Technologie- und Förderzentrum
im Kompetenzzentrum
für Nachwachsende Rohstoffe

Fuel quality and combustion behaviour of pure and kaolin additivated pellets from fen paludicultures in a small-scale biomass boiler

9th of March 2021

Dr. Daniel Kuptz, Carina Kuchler, Elisabeth Rist, Claudia Schön, Dr. Hans Hartmann

Research project MOOR*use*

MOOR*use*: Paludiculture on fen peatlands in Bavaria – plant establishment, climate impact and environmental effects, utilization and economics

Duration: 01.03.2016 - 31.12.2022

Coordination:

WEIHENSTEPHAN · TRIESDORF
University of Applied Sciences

Project partner:

LfL TFZ Fraunhofer IBP

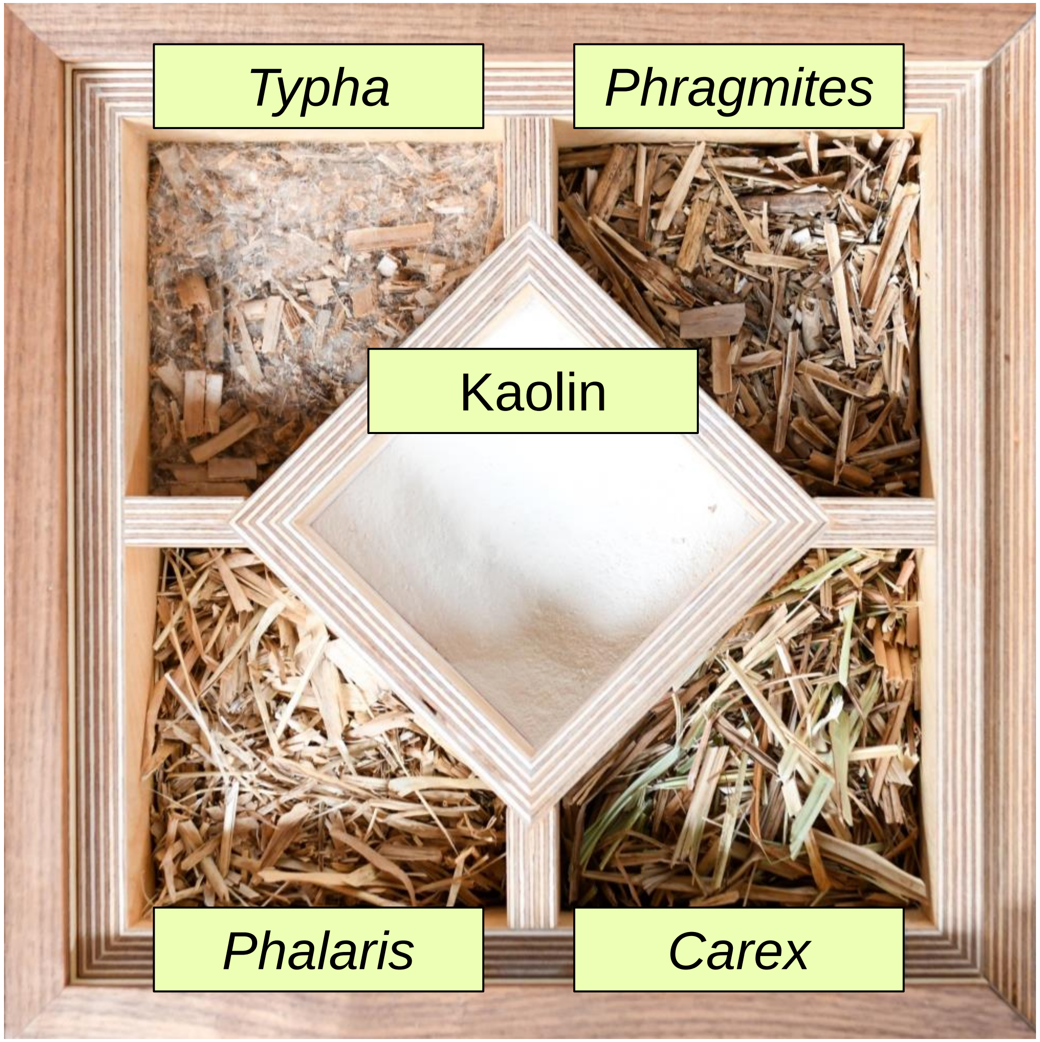
TUMCS Arbeitsgemeinschaft Schwäbisches Donaumoos e.V. Donaumoos Zweckverband *Heimat* verbindet.

