Pilot-scale upgrading of landfill gas and sequestration of CO_2 by MSWI bottom ash

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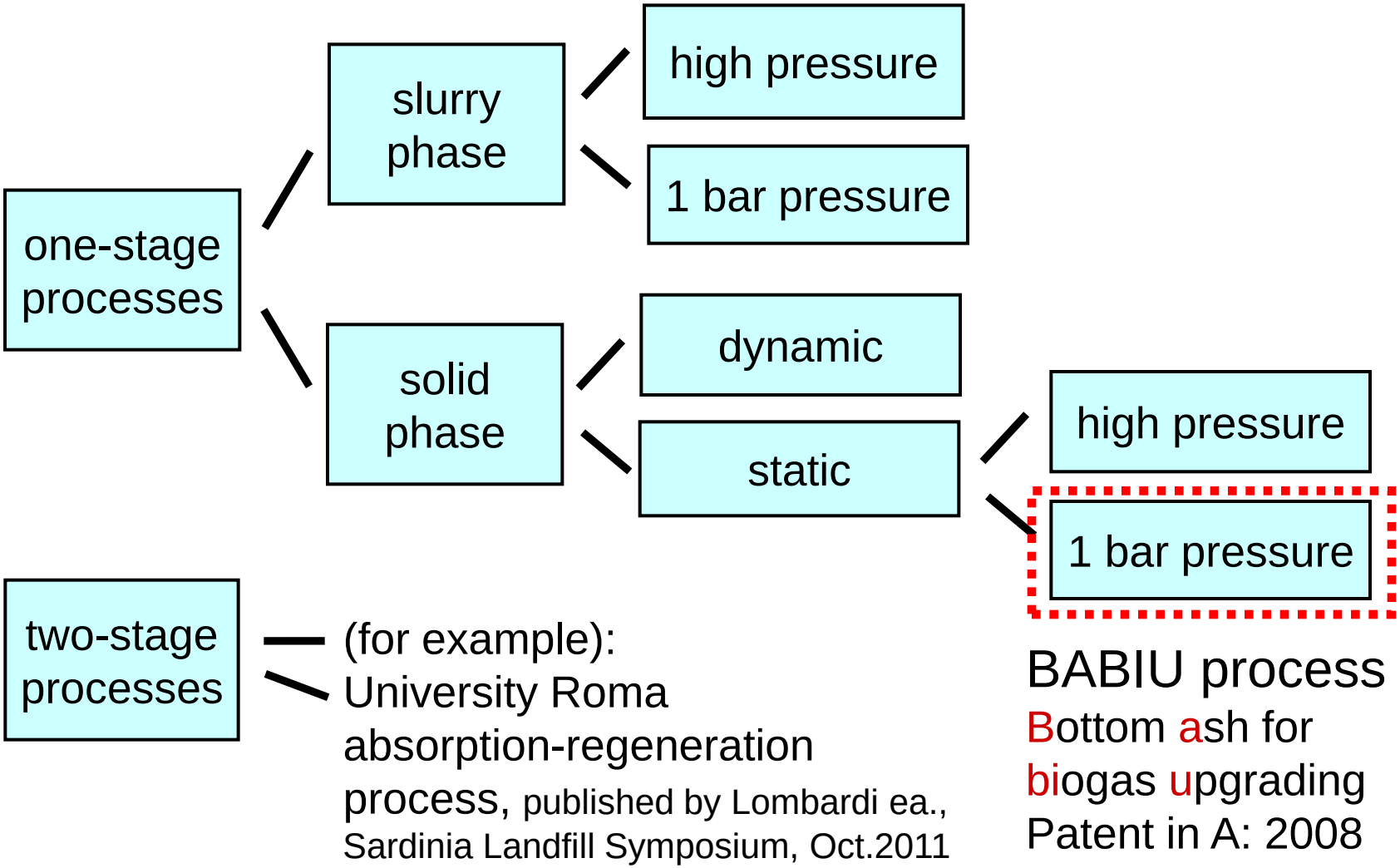
ASH 2012 - Stockholm

