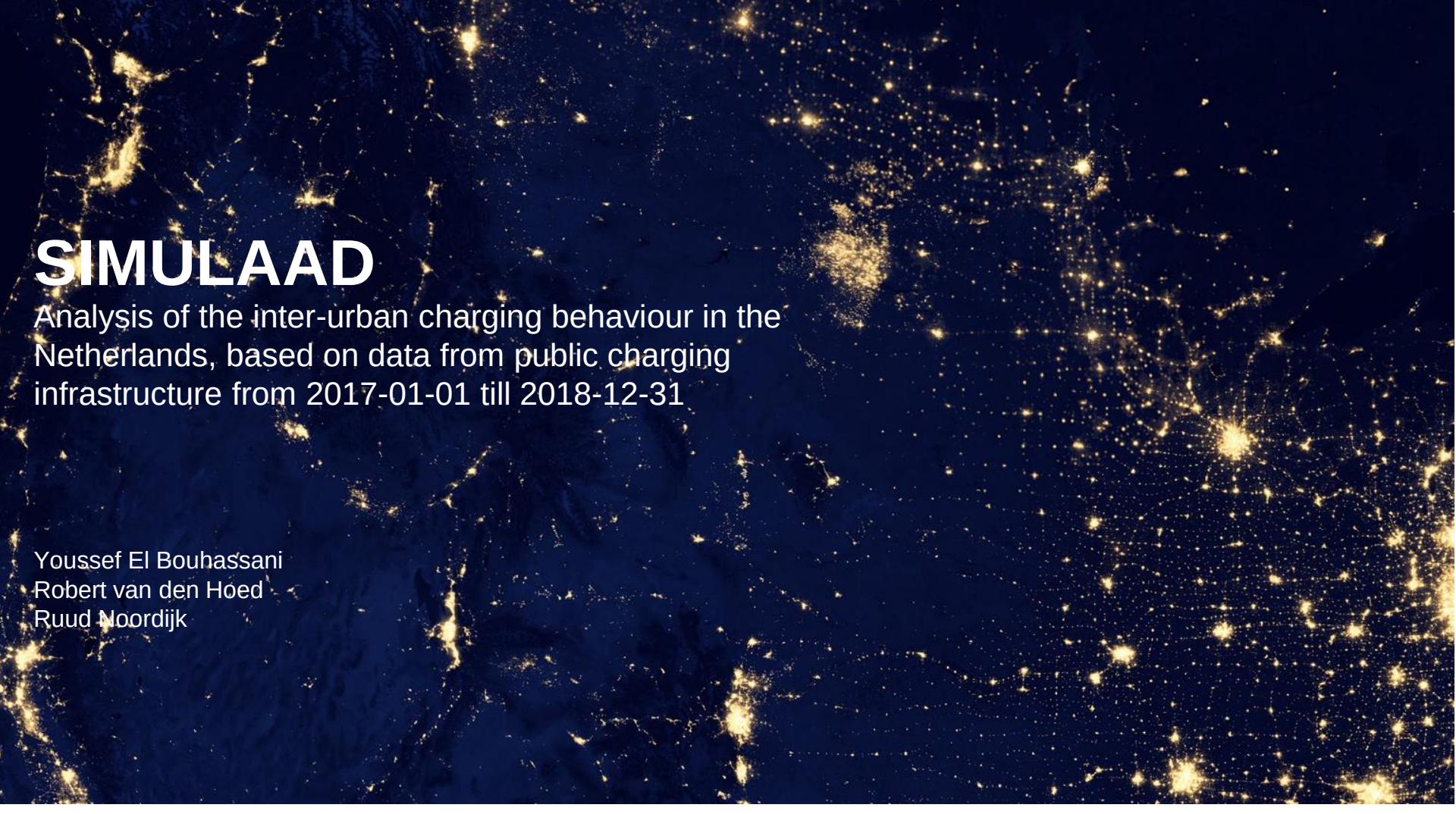

SIMULAAD

Analysis of the inter-urban charging behaviour in the Netherlands, based on data from public charging infrastructure from 2017-01-01 till 2018-12-31

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MRA elektrisch
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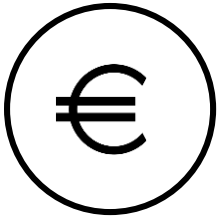
enpuls
PITPOINT CLEAN FUELS
Elaadnl
Rijkswaterstaat
Royal HaskoningDHV Enhancing Society Together

The goal of this study is to identify opportunities for adding CI * to serve EV drivers in places outside the busy cities and city centers



Cities have significant investments in public CI*

EV drivers are assumed to use public CI* outside their home city

Policy makers are interested in providing CI* outside busy cities and centers due to limited parking space.

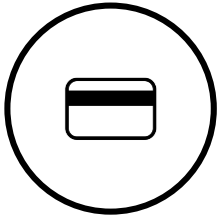
Research question:

To what extent can we distinguish inter-urban charging behavior? And to what extent does this provide opportunities for alternative facilitation with charging infrastructure outside of city centers?

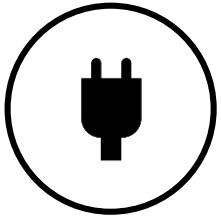
* CI = Charging infrastructure

The span and coverage of the data used for this study allows the assessment of inter-urban charging behaviour on public charging infrastructure on a national level in the Netherlands

The data used in this study is **from 1 januari 2017 to 31 december 2018**



The charging sessions are from **111.587 RFIDs**



The data contains **4.998.598** charging sessions from **public** charging **infrastructure**

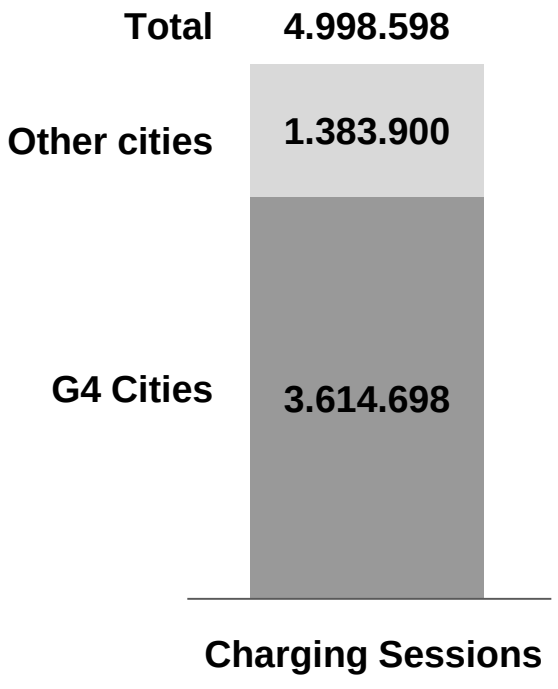
The data is from **urban and rural** areas including G4[1] cities, MRA-E[2], SGZH[3], and EVnetNL[4]

1: G4 cities include Amsterdam, Den Haag, Rotterdam and Utrecht
2: MRA-E is a collaboration between 80 municipalities in the regions of Noord Holland, Flevoland and Utrecht (source: www.evdata.nl)
3: SGZH is a collaboration of 19 municipalities in Zuid-Holland (source: www.evdata.nl)
4: EVnetNL data contains data from Noord Brabant, Gelderland and other non-Randstad regions.

About 72% of the charging sessions took place in the G4 cities. Within the G4 cities about 45% of the charging sessions took place in Amsterdam.

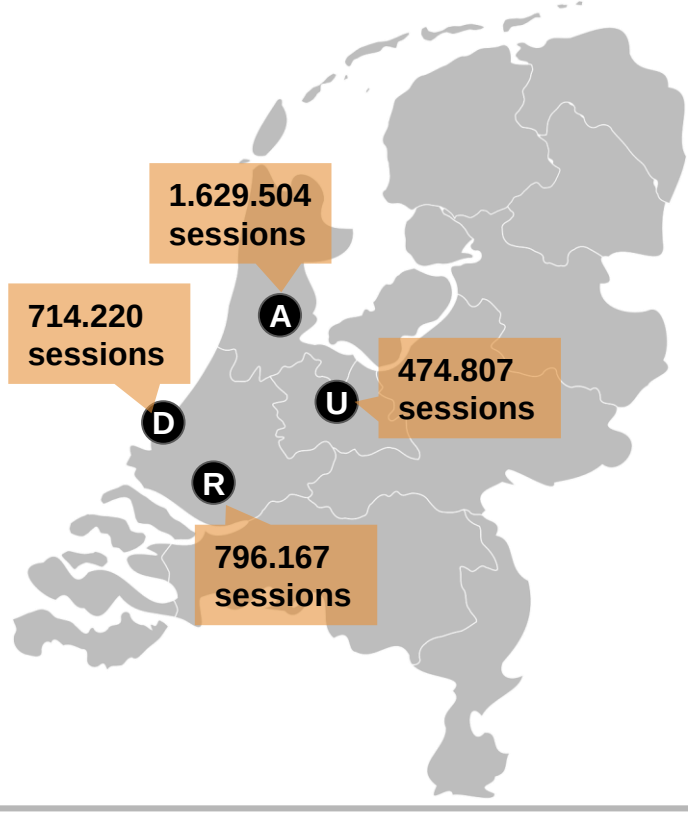
About 72% of the total charging sessions in the Netherlands take place in the G4 cities