Funding:

Bayerisches Staatsministerium für Umwelt und Verbraucherschutz

Europäische Union
Europäischer Fonds für regionale Entwicklung
EFRE BAYERN 2014 – 2020
www.efre-bayern.de

Materials and methods



Four fen paludicultures from Freisinger Moos were combusted as pure and additivated pellets in a 30 kW biomass boiler

- *Typha ssp.*
- *Phragmites australis*
- *Phalaris arundinacea*
- *Carex ssp.*

Evaluation of emission behaviour and slagging tendencies

Milling of the paludiculture biomass

Additivation of milled straw with kaolin and water

Pelletization with an Amandus Kahl pellet mill

Carex pellets with a diameter of 6 mm

Background: Kaolin as an additive for combustion

Potassium (K) is the main aerosol forming element in biomass fuels leading to increased total particle emissions (TPM emissions).

Additivation with kaolin might decrease aerosol formation as K is fixed in the ash.

$$\mathbf{Al_2Si_2O_5(OH)_4} \leftrightharpoons Al_2O_3 \cdot 2SiO_2 + 2H_2O$$

$$Al_2O_3 \cdot 2SiO_2 + \mathbf{2KCl} + 2H_2O \leftrightharpoons 2KAlSiO_4 + 2HCl$$

$$Al_2O_3 \cdot 2SiO_2 + 2SiO_2 + \mathbf{2KCl} + 2H_2O \leftrightharpoons 2KAlSi_2O_6 + 2HCl$$

$$Al_2O_3 \cdot 2SiO_2 + \mathbf{K_2SO_4} \leftrightharpoons 2KAlSiO_4 + SO_3$$

Additivation levels for paludiculture pellets were applied according to the guidelines of the ERANET- project „Bioflex!“

Paludiculture pellets

T. ssp. | *P. australis* | *P. arundinacea* | *C. ssp.*

Without kaolin

With kaolin

Physical fuel properties of paludiculture pellets

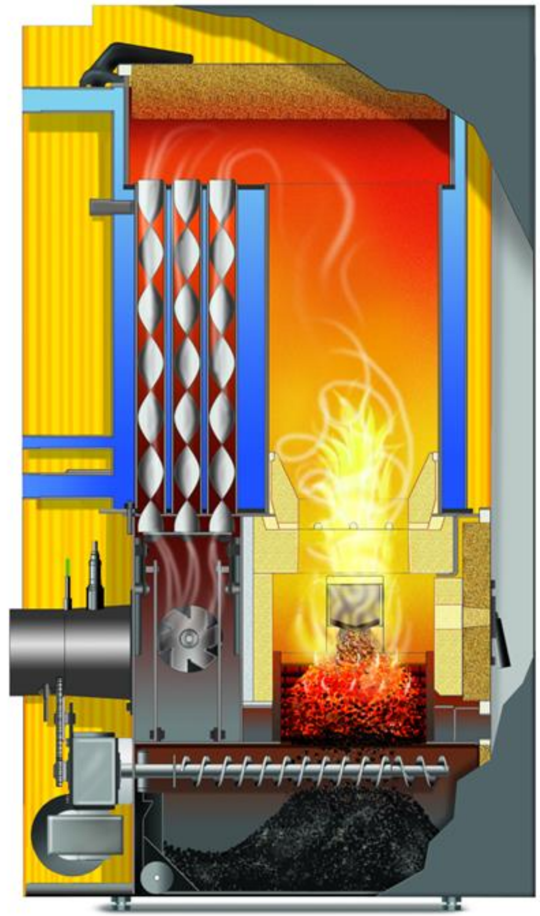
Fuel	Kaolin w-%, d.b.	Moisture content w-%	Bulk density kg/m³ (a.r.)	Ash content kg/m³ (a.r.)	Net cal. value kg/m³ (a.r.)	Mech. durability kg/m³ (a.r.)
ISO 17225-2 (A1) ISO 17225-6 (A) ISO 17225-6 (*P. arundinacea*)	-	≤ 10 ≤ 12 ≤ 12	≥ 600 ≥ 600 ≥ 550	≤ 0.7 ≤ 6.0 ≤ 8.0	≥ 16,5 ≥ 14,5 ≥ 14,5	≥ 97.5 ≥ 97.5 ≥ 96.5
Wood pellets (EN*plus* A1)	-	7.9	683	0.3	18.9	99.3
Wheat straw pellets	-	8.8	625	4.2	17.5	96.4
Typha ssp.	-	7.8	781	6.8	17.6	99.0
Phragmites australis	-	5.9	787	6.8	17.3	98.8
Phalaris arundinacea	-	5.5	796	4.8	17.9	98.7
Carex ssp.	-	5.4	790	5.2	17.8	99.3
Typha ssp. + Kaolin	2.3	11.8	787	4.3	18.2	99.0
Phragmites australis + Kaolin	0.6	7.7	747	7.1	17.5	98.9
Phalaris arundinacea + Kaolin	1.2	6.0	780	5.6	18.0	98.6
Carex ssp. + Kaolin	1.5	8.3	772	7.1	17.7	99.0

