RUGGEDISED
Designing smart, resilient cities for all

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Executive summary

Ruggedised is working on the implementation of a smart electrical grid at the Zuidplein area in Rotterdam. Part of the project is related to the large bus station at this location. At this station, there will be a need for a charging infrastructure for a large number of buses. Research by the Rotterdam School of Management, Erasmus University (RSM), see Abdelwahed et al (2020), focused on the question whether it would be feasible to supply part of this power by solar panels on-site and whether an energy storage system (e.g. a battery) could increase the utilization of the renewable energy generated by the solar panels for the charging of the buses.

For this analysis, RSM was provided with block assignment data by the public transport operator in Rotterdam (RET). This data describes the assignment of trips to the buses and thereby the location of each bus at each given time. Even though this could potentially be optimized, this block assignment is considered an input in this study and will therefore not be changed. This study only focuses on where, when and for how long each bus should charge during layovers.

In this study, the alignment between the energy generation from a solar panel and the energy consumption from charging buses is evaluated. In doing so, computer simulation is used to evaluate how much of the generated renewable energy can directly be used to charge the buses, without the need to supply energy to the grid. We further evaluate to what extend this can be further increased by adding an energy storage system at the station. In this simulation, we consider a conservative charging policy, in which each bus will charge whenever they have a sufficiently long layover at a station with a charger. This is more conservative than the already developed charging schedule optimization model, which would lead to fewer charging moments and better alignment between the energy supply and demand. This charging policy is not at all dependent on the availability of renewable energy. A smarter charging policy could increase the usage of renewable energy by considering the actual energy generation. This energy needed to charge the buses can either come directly from the solar panels, from the energy storage system (ESS) or from the grid. For the study both a small 870 m2 and a large 15.000 m2 solar park are considered. Also, an energy storage system is considered at Zuidplein to store unused renewables. The ESS will be charged when more energy is generated than used for charging.

First, we analyze the situation without renewable energy. For this, we only need to consider one day of operations for summer as well as for winter. This gives us an overview of the charging moments that result of the considered charging policy. Then, the renewable energy and the energy storage system are included in the study to evaluate the alignment between this generation of energy and the usage of energy as a result of the charging schedule. The analysis focused on the amount of energy used for fast charging at Zuidplein that can be supplied by renewable energy, with and without the energy storage system.

One risk of charging electric buses with renewable energy is that there might be a mismatch in the timing of the charging events and the generation of renewable energy. This study shows that for the Zuidplein area, this risk is rather low. Because of the large number of buses that need to charge at Zuidplein, there are only few moments during the day when no buses are charging. Thus, there are also few moments during the day at which generated renewable energy cannot be directly used for charging. With a small solar park more than 90% of the generated renewable energy can be used directly to charge electric buses. With the addition of an ESS, this number increases to almost 100%. One result of this strong alignment between the charging events and the energy generation is that the added value of an ESS is limited at this station. Adding an ESS would be more favorable at a station with fewer charging events. The main benefit of the ESS in this setting is that it can be charged in the morning when buses do not need charging yet and discharge in the evening after sunset.

A presentation for the final conference of RUGGEDISED is added to get more detailed information.

Contents

1. Introduction

As part of the RUGGEDISED project, a group of researchers from Rotterdam School of Management (RSM), Erasmus University has been working in collaboration with RET, the main public transport operator in the city of Rotterdam, in the project of electrifying the city's public transit bus network. The transition from conventional diesel to battery electric buses comes with several challenges and uncertainties. Electric buses have a limited driving range and require the planning of sufficient recharging sessions during the day to avoid running out of energy. Additionally, the impact of the new electrification parameters emerging into the system (e.g., the charging power, buses battery capacity, energy consumption rates) on the operational reliability and the electricity grid at large is uncertain as well. Therefore, the group from RSM focused on developing a discrete-event simulation which enables to simulate and evaluate various scenarios. Additionally, they developed an optimization model to optimize the charging schedule given various objectives while guaranteeing a minimum level of operational reliability (Abdelwahed et al. 2020).

Among the considered scenarios that required to be closely studied, is the installation of a photovoltaic solar park at the Zuidplein area in Rotterdam to provide charging power to electric buses there. Zuidplein has one of the largest bus stations in the city, where there will be a need to have a large charging infrastructure that is enough to charge from six to 12 buses. To supply the chargers with the required power, decisions needed to be made regarding the connection to the grid. In this process, the question arose whether it would be feasible to supply part of this power by solar panels on-site. A related question was whether an energy storage system (e.g. a battery) could increase the utilization of the renewable energy generated by the solar panels, by temporarily storing energy in the battery. In this study, we define utilization of energy as the amount of energy that can be used for charging of the buses, without the need to deliver it back to the grid. Of course, energy that cannot be used for charging will be send to the grid and will not be lost.

In this report, we use computer simulation to evaluate the impact of renewable energy generated by solar panels on the required energy from the grid to charge the buses of RET. In addition, we evaluate how an energy storage system (ESS) could help to increase the utilization of the renewable energy.

2. Experimental Design

2.1 Network structure

For this analysis, we will use data from the part of the bus network of the public transport operator in Rotterdam (RET) that will be electrified with the second tranche of 50 electric buses in the region. Since December 2019, the first 50 buses are operating, mainly in the Northern part of the city. This second tranche will operate in the Southern part of the city and will mainly charge at the Zuidplein station.

These 50 buses will operate on 7 bus lines and RET has provided us with the so-called block assignment, which serves as an input to our simulation. This block assignment assigns trips in the timetable to buses. This way, we know for each bus what trips it will operate during the day and thus where the bus is at any given time, and we will not change this in this study. We will only decide on the charging schedule that decides where, when and for how long each bus should charge during layovers.

In this network, fast-chargers will be installed at the Zuidplein station and the garage, all with a power of 300 KW. In the current design, 12 fast-chargers will be installed at the station and 4 will be installed at the garage. In addition to the fast-chargers, the garage will have sufficient slow-chargers for all the buses to charge overnight at a power of 50 KW. The batteries of the buses will have a capacity of 216 KWh. In this case, it is calculated that the bus uses 1,5 KWh/km. The bus has therefore a theoretical range of 145 km. One has to take into account that the battery cannot be fully used for safety reasons. The battery always has to have 20% of capacity left, for safety reasons. Therefor the actual range is 115 km in normal circumstances. Normal means: average temperature, average amount of persons and no use of high speed.

2.2 Charging policy

In this simulation, we will use a conservative charging policy, where each bus will charge whenever they have a sufficiently long layover at a station with a charger. In case the number of buses requesting a charging slot is larger than the number of chargers at the station, we will follow a First-In-First-Serve policy, where the bus that arrived first will get access to the charger. Given that the number of chargers that is available is larger than the maximum number of buses at the station this will never occur in our setting. We do not allow buses to use fast-chargers to charge the battery above a state-of-charge (SoC) of 90%, because charging becomes inefficient and unpredictable for a higher SoC.

For fast-charging, we consider a setup time of 1 minute, during which the charger will be occupied but no energy will be drawn from the charger. Furthermore, we only allow for charging events of at least 3 minutes, including the 1-minute setup time. At the end of the day, each bus will go to the garage where it directly connects to one of the slow-chargers for overnight charging to ensure a SoC of 100% at the beginning of the next day’s operation.

It is important to note that this charging policy is not at all dependent on the availability of renewable energy. It is assumed that there is always enough energy available from the electricity grid to supply all chargers. This energy for charging can either come directly from the solar panels (via direct DC line), from the ESS (via direct DC line), or from the grid (via AC-DC converter).

2.3 Energy consumption

For the energy consumption of the buses, we consider two scenarios that reflect the summer and winter situation. In both scenarios, we consider an active and passive energy consumption for the buses. The active energy consumption is the energy consumed while driving and is measured in KWh per kilometer, while the passive energy consumption is the energy consumption during layovers. Table 2-1 gives the parameters used in this study and were provided by RET. With these parameters, a bus can drive up to 110 kilometers with a full battery in winter and 140 kilometer in summer. We will use the summer parameters for the months April till September and the winter parameters for October till March.

