A systemic view of the nexus of energy, resources and climate change

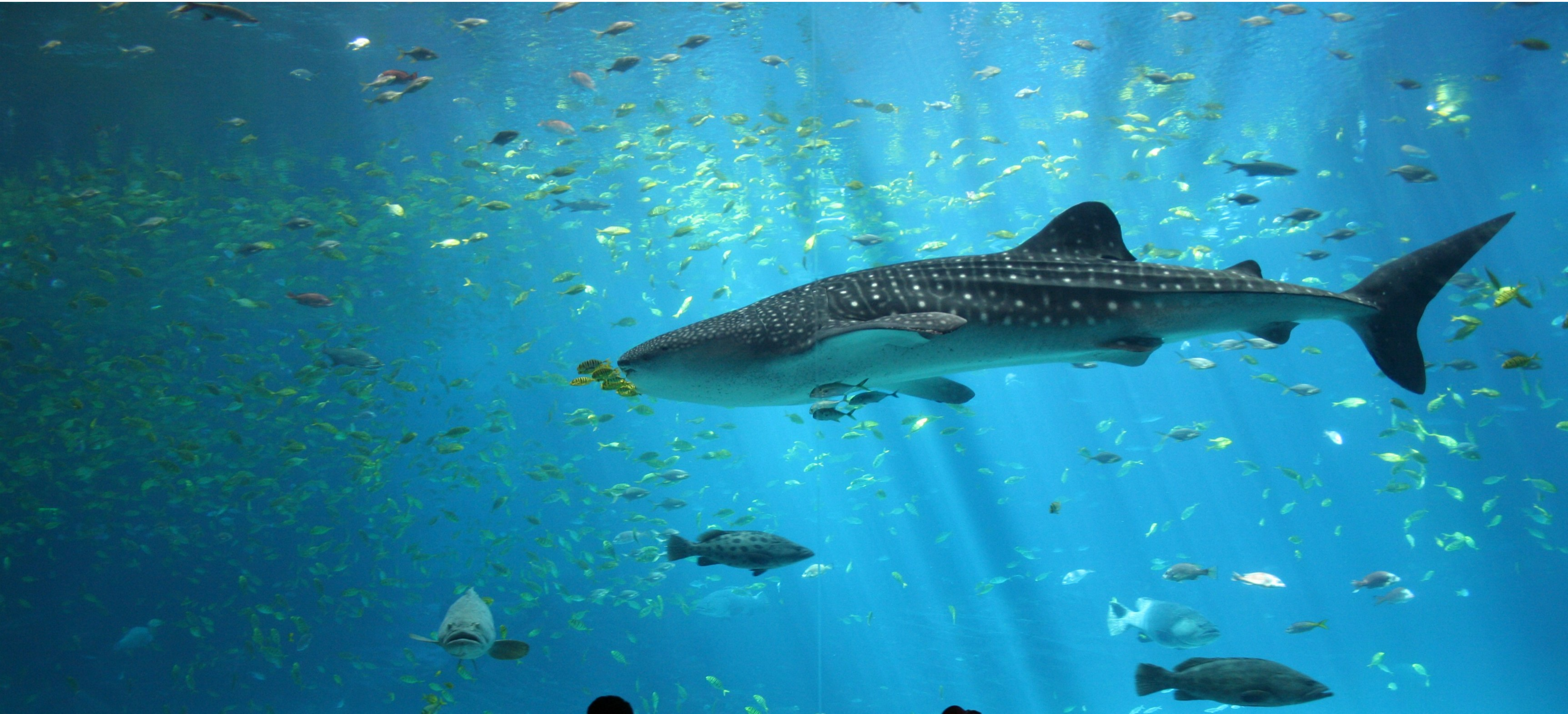
Prof. Dr. Harald Ulrik Sverdrup

Industrial Engineering, University of Iceand, Reykjavik, Iceland

Energy, resources and climate change

- Each issue seen as separate problems, but they are closely linked
- Reduce emissions of CO_2; the big ones are
  - Fossil fuel combustion
  - Calcination to cement
  - Roasting of carbonate ores
- Find new, large volume, cost-efficient, non-emitting ways to produce energy. Costs energy and needs rare materials to do that….
- Improve use efficiency in all aspects of finite material resources essential for technological development. Costs energy to do that
- Invent the necessary technologies not yet available

Understanding Germany in a bigger world



Hidden challenges emanating from the nexus of energy, resources and climate change

- Growth in a finite world is not growth but a redistribution of a limited amount of wealth.
- Erosion of the middle class, erodes the resilience of a modern prosperous nations, eroding democracy participation and governance efficiency

