.3. Even though, in the waiting list the FCFS order is Client B, C and then A, because the line on which Clients B and C are connected has more bottlenecks, Client A is granted capacity earlier.

The FCFS principle in itself is also a congestion management method. FCFS principle worked fine for a long time because there was little lack of capacity at the infrastructure and grid adaptations to increase capacity were not that time-consuming. It is arguably not the most efficient method if considered form the perspective of maximizing the value to society instead to treating everyone equal. From the need of making sure that the critical functions of the country are not hindered, the Social Prioritization emerges, which is described in the following section.

4.2. Social Prioritization

In this section the Social Prioritization framework is introduced. All the information about the framework is based on the open source documents published by the ACM and on the desk research done at Alliander [41]. This framework is only a draft, it does not represent the truth about which clients are socially important but is rather a step in the direction of developing smarter methods of distributing electric capacity at time of congestion on the energy grid.

4.2.1. The Basics of Social Prioritization Framework

Socially Important Clients	
Category	**Description and examples**
1. Congestion Reliever	A client to whom allocating transport capacity, results in more available transport space on the grid.
2. Safety	Clients who's activity concerns national security: • Emergency aid • Police and defense • Penitentiary services • Water safety • Equality category(parties that free up space by moving in favour of Safety clients)
3. Basic Needs	Activities of general interest and basic necessities of life: • Healthcare • Housing need • Water management • Waste management • Education • Public transport • Equality category
4. Sustainability	Producers of sustainable electricity are given priority over non-sustainable electricity. Also includes electricity consumers who commit to above-legal sustainability improvements.

Table 4.1: Summary of the categories of clients that are eligible for the social prioritization framework.

The basic principle of the Social Prioritization addition to the regulations by ACM is that parties that are performing an important public function are given priority above all other parties on the waiting list. Therefore, the first new rule is that the clients that fall under one of the categories, summarised in Table 4.1, are treated first. Only after those clients have been treated, other clients can be granted their capacity. Secondly, there is an internal priority order within the framework. That means that the clients in category 1 come first, then 2, 3 and finally 4. Within the categories the FCFS principle is still applied. For instance, if there is a request from a client within healthcare and education category, since theory are both within the Basic Needs category, the party that applied first will be treated first. At the moment, the only exception is the sustainability category. Producers of sustainable electricity that use cable pooling are given priority over other sustainability producers and wind farms are given priority over solar farms. According to ACM this distinction is made because cable pooling utilises transport capacity more efficiently and wind energy is considered more reliable than solar.

4.2.2. Categories Description

The first category, the congestion reliever, is at the top of the priority list because allocating capacity to such clients will lead to alleviating congestion. ACM states, that for example, under certain conditions that could be a storage solution party. Net-neutral parties, the ones that neither worsen or reduce congestion are explicitly excluded form this category. This is arguably a vague definition, however such clients' existence is theoretically possible. Currently, storage solutions are not treated as separate transport capacity requests. The only types of capacity requests are either production or consumption of electricity. Due to the nature of storage solutions, such as large scale batteries, they can operate in both modes, i.e. acting as a load and as a source of energy. It is common to consider capacity requests for storage as the worst case scenario for the local grid. That means that if the grid is heavier loaded by producers than consumers of energy, the electricity storage will be considered as load. In this way, the calculations are made to ensure the safety of the grid and that it can handle the battery if it is operated as a load. In the end, it is up to a DSO to decide whether a party qualifies as a congestion reliever.

The second category, safety, concerns the activities in the context of national security. This includes emergency services of ambulance and fire brigade, the core tasks of the police and defense, penitentiary institutions to support the police in maintaining public safety, and pumping stations and locks in the context of water safety. Some of these services are classified as an essential social service in Article 2 of Regulation (EU) 2017/1938 of the European Parliament and of the Council of 25 October 2017 on measures to safeguard security of gas supply and repealing Regulation (EU) No. 994/2010 (hereinafter: Security of Gas Supply Regulation) and/or are also excluded from the application of non-market-based congestion management due to their functioning (Article 9.43, fourth paragraph, of the Network Code). The security services mentioned also fall under Article 22, third paragraph, part a, of the Regulation on electricity tariff structures and conditions [41]. In addition to the parties in category 2, ACM adds a term ”equalisation”. These are the requests for parties that who’s activity does concern national safety but have been moved to a new location to enable safety activities.

The third category, basic needs, includes healthcare, housing, water management, waste management, education, public transport and those that fall under the term of ”equalisation”. Healthcare, housing needs and education fall under the Article 22 and 23 of Dutch Constitution and the government must make effort to promote it. Within the education category a distinction is made. Within healthcare, it is explicitly stated that only activities that can be linked directly to providing care to the patients are granted priority. In this way, a restaurant or a shop in the hospital does not qualify for priority. The healthcare category is not only limited to hospitals but also includes the development of nursing homes, care homes, homes for mentally and non-mentally disabled people, youth care with overnight accommodation and social care with overnight accommodation Only basic and secondary education is included in the priority framework. The choice for this distinction is related to the compulsory education and qualifications set out in paragraphs 2 and 2a of the Compulsory Education Act 1969 [41]. The public transport category only concerns the city and regional transport, as according to the ACM, the basic needs have a local and regional character. Water management is included in category 3 to ensure that new and/or expanded hospitals, residential areas and schools are supplied with clean drinking water and wastewater is purified. Waste management is included in category 3 to ensure that waste from new and/or expanded hospitals, residential areas and schools can be collected and processed.

Lastly, the sustainability category includes transport requests from producers of sustainable electricity and customers who are making large-scale sustainability efforts. This specifically excludes small-scale efforts, such as sustainability of homes or business premises. Transport requests from sustainable electricity producers that contribute to the climate and environment in the most efficient way for the grid are given the highest priority. Parties that are using cable pooling are given priority over other sustainable inputs, and inputs of electricity generated from wind farms are given priority over inputs of electricity generated from solar farms. Transport requests from customers who make large-scale and extra-legal sustainability efforts are also given priority, as long as they make enforceable agreements with the (de)central government and these agreements are sufficiently distinctive. This can also include for example extra-statutory CO2 reductions.

Only when the customers from the prioritization framework has been treated, the customers outside of the framework can be granted their transport capacity requests.

4.2.3. Requirements to be eligible

The main identifier that is used in the prioritization framework to distinguish priority clients is the SBI code of the party. Every company that registers in the Commercial Register (KVK) receives 1 or more SBI codes [24]. An SBI code is a 4 or 5-digit number and indicates what a company does. For the same business, for each activity, there is a separate SBI code registration. SBI codes can be used as an initial indication of a party’s business activities in the categories 2 and 3. The full list of all SBI codes with descriptions that are part of the framework can be seen in Table B.1. In a case, which is common, if a party is registered with multiple SBI codes in the KVK, the SBI code listed first in the trade register is used for the application of categories 2 and 3 of the prioritization framework. However, there is always an opportunity for such client to prove that the activity for which requested capacity is needed is indeed for the purposes of the activities within the prioritization framework.

In addition to that, there are extra measures taken into account to prevent the misuse of the framework. The party applying for the prioritization framework must prove that concrete legal tasks and/or objectives are in line with provisions from existing zoning or environmental plans or other concrete binding agreements with the (de)central government that show that a transport request from a party makes a concrete contribution to one of the categories mentioned in the prioritization framework. In addition to that, there must always be a person, representing the applicant, who is legally responsible for making sure that the granted priority capacity is used for its intended purposes. All the burden of proof lies with the party submitting the capacity request.

4.2.4. Evaluation and Reasoning by ACM

In general, there must be no discrimination when dealing with distribution of energy, especially since that task is handled by companies that have a monopoly in the region. Despite of that, ACM believes that social prioritization fits within the European law on non-discriminatory network access and the Dutch system of non-discriminatory allocation and distribution of transport capacity. Their main arguments are that the distinctions is based on an objective and reasonable criterion, which is linked to the European electricity legislation objectives, and that this distinction is necessary to ensure unrestricted achievement of public interest [41]. In their view, the distinctions are proportionate as this goal can not be achieved in some other less extreme way.

4.3. Other Examples of Prioritization

There is another example of deviating from the FCFS principle coming from Britain. Their Office of Gas and Electricity Markets (OFGEM) have announced a plan to change their policy on the FCFS principle in the energy queuing system and to treat stalled projects that are blocking the queue more harshly [40]. To summarise, the key change is that the clients in the waiting list will evaluated whether they are achieving their planned milestones, whether they have all the right permits and plans and so on. The idea is to check if the project is just occupying space only to reserve a spot or this project can undergo soon. This is a different perspective on waiting list management and deviation from FCFS basis. In contrast to ACM's approach, which seems to be more political and sociological, the decision by OFGEM can be called more utilitarian. In conclusion, there are different metrics for different goals, and they are not limited to subjective decisions on what is socially important.

4.4. Conclusion Chapter 4

This chapter describes the problem of waiting list management and the solution to it in the form of social prioritization framework. The framework does not solve the problem of waiting time itself but rather prioritizes socially important functions to insure that socially important functions are given the electric power they require as soon as possible.

The current, step-by-step process of waiting list management was described. It was revealed that the FCFS principle does not always strictly apply. The order in which clients on the waiting list are treated highly depends on technical constraints such as the reason for the bottleneck, the willingness of the client to be flexible, and the voltage level on which the client is connected to the distribution grid.

The social prioritization framework was introduced, including the reasoning of the ACM behind their choices. From the draft document, it can be argued that the main reasoning is legally based, in order to justify the deviation from the FCFS principle. Also, it was mentioned that a decentralised version of the framework was considered but not chosen due to its complexity but not elaborated further. Lastly, one of the most important components of the framework, SBI codes are used to establish the official function of a client.

Now that the waiting list nuances and the framework are understood, in the next chapter, the documented opinions of stakeholders are evaluated to get deeper insight into what the framework means. Stakeholders have a better understanding of the impacts this framework will lead to in their specific cases.

5

Stakeholder Opinions: Qualitative Analysis

This chapter is intended to answer *SQ2* and to provide an insight into the opinion of the stakeholder that have published their opinion on the ACM website.

SQ 2: *What are the opinions of the stakeholders on the new social prioritization framework?*

These stakeholders represent a variety of industries and functions that are either within or outside of the framework. Their opinion will help to uncover things that are positive, negative and questionable regarding the framework. From this, Energy Justice implications can be derived.

5.1. Dataset and ATLAS.ti

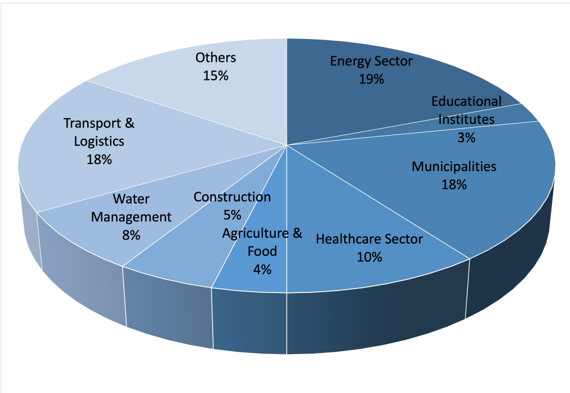


Figure 5.1: Distribution of number of responses to the ACM request to express opinions on Social Prioritization framework.

To gain better insight into the implications that Social Prioritization brings, the documented opinions of stakeholders are analyzed. The creation process of Social Prioritization has been explained by the ACM but to a limited extend [41]. It can be said that the consultation for the draft code that is analysed in this research has been done without the direct opinion of affected stakeholders. However, they were presented an opportunity to submit their official opinion to the ACM. This resulted in 78 total, publicly available opinions that are available on the ACM website [1]. The stakeholders were asked to give their open opinion and answer three specific questions. The three questions are asking to elaborate on:

1. What suggestions and improvements to categorization and functions in the framework can be given?
2. Is it common and necessary to have a link between the housing projects and commercial functions? Should the "housing needs" category be expanded?

3. Should the prioritization framework also include connection requests in addition to the transport capacity requests?

The published opinions can be split into 9 categories, based on the industry or function of the stakeholder. The categories are: the energy sector, educational institutions, municipalities, healthcare, agriculture & food, construction, water management, transport & logistics, and others. The distribution of a number of responses per stakeholder category is show on Figure 5.1, where it can be seen that the majority of the responses came from the Energy Sector, followed by municipalities and the Transport & Logistics sector.

These documents were machine-translated by Google Translate from Dutch to English for better understanding. However, this could results in some information loss. These documents were then uploaded to ATLAS.ti software for the identification of main themes and codes within the texts. Before reading through the texts some themes were paid attention to, namely the points of concern, uncertainty in understanding, whether the stakeholder exhibited a generally positive or negative attitude towards the framework. Throughout reading several additional themes were identified, namely general suggestions for improvements of the framework, specific suggestions of including a new category of clients in the framework, responsibility, problems of related to the lack of knowledge by the ACM, injustice concerns, and a positive opinion on question 3 posed by the ACM.

5.2. Energy Sector

Representing the Energy Sector, the following parties submitted their opinion that was made public:

1. Laka - Documentation and Research on Nuclear Energy.
2. VEMOBIN - Energy Association for Mobility and Industry.
3. Eneco - producer an supplier of natural gas, electricity and heat.
4. Groen Gas Platform - bundling of four players in the Dutch green gas industry.
5. NVDE - Dutch Sustainable Energy Association.
6. VEMW - Association for Energy, Environment and Water.
7. Ennatuurlijk - energy supplier.
8. Total Energies - energy and petroleum company.
9. FASTNED - owner and operator of fast charging EV stations.
10. Netbeheer Nederland - trade organization for electricity and gas network operators in the Netherlands.
11. Energy Storage NL - trade organization of the Dutch energy storage sector.
12. Holland Solar - trade association for the Dutch solar energy sector.
13. Gas Unie - Dutch natural gas infrastructure and transportation company.
14. Energie Nederland - trade association for energy companies.
15. Smart Delta Resources - transnational partnership of large energy and resource-intensive companies in the Schelde-Delta region.

Out of 15 responses from the Energy Sector, 10 parties in general exhibited a positive attitude towards the changes proposed by the ACM, 2 parties exhibited a general negative attitude and the rest was not clear. Overall, most of the representatives are in favour of, at the very least, the direction in which ACM is thinking. Holland Solar, although understands the desire to enable social prioritization, they question the feasibility of such an approach. Their main fear is that the extra administrative burden will in fact delay the energy transition instead of speeding it up. VEMW is the only stakeholder within the Energy Sector that openly stated is not in favour of redistributing the economic damage from the current congestion problems according to political preferences. The introduction of social prioritization will lead to high uncertainty for large consumers, which in turn will stall investments and potentially slow down the energy transition. It makes it challenging to plan investments. Another important comment is that in fact, large consumers do not operate in isolation. Same hospitals, still need instruments, sterilization of instruments, gloves made out of specific plastic, and so on. The chain effects that can be caused by social prioritization can hinder the operation of socially important consumers.

The parties that have indicated being in favour of the ACM's proposal, also comment that the framework is incomplete and should be expanded to add extra customers that they believe also perform a socially important function. For instance, according to Gas Unie, one category has been neglected. Namely, the parties that concern the national gas transport network as it is part of the vital national infrastructure [46]. This view has been supported by other respondents, such as NVDE and Smart Delta Resources. Moreover, there is a concern that electrification of mobility is not taken into account under the transport category. For instance, charging stations which are essential for national sustainability goals and electrification of the transport sector.

Another important consideration is that the last category, sustainability, allows for disproportional benefaction of large polluters that can financially support above-legal sustainability improvements. In the meantime, smaller-scale players that are for instance inherently more sustainable than in the previous example, can not show the same change. The exact wording from the ACM document makes it look like only companies with a polluting past (or present) appear to be eligible for priority. This category in general creates a lot of questions from the Energy Sector representatives and further elaboration is required.

Lastly, the majority seems to be in favour of using a prioritization framework also for connection requests. However, NVDE is against it, justifying it by the fact that it will hinder the physical expansion and works on the grid as the efficiency and planning will be damaged. This is because the connection requests are carefully planned so certain geographical locations receive multiple locations. Prioritizing connections will make it more difficult to efficiently plan physical technical work.

5.3. Educational Institution

From the sector of Education, the following parties have submitted their opinion:

1. Tilburg Institute of Law, Technology and Society
2. Foundation Interdenominational Vocational Education and Adult Education region Amersfoort (MBO Amersfort)
3. Vakopleiding Techniek. Offers training and courses in precision technology, mechatronics, metalworking and electrical engineering.

This category of stakeholders has all exhibited a generally positive attitude toward social prioritization. One of the respondents made a focus on the fact that deviation from the FCFS principle is currently an option and it is vaguely defined when a DSO should or must apply it. Using the framework in areas lacking designated congestion zones, but experiencing scarcity, is justified since the need to deviate stems from the scarcity scenario. However, two key considerations emerge: firstly, adherence to the principle of non-discrimination, particularly in proportionality, mandates that no less-reaching alternative is available. Therefore, it must be demonstrated why congestion management fails to sufficiently alleviate capacity constraints in the specific context. Secondly, it's imperative to avoid arbitrary decisions. Thus, the question arises whether opting to deviate from First-Come, First-Served (FCFS) both within and outside congestion zones might promote arbitrariness, as it would create situations where deviations are made selectively. Consequently, providing clear justifications in each specific circumstance for either deviating from FCFS or adhering to it instead of the prioritization framework becomes essential.

Additionally, it is not perfectly clear as if to why the ACM has chosen to move away from allowing local consideration in the framework towards the same framework for all geographical regions. The initial concern was that a framework allowing room for local authorities would be too complex. However, considering the rapid changes in the energy sector towards local systems, it's vital for local factors to influence decision-making. This becomes more concerning as municipalities will likely establish environmental visions guiding local systems in collaboration with market players and network operators. Neglecting to consider local interests and system dynamics poses a considerable issue.