Classification of evolving carbonation techniques / CO_2 sequestration processes



Project „UPGAS-LOWCO_2“, 2010 – 2012: www.upgas.eu

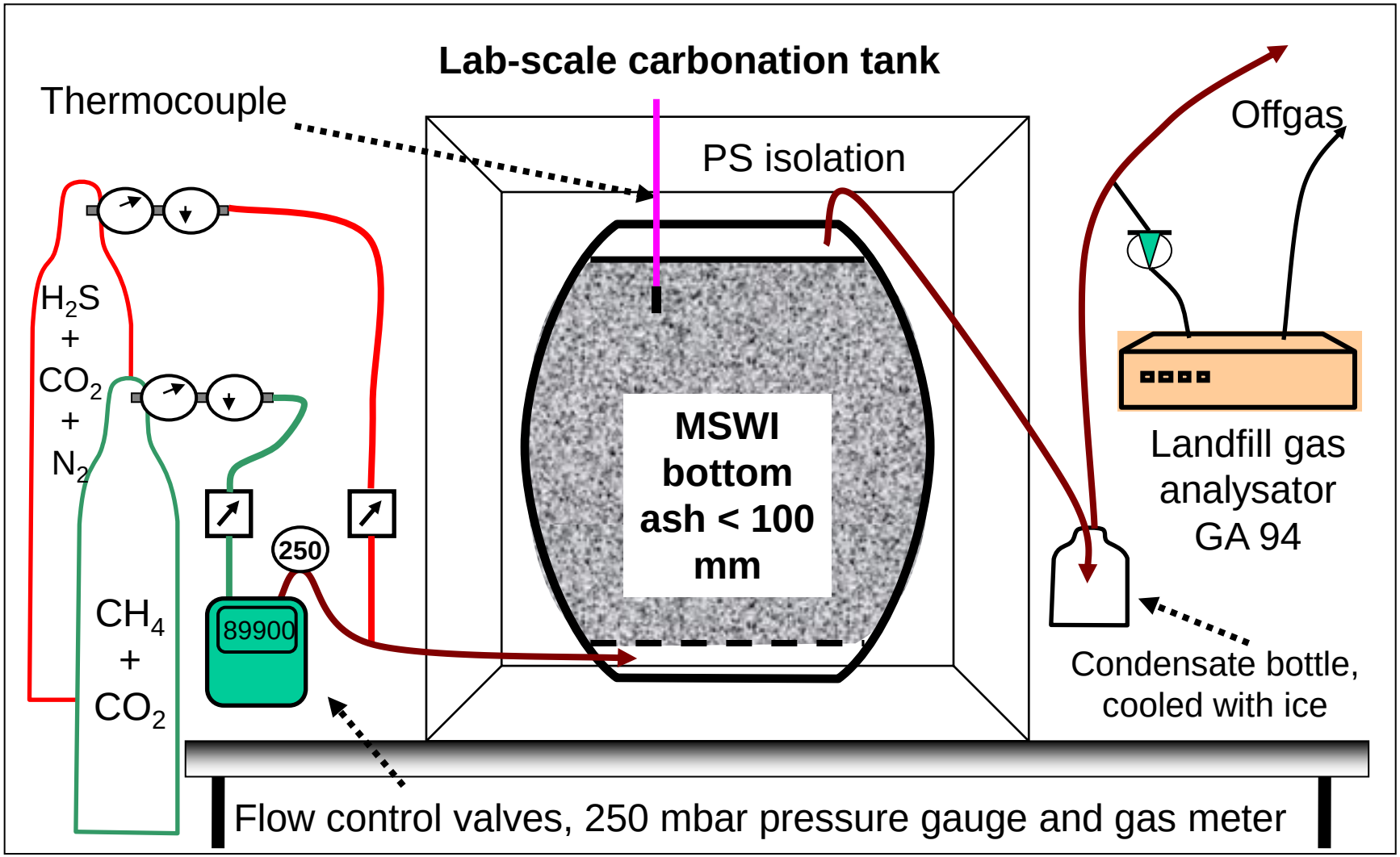
Co-funded by the EC in the frame of the **LIFE+ programme.**
Coordinated by **L. Lombardi**, **Dipartimento di Energetica, Firenze**

Objectives: Reduction of CO_2 emissions and development of two innovative techniques for upgrading of biogas: **1)** BABIU process
2) Absorption-regeneration process

1a) Finalized work package:
Lab-scale testing of the BABIU process with bottom ash from Italy and synthetic biogas „80 kg scale“

1b) Work packages in progress:
Construction of two pilot-scale reactors and operation with landfill gas in the field „1000 kg scale“

