Blending issues

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Beyond CO2: Bio Kerosene, engine emissions and technical constraints

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Background:

- Attempt to analyse bio kerosene emissions as part of burnFAIR project
  - Emissions measured at engine operated on bio kerosene blend
  - Reference measurements at other engine

- Results:
  - Expectation was that SO2 emissions of the bio kerosene blend would be below those of the conventional kerosene
  - Actual result was the exact opposite: Bio kerosene blend SO2 emissions were well <u>above</u> those of the conventional kerosene

  - Reason:
  - Bio kerosene blend supplied already blended by Neste
  - Reference conventional kerosene was kerosene locally used at Hamburg airport at time of measurement
  - Hamburg conventional kerosene turned out to be very low in sulphur (ca. 10 ppm)
  - Sulphur spec limit is 3,000 ppm

What did we realise?

- As far as blending with bio kerosene is concerned, conventional kerosene can not be considered to be homogeneous
  - Fuel used by Neste for blending had well more than twice the sulphur content of the Hamburg kerosene, preventing isolated measurement of bio kerosene effects
  - Hamburg kerosene would not have been suitable for 50% blending of bio kerosene, due to low aromatics content

- Properties of conventional kerosene have major effect on:
  - Maximum achievable blending ratio
  - Emissions improvements from bio kerosene use
  - Properties of the blend

- However:
  We know next to nothing about the actual properties of kerosene fueled in Germany

Study of fuel properties

- Study integrated into burnFAIR project

- Manual analysis of quality certificates of the following airports:

- BRE	- FMO	- LEJ	- SXF
- CGN	- FRA	- MUC	- TXL
- DUS	- HAJ	- NUE	
- DRS	- HAM	- STR	

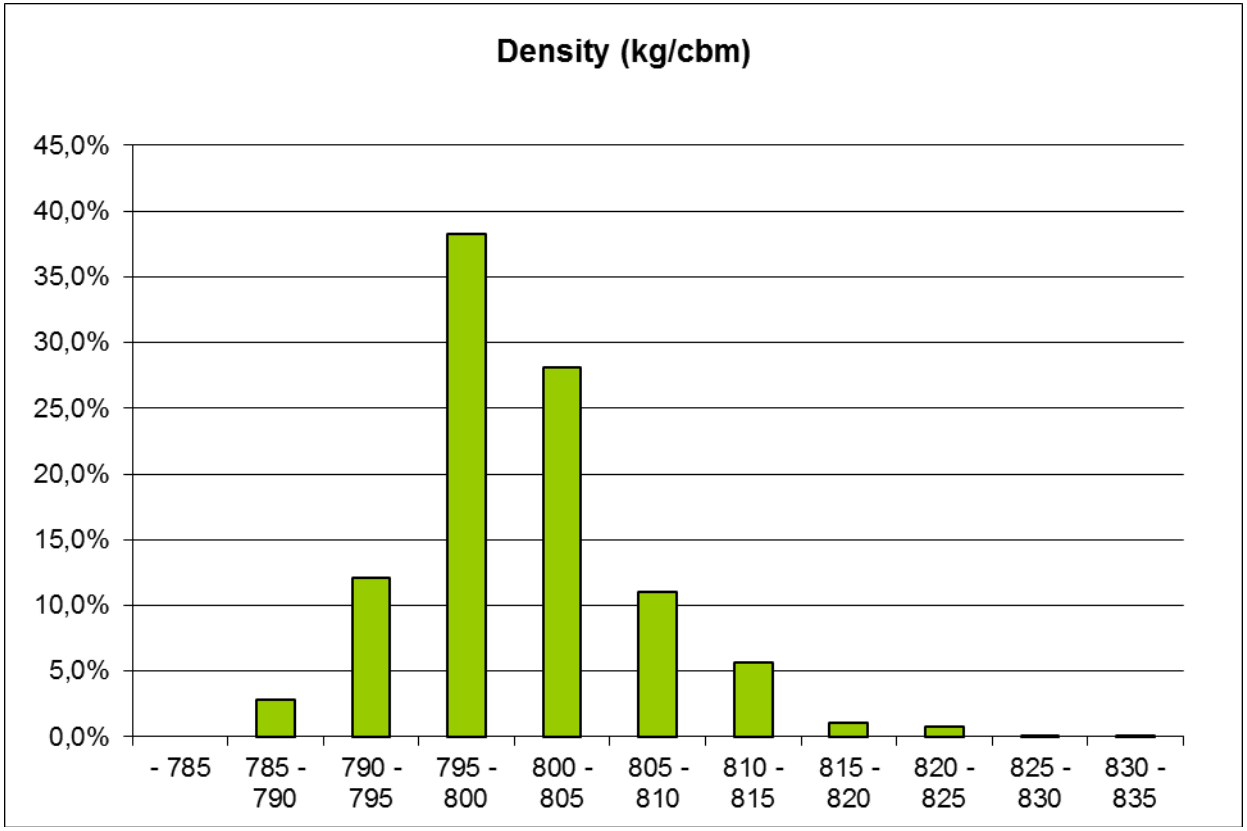
- In each case, data for twelve months convered
  - In most cases data for calender year 2011
  - For airports first analysed, data for November 2010 to October 2011 used

- Total of 2,400 quality certificates covered, including 400 cases of double counting due to more than one airport being supplied from one batch

- Parameters analysed: Sulphur content, aromatics content, density, freezing point, viscosity at minus 20 degrees, specific energy content, smokepoint