Table 2-1 Overview of parameter values used in the computer simulation

Parameter	Value	
Fast-charging power	300 KW	
Slow-charging power	50 KW	
Bus battery capacity	216 KWh	
Number of fast-chargers Zuidplein	12	
Number of fast-chargers Garage	4	
Number of slow-chargers Garage	50	
Number of buses	50	
Number of lines	7	
Setup time	1 minute	
Minimum charging time	3 minutes	
Upper limit SoC	90%	
	Summer value	**Winter value**
Active energy consumption	1.55 KWh/km	1.93 KWh/km

Passive energy consumption rate	6 kW	18 KW

2.4 Renewable energy generation

For the renewable energy, we consider two cases regarding solar panels in the Zuidplein area. In the first, we assume there will only be a small solar park, which would result in 870 m2 and a rated peak capacity of 152.25 KW, assuming 175 Wp/m2. In the second case, we assume additional solar panels which would lead to a total of 15,000 m2 and a peak rating of 2625 KW. To obtain the actual amount of generated energy, we use data for the year 2018, which provides the energy output per m2 for the city of Antwerp for every 15-minute time window. We assume that due to the proximity of Antwerp to Rotterdam, this data is representative. Figure 2-1 shows the total amount of energy generated per day for both the small and the large case and the total amount of energy added to the buses using fast-charging at Zuidplein.

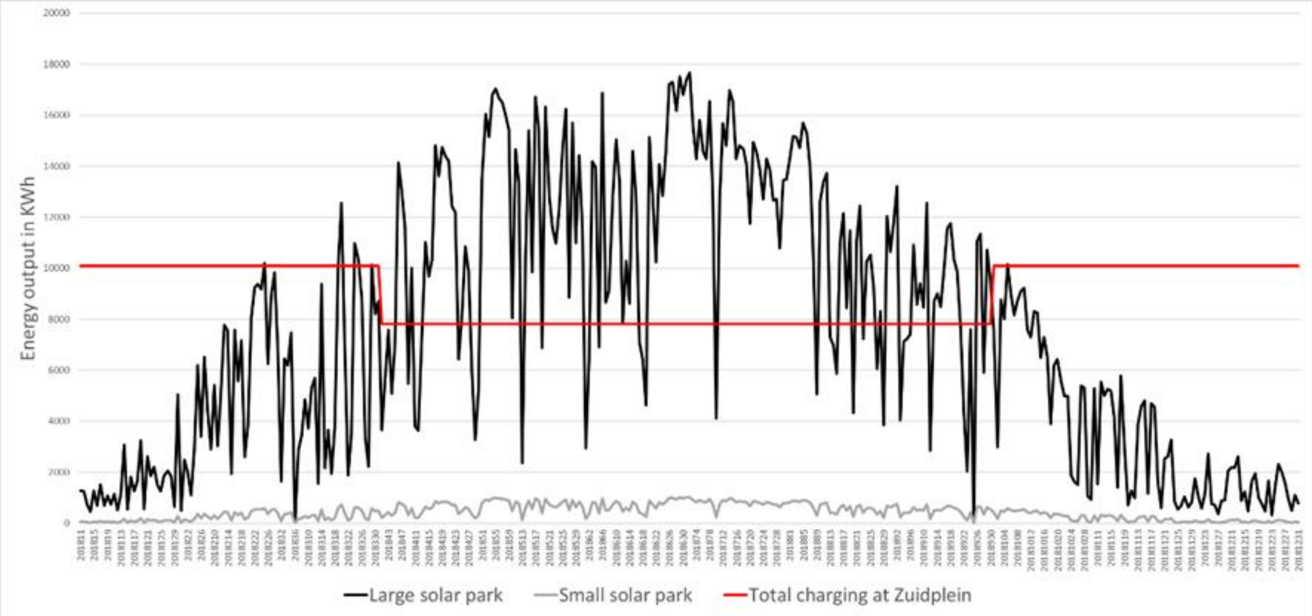

Figure 2-2 Renewable energy generation per day with large and small solar park. The red line indicates the total amount of energy required for charging at Zuidplein.

2.5 Energy storage system

In addition to the solar panels, we consider an energy storage system at Zuidplein to store unused renewable energy. We consider an ESS with a capacity of 600 KWh and a charging and discharging power of 300 KW. The ESS will be charged when more energy is generated by the solar panels than used for charging the electric buses. The ESS will be discharged if the amount of renewable energy generated is lower than the amount needed for charging.

3. Results

To better be able to interpret the results with the renewable energy from the solar panels, we first consider the case without the renewable energy. For this, we evaluate only one day of operations for the summer and the winter scenario with the different energy consumption rates, since the trip and charging schedules will be the same for each day as we do not consider any uncertainty. Afterwards, we will include the renewable energy and the ESS to the network and evaluate the impact. Here, we will run the network for a full year (2018), where the days differ in the amount of energy generated by the solar panels.

3.1 Analysis of network

Before we evaluate the charging events in the summer and winter scenario, we will consider the block assignment. Based on this assignment, we can determine the location of each bus during the day. This will give us the number of buses present at a station at each time, which gives us an upperbound on the number of buses charging at the same time. Figure 3-1 shows the upperbound on the number of buses that can occupy a charger at the same time.

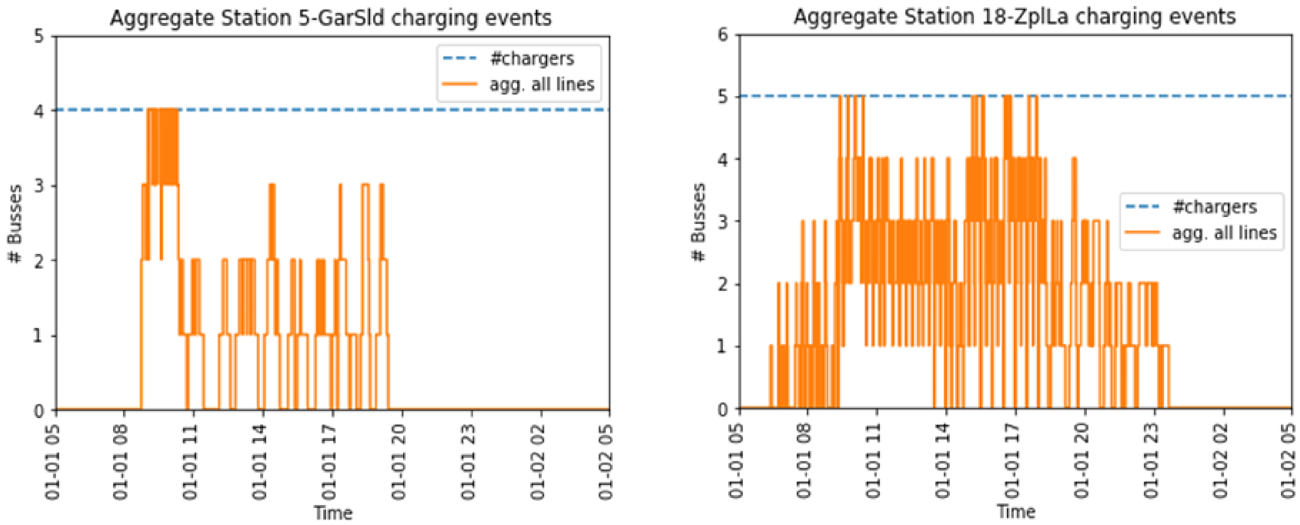

Figure 3-1 Upper limit on number of charging events for both the garage (left) and the Zuidplein station (right).

This figure shows that even though in the current plan 12 chargers will be installed at Zuidplein, at most 5 will be used at the same time based on the current block assignment. It should be noted that in the future, other bus lines might use the chargers at Zuidplein, which could justify the higher capacity.