MBO Amersfort and Vakopleiding Techniek both expressed their concerns that MBOs or secondary vocational education should also fall within category three of basic needs. One of the reasons is that students who have reached the age of sixteen but have not yet obtained a starting qualification are also required to attend school and this obligation to attend school only ends at the age of 18 or when they have obtained the starting qualification. Many participants are registered at MBO Amersfoort who are over 16 years old, but have not yet obtained a starting qualification.

5.4. Municipalities

1. Overbetuwe.
2. Utrecht.
3. Nijmegen.
4. Middelburg.
5. Bergen op Zoom.
6. Eindhoven.
7. G4 Amersfoort.
8. Maas.
9. Leiden.
10. Tilburg.
11. Gorinchem.
12. VNG - Vereniging van Nederlandse Gemeenten, or Association of Dutch Municipalities.
13. Delft.

Most of the responses from municipalities exhibit a generally positive attitude towards this deviation from the FCFS principle. Naturally, there are plenty of concerns and suggestions. One prominent theme that stood out was the local context. Many municipalities are in favour of decentralizing the decision on who is eligible for prioritization. They believe that priorities of areas such as Randstad, Eindhoven and more rural areas can significantly differ. Where is in one area there is a massive shortage of housing, the other areas could be suffering from the lack of schools. In addition to that, there are frequent occurrences where entities are misclassified under the incorrect SBI code due to administrative errors or delays. Adhering strictly to the framework can consequently result in a bureaucratic process with unfavorable consequences. While establishing a framework within SBI codes offers clarity on what constitutes 'significant public interest' and aids in prioritization, a stringent application of this framework poses the risk of disregarding its primary intent – to facilitate the swift progression of developments crucial to the public interest.

It was also noted, that the healthcare category is very limited and only addresses university medical centers, hospitals and categorical hospitals. It must be taken into account that local healthcare delivery, health centers and general practitioner (GP) practices are essential in ensuring the ongoing provision of healthcare at both local and regional levels. Moreover, there is a growing trend towards the intelligent integration of energy systems managed by commercial entities with nearby residential properties. For instance, supermarkets can emerge as significant collaborators in facilitating heat exchange and the establishment of local energy networks. In other words, the housing category is also claimed to by insufficiently wide. In addition to that, it was also proposed that the prioritization framework should also cover the traffic infrastructure, all forms of education, sports facilities, parties contributing to air quality, food supply, and innovative technologies that are contributing towards the strategic autonomy of the Netherlands, such as battery technology, hydrogen, heat storage.

From the region of Zeeland, a concern came from the fact that a lot of parties that are eligible for the sustainability category have placed very large capacity requests, and if prioritization framework is applied, this will have major effects on civil organizations. Middelburg municipality specifically requested to calculate the impact of social prioritization before implementation.

5.5. Healthcare

From the Healthcare sector the following parties have submitted their opinion:

1. Nordwest Ziekenhuisgroep - Northwest Hospital Group.
2. Actiz - trade association of healthcare organisations.
3. National Association of General Practitioners.
4. Health centers Bergen op Zoom.
5. Applied Medical Europe.
6. Nederlandse Verneging van Ziekenhuizen - Dutch Hospital Association.
7. Huisartsen Cooperatie West-Brabant - General Practitioners Cooperation West Brabant.
8. Landelijke Huisartse Vereniging - National General Practitioner Association.

The majority of the respondents show a generally positive attitude towards the proposed framework. In fact, they are pointing out the urgency of implementation of these changes because of the pressing electricity scarcity issue. There are of course several important concerns regarding the framework.

Some parties have indicated that it is a mistake to place healthcare in category 3 instead of category 2 of the social prioritization framework. The claim is based on the fact that hospitals directly contribute towards national security, for example in extreme cases, such as pandemics. They also believe that there is an inseparable connection between emergency care, which is in category 2, and hospitals, which are in category 3. In other words, this creates a scenario where an ambulance will arrive to the closed doors of a hospital due to the lack of electricity.

Then, there is a common desire among the healthcare sector representatives to expand the healthcare category to include all healthcare centers, and importantly - the General Practitioners (GPs). GPs are the essential link between the population and healthcare providers. GPs are often located in commercial buildings, not in the hospital, and therefore are using a shared connection. This connection request is most likely placed with a different SBI code than a healthcare organisation. This creates confusion and uncovers one of the limitations of using SBI codes as the primary indicator of socially important clients.

Lastly, Applied Medical has expressed an important opinion on the fact that hospitals and other healthcare organisation heavily rely on medical equipment suppliers. Such functions are not included in the prioritization framework. This suggests yet another limitation of the framework and it neglects the functions which are in the value chain of socially important clients.

5.6. Agriculture

Parties submitting opinion from the agriculture and food sectors:

1. Land en Tuinbouw Organisatie - Agriculture and Horticulture Organization.
2. FNLI - the umbrella organization of processing and importing companies and industries in the Dutch food sector.
3. CANS - Cellular Agriculture Netherlands.

All parties exhibit a generally positive attitude towards the social prioritization framework. The responses indicate a unanimous desire to include the food supply in the category 3, basic needs, of the framework. In their opinion, this should also cover the innovation effort to improve the sustainability of the food and agricultural sector. This is also linked to the comment on category 4, parties that make above legal sustainability efforts. In their interpretation of the framework, this can potentially lead to favouring major consumers of electricity, while small-scale consumers can potentially have greater social impact through their innovations.

5.7. Building and City Planning

Representing the Building and City planning stakeholder the following submission were published:

1. NEPROM - is the trade organization of socially involved project and area developers in the Netherlands.
2. RIALTO Vastgoedontwikkeling - real estate developer.
3. STADLANDER - housing society.
4. Bouwend Nederland - association for construction and infrastructure.

At least half of the respondents exhibit a clear general positive attitude. Naturally, there are some concerns about the way the social prioritization framework is structured. They believe, there indeed must be a link between commercial activities and housing needs. A lot of housing projects are financed and dependent on commercial activities. For instance, a supermarket that is palaces in a housing complex. It is both vital for the food supply of local communities and for making housing projects financially feasible. Severing the connection between civil development and commercial activities will have major negative consequences. It is also not always clear who should submit the transport capacity requests as many different parties are involved in the development of housing facilities.

5.8. Water Safety and Management

1. VEWIN - association of drinking water companies in the Netherlands.
2. St. Waternet - drinking water supplier.
3. Waterschap Amstel Gooi en Vecht - drinking water supplier.
4. Smart Delta Drechtsteden - a collaboration between government, entrepreneurs and education.
5. Unie van Waterschappen - the umbrella organization of the 21 water boards in the Netherlands.

All five respondents have indicated being in favour of the social prioritization framework. However, they are asking ACM to pay more attention to be paid to the theme of water. As it currently states in the framework, which is only referring to the Water Act to determine publicly important functions, various developments are not taken into account. Among the numerous functions that they are suggesting to include in the framework, they also propose to create and internal prioritization within water management. Such that drinking water is given utmost priority. Lastly, there is a shared desire for certainty, in terms of making the social prioritization mandatory instead of optional.

5.9. Transport & Logistics

1. Ministry of Infrastructure and Water management
2. Schiphol Airport.
3. Transport and Logistics Netherlands.
4. BOVAG - is a trade organization of more than 8,000 entrepreneurs involved in mobility.
5. ProRail - a Dutch government organisation responsible for the maintenance and extension of the national railway network infrastructure.
6. Port of Amsterdam.
7. Port of Rotterdam.
8. AIM - mobility tendering institute.
9. KNV - Royal Dutch Transport.
10. RAI - association committed to sustainable, safe and affordable mobility.
11. Shell Mobility.
12. evofenedex - formed by the associations EVO (Own Transporters Organization) and Fenedex (Federation of Dutch Exporters).
13. VDVN - association of clients in target group transport.
14. NS - the principal passenger railway operator in the Netherlands.

In the case of the Transport & Logistics sector the majority is also in favour of the social prioritization framework. Despite of the overall support, some parties request to expand the network to include additional categories of socially important capacity requests.

The framework is limited to only transport that operates within cities. This, therefore, omits the intercity transport such as intercity trains. NS and ProRail strongly believe that this category should be included in the framework. That desire also resonates with previous comments on the local context. Some areas mostly rely on public transport within cities, other more rural areas significantly rely on railway transport.

Other stakeholders from that sector also point out that there is special transport for vulnerable members of society. For example, ones that require assistance in transportation. Since all modes of transportation are aiming towards electrification, this sector should not be neglected. In addition to that, it was proposed to include transportation by taxi, busses, and passenger road transport. Schipol group has also proposed to include aviation. Combining all responses, there are requests to consider the entire public transport for social prioritization. A way of prioritization within the public transport sector could also be from the perspective of sustainability. Thus prioritising, public transport functions that are making sustainability efforts.

5.10. Others

There was also a number of responses that do not fall under any of those major stakeholders categories, namely:

1. Dutch Data - the Dutch data center association.
2. Investa - the center of expertise for gasification technologies.
3. KPN - telecommunications provider.
4. Vodafone Ziggo - telecommunications provider.
5. Microsoft - technology company.
6. NL Digital - is the trade association of the digital sector.
7. Nobian - chemical production.
8. RVB - manages government and defense buildings.
9. VNO-NCW MKB - represents the interests of companies of varying sizes and spread across all sectors.

The majority in this category is also in favour of the prioritization framework. One exception is NL Digital. Their main concern is that no consideration has been made for the digital processes in general, and in particular including the data centers. The same concern was expressed by the Dutch Data. They believe that they have been responsible in their energy consumption and made significant sustainability improvements and should also be included in the framework. The same can be said for telecommunications companies, such as KPN and Vodafone Ziggo.

A particularly interesting suggestion came from Microsoft, which recommended to look into implementing a similar prioritization logic as was done in the UK [40]. So instead of only looking at qualitative factors, also take into account the readiness of the project and prioritize those that can be finished quicker and are not stale.

In order to promote transparency and fairness, Nobian suggests that such important public decisions should also be made public. Publishing the ACM Netcode is not enough for that. It should be clear in the event of given priority to one client, which client will suffer the burden. In addition to that, social prioritization must not become an obstacle in the work of DSO, so as not to lead to further delays in grid expansion. It is thus important to assign clear roles and responsibilities while giving enough capacity for DSO to do their most important work.

While many parties are advocating for expanding the framework and including more categories in the priority list, some say that this creates extra issues. For instance, to limit the social prioritization only to emergency situations. Such a framework can of course potentially have errors in its execution, which can lead to confusion, legal issues and overall delays.

5.11. Conclusion Chapter 5

The qualitative analysis of stakeholder opinions indicated several areas which are relevant in the Energy Justice context. Several neglected or unrecognized groups have been identified. This falls under the Recognition Justice Pillar. Social prioritization itself is already a deviation from the equal opportunities scenario. This sacrifice is done to benefit the society as a whole. However, certain groups have been omitted from the prioritization framework, which could cause extra delays for these parties, while they are within the value chain of socially important activities.

Then, the local context emerged. Numerous responses indicated that the social prioritization framework should not be applied to all regions in the same way. Certain areas could potentially benefit more from this change in the waiting list management, while others would suffer, creating a concerning Distributive Justice case.

Lastly, the majority of stakeholder groups have commented and suggested expanding the framework to include additional parties, which in their opinion also serve an essential function to society. On the other hand, the more separate clients are included in the framework, the less effect it will have. *Prioritizing everyone is prioritizing no one*.

In the next chapter, the quantitative impacts are analyzed and that can be compared to the concerns that have emerged in Chapter 5. It will also help to uncover what kind of stakeholders are actually benefiting and which ones are suffering due to social prioritization.

6 Social Prioritization Impact: Quantitative Analysis

This chapter aims to answer *SQ3, SQ4 and SQ5*:

SQ 3: *What is the algorithm and what are the necessary components for the evaluation of social prioritization effects?*

SQ 4: *What are the appropriate metrics for evaluating the fairness of the social prioritization outcomes?*

SQ 5: *What is the impact of the social prioritization on the clients that are within and those outside of this framework?*

The goal of this analysis is to attempt an estimation of the expected total waiting time in the waiting list for each client for both before and after the implementation of the social prioritization framework. These changes are considered for both the clients that are eligible and not for the prioritization framework. First, the relevant data and quantities are described that can be used for the impact analysis. Then the impact analysis logic is presented, including all the limitations and necessary assumptions. After that, the results of the analysis are presented and discussed. The last part introduces potential metrics that can be used for understanding the Energy and Distributive Justice implications of the social prioritization framework.

6.1. Dataset Description and Relevant Quantities

The datasets used for the impact analysis were provided by Alliander. The two main datasets used came from the Waiting List and Development dashboards that are used by the employees of Alliander to perform congestion and waiting list management. With the help of the information gathered from the technical experts, the required variables for impact calculations were gathered. The full list and variables description can be seen in Appendix B. The information that is relevant can be described in categories, such as the time series data, transport capacity quantities for both the original request and what was contracted (definite), and the nature of the client i.e. the function. The datasets are treated separately for consumption and production transport capacity requests.

Time series data tells when the client first entered the waiting list (Waiting List Date) and when the client is expected to be granted their request (Bottleneck Solution Date). The Waiting List Date is used to structure the waiting list according to the FCFS principle and keep a chronological record. The Bottleneck Solution Date is assigned to the client based on either congestion management or grid expansion efforts. This date is usually assigned to groups of clients as it is a structural solution and not an individual one. The capacity data tells how much a client has originally requested (Requested Capacity) and how much that client was eventually granted (Contracted Capacity). Contracted Capacity is either smaller or equal to Requested Capacity. In many cases, Contracted Capacity is smaller than the Requested Capacity, which can happen for a variety of reasons. It happens that customers overestimated how much capacity they need and DSO are being more conservative due to the scarcity of the capacity on the grid. In addition to that, a type of connection is also important (AC type). AC type tells on what level the customer is connected to the grid, such as in Figure 4.2. This is relevant because, above a certain power level (AC6 and above), clients are treated separately as an entirely different infrastructure is required. Therefore, although they appear on the same waiting list as smaller customers, they do not influence the waiting list directly. Lastly, the nature of the client is identified by the name of the client (organisation registered name). This tells to what priority category a client might belong to or not.

It is important to note that the datasets are anonymised to protect privacy-sensitive information. Therefore, no real organisation name is shown, and only the relevant function is mentioned. Moreover, all numbers, including the time series data and capacity quantities are slightly modified so they can not be traced back but still show relevant dynamics for the analysis.

6.2. Impact Analysis Logic

6.2.1. Limitations and Assumptions

Before diving into the analysis logic, the main assumptions and limitations need to be stated. Limitations mostly come from the quality of data or lack thereof. From these limitations, necessary assumptions had to be made to tackle these limitations.

Limitations:

1. **No SBI codes in the dataset.** The lack of this information made it very challenging to perform an impact analysis on the whole waiting list. That would require an automated process that would link the clients on the waiting list to their SBI codes. With the time constraints, complexity of the task and some inaccuracies in the client information that option was not pursued.
2. **Missing solutions dates.** Not every client in the dataset is assigned a Bottleneck Solution Date. This usually occurs for the least mature or more recent clients because there was not enough time to do the whole evaluation process of the bottleneck.
3. **Complexity of treating consumption and production requests at the same time.** For the analysis it is important to understand the current situation and in what order the clients are being treated and given solutions now. The waiting list is, as mentioned earlier, is sorted by substations and the network architects that perform the net-checks see both consumption and production transport capacity requests. In some cases these requests require the same infrastructure and are thus treated as one list, in other cases it is a separate infrastructure, and therefore a production request could be treated separately from a consumption request.
4. **Bottleneck Reason Complexity.** As discussed in Chapter 4 the energy grid infrastructure is very complex and even though the waiting list is sorted by the substation level, the client on that substation has different type of connections and infrastructure required. This also includes bottlenecks that can happen on a level above of what a DSO is responsible for, such as HV TenneT level. For instance, if a client is prioritized, it doesn't necessarily mean that an earlier solution can be granted. This can be in a situation when all client before the priority clients have substation level bottlenecks and the priority client has an additional TenneT bottleneck.

Assumptions:

1. **Organisation (client) name can be linked to an SBI activity.** The first limitation can be overcome by taking smaller datasets and manually checking the officially registered activity of each organisation based on their actual name. If a clients, activity falls within one of the the social prioritization categories, it is assumed that this client is eligible for prioritization.
2. **Assign missing dates.** Missing dates can be filled in, especially for the clients who are at the bottom of the waiting list. An average time difference can be taken from the previously assigned solution dates. This number is then added to the latest known solution date. It is then assumed that these clients will be granted their contracted capacity at that date.
3. **Treat consumption and production requests separately.** The decision to treat the consumption and production requests either separately or in the same queue depends on many circumstances and is very case-specific. With the lack of clear rules, it is better to assume one scenario.

In addition to that, all AC6 and above capacity requests will be treated separately.

4. **All clients per substation experience the same congestion reason.** This assumption allows to do calculations without doing a full congestion management analysis that requires expert knowledge. Although this assumption is far from reality, it was considered acceptable and realistic enough by technical specialists to evaluate potential implications.

