INFRABEL

Metering data quality

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1. Introduction
2. Metering statistics
3. Diving into the data
4. Results
5. Conclustion

Introduction

Introduction

Railway Undertaking

commodity (€)

Energy market

grid fee (€)

operates trains

requests train-runs

Infrastructure Manager

kWh

kWh

data for validation, estimation and allocation

Settlement

EMS

On-board Energy Measurement System

LOC&PAS TSI:2018
Support retrofit in 2023
EN 50463:2017

ENE TSI:2018
EN 50463:2017
IRS 90930:2020

DCS

Data Collecting System on ground

CIR EU/2018/868
IRS 90930:2020

CIR EU/2018/868
IRS 90930:2020

Allocate:

- allocate consumptions to the correct end user
- distribute to correct actors in energy market

Validate/estimate:

- validate data coming from EMS
- estimate missing data

Exchange:

- allocate consumption to country where consumption took place
- distribute to correct settlement system

Introduction

Energy meters are common on trains, but their data is rarely used for invoicing.

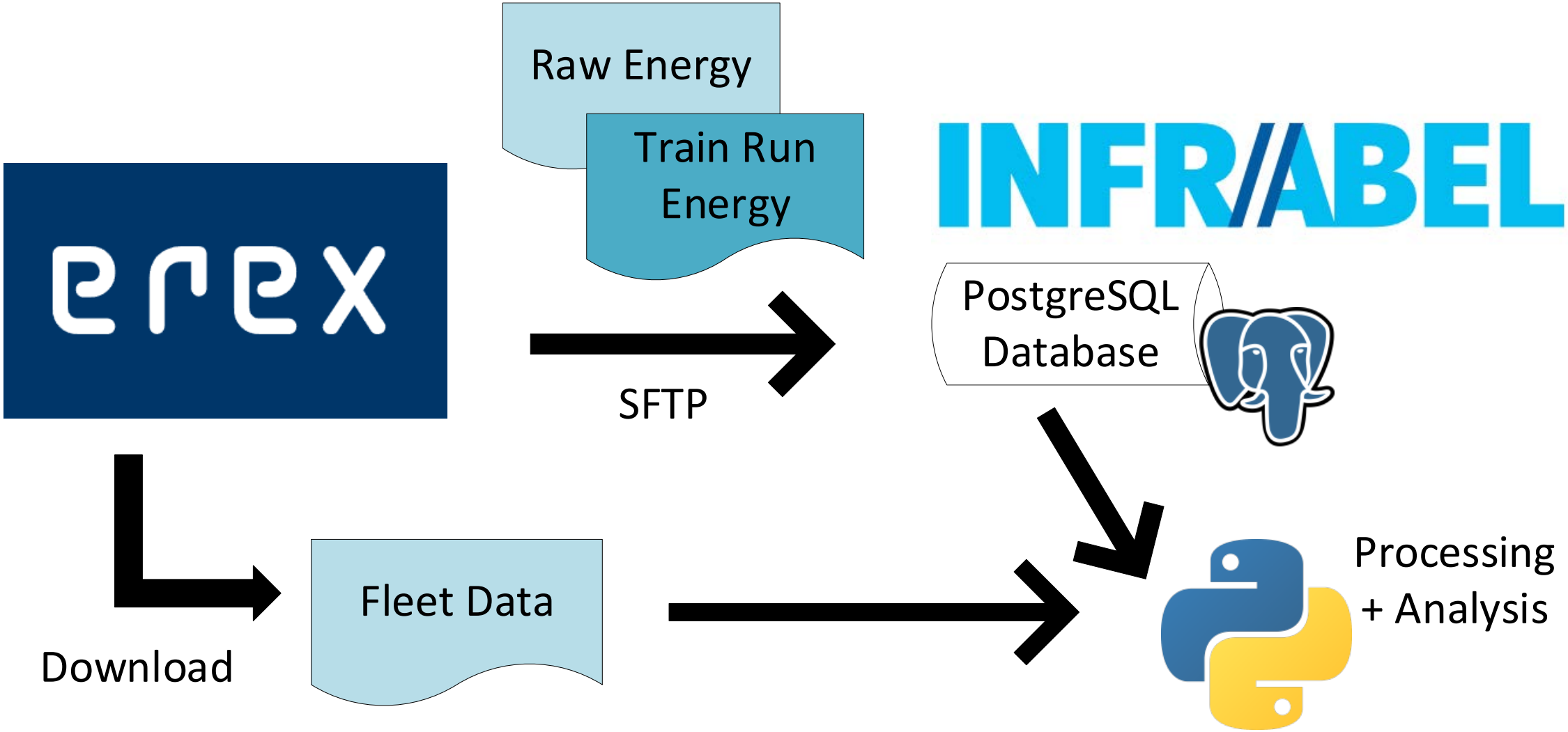
- Analyze:
  - How much data is actually used?
- Investigate:
  - Why is the data being ignored?
- Solve:
  - How do we improve utilization?

What data do we have

Erex data used for analysis:

- Raw Metering Data:
  - Measures energy consumption for a consumption point
- Train Run Data:
  - Energy data for a traction unit set
- Fleet Masterdata:
  - Crucial link to connect the consumption point to a specific vehicle (EVN), train type, and organization.

Process


Raw Energy
Train Run Energy
INFRABEL
PostgreSQL Database
SFTP
Download
Fleet Data
Processing + Analysis

Train run energy data

Consumption data
(measured and/or estimated)

Timestamp

EVN

Calculation type

Coordinates

Train ID	Operating day	Part start	Part end	Traffic catego	Traction unit set	Price category	Grid	Calculation type	Estimated	Metered C	Metered G	Net consu	Weight (to	Distance (	Estimated	Start lat	Start long	End lat	End long	Train part result type
1530	01/04/2024	01/04/2024 08:32	01/04/2024 08:57	Passengers	918886960650	Off-peak	Brussels	ESTIMATED	0	0	0	385.13	577	17.23	0	50.89193	4.428195	50.82267	4.24755	ESTIMATED
2126	01/04/2024	01/04/2024 04:55	01/04/2024 06:02	Passengers	918801809602	Off-peak	Wallonia	ESTIMATED	0	0	0	649	361	52.52	0	50.45273	4.823652	50.79661	4.650636	ESTIMATED
1529	01/04/2024	01/04/2024 07:35	01/04/2024 07:58	Passengers	918886960585	Off-peak	Brussels	ESTIMATED	0	0	0	238.95	358	17.23	0	50.89193	4.428195	50.82267	4.24755	ESTIMATED
2126	01/04/2024	01/04/2024 06:02	01/04/2024 06:24	Passengers	918801809602	Off-peak	Flanders	ESTIMATED	0	0	0	425.35	361	34.42	0	50.79661	4.650636	50.89193	4.428195	ESTIMATED
1529	01/04/2024	01/04/2024 06:28	01/04/2024 09:05	Passengers	918886960585	Off-peak	Flanders	ESTIMATED	0	0	0	2529.75	358	182.44	0	50.93112	5.32618	51.31243	3.133862	ESTIMATED
3879	01/04/2024	01/04/2024 09:06	01/04/2024 09:23	Passengers	948800808917	Off-peak	Brussels	METERED	55.73	100.7	29	71.7	146	10.68	0	50.83678	4.336922	50.88211	4.29833	PARTIALMETERED
3879	01/04/2024	01/04/2024 09:03	01/04/2024 09:06	Passengers	948800808917	Off-peak	Brussels	Shunting	0	0	0	3.4	0	0	0	50.83688	4.33737	50.83424	4.33377	Shunting
1945/1	31/03/2024	01/04/2024 00:00	01/04/2024 00:09	Passengers	948809651912_948809652316	Off-peak	Brussels	ESTIMATED	0	0	0	48.09	325	3.82	0	50.85966	4.360854	50.83678	4.336922	ESTIMATED
1976	01/04/2024	01/04/2024 06:41	01/04/2024 06:58	Passengers	948800802415	Off-peak	Wallonia	ESTIMATED	0	0	0	81.05	146	15.54	0	50.7305	4.378437	50.60054	4.334678	ESTIMATED
1976	01/04/2024	01/04/2024 06:31	01/04/2024 06:41	Passengers	948800802415	Off-peak	Flanders	ESTIMATED	0	0	0	30.6	146	5.87	0	50.77366	4.33956	50.7305	4.378437	ESTIMATED
727	01/04/2024	01/04/2024 05:07	01/04/2024 05:58	Passengers	948809645211	Off-peak	Flanders	ESTIMATED	0	0	0	231.19	163	36.62	0	50.85442	2.736304	50.82434	3.265676	ESTIMATED
727	01/04/2024	01/04/2024 05:58	01/04/2024 07:22	Passengers	948809645211_948809647316_9	Off-peak	Flanders	ESTIMATED	0	0	0	2017.84	489	106.54	0	50.82434	3.265676	51.21686	4.421242	ESTIMATED
3357	01/04/2024	01/04/2024 06:49	01/04/2024 08:44	Passengers	948800811812	Off-peak	Brussels	METERED	167.86	221.8	67.7	154.1	146	32.18	0	50.8887	4.404332	50.90386	4.419272	METERED
3357	01/04/2024	01/04/2024 00:00	01/04/2024 06:49	Passengers	948800811812	Off-peak	Brussels	Mixed	0	0	0	342	0	0	0	50.88828	4.40429	50.88811	4.40421	Mixed
527	01/04/2024	01/04/2024 05:43	01/04/2024 06:08	Passengers	918801806103_918801808307	Off-peak	Brussels	METERED	388.17	318.53	16.16	302.37	658	17.23	0	50.89193	4.428195	50.82267	4.24755	METERED
4008	01/04/2024	01/04/2024 08:43	01/04/2024 09:02	Passengers	948800818312	Off-peak	Wallonia	METERED	81.05	125.2	41.3	83.9	146	15.54	0	50.60054	4.334678	50.7305	4.378437	METERED