By running the model without the renewable energy for both summer and winter, we see (Figure 3-2) that lowest state-of-charge of any bus is equal to 47.65% in the summer and 32.78% in winter. This is because the charging schedule is developed while considering the winter parameters and a restriction on the minimum SoC of 30%. The number of charging events per bus varies between 2 and 14.

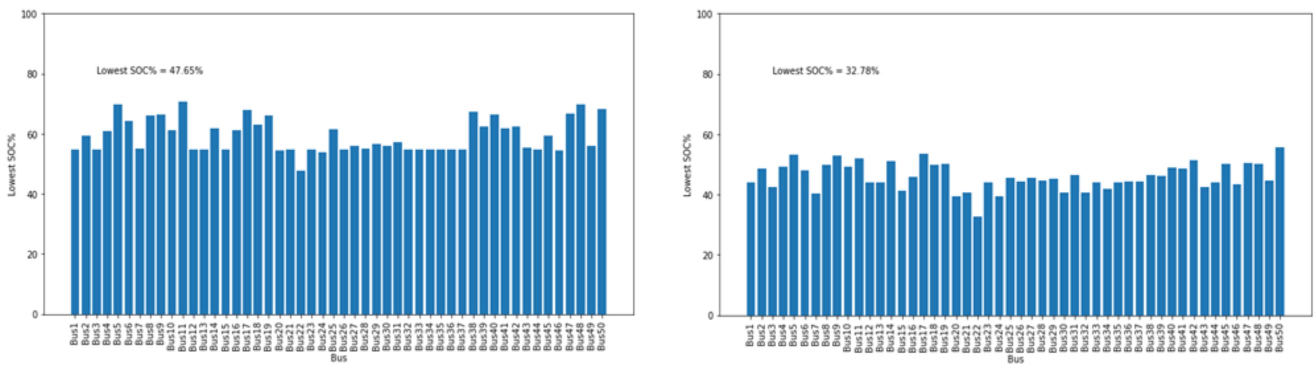

Figure 3-2 Lowest state-of-charge per bus for summer and winter parameters

In total, the buses will consume 15,221 KWh of energy during summer and 20,187 KWh during winter. In the summer scenario, 11,233 KWh comes from fast-charging during the day and 3988 KWh comes from overnight slow-charging. 7824 KWh (69.7%) of the fast-charging occurs at Zuidplein and can thus potentially be replaced by renewables. In the winter scenario, 14,707 KWh comes from fast-charging and

5480 KWh comes from overnight charging. 10,081 KWh (68.5%) of the fast-charging comes from the Zuidplein station.

Figure 3-3 Different types of slow and fast chargers within the city

3.2 Adding renewable energy

Now that we have evaluated the setting without the renewables, we can add the renewable energy and the ESS. Once again, note that this will in no way affect the charging schedule. All buses will use the exact same charging slots. In this analysis, we are interested in the amount of energy used for fast-charging at Zuidplein that can be supplied by the renewable energy. Clearly, this can never be more than the amount of renewable energy generated. Also, this can never be more that the amount of energy used for fast-charging at Zuidplein. So, depending on the setting, the two lines from Figure 2-1 both give an upperbound on the utilization of the renewables.

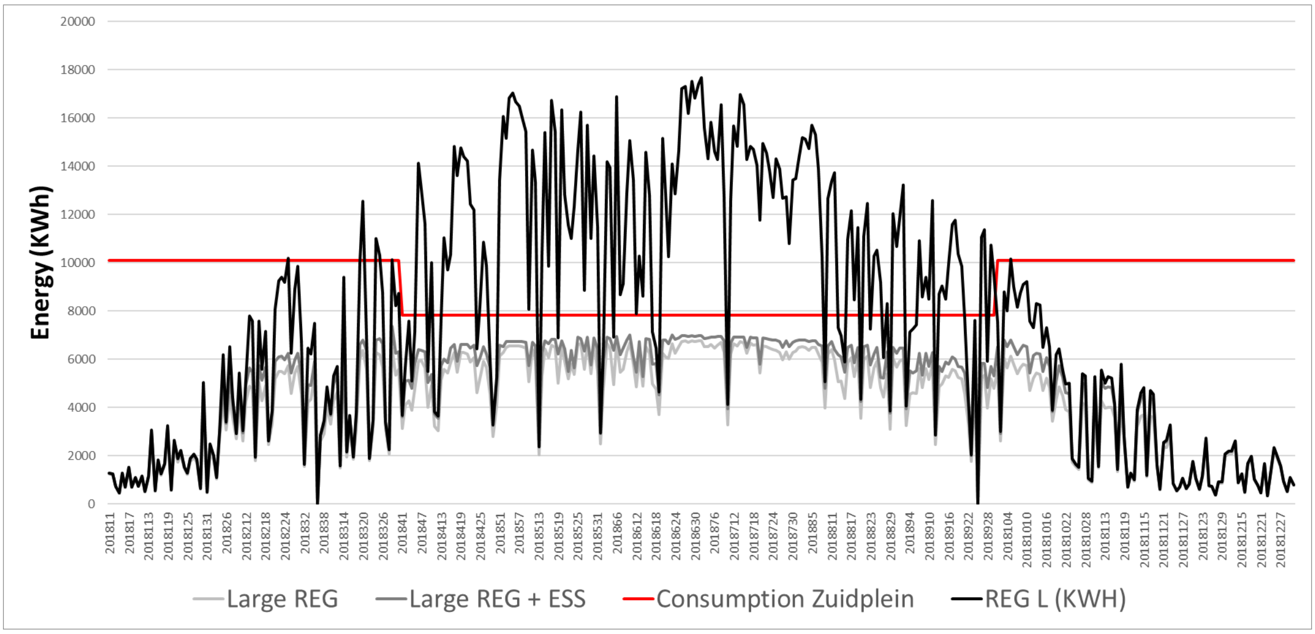

Figure 3-4 Renewable energy utilization with large solar park, with and without ESS

Figure 3-3 shows the utilization of the generated renewable energy for the large solar park, with and without the ESS. We see that during most of the winter, we can directly use most the generated renewables and the ESS has only very marginal benefit. In summer, we see that even though sufficient renewables are generated, we cannot fully supply the fast-chargers at Zuidplein with this energy. This is mainly due to charging events in the late evening when the sun is already down. With the energy storage system, we can increase the utilization.

Table 3-1 Average generation and consumption of renewable energy per day.

	Large solar	Large solar + ESS	Small solar	Small solar + ESS
Average usage at Zuidplein	8949 KWh	8949 KWh	8949 KWh	8949 KWh
Average generation	7545 KWh	7545 KWh	438 KWh	438 KWh
Average RE usage	4197 KWh	4633 KWh	394 KWh	437 KWh
Utilization (%)	55.6%	61.4%	90.0%	99.8%
Supplied by RE (%)	46.9%	51.8%	4.4%	4.9%
Utilization as % of upperbound	80.7%	88.4%	92.0%	99.9%

Table 3-1 gives the average generation and utilization for both the small and large solar park. We see that on average we can use 55.6% of the generated renewables without and 61.4% with the ESS. For the small solar park, this is 90.0% without and 99.8% with the ESS. This amounts to roughly 50% all energy consumed for fast-charging at Zuidplein for the large solar park and roughly 4.5% for the small solar park. The average increase in renewable energy utilization as a result of the ESS is 436 KWh, which corresponds to only 73% of the ESS capacity.

The final row gives the utilization as a percentage of the upperbound. This is a measure for the amount of renewable energy that is lost as a result of mismatch in timing between the charging events and the energy generation. It shows that even without the ESS, less than 20% of energy cannot be used efficiently. With the ESS, this goes down to 12%. With the small solar panel and the ESS, almost all generated renewable energy can be used for charging, without the need to send it back to the grid.

