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Sebastian Schaffer, Tobias Pröll, Rafat Al Afif, and Christoph Pfeifer, "Pyrolysis of cotton stalks and utilization of pyrolysis char for sustainable soil enhancement and carbon storage" in "Biochar: Production, Characterization and Applications", Franco Berruti, Western University, London, Ontario, Canada Raffaella Ocone, Heriot-Watt University, Edinburgh, UK Ondrej Masek, University of Edinburgh, Edinburgh, UK Eds, ECI Symposium Series, (2017). http://dc.engconfintl.org/biochar/51

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Biochar: Production, Characterization and Applications
August 20-25, 2017
Hotel Calissano, Alba, Italy

Pyrolysis of cotton stalks and utilization of pyrolysis char for sustainable soil enhancement and carbon storage

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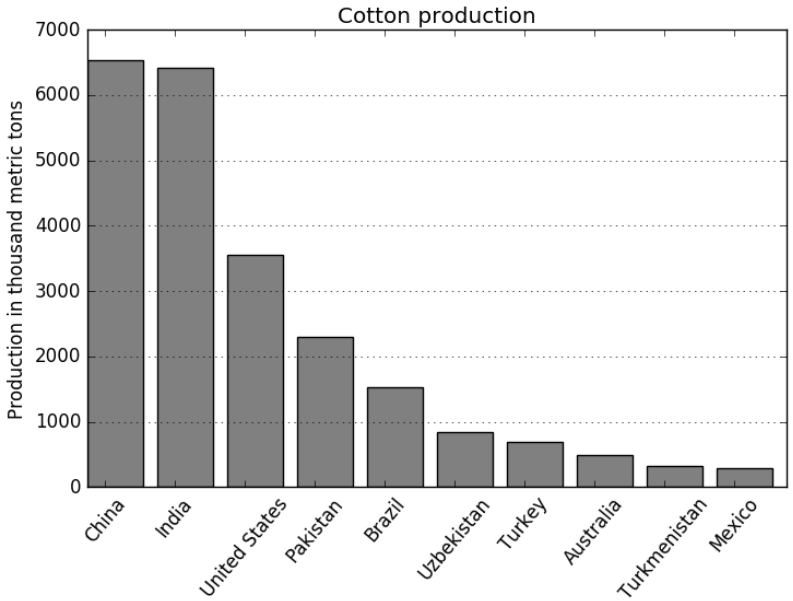
Outline

- Why cotton stalks?
- Rotary kiln pyrolysis technology
- Considered process configuration and performance
- Pyrolysis char for soil carbon storage
- Conclusion and outlook

Current Situation



Source : http://www.statista.com/

- Major amount of cotton produced with low environmental standards
- Thermal treatment necessary to avoid survival of pests