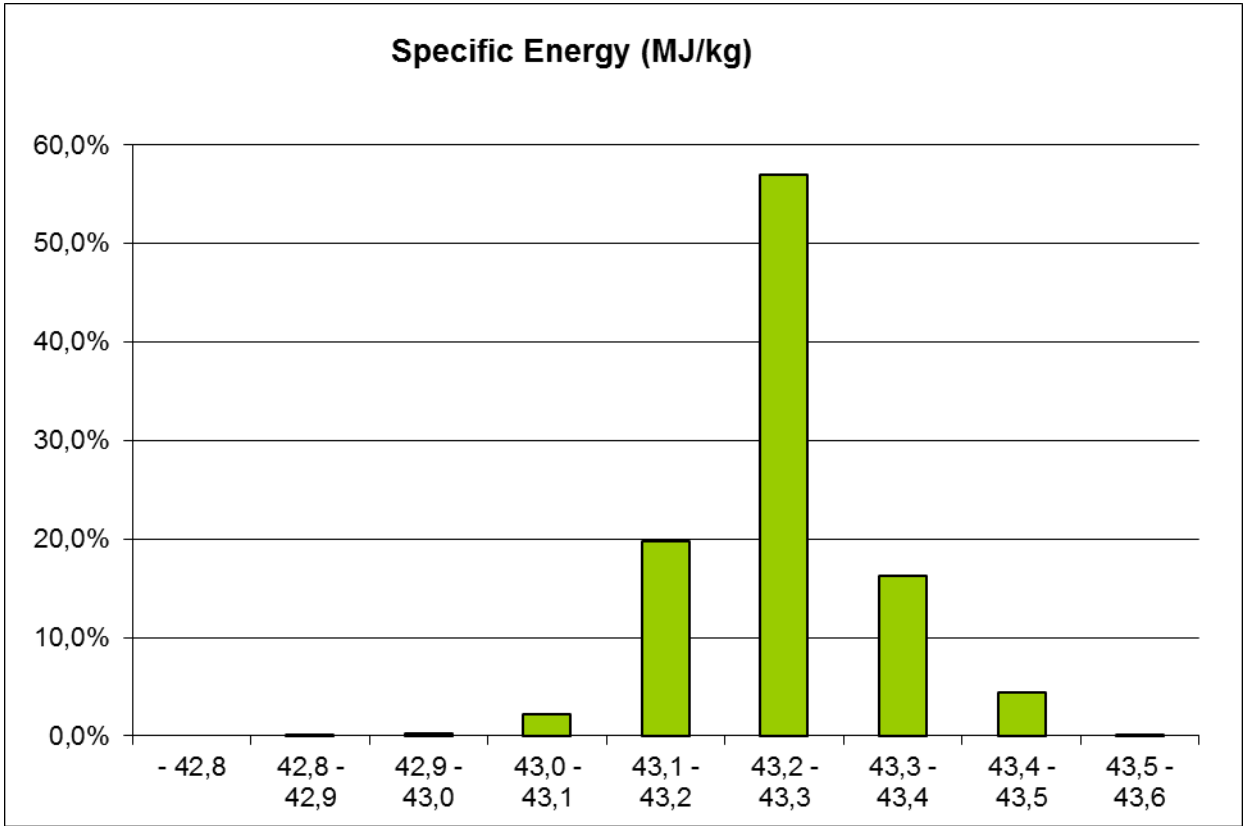
Specific energy and density

Density



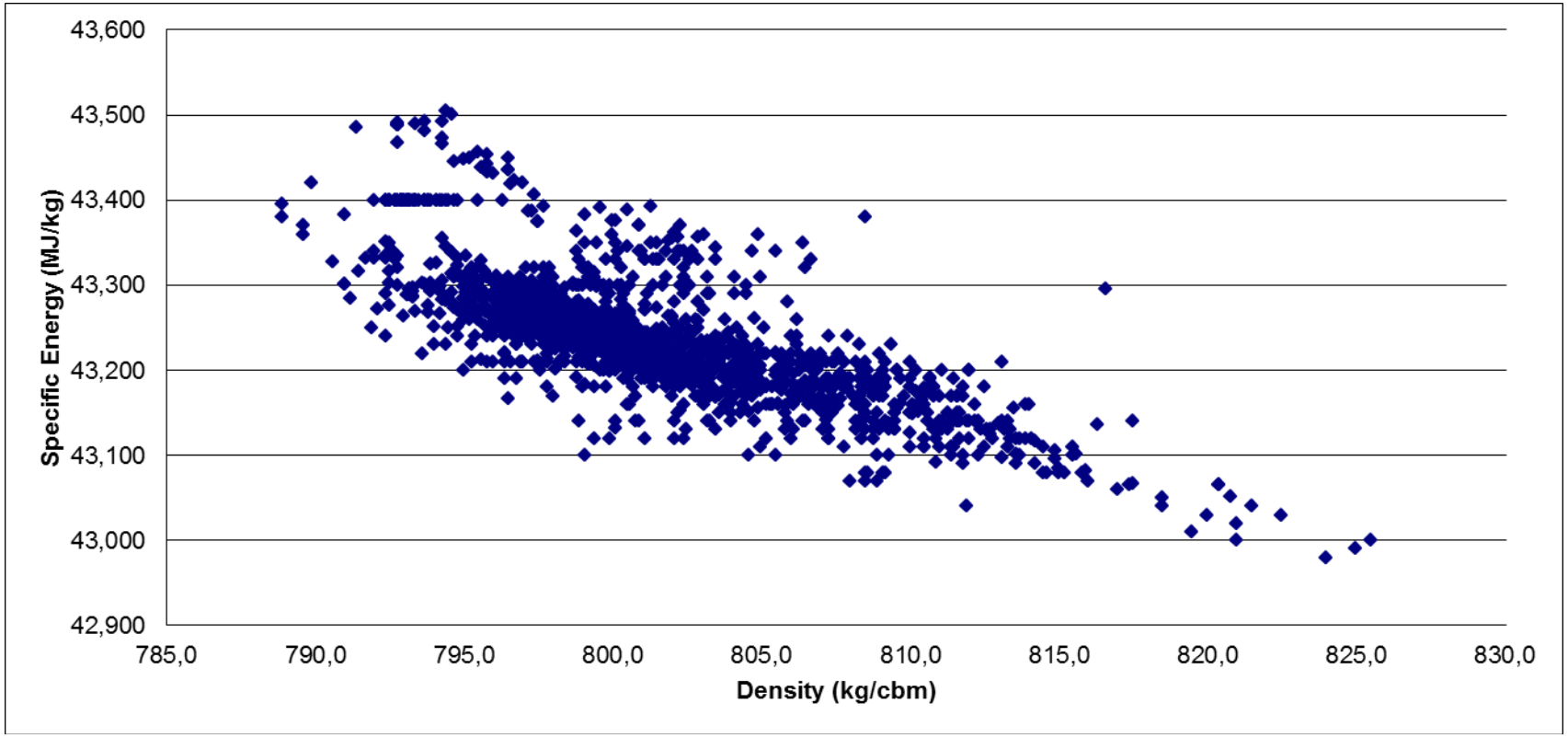
- Range: 786.9 bis 834.2
- Average: 800.5
- Skewed distribution