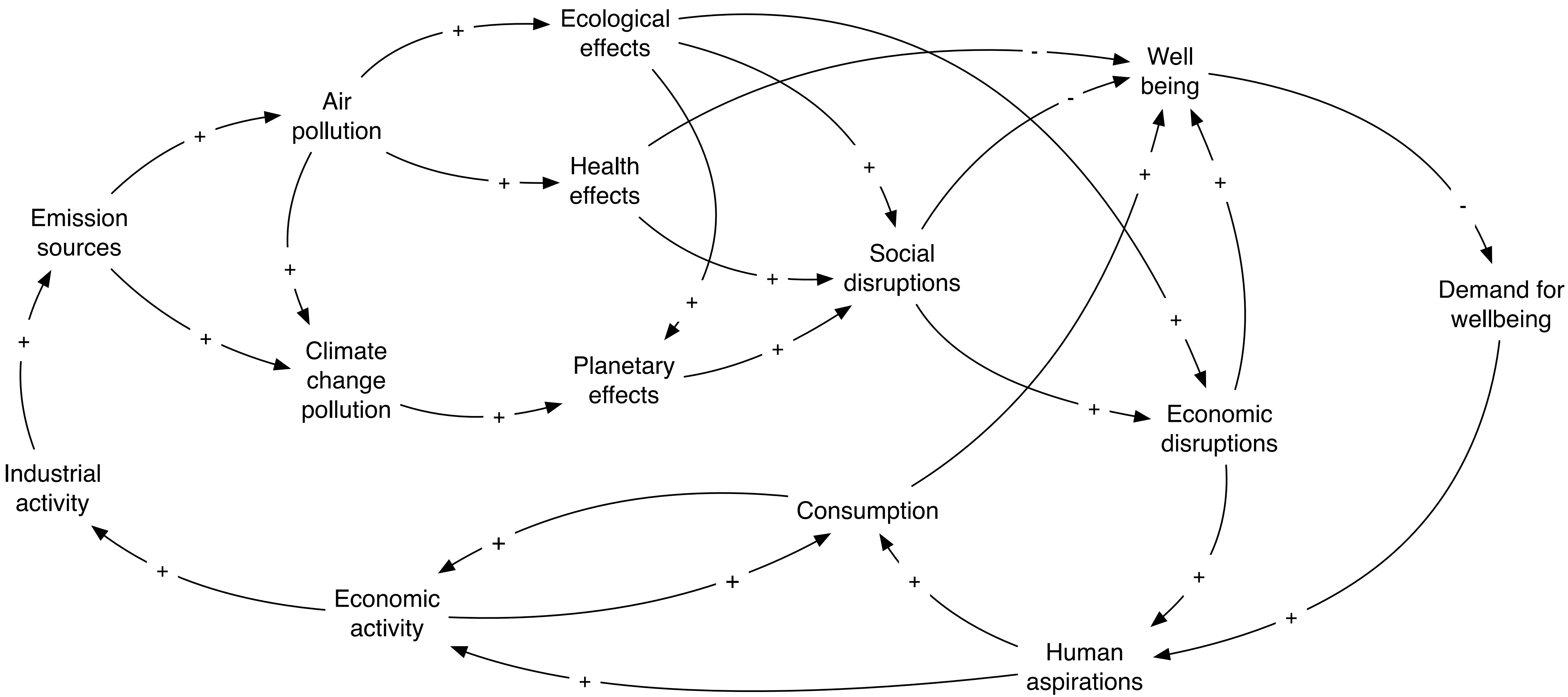
Solutions in view

- Elimination of fossil fuel combustion mitigates:
  - CO_2, N_2O and CH_4 pollution that drive climate change
  - Long range transboundary air pollution (SO_2, NO_x, O_3, particles), toxic residuals.
  - Large scale land degradation through huge scale mining operations and waste landfills
  - Running out of fossil fuels unprepared
- Take Germany away from dependency on oil and gas imports, save money for domestic needs, industrial structural change. Probably more jobs, but different ones…
- Keep German industry competitive by being innovators and initiators

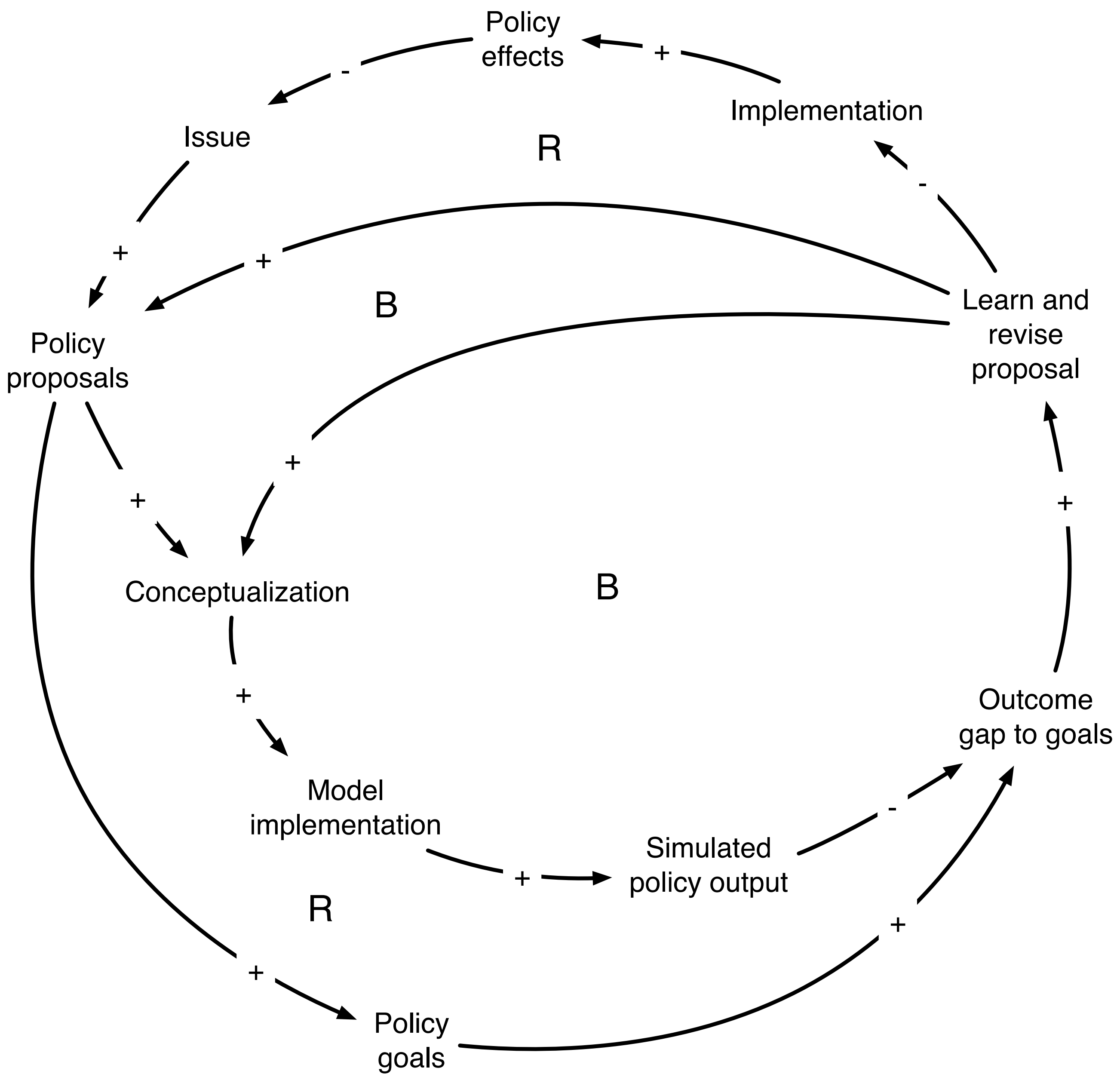
Our language for understanding this nexus

- Systems thinking
  - Think of the whole made up from parts
- Causal loop mapping,
  - finding things out,
  - mapping knowledge and understanding
  - Mapping lack of understanding
- Modelling;
  - simplified reconstructions of world parts to explain
  - use models to investigate the outputs of interventions or lack of interventions