3.4 Contribution of energy storage system

We have already seen the average contribution over the year of adding an energy storage system to store renewable energy. It is interesting to see, when the ESS provides the highest contribution. Figure 3-4 shows the relation between the total amount of renewables generated and the additional utilization as a result of the ESS.

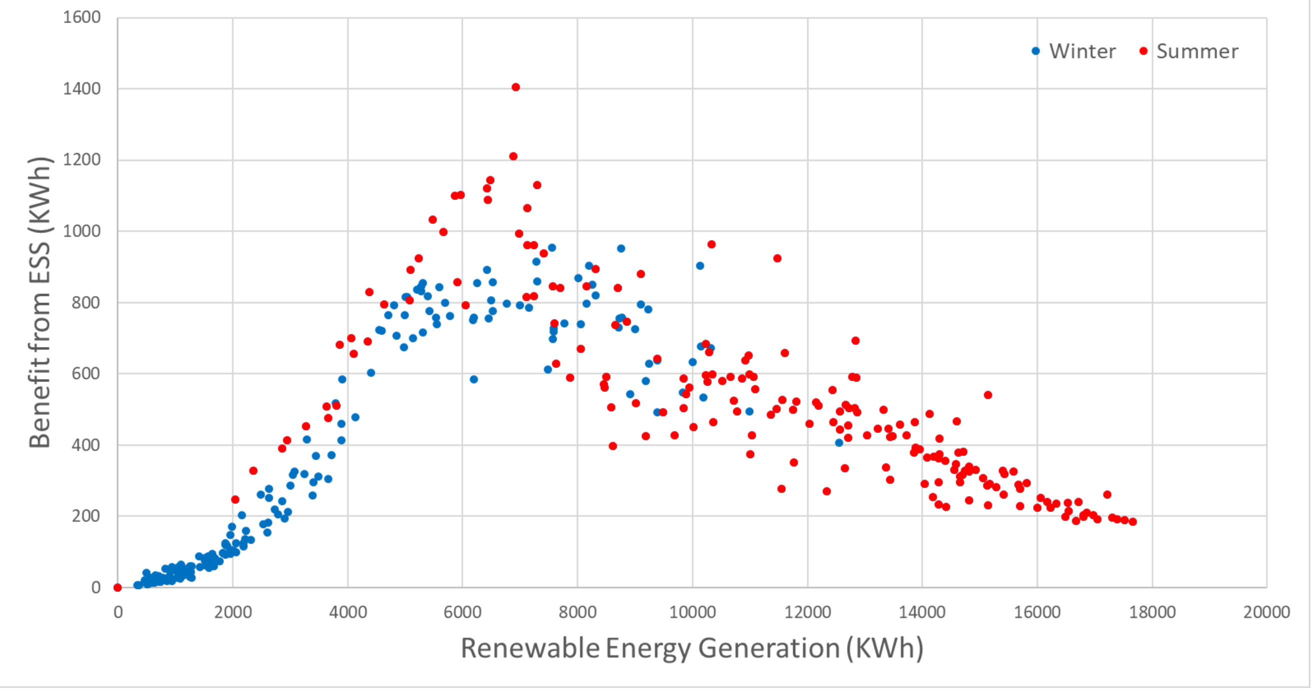

Figure 3-4 Relationship between renewable energy generation and utilization

Interestingly, we see that the ESS does not provide the maximum contribution for days with very high renewable energy generation. The ESS leads to the highest benefit if the total generation is neither too high nor too low. If the total generation is too low, we can directly use all energy and there is no need for an ESS. If the total generation is too high, we can quickly charge the ESS, but there is almost no possibility to discharge the ESS, thereby limiting the contribution of the ESS to its capacity. At the sweet spot, there is enough generation to charge the ESS at some times, but not enough to charge all buses at some other times. The maximum increase in renewable energy utilization is 1405 KWh, which corresponds to 2.34 times the capacity of the ESS.

We further see that the contribution of the ESS, given a fixed total generation, is higher in the summer. This can be result of the higher spread in energy generation because of earlier sunrise and later sunset in the summer. Especially the earlier sunrise allows for storing energy generated in the early morning when buses are not yet charging.

4. Conclusions

This study evaluates the impact of adding locally available renewable energy sources to a battery electric transit bus network. One risk of optimizing charging infrastructures of electric buses with local PV is that there might be a mismatch in the timing of the charging events and storage capacities for local generation.

This study shows that for the Zuidplein area, this risk is rather low. Less than 20% of locally generated energy cannot directly be used as a result of this mismatch. The main reason for the low utilization of renewable energy is that more energy is generated than there is consumed by charging. For the case with a small solar park, more than 90% of maximum generated renewables can be used directly to charge electric buses. With the addition of an ESS, this number increases to almost 100%. The main reason for this is the large number of buses that need charging at Zuidplein. For most of the day, at least one bus is charging at this station, which can use the generated renewable energy. As a result of this, the added value of an ESS is limited at this station. Adding an ESS would be more favorable at a station with fewer charging events. This study shows that an ESS has most benefit if there are both times with under- as well as over-supply of renewable energy, which is rarely the case in the setting under study.

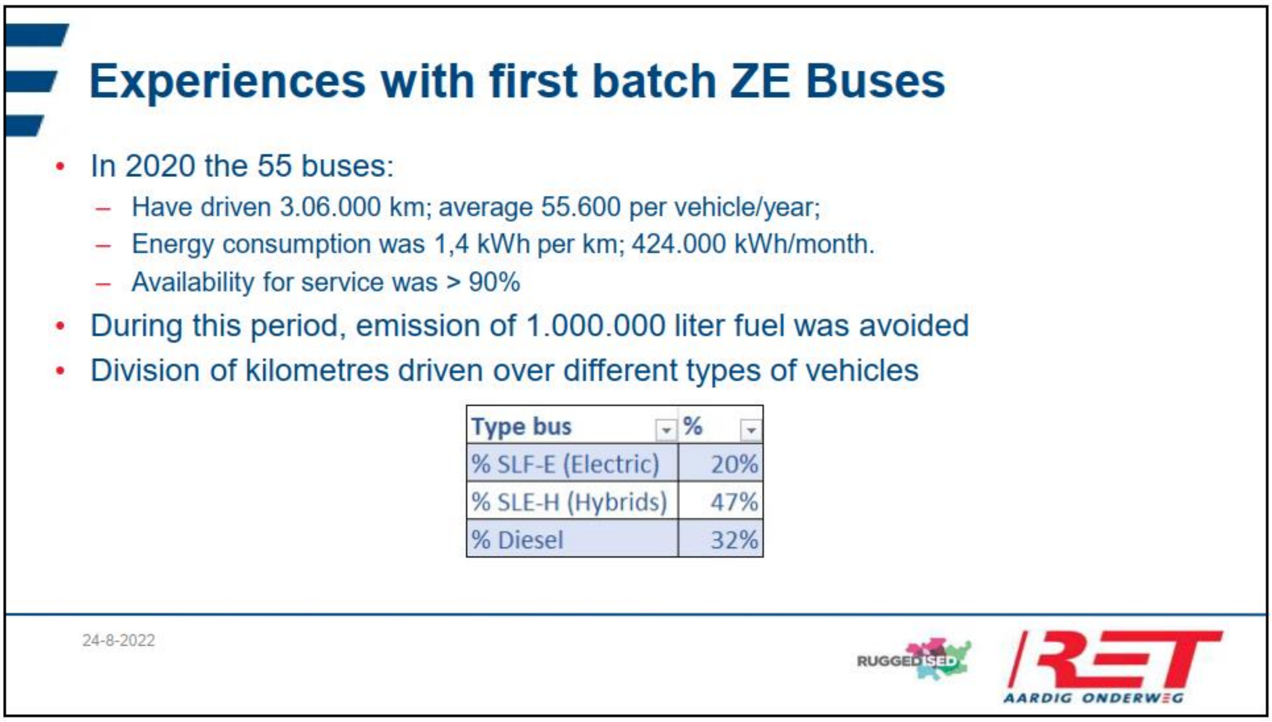

Figure 4-1 Slide out of the presentation of the Final conference RUGGEDISED by RET

6. References

A. Abdelwahed, P.L. van den Berg, T. Brandt, J. Collins & W. Ketter (2020). Evaluating and Optimizing Opportunity Fast-Charging Schedules in Transit Battery Electric Bus Networks. Transportation Science 54(6): 1601-1615.

