Industrial Ecology in Practice: Substituting Aluminum Raw Materials

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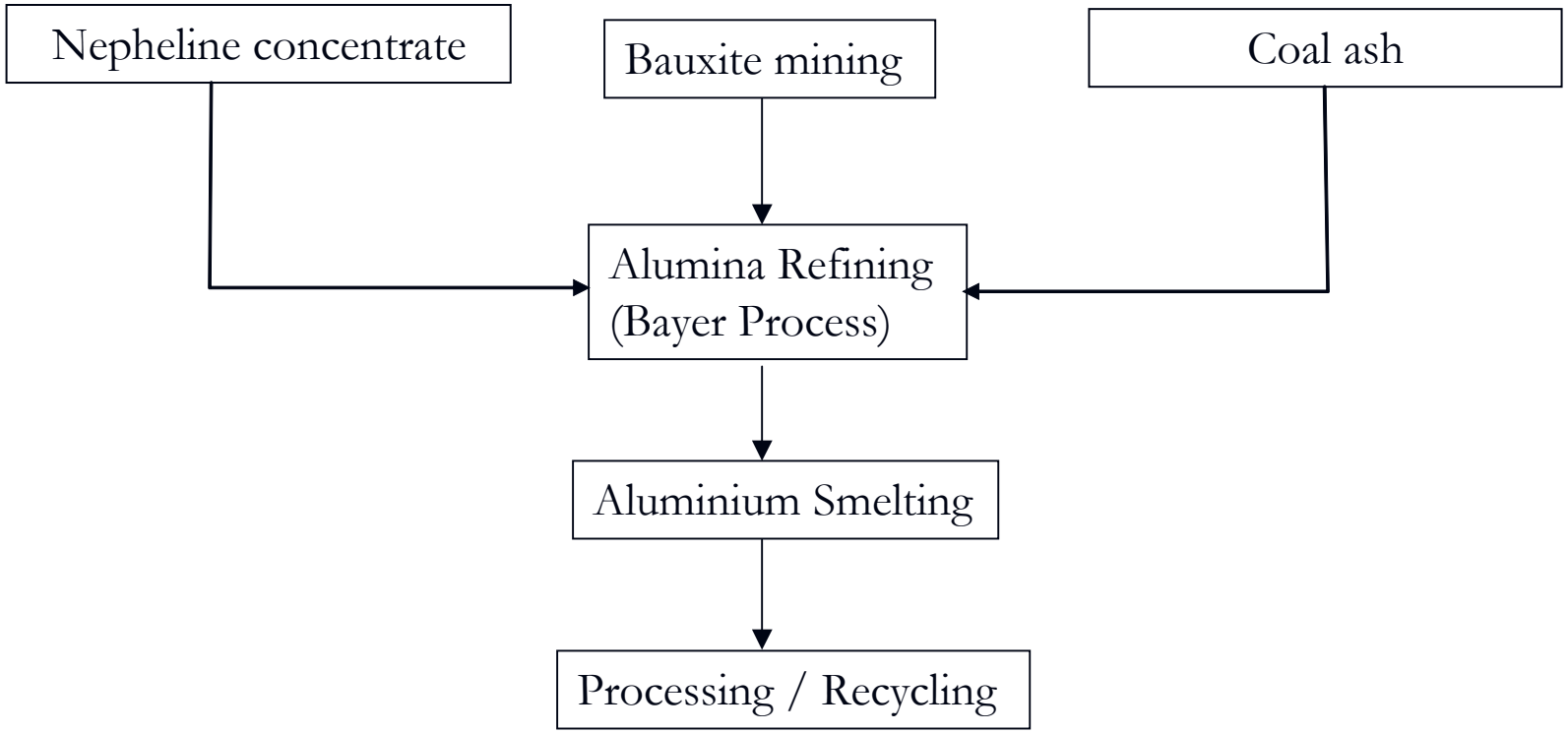
IE guidelines or EIP guidelines?