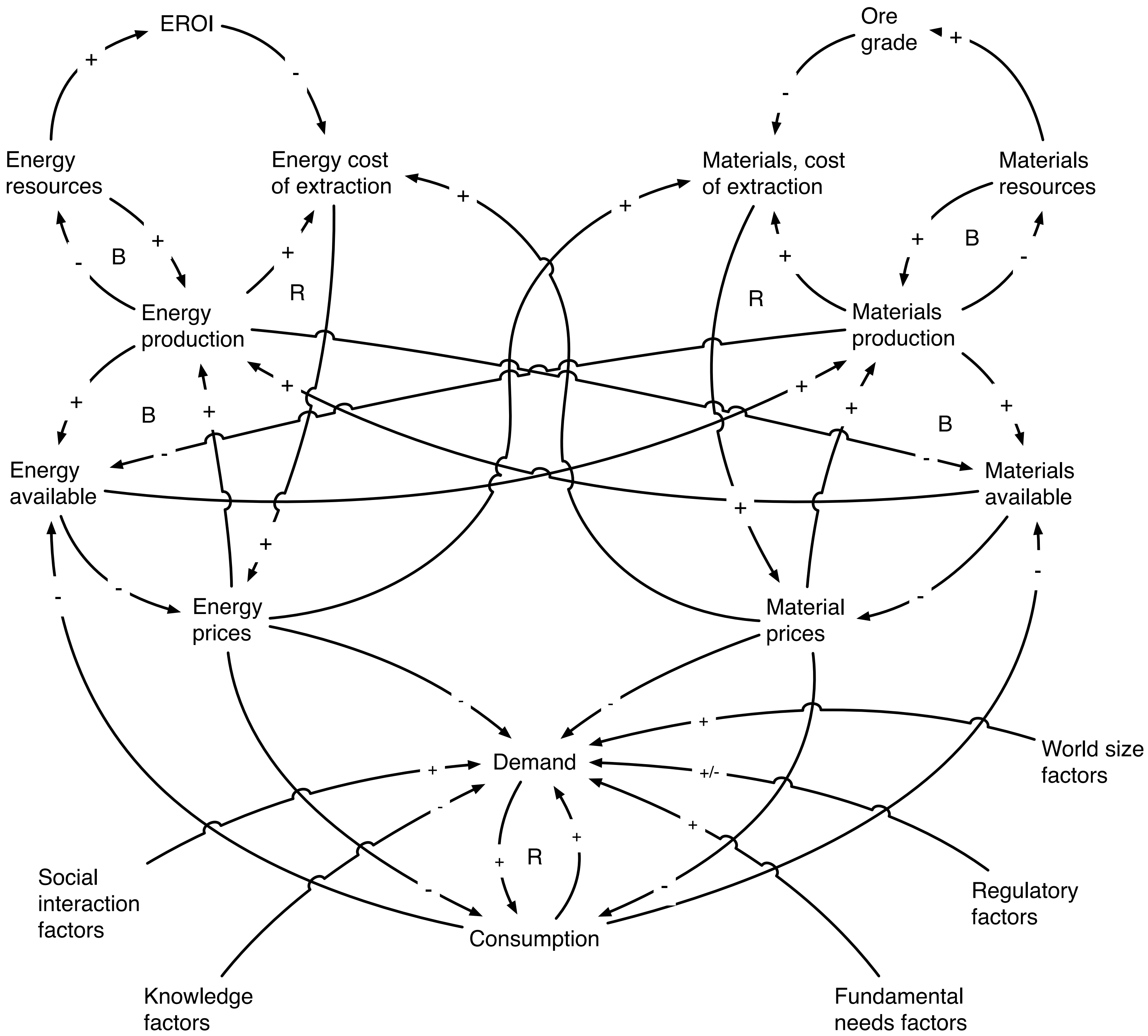
From effects to policy



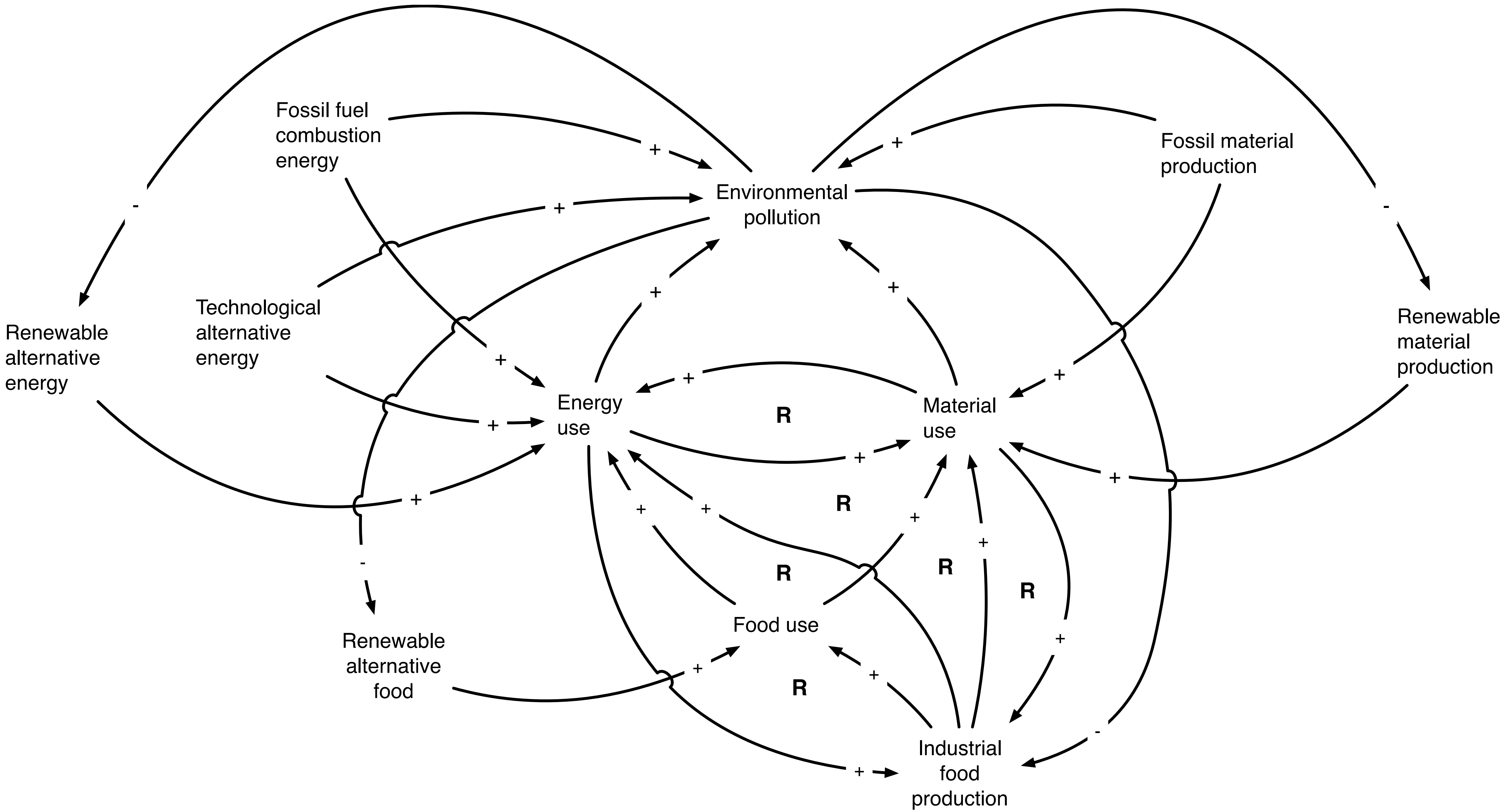
From issues over policy and to solutions