Specific energy



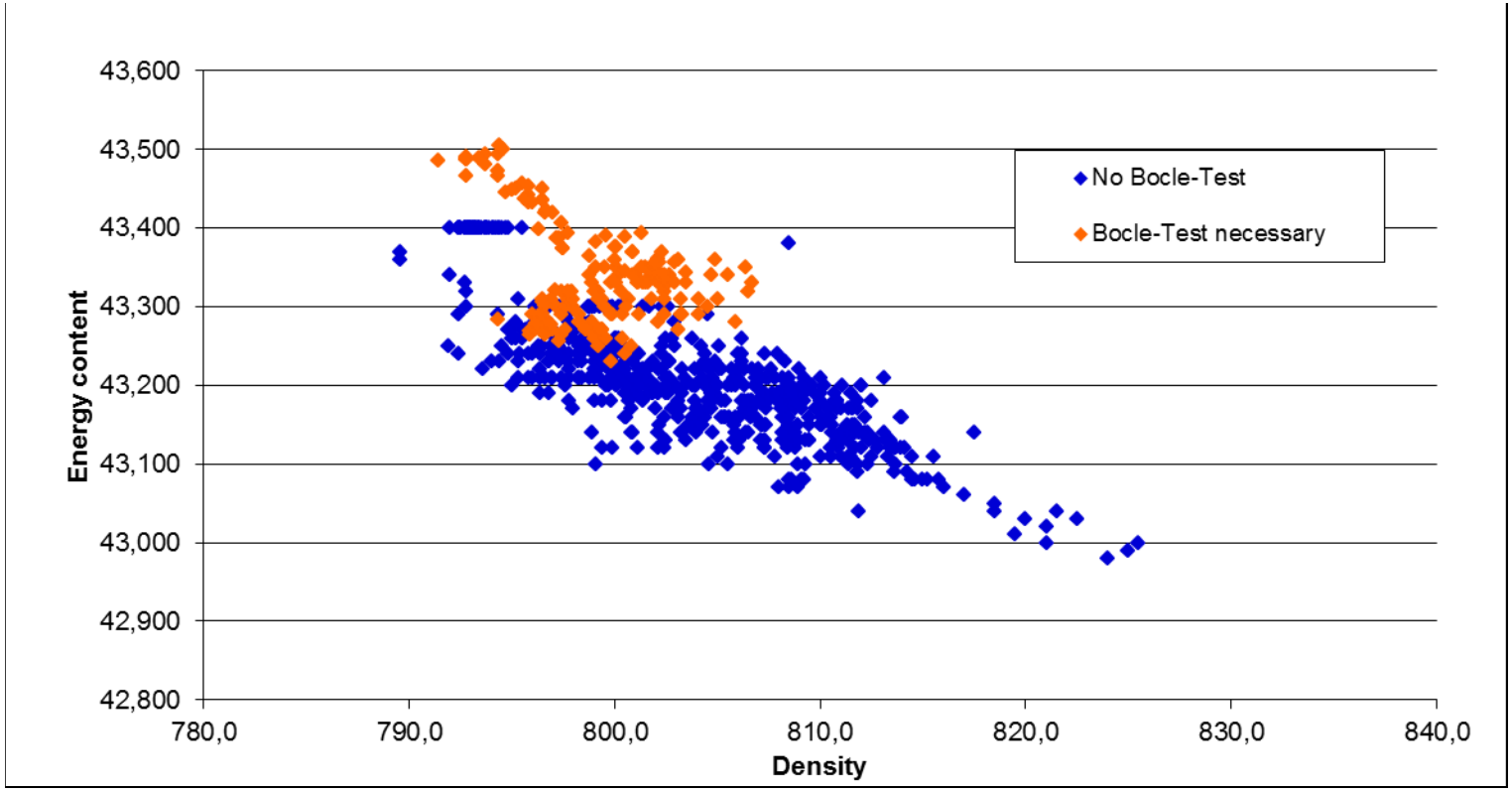
- Range: 42.85 bis 43.505
- Most observations between 43.3 and 43.3

Relationship between density and specific energy



- Evident relationship between density and specific energy
- However, bifurcation of relationship at ca. 800 kg/cbm

Relationship between density and specific energy – in detail



- Differentiating between "severely hydroprocessed" and "not severely hydroprocessed" kerosene explains bifurcation
- Severely hydroprocessed kerosene identifiable by need for BOCLE-Test

Reflections

- Difference between maximum (43.505) and mimimum (42.85) observed energy density is 1.53%
  ➡ For ten-hour flight, more than nine minutes flight endurance difference

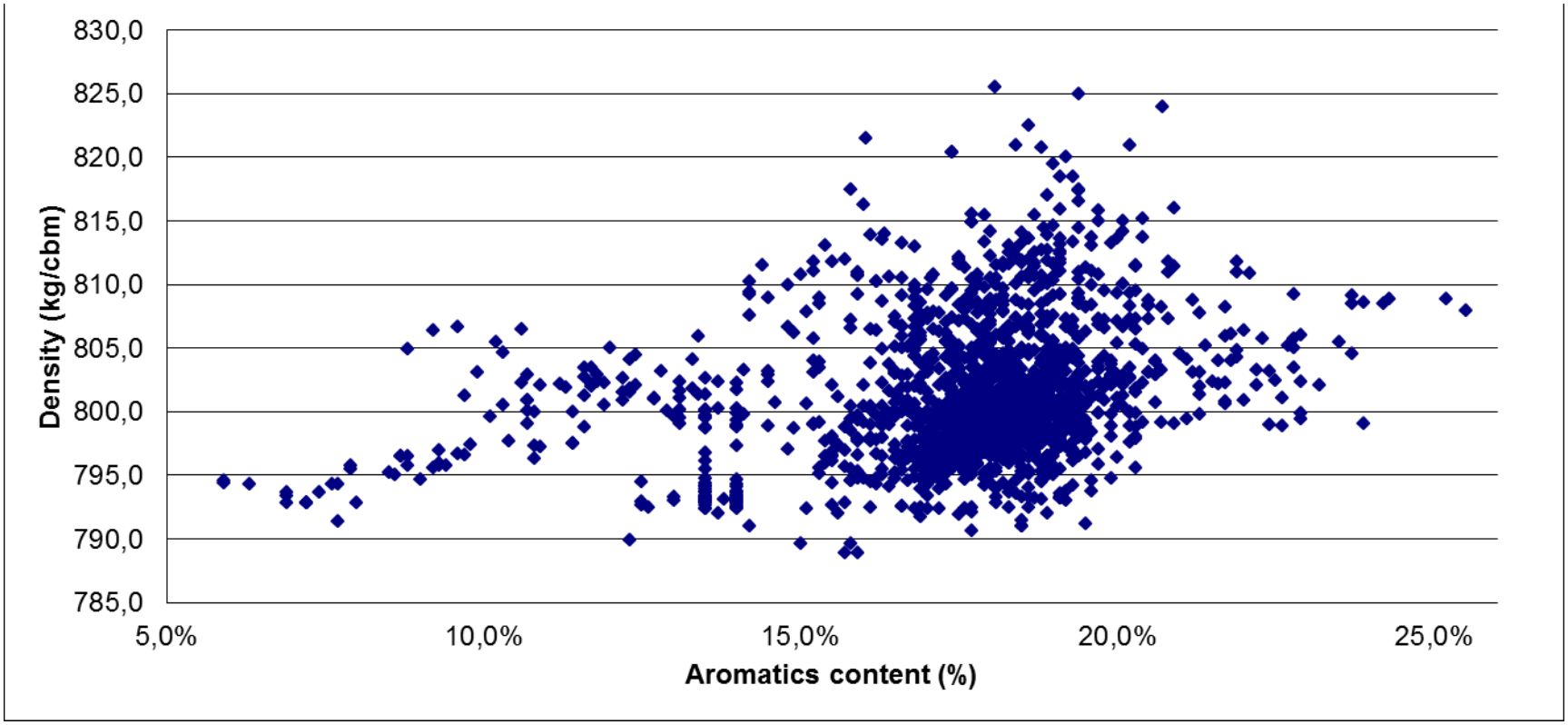
- 50% bio fuel blends expected to have even higher energy density (43.6 to 43.7)

- In principle, possibility to dedicate bio kerosene to long-haul flights
  - Could permit carrying of lower fuel loads by weight
  - However, unlikely in practice
  - Similiar results could already be achieved by using dedicated severely hydroprocessed fuel
  - Nobody does that due to practical problems (e.g. dedicated infrastructure)

- However, high percentage blends will increase variability of energy density

- Implications for
  - Flight operations (e.g. fuel check)
  - Aircraft certification
  - Possibly fuel indication systems