6.2.2. Impact Analysis Logic Flow

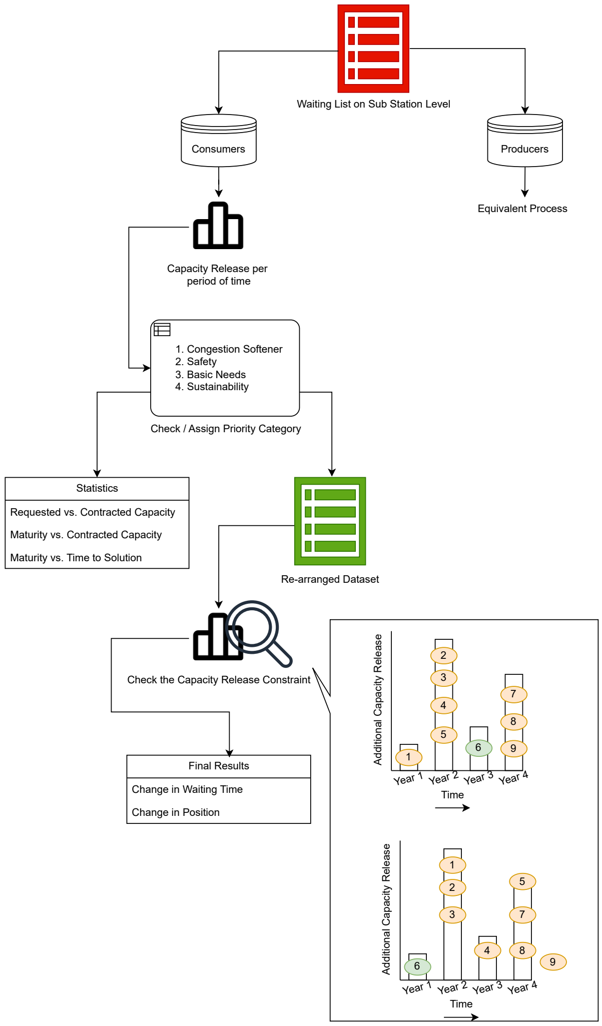


Figure 6.1: The diagram of the logic used for the impact analysis to estimate the change in waiting time for all the clients on the waiting list of a substation.

The logic flow for the impact analysis is illustrated in Figure 6.1. The initial dataset contains the whole waiting list of clients on a specific substation. This dataset is then separated into consumption and production transport capacity requests. The analysis process for these two categories is identical. Then the first calculation is made to estimate what is the minimum additional capacity is going to be available in the future per period of time. This is done by summing up the contracted capacities at the same Solution Date. Then, the priority clients are identified and assigned priority status, either 1, 2, 3 or 4. At the same time, the initial analysis can be done to understand the general statistics and dynamics on that specific waiting list. The quantities that are paid attention to hear are the Maturity, Contracted Capacity and Time to Solution of each client, as well as the relationships between them. The list is then rearranged by placing the priority clients at the top of the waiting list and arranging everyone else in the FCFS order. An important step here is that priority clients are kept in the FCFS order within their categories. Non-priority clients, on the other hand, are arranged in two steps. First arrangement is done by the Solution Date groups, then within those groups the clients are arranged in the FCFS order. This is done so there are no irregularities caused by the non-chronological order of assigning the Solution Date.

Now that all the clients are in a correct chronological solution order, the Time to Solution can be re-calculated. Just placing a customer on top of the waiting list doesn't mean that this customer will be granted a solution earlier. There must be enough available capacity in the future for their contracted capacity request. For example, in Figure 6.1, the priority request is number 6. We assume that it fits in the additional capacity that will be released in Year 1. However, the client that used to be in the first position no longer fits within that capacity release and has to be moved to the next capacity release in Year 2. This creates a chain reaction and for client 9 it is unknown when a solution can be granted.

The updated Solution Date is then assigned to all the clients on the rearranged waiting list.

6.3. Real Data Impact Analysis Results

This subsection is intended to show the real-life implications of the social prioritization framework. This is achieved by recalculating the Time to Solution of each client if there is a priority clients in the waiting list. Five different substations were chosen for impact analysis. They were chosen because they were among the top five cases either in terms of most total contracted capacity, maximum waiting time or most number of clients on the waiting list. This was done so the worst case could be taken into account. In addition to that, the waiting lists were examined for the presence of either potential priority clients or clients that were suggested to be in the prioritization frameworks by stakeholders, as mentioned in Chapter 5. In this section, the effects are summarised in tables that only include the clients that have either been affected by prioritization or the ones that have a priority status.

The tables in this section are composed of the following data:

- **Entry Date.** The date when the client entered the waiting list.
- **Client.** The name of the client shows only the main function, according to the social prioritization framework description.
- **Contracted Capacity.** This shows the capacity that is contracted for each clients.
- **Solution Date.** Indicates the originally estimated date of when the contracted capacity request can be granted.
- **Priority.** Tells the priority status of each client according to the social prioritization framework, where 1 is the highest priority, 4 is the lowest priority and 0 is no priority.
- **New Solution Date.** Indicates an updated estimated solution date, applying the previously stated logic.
- **△ETS.** This is the change in Estimated Time to Solution. A negative number mean a decrease in the amount of total waiting days, a positive number means an increase and zero means no change.

Moreover, this section discusses other important statistics that could help identify trends that are occurring within the waiting lists and potential Energy Justice implications. All the relevant figures can be consulted in Appendix C. For this purpose the following quantities are examined in relation to each other:

- **Clients Contracted Capacity and Requested Capacity relation.** This to identify which clients have received in the end Contracted Capacity lower than what they requested.
- **Clients Maturity and Contracted Capacity relation.** This shows the relation between the clients position on the waiting list, the time client has already spent on the waiting list (maturity) and the Contracted Capacity.
- **Clients Maturity and Time to Solution relation.** This indicates the relation between how much time the client has already spent on the waiting list and the total expected Time to Solution.

6.3.1. Substation 1

The first substation waiting list has 21 transport capacity requests for consumption and 5 for production. Among the consumption requests three priority clients were identified. Client that do not fall under the social prioritization framework were mainly businesses (B.V.), sport clubs a healthcare organisation and food producers. Among the production requests, only one priority client was identified. The rest were businesses and a sport club.

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	Δ ETS [days]
2022-05-15	Hospital	576	2025-08-01	3	2025-08-01	0
2022-06-17	Hospital	12	2026-07-01	3	2025-08-01	-334
2023-05-13	Higher Education	244	2028-10-01	3	2025-08-01	-1157
2023-04-20	B.V. 1	356	2025-08-01	0	2028-02-01	914
2022-08-12	Sport Club	8	2026-09-01	0	2028-02-01	518
2023-01-10	Sport Club	782	2028-02-01	0	2028-10-01	243
2023-01-31	Religious Education	21	2028-02-01	0	2028-10-01	243
2023-03-16	B.V. 2	46	2028-04-01	0	2028-10-01	183

Table 6.1: Estimated impact of social prioritization on the waiting list of Substation 1 for clients that have requests transport capacity as consumers.

In the case of consumer requests (Table 6.1) case, two definite priority clients were identified, namely two hospitals. In addition to that, a potential priority client was taken into account which was the request from a Higher Education Institute. The first request from a hospital had no impact because it was the first in-line client. Two priority clients has an improvement in their estimated time to solution and one client had no change because that request was originally the first to be granted capacity. To accommodate for the capacity of priority clients, five other non-priority requests are delayed.

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	Δ ETS [days]
2023-03-19	School	130	2025-08-01	3	2025-08-01	0
2023-02-05	B.V. 1	75	2025-01-01	0	2025-08-01	212

Table 6.2: Estimated impact of social prioritization on the waiting list of Substation 1 for clients that have requests transport capacity as producers.

When looking at the production requests (Table 6.2), the priority client, although pushed to the top of the waiting list will not have any improvements in the waiting time due to the released capacity constraint. However, the business that was pushed down the queue will experience a delay. This situation can happen if strictly adhering to the rule of first granting a connection to the priority clients even if other smaller requests could be granted their capacity first.

On this specific waiting list, the number of consumption requests is much greater than consumption requests. This could be an explanation behind the fact that consumption Contracted Capacity is in almost all cases lower than Requested Capacity, including the priority clients. The most mature clients in the waiting list were relatively high capacity requests and could be a reason behind the bottleneck. On Figure C.3 that shows the relationship between Estimated Time to Solution and Maturity, a trend can be seen. There are two clusters of customers can be seen, which are in different capacity release groups. With the increase in Maturity, the Estimated Time to Solution also increases. This tells that there is actually an inverse relation if compared to FCFS.

6.3.2. Substation 2

The second substation waiting list has 22 transport capacity requests for consumption and 23 requests for production. Among the consumption requests, four priority clients were identified. The rest were the requests from mostly businesses, a supermarket, sport facility and a research facility. Among the production requests, two clients were identifies as priority clients. The rest were the requests from mostly businesses, a religious education center, a medical center and a food producer.

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	Δ ETS [days]
2023-03-29	Nursing Home	221	2029-12-31	3	2029-12-31	0
2023-08-23	Waste Management	58	2031-12-31	3	2029-12-31	-730
2023-01-25	Green Energy	55	2029-12-31	4	2029-12-31	0
2023-02-11	Green Energy	22	2029-12-31	4	2029-12-31	0
2021-12-26	Communications	107	2025-07-01	0	2029-12-31	1644
2022-10-21	B.V. 1	7	2025-07-01	0	2029-12-31	1644
2023-05-04	B.V. 2	778	2029-12-31	0	2031-12-31	730
2023-05-13	B.V. 3	6	2029-12-31	0	2031-12-31	730

Table 6.3: Estimated impact of social prioritization on the waiting list of Substation 2 for clients that have requests transport capacity as consumers.

Four priority clients were identified in the waiting list of Substations 2 waiting list for consumer capacity requests (Table 6.3). Only one of those clients, a Waste Management company, have actually benefited from prioritization. There was not enough capacity to accommodate other priority requests, earlier. Because four other non-priority clients had to wait before priority requests could be granted, they have received significant delays.

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	Δ ETS [days]
2022-10-03	Essential Gov. Function	180	2028-12-31	2	2028-12-01	-30
2022-06-25	Waste Management	100	2028-12-31	3	2028-12-31	0
2022-01-15	B.V.	250	2028-12-01	0	2028-12-31	30

Table 6.4: Estimated impact of social prioritization on the waiting list of Substation 2 for clients that have requests transport capacity as producers.

The effects in the queue for production requests are more even. A priority client, representing an Essential Government function could be connected slightly earlier at the expense of equal delay for a business. The request from the Waste Management client experienced no change after the prioritization.

The second Substation also shows a trend of consumption requests having lower Contracted Capacity than the Requested Capacity, while production requests are a little more equal. There seems to be no extremely high requests at the beginning of the waiting list and most requests tend to be clustered bellow 200 kVA. When looking at Estimated Time to Solution against Maturity, the two most mature consumption clients are indeed with the least expected original waiting time. After those two clients, the trend again is showing an increase in waiting time with an increase in maturity because the clients are clustered by the common solution date.

6.3.3. Substation 3

The third substation waiting list has 23 clients with consumption requests and 17 requests for production. Among the consumption requests, three priority clients are identified. The rest of the consumption requests were once again from mostly businesses, and education center, data center and local municipality. On the production side, there are two priority requests. The rest of the requests are mostly from businesses, and non-priority healthcare centers.

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	△ ETS [days]
2023-03-16	Asylum Help	23	2029-12-31	3	2029-01-01	-364
2023-10-30	Waste Management	248	2030-12-31	3	2029-12-31	-365
2023-01-09	Solar	11	2029-12-31	4	2029-12-31	0
2022-11-25	BV 1	77	2029-01-01	0	2029-12-31	364
2023-05-10	Education Center	192	2029-12-31	0	2030-12-31	365
2023-06-15	BV 2	9	2029-12-31	0	2030-12-31	365
2023-06-15	Gemeente	41	2029-12-31	0	2030-12-31	365
2023-07-09	BV 3	33	2029-12-31	0	2030-12-31	365

Table 6.5: Estimated impact of social prioritization on the waiting list of Substation 3 for clients that have requests transport capacity as consumers.

In the waiting list of the third Substation, three priority consumer requests were identified (Table 6.5). Benefiting from prioritization were the clients that represented an Asylum Help center and a Waste Management company. Approximately a year earlier each. The consumption request for a green energy producer (Solar) had no change. The disadvantages were distributed to five non-priority clients. Approximately a year of delay each as well.

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	△ ETS [days]
2023-03-08	Water Treatment	42	2028-12-31	3	2028-12-31	0
2023-03-27	Nursing Home	50	2029-12-31	3	2029-01-01	-364
2022-11-15	BV 1	90	2029-01-01	0	2029-01-02	1
2022-04-25	BV 2	165	2029-01-02	0	2029-10-01	272
2022-06-15	BV 3	173	2029-10-01	0	2029-12-31	91

Table 6.6: Estimated impact of social prioritization on the waiting list of Substation 3 for clients that have requests transport capacity as producers.

The producers queue at Substation 3 had two priority clients (Table 6.6). There was a request from a client representing a Water Treatment facility and a Nursing Home. The only improvement, compared to the original waiting time, was for the Nursing Home of approximately one year. The disadvantaged client were mainly two businesses. A delay of one day can be considered insignificant, while the other two could experience delays of 272 and 91 days.

Most of the capacity requests at Substation 3 are lower than 250 kVA, with Contracted Capacity lower than the Requested Capacity. The production requests tend to have a more equal relation of Requested and Contracted Capacity. There seem to be no capacity requests at the beginning of the waiting list which can be causing congestion. Once again, when looking at the Estimated Time to Solution against Maturity, the waiting time increases with the increase in maturity of a client.

6.3.4. Substation 4

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	∆ ETS [days]
2023-10-13	EV Charging	22	2030-12-31	3	2023-12-31	-2557
2023-05-19	BV 1	625	2023-12-31	0	2028-12-01	1797
2022-07-21	BV 2	110	2028-12-01	0	2028-12-31	30
2023-04-09	BV 3	162	2028-12-31	0	2029-01-01	1
2022-04-29	BV 4	2255	2029-01-01	0	2029-02-01	31
2022-09-18	BV 5	20	2029-01-01	0	2029-02-01	31
2022-03-23	BV 6	170	2029-02-01	0	2029-12-31	333
2023-06-12	BV 7	65	2029-12-31	0	2030-12-31	365

Table 6.7: Estimated impact of social prioritization on the waiting list of Substation 4 for clients that have requests transport capacity as producers.

The queue of consumer requests at Substation 4 had no priority clients and therefore is omitted from this analysis. The producer's queue on the other hand (Table 6.7), is a great example of how even one priority client can cause a large-scale chain reaction. An EV charging station, which can be categorise as Category four of the social prioritization framework, has a relatively small capacity request. Thanks to prioritization, the waiting time for that client can be drastically improved. However, because of the large difference in Solution Dates and capacity release constraints, seven other businesses will have to bear the delays.

Substation 4 clearly shows more cases of granting the Contracted Capacity same as the Requested for the production requests. The production request queue has an instance of a very high contracted capacity. For the consumption queue, the first-in-line client has the second highest contracted capacity, which could be the initial bottleneck reason. This client is a non-priority client. Estimated Time to Solution against Maturity is showing the same trends as in previous Substations.

6.3.5. Substation 5

Entry Date	Client	Contracted Capacity [kVA]	Solution Date	Priority	New Solution Date	∆ ETS [days]
2021-09-26	Nursing Home	25	2029-01-01	3	2029-01-01	0
2022-09-15	School	81	2029-01-01	3	2029-01-01	0
2022-12-18	Water Safety	112	2029-12-31	3	2029-01-01	-364
2023-07-13	Sustainability B.V.	51	2031-12-31	4	2029-01-01	-1094
2022-07-21	BV 1	17	2028-03-22	0	2029-01-01	285
2022-11-17	BV 2	285	2029-01-01	0	2029-12-31	364
2022-11-25	BV 3	41	2029-01-01	0	2029-12-31	364
2022-05-09	BV 4	23	2029-03-01	0	2029-12-31	305
2023-01-11	BV 5	43	2029-12-31	0	2030-12-01	335
2023-04-05	BV 6	16	2029-12-31	0	2030-12-01	335
2023-07-06	BV 7	620	2030-12-01	0	2030-12-31	30
2023-07-06	BV 8	102	2030-12-31	0	2031-12-31	365

Table 6.8: Estimated impact of social prioritization on the waiting list of Substation 4 for clients that have requests transport capacity as producers.

Similar to the previous case, the consumer queue had no priority clients, while the producer's queue had four (Table 6.8) The first two priority clients had no change in their estimated time to solution, while the other had an improvement. A decrease of approximately a year for a Water Safety related client and approximately three years decrease for a Sustainable business. As a result, eight other businesses can have delays of approximately a year each.

The fifth Substation consumption queue exhibits lower Contracted Capacity when compared to the Requested. For producers, the situation is slightly better. More mature clients do not show excessive Contracted Capacity. The estimated Time to Solution shows clusters based on the Solution Date and the increase in waiting time with an increase in maturity.

6.4. Justice Metrics

6.4.1. Concept Jusitce Metrics

This impact analysis is used for prospective analysis and not retrospective because the changes have not yet been implemented. One important metric has already been introduced in the previous section, namely the Δ ETS. Since the waiting time for socially important functions is the main problem that is being tackled by social prioritization, the Δ ETS is the core indicator of the prospective results. Considering the Energy Justice, the changes in the waiting list management entail all three tenets. Looking at the available quantities there is a possibility to develop a metric that addresses the Distributive Justice principles, which look at the distribution of burdens and benefits [21]. The burden is then considered to be a delays in waiting time and benefit - the decrease in waiting time. Moreover, time is not the only quantity that is being distributed. It is also the Contracted Capacity. The second consideratio that can be taken from the Distributive Justice principles is that the situation can be investigated by identifying groups of clients that are either advantaged or disadvantaged by the social prioritization. To better categorize the possible metrics, they are defined in accordance to the five comprehensiveness categories [3].