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Annex A – Presentation RET

Presentation by RET about the environment friendly busses at RET Rotterdam. It was shown during the final conference in September 2022.

Environment friendly buses at RET Rotterdam - NL

Action 2017-NL-TM-0060-W - REMETBUS2 Rotterdam, E-mobility in public transport

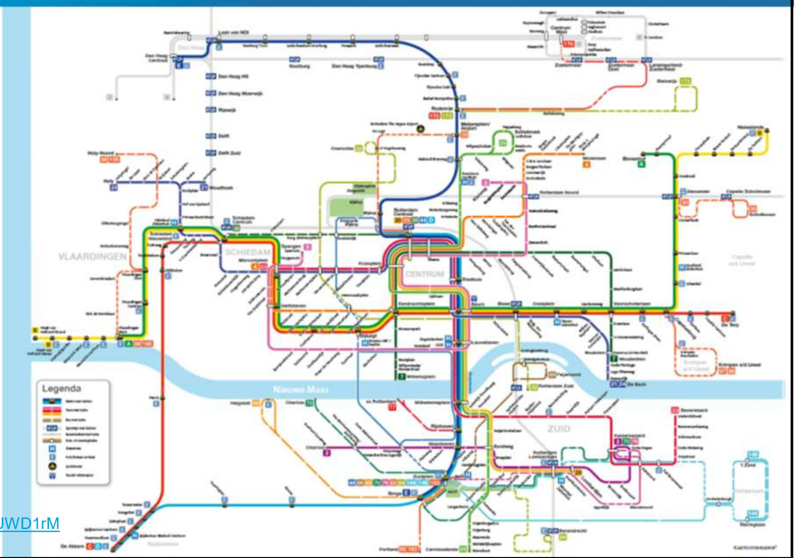
1

Introduction & key figures

RET is the public transport operator for the greater Rotterdam Region

Key figures RET (2021)	
Established	1878
FTE	2.599
Traveler kilometers	533 mln
Metro's	166
Metro lines	5
Busses	284
Bus lines	57
Trams	112
Tram lines	9

Key figures Emissions	
CO2 emission Bus	12,8 mln KG
CO2 emission Tram	1,8 mln KG
CO2 emission Metro	6,1 mln KG
Energy consumption Bus	41,7 mln kWh
Energy consumption Tram	24,6 mln kWh
Energy consumption Metro	82,4 mln kWh



RET company movie: https://www.youtube.com/watch?v=36OZcUWD1rM

3

What have we accomplished so far?

We started in 2006 with several sustainable initiatives…

2006
Uitvoerings-plan Milieu concessie Rail en Bus

2007
Partner Rotterdam Climate Initiative

2008
Start EU-project Duurzame remises

2009
Proef diesel Hybride bussen

2010
Start EU-project

2011
- Eerste editie Aardig Onderweg Award
- Opening duurzame remise Beverwaard

2012 2013
- Visie op Duurzaam ondernemen
- Gericht inzetten op instroom jongeren

2015
MVO in het RET businessplan

KPI
Strategische doelstelling:
- Milieuvriendelijker openbaar vervoer van een maatschappelijk betrokken RET
Target (2021): ????

2016
- Aankoop Waterstofbussen;
- Concessie Rail: Oog voor maatschappelijk belang

2017
- Opzet duurzaam inkoopbeleid en MVI gedragscode
- Opzet ISO 14001 milieumanagement gestart
- Convenant verduurzaming railassets gesloten

Concessiedocument 2: Programma van Eisen

2018
- Duurzaam aanbesteden infra onderhouds- en vervangingsprojecten
- Topacademie Participatiewet

2019
Start Busconcessie: 55 e-bussen, 110 hybrides

Zonnepanelen op daken bovengrondse stations

2020
Start contract 100% duurzame energie

5

5

What have we accomplished so far?

…based on the 17 SDG we focused on four domains…

Doelstelling:

Duurzaam vervoeren	Klimaatneutraal vervoer in 2030
Duurzaam bouwen	Energieneutraal en circulair bouwen in 2040
Duurzaam werken	Circulair, fair en transparant werken in 2030
Duurzaam verbinden	Sociaal betrokken en inclusieve werkgever in 2025

6

6

What have we accomplished so far

Sustainability is a strategic goal set in our businessplan

- **Objective 2024:** More travelers experience 'the perfect trip' because we work together on a flexible, reliable and sustainable service
- We are visibly sustainable by setting up monitoring, taking measures with impact and show our results to further build our reputation

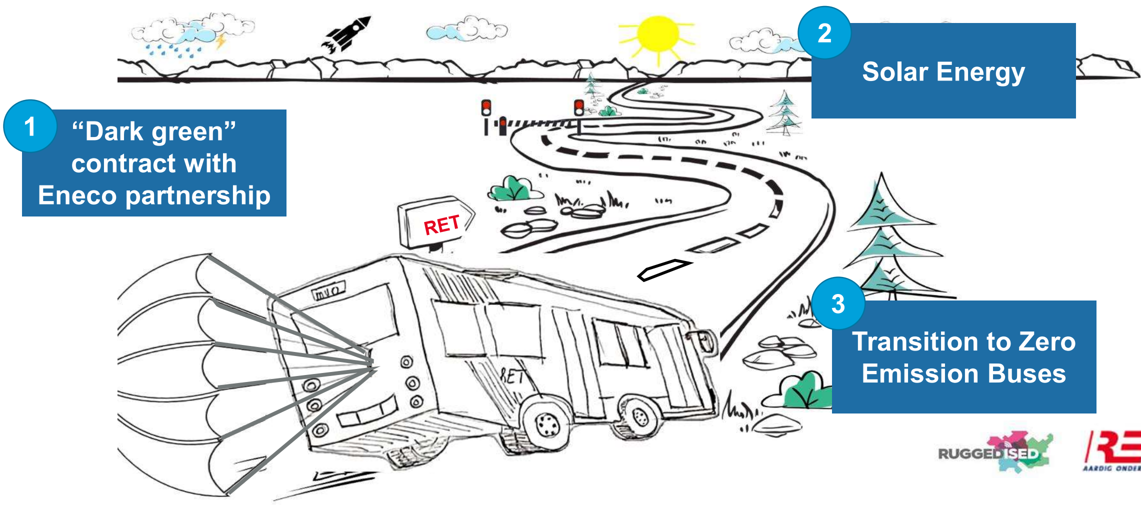
RET gaat voor een duurzame samenleving
nu en in de toekomst

Duurzaam vervoeren 2030	Duurzaam bouwen 2040
0% emissions in 2030	All RET buildings use green energy (generated or bought) in 2040
Duurzaam werken 2030	**Duurzaam verbinden 2025**
Collaborate with suppliers for further improvements in the supply chain	Be an inclusive employer

7

What have we accomplished so far

The road ahead started with implementing quick wins to reach our sustainable goals



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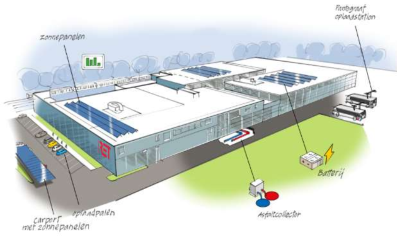
2. What have we accomplished so far?

