

# Industrial Ecology in Practice: Substituting Aluminum Raw Materials

Olli Salmi

Helsinki University of Technology  
Laboratory of Environmental Protection

PO Box 2300, 02015 TKK

Otakaari 8

[oli.salmi@tkk.fi](mailto:oli.salmi@tkk.fi)

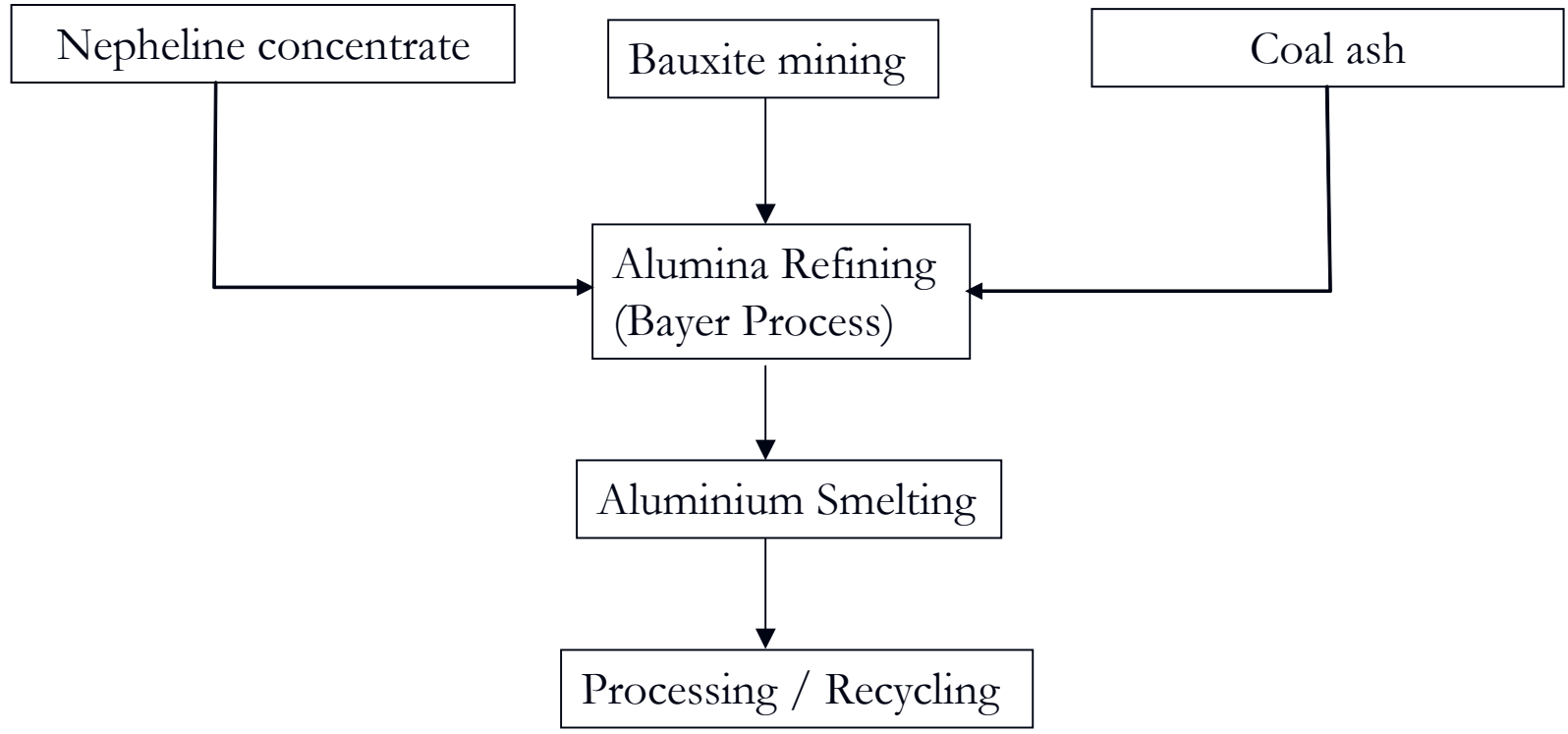
040-7342154

# IE guidelines or EIP guidelines?

- Tibbs (1993): Six Criteria for Industrial Ecology
- Lowe et.al (1997): Five Strategies for Designing an Eco-Industrial Park
- Chertow (2000): Five Possible Waste Exchange Types in Industrial Symbiosis