1. **Tenets of equity and justice:** Distributional Justice. Addressing the distribution of burdens and benefits with the introduction of the social prioritization framework.
2. **Spatial and temporal:** the impacts are considered on a local scale. More specifically on the level of a substation. Regarding the temporal consideratio, the impacts are both near and long-term.
3. **Sectoral:** The current analysis is inter-sectoral because it addresses the waiting list per substation and these waiting lists contain a variety of different sector representatives.
4. **Impacts on people:** to better address the temporal consideratio the metrics can be considered from financial, technical and psychological level. These impacts can be both near and long term. An expected delay in granting capacity requests can lead to immediate issues with business financing or investments. Technical impacts can be near-term since the congestion is a current problem and they can be long-term due to previously shown chain reaction and long delays. Lastly, the psychological impact can me immediate when a customer finds out about the change in prospective waiting time. That can also be long-term.
5. **Life cycle:** this presents a very limited life cycle as the focus is only on the waiting time distribution at the moment of implementation of the framework. Other potential consequences are not taken into account.

Taking this into account, the following measurements are proposed.

$$Time\ Equity\ Disparity = |Waiting\ Time_{priority} - Waiting\ Time_{non-priority}| \tag{6.1}$$

The Time Equity Disparity (TED) can be used as an indicator of the gab that can potentially exist between the priority and non-priority clients. This can be expressed in maximum and mean TED, where maximum TED is calculated by finding an instance of the largest gap and mean is calculated by taking average waiting times of the two groups. There is an additional distinction that can be made between the groups of clients. Instead of categorising them by whether they are eligible for social prioritization framework or not, they can be separated into advantaged and disadvantaged clients because, as results show, not every priority client will experience a decrease in waiting time and not every non-priority client will experience a delay in waiting time. Here, the calculations are limited only to the priority and non-priority distinction. This way it will not only show the distribution of time but also the effectiveness of the framework. Moreover, the comparison of course needs to be made between the original scenario and when the framework is applied.

$$\Delta ETS\ ratio = \frac{\sum \Delta\ ETS_{priority}}{\sum \Delta\ ETS_{non-priority}} \tag{6.2}$$

The change in Estimated Time to Solution ratio (ΔETS) can be another indicator regarding the fairness of waiting time distribution. It is similar to TED Equation 6.1 in nature but is represents the situation differently. There the difference or gap is shown as a ratio to better show how much one group is being advantaged over the other one and vice versa. For values greater than one, it means that the framework is benefiting socially important clients more than it is disadvantaging the non-priority clients. This can be considered a favourable outcome.

$$Capacity\ Ratio = \frac{\sum Advantaged\ Capacity\ Requests}{\sum Disdvantaged\ Capacity\ Requests} \tag{6.3}$$

The Capacity Ratio can show how much capacity, instead of just clients, is being prioritized. In this case it is important to consider only the advantaged and disadvantaged clients as this is more of a technical measure. This can be considered if the goal is not to prioritize as many socially valuable functions as possible but rather to prioritize the amount of function. In this case, the capacity quantity can be considered as an indicator of how much the function will contribute positively to society. For instance, it could be argued, a 1000 kVA capacity request from a water treatment facility will bring more benefits than a 100 kVA capacity request.

6.4.2. Concept Justice Metrics Applied

Applying the Equations 6.1, 6.2 and 6.3 for the first substation the following results were calculated. First the consumption requests queue:

$$\begin{aligned} TED_{mean,original} = 48[days],\ TED_{mean,prospective} = -565[days] \\ TED_{max,original} = 1134[days],\ TED_{max,prospective} = 255[days] \\ \Delta ETS\ ratio = 0.7 \\ Capacity\ Ratio = 0.2 \end{aligned}$$

The TED results show that the gap in waiting time on average is changed in favour of priority clients, and significantly. The same can be said for the maximum TED. The ETS ratio of 0.7 says that the total improvement for priority clients was smaller than disadvantages for non-priority customers. The capacity ratio of 0.2 indicates that the priority capacity is smaller than non-priority capacity by 80%.

For the production requests queue the results are as follows:

$$\begin{aligned} TED_{mean,original} = -36[days],\ TED_{mean,prospective} = -89[days] \\ TED_{max,original} = 170[days],\ TED_{max,prospective} = -26[days] \\ \Delta ETS\ ratio = 0 \\ Capacity\ Ratio = 0. \end{aligned}$$

This is a unique case, where the original gap in waiting time was in favour of priority clients, and with social prioritization this gap increases. It can be said that this change is unnecessary as it only worsens the situation. Both ETS ratio and capacity ratio show that no capacity has been granted earlier than expected and the framework only caused delays.

For the second substation, consumption queue results are

$$\begin{aligned} TED_{mean,original} = 132[days],\ TED_{mean,prospective} = -276[days] \\ TED_{max,original} = 2068[days],\ TED_{max,prospective} = 92[days] \\ \Delta ETS\ ratio = 0.15 \\ Capacity\ Ratio = 0.06 \end{aligned}$$

Both maximum and mean TED values indicate a shift in the gap of waiting time in favour of the priority clients. The maximum time equity disparity has shown a significant change and the mean values changed in a more moderate way. The ETS ratio of 0.15 contributes to understanding because it is now possible to tell that the improvement for priority clients came at a greater disadvantage for other clients. Finally, the capacity ratio of 0.06 indicates that only a small portion of capacity in this particular queue was granted earlier than before.

For production requests the results are

$$TED_{mean,original} = 30[days],\ TED_{mean,prospective} = 14[days]$$
$$TED_{max,original} = 370[days],\ TED_{max,prospective} = 370[days]$$
$$\Delta ETS\ ratio = 1$$
$$Capacity\ Ratio = 0.72.$$

The situation with production requests is different and can be considered as more balanced. There was a slight improvement in mean TED and no change in the maximum TED. This is also supported by the ETS ratio of 1, which tells that priority clients have been advantaged equally to the disadvantages experienced by non-priority clients. The capacity ratio of 0.72 shows that the capacity that was prioritized is comparable to in quantity the delayed capacity.

For the third substation, consumption queue results are

$$TED_{mean,original} = 47[days],\ TED_{mean,prospective} = -278[days]$$
$$TED_{max,original} = 390[days],\ TED_{max,prospective} = 120[days]$$
$$\Delta ETS\ ratio = 0.4$$
$$Capacity\ Ratio = 0.8$$

Once more, TED values show a beneficial results for the priority customers. The mean TED became negative, therefore on average priority customers will wait less in the waiting list. The ETS ratio of 0.4, indicates greater burdens for non-priority clients than benefits for priority customers. The capacity ratio, on the other hand is higher than in previous cases, which tells that the capacity that has been effectively prioritized is almost equal to the capacity that is delayed.

For production requests the results are

$$TED_{mean,original} = -178[days],\ TED_{mean,prospective} = -384[days]$$
$$TED_{max,original} = 232[days],\ TED_{max,prospective} = -115[days]$$
$$\Delta ETS\ ratio = 1$$
$$Capacity\ Ratio = 0.1.$$

In case for production queue, the benefit for priority clients is much greater than the disadvantage for non-priority clients. Although, the change in waiting time in total is proportionate for both parties, which is indicated by the ETS ratio of 1. The downside of these changes is that the capacity that has been effectively prioritized is significantly smaller to the capacity that has been delayed.

For the fourth substation, consumption queue results are not applicable because no priority client was identified, while for production requests the results are

$$TED_{mean,original} = 400[days],\ TED_{mean,prospective} = -2318[days]$$
$$TED_{max,original} = 2410[days],\ TED_{max,prospective} = -1944[days]$$
$$\Delta ETS\ ratio = 0.98$$
$$Capacity\ Ratio = 0.006.$$

This case exhibits a very significant change with the introduction of the prioritization framework. The only priority clients, could be connected 7 years earlier than before. The TED results show the results are skewed against the non-priority clients. However, because it was a drastic improvement for a single priority client, the ETS ratio is close to one. The capacity ratio of 0.006 indicates how small the effective priority capacity in comparison to the capacity that was delayed.

For the fifth substation, consumption queue results are not applicable because no priority client was identified, while for production requests the results are

$$
\begin{aligned}
TED_{mean,original} = 70[days],\ TED_{mean,prospective} &= -407[days] \\
TED_{max,original} = 1022[days],\ TED_{max,prospective} &= 403[days] \\
\Delta ETS\ ratio &= 0.6 \\
Capacity\ Ratio &= 0.14.
\end{aligned}
$$

The original mean TED did not show a significant gap, while the maximum TED indicated much larger waiting times for socially important clients. With the social prioritization framework the has been narrowed in favour of priority clients.The ETS ratio shows a smaller decreases in waiting time for priority clients compared to an increase of waiting time for non-priority clients. Finally the capacity ratio, shows that effectively prioritized capacity is smaller compared to the quantity of the delayed capacity.

6.5. Tool for Investigating Hypothetical Scenarios

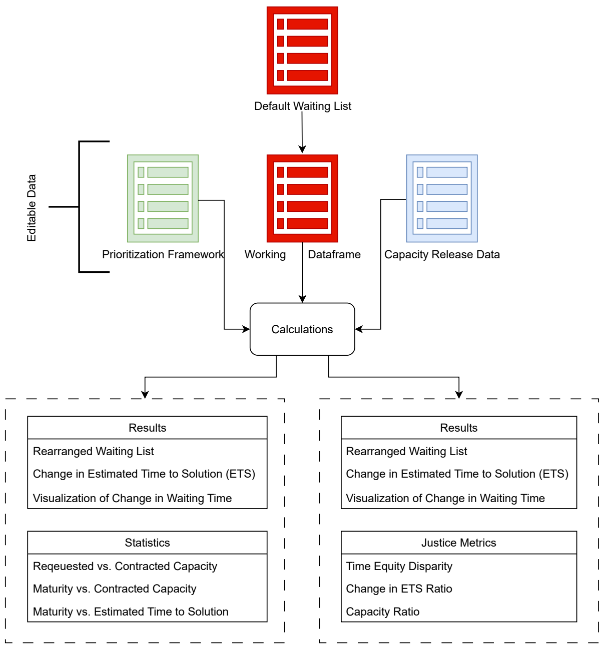


Figure 6.2: The diagram of the functionality flow for the concept application that can be used for designing a prioritization framework and estimating the impact.

To further improve the understanding and justice implications of deviating from FCFS principle in favour of a prioritization framework, a tool is proposed. The main goal of such a tool is to be able to directly influence the three components of the system: the waiting list, the prioritization framework and the technical constraints such as limited capacity released per unit time. All three components are editable by a potential user.

A hypothetical waiting list is provided from the start as the default version. It represents a list of common transport capacity requests from clients performing a variety of functions. The amount of their capacity requests is in the range of what was found on the real waiting list dataset. The default waiting list

Entry Date	Client	Contracted Capacity [kVA]	Requested Capacity [kVA]	Solution Date	Priority	SBI
2021-03-16	A	269	345	2025-01-01	0	46311
2021-03-21	B	114	114	2025-01-01	0	111
2021-05-03	C	130	130	2025-01-01	0	8560
2021-06-30	D	100	250	2026-12-12	0	43221
2021-08-11	E	100	100	2026-12-12	0	9002
2021-10-25	F	160	160	2026-12-12	0	3103
2021-11-19	G	150	150	2026-12-12	0	46699
2021-12-30	H	50	90	2028-01-01	0	6420
2022-02-05	I	909	1000	2028-01-01	0	9604
2022-06-12	J	599	650	2028-01-01	0	4941
2022-09-30	K	41	41	2028-01-01	0	46215
2022-11-22	L	543	543	2029-01-01	0	86102
2022-12-27	M	39	120	2029-01-01	0	93211
2023-01-17	N	118	118	2029-01-01	0	6420
2023-02-13	O	200	200	2030-01-01	0	4663
2023-03-21	P	40	40	2031-01-01	0	8424

Table 6.9: Default waiting list for the customizable analysis tool.

consists of 16 requests and the information is complete SBI codes that would be available in the ideal scenario and can be seen in Table 6.9.

The second component, the prioritization framework, is initially provided for a default version as well and is the same as the one proposed by the ACM in Table B.1 [41]. The third component, the capacity release, is composed out of two types of values: the minimum capacity release, which is calculated from the contracted capacity over time, and the theoretical values of how much additional capacity is actually released at that time. The assumption is that the contracted capacity values are lower than what the maximum technical constraint is.

These three components, or datasets are then used for the same calculations as done in the case of the real data to calculate the change in waiting time based on priority. The priority is assigned to clients if their SBI code matches the one in the framework. Then there are two options. The first one is to only view the end results of prioritization, which means the rearranged waiting list with a new estimated time to solution, and the descriptive statistics related to the waiting list. The second option is to view the results and the proposed justice metrics. All is intended to have an easy experience of developing the prioritization framework under constraints and investigate the effects on any hypothetical waiting list case.

This way there is no need to carefully select real data and fill in the gaps where the information is missing. Statistical data can be taken from the real waiting list to create typical scenarios to certain locations waiting list and investigate how the same or different prioritization frameworks will impact the clients on the waiting list. The change in waiting is the main indicator of the effectiveness and impacts, which can be supplemented by the justice metrics to be better understand the situation.

For example, if the current ACM social prioritization framework is applied to the default waiting list as shown in Table 6.9, two client will be assigned priority. Namely, the client ”L” with the SBI code 86102, which stand for a general hospital, and client ”P” with the SBI code 8424, which stand for police. Police transport capacity request is the assigned priority category 2 and the hospital request is assigned category 3. After applying this data and recalculating the waiting time, the results of social prioritization on this hypothetical waiting list can be seen in Table 6.10. It can be seen that the priority clients are gaining a substantial decrease in their estimated waiting time, while the rest of the clients, who do not fall within the framework will experience delays.

Entry Date	Client	Contracted Capacity [kVA]	Requested Capacity [kVA]	Solution Date	Priority	SBI	New Solution Date	Δ ETS
2023-03-21	P	40	40	2031-01-01	2	8424	2025-01-01	-2,191
2022-11-22	L	543	543	2029-01-01	3	86102	2026-12-12	-751
2021-03-16	A	269	345	2025-01-01	0	46311	2026-12-12	710
2021-03-21	B	114	114	2025-01-01	0	111	2026-12-12	710
2021-05-03	C	130	130	2025-01-01	0	8560	2028-01-01	1,095
2021-06-30	D	100	250	2026-12-12	0	43221	2028-01-01	385
2021-08-11	E	100	100	2026-12-12	0	9002	2028-01-01	385
2021-10-25	F	160	160	2026-12-12	0	3103	2028-01-01	385
2021-11-19	G	150	150	2026-12-12	0	46699	2028-01-01	385
2021-12-30	H	50	90	2028-01-01	0	6420	2028-01-01	0
2022-02-05	I	909	1,000	2028-01-01	0	9604	2028-01-01	0
2022-06-12	J	599	650	2028-01-01	0	4941	2029-01-01	366
2022-09-30	K	41	41	2028-01-01	0	46215	2029-01-01	366
2022-12-27	M	39	120	2029-01-01	0	93211	2029-01-01	0
2023-01-17	N	118	118	2029-01-01	0	6420	2030-01-01	365
2023-02-13	O	200	200	2030-01-01	0	4663	2031-01-01	365

Table 6.10: Results of social prioritization on the default hypothetical waiting list from the custom analysis tool.

In addition to that, the justice metrics could provided a summarised information on what the effects of prioritization are. For this hypothetical scenario, with a police and hospital requests given priority, the metrics are as follows.

$$TED_{mean,original} = 682[days],\ TED_{mean,prospective} = -1290[days]$$
$$TED_{max,original} = 852[days],\ TED_{max,prospective} = -611[days]$$
$$\Delta ETS\ ratio = 0.53$$
$$Capacity\ Ratio = 0.29$$

This tells that the gap in waiting time has been shifted in favour of the priority clients. From the ETS ratio, we can tell that the amount of days by which the priority clients have been advanced is about half of how many days the non-priority clients have been delayed. This has been done in order to effectively prioritize the capacity, which is only 29% of the total delayed capacity.

6.6. Conclusion Chapter 6

First of all, this chapter has identified the available data on the waiting list that can be used for assessing the current situation and to estimate the impact of the social prioritization framework. There were limitations to the analysis, which partly relate to the lack of some data. Mainly the SBI codes and Estimated Time to Solution in some cases. Then there were limitations related to the complexity of calculations. These limitations were addressed through some necessary calculations and assumptions. Then the way to calculate the change in waiting time of each client on the waiting list was proposed. The main finding was the technical constraint such as the transport capacity release. This indicated how much additional transport capacity will be available in the future and that can be redistributed among the clients.

Then, the real data from five sub-stations was used to calculate the change in waiting time due to the social prioritization through the proposed process. Every waiting list showed at least some reduction in waiting time for the identified priority clients and delays for some of the non-priority clients. It was also evident that every waiting list had unique results caused by unique constraints, transport capacity requests, and the number and nature of clients.

Based on the available data and results in a change of waiting time, concept metrics are proposed to assess the distribution of benefits and burden across the waiting lists or sub-stations. Similar to the related literature, the groups were identified as the ones that benefit and the ones that suffer from social prioritization. The gap in waiting times, ratios in a change in waiting time, and the transport capacity per group were evaluated. These values could be indicators of the fairness in the distribution of benefits and burdens between priority and non-priority clients. Moreover, the capacity ratio is an indicator of the effectiveness of social prioritization in terms of transport capacity prioritization.

Lastly, all the findings from this chapter were synthesized in a concept tool that can be used for quick analysis of the impacts of the social prioritization framework. It allows to easily modify the framework itself, the technical constraints, and the waiting list. In the next chapter, a discussion of the results is provided.