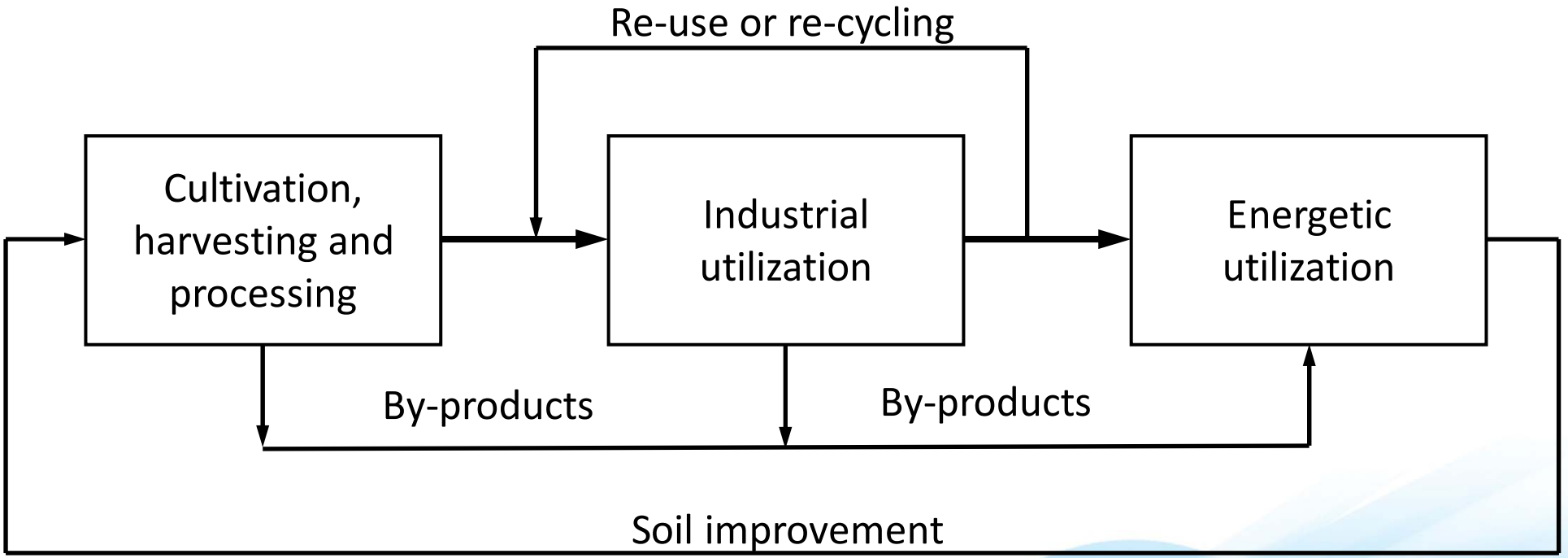
→ **Leads to high local emission and pollution**

Cotton stalks

- Ligno-cellulosic residue. Major part of biomass in cotton crops.
- Approximately 75 million tons of cotton waste per year