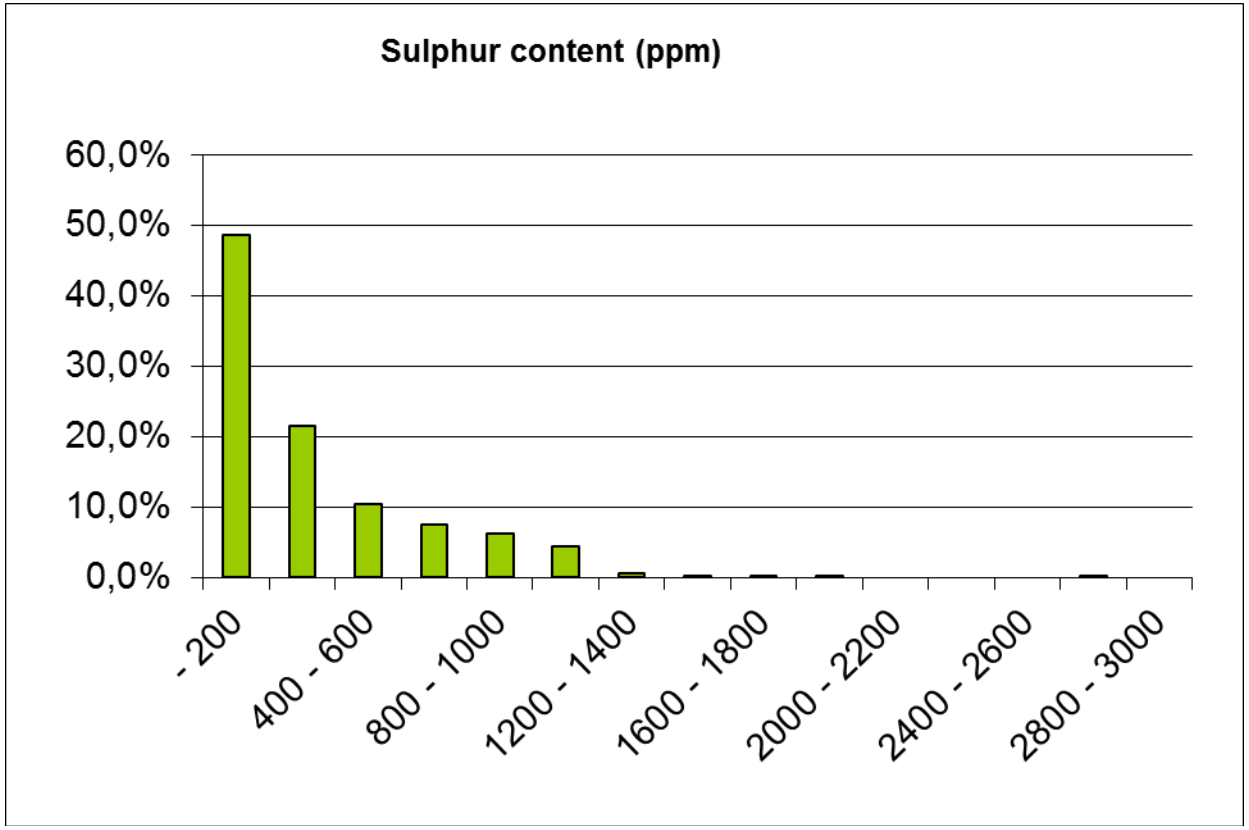
Relationship between aromatics content and density



- No real relationship between aromatics content and density
- Had been expected differently, as low density of synthetic kerosene is often explained in literature by lack of aromatics

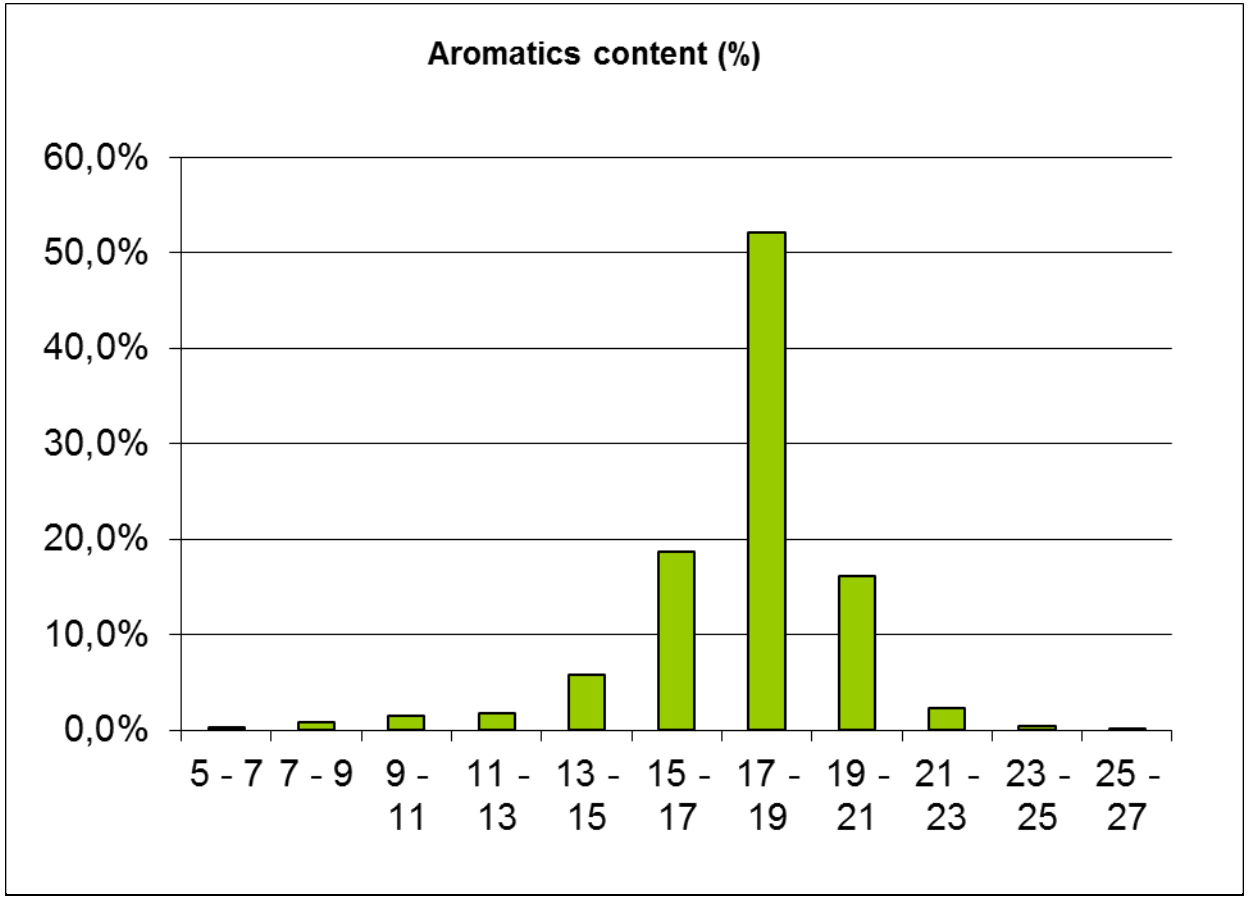
Sulphur content, aromatics content, smoke point