Charging sessions from 01-01-2017 to 31-12-2018

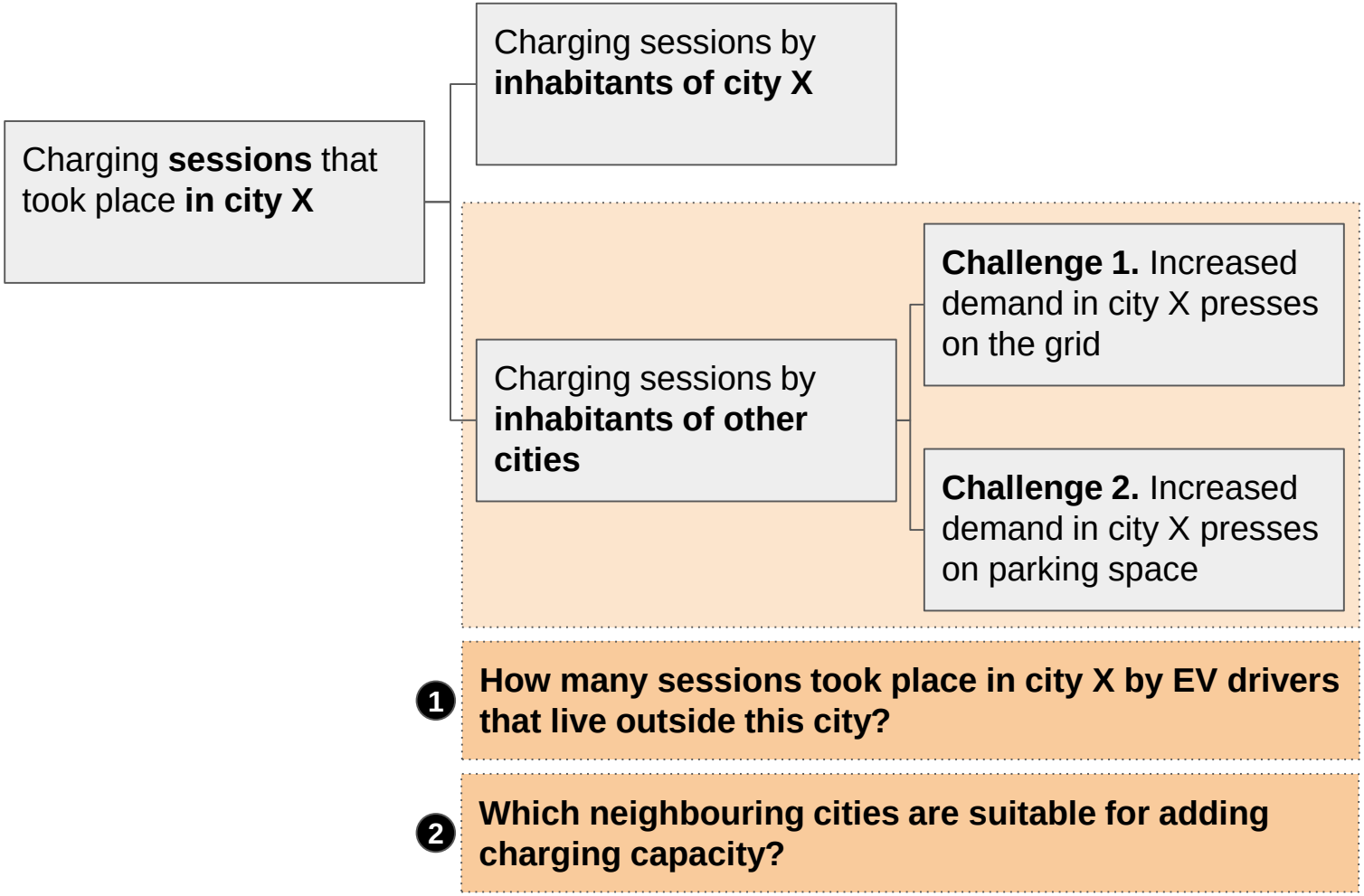


Most charging sessions are in Amsterdam, followed by Rotterdam, Den Haag and Utrecht

Charging sessions from 01-01-2017 to 31-12-2018

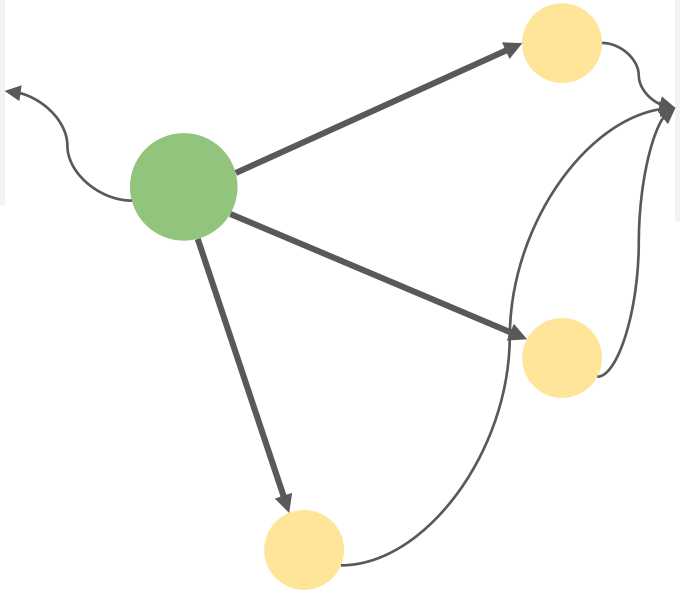


The aim of this research is to quantify inter-urban charging behaviour and identify cities where charging capacity should be added.



In this study the terms home city and host city are used to indicate the city where the EV drivers lives and where they charge respectively

Home city
The city where an EV driver has the **most night sessions** *



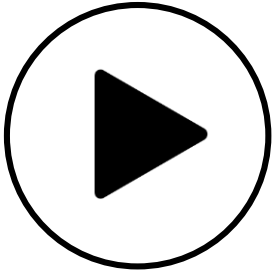
Host city
The city where an EV driver often **charges outside** their **home city**

* EV drivers with a low number of sessions are considered here as well. See next figure for the definition of night charging sessions

The number of night sessions is used as an identifier of the home city for each RFID

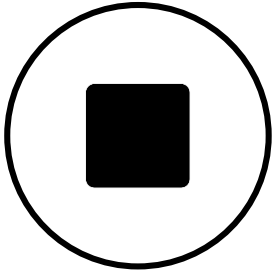
A night session is defined as…

=



… a session that starts after 18:00

&

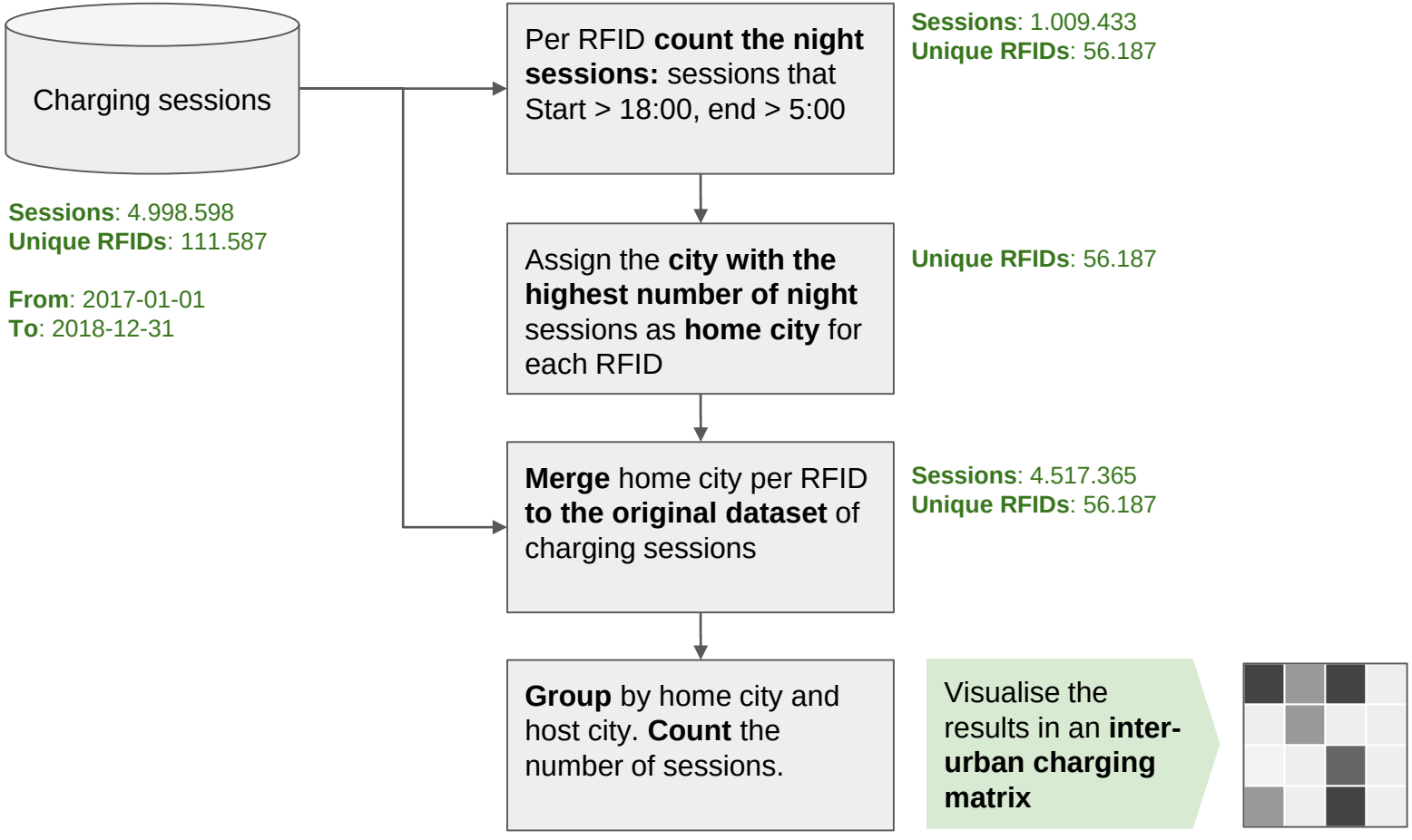


… and stops after 05:00

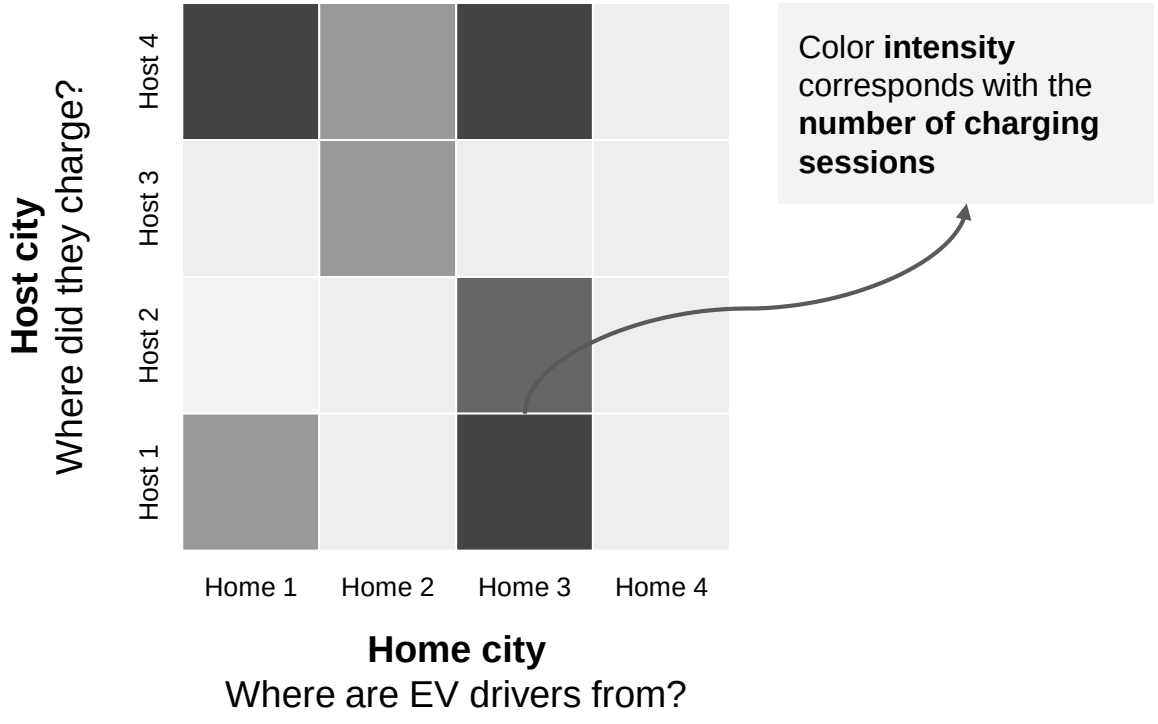
Analysis of inter-urban charging behaviour for regular users