- High potassium and chlorine content causes ash melting and corrosion issues upon combustion or gasification systems

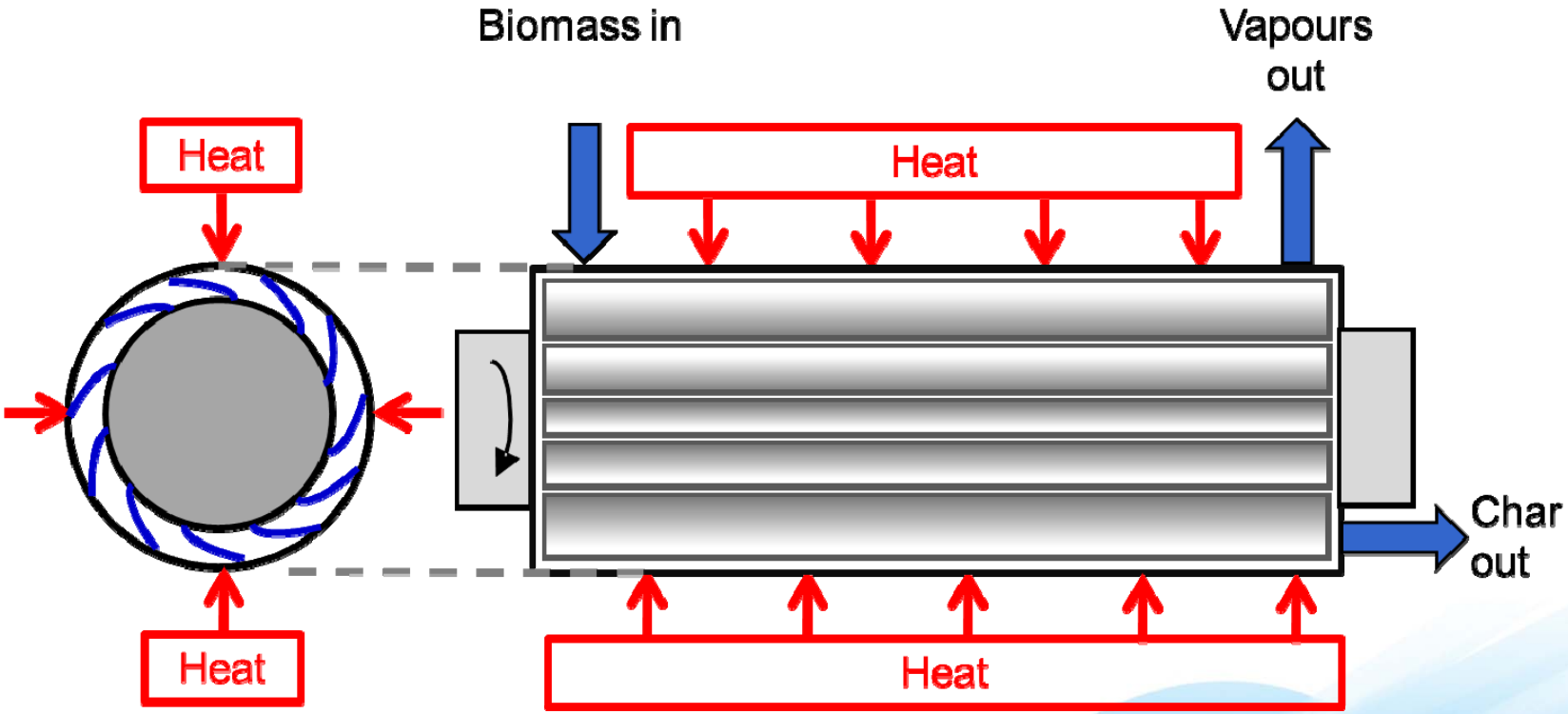
→ **Pyrolysis treatment at 500-600°C avoids ash melting.**