Sulphur content



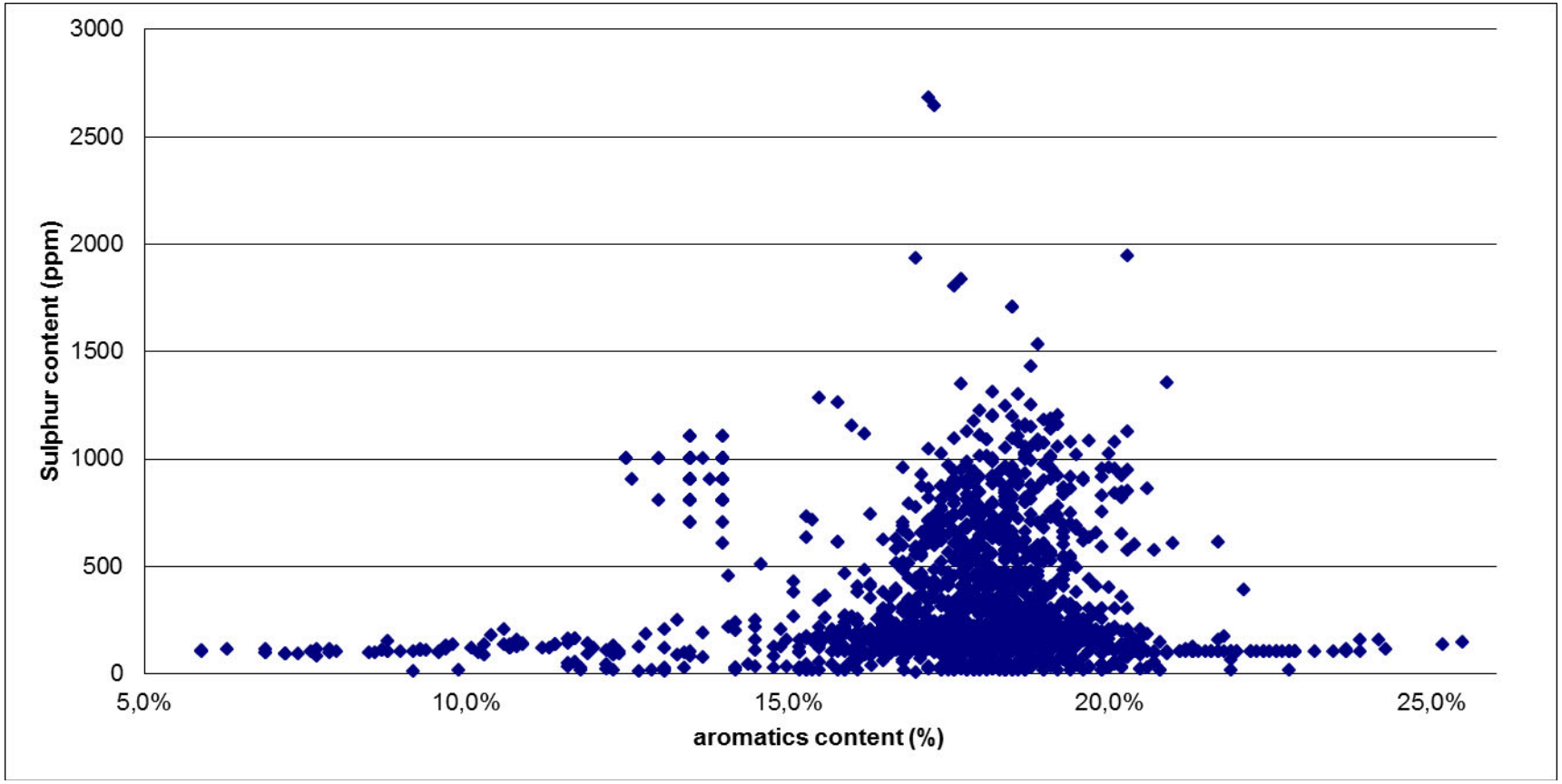
- Mainly low sulphur content, some 50% of observations below 200 ppm
- Range: 1 ppm to 2.676 ppm

Aromatics content



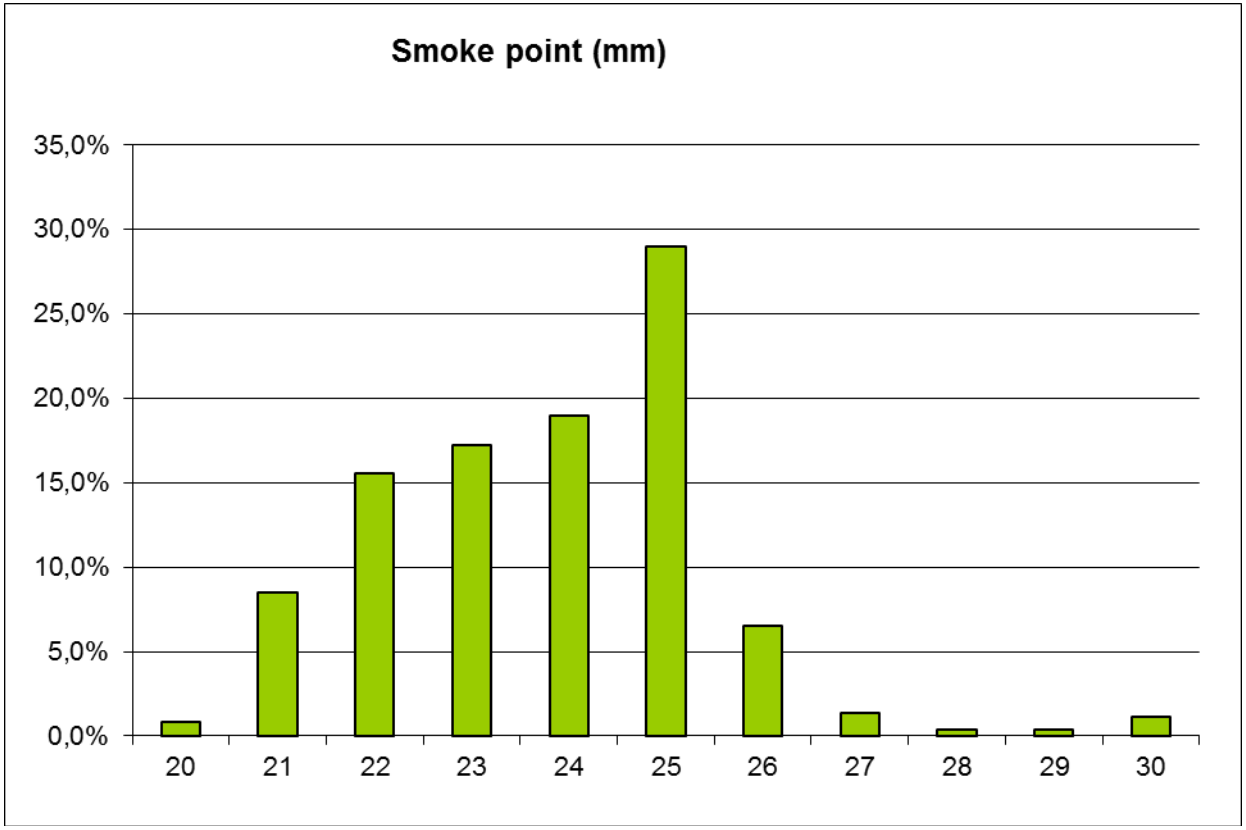
- Range: 5,9% bis 25,5%
- Note: Slight distortion due to existence of two different measuring methods