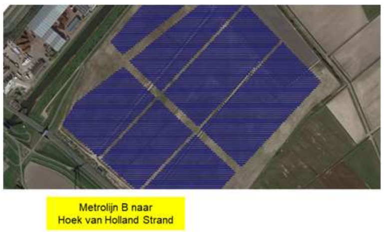
‘Dark green’ energy contract with Eneco and working together on systainable projects

- **The RET and Eneco** have reached a 10-year PPA - ‘dark green’ energy contract (2020-2029) for 135GWh a year
- Yearly supply of 5GWh from local windpark (landtong Rozenburg)



- **Showcase Kleiweg**
- Energy neutral workshop
- Production of sustainable energy
- Innovative measures; storage of energy in old battteries

- Working together on a **communication campaign** to create awareness for sustainable travel with RET
- **Energy positive** public transport in Rotterdam



- Opportunity of **new solar panel park** Hoek van Holland
- In cooperation with energy supplier
- Connection of solar power to metro grid

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2. What have we accomplished so far?

Quick wins with solar panels realized, additional panels are more challenging

- 4 stations; 3 depots equiped with **solar panels**

- **Constraints in constructions** for other roofs
  - Weight; roofs in curves, maintenance programs etc.
- Working together with the municipality; study for other **possibilities**
  - Metro viaduct, bridges, green strips next to tracks etc.

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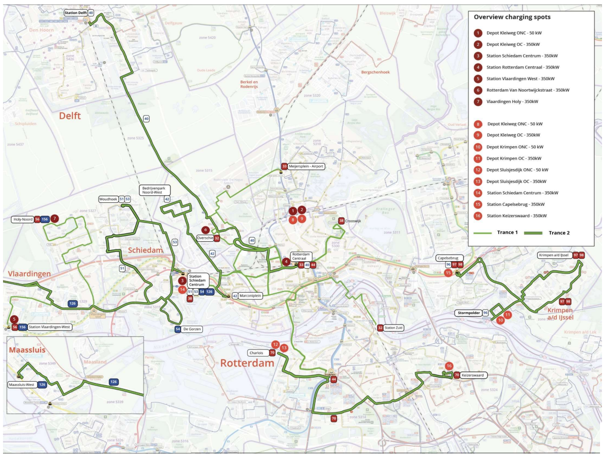
What have we accomplished so far?

Zero Emission Buses – phase 1 + 2 realized, phase 3 + 4 still to go



- 105 full electric
- 103 hybrid
- 40 EURO VI
- Infrastructure realized for opportunity and overnight charging

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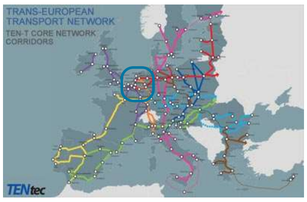

Context in The Netherlands

Grant of € 3,2 mio for
Action 2017-NL-TM-0060-W - REMETBUS2 Rotterdam

Medegefinancierd door de Europese Unie
Trans-Europees vervoersnetwerk (TEN-T)

RET

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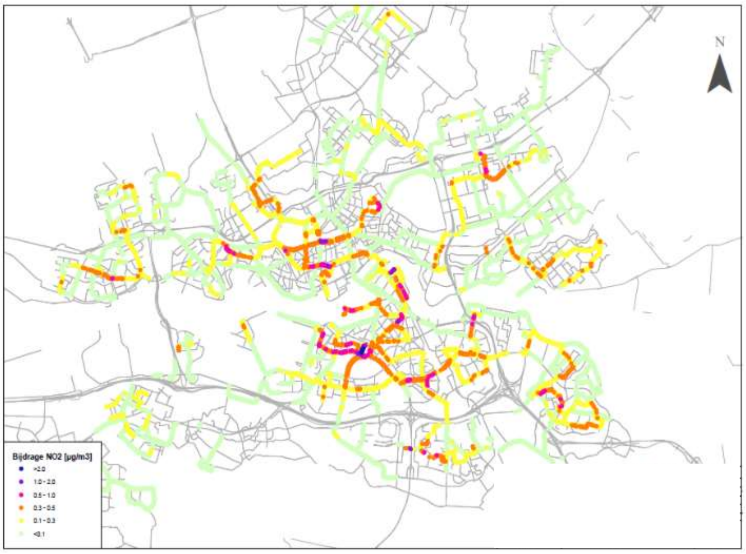
Context in Rotterdam

Air quality on bus routes



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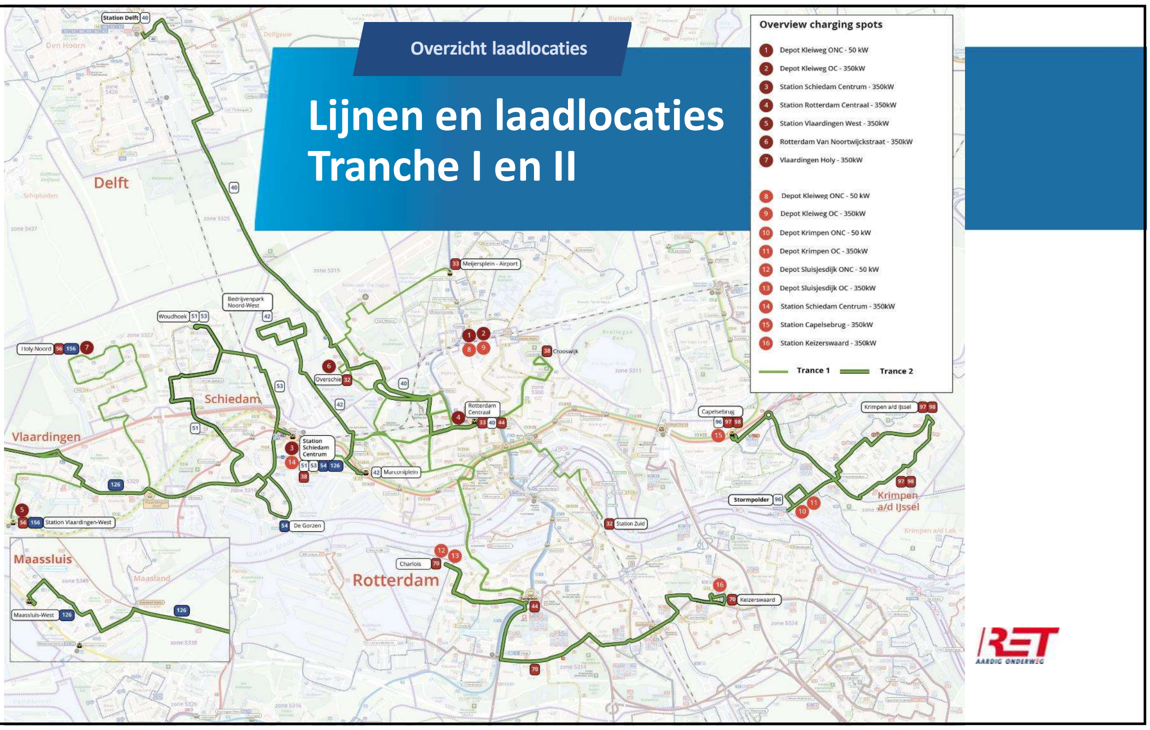

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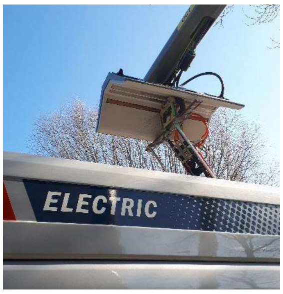
Impression of the vehicles and chargers



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Experiences with first batch ZE Buses

- In 2020 the 55 buses:
  - Have driven 3.06.000 km; average 55.600 per vehicle/year;
  - Energy consumption was 1,4 kWh per km; 424.000 kWh/month.
  - Availability for service was > 90%
- During this period, emission of 1.000.000 liter fuel was avoided
- Division of kilometres driven over different types of vehicles