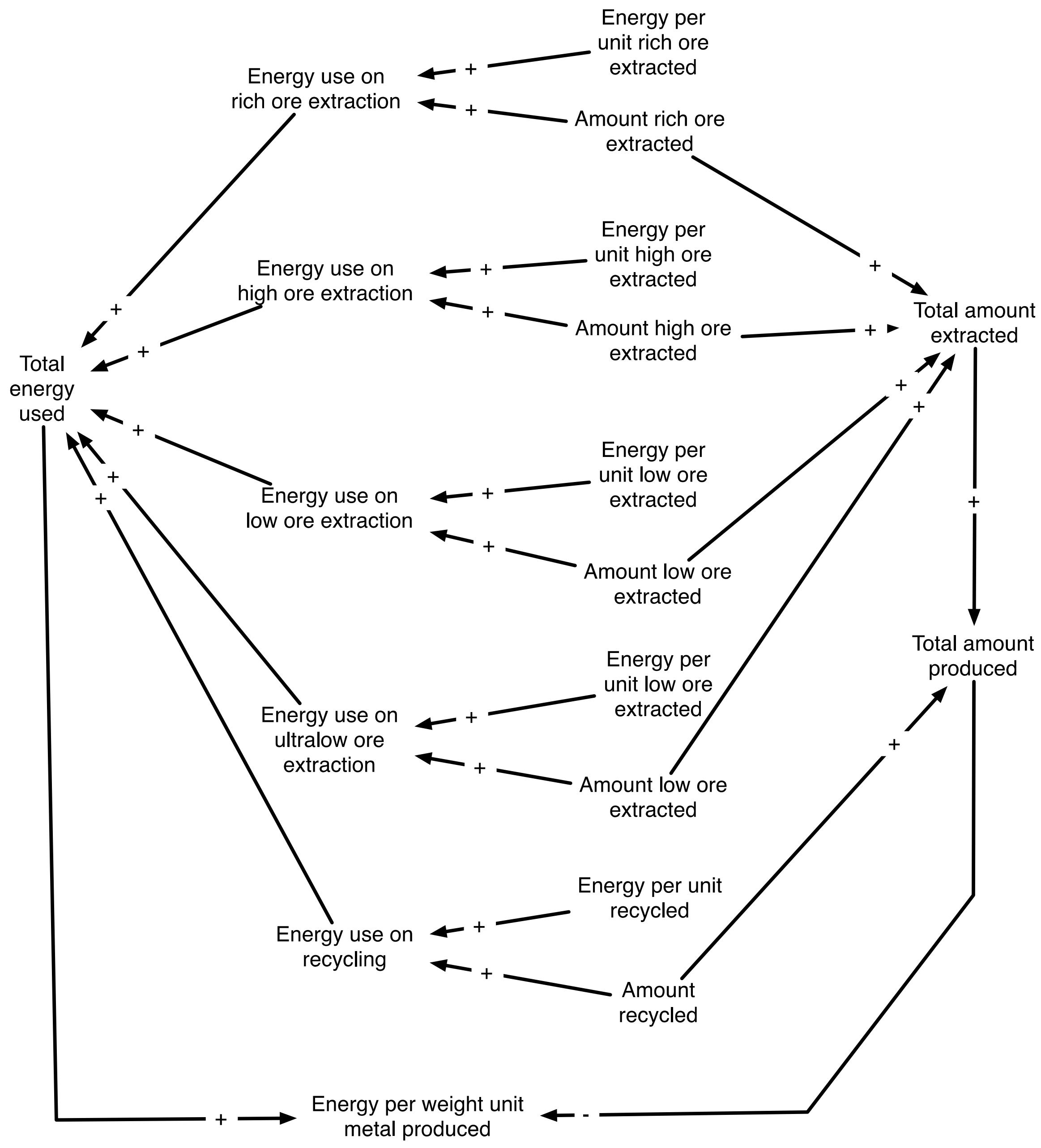


Everything is connected, and our sustainability policies must reflect that understanding to be useful