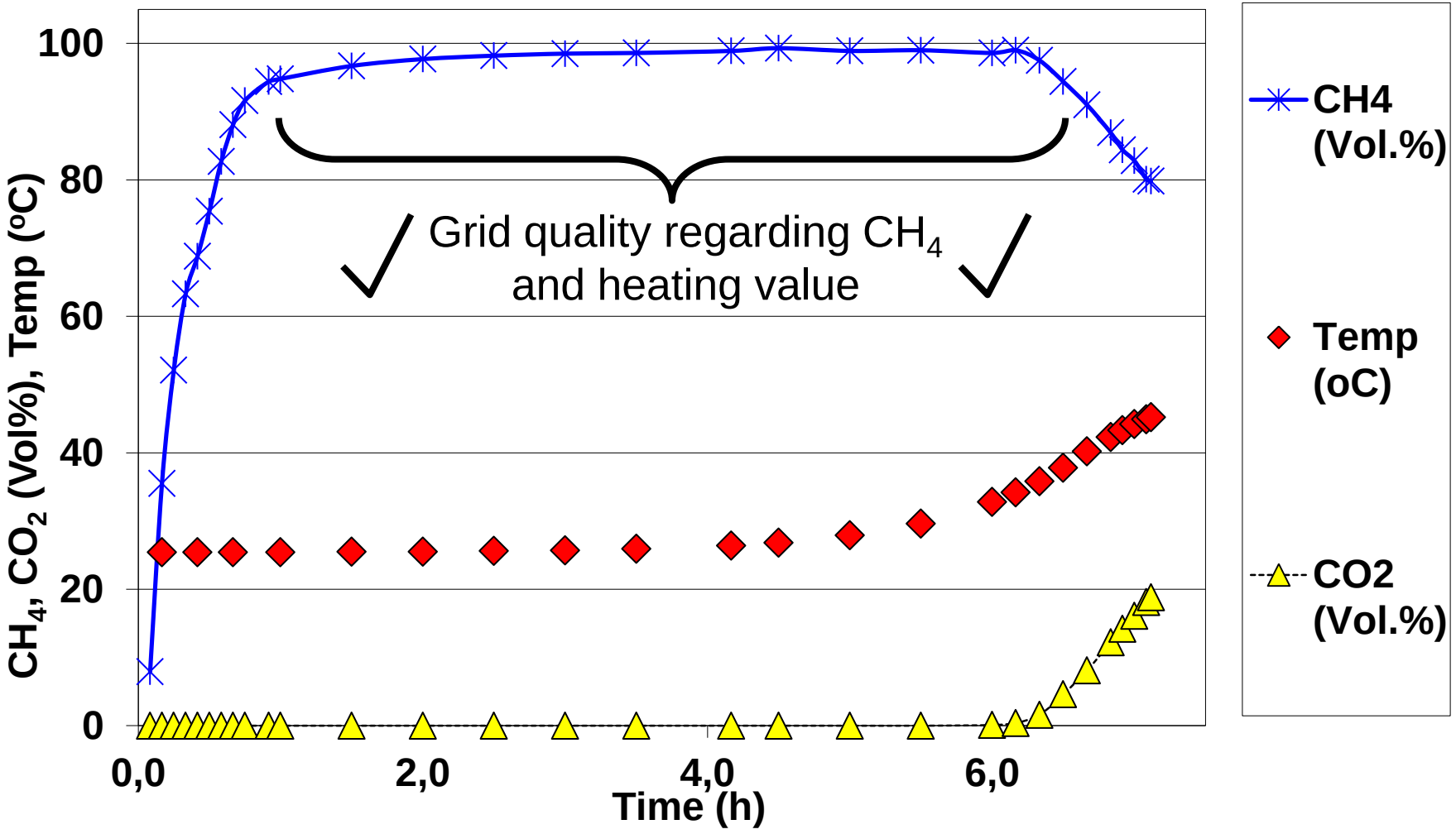
80 kg - scale upgrading of synthetic biogas: experimental



