The “beReal” test method for pellet stoves

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- Method description
- Results from field demonstration measurements
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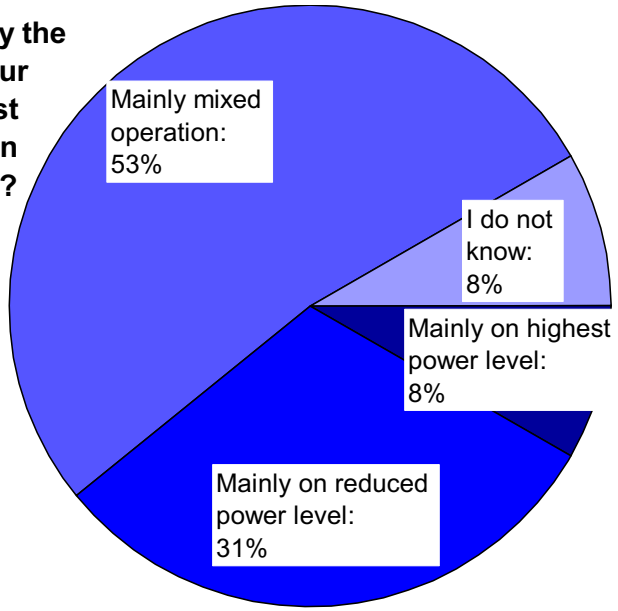
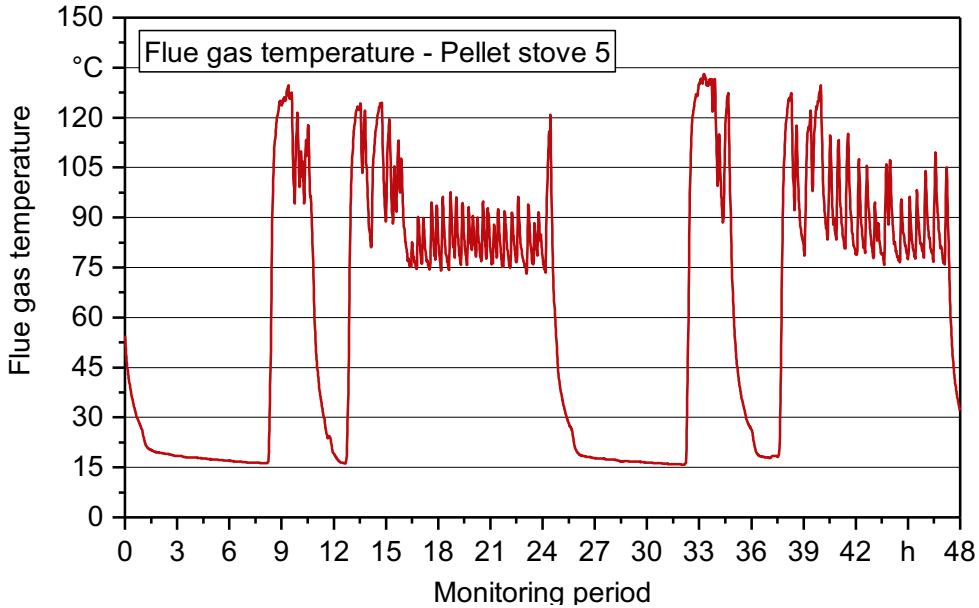
pellet stove (room heater)