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

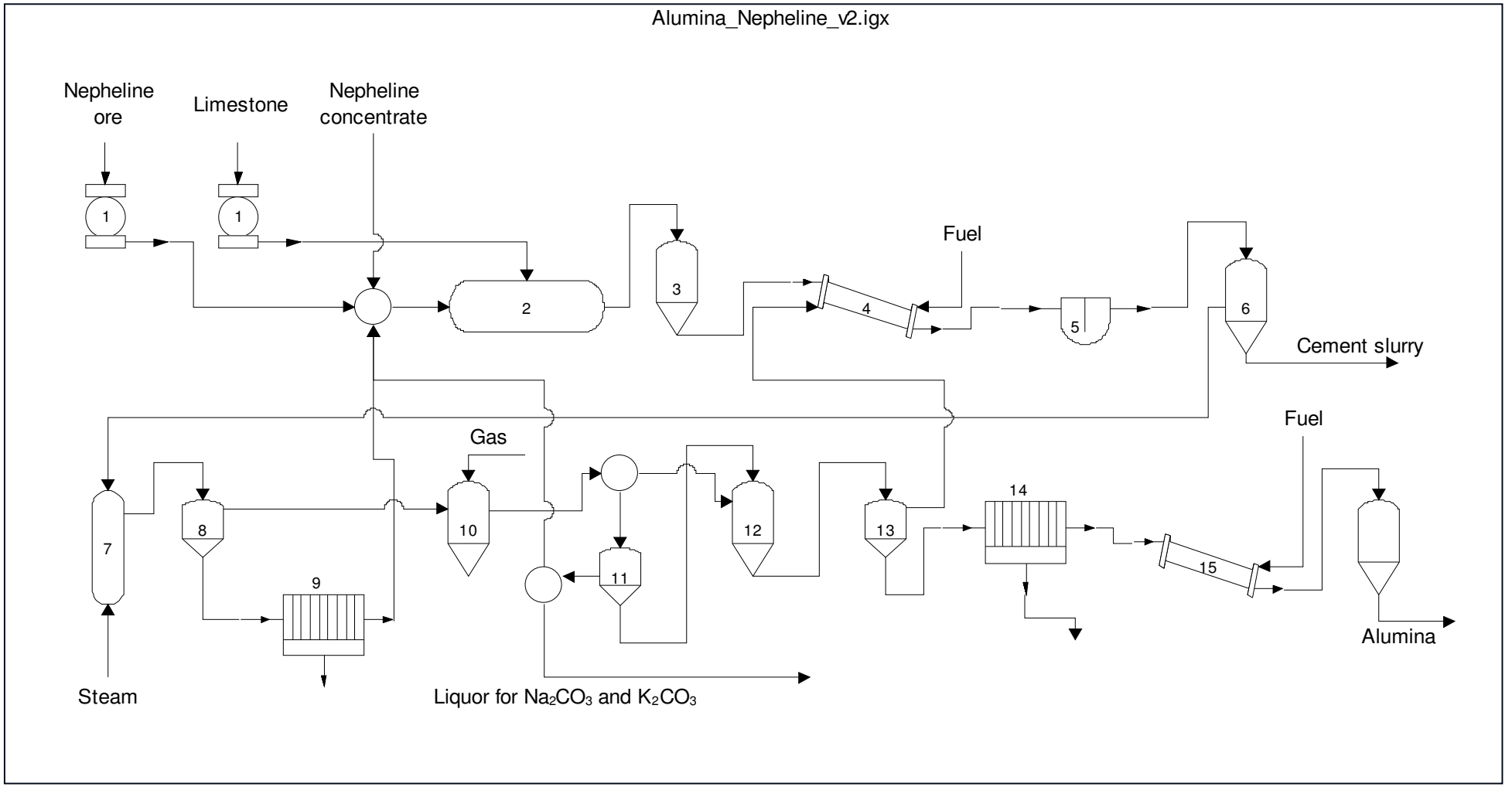
Aluminum: a Lense to IES in a Value Chain