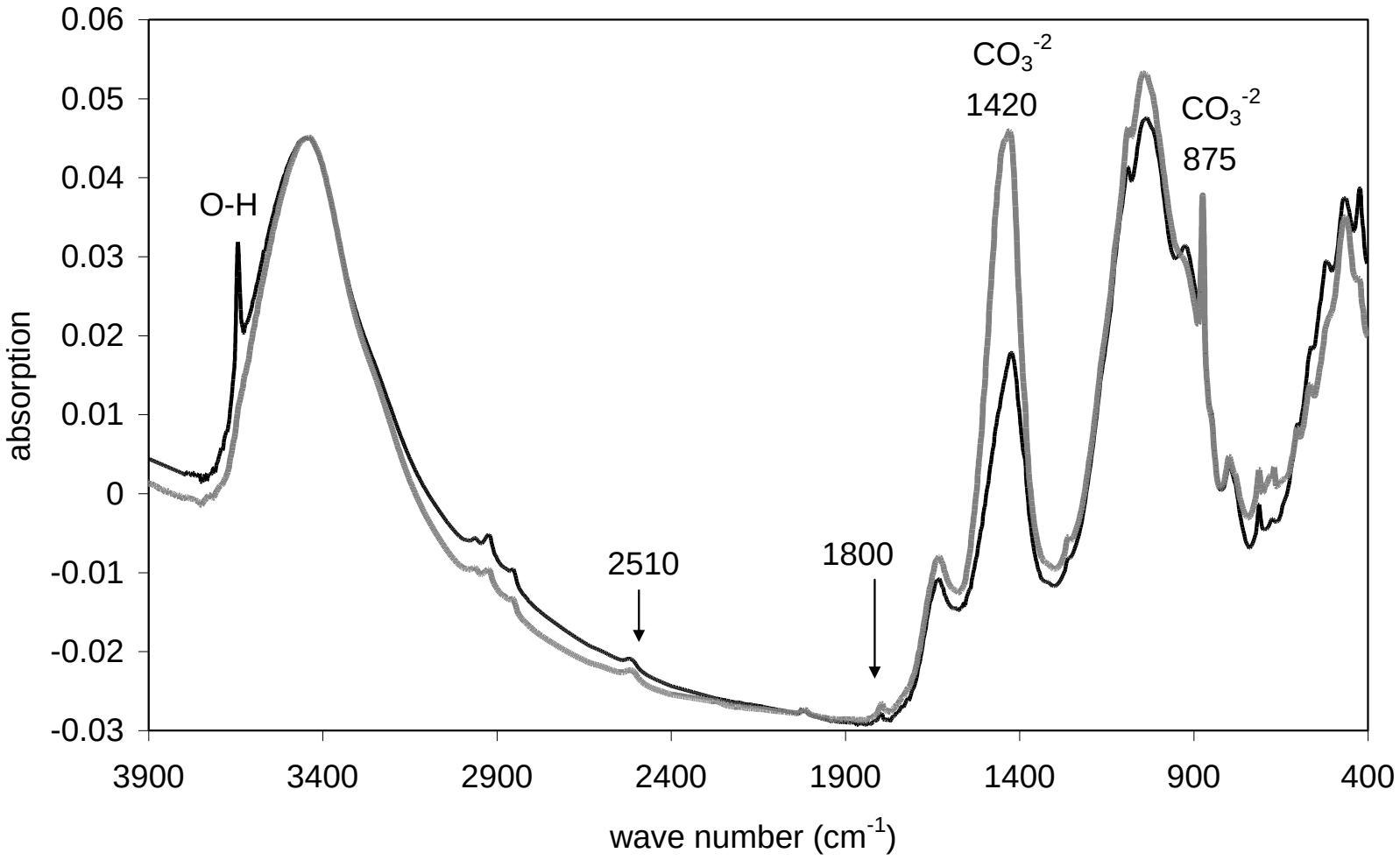
80 kg scale - experimental condition

Experiment No.	No.1	No.2	No.3
Bottom ash mass <100 mm (wet, kg WS / dry, kg DM)	82.25 / 67.8	81.89 / 67.4	74.82 / 61.7
Height of bottom ash (cm)	approx. 36	approx. 36	approx. 33
Input gas composition (synthetix mixture, simulating landfill gas)	43.1 Vol% CO_2, 56.9 Vol% CH_4	43.1 Vol% CO_2, 56.9 Vol% CH_4	43.3 Vol% CO_2, 56.6 Vol% CH_4, 0.1 Vol% N_2, 237 ppm H_2S
Input gas flow (l/min)	4.24 during the first two hours, then: 2.70	2.69	3.00
Specific input gas flow (m^3/h/t bottom ash)	3.09 during the first two hours, then: 1.97	1.97	2.40
Initial temperature of the bottom ash <100 mm (^oC)	23.1	25.4	27.0

80 kg scale - experiment No.2 – composition of upgraded gas, temperature



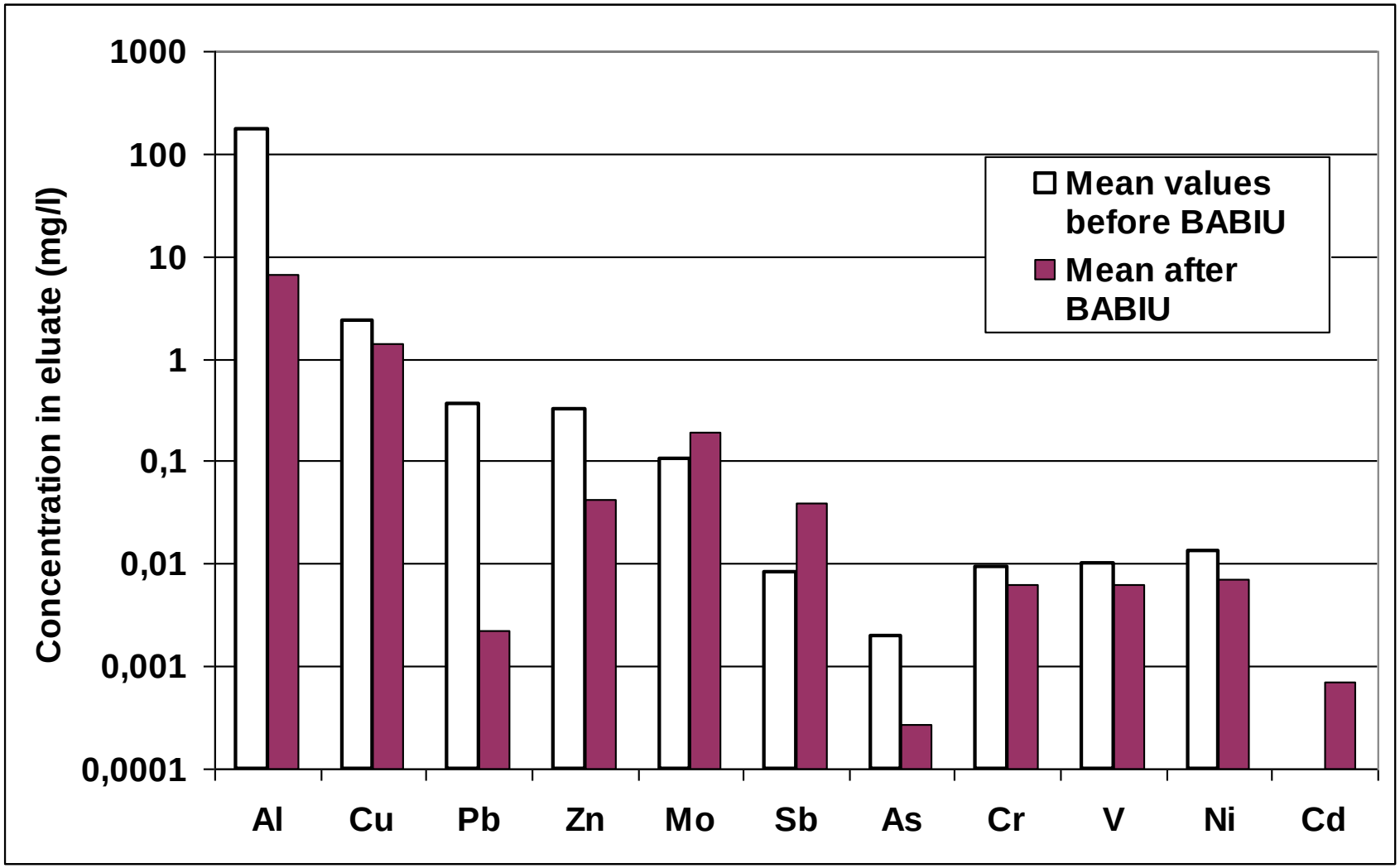
Mineralogical changes / FTIR spectra: CO_2 was fixed as calcite ($CaCO_3$)