Sustainable biomass life cycle



- Priority is given to industrial utilization (food, feed, raw material)
- By-products for energetic use appear in all process steps
- Closed life cycle includes **sustainable soil management**

Considered process: Rotary kiln pyrolysis



Source: www.pyne.co.uk

- Heated horizontal drum, atmospheric pressure, 500-600°C
- Product distribution depends on temperature and throughput
- Robust and industrially proven technology

70 t/d industrial waste pyrolysis plant Burgau/Günzburg (operated 1982-2015)

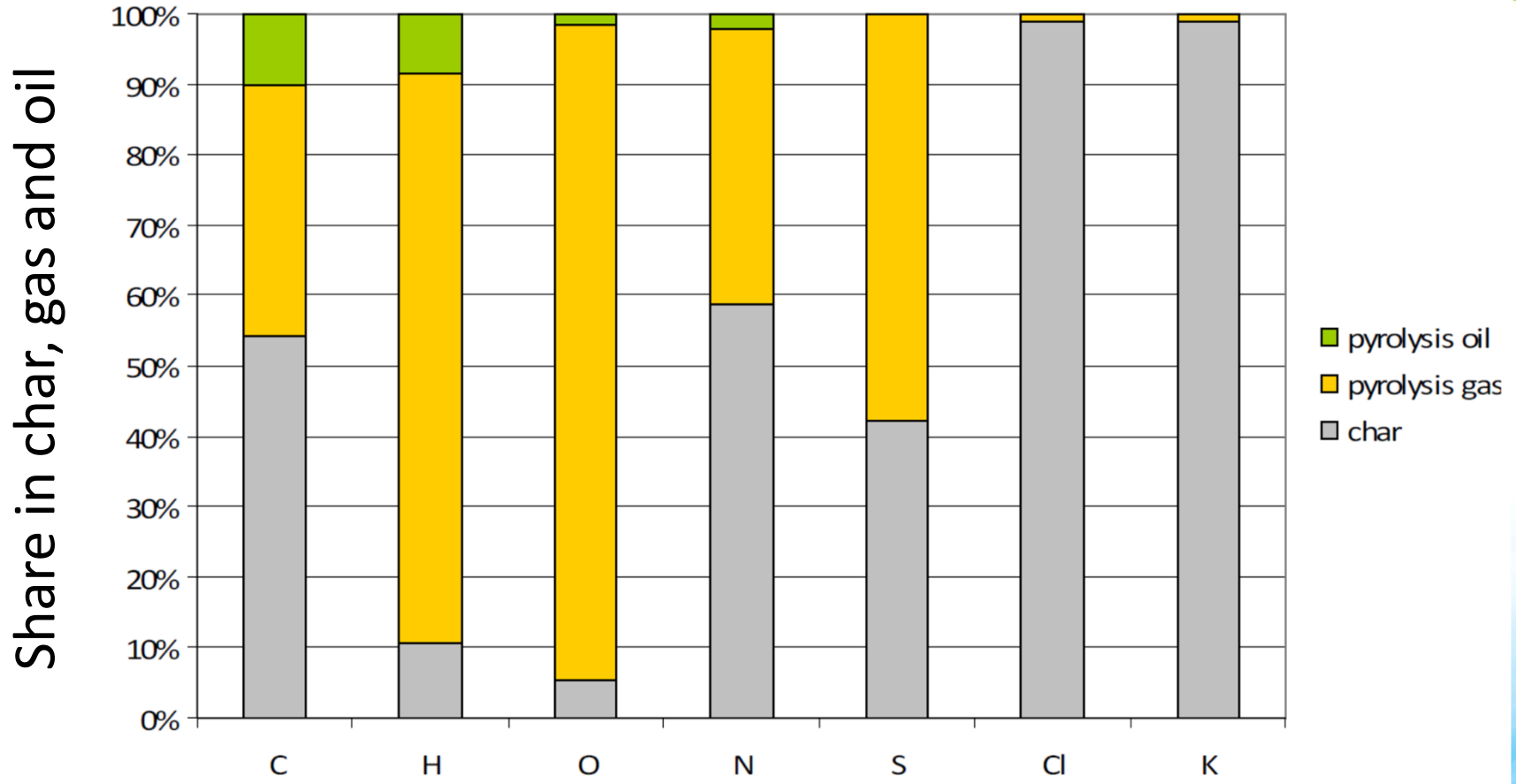
Source: Kreisabfallverband Günzburg, online

Previous work: 3 MW_{th} pilot plant Dürnrohr

Photograph: S. Kern, TU Wien

- Operated 2008 – 2010, feed: wheat straw, others
- Reference: Kern et al. Journal of Analytical and Applied Pyrolysis 2012;97:1-10.

Path of elements (wheat straw, 0.5 t/h, 550°C)



Source: Stefan Kern, Master Thesis, TU Wien, 2010.

- Chlorine and potassium stay in the char fraction.

→ Char not suitable as fuel for boilers → soil application.