Energy, resources, food and pollution links





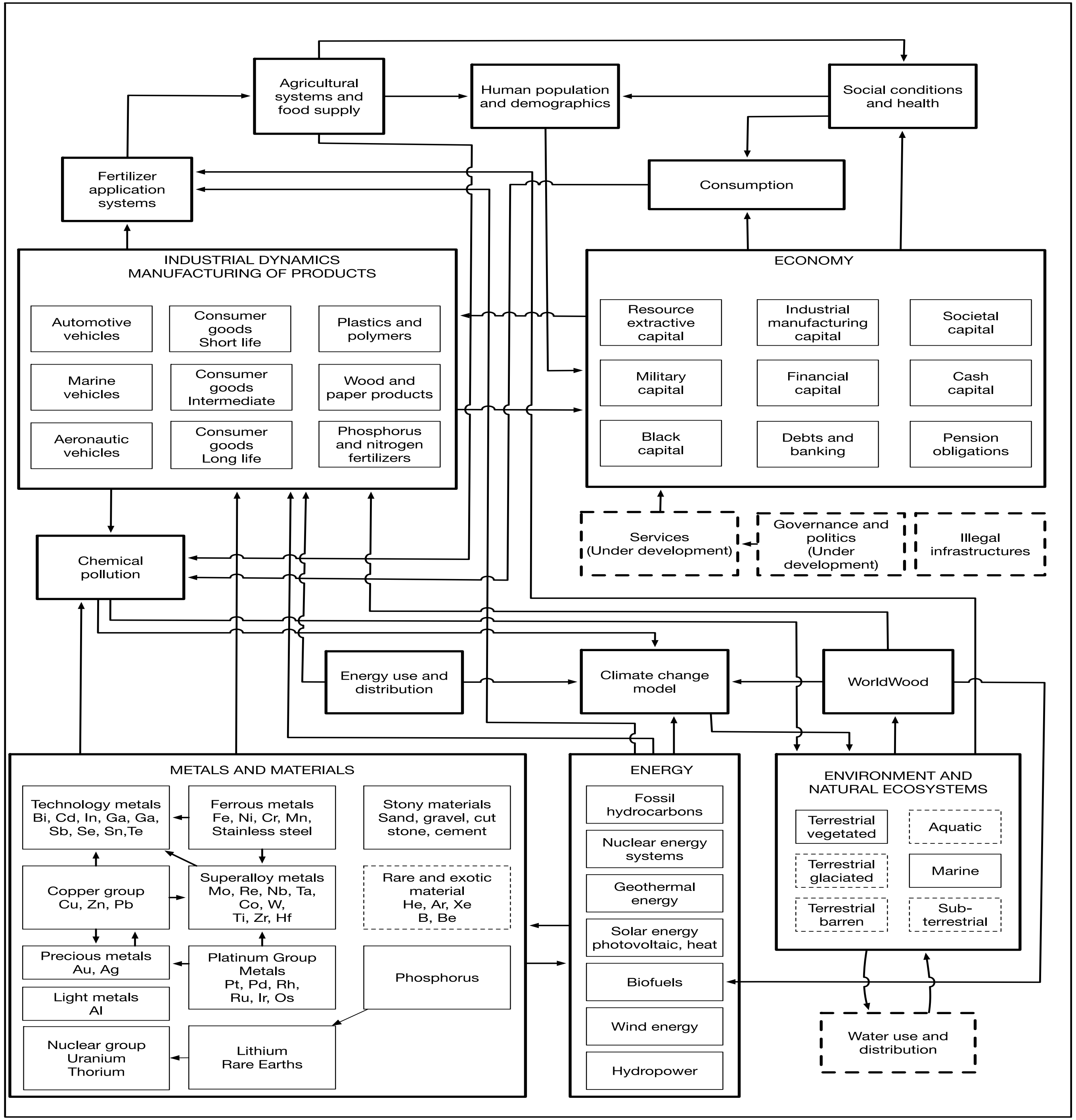
Energy use
of fossil fuels, metal and materials production

&

Calcination of carbonate rocks as ore and for cement

gives

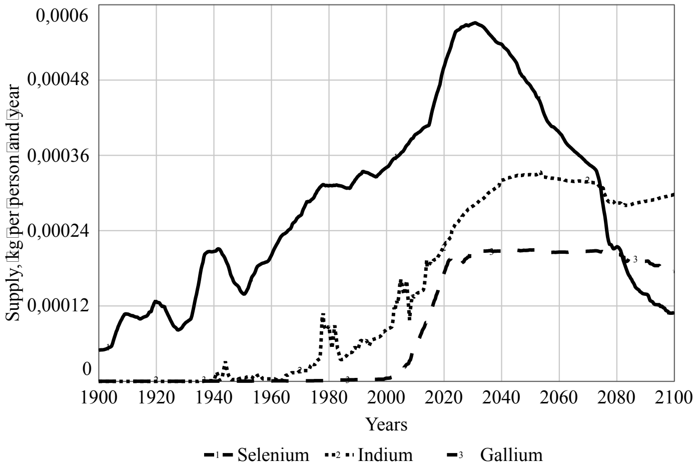
CO_2 emissions

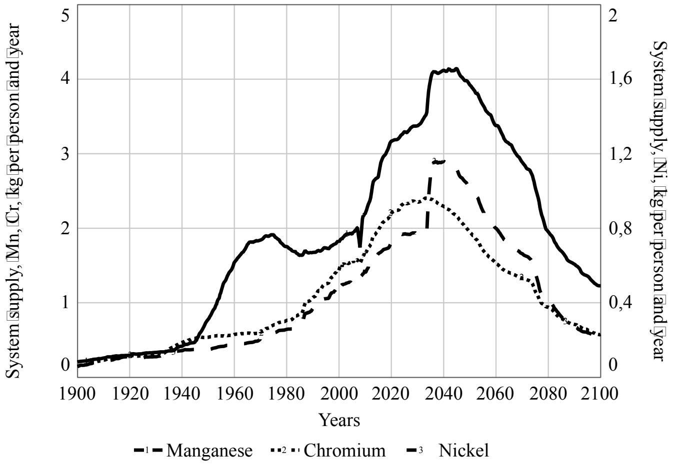


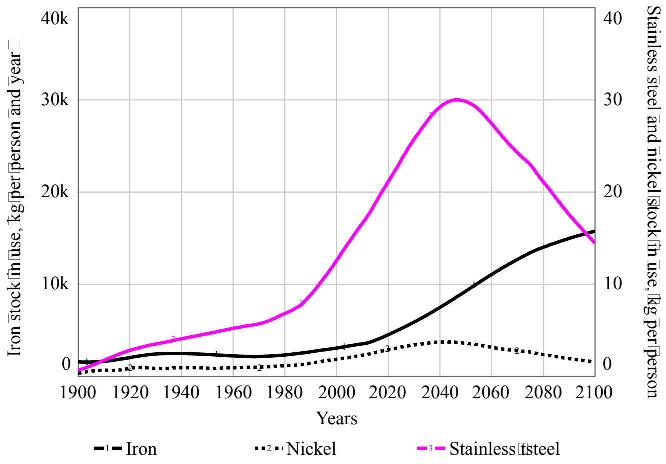
The WORLD6 global system dynamics model….