The way to beReal – European online survey and field monitoring

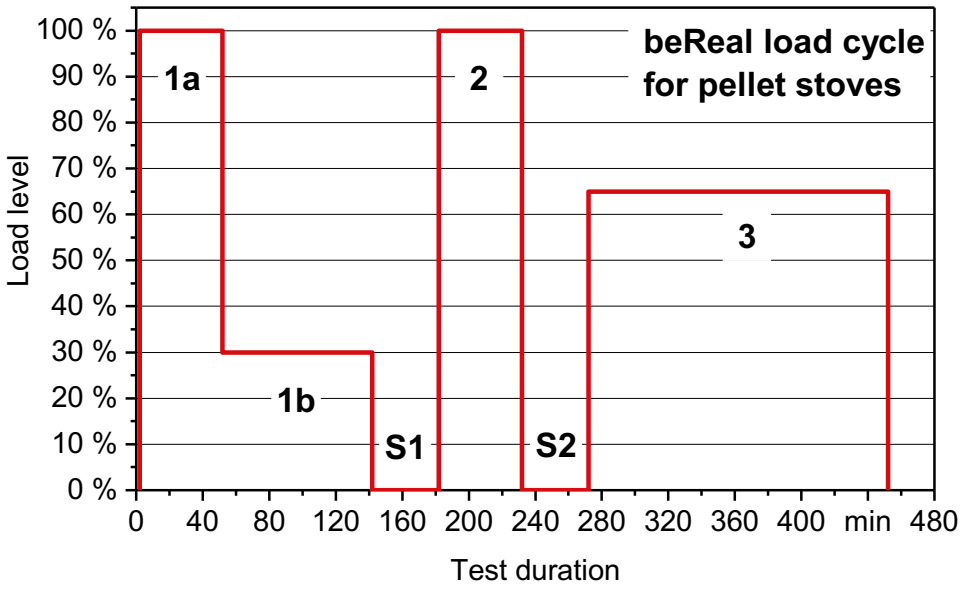
Which is normally the heat output of your stove if you adjust the heat output on the control panel? (n= 120)





- Manual adjustments of the pellet stove power by the user, frequent load changes, start-stop-phases and warm starts occur typically in real life operation.
- Operation is dominated by partial load (90 %) while full load is only achieved during 10 % of the operational hours.
- Steady state operation is rare. Such measurements cannot reflect real life conditions. Also ignition phases happen frequently and need to be regarded.

The developed “beReal” test method (1)



Phase	Operation	Load level*	Duration°
1a	Cold start	High load	50 min
1b	Load change	Low load	90 min
S1	Standby	0%	40 min
2a	Warm start	High load	50 min
S2	Standby	0%	40 min
3	Warm start	Medium load	180 min

° **Duration:** The recording of measurement parameters is launched when starting stove operation (i.e. when pushing the start button for ignition).
The duration of specified phases 1a / 2 / 3 starts when the CO-concentration in the flue gas has risen to 10 ppm.

* **Definition “Load level”:**

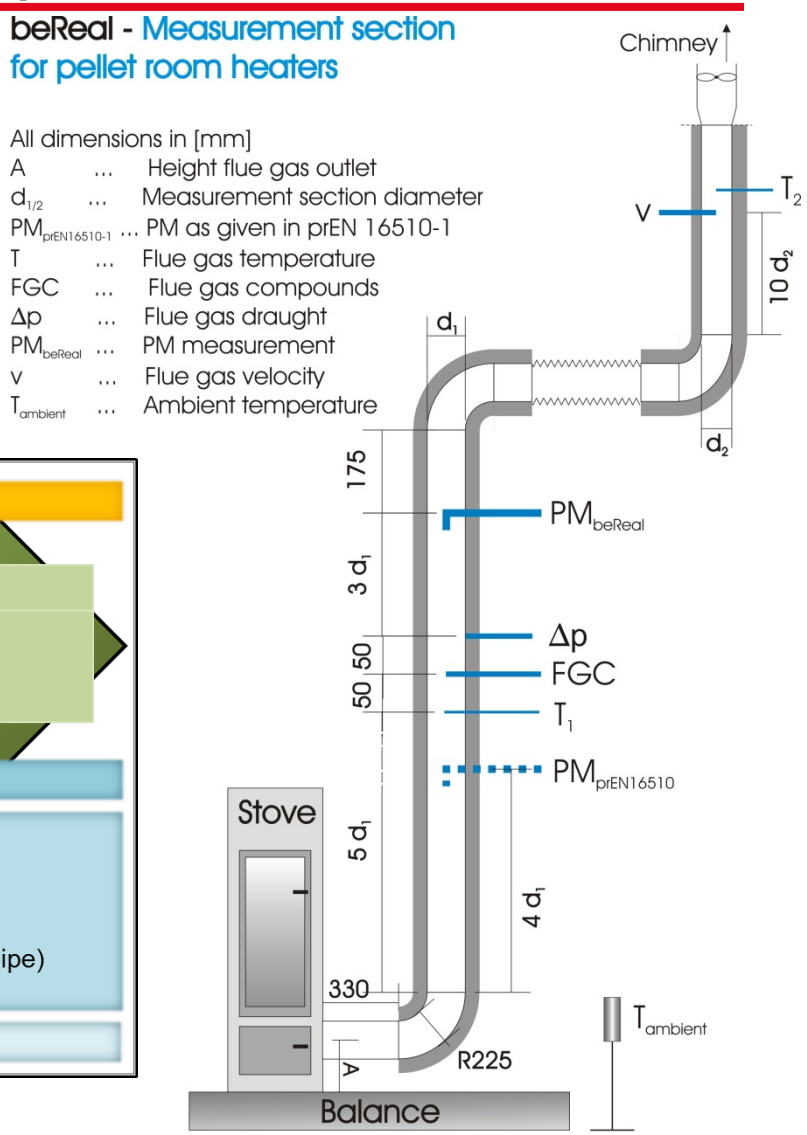
High load = maximum heat output level adjustable by end user,