7 Discussion

In this chapter, all the results from previous chapters are discusses. First, the results are evaluated with respect to the Energy Justice, which will help with answering the main research questions, and makes a connection with the distributive justice principles that were introduced in Chapter 3. Then the effectiveness of the social prioritization framework is evaluated. Lastly, the main limitations of this research are addressed.

7.1. Energy Justice Implications

To address the main topic of this research, the Energy Justice implications are assessed based on the results presented before. More specifically, the findings are based on the document analysis of stakeholder opinions, desk research and quantitative analysis of the social prioritization impacts. The focus of this research from the beginning was on Distributive Justice implication, but throughout the process, it is beneficial to address other tenets of Energy Justice, such as procedural and Recognition Justice.

7.1.1. Distributive Justice

In this part, the situation is looked at from the Distributive Justice perspective to analyze whether the proposed framework worsens existing inequalities or contributes to a fair distribution of energy resources, burdens and benefits. Moreover, the main Distributive Justice principles are examined to assess whether prioritizing certain clients aligns with principles of equity and fairness [10].

Strict Egalitarianism principle can be simply described as radical equality. It is justified on the basis that people are morally equal, which means every person should have the same amount of goods and burdens. This principle is extremely simplistic and it is hard to apply to the waiting list problem. First of all, all clients have different needs. Secondly, there can be so-called 'Pareto superior' allocations of goods. It happens when making some clients better off will not make any other clients worse off [42]. These scenarios can be seen in the cases of Substation 2 and Substation 3. Small capacity requests from some clients are being delayed because they have to wait for a larger priority capacity request. In some cases, granting transport capacity to small businesses would not affect the waiting time for priority clients. Overall, Strict Egalitarianism is neither applicable to the original FCFS principle, nor to the additional social prioritization.

Difference Principle is similar to the concept of strict equality except that it permits material inequality if it raises the level of the least advantaged members of society. The limitations of this research do not allow for the identification of the least advantaged categories of society members. From the stakeholder analysis, disadvantaged groups have indeed been identified. For instance the cases of where businesses are forced by law to electrify their operation in pursuit of sustainability growth and are not able to implement these changes due to the congested grid. However, it is hard to tell, which groups suffer more from this. It could be argued that the disadvantages are categorized by geographical location rather than the industry. Some areas in the Netherlands are more congested than others, which results in longer waiting lists in those locations [27]. The social prioritization framework does not address the needs of the most disadvantaged groups, its purpose is to increase the societal value, at the cost of creating more disadvantages to those that are not in the framework.

Welfare-Based Principle fits well within the intentions of the social prioritization framework. Historically, this has also been called the utilitarian principle, where the main unit of fairness is measured by utility [10]. Although, the utility has different definitions this concept can be applied to the social prioritization. Since the goal is to benefit society, the utility can be measured in either the function that is performed by the socially important clients or by the capacity that is granted to them and then utilised for their functions. This can be linked to the Capacity Ratio proposed earlier. The greater the ratio, the greater the utility to society. In other words, the framework should be designed and implemented in such a way that the effective contracted capacity for socially important clients is maximised. This, however, still leaves up to debate the definition and ranking of social importance.

Desert-Based Principle can help address the previous point about defining what is socially important. The Desert-Based Principle is a principle that defines the fairness of distribution by defining who deserves more benefits. More specifically, contemporary desert-based principles share the notion that only the functions that raise the societal benefits deserve benefits in return [10]. The counterargument to that is the fact that sometimes people have very little control over factors that can determine their input into society [45]. The only, category in the social prioritization framework that undoubtedly can be placed in category is 1 the Congestion Softener. Very few arguments can be made against other categories, such as firefighters, ambulances, schools and waste management facilities. However, it is hard to reason the importance of one over the other.

Lastly, the **Libertarian Principles**, state that fair outcomes are achieved via separate and individual just actions [10]. This principle is complex and one of the definitions closely relates to the FCFS principle [9]. It states that a person who acquires something first in a just way is entitled to it. Moreover, the government role should be restricted to the protection of property rights and not its distribution. This goes against the social prioritization framework, especially if it is going to be implemented on a national scale. The calls from some of the stakeholders indeed state that the final decisions on prioritization should be decentralized and it will have more effect in the fair distribution of scarce electric capacity.

7.1.2. Procedural Justice

After the performed analysis, some comments can be made with regard to Procedural Justice, which evaluates the transparency, inclusivity, and fairness of the decision-making process surrounding the proposed regulations [22]. The analysis of stakeholder opinions helps to assess whether all relevant stakeholders, have had meaningful opportunities to participate in the decision-making process and voice their concerns. The ACM clearly gave an opportunity to voice their opinions when the ACM asked to provide it and published it on their website [1]. It still remains to be seen what the final version of the social prioritization will look like and to what extent their concerns have been taken into account.

Despite that, some things can be said already. From the decision of the ACM it can be said that the framework will have a national character rather than local, and local municipalities will not have an opportunity to influence how the framework looks like after its implemented. The framework will be applied the same way everywhere. Some stakeholders, including the municipalities, are concerned over that decision and claim that the local context is very important and that they should be able to decide what function is currently holding the most importance for local society. Based on that, it looks like their opinion was either not taken into account initially or was considered but the decision went in another direction. In the description of the draft framework itself, ACM lacks the explanation behind why it was decided to keep the framework the same for everyone [41].

Moreover, it is in the ACM plans to evaluate the effects of social prioritization one year after its implementation and base it on the reports of DSOs and any client complaints [41]. It can be argued that the one-year period is too long to see the immediate effects and too short to see the long-term effects. The immediate effects could be financial, psychological or technical [3]. From the quantitative analysis, it has been shown that by rearranging the waiting list some immediate effects can be seen, such as the change in estimated time to solution. This change will be eventually communicated to the affected clients on the waiting list. The clients that will experience further delays will have to deal with an increased sense of uncertainty. There might be situations in the future that will further delay their capacity request, such as more priority clients in the area. This could cause financial consequences as it will be harder to plan the project's expenses and harder to attract investments if the completion date is unknown. The long-term effects will not be known for certain for up to a decade judging by how long some technical solutions will take. It is, therefore, a necessity to predict and estimate the long-term effects as early as possible. Moreover, it is important to evaluate how the affected parties and society will be able to participate in the feedback loop.

7.1.3. Recognition Justice

Within the Recognition Justice, it is considered whether the proposed regulations recognize and address the unique needs, preferences, and vulnerabilities of different client groups [21]. It is hard to apply the recognition justice concepts here because the main purpose of the framework is to address the societal needs as a whole. However, they can be addressed if there is a distinction made between the different societal needs as the ACM does by distinguishing the clients by categories such as safety and basic needs. To return back to the local context, it has been stated by some of the stakeholders that based on the area the local needs might differ from what ACM prescribes. It can be said that the framework is limited in recognition of societal needs because of the high level of distinction. The clients within the priority groups are treated by FCFS principle. Instances, where on the same waiting list, there are clients from the same priority category has been seen. Substation 2 and 5 have shown the highest number of priority clients out of the data samples with 4 priority clients each. On substation two there is a nursing home, a waste management client and two green energy companies. On substation 5 there is a nursing home, a school, a water safety client, and a client from the sustainability category. It could be argued that sustainable energy production is not as urgent as for the local community but water safety provides a more immediate need. Therefore, if the framework is still going to be structured by categories of priority, there might be a need to consider the internal priority within these categories.

7.2. Effectiveness of the framework by ACM

Applying the framework on the real-world waiting list has shown improvement for priority clients in almost all cases except for the production transport capacity requests on substation 1. According to the framework, the non-priority client requests can only be treated after the priority client has been granted their capacity [41]. Although this can be interpreted differently and still requires clarification, based on the desk research and internal information, this rule will be taken very seriously. Thus, it is assumed that non-priority clients can not get a connection earlier than the priority clients. In the scenario of substation 2, it creates a situation where a business is delayed, even though this gives no advantage to the capacity request from a school. These cases must be absolutely avoided as they only worsen the situation.

Then, there are situations like with Substation 4. The sustainability category client with a very small capacity request compared to other non-priority clients gains a great reduction in waiting time. However, because of that, the first-in-line business with a much greater capacity request will experience a very significant delay. By prioritizing a small capacity request, a much larger request is delayed. This kind of scenario creates a concern about the way the welfare to society is measured as currently the social prioritization only considers the function the the client performs. Although the function is important, the capacity request can be small and potentially less significant to society than a large request from a normal business function that can create jobs and important goods. That is why one of the justice metrics that is proposed is the capacity ratio. A more careful look at the technical data within the waiting lists could prevent unnecessary delays.

Lastly, the effectiveness of the social prioritization framework can be reduced by the technical constraints. In this analysis, it assumed that if there is enough capacity, the client could be granted their capacity request earlier. However, this is more complicated in real life and discussed later in the limitations section. The button line is that by assigning priority to the client does not always mean an earlier granted capacity request. Sometimes there is nothing in power of the DSOs to influence that.

7.3. Limitations

This study has encountered several limitations. The main one being is the lack of data in the waiting list dataset. The SBI codes, that are necessary for applying the social prioritization framework, were not available. That is why the analysis was limited to only five substations. With the SBI codes known, the same analysis could be applied to the entire waiting list, which consists of more than 60,000 clients. It would make it possible to identify the vulnerable groups by seeing which categories of clients are waiting the most time to solution and what are their capacity requests. It would also allow to do a more geographically oriented analysis and see how the situation would differ across different areas. The second data component that was not complete in the dataset is the solution date. Therefore, assumptions had to be made to assign the missing data. This decreased the accuracy of the analysis and by making a wrong assumption the situation could significantly change, especially if the missing information is for the priority clients.

The next limitation to discuss is the complexity of the energy grid topology and the way bottlenecks causing congestion are created and managed. As stated in previous chapters, it is assumed that since the clients are connected to the same substation, they are experiencing the same bottleneck. This is not the case in real life. There is a variety of reasons behind the bottlenecks and for clients to effectively switch positions in the waiting list order, these clients need to have the same bottlenecks.

Another limitation was the language barrier when analysing the stakeholder opinions. All of them were published in Dutch and then machine-translated by Google Translate for the purpose of this study. Although the results were readable and logically sound, there were instances when some sentences were clearly wrongly translated. This could have potentially caused a certain degree of misunderstanding and information loss.

8 Conclusions and Reflection

This research has timely addressed the development of a new social prioritization framework that would allow DSOs in the Netherlands to deviate from the FCFS principle and to give priority to the transport capacity requests from clients whose functions are considered to be important to society. That means that a client's request for transport capacity who falls under either a congestion reliever, safety, basic needs or sustainability category will be treated first and only then the rest of the clients on the waiting list. The reason behind such a measure is the worsening congestion of the Dutch energy grid and long waiting times to get a new power connection or transport capacity, for both producers and consumers of electricity. This way the socially important functions could be given the necessary capacity earlier to benefit the population. Although this deviation from FCFS principle seems logical and necessary, the social prioritization framework is a big change and can potentially cause significant effects to the clients on the waiting list and society in general. Moreover, prioritizing one group of clients over the others calls to discuss the fairness of such a decision. That is why the Energy Justice framework was used to understand the justice implications of social prioritization.

To achieve that, first the literature review (Chapter 3) was conducted to identify relevant theoretical knowledge and the academic gaps in the Energy Justice research. Examples of quantitative metrics for the purpose of measuring Energy Justice implications were investigated, as well as other relevant research areas were consulted. The current waiting list management process was described in Chapter 4, as well as the proposed social prioritization framework by ACM. Then, to get an insight into the effects of social prioritization, a qualitative analysis (Chapter 5) has been done on the stakeholder opinions. Main themes, suggestions and concerns were identified, as well as the industry groups tat stakeholders represent. After that, a quantitative analysis (Chapter 6) was done to estimate the potential impact on the waiting times to solution for both priority and non priority clients. This part also gave an understanding of what components and algorithms would be needed to make these estimates more accurate. Conceptual Energy Justices metrics were proposed to measure the distributive effects of social prioritization. The goal of this was to give insight into the fairness of waiting time distribution. Lastly, a concept tool is proposed that could help in designing of social prioritization framework and directly seeing the impact.

The key results are discussed in more detail in the next section with a reflection on the research questions.

8.1. Reflection on the Research Questions

Main Research Question: How can the distributive justice implications for new energy grid waiting list prioritization framework be structurally identified and deliberated?

SQ 1: *What is the problem at hand and and what is the proposed solution to benefit the society?*

The waiting list management process has always been done by adhering to the FCFS principle. That means that the normal queuing method is applied, where the first in line will be treated first, then next and so on. Theoretically, that would mean that the client that have appeared on the waiting list the last would have to wait the longest for a solution (or granted their contracted transport capacity). However, the data shows that this is not the case due to the nature of the capacity expansion on the energy grid. Additional capacity is created via either congestion management methods or investments in the infrastructure. In any case, the contracted capacity is not given to the clients one by one but rather in groups. For example, in a waiting list of 20 clients there are no 20 separate capacity expansions but could 4 or 5. That means that within those capacity expansion groups, the client that entered the waiting list last will actually have the lowest waiting time. Nevertheless, the FCFS principle still applies and there are situations where socially important clients have to wait their turn for many years. The social prioritization framework tackles this problem by allowing DSOs to deviate from the FCFS principle and grant the contracted capacity to the priority client as early as technically possible.

It was also identified that the waiting list is much more complex than just one queue per certain geographical location. The highest voltage level, or TenneT operated level, is managed solely by TenneT and DSOs have no influence over that part of the energy grid. The waiting lists are initially grouped by substations, starting from the 50 kV level. Then the grid spreads out to multiple other connections, starting at the Transport Network, then to the Distribution Network Medium Voltage and then the Distribution Network Low Voltage. The waiting lists then consist of all the client on these three levels. Because the infrastructure is different on these levels, the clients experience different constraints or bottlenecks. Therefore, just rearranging the waiting list based on social priority does not always mean that an earlier technical solution will be possible.

SQ 2: *What are the opinions of the stakeholders on the new social prioritization framework?*

The opinions of stakeholders were first grouped by the industry or function that the stakeholder represented. Nine main categories were identified from 78 published opinions: energy sector, municipalities, transport & logistics, healthcare, water management, agriculture & food, construction, educational institutes and others. With the ”others” category there is a wide variety of stakeholders such as representatives of data centers, communications companies, software companies chemical production, etc.

These documents were analyzed to identify the prevalent themes expressed by the stakeholder such as points of concern, uncertainty in understanding, whether the stakeholder exhibited a generally positive or negative attitude towards the framework, general suggestions for improvements of the framework, specific suggestions of including a new category of clients in the framework, responsibility, problems of related to the lack of knowledge by the ACM, injustice concerns, and a an opinion on question 3 posed by the ACM. In general, it can be said that the majority of the clients exhibit a positive attitude towards the social prioritization framework. They recognize the need for deviating from the FCFS principle in favour of socially important functions. However, almost very response contained a concern or a suggestion to how the framework could be improved.

Energy sector representatives are worried about the uncertainty created by the social prioritization framework, fearing delays in investment planning and administrative burdens. They argue for including gas infrastructure and mobility electrification to meet national sustainability goals. However, they express concern that prioritizing sustainability may favor large polluters. Regarding power connections, stakeholders doubt the efficiency of applying prioritization compared to transport capacity requests due to more extensive planning requirements.

Educational stakeholders find the vague application guidelines of the framework problematic, potentially leading to bureaucratic delays. They question the exclusion of higher education institutions. Municipalities desire decentralized decision-making, believing local needs vary and a strict framework could impede societal progress. They also suggest including GPs and traffic infrastructure in priority categories.

Healthcare stakeholders emphasize the importance of including GPs in the framework and suggest elevating hospitals' priority due to their role in national emergencies. Agricultural representatives advocate for including food supply in the framework and share concerns about large players benefiting disproportionately from sustainability criteria.

Building and city planning stakeholders stress the link between commercial activities and housing needs, emphasizing the importance of including commercial ventures in housing projects. They highlight uncertainties regarding transport capacity requests in housing development.

Water management stakeholders propose prioritizing drinking water and advocate for making social prioritization mandatory. Transport sector stakeholders call for the inclusion of intercity options and special transport for vulnerable groups, prioritizing social needs across all modes.

Other stakeholders warn against overlooking digital processes, urging their inclusion alongside telecommunications companies. Microsoft recommends prioritizing projects based on readiness and speed of completion, while Nobian emphasizes transparency and warns against hindering DSOs. There are cautions against expanding the framework to avoid errors, confusion, and delays.

SQ 3: *What is the algorithm and what are the necessary components for the evaluation of social prioritization effects?*

The waiting list management problem consists of many components. The following components were identified that would create meaningful results for the evaluation of the social prioritization framework: original waiting list entry date, the clients name, SBI codes, contracted and requested transport capacity, type of connection to the grid, estimated solution date and congestion (bottleneck) reason. Unfortunately, the SBI codes were not available and could not be linked to the waiting list dataset automatically. To address this limitation, the dataset was limited to make it possible to manually assign priority to clients. The estimated solution date was also incomplete for some of the clients on the waiting list. This limitation was addressed by assigning solution dates by making an assumption that it will be later than the latest known solution date by a similar amount to the difference between the known solution dates. Lastly, the bottleneck reasons were neglected due to the extreme complexity of calculations.

This data could then be used to re-calculate the waiting time for each client and compare to the original waiting list. First, the waiting list is rearranged if there are any priority clients present. After rearranging the order is first influenced by priority categories. Within the priority categories, FCFS principle applies. Then the non priority clients are arranged in chronological order by solution date. Clients within the same solution date group are also arranged by the FCFS principle. To calculate, whether this rearrangement would cause any change in waiting time, a technical constraint need to be considered, such as the available additional capacity in the future per period of time.