# Aluminum: a Lense to IES in a Value Chain

- Aluminum: praised environmental properties:
  - 100% recyclable
  - Key to dematerialization of consumer products (e.g. car production)
  - Key to energy efficiency in manufacturing and consumer products
- However:
  - Voluminous bauxite mining required
  - High energy requirements in smelting



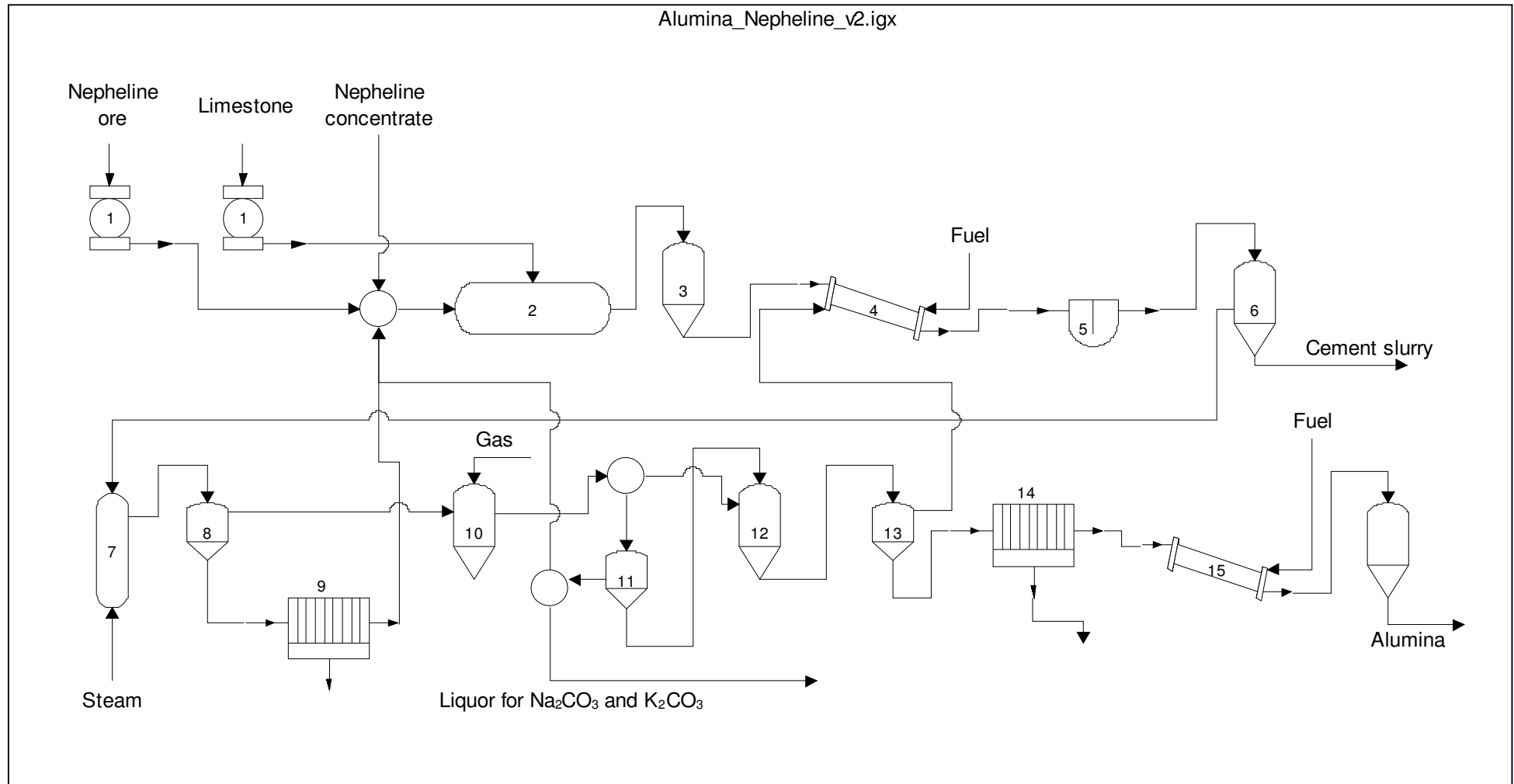
# Aluminum raw materials

## ■ Bauxite

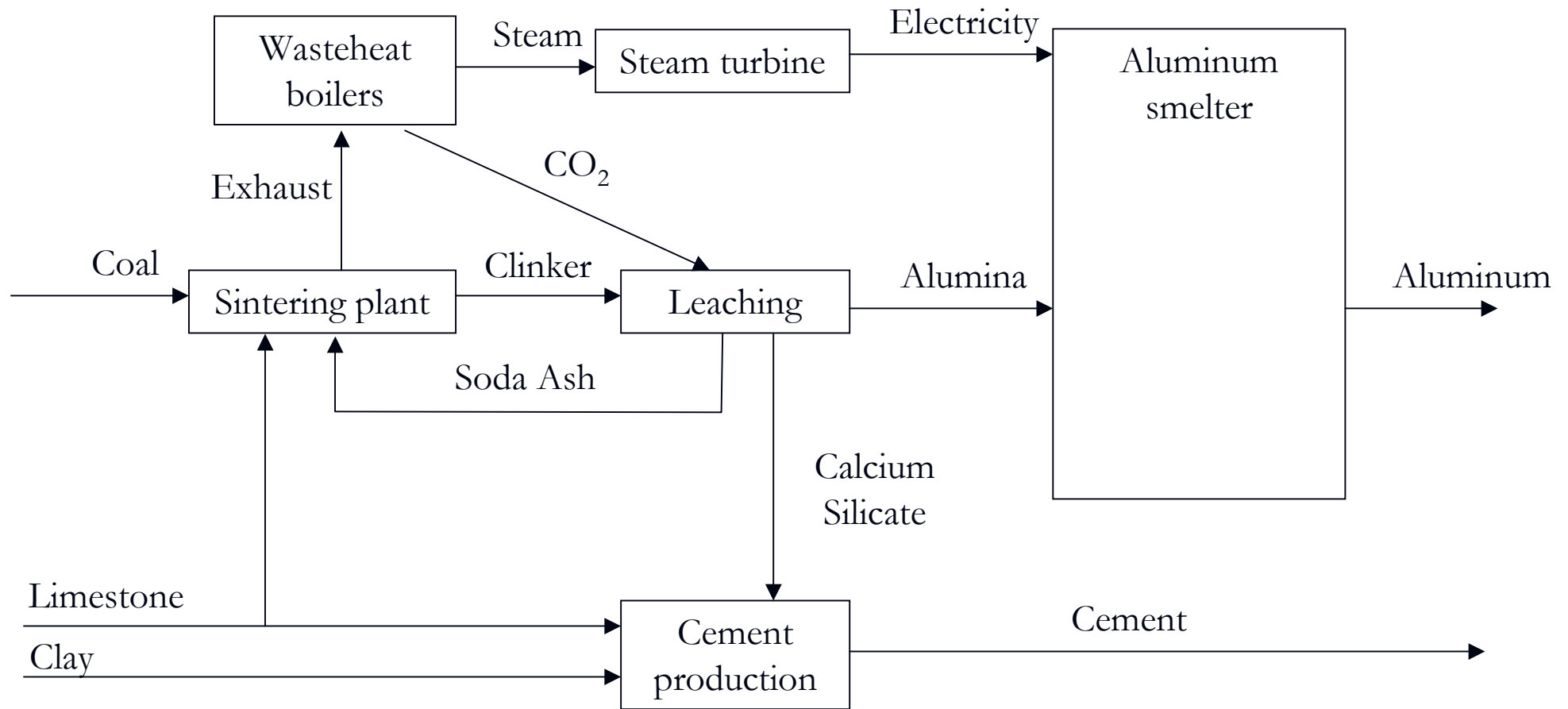
- 40% - 60%  $\text{Al}_2\text{O}_3$
- 18-20 €/t (USGS average)  $\Rightarrow$  40 €/t  $\text{Al}_2\text{O}_3$