Raw energy data

Timestamp

Energy offtake/injection

GPS coordinates

		Energy					Starting position		Ending position		
Time	UTC+-	Active Consumption	Active Generation	Reactive Consumptior	Reactive Generation	Quality	Latitude	Longitude	Latitude	Longitude	Quality
08.02.2025 00:01	1	0.002	0			MEASURED	50.81670	3.24658	50.81671	3.24653	MEASURED
08.02.2025 00:02	1	0.003	0			MEASURED	50.81671	3.24653	50.81669	3.24653	MEASURED
08.02.2025 00:03	1	0.002	0			MEASURED	50.81669	3.24653	50.81668	3.24656	MEASURED
08.02.2025 00:04	1	0.001	0			MEASURED	50.81668	3.24656	50.81668	3.24658	MEASURED
08.02.2025 00:05	1	0.002	0			MEASURED	50.81668	3.24658	50.81668	3.24658	MEASURED
08.02.2025 00:06	1	0.002	0			MEASURED	50.81668	3.24658	50.81668	3.24658	MEASURED
08.02.2025 00:07	1	0.002	0			MEASURED	50.81668	3.24658	50.81668	3.24658	MEASURED
08.02.2025 00:08	1	0.002	0			MEASURED	50.81668	3.24658	50.81669	3.24657	MEASURED
08.02.2025 00:09	1	0.002	0			MEASURED	50.81669	3.24657	50.81668	3.24657	MEASURED
08.02.2025 00:10	1	0.002	0			MEASURED	50.81668	3.24657	50.81667	3.24658	MEASURED

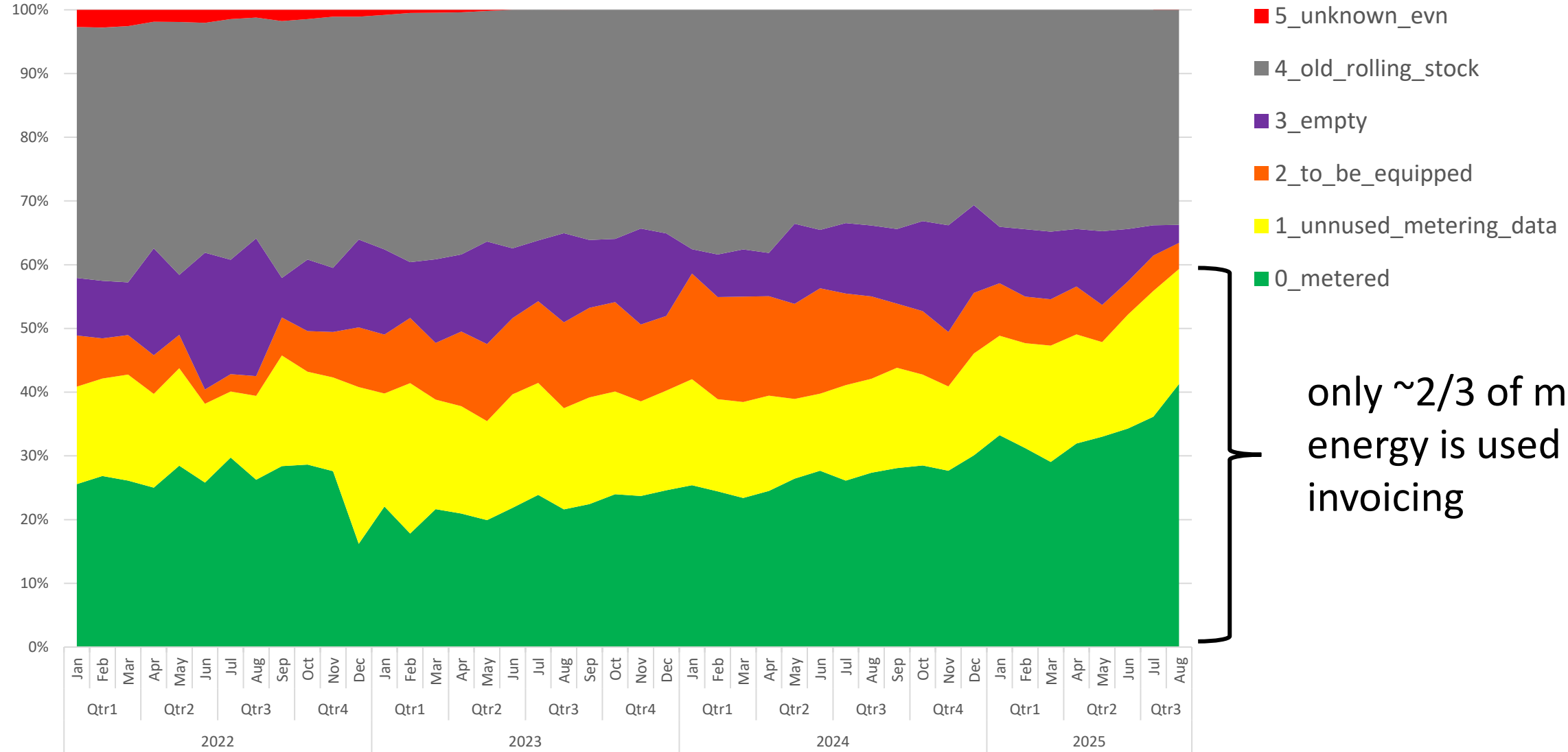
Quality flags

Metering statistics

General metering statistics

- Goal: current metering % and room for improvement
- Divide train runs into different categories:
  - **Metered**: energy is 100% metered (includes shunting and stabling)
  - **Unnused meter energy**: energy is estimated, but traction unit is metered and has had metered train runs in the past.
  - **To be equipped**: traction unit type is part of a newer series and will be equipped with a meter in the nearby future
  - **Old rolling stock**: traction unit is part of an older series that will probably never be equipped with meters
  - **Empty**: traction unit type is ‘empty’ (missing train composition data)
  - **Unknown**: traction unit type not found in fleet masterdata

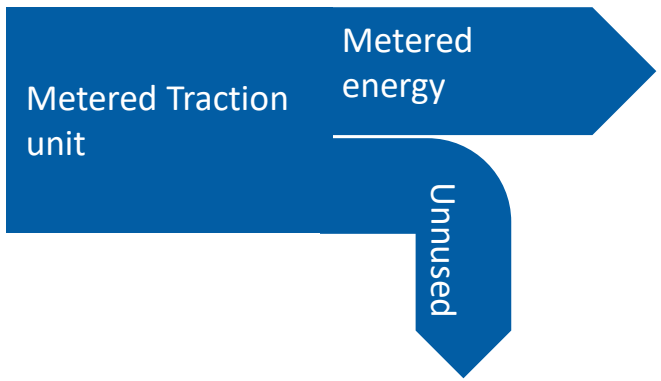
Using all metered energy would improve metered% from 40% to 60%