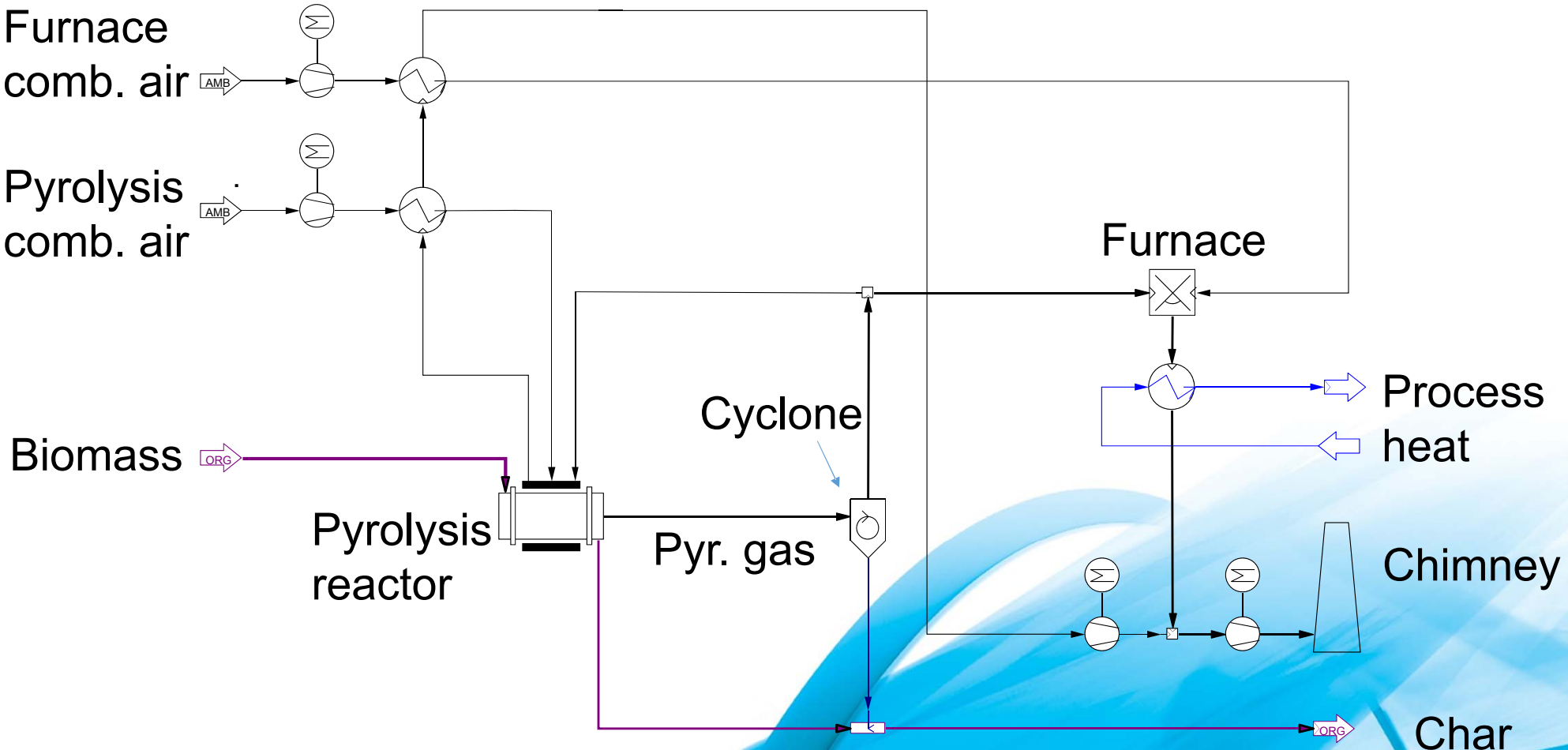
Methodology and assumptions

- Simple process configuration, char as a product
- Direct gas combustion without cooling
- Mass and energy balance model based on pilot plant data
- Similar splitting ratios for wheat straw and cotton stalks

	Unit	Cotton stalks	Wheat straw
Ash	wt%	5.18	4.35
Volatile matter	wt%	71	79
Fixed carbon	wt%	24	17
Carbon	wt%	46.07	47.82
Hydrogen	wt%	5.93	5.29
Nitrogen	wt%	1.1	0.47
Sulfur	wt%	0.12	0.08
Oxygen	wt%	41.6	41.59
Net calorific value (LHV)	MJ/kg	17.3	17.7