….connecting economy, society and physical reality

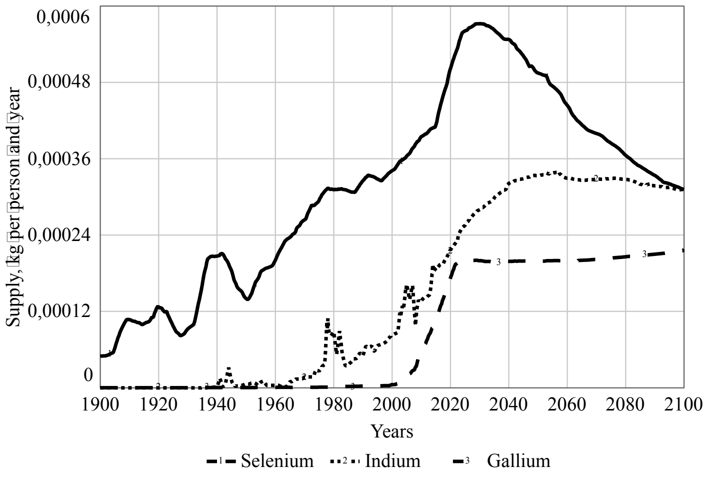
A global Energiewende may cause som intermittent problems with some resources

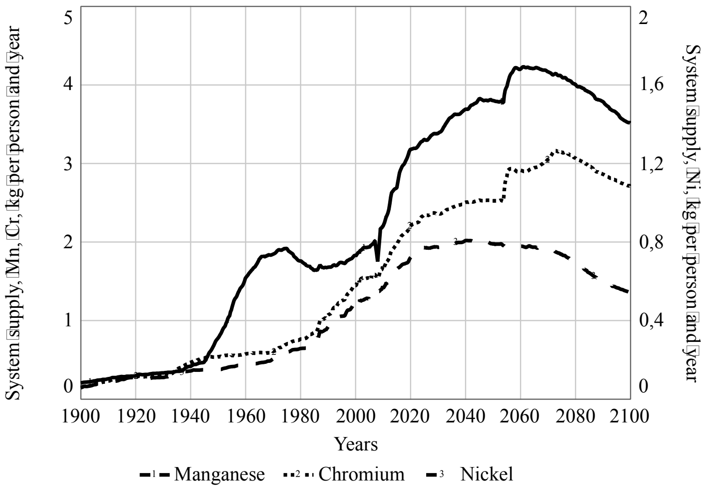


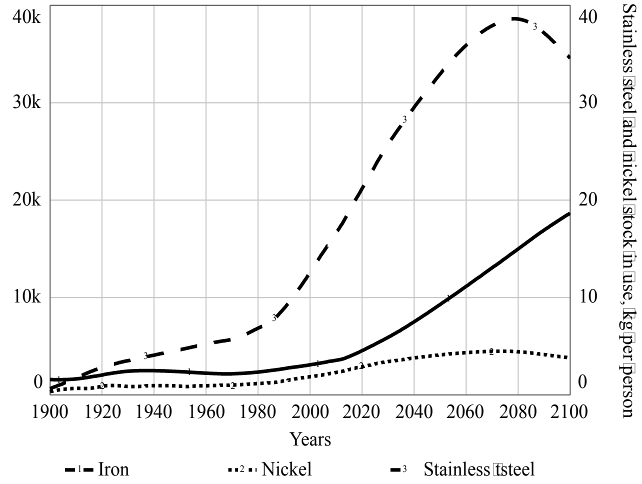




Cut-away



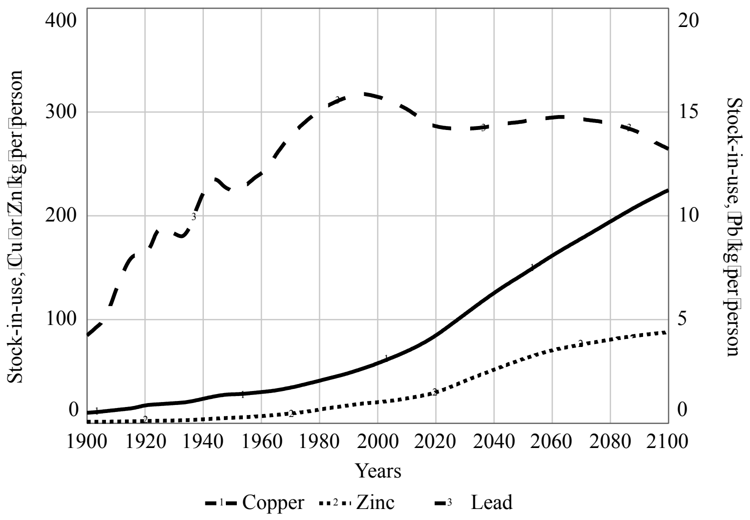


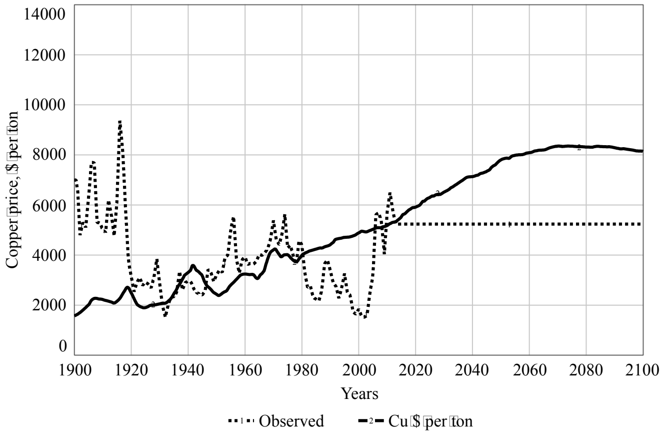


Business As usual

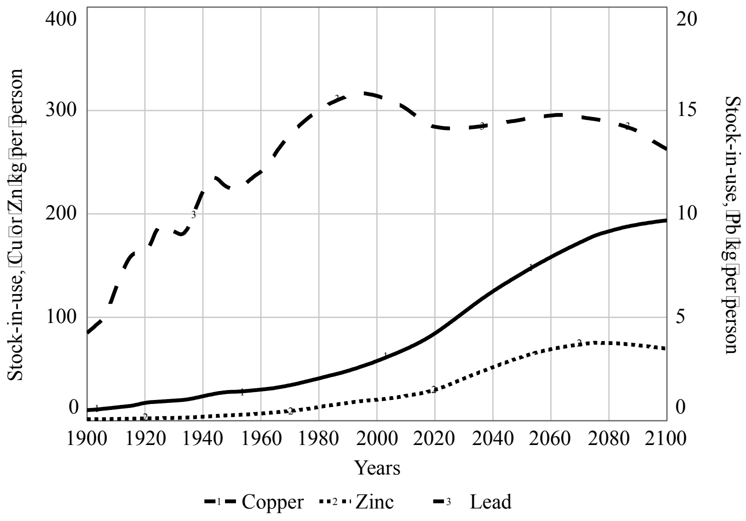
For copper, zinc and lead, physical supply will be fine, but prices will og up