Low load = minimum heat output level adjustable by end user,

Medium load = heat output level adjustable by the end user closest to the mean between high and low load.

The developed “beReal” test method (2)

Sketch of beReal test stand and experimental setup:



Sketch of the beReal measurement procedure for pellet stoves:

beReal – Pellet room heater – Measurement cycle

Phase 1 a	Phase 1 b		Phase 2		Phase 3
Nominal load – 100 %	Minimum load – 30 %	Stand by	Nominal Load – 100 %	Stand by	Partial load – 65 %
PM 1			PM 2		PM 3

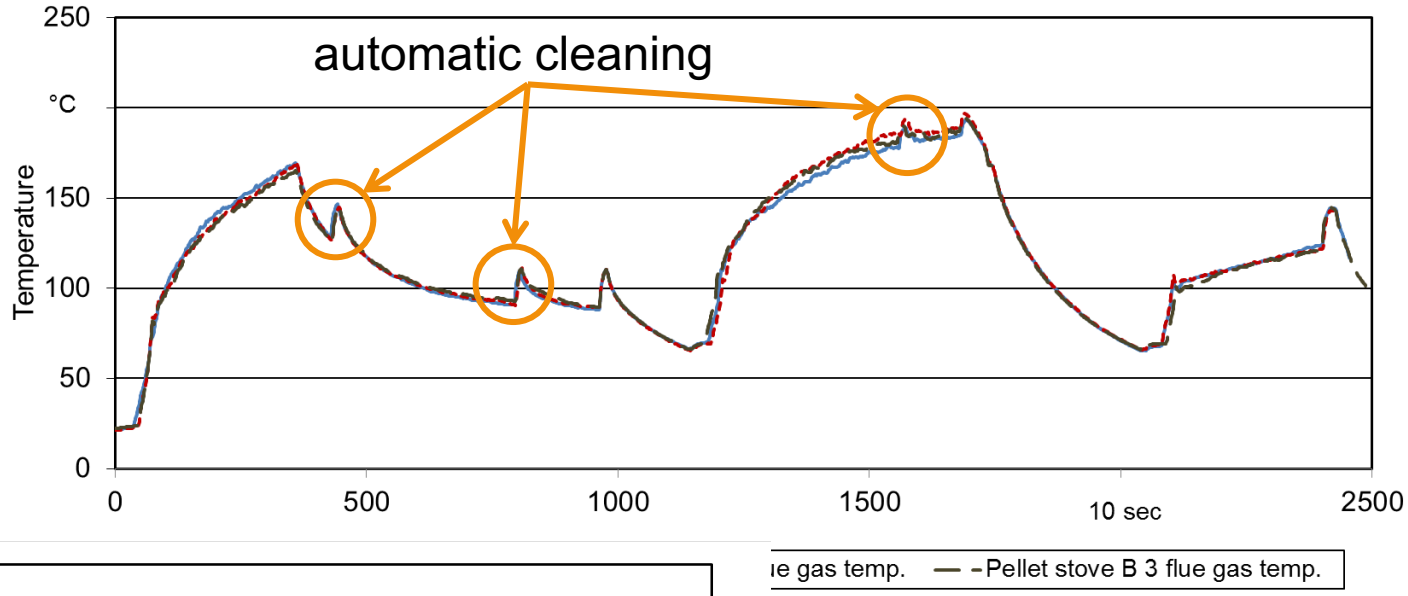
Constant measurement of:

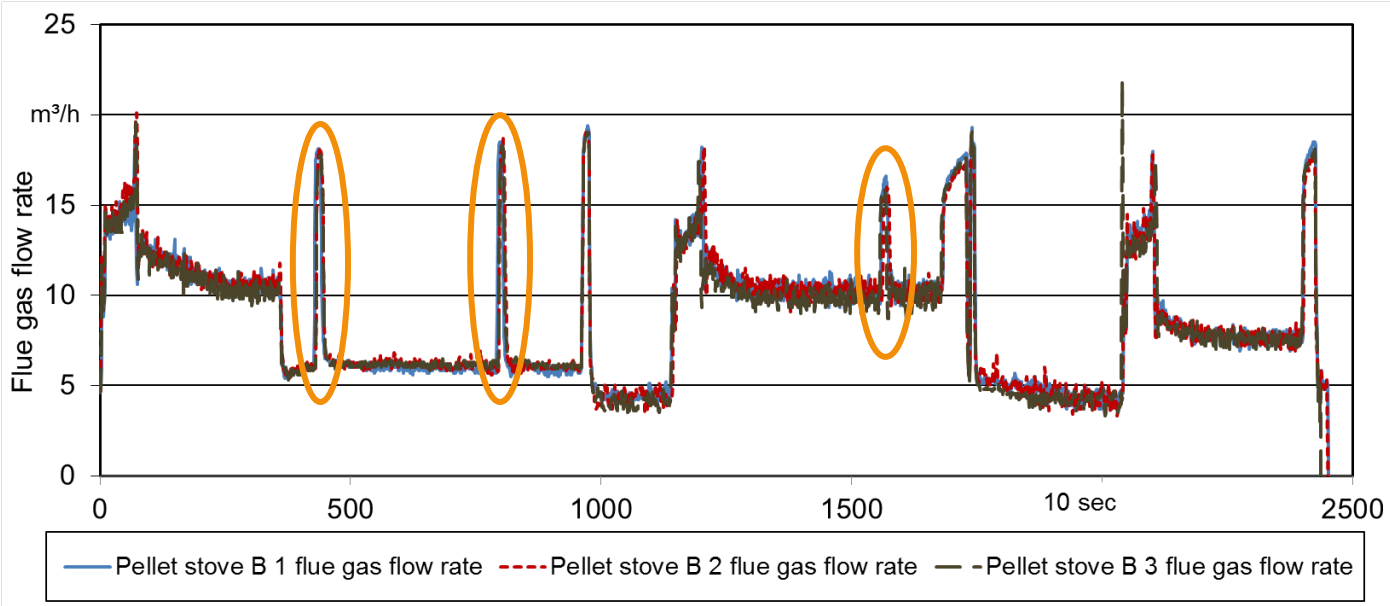
- Gaseous flue gas compounds **FGC**: O_2, CO_2, CO, OGC and NO_x emissions
- Flue gas velocity **v**
- Flue gas temperature T_1 at FGC position and T_2 at velocity measurement position, ambient temperature $T_{ambient}$ (measured with thermocouple, centrally placed in the flue gas pipe)

Discontinuous gravimetric PM measurement at phases 1 (a + b), 2 and 3

Constant controlled flue gas draught (Δp): -12 Pa ± 2 Pa

The developed “beReal” test method (3): Pretesting





Field test campaign – Framework conditions (1)

Purpose:

- Gain data on real-life emissions by performing field tests at typical end users
- Achieve results on the influence of the fuel used
- Compare typical end-user heating behavior with the beReal test procedure to prove appropriateness of the beReal approach as “real-life relevant”
- To rate the official type test results with results from the test stand and from the field test

Framework conditions:

- In total 4 pellet stoves were considered.
- The stoves were installed in Austria, Germany (2 stoves), and Sweden.