- 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

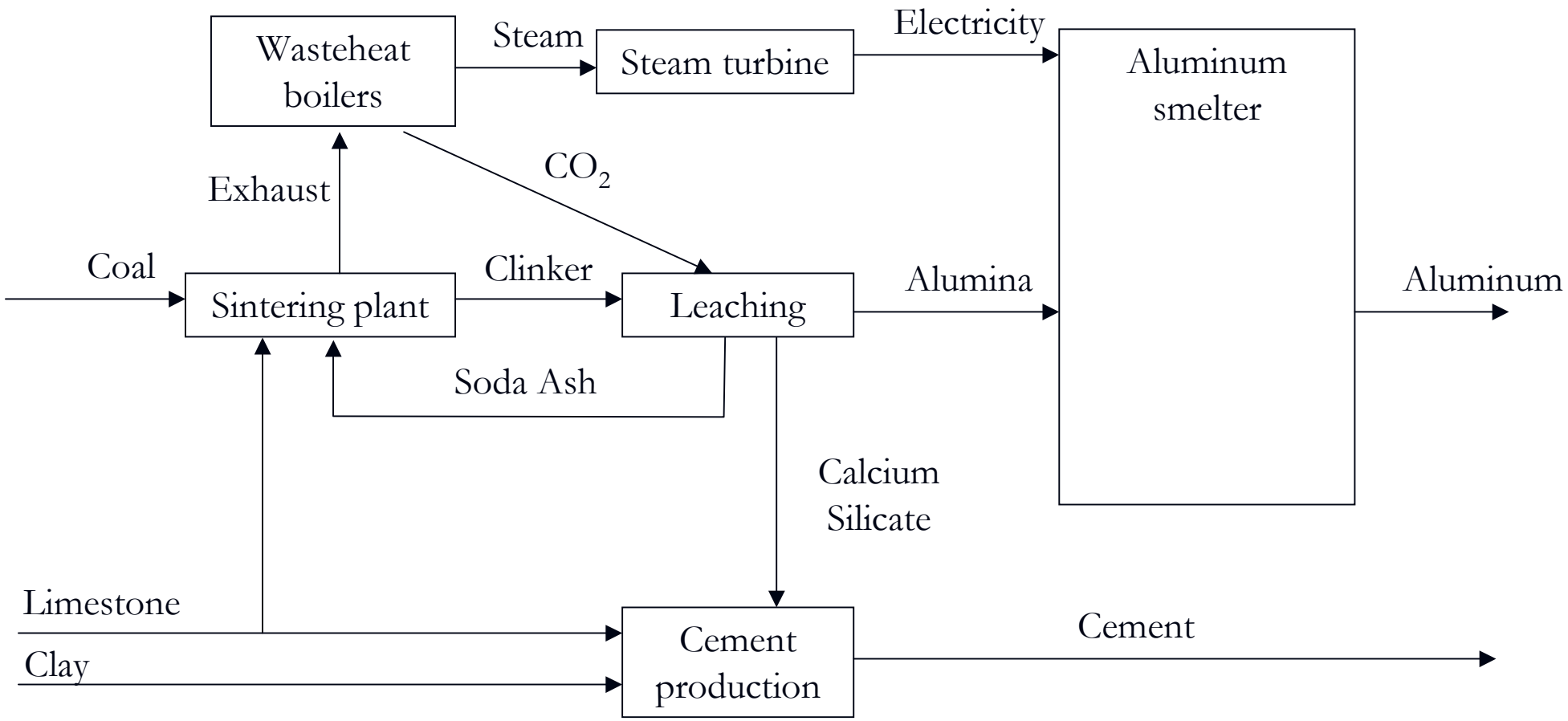

Nepheline concentrate
Bauxite mining
Coal ash
Alumina Refining
(Bayer Process)
Aluminium Smelting
Processing / Recycling

Aluminum raw materials

- Bauxite
  - 40% - 60% Al_2O_3
  - 18-20 €/t (USGS average) => 40 €/t Al_2O_3
- Nepheline: (Na, K, Fe)$AlSiO_4$
  - 30% Al_2O_3
  - Nepheline Syenite (Stjernoyen, Norway): 30 €/t => 100 €/t Al_2O_3
  - Khibiny nepheline (Kola Peninsula, Russia): 15 €/t => 50 €/t Al_2O_3



Al_2O_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 mut 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.