Image source: www.zap-map.com

Data preparation steps for the analysis of inter urban charging behaviour for regular users

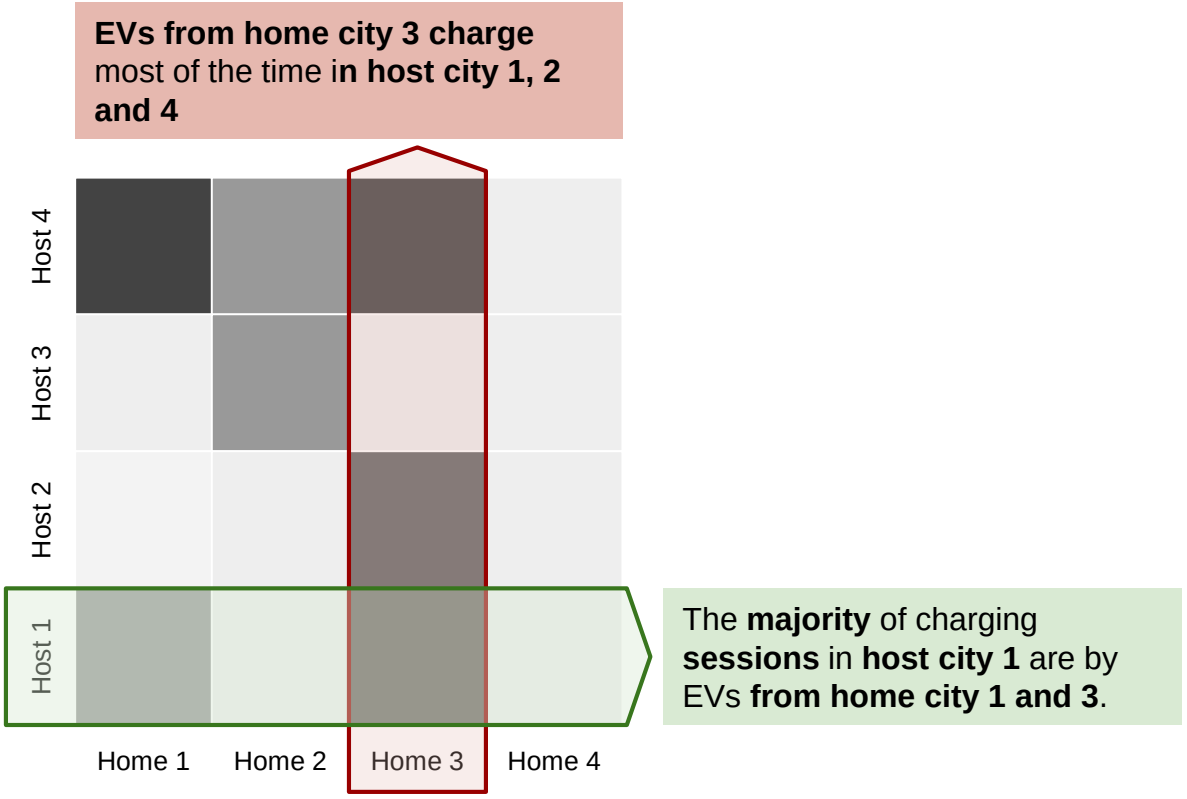


The inter-urban charging matrix gives the number of charging sessions from a given home city that took place in a given host city

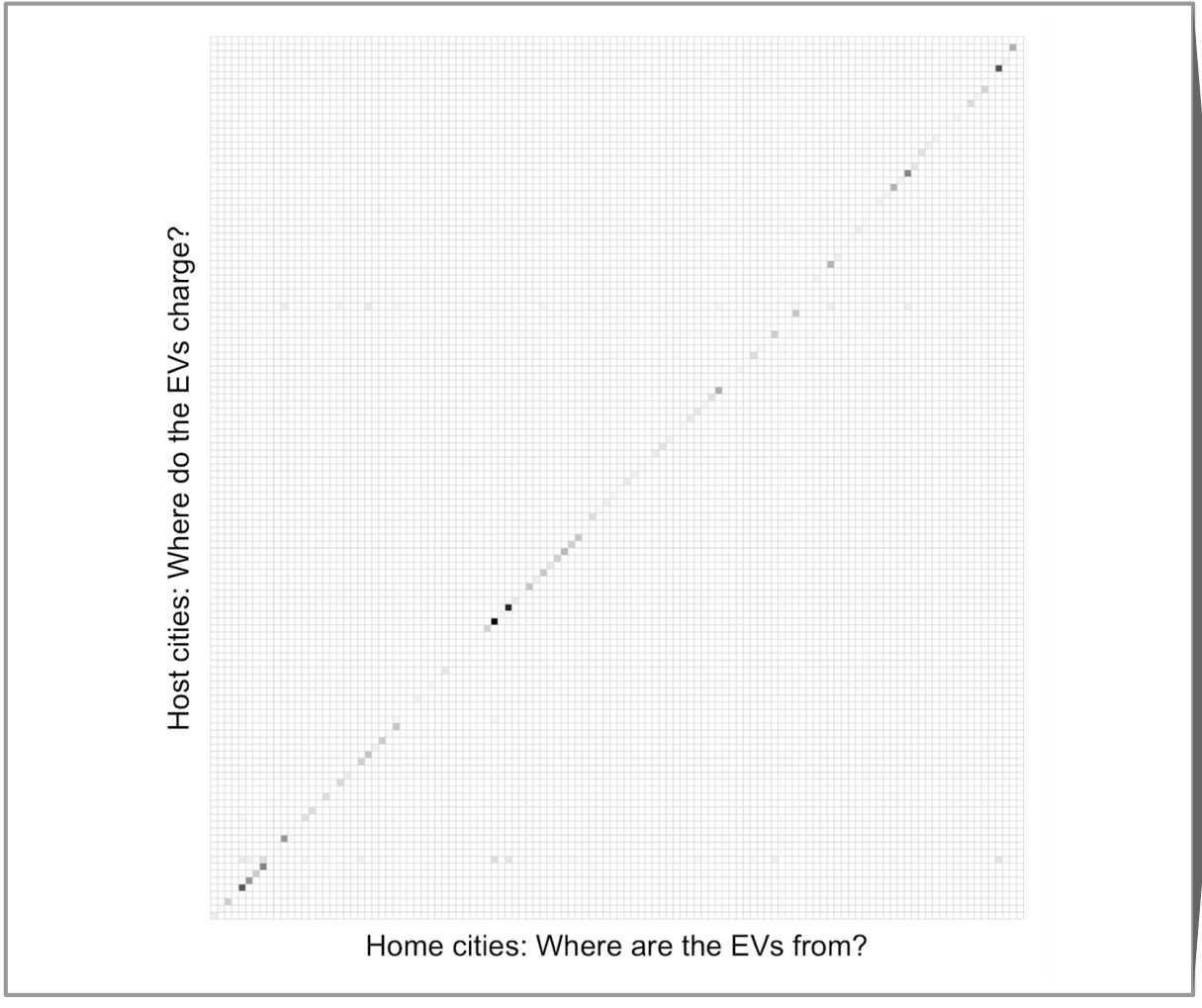


The inter-urban charging matrix shows the inter-urban charging behaviors from two perspectives.

Illustration of how to read the inter-urban charging matrix



For all cities considered, the majority of charging sessions take place in the home cities



The **matrix** shows high number of sessions along the **diagonal**.

This indicates that the **number** of **sessions** is **high** when the **home city** is the **same as** the **host city**.

This **implies** that **most** of the time **EV** drivers **charge in** their **home city.**

To understand inter-urban charging behaviour, charging **sessions** that took place **in** the **home city** of EV drivers **should be filtered out**.

In total there are 116 home cities and 126 host cities. The names of the cities are left out from this matrix. The goal of this matrix it to show the general patterns rather than the details.

The charging sessions that took place in the home city should be removed to make the inter-urban charging behaviour more visible

Charging sessions

Sessions: 4.998.598
Unique RFIDs: 111.587

From: 2017-01-01
To: 2018-12-31

Per RFID **count the night sessions:** sessions that Start > 18:00, end > 5:00

Sessions: 1.009.433
Unique RFIDs: 56.187

Assign the **city with the highest number of night** sessions as **home city** for each RFID

Unique RFIDs: 56.187

Merge home city per RFID **to the original dataset** of charging sessions

Sessions: 4.517.365
Unique RFIDs: 56.187

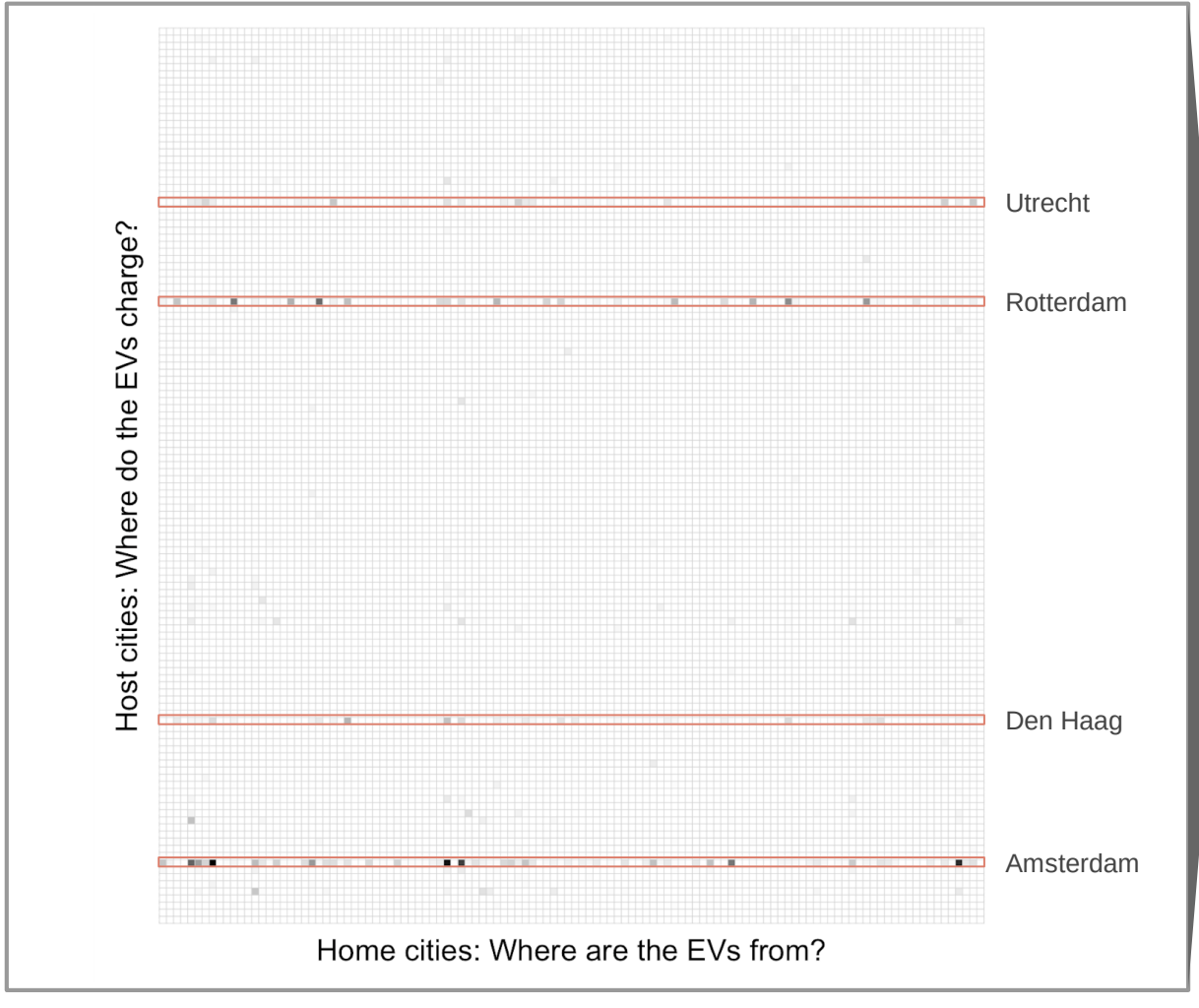
Group by home city and host city. **Count** the number of sessions.