only ~2/3 of metered energy is used for invoicing

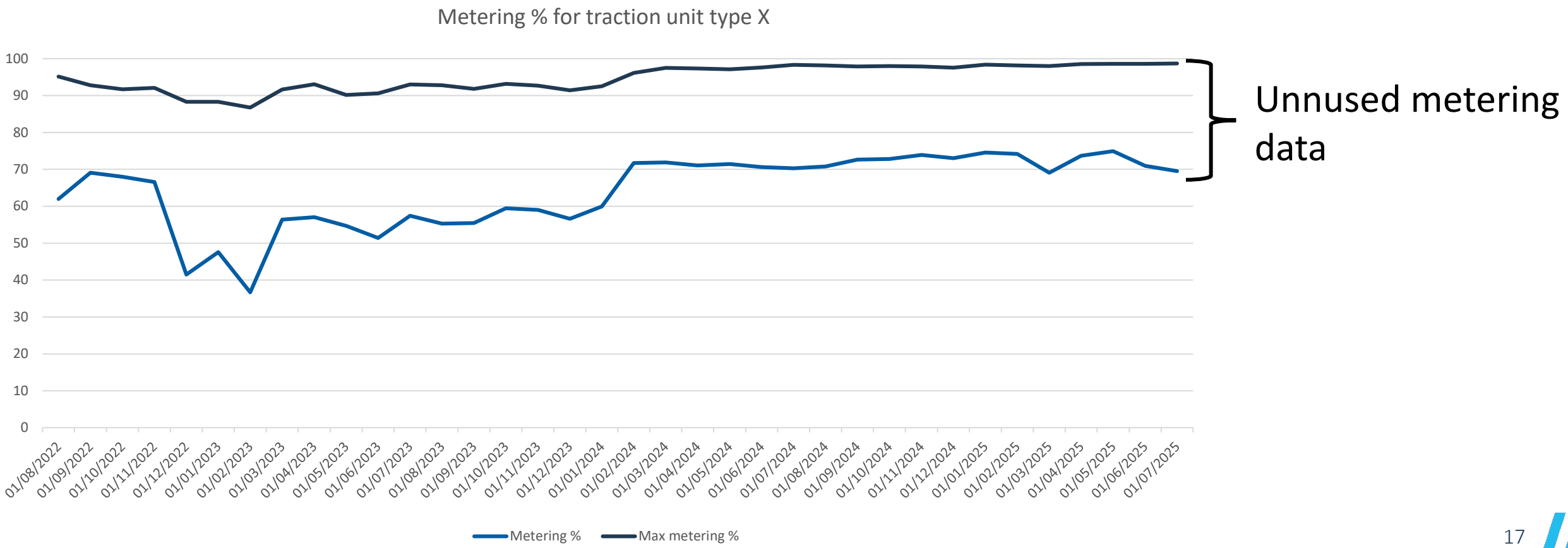
Metering statistics per traction unit type

- Goal: evolution in metering % and metering usage per traction unit type
- Gebruik Sankey diagram:
  - $E_{metered}$: energy that is metered (includes shunting and stabling)
  - $E_{unnused}$: energy is estimated, but traction unit is metered and has had metered train runs in the past.
  - **Usage %**: metered energy / (metered energy + Unnused meter energy)



Current metering statistics per traction unit type

Some Traction types: 100% equipped with meters, but 30% of energy is estimated



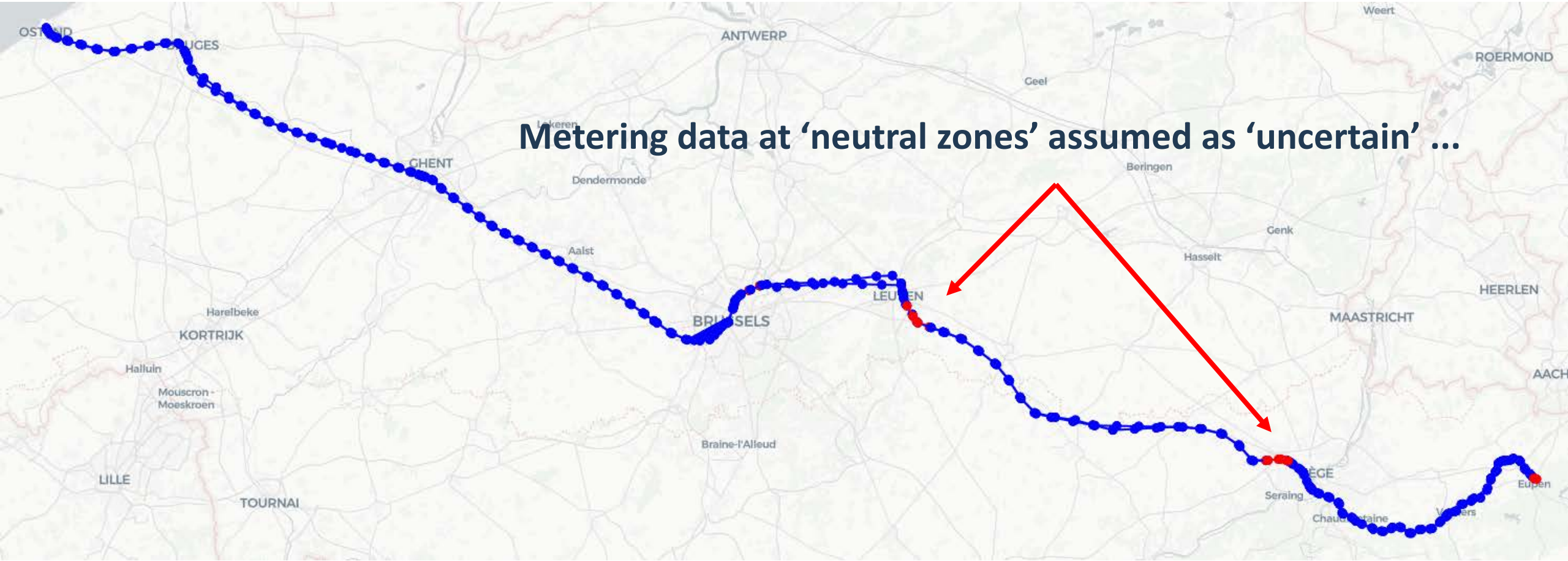
Diving into the data

Causes for low metering usage

How to close the gap and improve metering usage?

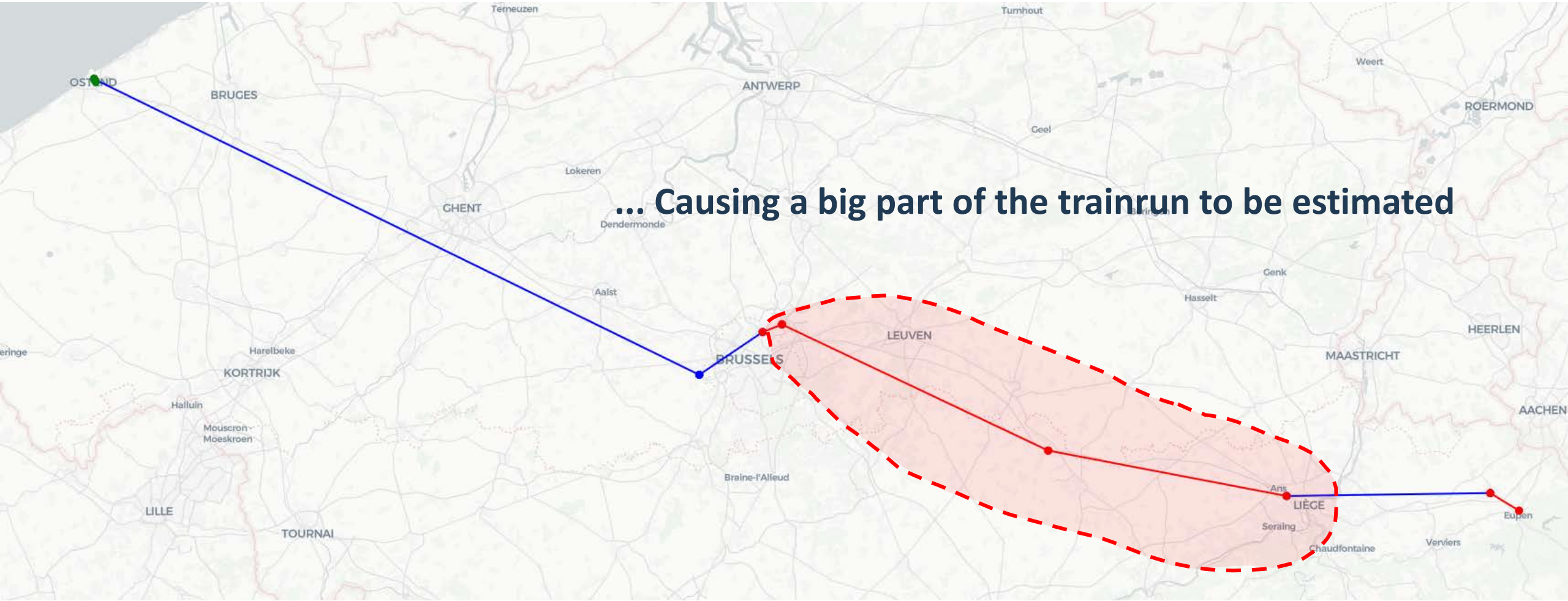
- Find root causes for low metering usage
- Analyse raw metering data and compare with corresponding train run data