SQ 4: *What are the appropriate metrics for evaluating the fairness of the social prioritization outcomes?*

None of the metrics that have been seen in the literature would apply to this research, at least at this stage. It seems that the metrics are either extremely generalise, on the national level, or extremely case-specific. This is a very case specific research. Nevertheless, the logic of creating the distributive justice metrics can be applied here. First the groups are identified. Because of the lack of data, the most straightforward approach it to create two groups: priority clients and non-priority clients. Then the available quantitative data is considered, where the waiting times and contracted capacity are promising candidates. Out of these quantities, the following metrics are proposed: time equity disparity, change in the estimated time to solution ratio and the capacity ratio.

Time equity disparity tells what kind of gap exists between the socially important clients and other, before and after the framework is applied. Then the change in estimated time to solution tells at what cost the priority clients waiting time has been decreased. The higher the ratio, the better, which means that the waiting time for socially important clients has decreased more that delays caused to other clients. Lastly, the capacity ratio tells what was the weight of the effectively prioritized quantity of capacity in comparison to the capacity that was delayed. This could be used especially if there is a way to translate capacity to societal welfare.

SQ 5: *What is the impact of the social prioritization on the clients that are within and those outside of this framework?*

Five real waiting lists were investigated for the effects cased by the social prioritization framework. Rearranging the waiting lists in order of social priority resulted in delays for some priority clients and delays for some of the non priority clients. Therefore, it was neither 100% effective for decreasing the waiting time for socially important capacity requests, neither it was delaying all of the non priority clients. However, in all cases, there was some effect that is described in detail in Chapter 6. In any cases, wherever there was a priority client present, a delay occurred for some of the non priority client requests. Strict adherence to the social prioritization framework has indeed resulted in cases where there was no improvement in waiting time for priority clients but it caused a delay for others. The impact estimations also present additional illogical situations where very small capacity requests were given priority at a very high expense for non priority clients.

The concept of distributive justice metrics proposed here are designed to understand the trade-off in the distribution of benefits and burdens. If fairness is considered, the equal waiting time for priority and non priority clients, the gap is definitely closing and in some cases becomes skewed in favour of priority clients. In fact, the gap in almost all cases of the original waiting lists was in favour of non priority clients. Benefit that are distributed here are quantified in the decrease in waiting time and burdens in the delay. All datasets showed higher burdens for non priority clients than benefits for priority ones. The metrics also show that while causing more delays, a very small percentage of capacity is actually prioritized. This is of course related to the fact that there are less priority clients but it can be considered unfavorable if the benefit to society is measured in an effectively prioritized capacity.

All of the aforementioned effects can be extended to the financial, technical and psychological impacts. Financial and psychological impacts are linked directly to the uncertainty that this framework creates. The businesses will have a harder time attracting investments and planning the business when it will be always unknown whether your transport capacity is going to be suddenly delayed. The technical impacts are linked directly to the lack of transport capacity, which means businesses can be opened, additional machinery can't be powered and so on.

That being said, the current energy grid situation needs to be kept in mind. Currently, everyone on the waiting list are experiencing delays. It is fair that the functions, without which the society will significantly suffer should be prioritized, even if it comes at cost. The main suggestion from this research is that prioritization can be done in a more efficient way by improving the feedback loop, including relevant stakeholders, allowing for flexibility when social prioritization causes more harm than good. That is why in this research also a tool is proposed that can potentially help with the design of the social prioritization framework. With this tool, the impacts of differently formed priority categories can be analyzed on any waiting list with adjustable constraints.

8.2. Practical and Societal Relevance

This research is practically relevant because it sheds light on the data and logic that is needed to estimate the impacts of a regulatory framework designed to deviate from the FCFS principle of waiting list management in favour of the transport capacity requests that are coming from socially important clients. With certain improvements, this algorithm can be used by the DSOs to adjust their waiting list management process and to improve on explainability and transparency for the clients. Moreover, the tool proposed in this research can be applied by the policy makers, especially if improvements were made it its usability so a user does not need to have a technical background to understand the internal mechanisms and the impacts.

For society, the relevance is offered in the form of first the addressing elaborating on the concerns of the stakeholders and linking them to the real date impact analysis. This research suggests improvements to the framework that could potentially improve the overall benefit to society that is being targeted by the social prioritization framework. Such consideration of local context, consideration for additional important societal functions and raising awareness about potential negative consequences of the framework.

8.3. Academic Relevance

This research adds to the academic knowledge about the Energy Justice and Energy Justice metrics. There is a lack of quantifiable means of addressing energy justice implications [3]. These metrics are necessary to address the impacts of energy policies in a meaningful way and to be able to support the conclusions by real data. Moreover, it adds to the existing body of research on Energy Justice in the context of the Netherlands [33, 38]. Although the dataset used for analysis can not be representative of the situation on the national scale, the direction of research is not focused on a very local or specific context but targeting a very complex analysis of societal benefits.

The literature on the Energy Justice metrics and prioritization when it comes to distribution of energy indicates how the policies could be developed to take into account the societal and stakeholder values. To do so the values and quantities to measure the costs to stakeholders need to be identified. This research provides and overview of the stakeholder opinions, the quantities identified through available datasets and a proposed way of synthesising these quantities to measure the fairness of the social prioritization framework outcomes. The main findings resulted in a proposed tool that summarises the required inputs to generate a meaningful impact anlaysis. Therefore, this research covers and synthesises a wide range of literature in a very specific and novel case.

This work is done as part of the MSc. Management of Technology (MOT) program at the Technology, Policy and Management faculty of TU Delft. This study is relevant to the MOT program because it investigates societal implications within the technological context. There is an upcoming change in a technical process, such as the waiting list for energy grid management, that is going to have an impact on society by allowing certain members of society to have their contracted transport capacity granted earlier. In the MOT program, students are being taught the importance of responsible innovation and the impact it can have. This study addresses that.

8.4. Directions for Future Research

This section addresses the directions in which this research could be improved or taken further to better answer the questions related to the impacts of social prioritization and to add to the body of knowledge on Energy Justice.

- **Incorporate historical data.** By consulting the historical data a more accurate impact analysis can be done because all the required data for the analysis will be known for certain. It would allow to confidently say what the impact of social prioritization would have been and translate these results into a prospective analysis.
- **Obtain SBI codes for all clients.** By assigning all the client their SBI codes, this research could be significantly improved. By linking the SBI codes to the waiting list data such as capacity and waiting time, vulnerable groups could be identified. Which then would extend the understanding of the impacts and effectiveness of the social prioritization framework.
- **Policy development tool.** The tool that is proposed here that can potentially help with designing the prioritization policy can be significantly improved and used for future analysis. First, the accuracy can be improved by obtaining SBI codes, and taking into account the complexity of the energy distribution system with all the different bottleneck reasons and applying it on the actual waiting list data. Finally, potential users and stakeholders can be consulted on the usefulness and implications that this tool would entail.
- **Participatory Value Evaluation (PVE) research and improved feedback loop analysis.** As was mentioned earlier, the feedback loop could be improved by including all the relevant stakeholders in a timely manner. In addition to the industry representatives, the general public can be consulted via the PVE research. Societal values could be compared over the geographical areas which could uncover more knowledge about the local context of the congestion problem and relevant solutions. In addition to that, the distributive justice theory could be implemented by allowing the participants to simply select which of the schools of ethics they would adhere to in the development of the social prioritization framework.

- **Analyse other tenets of Energy Justice.** The academic world mostly focuses on the distributive aspect of energy justice and other tenets are usually less paid attention to. Other pillars such as procedural, recognition, restorative and cosmopolitan justice, if applicable.
- **Connect the quantitative implication results to societal values.** The analysis can be taken a step further by creating a link between the waiting time, capacity and the actual benefits to society. For instance, what does one year of waiting for 100 kVA of police station capacity translate to in terms of the values to society? How does it compare to the waiting time and capacity of other clients?

9 Recommendations

This chapter provides recommendations that are the results of the investigation into the implications of the social prioritization framework. These recommendations are aimed at policy makers, parties that will be involved in the implementation of the social prioritization, and the involved stakeholders.

9.1. Recommendation 1: Flexibility

According to the latest draft of the social prioritization by the ACM, the priority client requests must be treated first, in the order of priority weight, only then all the other requests can be treated [41]. In Chapter 6, the estimated impact on the waiting time was demonstrated. One of the results, Substation 1 production, showed that strict adherence to the framework would result in an unnecessary delay for a business by prioritizing school with no effect on the school. Similar situations are shown within the Substation 2 waiting list. The bottom line is, that strict adherence to the rule can unnecessarily place burdens on non-priority clients with no benefit for priority clients.

The recommendation is then to allow for flexibility in prioritization, depending on individual waiting list cases. There should be room for exceptions in the interest of more effective implementation. The party that is in the best position to identify these exception cases is the DSO. DSOs have the necessary data and technical knowledge to estimate the consequences before the decisions come into effect. If a DSO can identify these cases, there must be a procedure on how to act in such situations. For instance, through an addition to the social prioritization policy or by creating a communications channel between the DSOs and ACM, to report these kinds of cases. One of the ways of identifying such cases could be the energy justice metrics proposed in this research.

Furthermore, the flexibility recommendation can also be considered in situations where the non-priority clients on the waiting list keep getting delayed by newly added priority clients. The limits of the social prioritization framework need to be considered. For example, what is the maximum delay for non-priority clients that can be permitted?

Lastly, the local context, has been mentioned earlier. Some municipalities are advocating for allowing them to adjust the framework based on the local needs and situations. This desire is reasonable, even though it adds extra complexity to the framework. However, if the framework allowed for local input and modifications, it could partially be governed by the municipalities themselves and alleviate some labour costs from parties like ACM and more importantly, serve the local needs more accurately.

9.2. Recommendation 2: Feedback Loop

This recommendation is two-fold. First of all, the parties that possess crucial knowledge and an understanding of the congestion problem are the municipalities, DSOs and the ACM. The municipalities have better knowledge of local needs and nuances, such as the functions of clients on the waiting list and the SBI codes. DSOs have access to data and technical skills that allow for a deep understanding of what restructuring the waiting list order will result in. Finally, the ACM has the knowledge and power to develop new policies. To ensure a more effective social prioritization in times of scarcity, there should be better communication and collaboration between these three parties.

Another argument in favour of this collaboration is the time scale at which the social prioritization framework implementation is evaluated. Currently, the proposition is to evaluate the results after one year of implementation. However, in accordance with previous statements, there should be more flexibility and quicker responses to the impact that social prioritization can cause. As established earlier, the impact is not only technical but also psychological and financial. The psychological and financial impact on the clients on the waiting list can be instantaneous. Therefore, the feedback loop should be much shorter and ideally supported by preemptive analysis. The preemptive analysis could be done with the help of an analysis tool such as proposed in this research.

9.3. Recommendation 3: Expanding on Value to Society

The social prioritization framework aims to support socially important clients because in turn, they bring value to society. Currently, the socially important clients are only identified by their legally performed function. Aspects such as the amount of the requested power capacity are not considered. A large request from a hospital is treated with the same priority as a smaller request from another hospital. This is one of the framework's limitations. On one hand, a larger request could mean better infrastructure for the hospital and thus should be prioritized. On the other hand, the large request could cause a lot of additional delays, while the small request could mean a crucial improvement to the functions of the hospital. Ideally, the societal value should be better investigated and not limited to just the legal function of the client on the waiting list. The understanding of values could be expanded to the local context, the amount of requested transport capacity, the end use of the transport capacity and the public needs. This is a good avenue for a potential PVE research.

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A

Source Code for Calculating the Social Prioritization Impact

```
import pandas as pd
import matplotlib as mpl
import matplotlib.pyplot as plt
from datetime import datetime
import numpy as np
import seaborn as sns

# Load the data from the Excel file that gives a default Sub-Station data
file_path_LDN = 'filepath.csv'
file_path_ODN = 'filepath.csv'
df_LDN = pd.read_csv(file_path_LDN)
df_ODN = pd.read_csv(file_path_ODN)

month_map = {
    'jan.': 'Jan',
    'feb.': 'Feb',
    'mrt.': 'Mar',
    'apr.': 'Apr',
    'mei': 'May',
    'jun.': 'Jun',
    'jul.': 'Jul',
    'aug.': 'Aug',
    'sep.': 'Sep',
    'okt.': 'Oct',
    'nov.': 'Nov',
    'dec.': 'Dec'
}

### Converting LDN Entry Date Format
# Convert the date column to datetime format using the custom mapping
df_LDN['EntryDate'] = df_LDN['EntryDate'].apply(lambda x: '␣'.join([month_map[x.split()[1].lower()], x.split()[0], x.split()[2]]))
df_LDN['EntryDate'] = pd.to_datetime(df_LDN['EntryDate'], format='%b␣%d␣%Y')

# Convert the datetime format to the desired string format
#df_LDN['EntryDate'] = df_LDN['EntryDate'].dt.strftime('%d-%m-%Y')

### Converting ODN Entry Date Format
# Convert the date column to datetime format using the custom mapping
df_ODN['EntryDate'] = df_ODN['EntryDate'].apply(lambda x: '␣'.join([month_map[x.split()[1].lower()], x.split()[0], x.split()[2]]))
df_ODN['EntryDate'] = pd.to_datetime(df_ODN['EntryDate'], format='%b␣%d␣%Y')

# Convert the datetime format to the desired string format
#df_ODN['EntryDate'] = df_ODN['EntryDate'].dt.strftime('%d-%m-%Y')