Type bus	%
% SLF-E (Electric)	20%
% SLE-H (Hybrids)	47%
% Diesel	32%

24-8-2022

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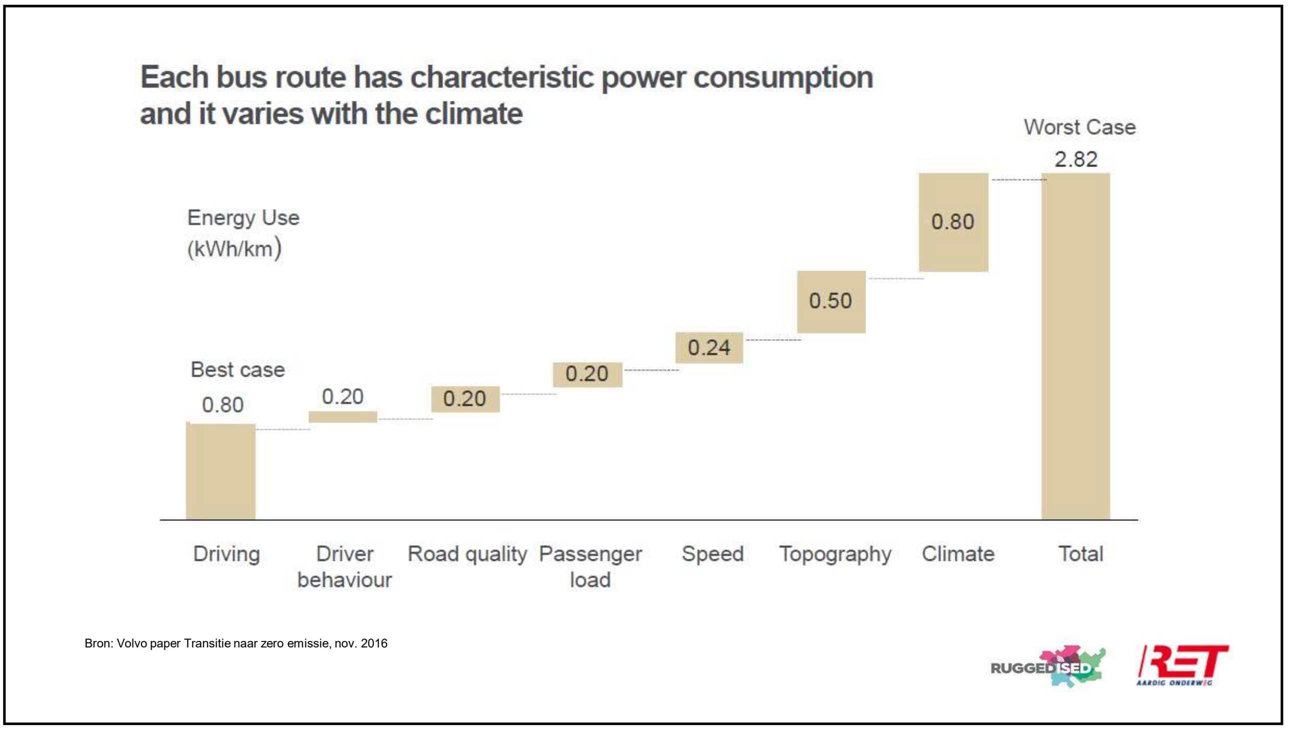

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Considerations spots for opportunity charging

- Goals MRDH and municipality of Rotterdam
  - Aim for 40% zero emission public bus transport in 2021
  - Aim for 0-emission zones in area between highways in 2025.
- Main busstation Zuidplein needs placement of opportunity chargers
  - Station to be fully refurbished by the municipality; takes over 2 years;
  - Placement opportunity chargers only possible afterwards
- Spot near tram depot on south bank is a good opportunity for new depot
  - Connection to grid for tram available to charge buses;
  - Synergy with deployment of tram and bus on one spot;
  - Investment in surface, buildings, charging facilities; spatial procedure is started
  - Available for overnight parking, maintenance and charging in Q1-2023.

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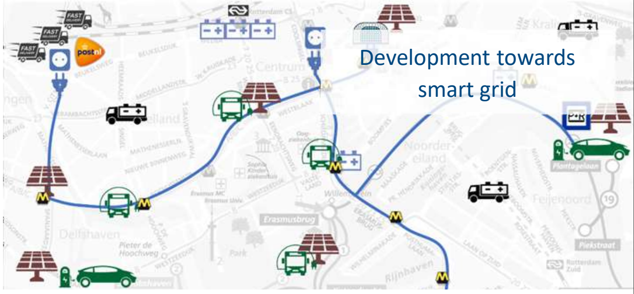
Increasing pressure on electric grid



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Two important challenges for electric grid

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Lessons learned

- Teething problems electric vehicles
- Hard to get agreements and licenses from munitipalities for placement of chargers (agreed on ZE transition, but *not in my backyard*) and extra requirements f.i. for design pillars
- Grid owners are hardly capable to deliver connections for charging infrastructure

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Lessons learned from RUGGEDISED

> Simulation actieradius and charging moments for e-buses
> Simulation storage sustainable energy for e-buses

> Calculations grid connections for opportunity chargers

> Application MINBus in planningstool HASTUS

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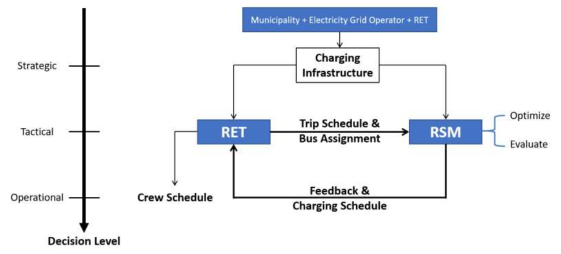
Simulation actieradius and charging moments for e-buses

A Boost for Urban Sustainability: Optimizing Electric Transit Bus Networks in Rotterdam

Ayman Abdelwahed e.a.

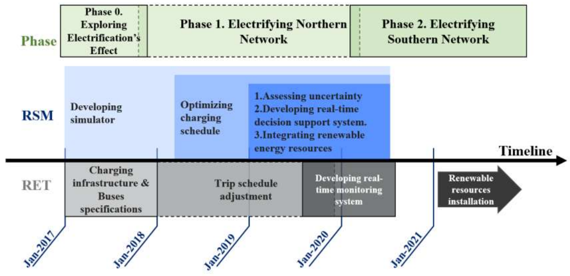
Abdelwahed et al.: *Optimizing Electric Transit Bus Networks*
Article submitted to *INFORMS Journal on Applied Analytics*; manuscript no. (Please, provide the manuscript number!)

Figure 1 Decision levels structure and allocation on different involved parties in the project



Abdelwahed et al.: *Optimizing Electric Transit Bus Networks*
Article submitted to *INFORMS Journal on Applied Analytics*; manuscript no. (Please, provide the manuscript number!)

Figure 3 Timeline of the progress of our cooperation with RET



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Simulation storage sustainable energy for e-buses

A Boost for Urban Sustainability: Optimizing Electric Transit Bus Networks in Rotterdam

Ayman Abdelwahed e.a.