## ■ Nepheline: $(\text{Na}, \text{K}, \text{Fe})\text{AlSiO}_4$

- 30%  $\text{Al}_2\text{O}_3$
- Nepheline Syenite (Stjernøyen, Norway): 30 €/t  $\Rightarrow$  100 €/t  $\text{Al}_2\text{O}_3$
- Khibiny nepheline (Kola Peninsula, Russia): 15 €/t  $\Rightarrow$  50 €/t  $\text{Al}_2\text{O}_3$



$\text{Al}_2\text{O}_3$  production from nepheline. 1: Crushing. 2: Wet grinding. 3: Pulp correction. 4: Sintering. 5: Leaching. 6: Thickening and washing. 7: Desilication. 8: White mud thickening. 9: White mud filtration. 10: Liquor carbonization. 11: Seed thickening. 12: Precipitation. 13: Thickening. 14: Filtration. 15: Calcination. Modified from Smirnov, V (1996): Alumina production in Russia Part I: Historical Background. JOM 48(8): 24-26.

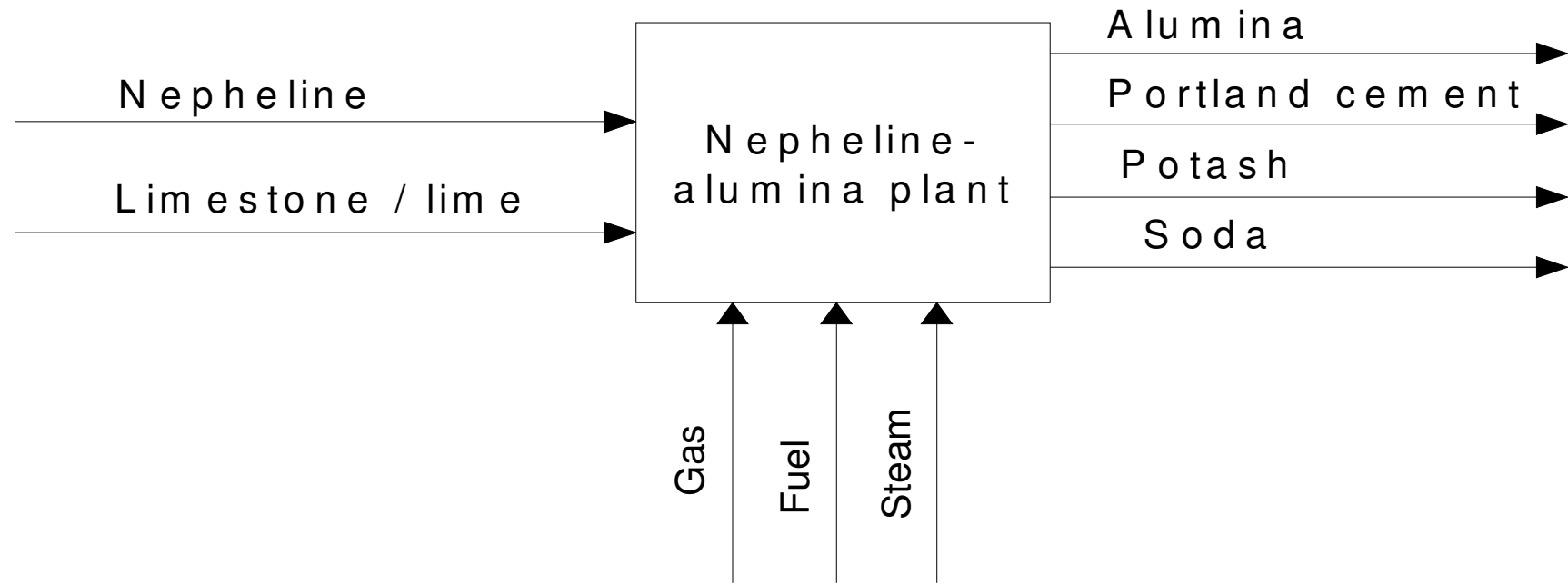


$\text{Al}_2\text{O}_3$  production from coal ash: Adapted from: Ayres, R: On Industrial Ecosystems. In Ayres, R. and Leslie W. Ayres: A Handbook of Industrial Ecology. Edward Elgar. 2002: 44-59.