```

```
## Removing the \t
df_LDN['Solution_C_Date'].astype(str)
df_LDN['Solution_C_Date'] = df_LDN['Solution_C_Date'].str.replace('\t', '')
df_LDN['Solution_C_Date'] = pd.to_datetime(df_LDN['Solution_C_Date'], format='%Y␣%m␣%d')

df_ODN['Solution_P_Date'].astype(str)
df_ODN['Solution_P_Date'] = df_ODN['Solution_P_Date'].str.replace('\t', '')
df_ODN['Solution_P_Date'] = pd.to_datetime(df_ODN['Solution_P_Date'], format='%Y␣%m␣%d')

df_LDN = df_LDN.sort_values(by='Solution_C_Date', ascending=True)
df_ODN = df_ODN.sort_values(by='Solution_P_Date', ascending=True)


df_LDN

df_ODN

# Calculating the capacity releases per date time for both ODN and LDN requests.

# Convert time columns to datetime format
#df_LDN['END_LDN'] = pd.to_datetime(df['Knelpunt Transport LDN Verwachte Einddatum'], format='%d-%m-%y')
#df['END_ODN'] = pd.to_datetime(df['Knelpunt Transport ODN Verwachte Einddatum'], format='%d-%m-%y')


grouped_LDN_r = df_LDN.groupby(df_LDN['Solution_C_Date'])['Contracted_C_kVA'].sum()
grouped_ODN_r = df_ODN.groupby(df_ODN['Solution_P_Date'])['Contracted_P_kVA'].sum()

yearlyODNrelease = pd.DataFrame(grouped_ODN_r)
yearlyLDNrelease = pd.DataFrame(grouped_LDN_r)

yearlyLDNrelease.reset_index(inplace=True)
yearlyODNrelease.reset_index(inplace=True)

yearlyLDNrelease = yearlyLDNrelease.rename(columns={'Contracted_C_kVA': 'cap_rel_LDN'})
yearlyLDNrelease = yearlyLDNrelease.rename(columns={'Solution_C_Date': 'cap_rel_LDN_date'})

yearlyODNrelease = yearlyODNrelease.rename(columns={'Contracted_P_kVA': 'cap_rel_ODN'})
yearlyODNrelease = yearlyODNrelease.rename(columns={'Solution_P_Date': 'cap_rel_ODN_date'})



yearlyLDNrelease

### Calculating Maturity and Time to Solution

current_date = datetime.now()
df_LDN['Maturity'] = (current_date - df_LDN['EntryDate']).dt.days
df_ODN['Maturity'] = (current_date - df_ODN['EntryDate']).dt.days

# Calculate 'TimeToSolution' as the difference between EntryDate and Solution_C_Date in days
df_LDN['TimeToSolution'] = (df_LDN['Solution_C_Date'] - df_LDN['EntryDate']).dt.days
df_ODN['TimeToSolution'] = (df_ODN['Solution_P_Date'] - df_ODN['EntryDate']).dt.days

### Rearranging DataFrames based on priority and reculclulating Time to Solution LDN Cases

priority_1_df = df_LDN[df_LDN['Priority'] == 1]
priority_2_df = df_LDN[df_LDN['Priority'] == 2]
priority_3_df = df_LDN[df_LDN['Priority'] == 3]
priority_4_df = df_LDN[df_LDN['Priority'] == 4]
priority_0_df = df_LDN[df_LDN['Priority'] == 0]

priority_1_df = priority_1_df.groupby('Solution_C_Date', group_keys=False).apply(
    lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
priority_2_df = priority_2_df.groupby('Solution_C_Date', group_keys=False).apply(
    lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
priority_3_df = priority_3_df.groupby('Solution_C_Date', group_keys=False).apply(
    lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
priority_4_df = priority_4_df.groupby('Solution_C_Date', group_keys=False).apply(
    lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
```

```
priority_0_df = priority_0_df.groupby('Solution_C_Date', group_keys=False).apply(
    lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)



# Concatenate the DataFrames in the order of priority
rearranged_LDN = pd.concat([priority_1_df, priority_2_df, priority_3_df,
                            priority_4_df, priority_0_df]).reset_index(drop=True)

#result = rearranged_LDN.groupby('Solution_C_Date').apply(lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)

### Calculating the new end date

rearranged_LDN['New_End_Date'] = pd.NaT

# Start with the first Min_Cap_Rel_kVA
current_min_cap = yearlyLDNrelease['cap_rel_LDN'][0]
current_date_index = 0

# Iterate over each client
for _, client in rearranged_LDN.iterrows():
    while current_date_index < len(yearlyLDNrelease):
        # Check if the client's Contracted_C_kVA fits in the current cap_rel_LDN
        if client['Contracted_C_kVA'] <= current_min_cap:
            # Assign the New_End_Date
            rearranged_LDN.at[client.name, 'New_End_Date'] = yearlyLDNrelease['cap_rel_LDN_date'][current_date_index]

            # Update the current Min_Cap_Rel_kVA
            current_min_cap -= client['Contracted_C_kVA']
            break
        else:
            # Move to the next Min_Cap_Rel_kVA, carrying over the unused capacity
            current_date_index += 1
            if current_date_index < len(yearlyLDNrelease):
                current_min_cap += yearlyLDNrelease['cap_rel_LDN'][current_date_index]

rearranged_LDN['New_TimeToSolution'] = (rearranged_LDN['New_End_Date'] - rearranged_LDN['EntryDate']).dt.days
rearranged_LDN['DeltaETS'] = (rearranged_LDN['New_TimeToSolution'] - rearranged_LDN['TimeToSolution'])


rearranged_LDN

### Rearranging DataFrames based on priority and reculclulating Time to Solution LDN Cases

priority_1_df = df_ODN[df_ODN['Priority'] == 1]
priority_2_df = df_ODN[df_ODN['Priority'] == 2]
priority_3_df = df_ODN[df_ODN['Priority'] == 3]
priority_4_df = df_ODN[df_ODN['Priority'] == 4]
priority_0_df = df_ODN[df_ODN['Priority'] == 0]

priority_1_df = priority_1_df.groupby('Solution_P_Date', group_keys=False).apply(lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
priority_2_df = priority_2_df.groupby('Solution_P_Date', group_keys=False).apply(lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
priority_3_df = priority_3_df.groupby('Solution_P_Date', group_keys=False).apply(lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
priority_4_df = priority_4_df.groupby('Solution_P_Date', group_keys=False).apply(lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)
priority_0_df = priority_0_df.groupby('Solution_P_Date', group_keys=False).apply(lambda x: x.sort_values('EntryDate', ascending=True)).reset_index(drop=True)


# Concatenate the DataFrames in the order of priority
rearranged_ODN = pd.concat([priority_1_df, priority_2_df, priority_3_df, priority_4_df, priority_0_df]).reset_index(drop=True)
```

```
### Calculating the new end date

rearranged_ODN['New_End_Date'] = pd.NaT

# Start with the first Min_Cap_Rel_kVA
current_min_cap = yearlyODNrelease['cap_rel_ODN'][0]
current_date_index = 0

# Iterate over each client
for _, client in rearranged_ODN.iterrows():
    while current_date_index < len(yearlyODNrelease):
        # Check if the client's Contracted_C_kVA fits in the current cap_rel_LDN
        if client['Contracted_P_kVA'] <= current_min_cap:
            # Assign the New_End_Date
            rearranged_ODN.at[client.name, 'New_End_Date'] = yearlyODNrelease['
                cap_rel_ODN_date'][current_date_index]

            # Update the current Min_Cap_Rel_kVA
            current_min_cap -= client['Contracted_P_kVA']
            break
        else:
            # Move to the next Min_Cap_Rel_kVA, carrying over the unused capacity
            current_date_index += 1
            if current_date_index < len(yearlyODNrelease):
                current_min_cap += yearlyODNrelease['cap_rel_ODN'][current_date_index]

rearranged_ODN['New_TimeToSolution'] = (rearranged_ODN['New_End_Date'] - rearranged_ODN['
    EntryDate']).dt.days
rearranged_ODN['DeltaETS'] = (rearranged_ODN['New_TimeToSolution'] - rearranged_ODN['
    TimeToSolution'])


rearranged_ODN

### Plotting Requested vs. Contracted Capacity for LDN list

sns.scatterplot(y='Contracted_C_kVA', x='Requested_C_kVA', hue='Priority',
            data=df_LDN, palette="deep")

# Plotting the line x=y
x = np.linspace(min(df_LDN[['Requested_C_kVA', 'Contracted_C_kVA']].min()),
                max(df_LDN[['Requested_C_kVA', 'Contracted_C_kVA']].max()), 100)
plt.plot(x, x, color='red', linestyle='--', label='Ideal␣Situation␣(x=y)')

# Annotate each point with its index
#for i, (x_val, y_val) in enumerate(zip(df_LDN['Requested_C_kVA'], df_LDN['Contracted_C_kVA
    '])):
#    plt.annotate(f'{i}', (x_val, y_val), textcoords="offset points",
#                 xytext=(0,5), ha='center', fontsize=8, color='blue')


# Adding labels and title
plt.xlabel('Requested_C_kVA')
plt.ylabel('Contracted_C_kVA')
plt.title('Requested␣vs␣Contracted␣LDN␣kVA')
plt.grid(True)

# Adding a legend
plt.legend()

# Annotating each point with its index value
for i, point in df_LDN.iterrows():
    plt.annotate(i, (point['Requested_C_kVA'], point['Contracted_C_kVA']))


# Show the plot
plt.show()

### Plotting Requested vs. Contracted Capacity for ODN list

sns.scatterplot(y='Contracted_P_kVA', x='Requested_P_kVA', hue='Priority',
```

```
            data=df_ODN, palette="deep")

# Plotting the line x=y
x = np.linspace(min(df_ODN[['Requested_P_kVA', 'Contracted_P_kVA']].min()),
                max(df_ODN[['Requested_P_kVA', 'Contracted_P_kVA']].max()), 100)
plt.plot(x, x, color='red', linestyle='--', label='Ideal␣Situation␣(x=y)')

# Annotate each point with its index
#for i, (x_val, y_val) in enumerate(zip(df_LDN['Requested_C_kVA'], df_LDN['Contracted_C_kVA'])):
#    plt.annotate(f'{i}', (x_val, y_val), textcoords="offset points",
#                 xytext=(0,5), ha='center', fontsize=8, color='blue')


# Adding labels and title
plt.xlabel('Requested␣Capacity␣[kVA]')
plt.ylabel('Contracted␣Capacity␣[kVA]')
plt.title('Requested␣vs␣Contracted␣ODN␣kVA')
plt.grid(True)

# Adding a legend
plt.legend()

# Annotating each point with its index value
for i, point in df_ODN.iterrows():
    plt.annotate(i, (point['Requested_P_kVA'], point['Contracted_P_kVA']))


# Show the plot
plt.show()

### Plotting Maturity vs. Contracted Capacity LDN

sns.scatterplot(x='Maturity', y='Contracted_C_kVA', hue='Priority',
                data=df_LDN, palette="deep")

# Adding labels and title
plt.ylabel('Contracted␣Capacity␣[kVA]')
plt.xlabel('Maturity␣[days]')
plt.title('Contracted␣LDN␣kVA␣against␣Maturity')
plt.grid(True)

# Adding a legend
plt.legend()

# Annotating each point with its index value
for i, point in df_LDN.iterrows():
    plt.annotate(i, (point['Maturity'], point['Contracted_C_kVA']))


# Show the plot
plt.show()

### Plotting Maturity vs. Contracted Capacity ODN

sns.scatterplot(x='Maturity', y='Contracted_P_kVA', hue='Priority',
                data=df_ODN, palette="deep")

# Adding labels and title
plt.ylabel('Contracted␣Capacity␣[kVA]')
plt.xlabel('Maturity␣[days]')
plt.title('Contracted␣ODN␣kVA␣against␣Maturity')
plt.grid(True)

# Adding a legend
plt.legend()

# Annotating each point with its index value
for i, point in df_ODN.iterrows():
    plt.annotate(i, (point['Maturity'], point['Contracted_P_kVA']))

```

```

# Show the plot
plt.show()

### Plotting Maturity vs. TimeToSolution LDN

sns.scatterplot(x='Maturity', y='TimeToSolution', hue='Priority',
                data=df_LDN, palette="deep")

# Adding labels and title
plt.ylabel('Estimated␣Time␣to␣Solution␣[days]')
plt.xlabel('Maturity␣[days]')
plt.title('Maturity␣against␣Estimated␣Time␣to␣Solution␣LDN')
plt.grid(True)

# Adding a legend
plt.legend()

# Annotating each point with its index value
for i, point in df_LDN.iterrows():
    plt.annotate(i, (point['Maturity'], point['TimeToSolution']))


# Show the plot
plt.show()

### Plotting Maturity vs. TimeToSolution ODN

sns.scatterplot(x='Maturity', y='TimeToSolution', hue='Priority',
                data=df_ODN, palette="deep")

# Adding labels and title
plt.ylabel('Estimated␣Time␣to␣Solution␣[days]')
plt.xlabel('Maturity␣[days]')
plt.title('Maturity␣against␣Estimated␣Time␣to␣Solution␣LDN')
plt.grid(True)

# Adding a legend
plt.legend()

# Annotating each point with its index value
for i, point in df_ODN.iterrows():
    plt.annotate(i, (point['Maturity'], point['TimeToSolution']))


# Show the plot
plt.show()

# Convert DataFrame to LaTeX table
latex_table_LDN = df_LDN.to_latex(index=False)

# Print or save the LaTeX table
print(latex_table_LDN)
# Or save to a file
# with open('table.tex', 'w') as f:
#     f.write(latex_table)
```

B

Full Social Prioritization Table & Variables of Interest

Categorie	Naam	SBI
1	Congestieverzachters	Nvt
2	Defensie	8422
2	Politie	8424
2	Brandweer	8425
2	Penitentiaire Inrichtingen	84232
2	Ambulancediensten En Centrale Posten	86925
2	Waterveiligheid	Nvt
3	Winning En Distributie Van Water	36
3	Afvalwaterinzameling En Behandeling	37
3	Inzameling Van Onschadelijk Afval	3811
3	Inzameling Van Schadelijk Afval	3812
3	Behandeling Van Onschadelijk Afval	3821
3	Behandeling Van Schadelijk Afval	3822
3	Projectontwikkeling	411
3	Algemene Burgelijke En Utiliteitsbouw	412
3	Leggen Van Rioleringen, Buizen En Pijpleidingen; Aanleg Van Bronbemaling	4221
3	Openbaar Vervoer Binnen Steden	4931
3	Streekvervoer Per Bus, Tram En Metro	49392
3	Basisonderwijs Voor Leerplichtigen	85201
3	Speciaal Basisonderwijs	85202
3	Speciaal Onderwijs In Expertisecentra	85203
3	Havo En Vwo	85311
3	Voorbereidend Middelbaar Beroepsonderwijs	85312
3	Praktijkonderwijs	85313
3	Brede Scholengemeenschappen Voor Voortgezet Onderwijs	85314
3	Universitair Medische Centra	86101
3	Algemene Ziekenhuizen	86102
3	Categorale Ziekenhuizen	86103
4	Een Producent Van Duurzame Elektriciteit Krijgt Voorrang Op Een Producent Van Niet-Duurzame Energie.	Nvt
4	Afnemers Van Elektriciteit Die Grootschalig En Bovenwettelijk Verduurzamen Kunnen Voorrang Krijgen Indien Zij Hiertoe Concrete, Expliciete En Bindende Afspraken Hebben Gemaakt Met De Overheid.	Nvt

Table B.1: Full list of clients elegible for social priortization according to ACM.

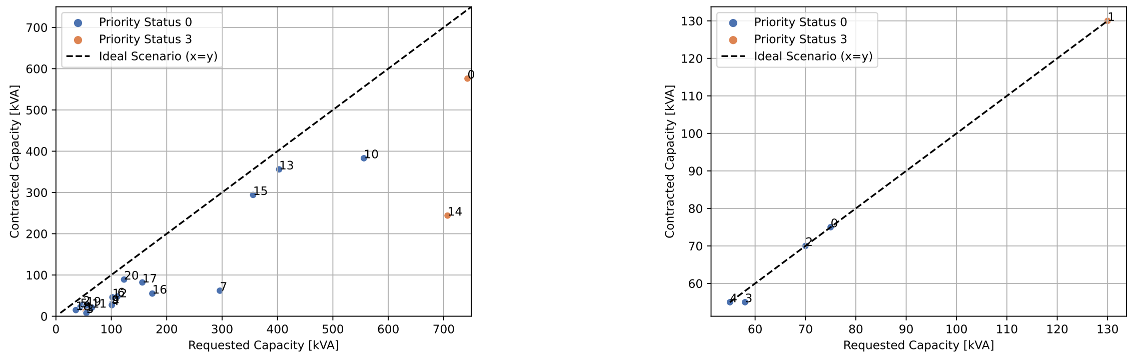
Variable Name	Variable Code Name	Description	Units / Notation
Waiting List Date	entry_date	The date on which a client has officially entered the waiting list. This date is used to structure the waiting list in order of the FCFS.	dd/mm/yyyy
Client Name	client	Client name as entered in the waiting list dashboard.	String.
Contracted Consumption Capacity	Contracted_C_kVA	The transport capacity that has been contracted with the client for consumption. It is the definite capacity that client will receive in the end.	[kVA]
Contracted Production Capacity	Contracted_P_kVA	The transport capacity that has been contracted with the client for production. It is the definite capacity that client will receive in the end.	[kVA]
Requested Consumption Capacity	Requested_C_kVA	The transport capacity that client has originally requested for consumption purposes.	[kVA]
Requested Production Capacity	Requested_P_kVA	The transport capacity that client has originally requested for production purposes.	[kVA]
AC Connection	AC	The type of connection that depends on the level of electricity that either supplied to or provided by the customer.	AC#
Bottleneck Solution Date Consumption	end_date_LDN	Estimated date when the bottleneck for the connection of each specific client will be solved. Indicates the earliest possible date of granting the contracted capacity to the client	dd/mm/yyyy
Bottleneck Solution Date Production	end_date_ODN	Estimated date when the bottleneck for the connection of each specific client will be solved. Indicates the earliest possible date of granting the contracted capacity to the client	dd/mm/yyyy

Table B.2: Variables of Interest that are needed for the impact analysis of the social prioritization framework.

C

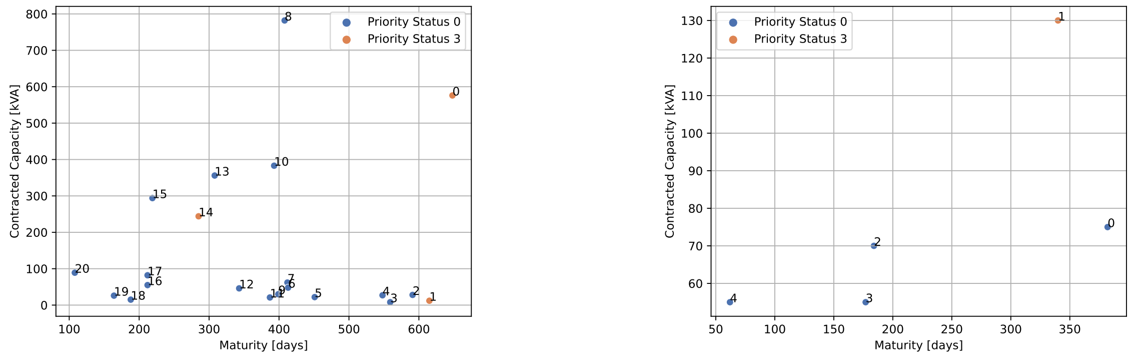
Relations Between Maturity, Capacity and Time to Solution

C.1. Substation 1



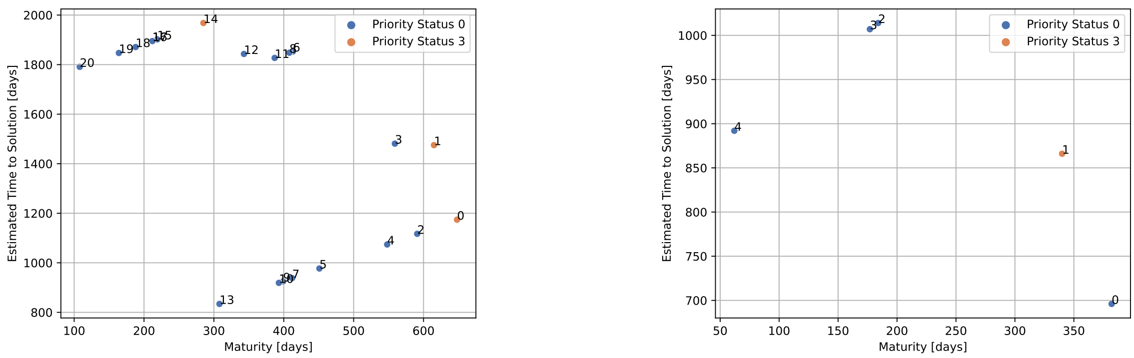
(a) Consumption Requests. **(b)** Production Requests.

Figure C.1: Requested Capacity plotted against Contracted capacity for clients on the waiting list of Substation 1 for consumers C.1a and producers C.1b.



(a) Consumption Requests. **(b)** Production Requests.

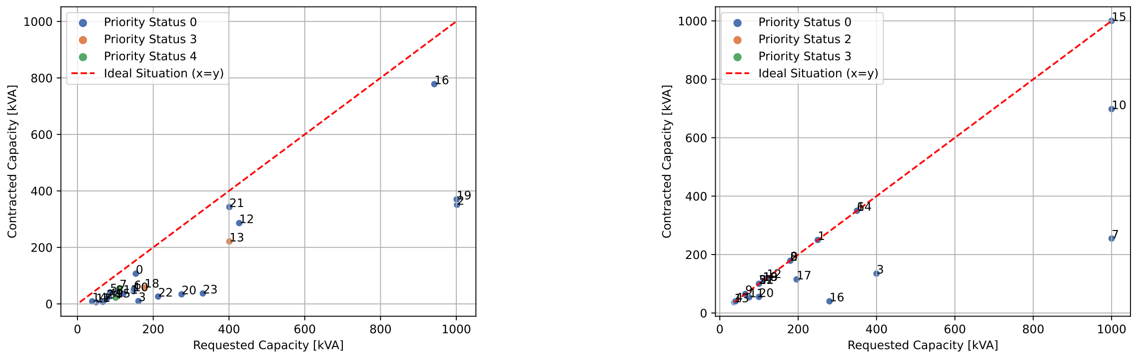
Figure C.2: Maturity plotted against Contracted Capacity for clients on the waiting list of Substation 1 for consumers C.2a and producers C.2b.