Impact of low metering quality



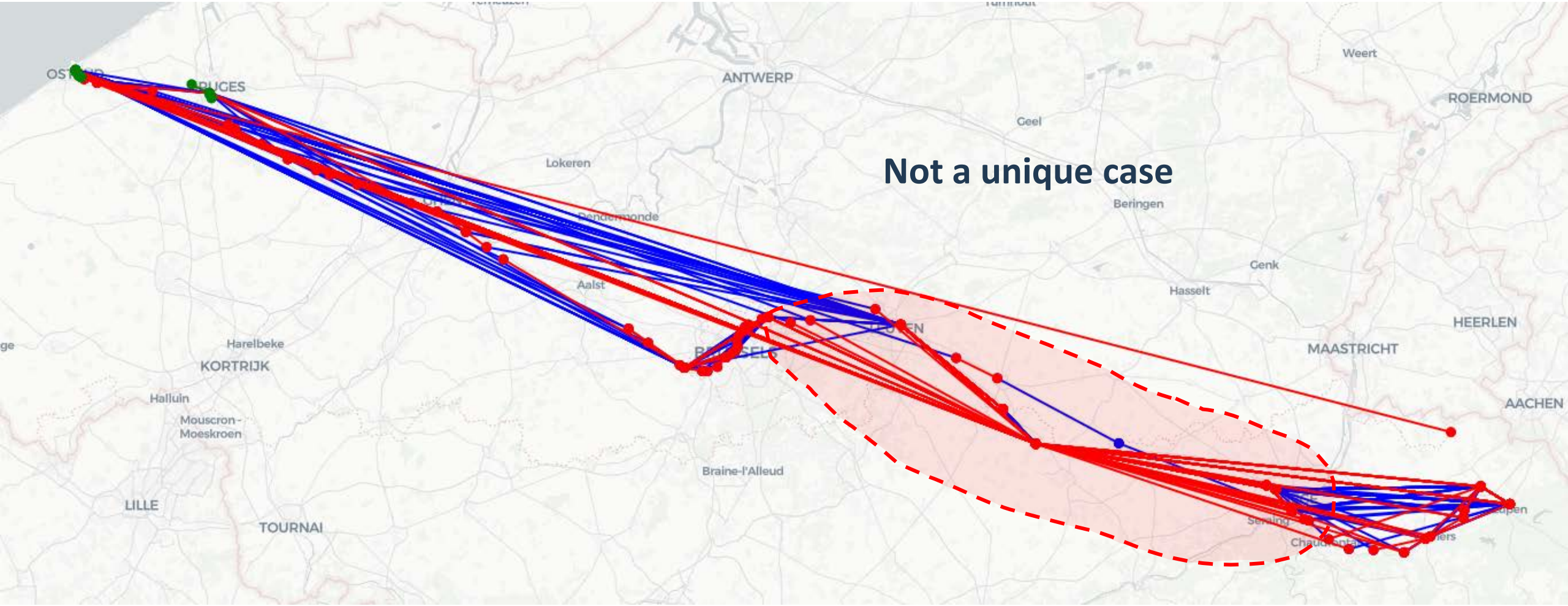
Plot Raw metering data by metering quality: Measured = blue, Uncertain = red

Impact of low metering quality



Plot train run by quality: Measured = blue, Estimated = red

Impact of low metering quality



Plot train run (same train ID over a period of 3 months) by quality: Measured = blue, Estimated = red

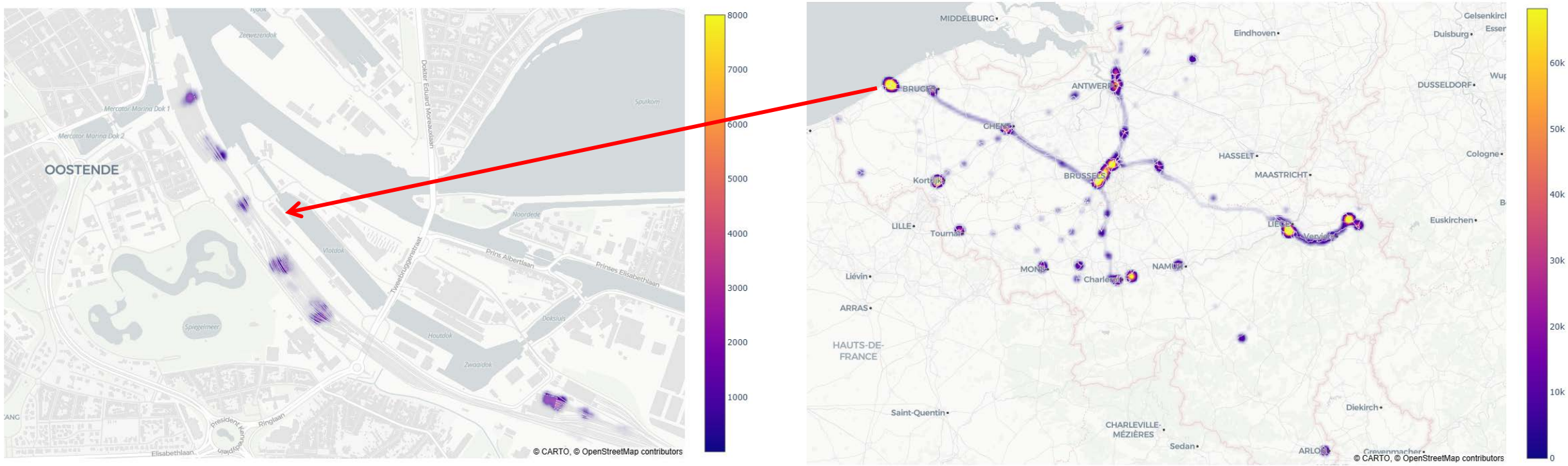
Analysing raw data

Analysing raw energy data over a 4-month period

- Huge amount of data (40+ million datapoints)
  - Challenging to process and visualise data
  - Mix of 1- and 5-minute data
  - Group data on coordinates and split between low and high energy metering quality
- Data plotted using heatmaps
  - Count: ∑ datapoints at a coordinate
    - Where has a train been driving?
  - Specific consumption: ∑ consumption / ∑ datapoints in a group [MWh/minute]

Plotting location

- Just plotting all data doesn't tell much
  - Trains are stabled for most of the time
- Need to distinguish between 'driving' and 'stabling/shunting'

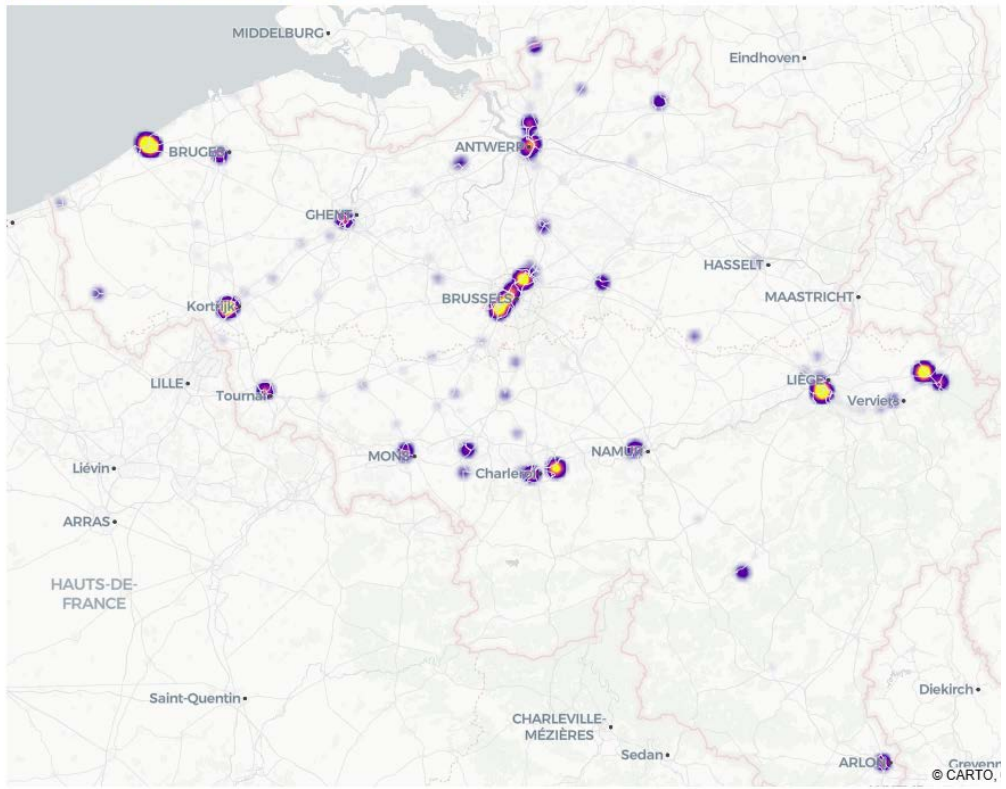


Heatmap plot showing the location of trains ('count') based on raw energy data. Yellow = more data points at this location