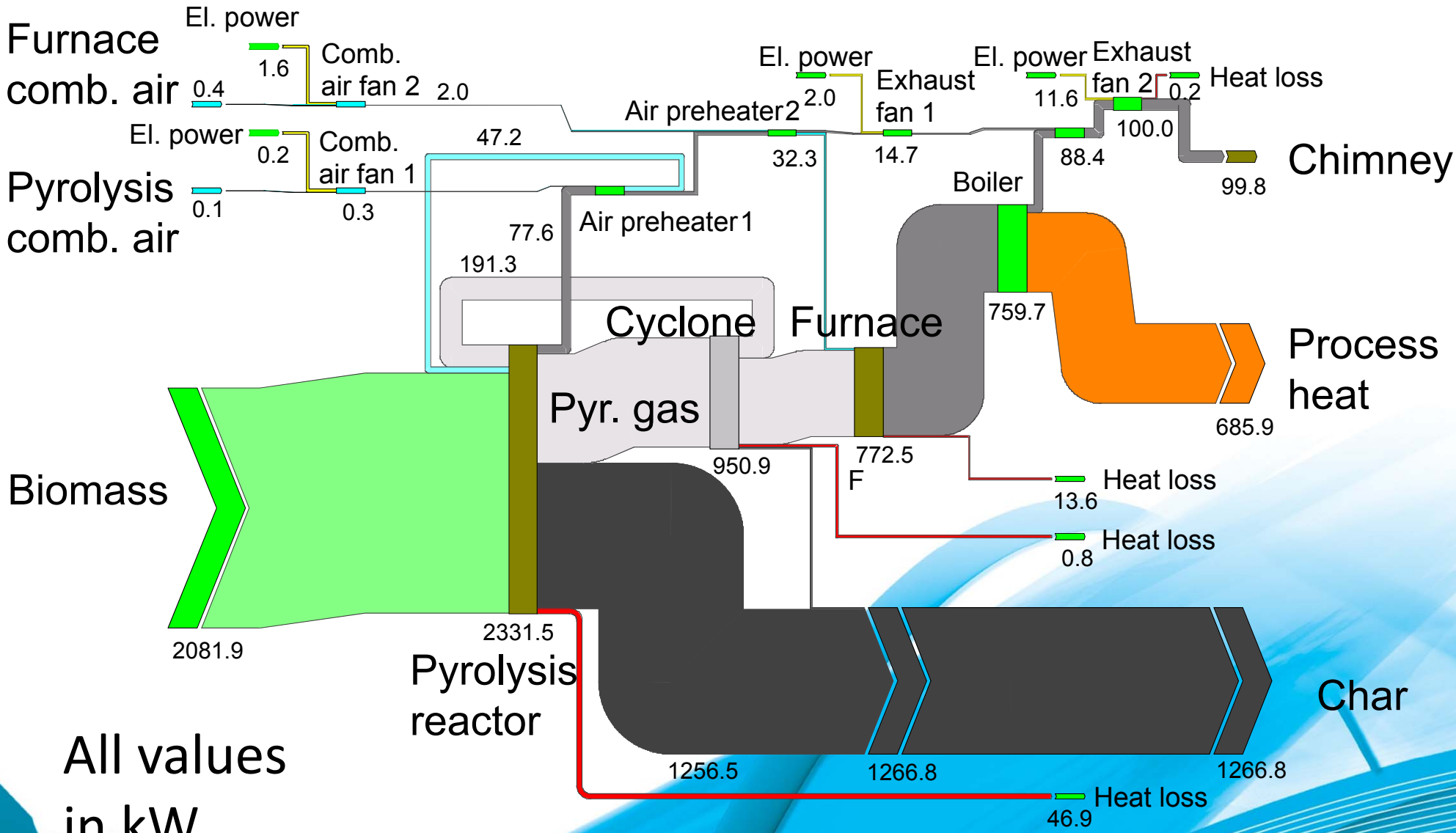
Sources: ECN/Phyllis2 and Ahmed et al. Journal of American Science 2010;6:1306-13.