(a) Consumption Requests. **(b)** Production Requests.

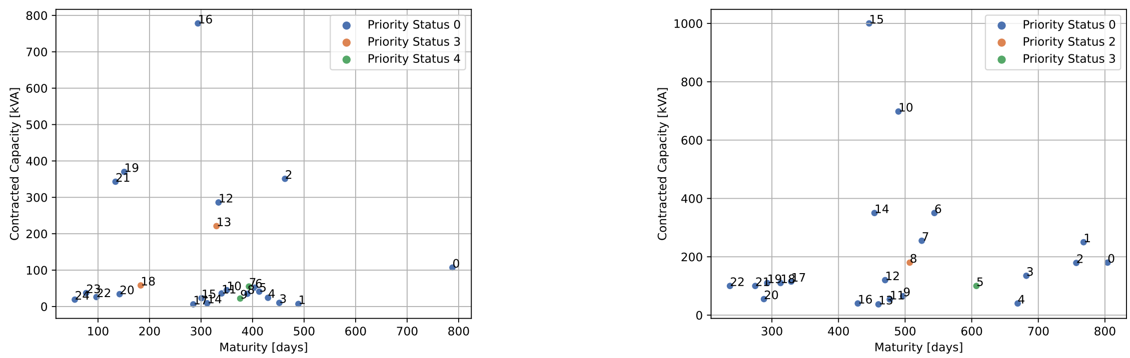
Figure C.3: Estimated Time to Solution plotted against Maturity for clients on the waiting list of Substation 1 for consumers C.3a and producers C.3b.

C.2. Substation 2



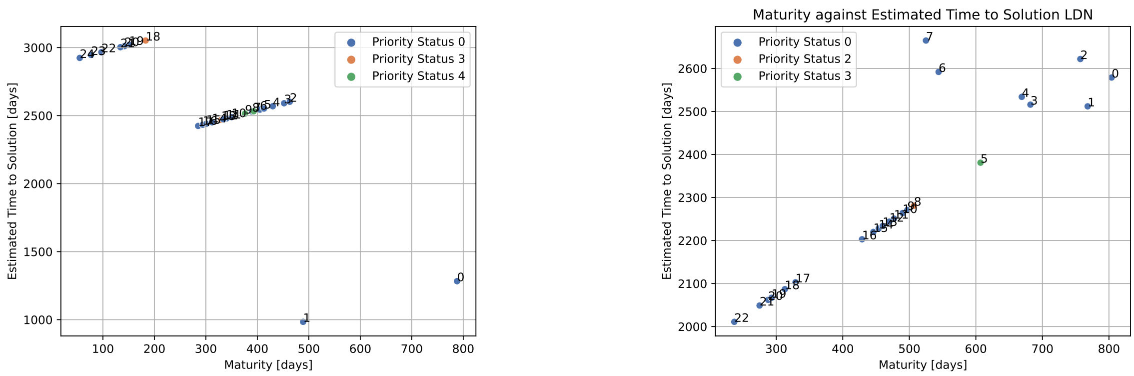
(a) Consumption Requests. **(b)** Production Requests.

Figure C.4: Requested Capacity plotted against Contracted capacity for clients on the waiting list of Substation 2 for consumers C.4a and producers C.4b.



(a) Consumption Requests. **(b)** Production Requests.

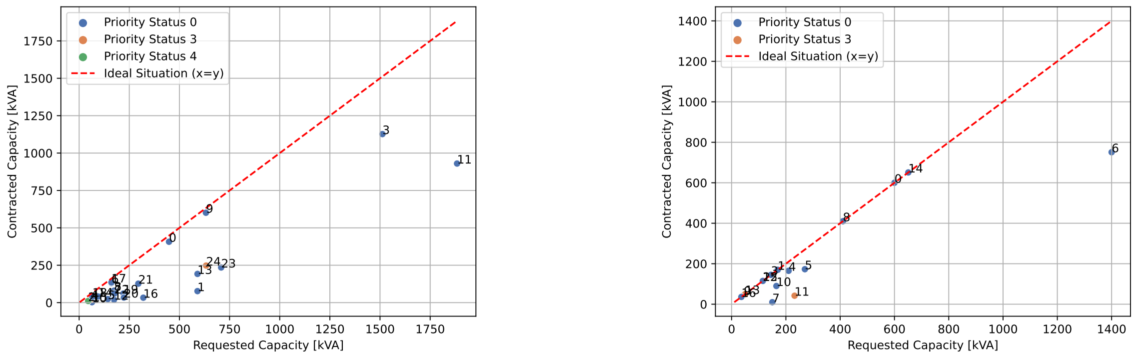
Figure C.5: Maturity plotted against Contracted Capacity for clients on the waiting list of Substation 2 for consumers C.5a and producers C.5b.



(a) LDN **(b)** ODN

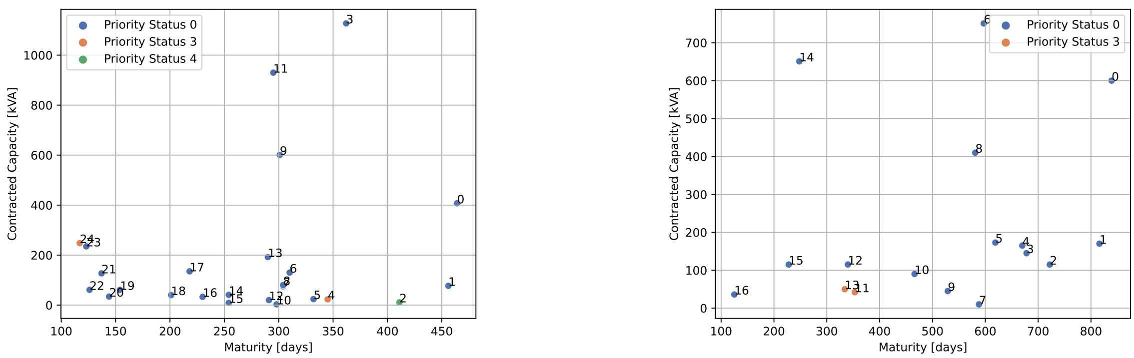
Figure C.6: Estimated Time to Solution plotted against Maturity for clients on the waiting list of Substation 2 for consumers C.6a and producers C.6b.

C.3. Substation 3



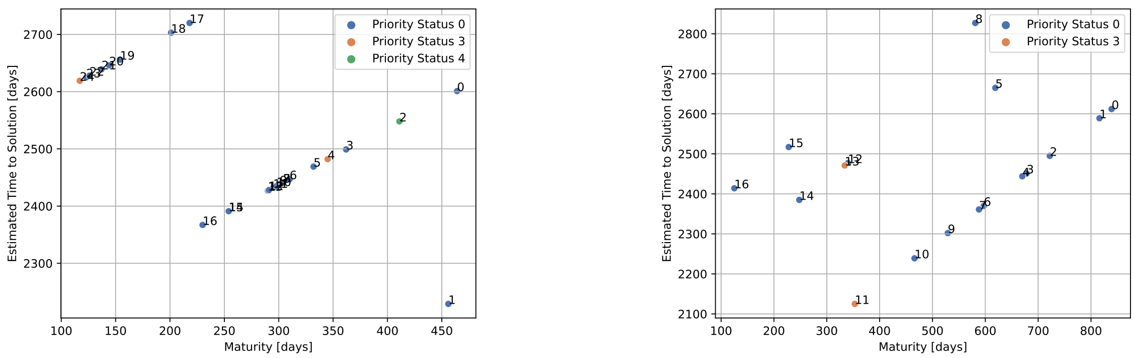
(a) Consumption Requests. **(b)** Production Requests.

Figure C.7: Requested Capacity plotted against Contracted capacity for clients on the waiting list of Substation 3 for consumers C.7a and producers C.7b.



(a) Consumption Requests. **(b)** Production Requests.

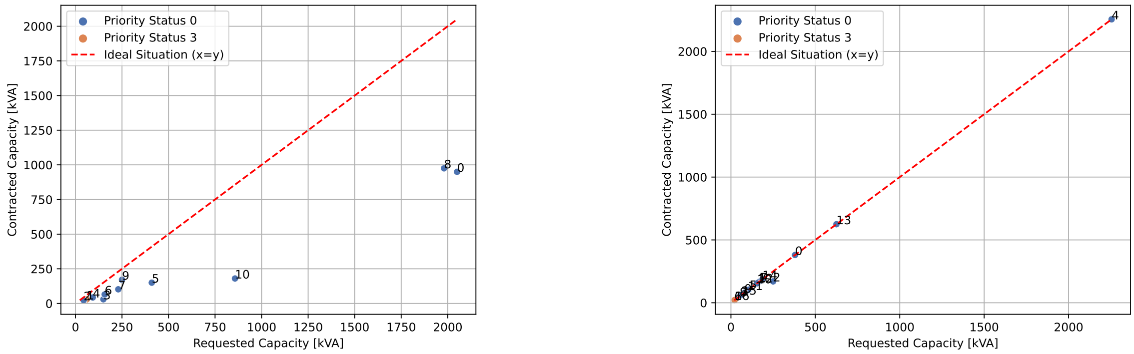
Figure C.8: Maturity plotted against Contracted Capacity for clients on the waiting list of Substation 3 for consumers C.8a and producers C.8b.



(a) Consumption Requests. **(b)** Production Requests.

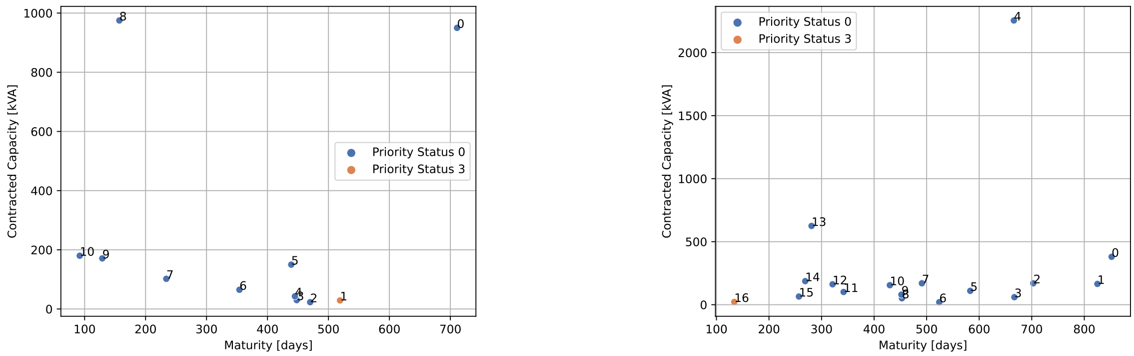
Figure C.9: Estimated Time to Solution plotted against Maturity for clients on the waiting list of Substation 3 for consumers C.9a and producers C.9b.

C.4. Substation 4



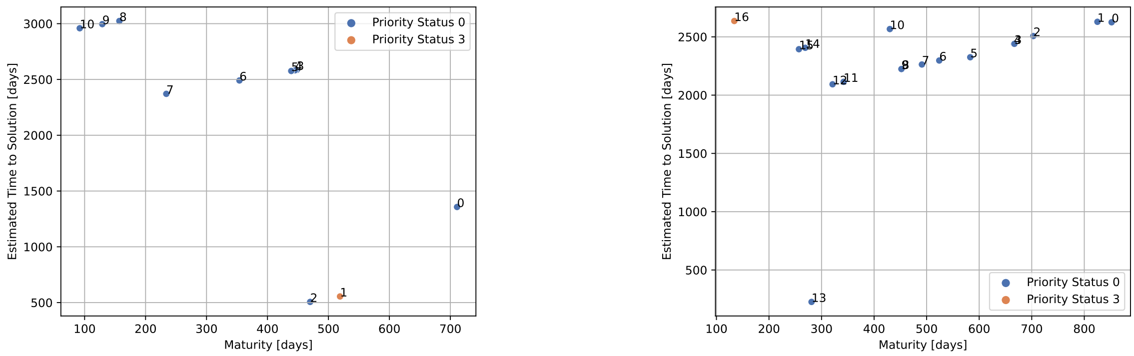
(a) Consumption Requests. **(b)** Production Requests.

Figure C.10: Requested Capacity plotted against Contracted capacity for clients on the waiting list of Substation 4 for consumers C.10a and producers C.10b.



(a) Consumption Requests. **(b)** Production Requests.

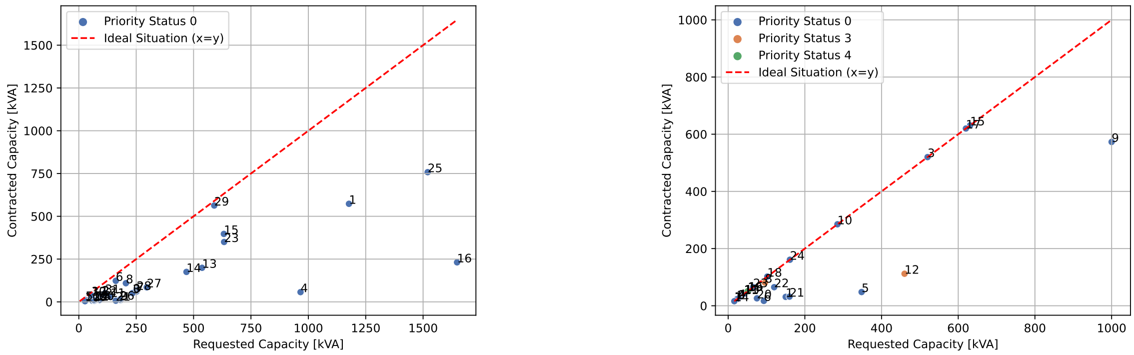
Figure C.11: Maturity plotted against Contracted Capacity for clients on the waiting list of Substation 4 for consumers C.11a and producers C.11b.



(a) Consumption Requests. **(b)** Production Requests.

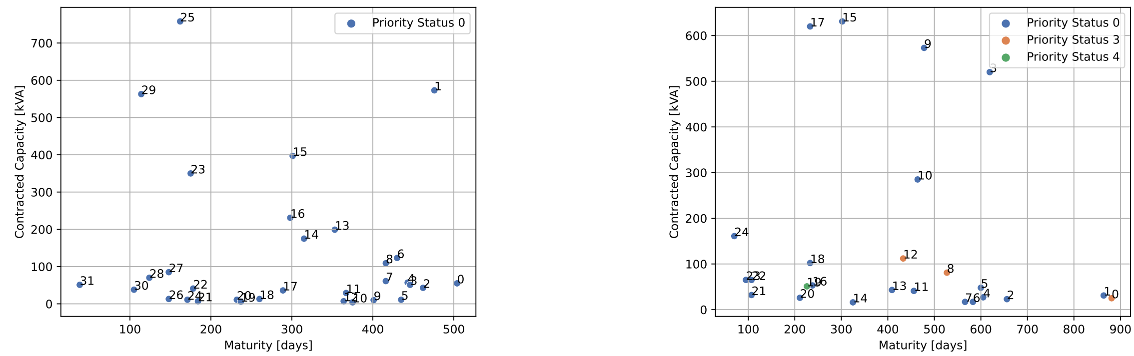
Figure C.12: Estimated Time to Solution plotted against Maturity for clients on the waiting list of Substation 4 for consumers C.12a and producers C.12b.

C.5. Substation 5



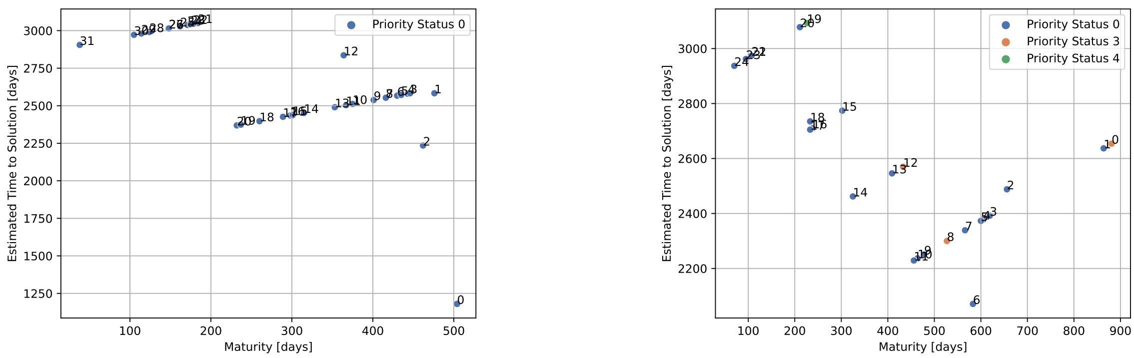
(a) Consumption Requests. **(b)** Production Requests.

Figure C.13: Requested Capacity plotted against Contracted capacity for clients on the waiting list of Substation 5 for consumers C.13a and producers C.13b.



(a) Consumption Requests. **(b)** Production Requests.

Figure C.14: Maturity plotted against Contracted Capacity for clients on the waiting list of Substation 5 for consumers C.14a and producers C.14b.



(a) Consumption Requests. **(b)** Production Requests.

Figure C.15: Estimated Time to Solution plotted against Maturity for clients on the waiting list of Substation 5 for consumers C.15a and producers C.15b.