Field test campaign – Framework conditions (2)

Procedure:

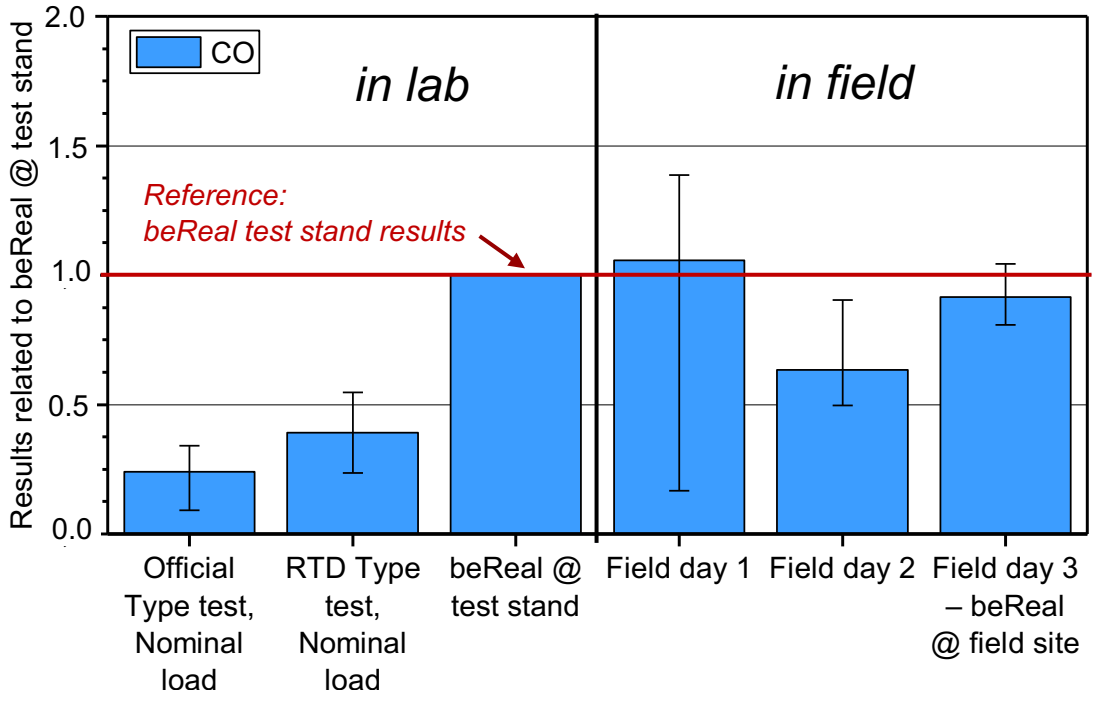
- Stoves were set up in private houses. They were installed in due time to give the end user enough time to obtain own habits and routines with his stove before testing.
- During field measurements emissions (CO, OGC, NO_x, PM) and flue gas velocity were monitored. The flue gas temperature was determined to calculate the efficiency.