Filter host city equal to home city to remove the peaks*

Visualise the results in an **inter-urban charging matrix**

* Each RFID has the majority of their charging sessions in their home city. To quantify the number of sessions coming from other cities, the sessions where home city equals the host city should be filtered out

The inter-urban charging behaviour consists of charging sessions in the G4 cities by EV drivers from neighbouring cities

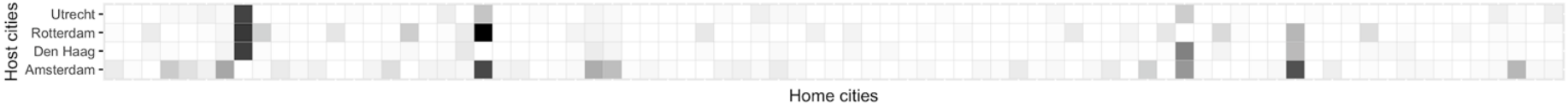


The **G4** cities **are often host cities** for EV drivers from a different number of home cities.

The **inter-urban** charging behaviour consists **mainly** of the **influx** of charging sessions in the **G4** cities from other cities.

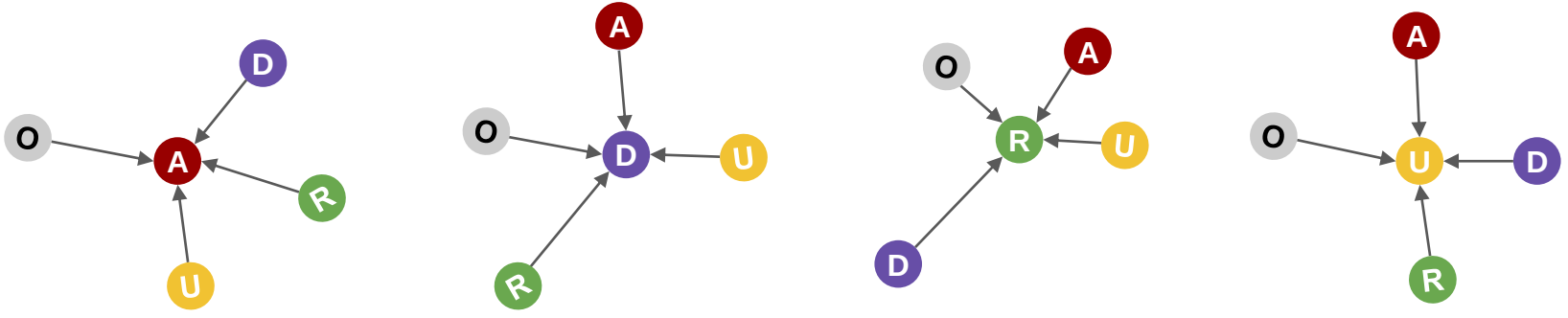
The majority of inter-urban charging consists of the influx of EV drivers to the G4 cities.

Representation of data using the inter-urban charging matrix [1]



1: The charging sessions that take place in each city by EV drivers that live there are not shown here.

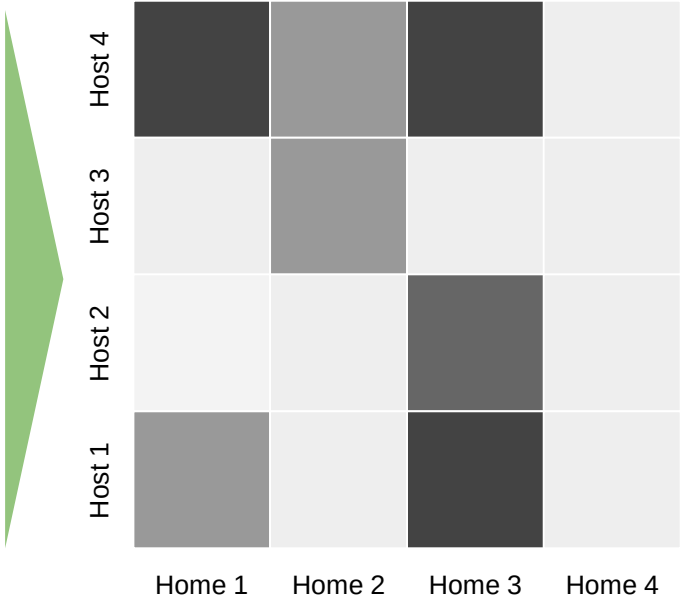
Interpretation of the pattern found in the data: inter-urban charging behaviour is mostly the influx to G4 cities both from the G4 cities and other cities.



The inter-urban charging behaviour can be analysed from two different perspectives: from the perspective of the home cities and from the perspective of the host cities

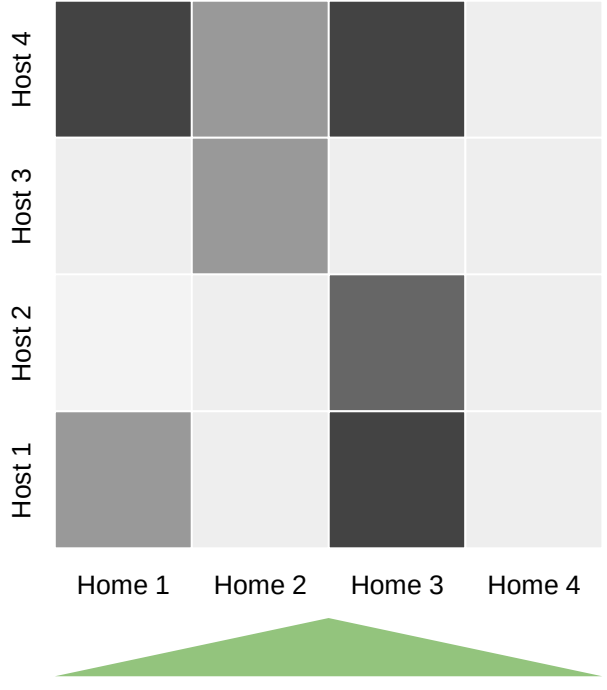
Host city perspective

How many sessions took place in each city relative to the total sessions in each host city.



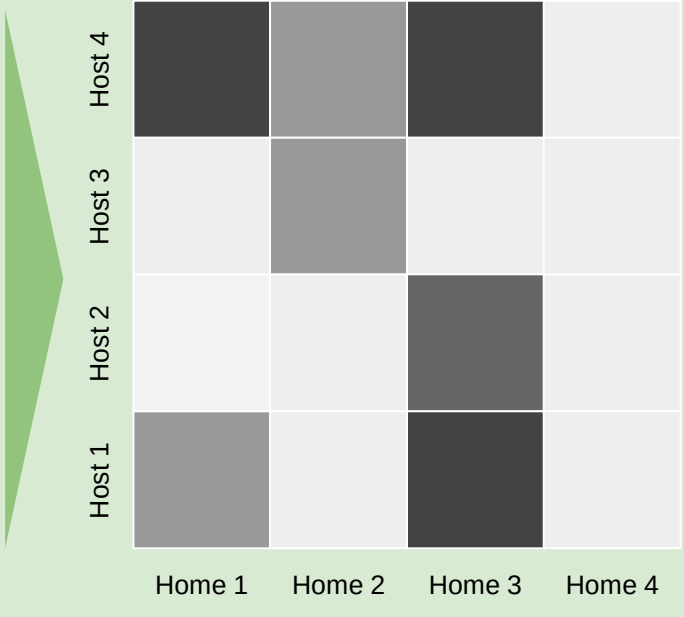
Home city perspective

How many sessions took place in each city relative to the total sessions from each home city

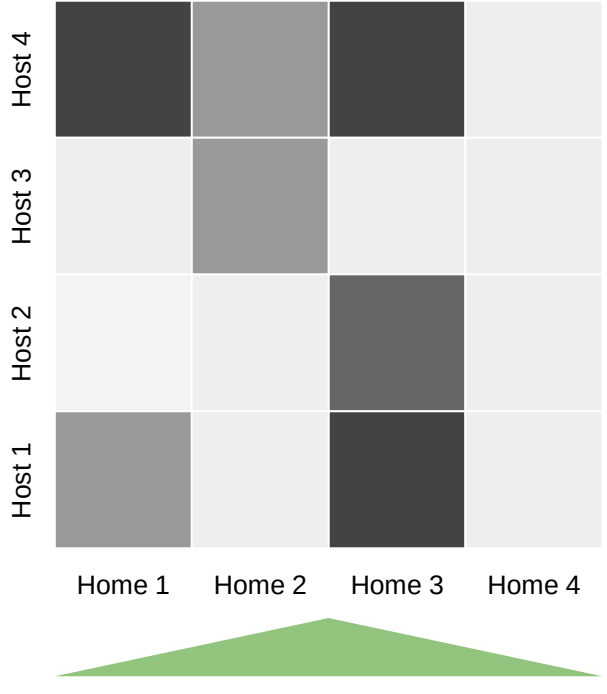


The inter-urban charging behaviour can be analysed from two different perspectives: from the perspective of the home cities and from the perspective of the host cities

Host city perspective
How many sessions took place in each city relative to the total sessions in each host city.