Distribution of aromatics content and sulphur content



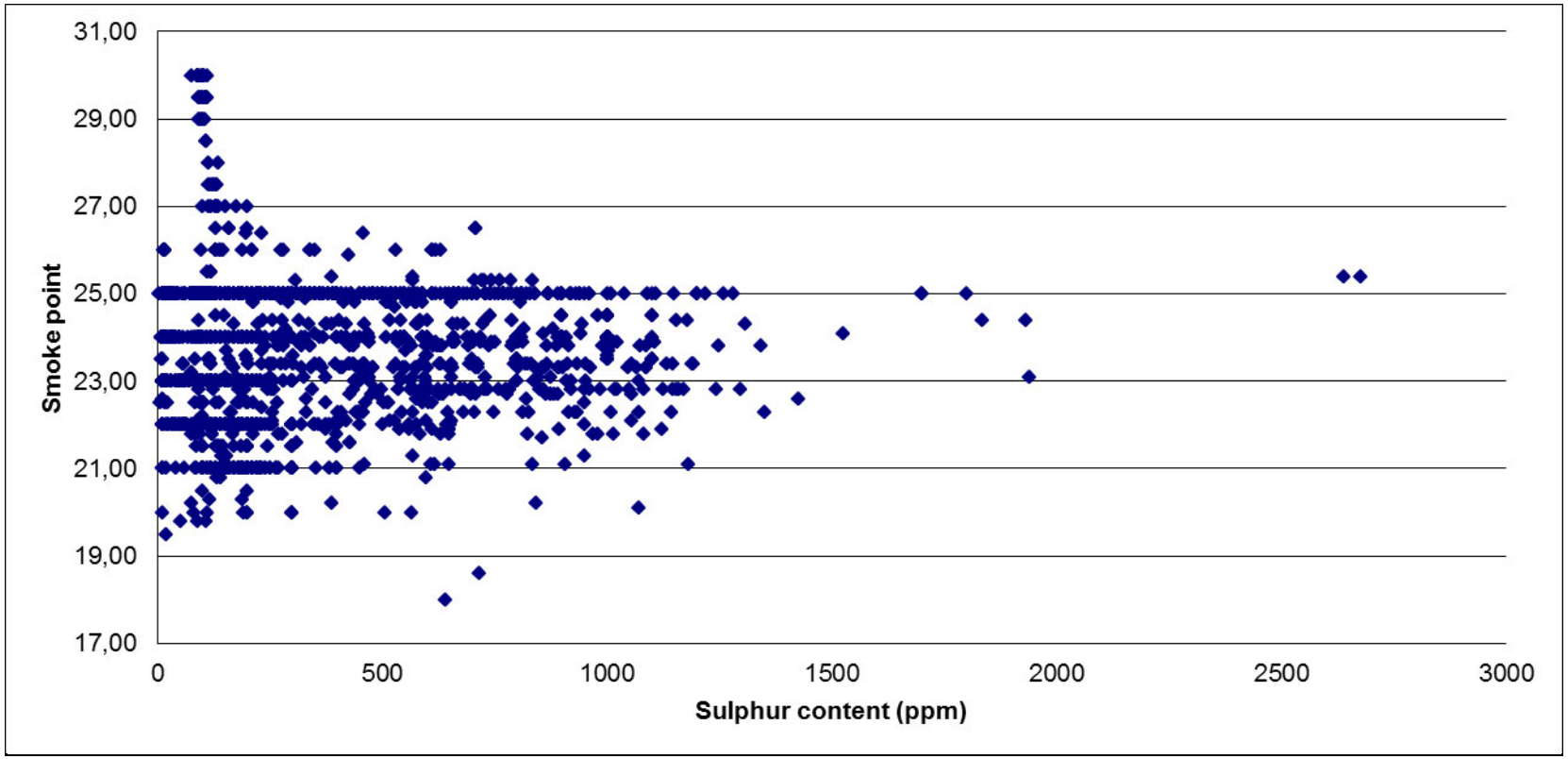
- No recognisable relationship between aromatics content and sulphur content

Smoke point



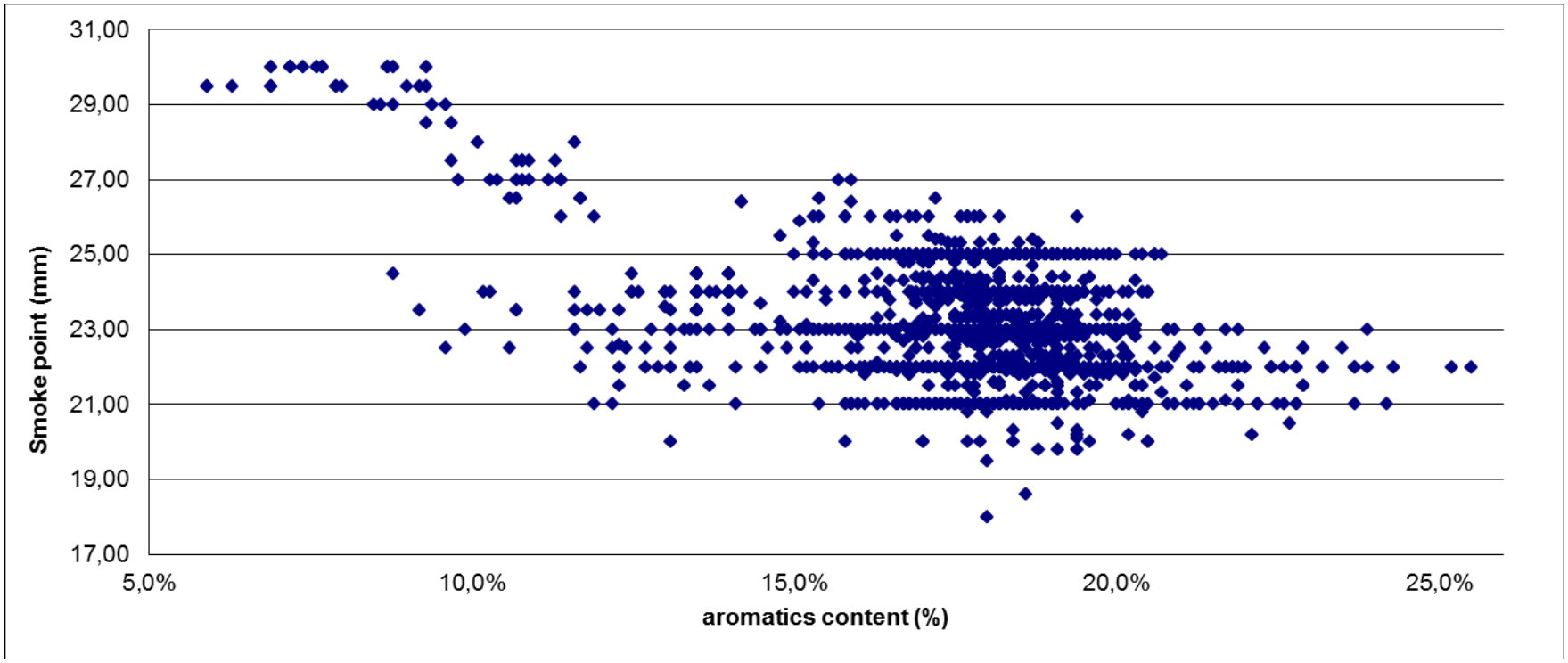
- Range: 18 bis 30
- In many cases only given in full millimeters