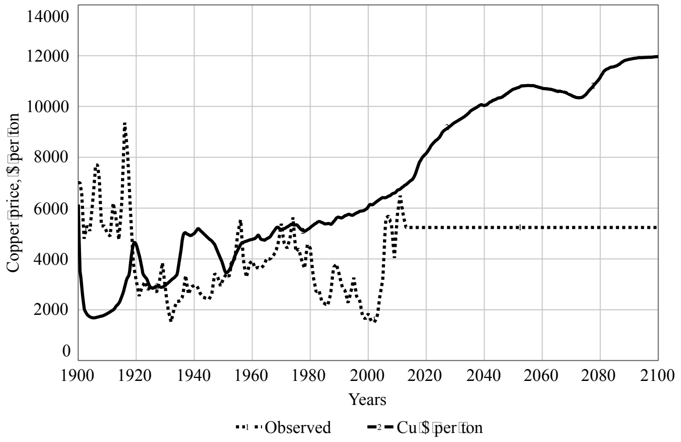
Business-as-usual



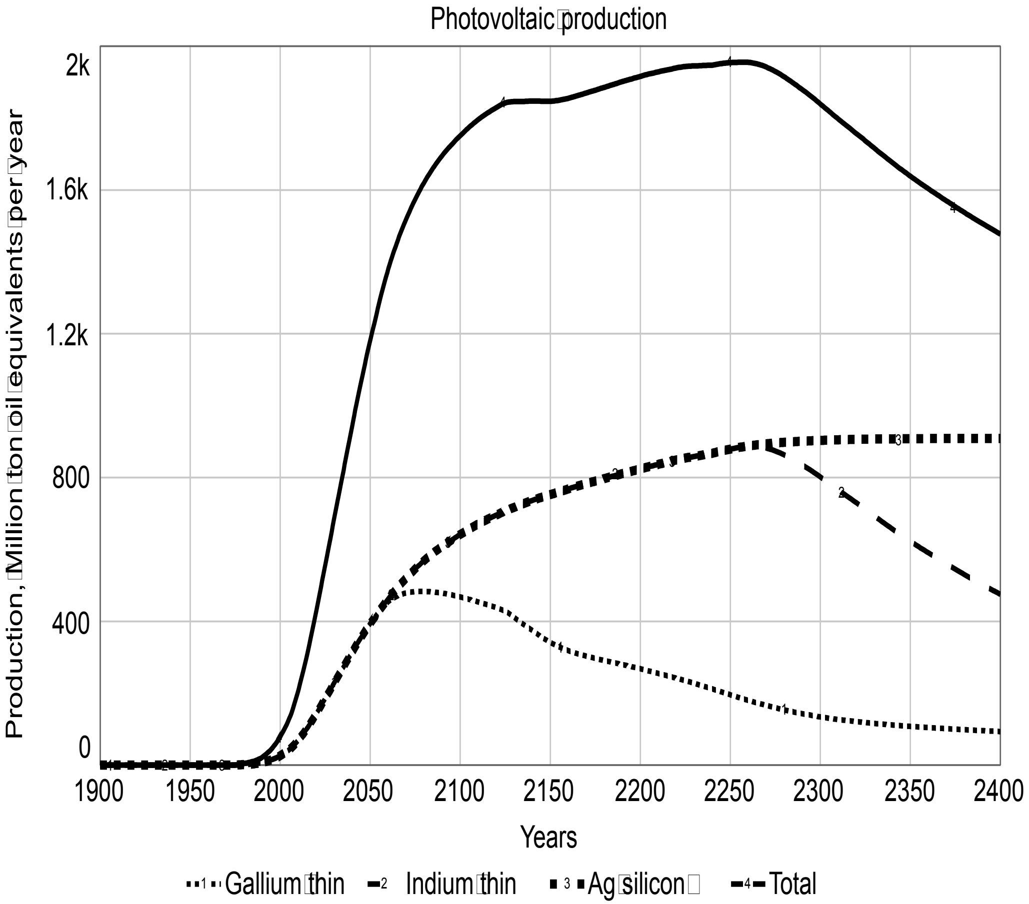


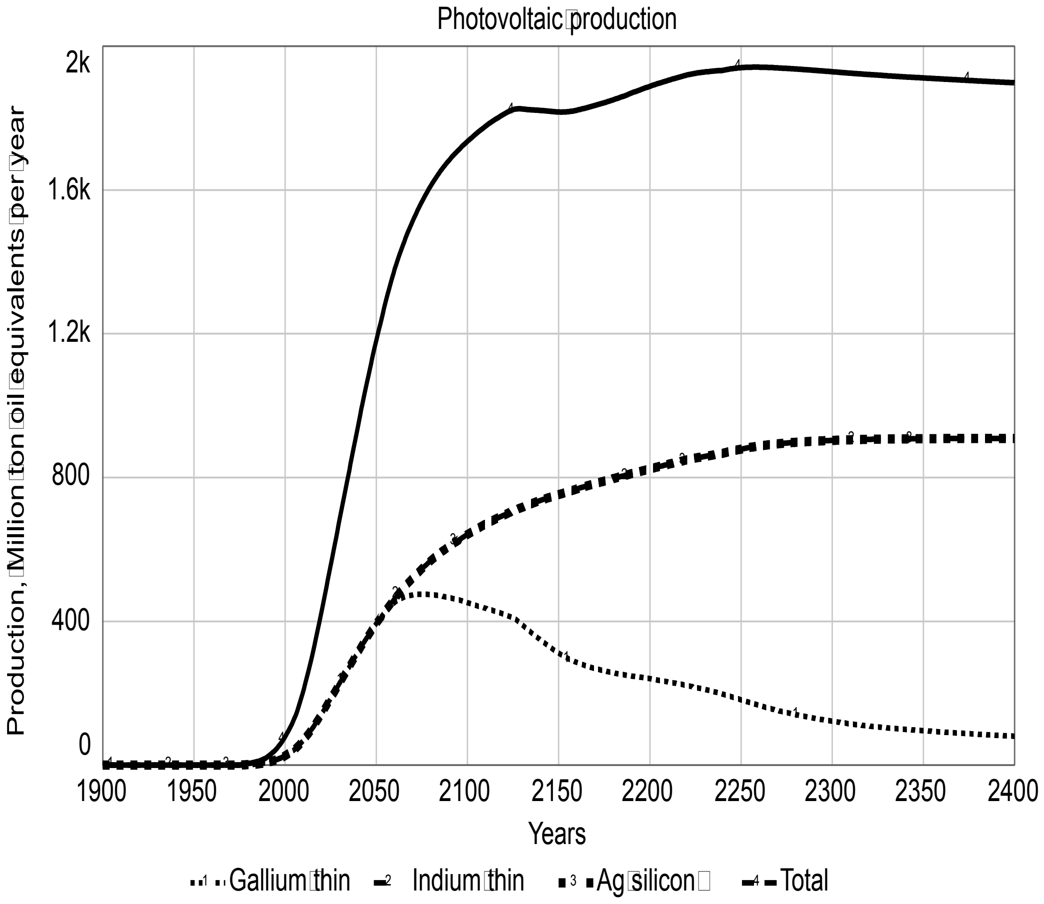
Radical fossil fuel shutdown





Photovoltaic collector may become limited on