Home city perspective
How many sessions took place in each city relative to the total sessions from each home city



The host city perspective answers the following question for the policy makers:

Question of policy maker
Where do the EV drivers come from that charge in our city? Who do we ‘host’?

Illustrative example for using the host city perspective

Step 1.
Row wise totals
For each host city compute the total number of sessions

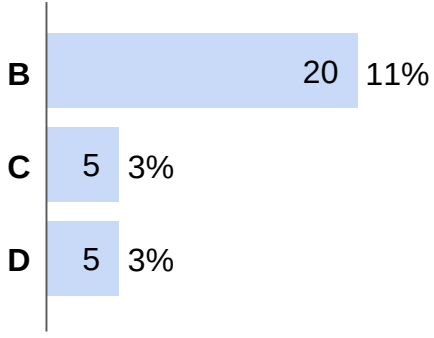
	A	B	C	D	Total
D	4	6	10	50	70
C	5	20	150	5	180
B	15	200	20	5	240
A	100	1	4	20	125

Step 2.
Row wise percents
Normalise the rows by dividing each row by its total

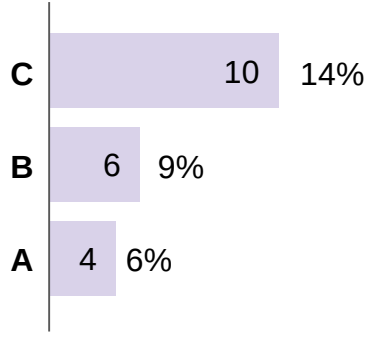
	A	B	C	D
D	0.06	0.09	0.14	0.71
C	0.03	0.11	0.83	0.03
B	0.06	0.83	0.08	0.02
A	0.80	0.01	0.03	0.16

Step 3. **Row wise plots** [1]
For each host city plot the totals and percentage of the inter-urban charging sessions

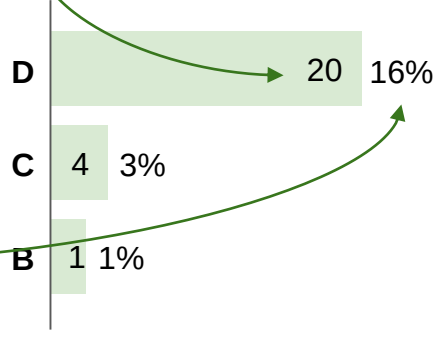
Contribution to host city C from other cities



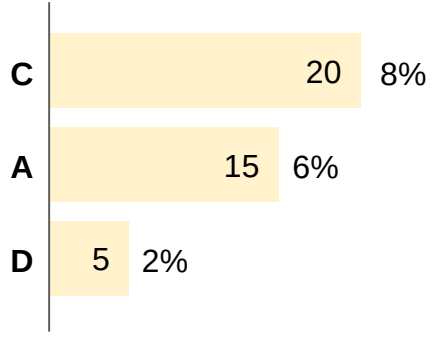
Contribution to host city D from other cities