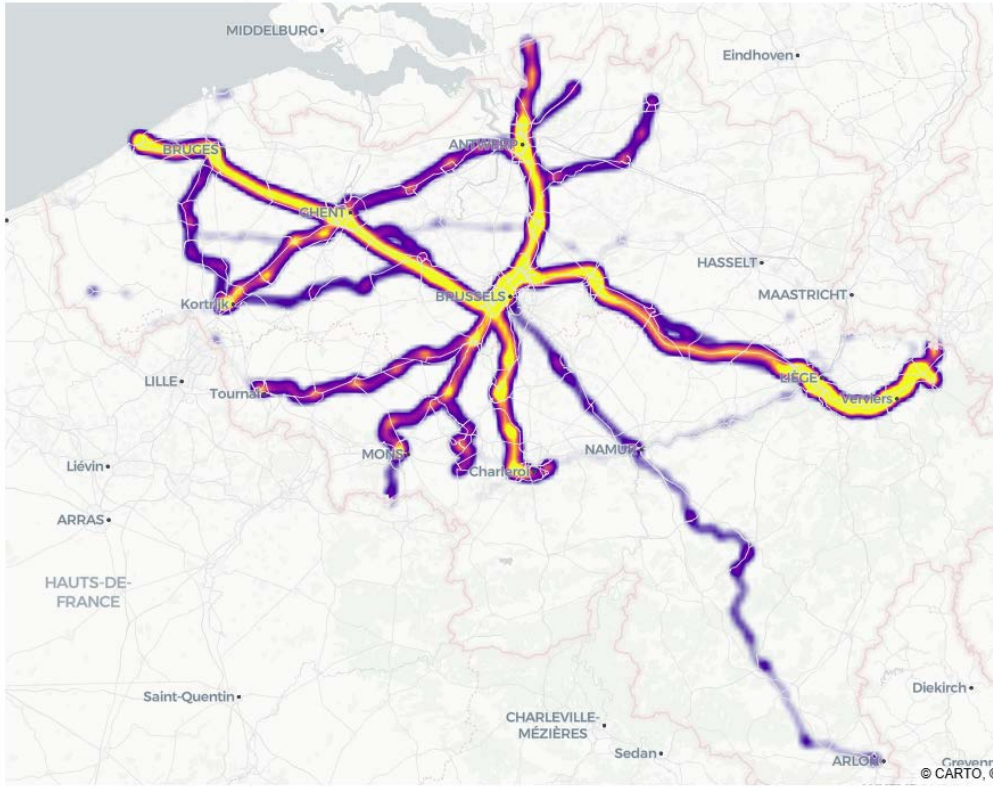
Plotting location

- Calculate average speed based on start- and end-coordinates
- Split data between shunting/stabling and driving

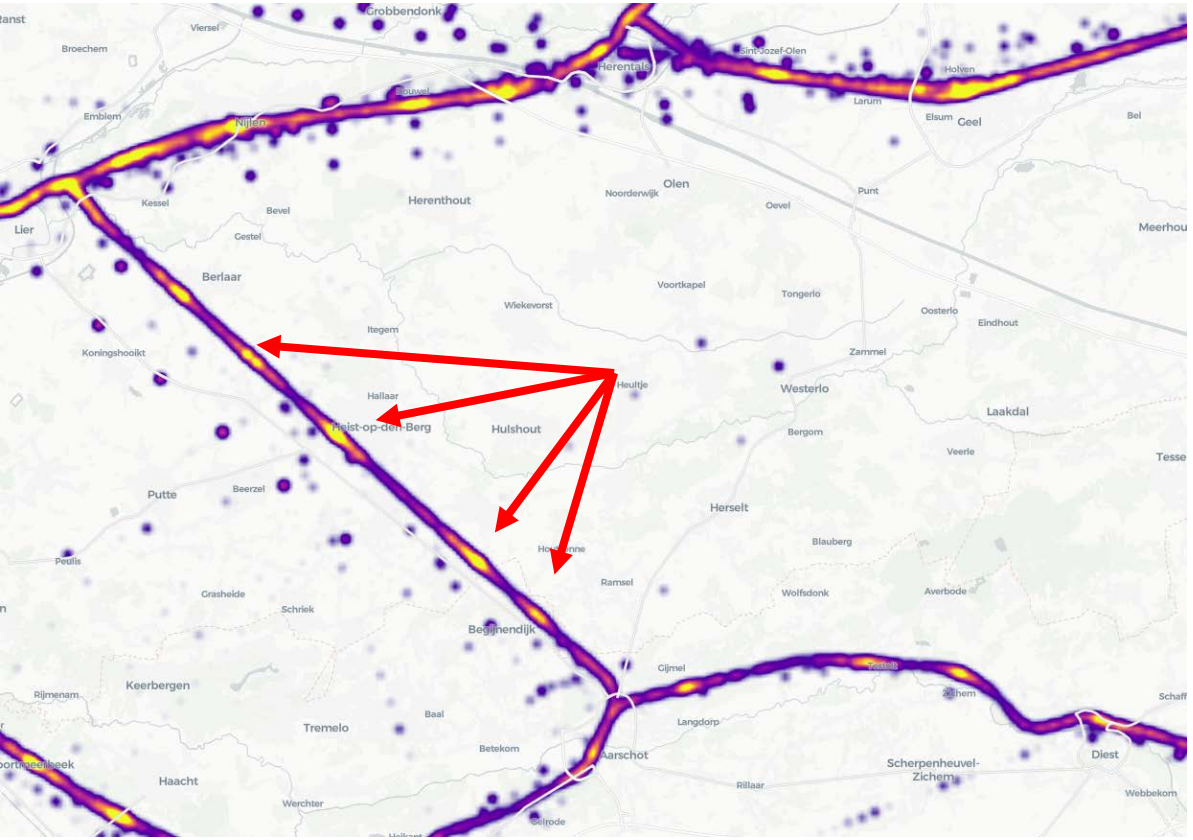
speed < 10 km/h(all)



speed > 10 km/h(all)