Relationship between smoke point and sulphur content



- No recognisable relationship between aromatics content and sulphur content
- Compatible with scientific literature, which found effects of sulphur content on soot formation only at concentrations above 2.000 ppm

Relationship between smoke point and aromatics content



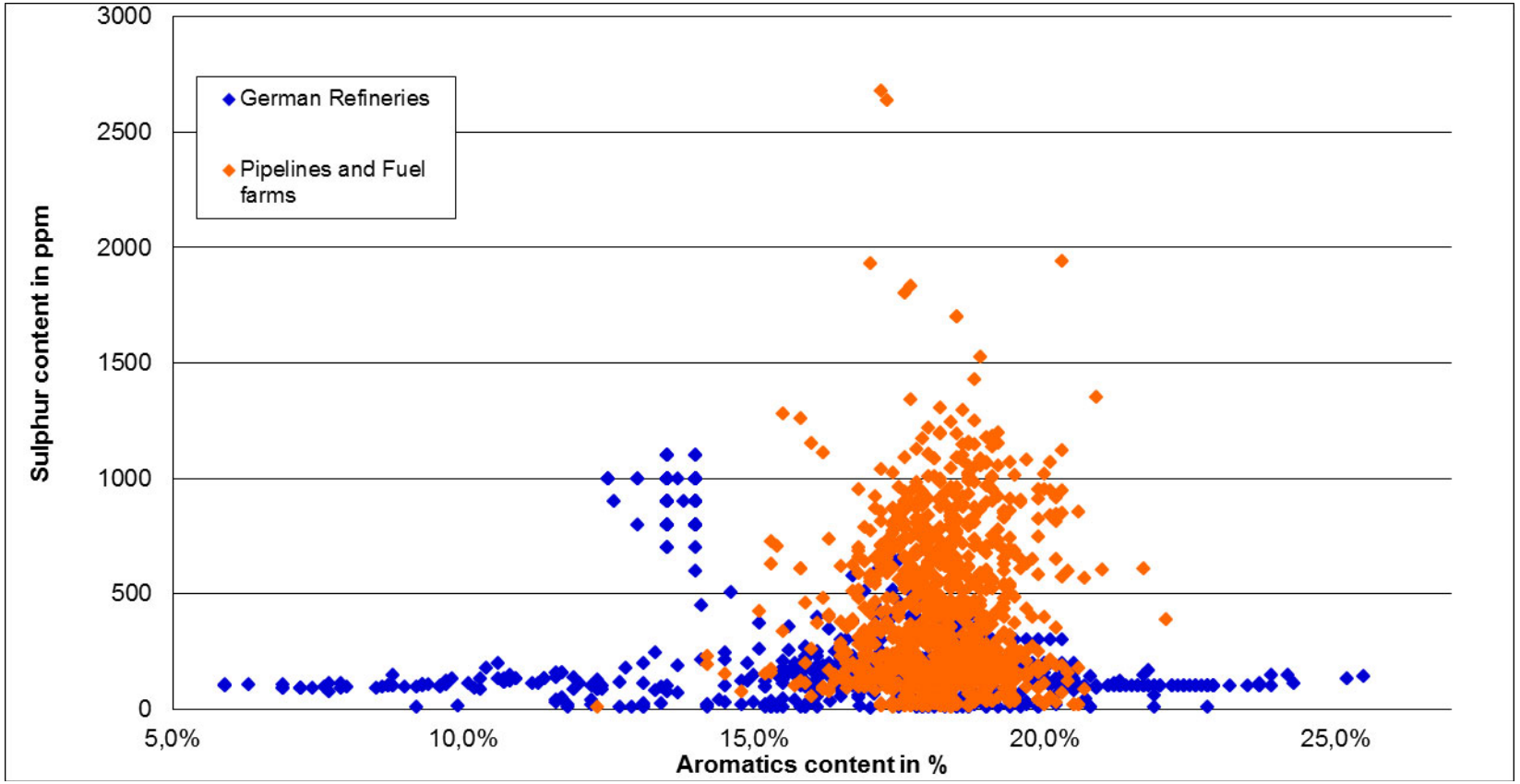
- Evident relationship between aromatics content and sulphur content
- Would probably be better if smoke point figures were not rounded
- High smoke point implies low sooting tendency

Reflections

- Many observations of batches of conventional kerosene with aromatics content below synthetic blends minimum of 8.4%
  - Concentrated at a few airports, where for several months all fuel had aromatics content below 8.4%
  - Went completely unnoticed, no operational issues observed
- Minimum aromatics content for synthetic blends probably too conservative
  - However, no experience with situation where all airports have low aromatics fuel
  - Data for other countries desirable, particularly Asia
- Achievable reduction in So_x by bio kerosene use will depend on properties of conventional kerosene used in blending
  - For blending kerosene with several hundred ppm sulphur content considerable reduction possible
  - For blending kerosene with only a few ppm sulphur content reduction unlikely to be measurable
- Also, modelling of environmental effects needs to take account of existing variability in fuels

Analysing sulphur and aromatics content in detail

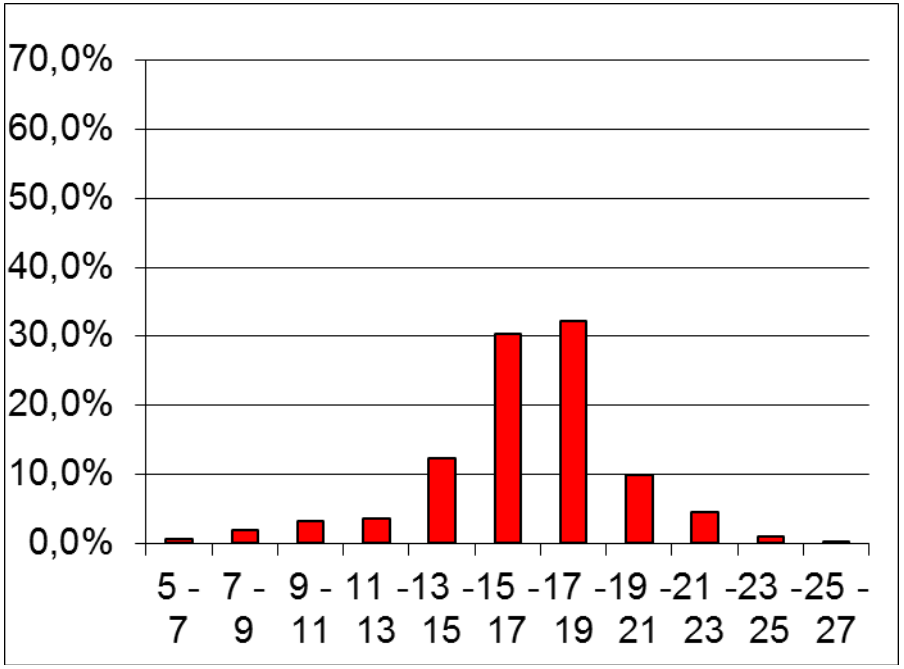
Aromatics content and sulphur content: Production of German refineries vs. Pipelines und tank farms