Considered process configuration

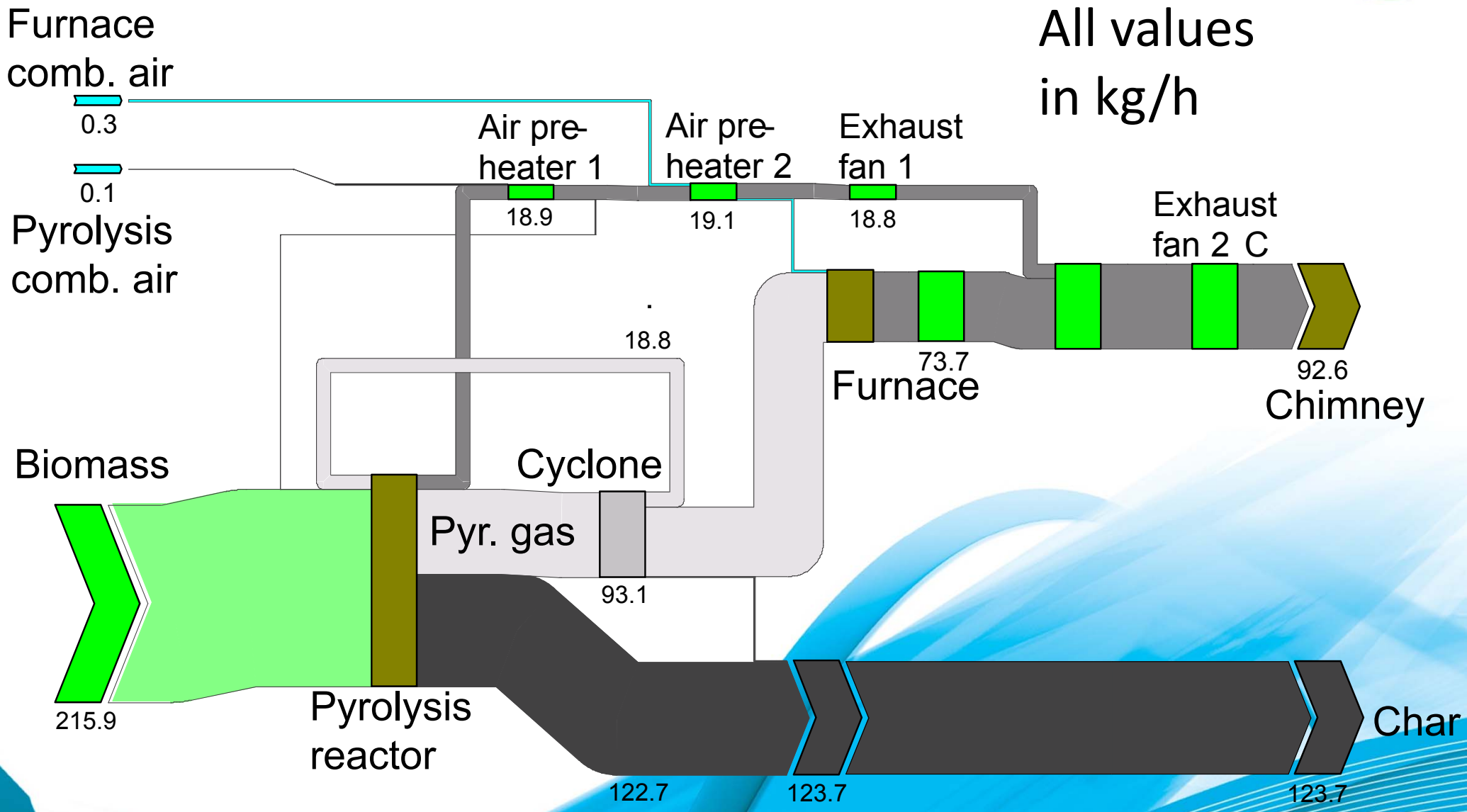


- Simulation tool: IPSEpro / PGP-Lib model library + own unit models

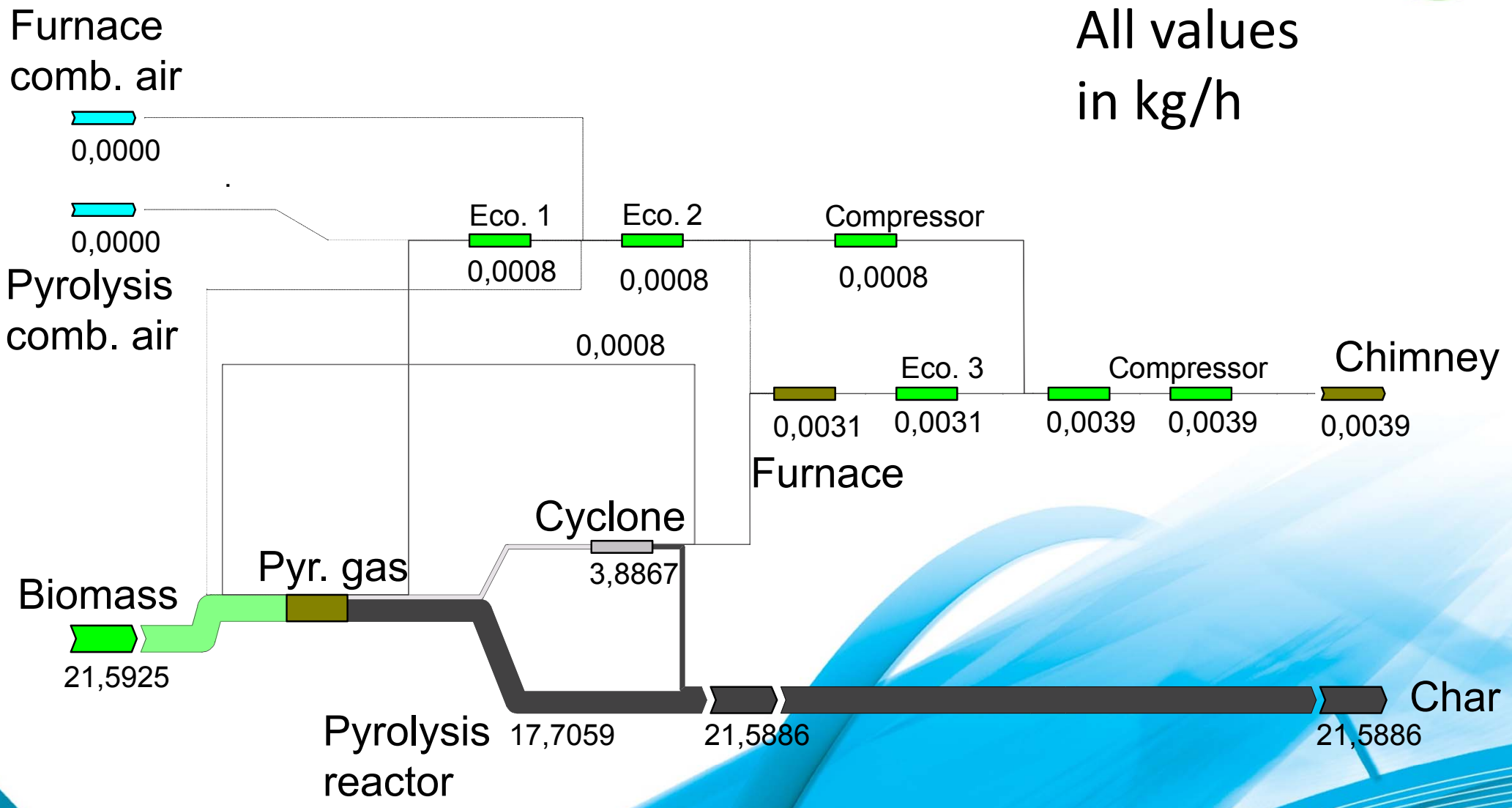
Energy flow diagram



Carbon flow diagram



Ash flow diagram



Pyrolysis char for soil carbon storage

How long will the carbon stay in the soil?

Several studies available in the literature

- K.A. Spokas (2010): half-life > 1000 years for O:C molar ratio < 0.2 (Carbon Management 1(2), 289–303)
- O:C < 0.2 easily reached in rotary kiln pyrolysis

→ Soils as safe and sustainable carbon sink

→ Positive side-effects from storage (soil quality increase)

→ Equal or better climate change mitigation effect compared to electricity generation from biomass*

*Pröll et al. (2017). Energy Procedia 114:6057-66.

Conclusion / Outlook

- Sustainable biomass utilization involves nutrient cycles and soil management.
- 40% of the carbon captured by cotton crops is stored in the char
- Biomass-derived charcoal can serve as long-term carbon storage
- Cotton good test case for biochar application as it is in the non-food domain
- Further work required on
  - Conversion process and char properties/composition
  - Char application effects on soil quality and environment

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Questions ?? / Discussion

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