Specific consumption

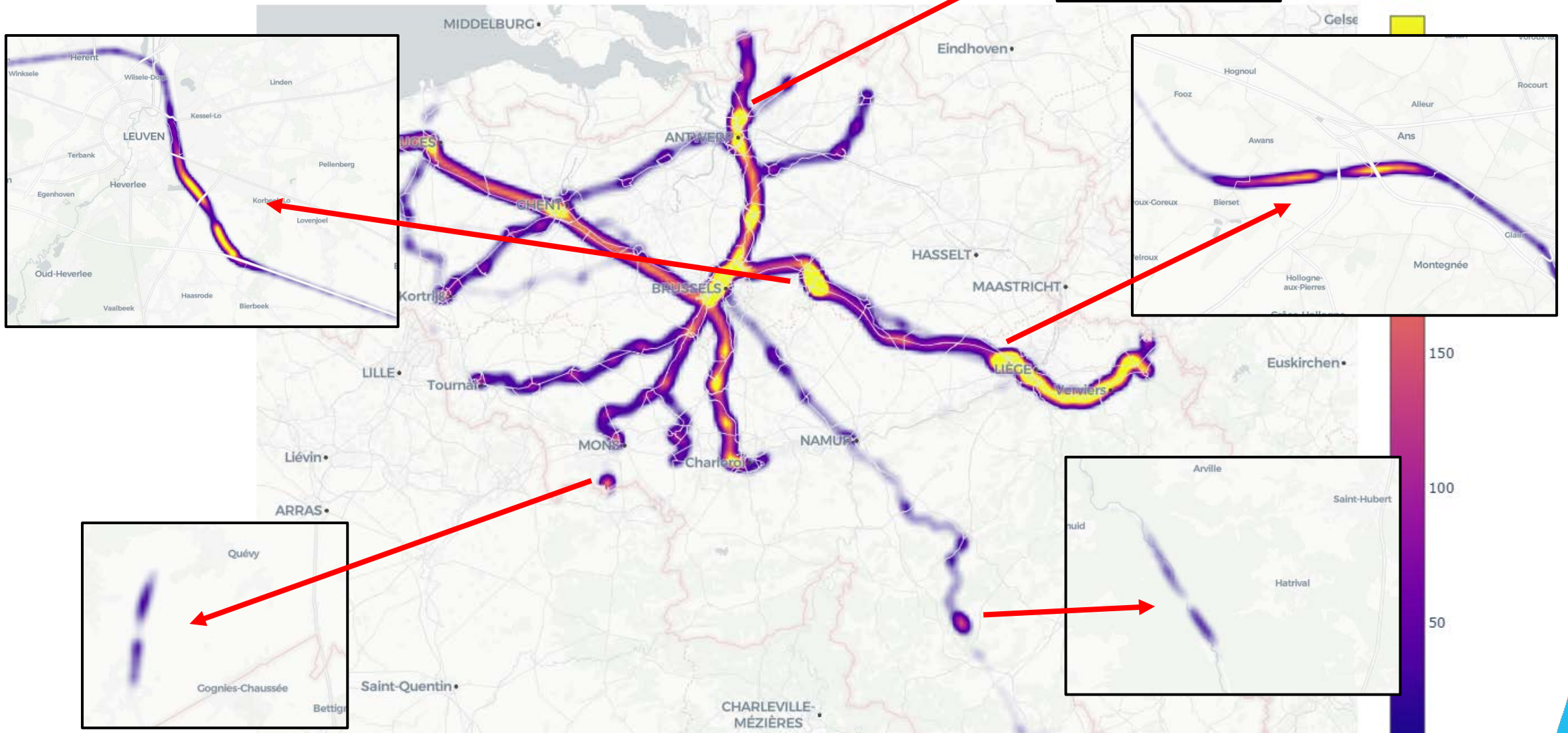


- Specific consumption is higher around stations due to stopping and accelerating

Heatmap plot showing the specific consumption of trains based on raw energy data.
Yellow = higher specific consumption at this location

Results

Low metering quality at neutral zones (split between 3kV DC and 25 kV AC)



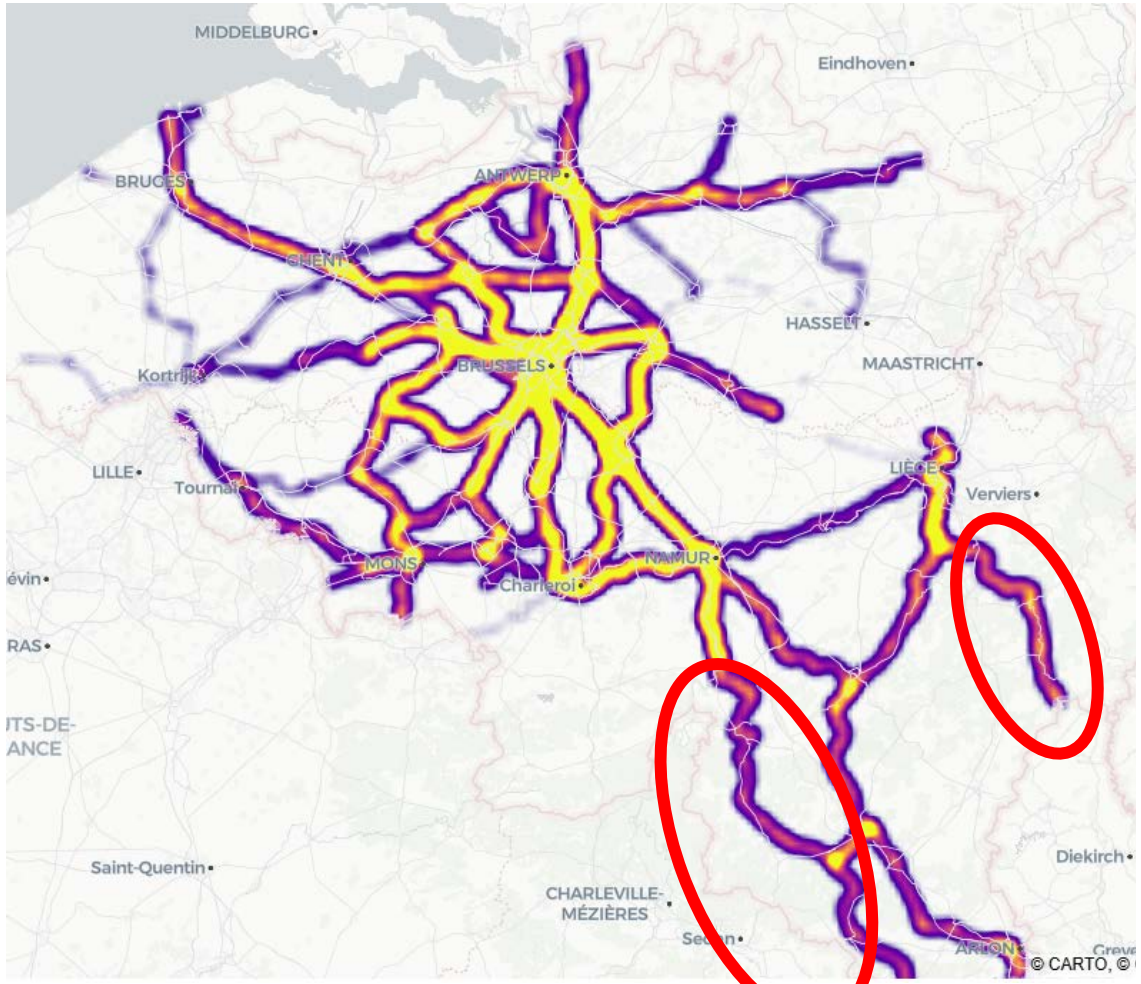
Low metering quality at neutral zones

Quality fraction

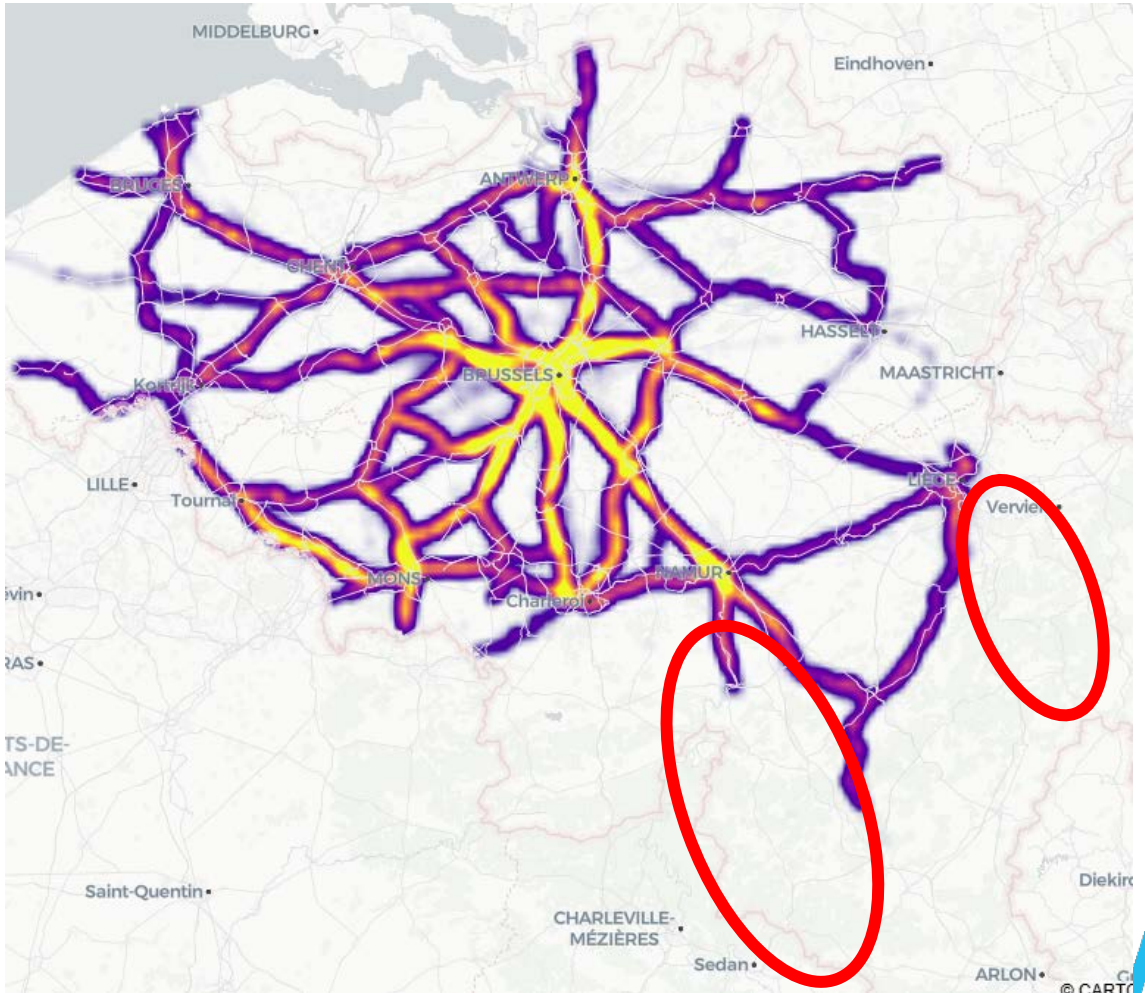
- **Green** = 100% ‘measured’
- **Red** = 100% ‘uncertain’