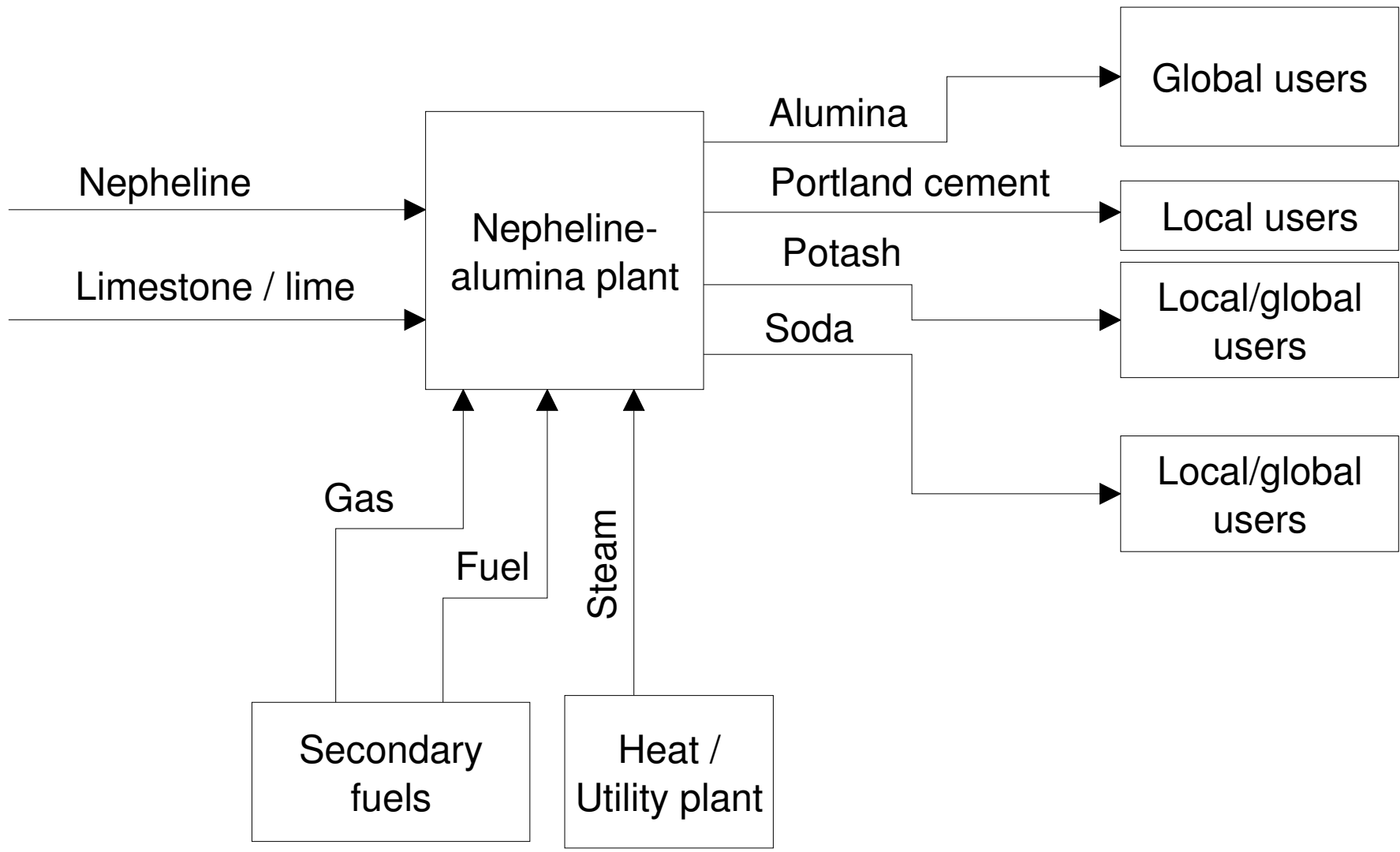
MB: 1.9Mt coal + 3.9Mt limestone => 200 kt alumina + 3.3 Mt cement