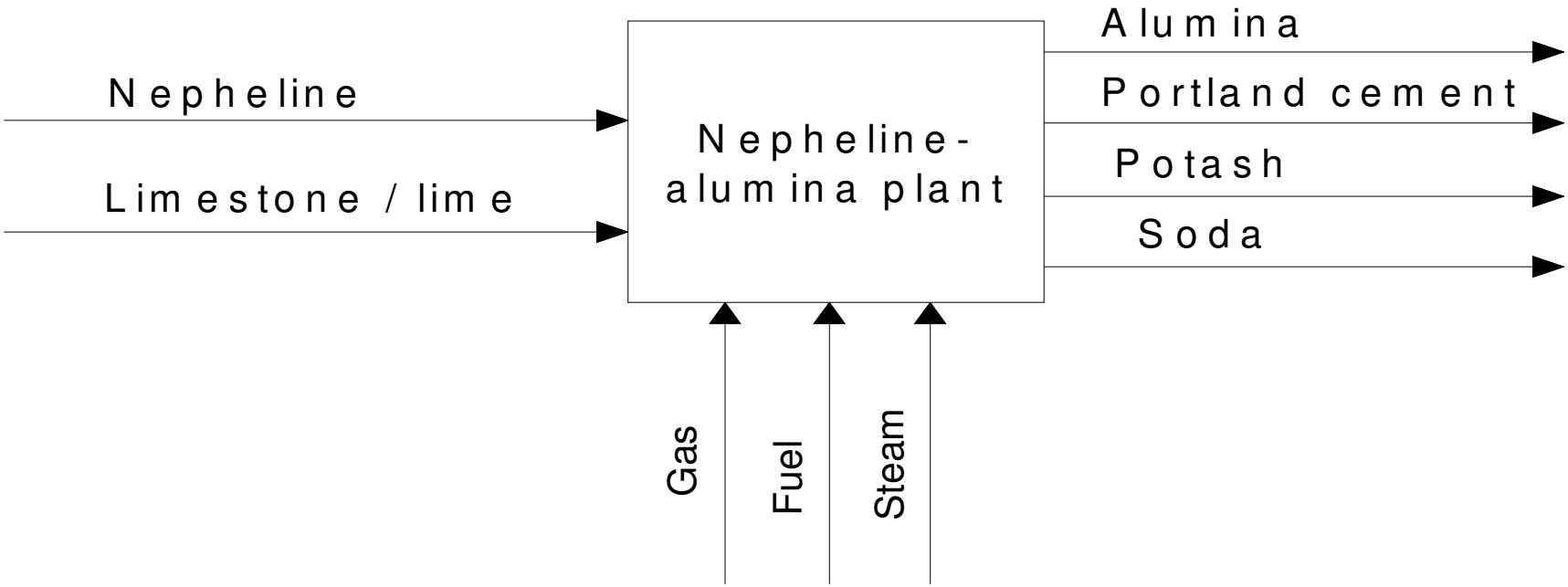


Al_2O_3 production from coal ash: Adapted from: Ayres, R: On Industrial Ecosystems. In Ayres, R. and Leslie W. Ayres: A Handbook of Industrial Ecology. Edward Elgar. 2002: 44-59.

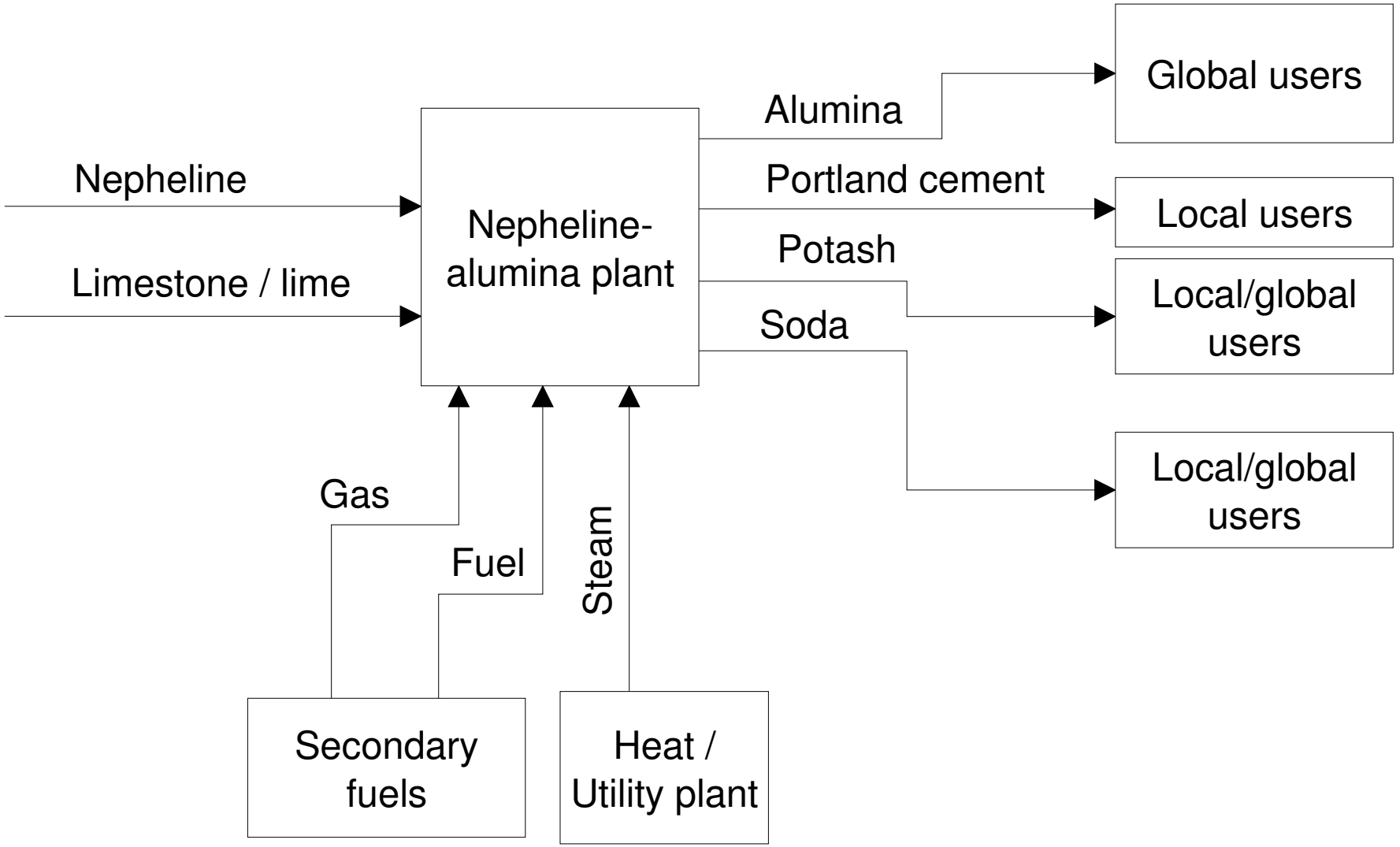
MB: 1.9Mt coal + 3.9Mt limestone => 200 kt alumina + 3.3 Mt cement