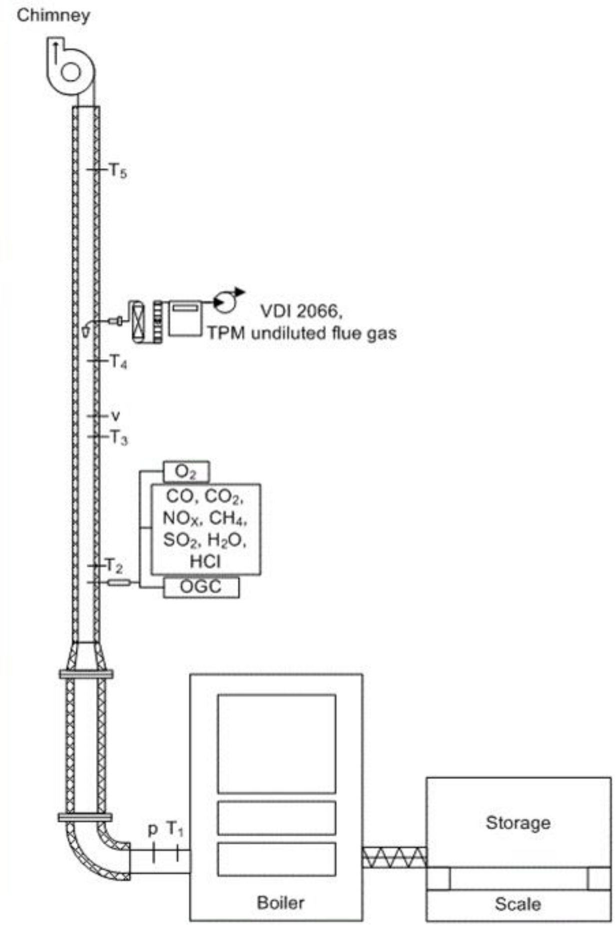
Chemical fuel quality of paludiculture pellets

Fuel	N w-%, d.b.	S w-%, d.b.	Cl w-%, d.b.	Al mg/kg, d.b.	K mg/kg, d.b.	Si mg/kg, d.b.
ISO 17225-2 (A1) ISO 17225-6 (A) ISO 17225-6 (*P. arundinacea*)	< 0.3 < 1.5 < 2.0	< 0.04 < 0.20 < 0.20	< 0.02 < 0.10 < 0.10	-	-	-
Wood pellets (EN*plus* A1)	0.1	0.01	0.01	25	414	166
Wheat straw pellets	0.4	0.07	0.21	145	8,450	9,460
Typha ssp.	1.0	0.09	0.20	262	1,420	681
Phragmites australis	0.6	0.07	0.07	171	740	11,800
Phalaris arundinacea	1.3	0.14	0.09	568	2,150	8,460
Carex ssp.	1.2	0.17	0.19	172	2,460	9,070
Typha ssp. + Kaolin	1.0	0.09	0.20	4,062	1,661	5,246
Phragmites australis + Kaolin	0.6	0.07	0.07	1,128	805	12,885
Phalaris arundinacea + Kaolin	1.2	0.14	0.09	2,568	2,268	10,773
Carex ssp. + Kaolin	1.1	0.11	0.18	2,654	2,602	11,925