Contribution to host city A from other cities

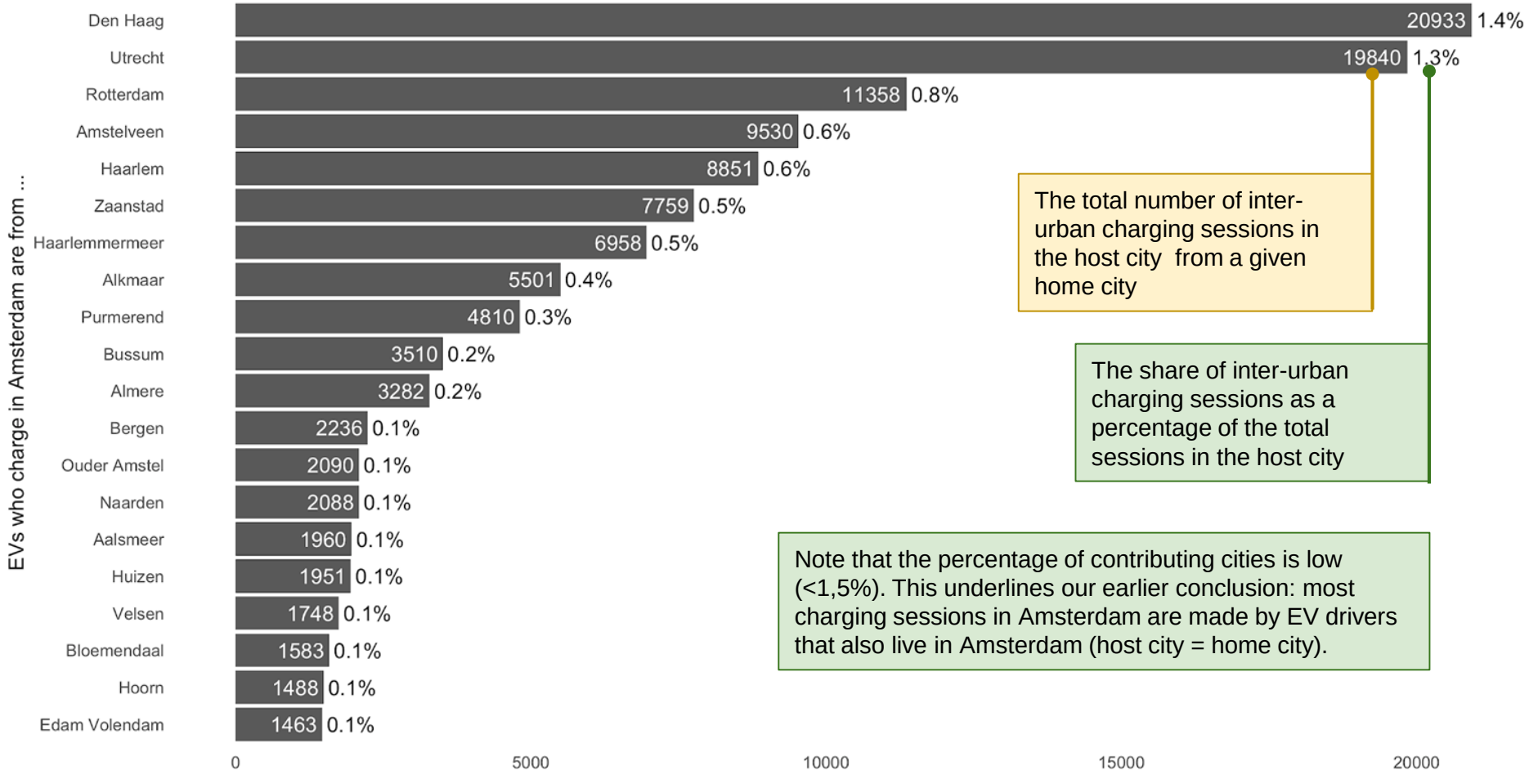


Contribution to host city B from other cities

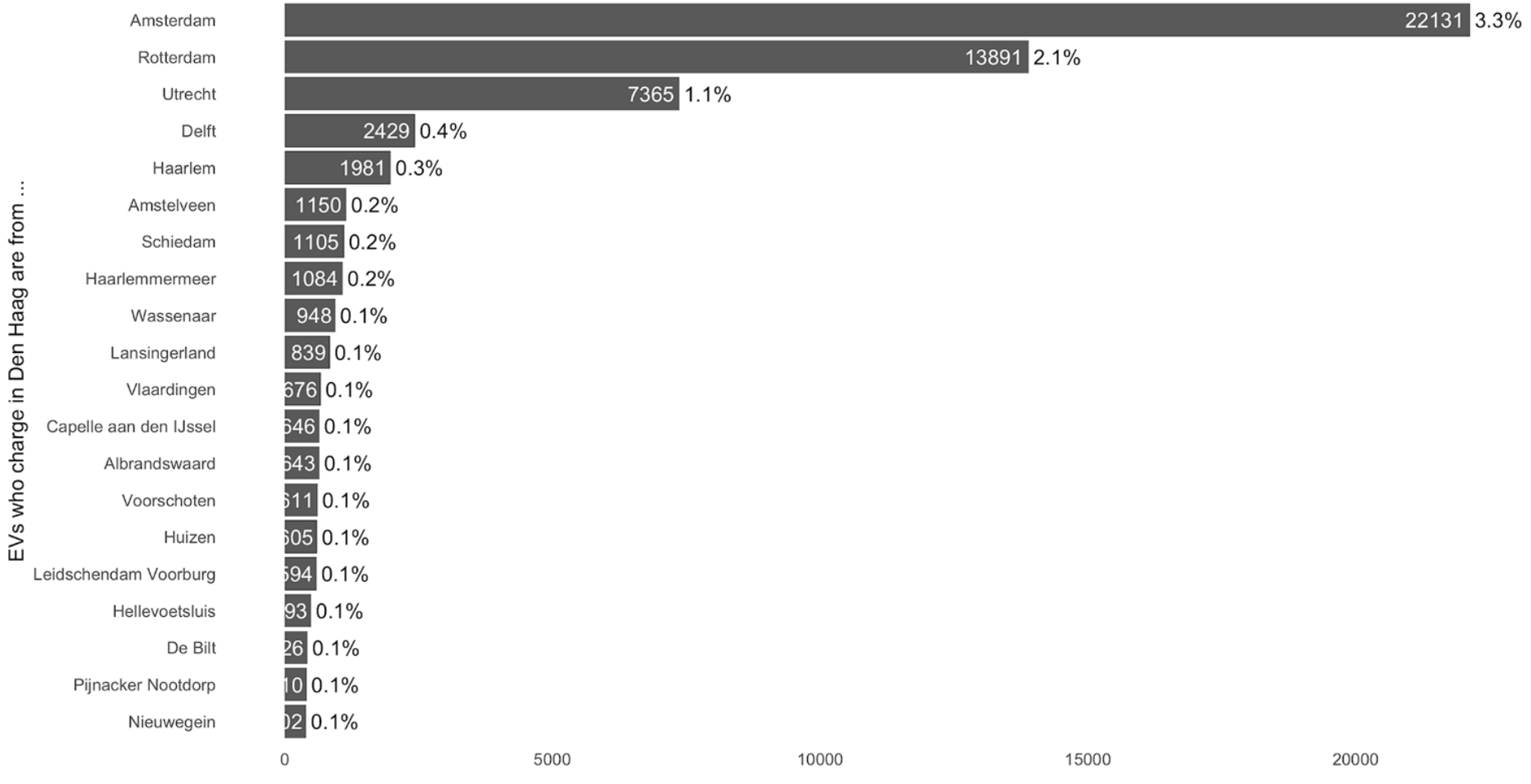


1: The plots are illustrative and may not be to scale

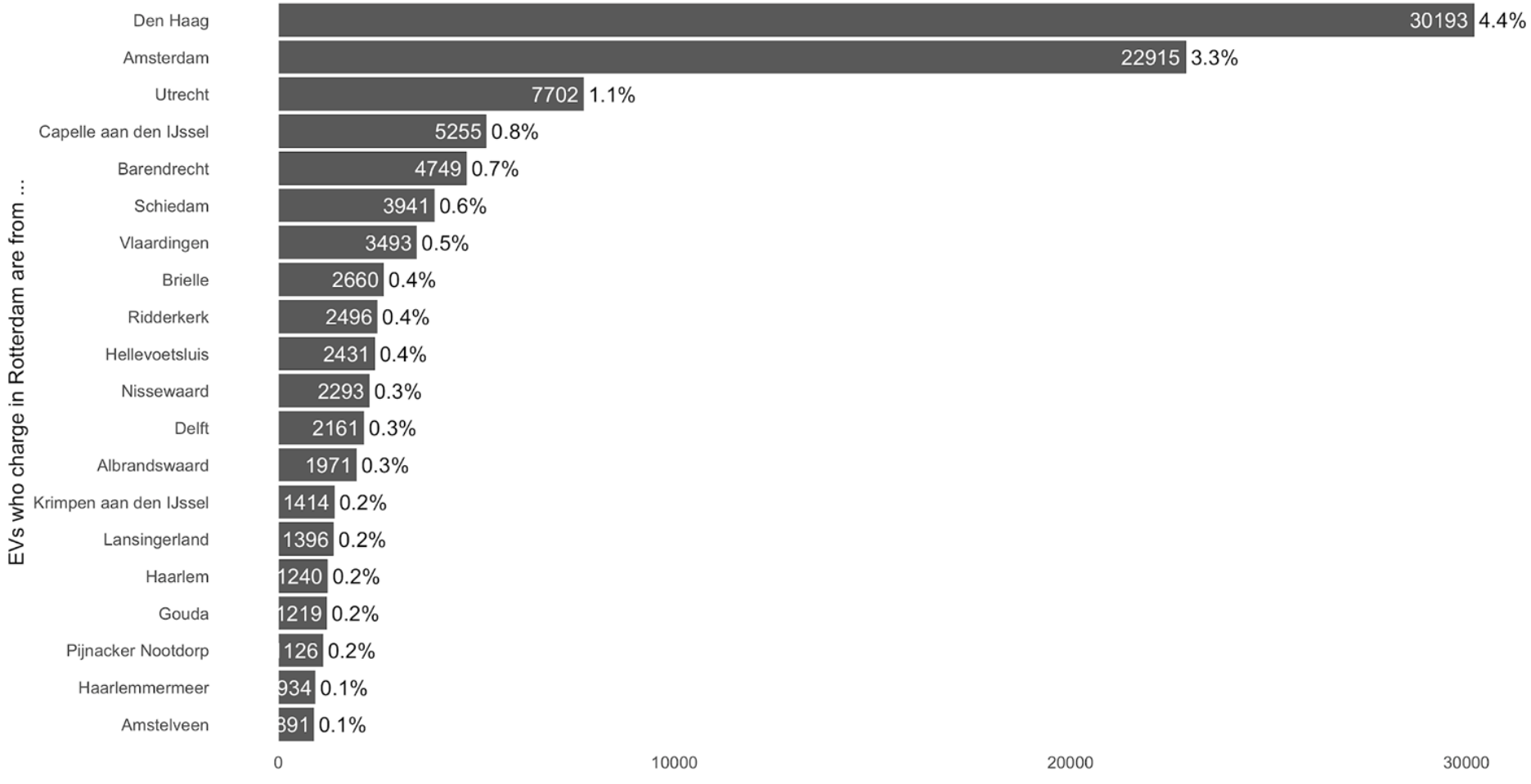
A Den Haag and Utrecht contribute most to inter-urban charging sessions in Amsterdam (1.4% and 1.3% of all sessions in Amsterdam)



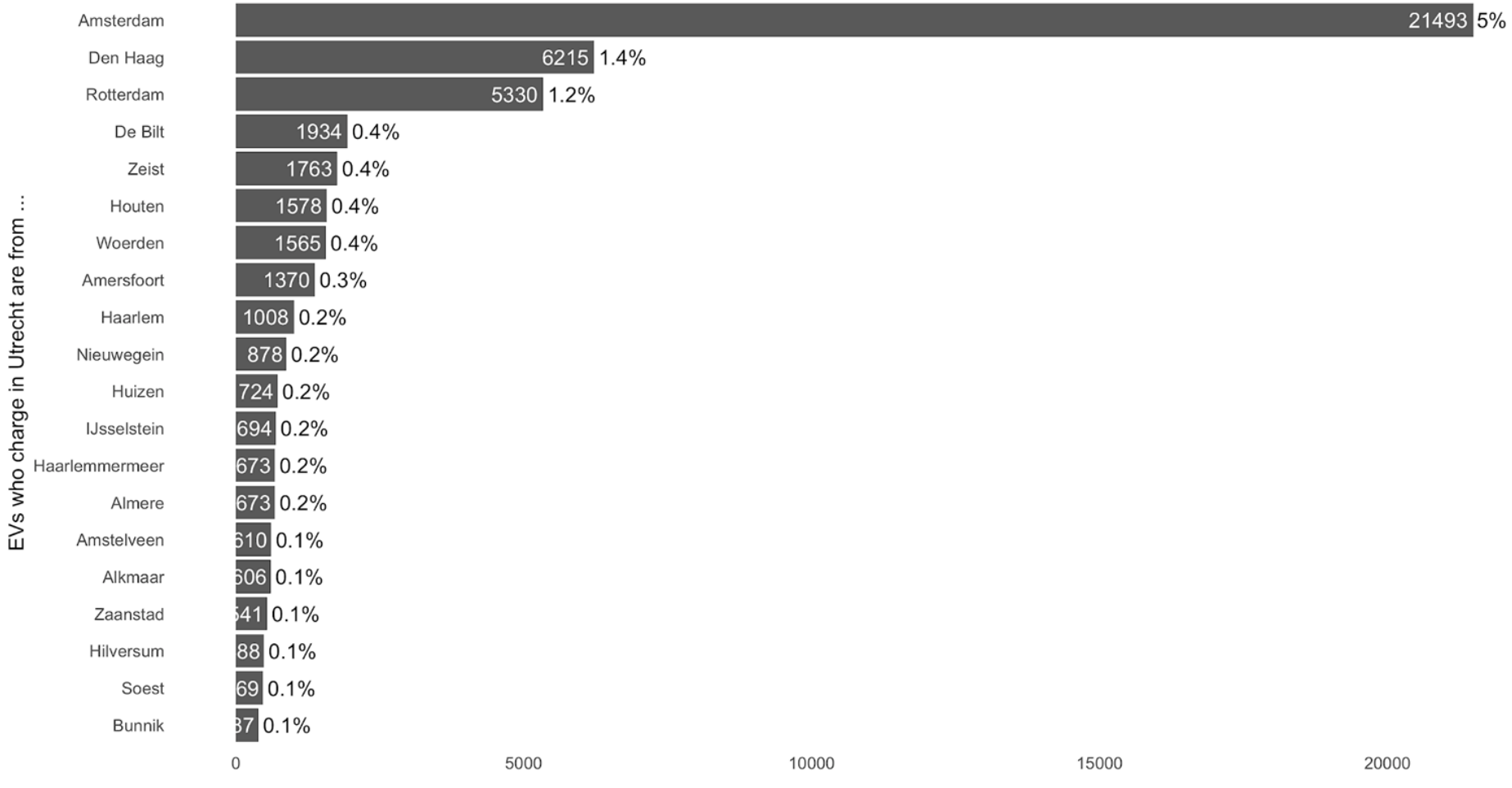
D Amsterdam and Rotterdam contribute most to inter-urban charging sessions in Den Haag (3.3% and 2.1%)



Den Haag and Amsterdam contribute most to inter-urban charging sessions in Rotterdam (4.4% and 3.3%)



Amsterdam is the main contributor to inter-urban charging sessions in Utrecht (5%)

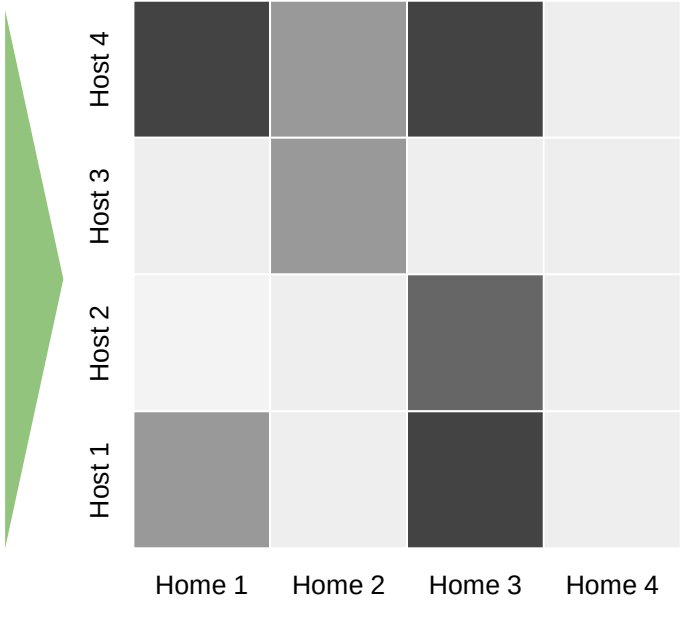


Overview: which cities to focus on from the perspective of the host cities

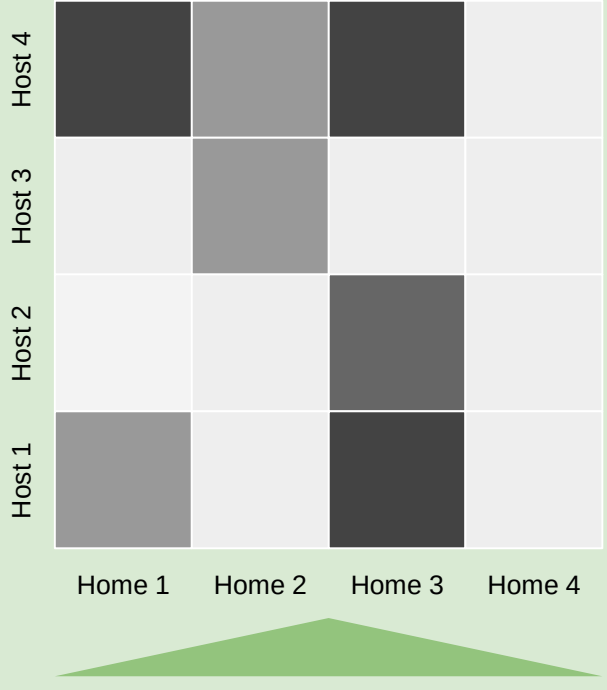
	Visitors from G4 cities (> 1.25% of total sessions)	**Visitors from other cities** (> 0.25% of total sessions)
Amsterdam	Den Haag, Utrecht	Amstelveen, Haarlem, Zaanstad, Haarlemmermeer, Alkmaar, Purmerend.
Den Haag	Amsterdam, Rotterdam, Utrecht	Delft, Haarlem
Rotterdam	Den Haag, Amsterdam	Capelle, Barendrecht, Schiedam, Vlaardingen, Brielle, Ridderkerk, Hellevoetsluis, Nissewaard, Delft, Albrandswaard
Utrecht	Amsterdam, Den Haag	De Bilt, Zeist, Houten, Woerden, Amersfoort

The inter-urban charging behaviour can be analysed from two different perspectives: from the perspective of the home cities and from the perspective of the host cities

Host city perspective
How many sessions took place in each city relative to the total sessions in each host city.