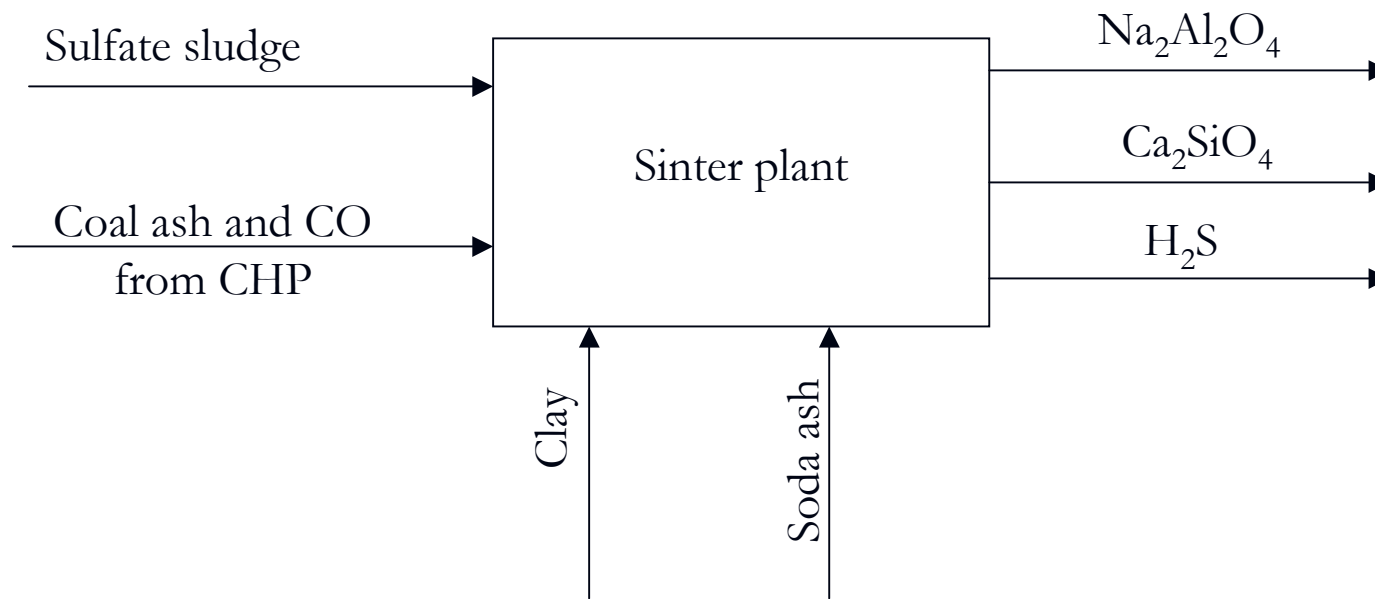
# Aluminum raw materials

- Fe-content determines price and use...
  - Glass and ceramics (Norway)
  - Alumina production (Russia)
- ...but auxiliary products determine total revenue
  - $\text{Na}_2\text{CO}_3$ : 55 €/t (USGS average)
  - $\text{K}_2\text{CO}_3$  ( $\text{K}_2\text{O}$ ): 165 €/t (USGS average)



MB: 1Mt nepheline + 1.875Mt limestone => 250kt alumina + 200kt soda + 75kt potash + 2.5Mt cement





# Critical Remarks

- Transport costs vs. savings of virgin ore
- Impurities
- Small profit margins
- Slow growth industry
- Post-production value chain: are we dematerializing after all?

# Conclusions

- Determined spatio-temporal boundary-crossing is needed in both brownfield and greenfield solutions for heavy industry
- Thus, a practicing industrial ecologist moves across and between traditional categories for industrial production
- IE/IES/IS classifications that stimulate boundary crossing bear high use value