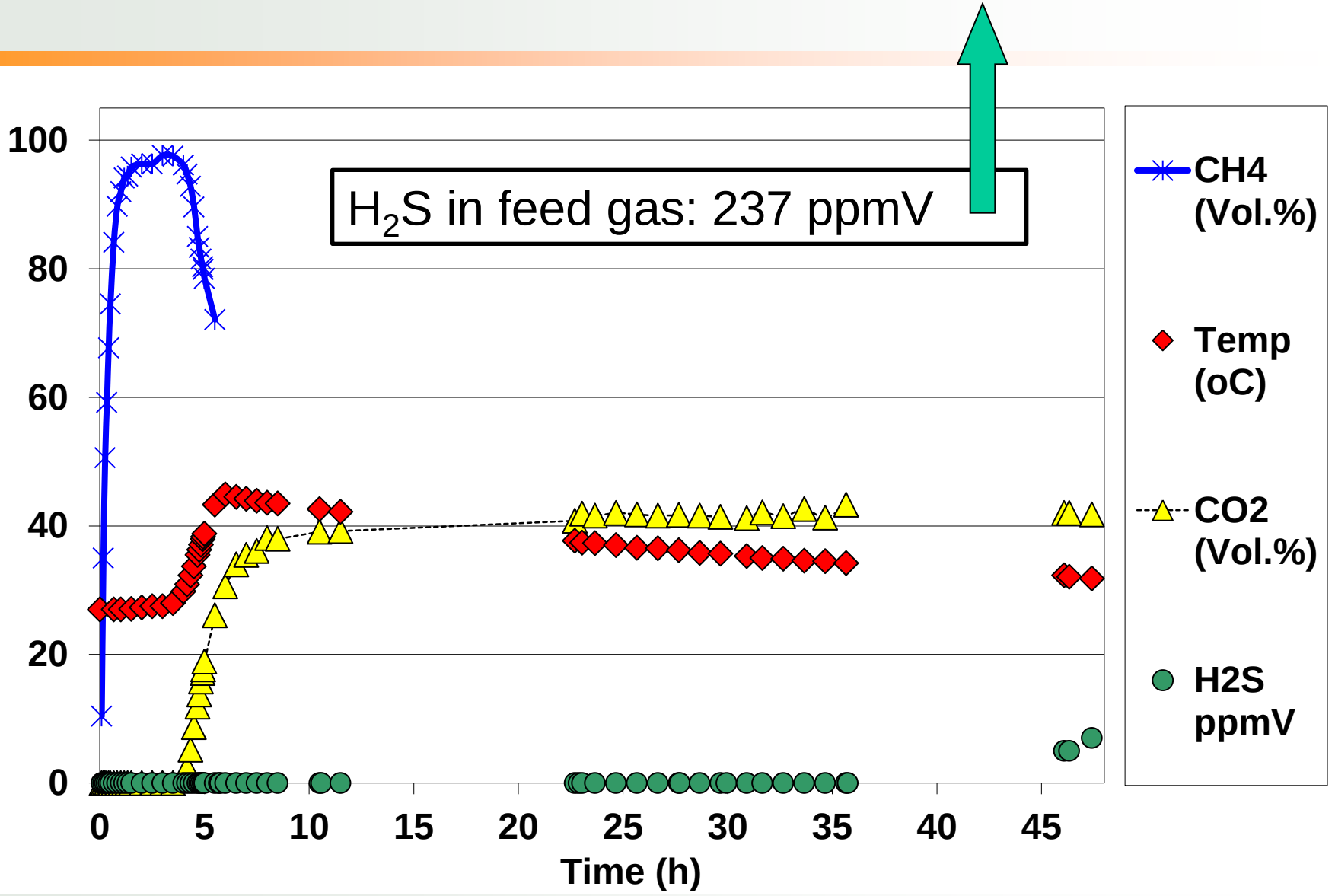
Comparision to previous BABIU projects

Plant / age of BA	Plant S, fresh	Plant S, stored for 6 to 18 d in laboratory	Plant B, stored several weeks in piles	Plant A, stored 8 to 16 d in laboratory
Grain size (mm)	< 20	< 20	0 -11	< 100
Origin (country)	AT	AT	GE	IT
CH_4 concentration: maxima (Vol%)	91 - 98	91 – 99	n.d. e)	98 - 99
CO_2 uptake (kg/tFM)	10,7 – 21,5	15,7 – 25,9 a)	18,5 d)	10,5 – 11,3
CO_2 breakthrough time (h)	10, 12, 43 b)	12 – 23	ca. 3 e)	5,7, 6,3 f)
H_2S breakthrough time (h)	> 19	> 48	> 180 e)	46
H_2S uptake per t ofash (g/tFM)	n.d.	> 60	900	37 g)
Temp. maxima (°C)	43,7 – 59,4	43,7 – 57,4 a)	ca.40 e)	43,3 – 45,2