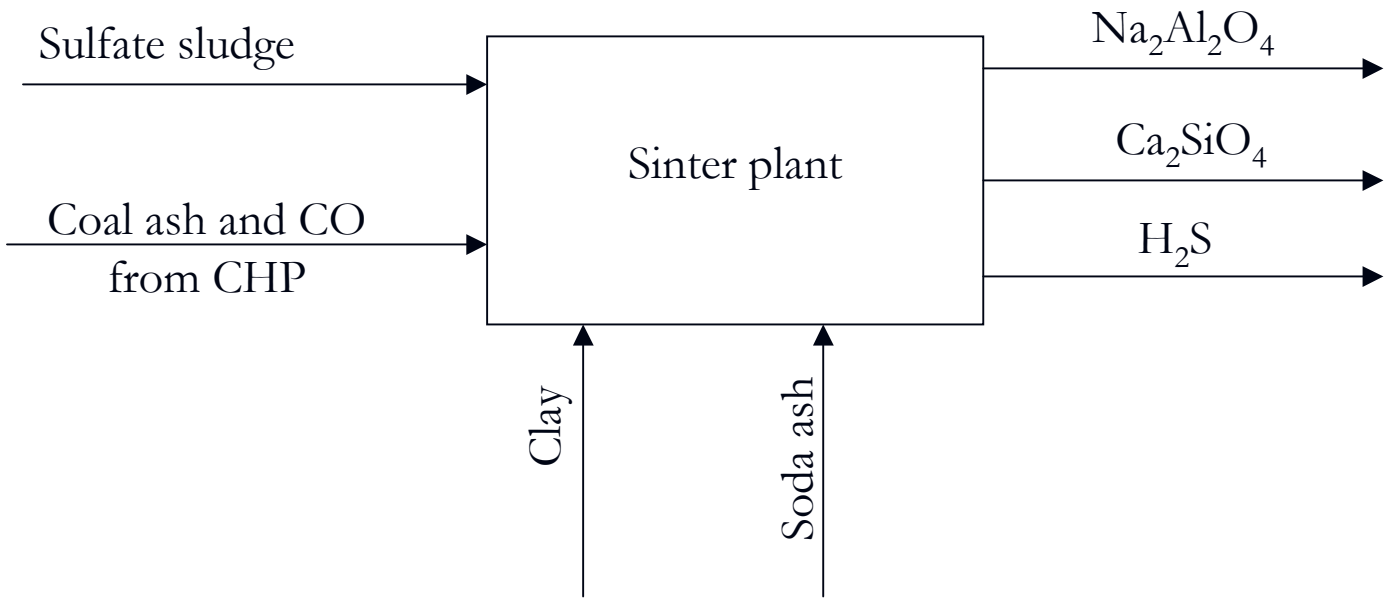
Aluminum raw materials

- Fe-content determines price and use...
  - Glass and ceramics (Norway)
  - Alumina production (Russia)
- ...but auxilliary products determine total revenue
  - Na_2CO_3: 55 €/t (USGS average)
  - K_2CO_3 (K_2O): 165 €/t (USGS average)



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


Nepheline
Limestone / lime
Nepheline-alumina plant
Alumina
Portland cement
Potash
Soda
Global users
Local users
Local/global users
Local/global users
Gas
Fuel
Steam
Secondary fuels
Heat / Utility plant


Sulfate sludge
Coal ash and CO
from CHP
Sinter plant
Clay
Soda ash
$Na_2Al_2O_4$
Ca_2SiO_4
H_2S

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 practitioning industrial ecologist moves accross and between traditional categories for industrial production
- IE/IES/IS classifications that stimulate boundary crossing bear high use value