Figure 7 The structure of the TBN with central RDSS

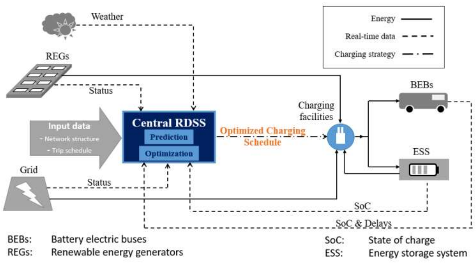
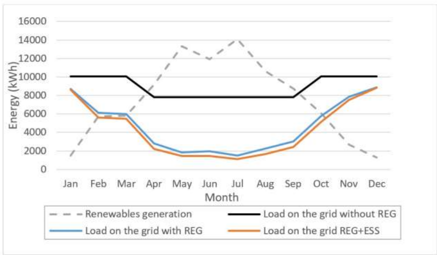


Figure 8 Daily average renewable energy generation and load on the grid at Zuidplein with the different settings



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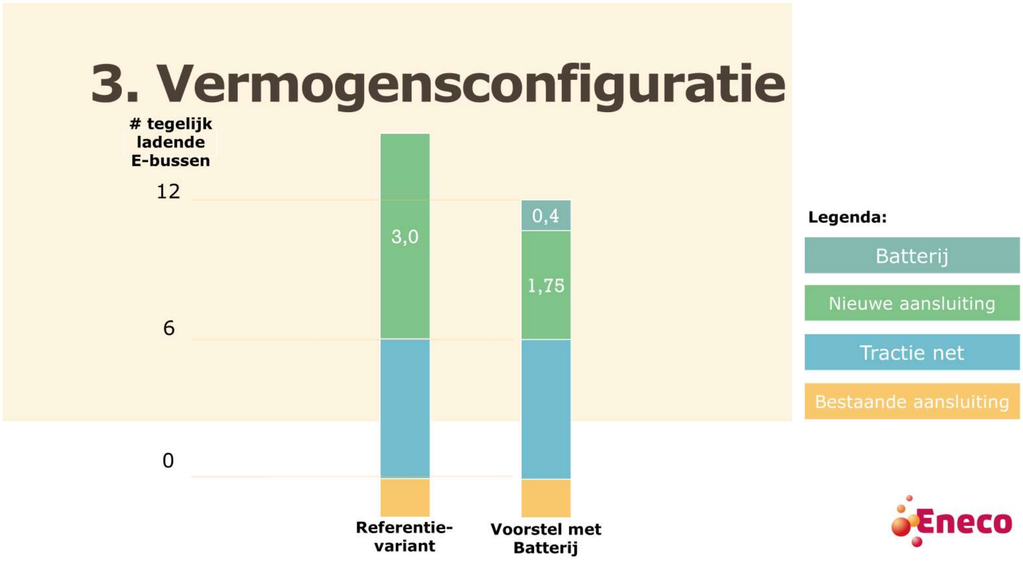
Calculations grid connections for opportunity chargers



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Application MINBus in planningstool HASTUS

MINBus is used for:

- Classify electric vehicles;
  - taking into account range and charging facilities
  - study purposes;
- Impact of different types of electric vehicles
  - (battery capacity; options for opportunity charging; etc.)
  - Impact of sustainable energy use
  - (time of generation and storage; possibly apply interim storage in battery; etc.)

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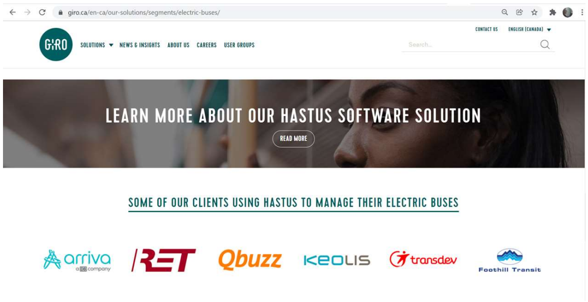
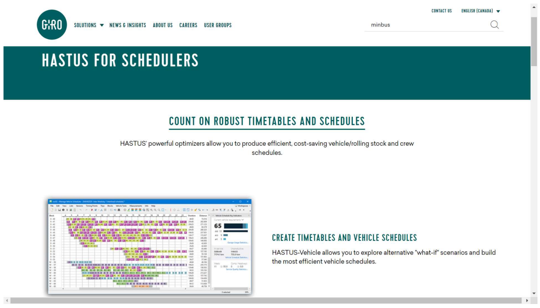
Current use knowledge from RUGGEDISED

> Application MINBus in planningstool HASTUS





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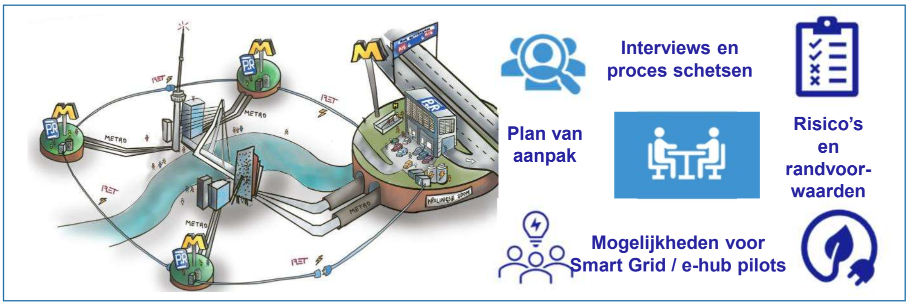
Current use knowledge from RUGGEDISED

> Development roadmap / strategie for Smart Grid and e-hub pilots



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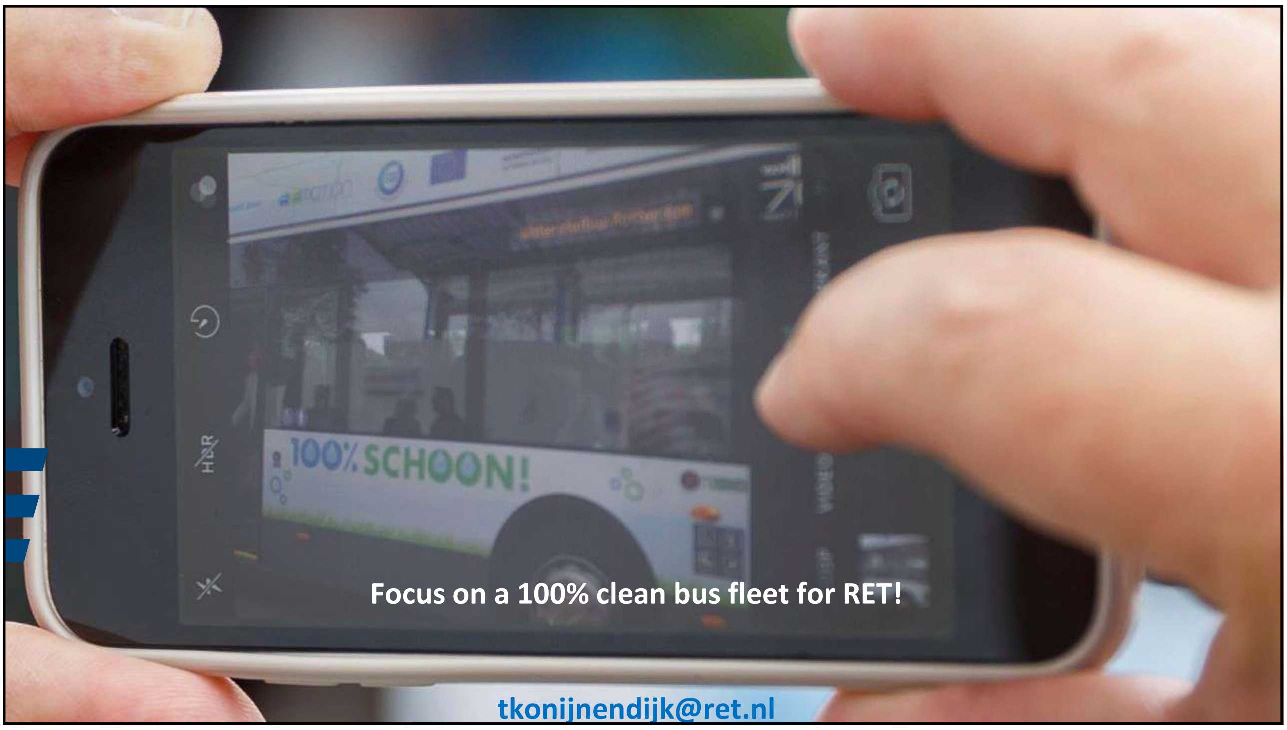

Focus on a 100% clean bus fleet for RET!

tkonijnendijk@ret.nl

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