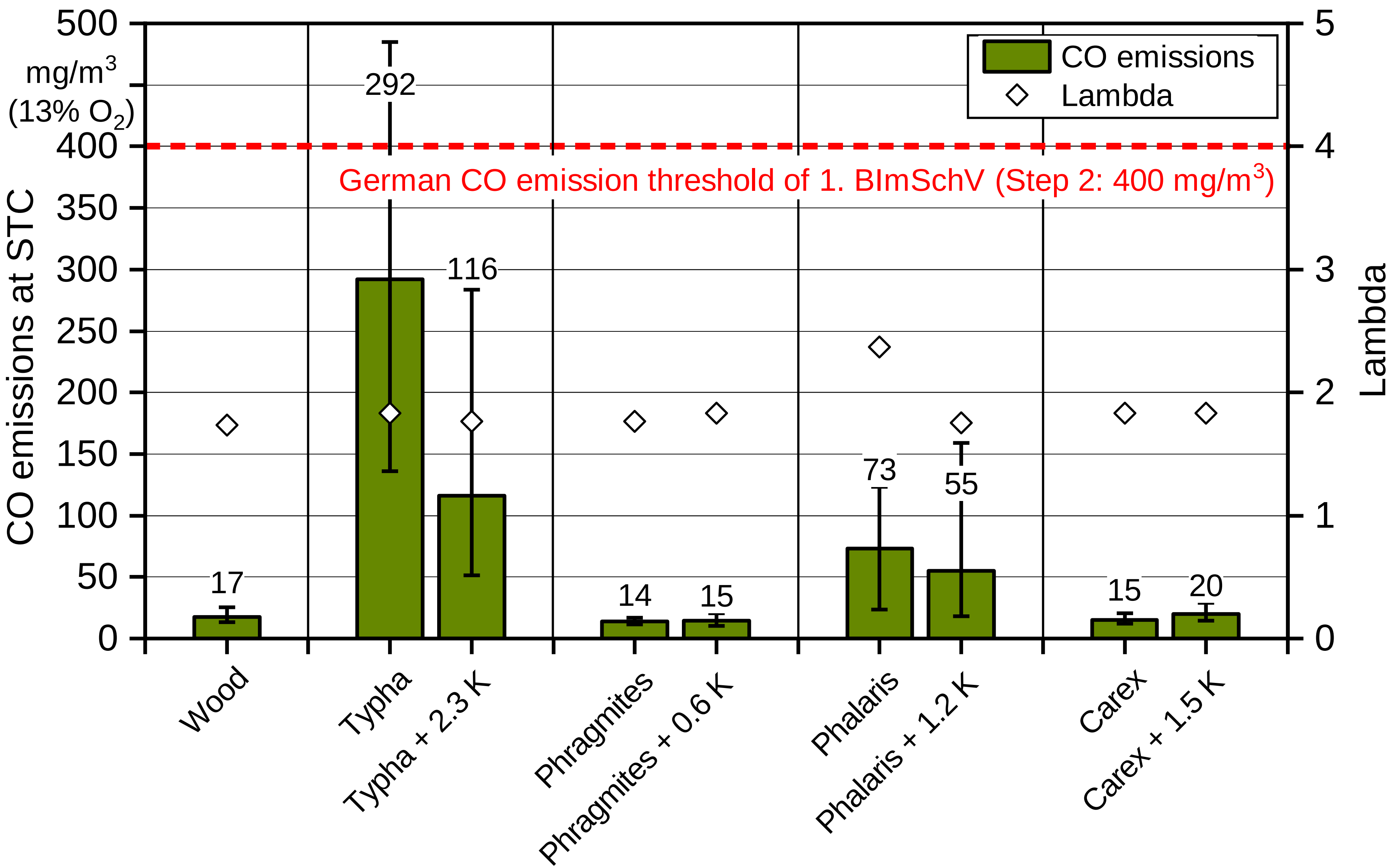
Combustion trials

- Boiler: Guntamatic Powerchip 20/30 (30 kW), suitable for wood and agricultural fuels
- Pre-heating phase of 2 h
- Nominal load phase of 6 h
- Continuous gas measurement throughout trial: CO, CO_2, O_2, NO_X, HCl, CH_4
- 5 samples for total dust emissions according to VDI 2066
- Granulometric analysis of total ash