Testing schedule:

- Before field testing each stove had initially been tested at the RTD test stand for:
  - RTD-performed type test
  - beReal test procedure in laboratory

- Then at the field testing sites:
  - Field day 1: typical end user behavior in terms of heating procedure and fuel quality
  - Field day 2: typical end user behavior in terms of heating procedure, but fuel supplied by RTD
  - Field day 3: beReal test procedure at field site with RTD fuel

Field test campaign – Measurement results

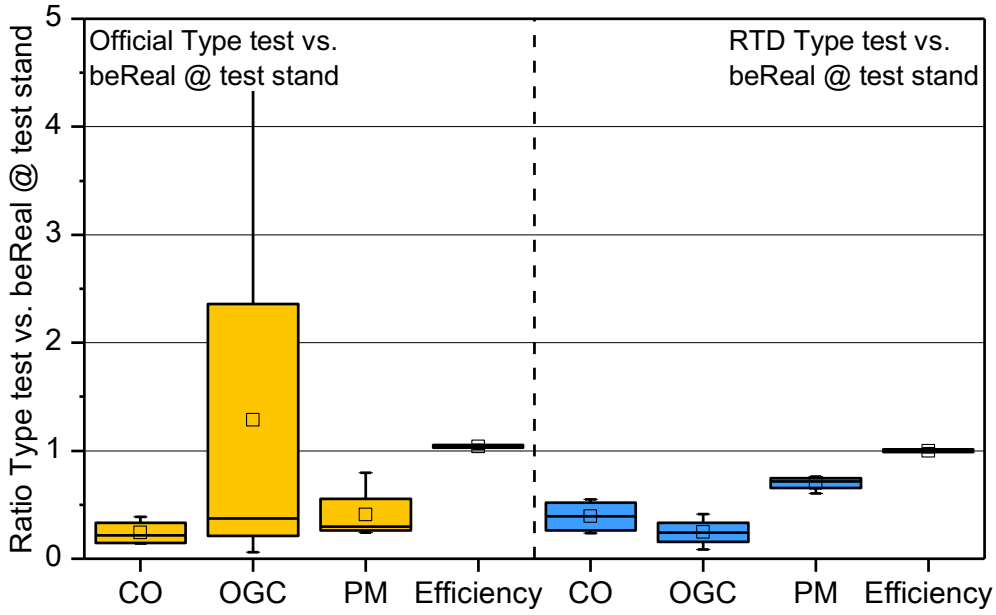


→ Mean value from n=4 'test ratios'. The error bars display minimum and maximum values.

	Official Type test, Nominal load	RTD Type test, Nominal load	beReal @ test stand	Field day 1	Field day 2	Field day 3 – beReal @ field site
CO ($mg/Nm^3 13\%O_2$)	107	166	428	455	269	394
PM ($mg/Nm^3 13\%O_2$)	19	40	56	72	48	49
OGC ($mg/Nm^3 13\%O_2$)	3	3	9	31	5	8
Efficiency (%)	91	87	88	85	86	86

Field test campaign – Summary and conclusion

- The pellet fuel used influences the emission results considerably (see results from field day 1 vs. field day 2).
- The beReal lab test cycle nicely complies with typical end user behaviour (day 1). This indicates that the beReal method can reflect typical real life heating behavior.
- Deviations between beReal tests performed at the test stand and those performed in the field (day 3) should to be attributed to influences from natural draught and variable site conditions.
- No constant conversion factor between type test and beReal results can be found. Such ratios are highly stove dependent.



Round robin test – Framework conditions (1)

Objective and definition:

- The objective of the round robin was to verify
  - The reproducibility of the type test
  - The reproducibility and the repeatability of the beReal test method
  - The influence and effect of fuel quality

- **Repeatability**: How good can the method be repeated within a single laboratory
  (s_r = repeatability standard deviation; r = repeatability limit (confidence interval based on s_r))
- **Reproducibility**: How good can the method be reproduced between laboratories
  (s_L = between laboratory standard deviation; CV_L = between laboratory coefficient of variation = 100 * s_L/X;
  s_R = reproducibility standard deviation; CV_R = reproducibility coefficient of variation = 100 * s_R/X)
- The analysis involves each main parameter defined as outcome from the test procedure: CO, OGC, NO_x, PM and Efficiency