Home city perspective
How many sessions took place in each city relative to the total sessions from each home city



The home city perspective answers the following question for the policy makers:

Question of policy maker

Where do the EV drivers, that we host in our own city, also charge? Which contribution do our hosted EV drivers have on charging in the G4 cities?

Illustrative example for using the home city perspective

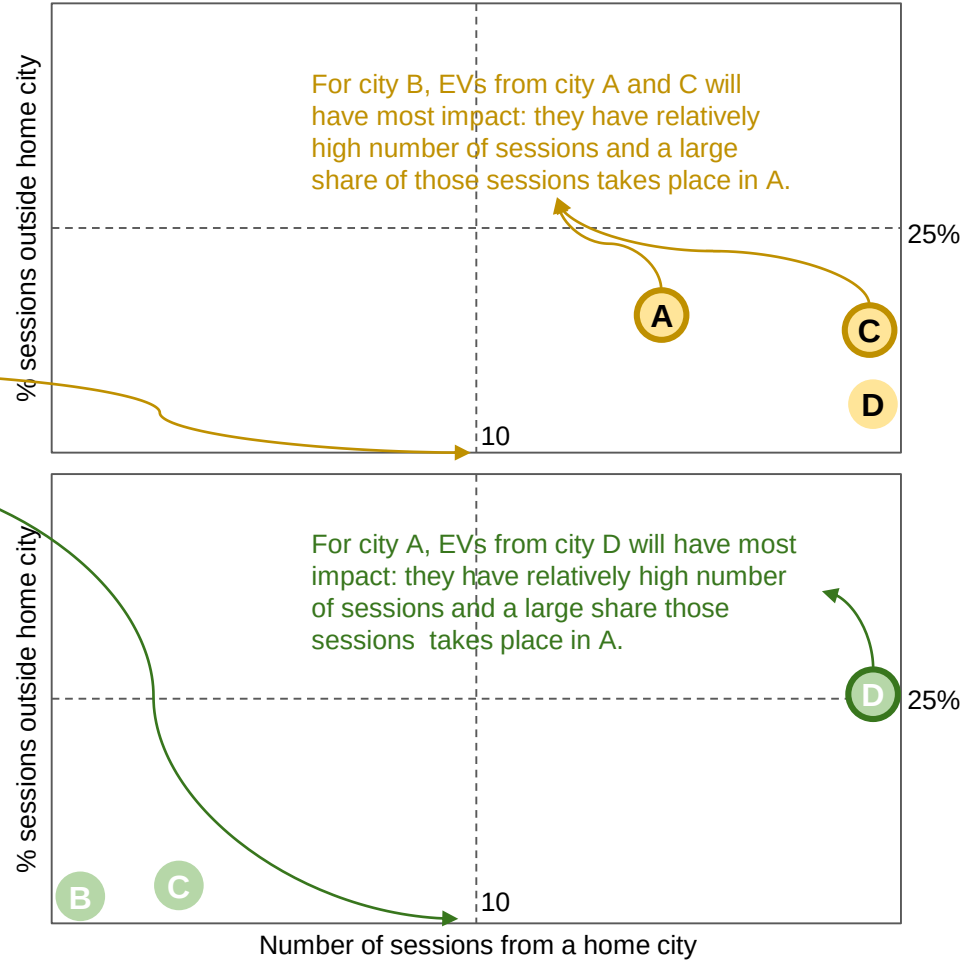
	A	B	C	D
Total	124	227	184	80
D	4	6	10	50
C	5	20	150	5
B	15	200	20	5
A	100	1	4	20

Step 1.
Column wise totals
For each host city compute the total number of sessions

	A	B	C	D
D	0.03	0.03	0.05	0.63
C	0.04	0.09	0.82	0.06
B	0.12	0.88	0.11	0.06
A	0.81	0.0	0.02	0,25

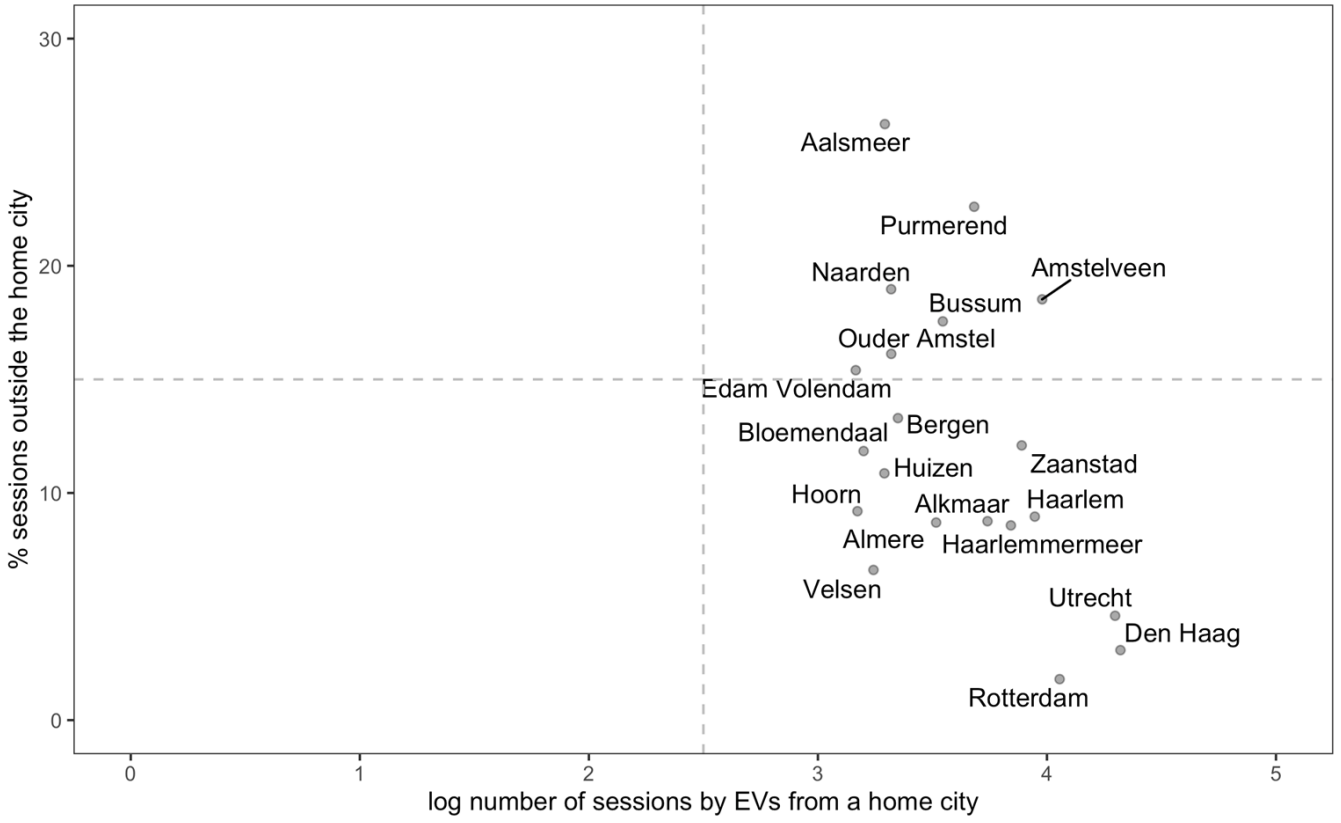
Step 2.
Column wise perc.
For each host city compute the total number of sessions

Step 3. Plot sessions and percentages [1]
For each host city plot the total sessions and percentage of the inter-urban charging sessions



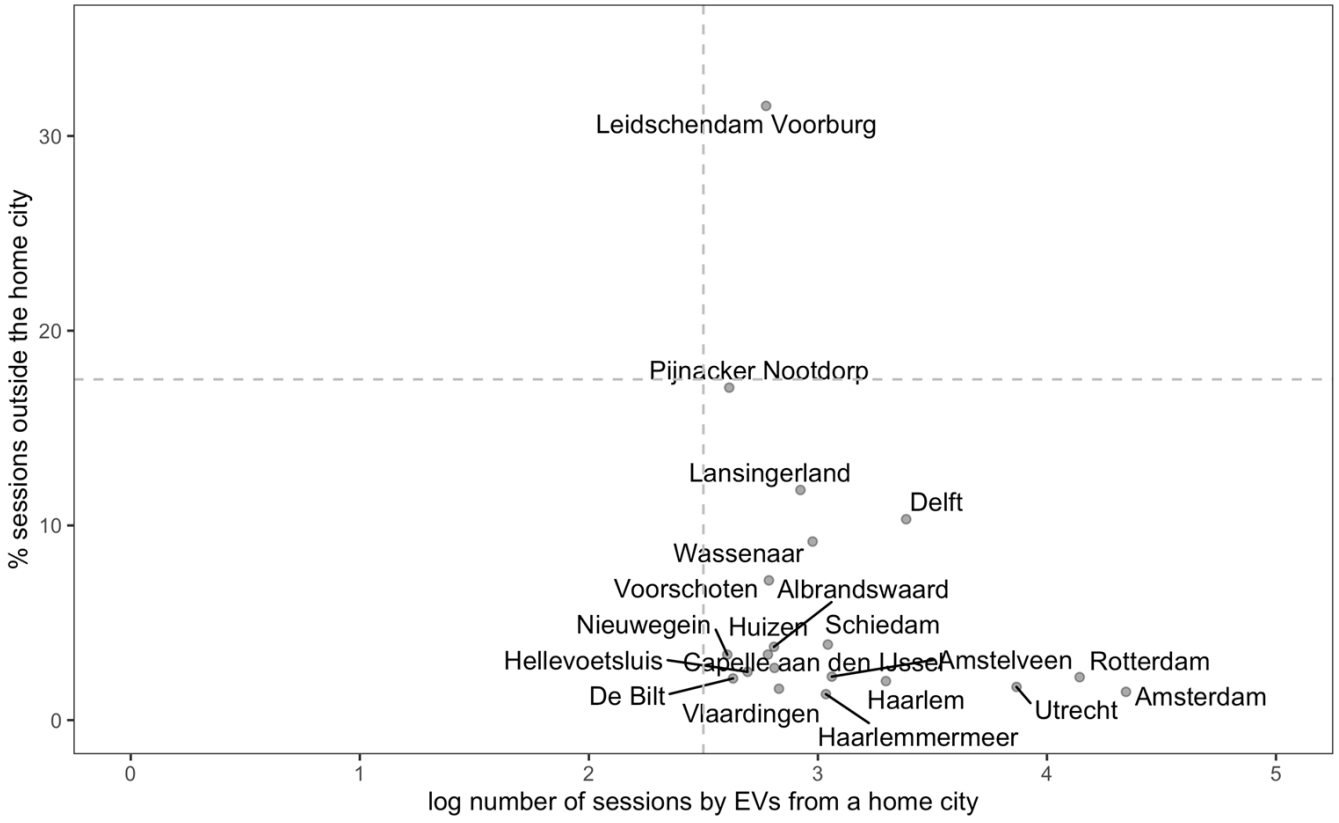
1: The plots are illustrative and may not be to scale