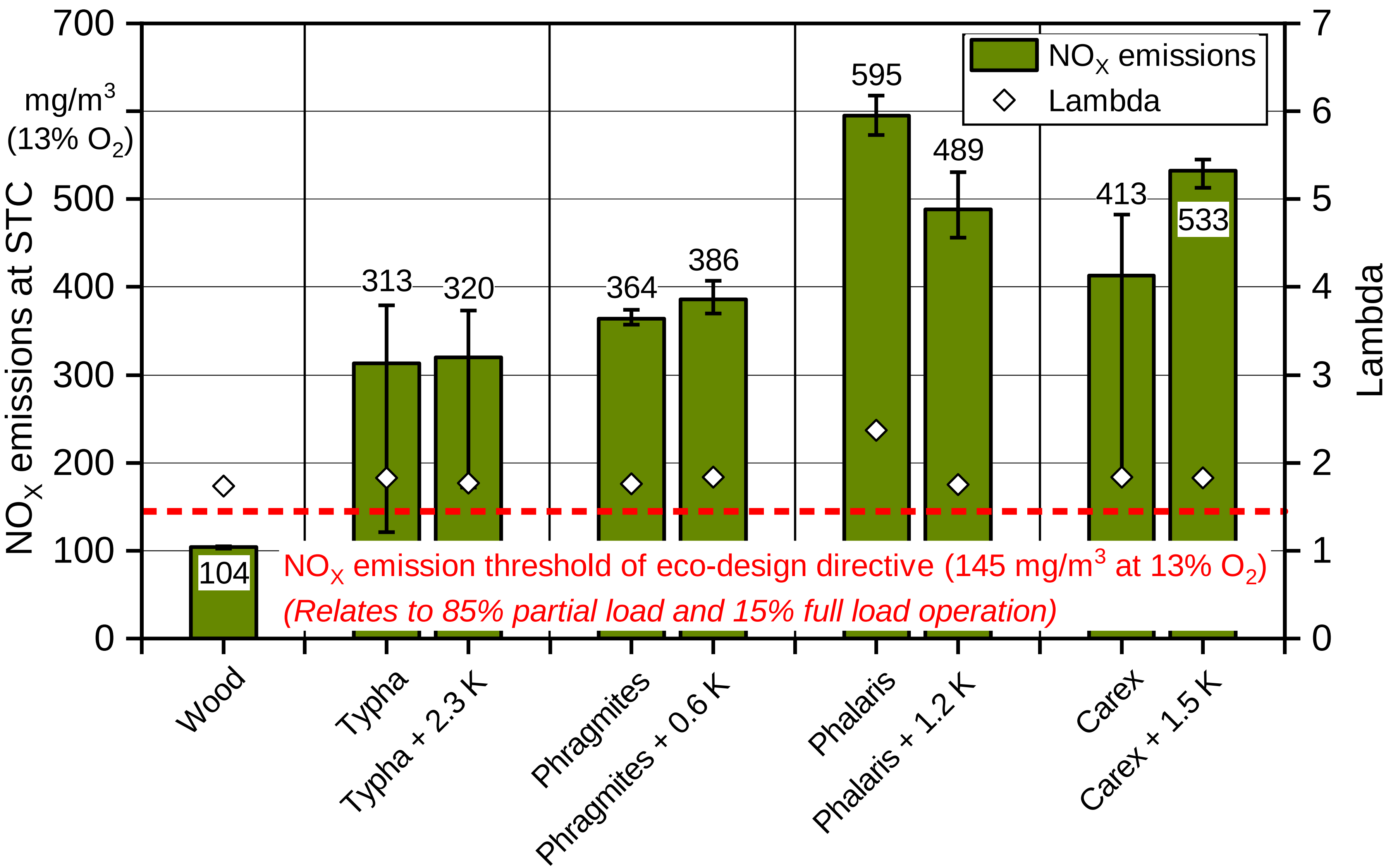




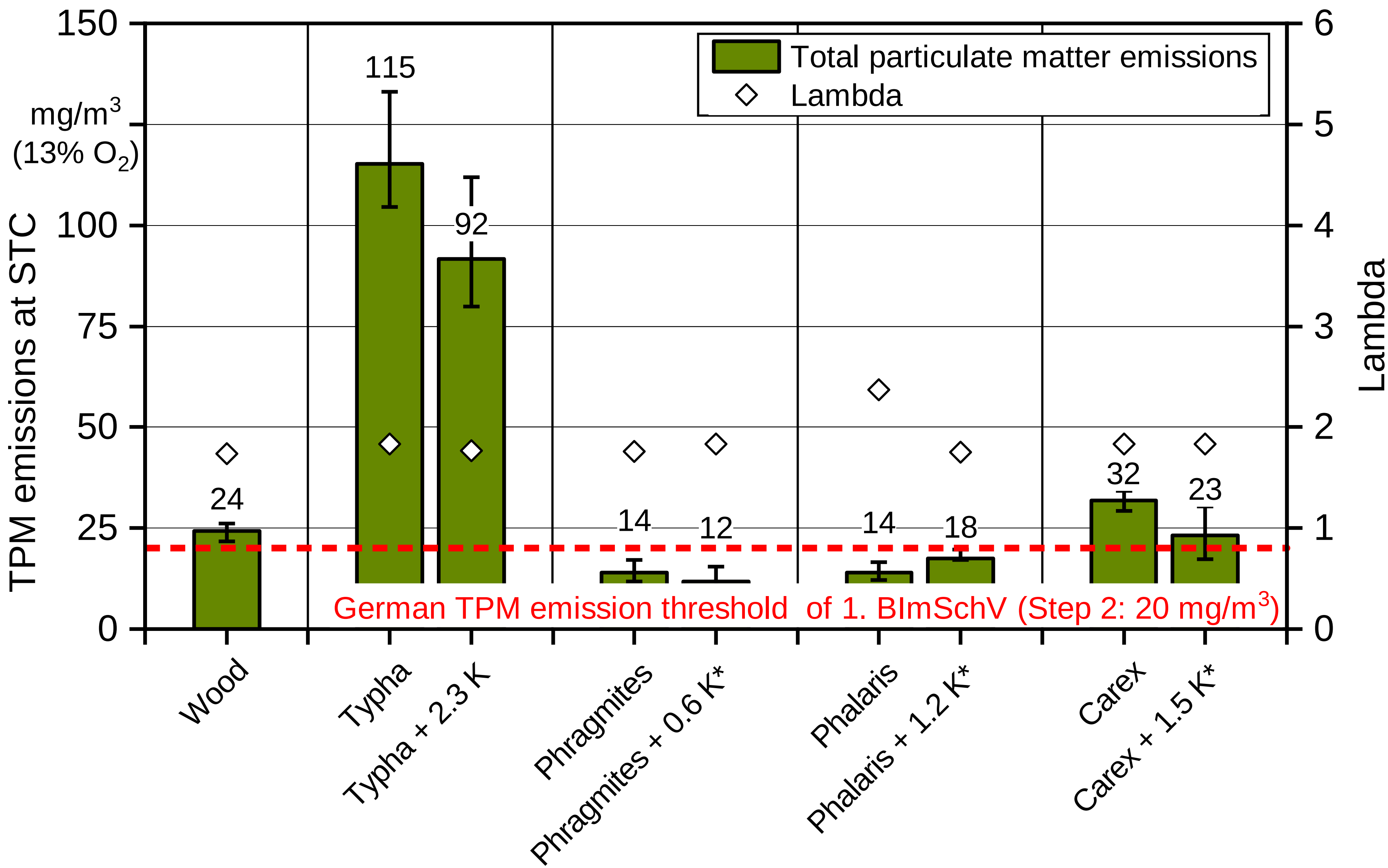
CO emissions



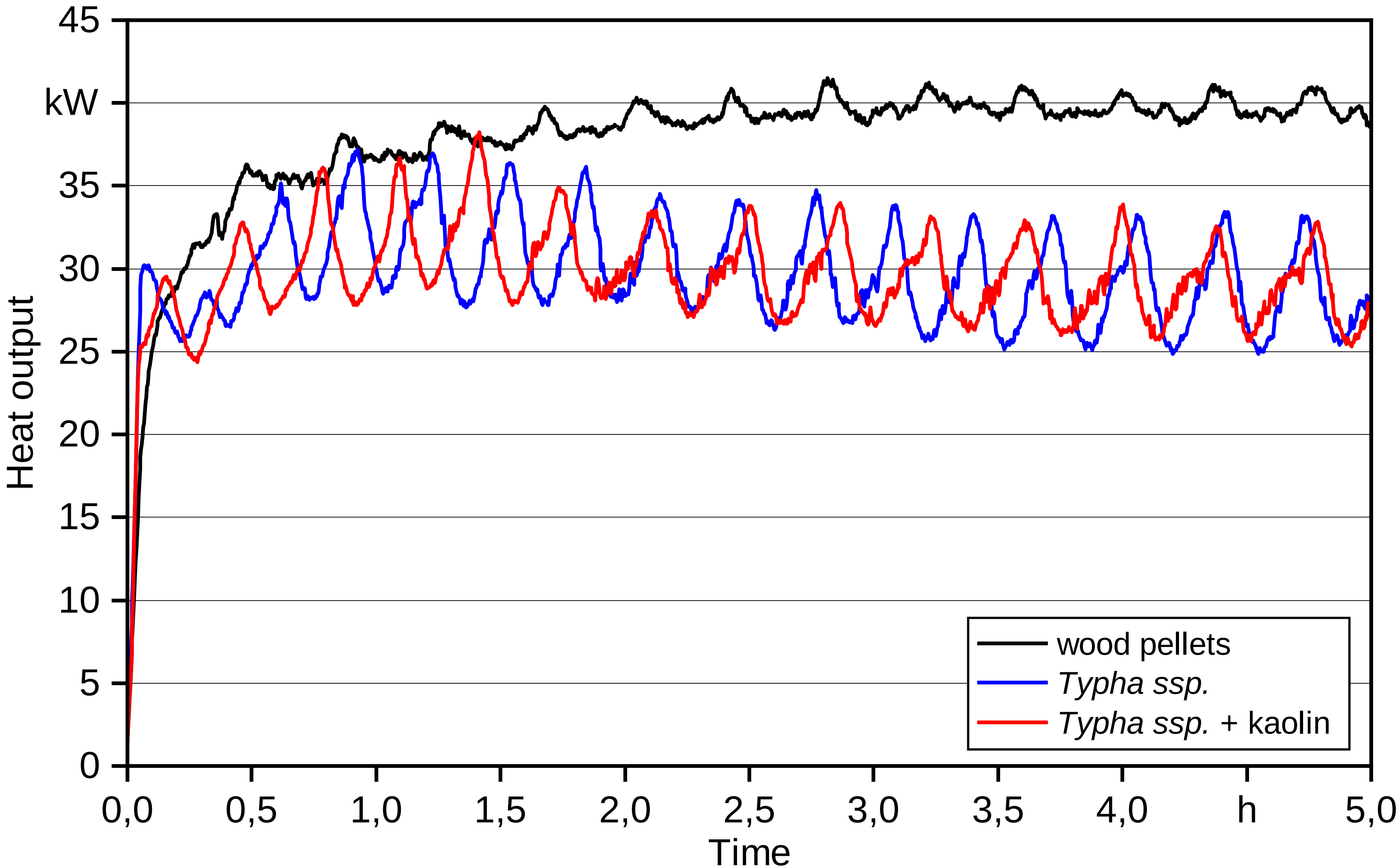
NO_X emissions



Total particle emissions



Heat output



45
kW
35
30
25
20
15
10
5
0
Heat output
0,0
0,5
1,0
1,5
2,0
2,5
3,0
3,5
4,0
h
5,0
Time
wood pellets
Typha ssp.
Typha ssp. + kaolin

Slag formation in the boiler (example: *P. arundinacea*)

Summary and conclusion

- Fuel quality of paludiculture pellets met the specifications of ISO 17225-6, i.e. the current ISO standard for solid biofuel pellet from agricultural biomass.
- Combustion of *Typha ssp*. led to high CO and total particle emissions while combustion of *Phragmites australis*, *Phalaris arundinacea* and *Carex ssp*. led to extreme slagging.
- NO_X emissions were increased for all four biomasses compared to the use of certified wood pellets.
- Additivation with kaolin did not improve combustion. Higher additivation levels, fuel blendings (with wood) or technical solutions are needed.
- Paludicultures are a challenging fuel for small-scale application. Legally, their use as a biofuel in Germany is currently limited to boilers > 100 kW as no boiler < 100 kW is tested (so far) for these fuels according to German legislation.
- Technical solutions to improve combustion behaviour might be easier applied in larger facilities.

Thank you for your attention

Dr. Daniel Kuptz
Technologie- und Förderzentrum
im Kompetenzzentrum für Nachwachsende Rohstoffe (TFZ)
Schulgasse 18, 94315 Straubing
Email: daniel.kuptz@tfz.bayern.de
Internet: www.tfz.bayern.de
Tel.: 09421 / 300-118

Ash particle size