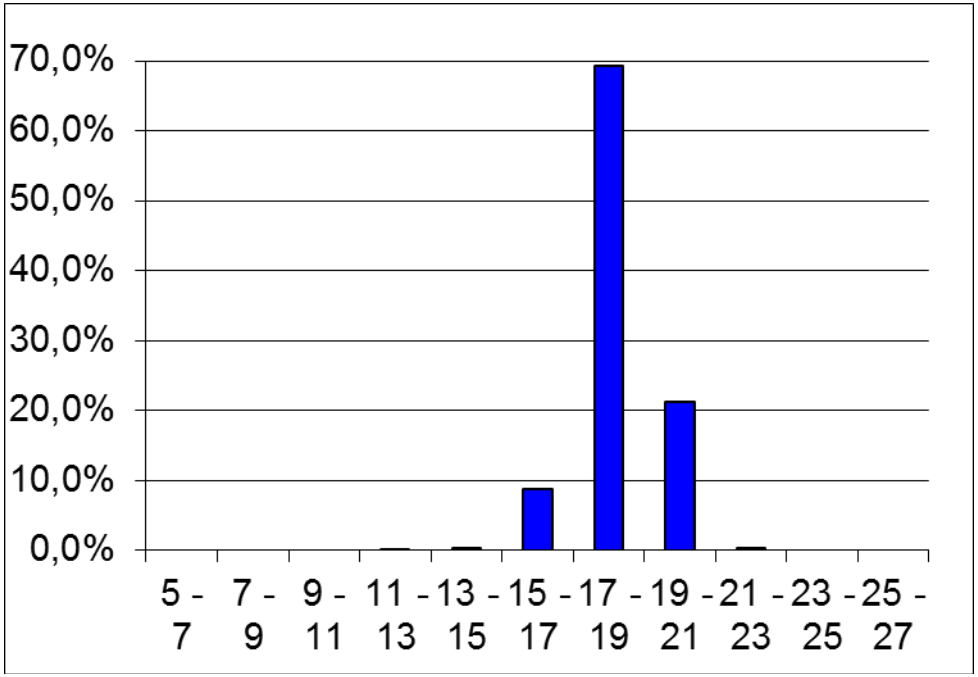
- Data permit distinction between direct deliveries from German refineries and supplies via pipelines and fuel farms (with high import content)
- Distribution is quite different

Distribution of aromatics content

German produktion



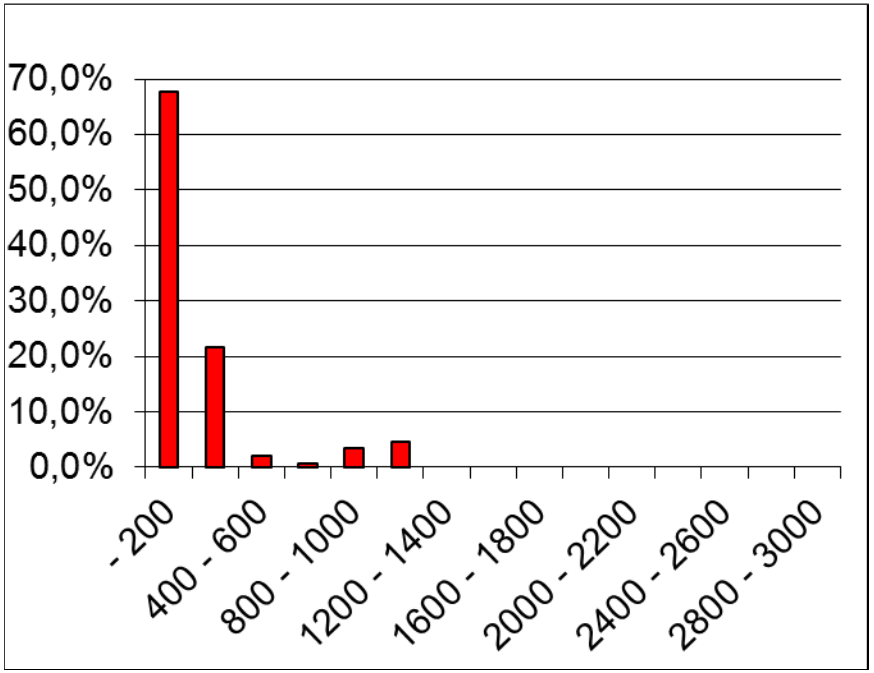
Pipelines and tank farms



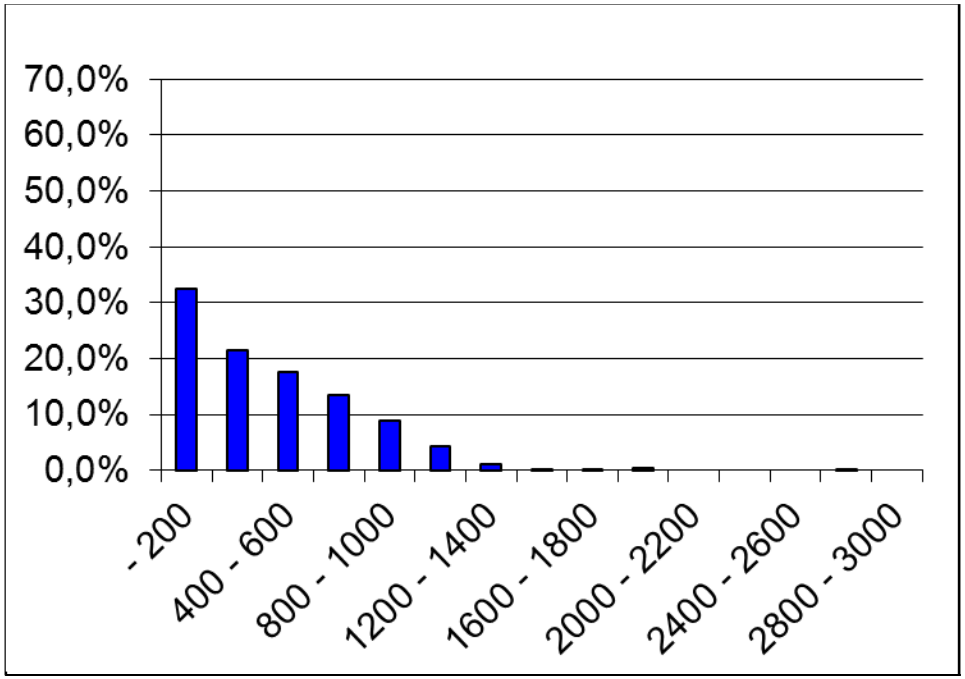
- Large range for production from German refineries
- Fuel from pipelines und tank farms concentrated in middle range, probably due to mixing as fuel passes through the logistics system
- On average, lower aromatics content of fuel produced by Geman refineries
- 49% of all kerosene produced in Germany below 16.8% aromatics content

Distribution of sulphur content

German produktion



Pipelines and tank farms



- Almost 70% of German produktion below 200 ppm, some 90% below 400 ppm
- All observations above 1,100 ppm Kerosene from Pipelines and tank farms

Reflections

- Due to specification minima for lubricity and aromatics content, blending is likely to be easiest for "dirty" kerosenes with high sulphur and high aromatics content

- In Germany, and by anecdotal evidence in most of the EU, this fuel is typically not produced locally

- For some locally produced kerosene batches, no blending possible for even very small percentages

  Further investigation of issue planned as part of blending study for EU

  Consideration of blending logistics needs to be part of any decision on siting bio kerosene production facilities

  Medium term, review of specification minima necessary