A EV drivers from Aalsmeer have the highest share of charging sessions that take place in Amsterdam (26%)



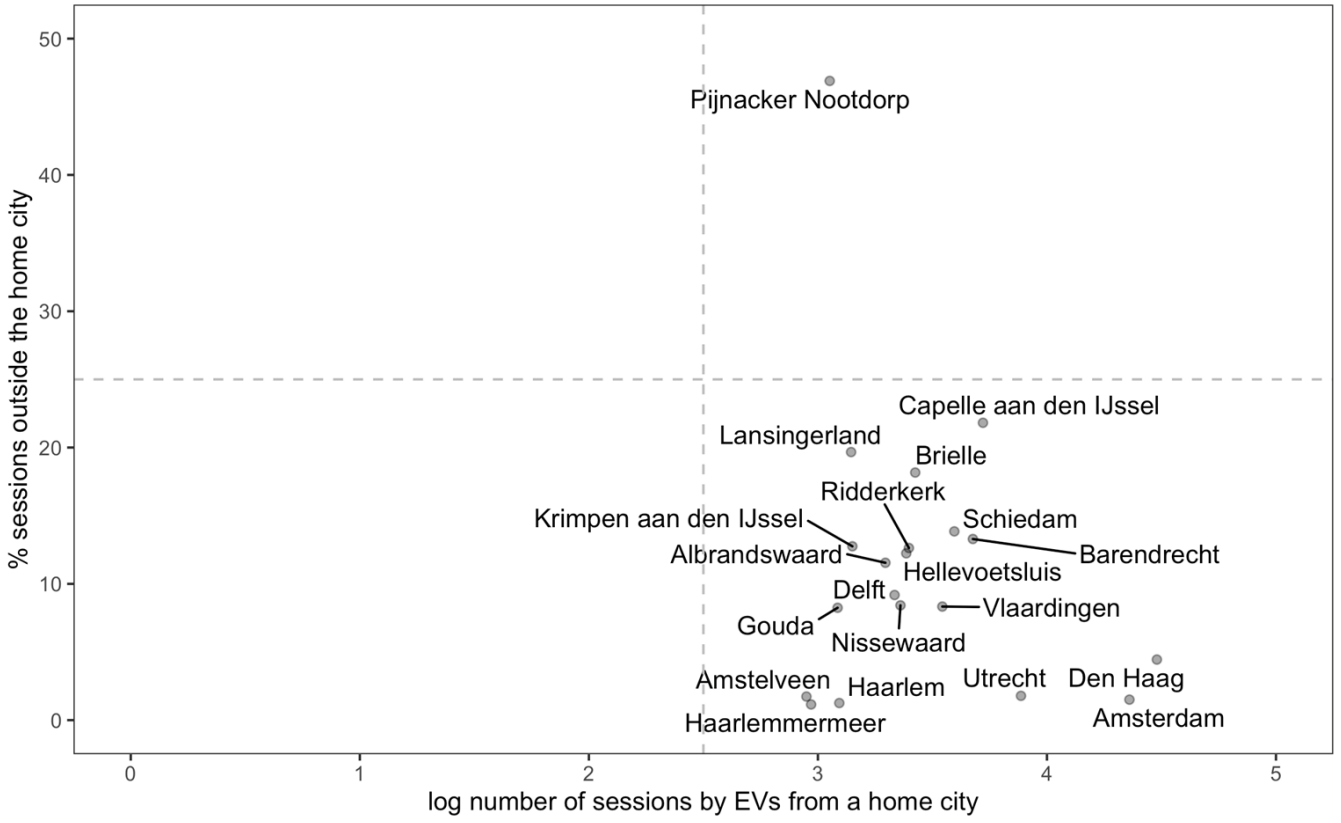
Take away for Amsterdam policy makers
New EV drivers in cities like Aalsmeer, Purmerend, Naarden and Amstelveen will also lead to extra charging demand in Amsterdam.

D EV drivers from Leidschendam Voorburg have the highest share of charging sessions that take place in Den Haag (32%)



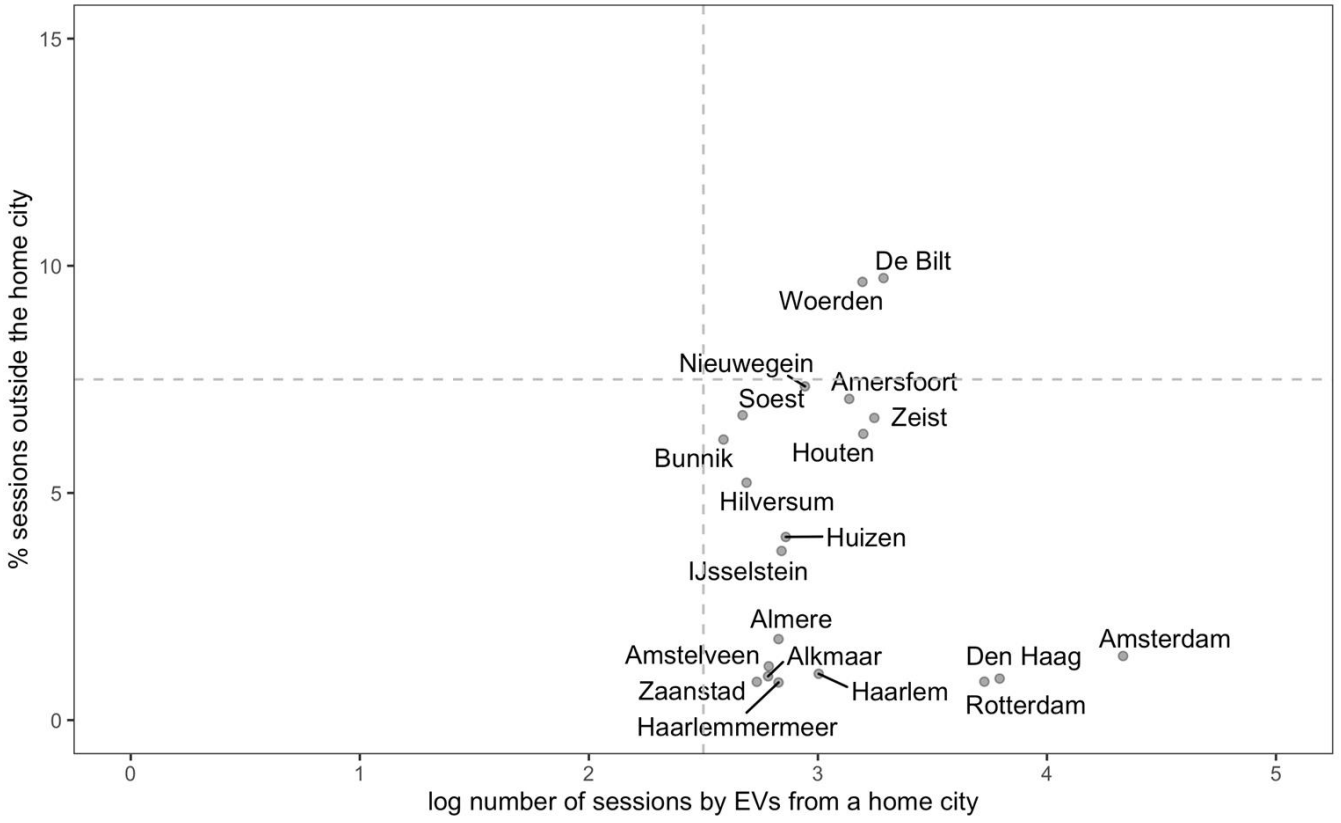
Take away for Den Haag policy makers
New EV drivers in cities like Leidschendam, Nootdorp, Lansingerland and Delft will also lead to extra charging demand in Den Haag.

EV drivers from Pijnacker Nootdorp have the highest share of charging sessions that take place in Rotterdam (47%)



Take away for Rotterdam policy makers
New EV drivers in cities like Pijnacker, Capelle, Brielle, Schiedam and Barendrecht will also lead to extra charging demand in Rotterdam.

EV drivers from De Bilt have the highest share of charging sessions that take place in Utrecht (10%)



Take away for Utrecht policy makers
New EV drivers in cities as De Bilt, Woerden, Amersfoort and Zeist will also lead to extra charging demand in Utrecht.

Key insights

1. For the most RFIDs the majority of charging sessions take place in the home city (>90%). EV drivers living in Utrecht charge in Utrecht.
2. Inter-urban charging behavior has a relatively minor contribution to charging sessions in host-cities (<10% in G4 cities).
3. Inter-urban charging is dominated by RFIDs from the G4 cities charging in other G4 cities (caused by sheer size of EVs in G4). E.g. inter-urban charging in Den Haag is likely to originate from Rotterdam, Utrecht and Amsterdam.
4. Second source of inter-urban charging comes from cities neighbouring the G4 cities. E.g. most inter-urban charging sessions in Amsterdam come from Amstelveen and Haarlem.
5. Some neighbouring cities depend significantly on charging opportunities in the G4 cities. E.g. 22% of the charging sessions by RFIDs that home-charge in Capelle are facilitated by Rotterdam.
6. Policy makers should keep monitoring changing contributions of dominant neighbouring cities to the utilization of its charging infrastructure to anticipate future charging needs.

Recommendation for further research

1. The night sessions are defined in this study as sessions that start after 18:00 and stop after 5:00. A sensitivity analysis of this definition is required that may alter the population.
2. Inter-urban charging behaviour is expressed in this study in terms of charging sessions. A similar analysis where inter-uban charging behaviour is expressed in terms of charging sessions per charging point will provide better insight in where the need of adding infrastructure is highest. Similarly the indicator #RFIDs/inhabitants could compensate for the sheer size of EVs in the G4 cities.
3. Further research can be done to differentiate characteristics of inter-urban charging sessions in terms of start time and connection time. In combination with utilization levels this may further establish whether and to what extent inter-urban sessions lead to a strain on the infrastructure.
4. In this study the charging sessions of 2017 and 2018 are used. A recommendation for further research is to study the inter-urban charging behaviour over time.