Issues with metering of 25kV

Count



Specific consumption

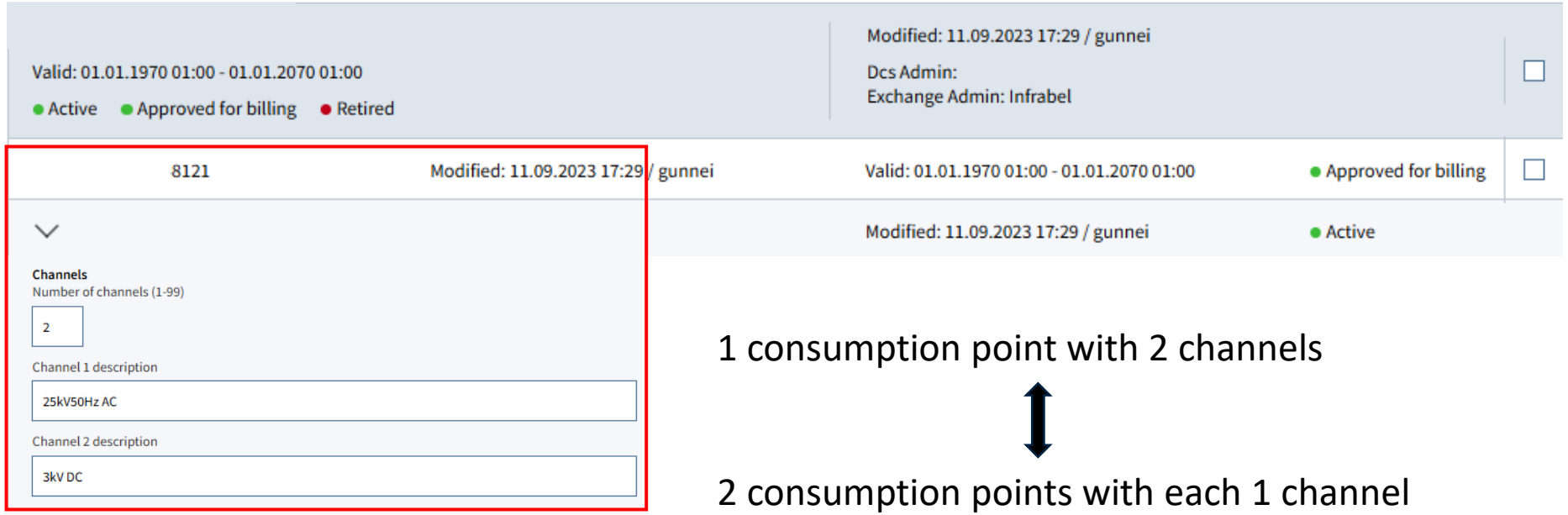


Issues with metering of 25kV

- No metering of energy for lines with 25kV OCL for a specific train type
- Root cause:
  - metering of 25kV was disabled due to issue with meter
  - Energy data always 0 MWh/minute
- Incoherence between Settlement Belgium and Exchange
- Train runs are always estimated

Difference in fleet masterdata

Exchange:

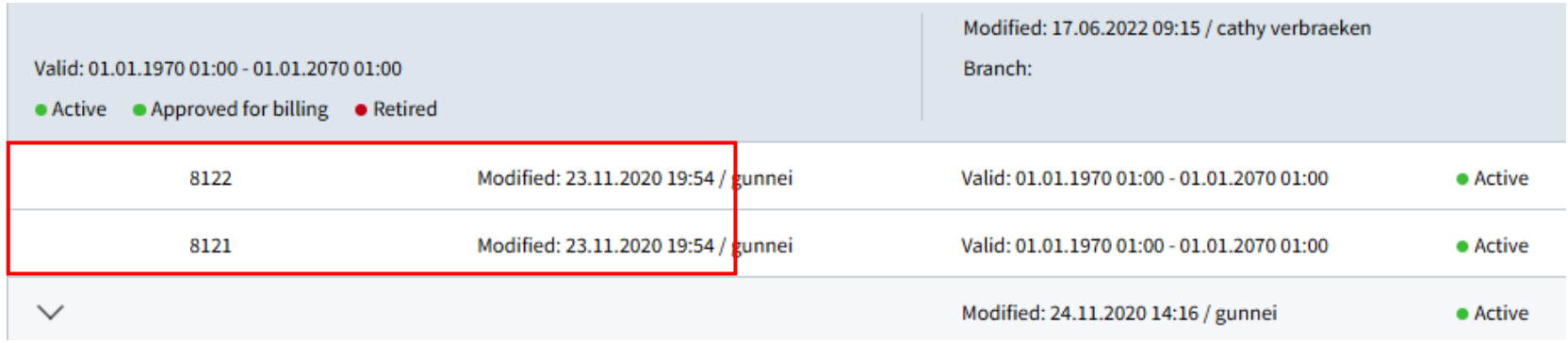


1 consumption point with 2 channels

↕

2 consumption points with each 1 channel

Belgian settlement:

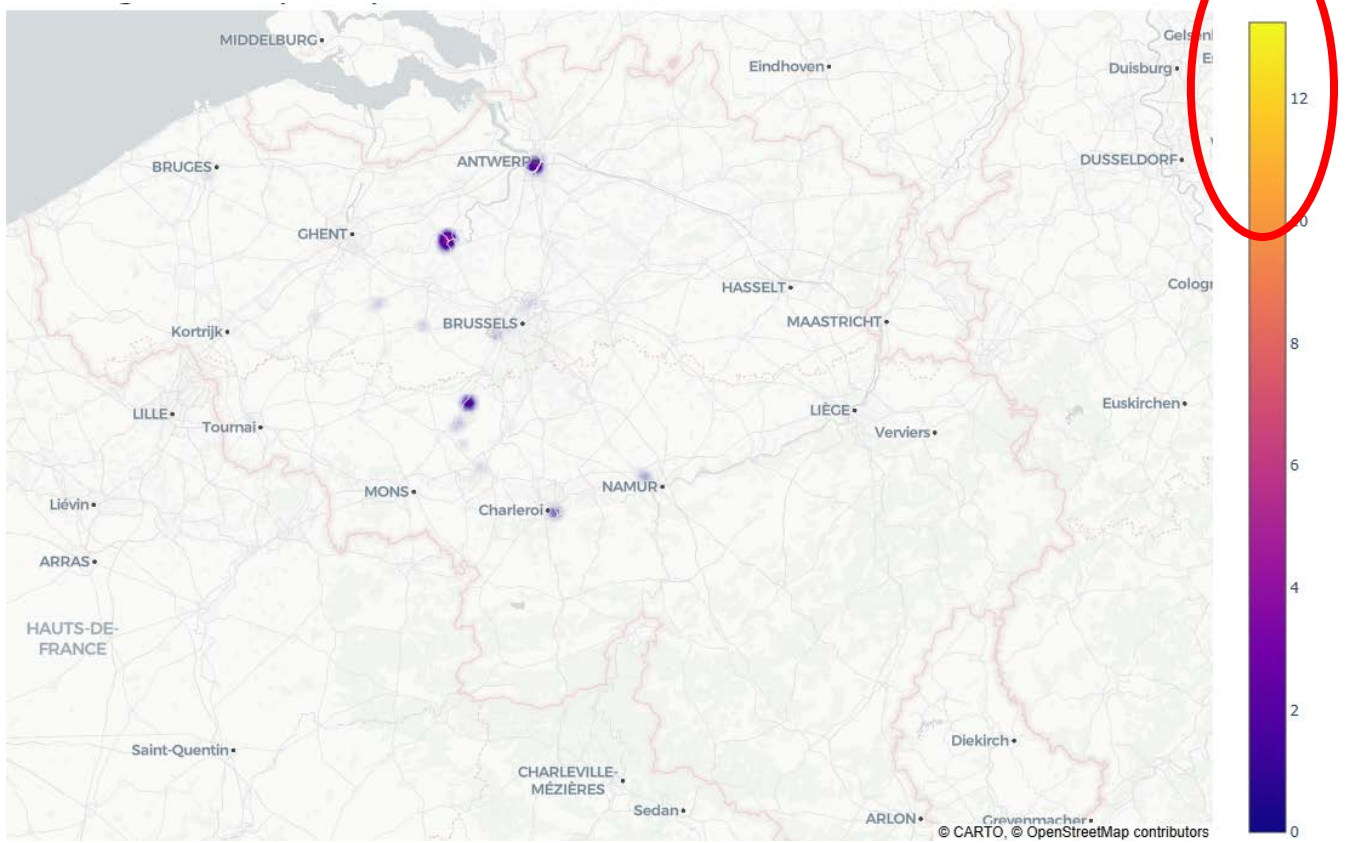


Conclusion

Quality flag can indicate nonsense data:

- Unrealistic high specific consumption

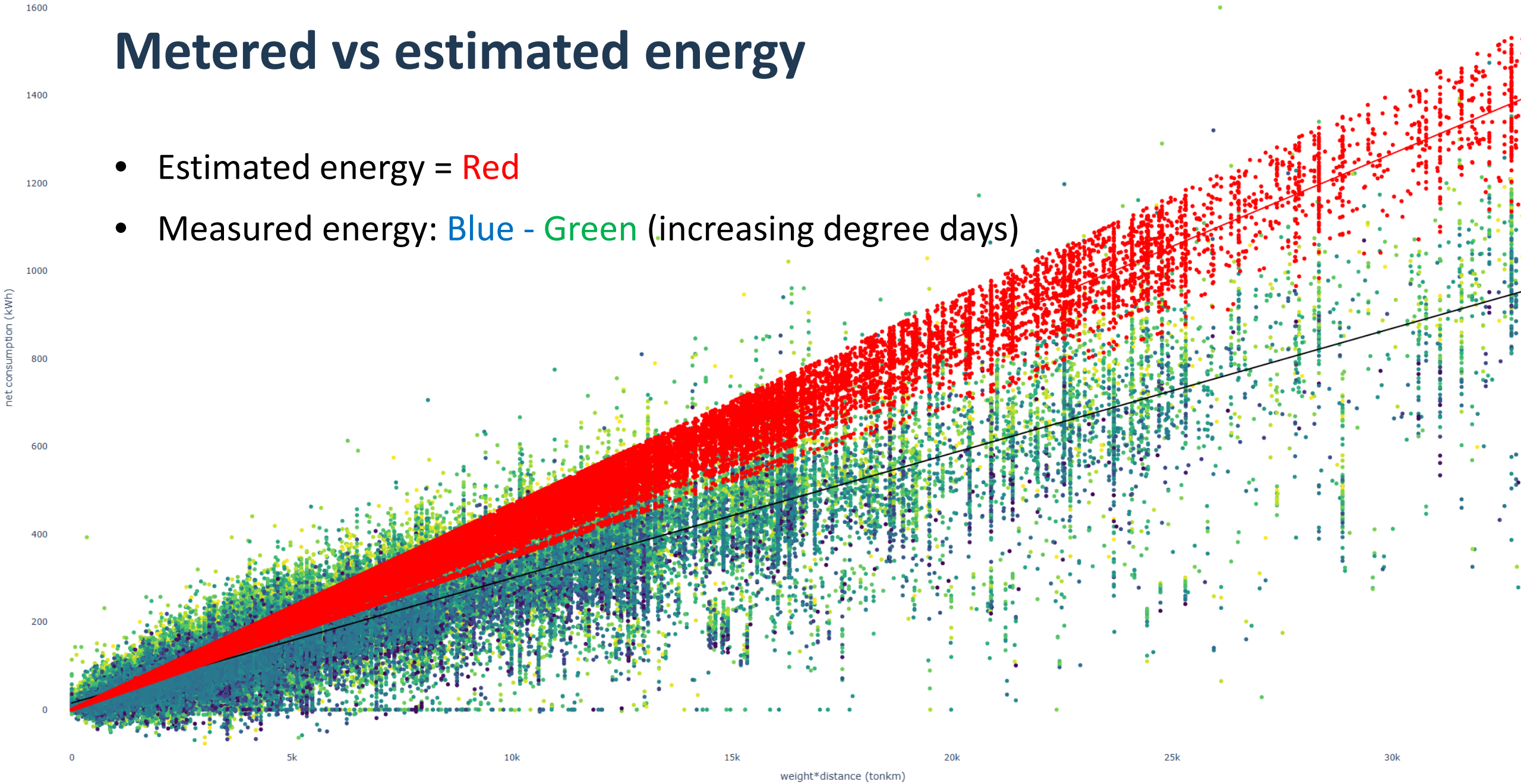
12 MWh/minuut (= 720 MW)



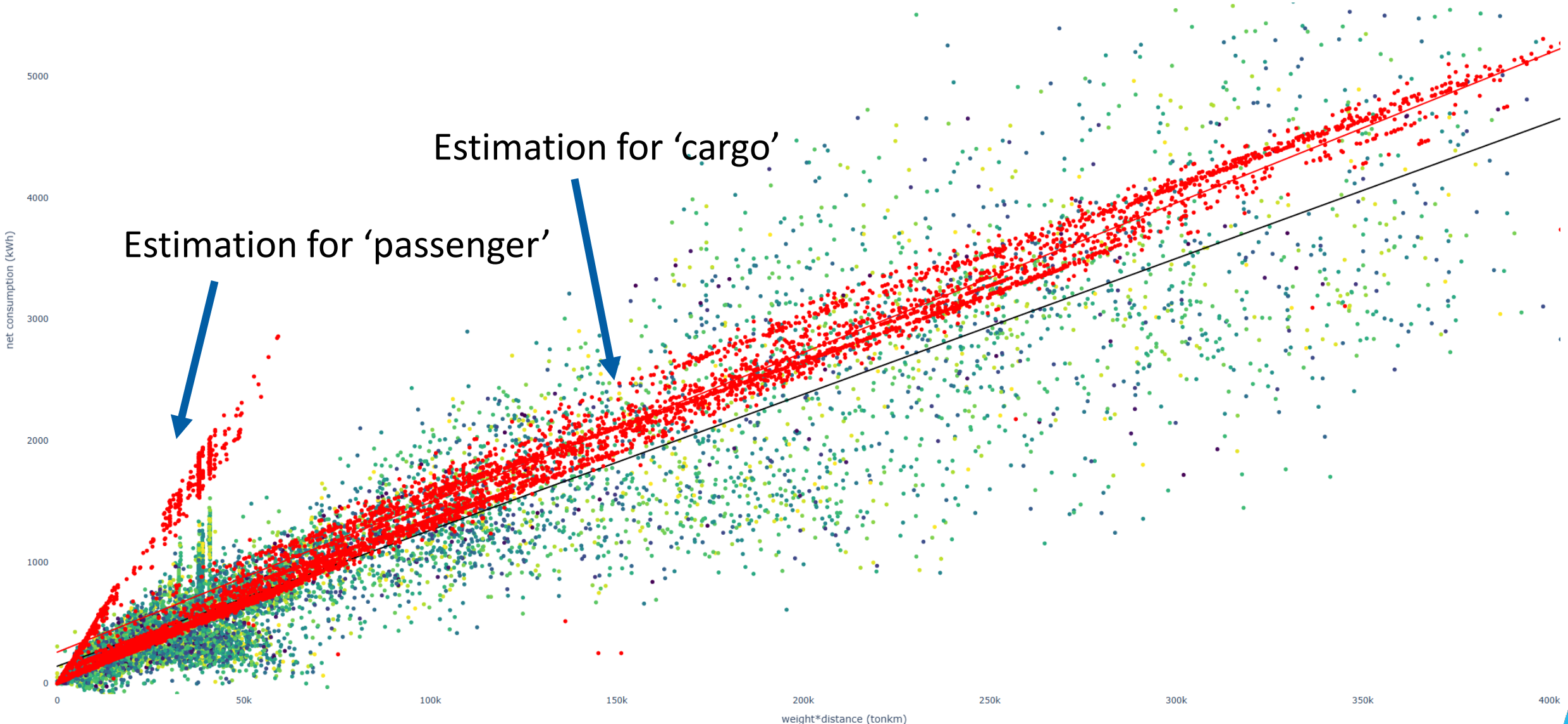
Heatmap plot showing the specific consumption for a specific train type (only low quality metering data). The scale shows data points with unrealistic specific consumption at this location

Metered vs estimated energy

- Estimated energy = Red
- Measured energy: Blue - Green (increasing degree days)



Metered vs estimated energy



Metered vs estimated

→ Big variation in measured consumption for similar payloads (distance * weight)

→ Metering based invoicing is important to sufficiently incentivise energy efficiency

Conclusion

Conclusion

- Efficient algorithms are essential for effective data processing
- Significant potential for improvement in Belgium
- Correct usage of quality flag is important, impact on train run data is significant
- Major variances between estimated and metered values, and also among metered results for similar payloads
- A large amount of data is available and can give interesting insights
  - Further analysis is ongoing

Conclusion

- Questions:
  - How do you use and analyse data from Erex?
  - Do you collect statistics about metering data (usage)?
  - What problems do you encounter?

Thank you ☺