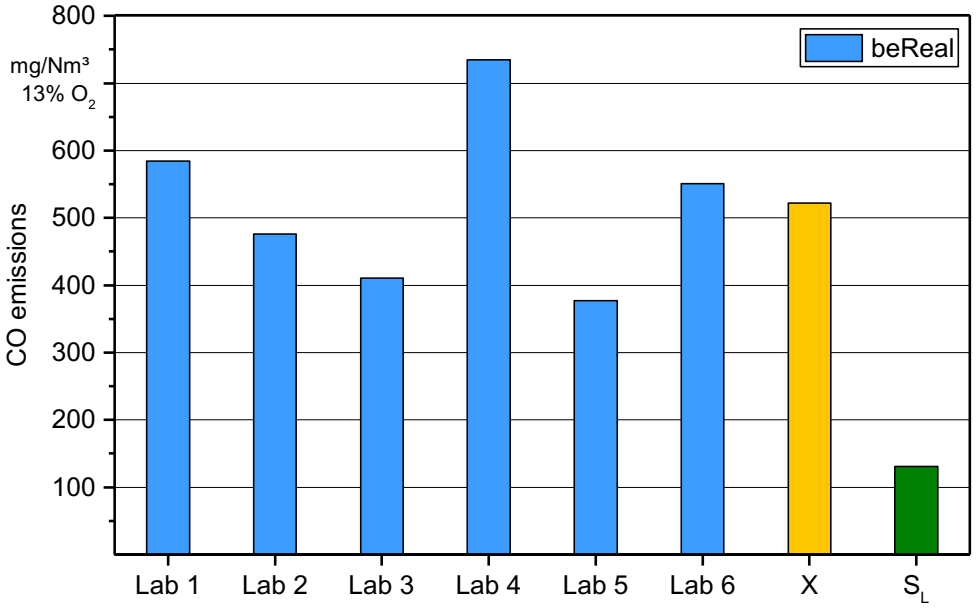
Round robin test – Framework conditions (2)

Procedure:

- One pellet stove was investigated at six participating test institutes (incl. three notified bodies) in four countries (D, A, DK, S)
- Three days of measurements were performed:
  - beReal using uniform test fuel,
  - beReal using local fuel,
  - Type test (acc. to prEN 16510) using uniform test fuel (3 x nominal load and 3 x partial load)
- The first partner performed a test at the beginning and at the end of the round robin, to secure comparable results.

Round robin test – CO measurement results

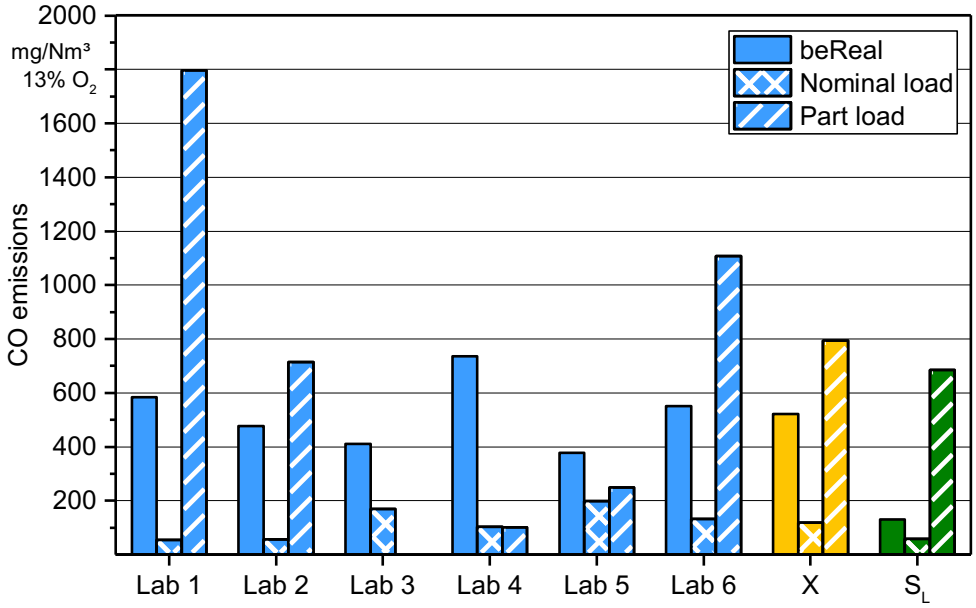
Results from beReal measurement



Results from round robin measurements for beReal method with test fuel for CO emissions for:

- Six participating institutes (lab 1 – lab 6)
- Mean value X
- between-laboratory standard deviation s_L

Results from beReal vs. type test (NL & PL)



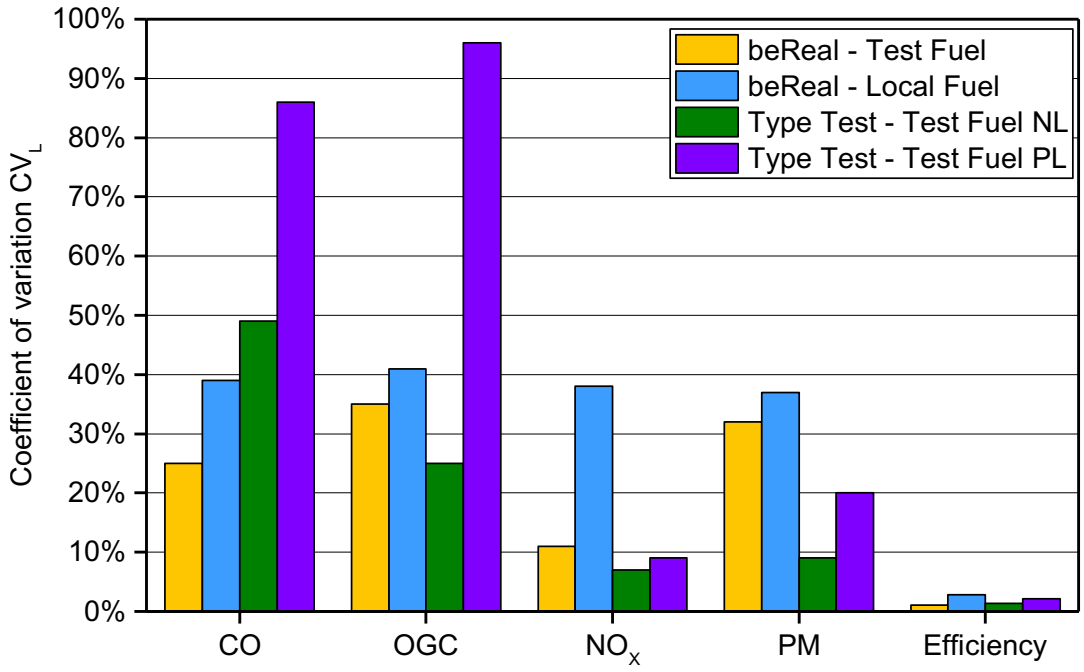
Results from round robin measurements with uniform test fuel

(NL: nominal load, PL: partial load)

Round robin test – Summary and conclusion

- The best reproducibility for the emissions is achieved for NOx, followed by CO, PM and OGC for the pellet stove.
- Reproducibility values for the beReal method can be as are high or even higher than for type testing results (for CO, OGC, efficiency), although load changes happen.
- The use of local pellets generally leads to higher variations compared to test pellets
  - → a common test fuel with clearly defined properties leads to an increased reproducibility
  - → clear test fuel definitions could be considered.

Reproducibility (pellet stove):



beReal method for pellet stoves – Advantages and conclusions

- The method **reflects the real life user behavior more realistically:**
  - Measuring periods include **ignition and burn out phases**.
  - The beReal method includes **different load levels and load changes**.
  - **Cleaning intervals** are considered.
- Measurment results do not need to be differentiated for nominal and partial load operation (**only one measurement value**).
- The measured **operation times are sufficiently long** and therefore more meaningful.
- Measuring a whole cycle **prohibits selecting of phases** with best test results.
- **Strict requirements** are given for the fuel, for the measurement setup, and for the measurement procedure.
- An **increased repeatability** is achieved by considering a complete cycle.
- **High quality stoves can easier be distinguished from low quality appliances**

Thank s for listening !

www.bereal-project.eu

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