Reduction of leachability (2007)



80 kg scale: H_2S was removed completely

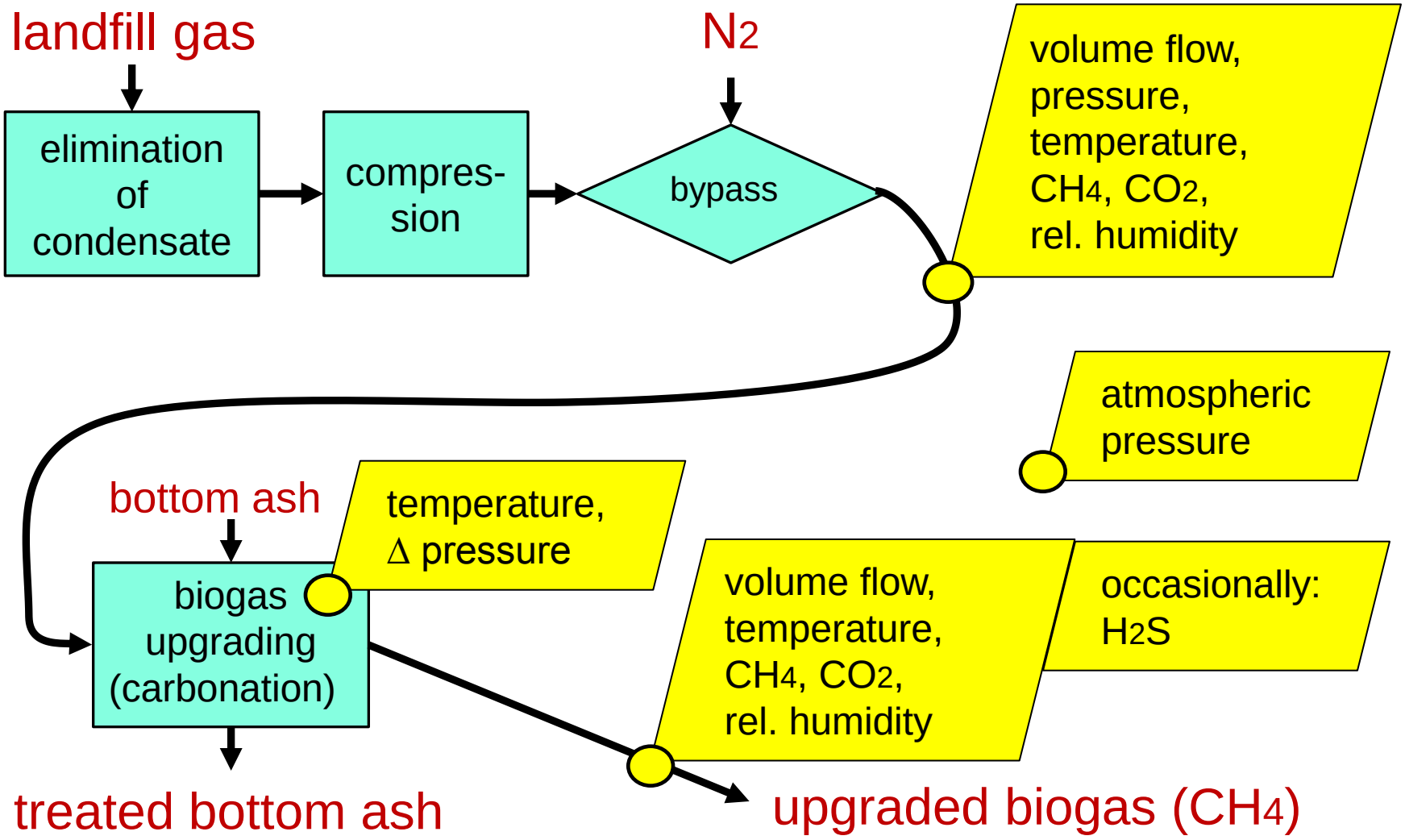


H_2S uptake, bottom ash from different plants

Data source	Country / bottom ash / material	H_2S uptake (g H_2S / kg WS)
MOSTBAUER et al., 2008	A, bottom ash fraction < 20 mm, age 0 to 7 d	> 0,06
DUCOM et al., 2009	F, dried and re-wetted bottom ash, age was a few days	3
PARKER et al, 2009	UK, fresh bottom ash	approx. 0,17 ??
Unpublished BOKU-ABF data, 2009	GE, upgraded fine fraction of bottom ash, age 4 to 5 months	0,09
Unpublished BOKU-ABF data, 2011	IT, bottom ash < 100 mm, Age: a few days	0,037

→ No “breakthrough” of H_2S during CO_2 sequestration

Design of pilot-scale BABIU system



Design of pilot-scale BABIU system

compressor / analyzers / 2 carbonation tanks / N_2 bottle

MSW disposal in the Tuscany region (Italy)

Tuscany region today: MSW from Florence is deposited in a landfill + Part of MSW incinerated at Arezzo

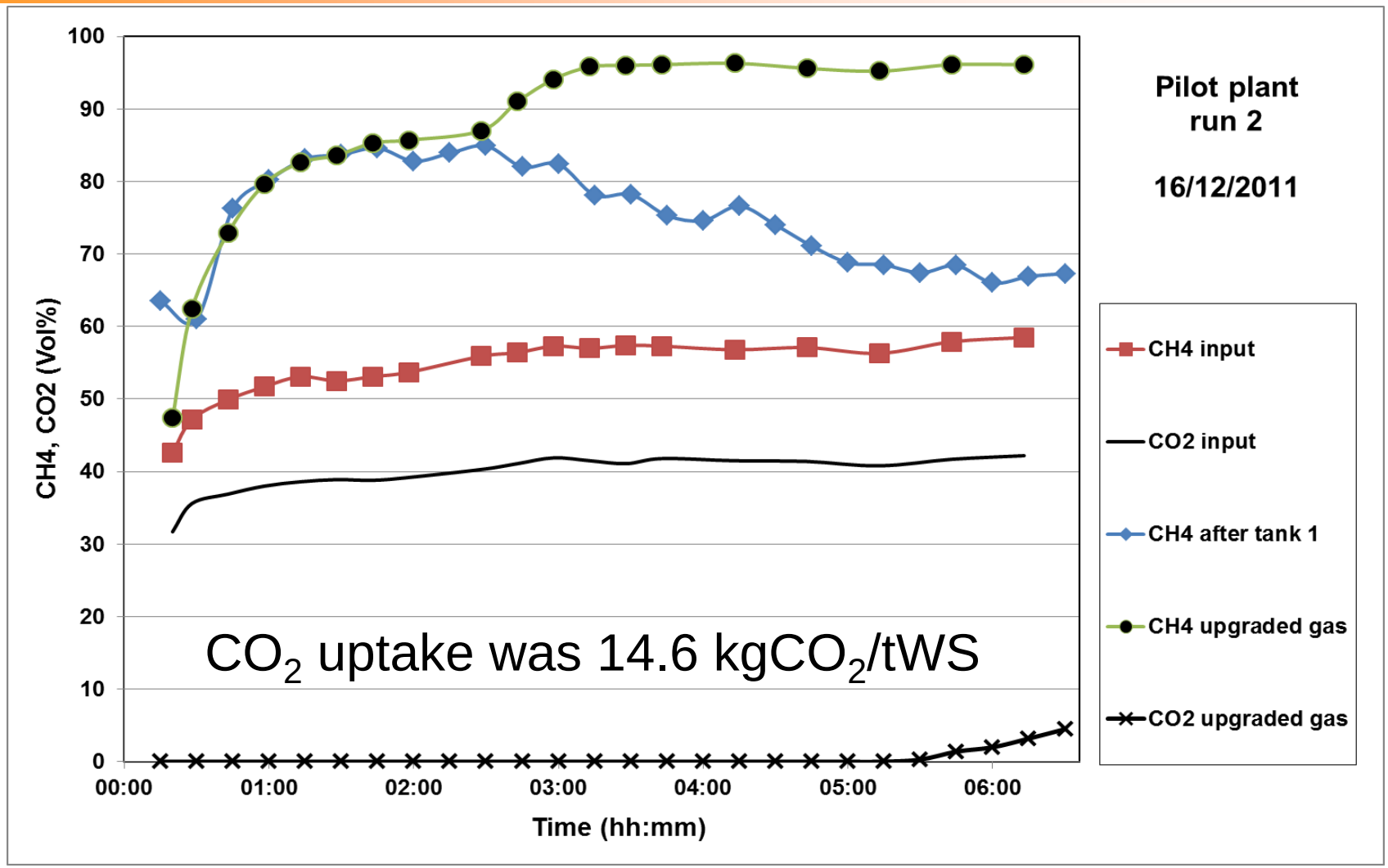
LFG flares

Test run No.2, Dec. 2011

Bottom ash from Arezzo

- stored for 8 days
- coarse metals (≥ 20 cm) removed by hand
- 500 kg filled in each of the tanks →
- flushed with N_2, 20 min
- treated with 20.1 m^3 real landfill gas
- 3 gas analyzers: CH_4, CO_2, O_2, H_2S input + output
- flushed with N_2 again, 15 min

Test run No.2 - results



Preliminary technical assessment based on lab-scale and pilot-scale results

Initial flushing:

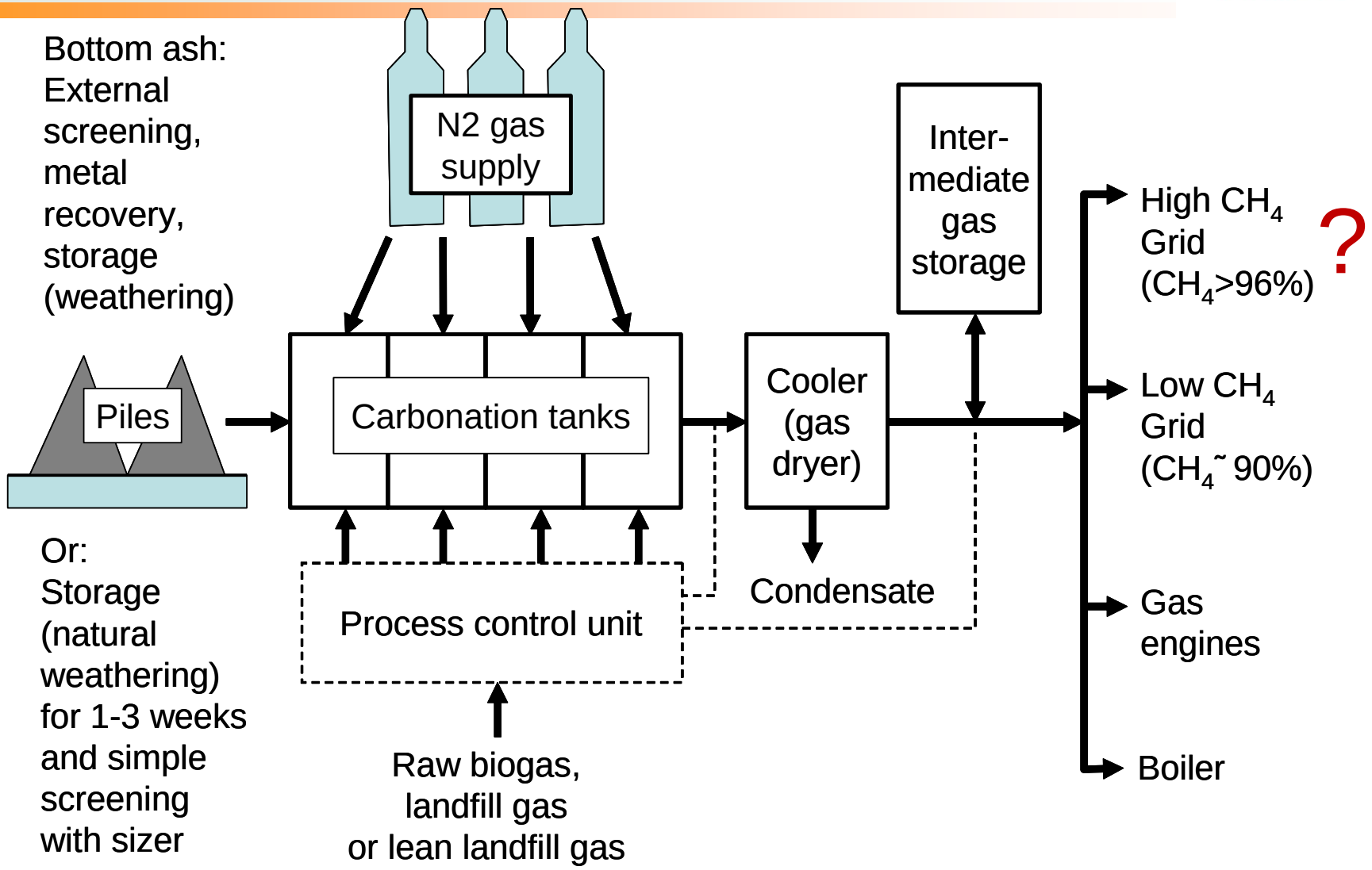
- 15 min sufficient
- N_2 demand for industrial application: approx. 0.8 m^3/t

Gas quality and CO_2 removal:

- It is questionable if H-gas quality can be reached, as landfill gas contains N_2
- L-gas quality can me obtained (Obstacle: DVGW G-262 banns feed-in of landfill gas)
- For lean landfill gas, engine quality (>40%CH_4) is obtained
- CO_2 is < 0.1% for a significant time
- CO_2 fixed as $CaCO_3$

H_2S removal: complete

Potential industrial applications



Other potential industrial applications

- Use of bottom ash / bottom ash fractions for removal of H_2S primarily
- Application of BABIU process for fast carbonation of ashes and subsequent use of treated ash for construction (BA) or (coal ash) fertilization
- Prolong conventional gas utilization in the long-term at landfills by treatment of a part of the lean landfill gas = admixture of BABIU gas to lean landfill gas

Open questions: ? ? ?

- H_2S retaining mechanism
- H_2S uptake capacity
- Behavior of siloxanes in the BABIU system
- Market for ash-derived secondary construction material

BABIU process - summary

Upgrading to grid quality:

- Biogas upgrading to H-Gas or L-Gas quality technically feasible
- L-Gas quality from LFG: technically feasible, but prohibited in Germany

Other applications:

- Use of bottom ash / bottom ash fractions for removal of H_2S from biogas or LFG
- Accelerated carbonation of ashes
- Lean landfill gas problem: Prolong conventional gas utilization