global level unless recycling is amplified





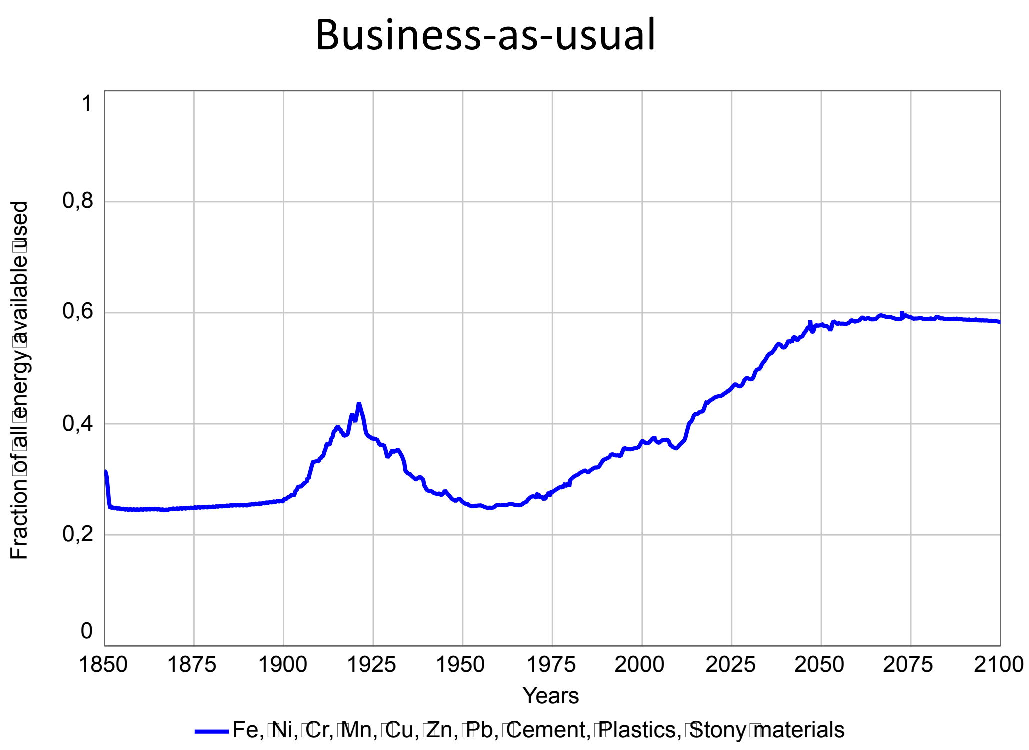
Electric vehicles need resource management, with focus on lithium and cobalt

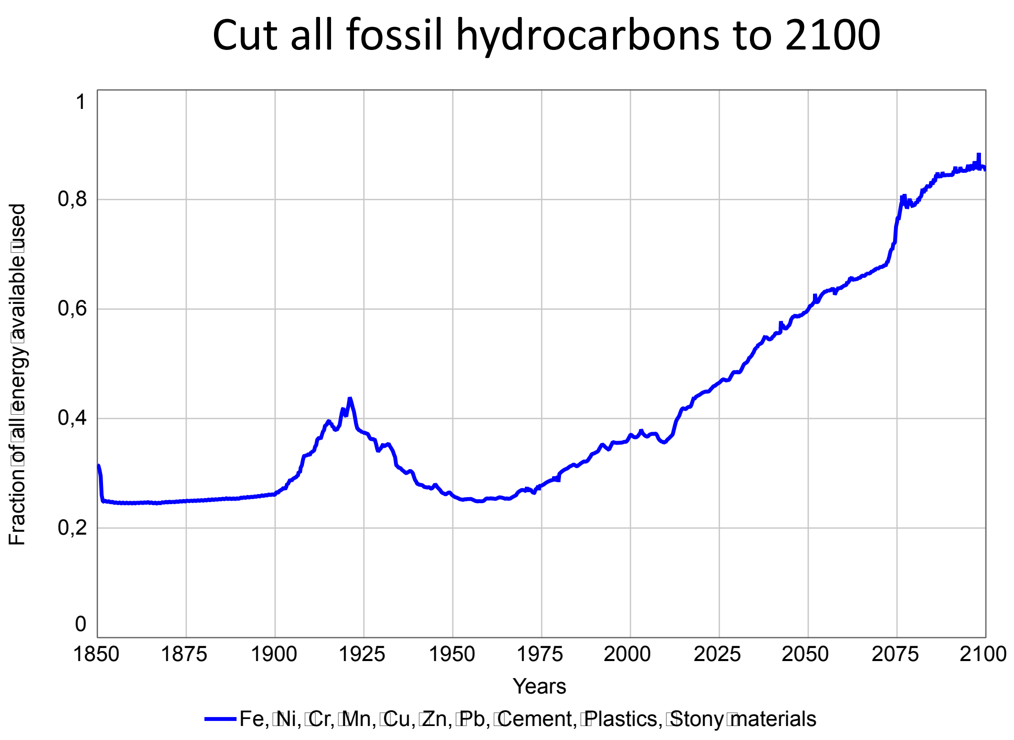
Electric vehicle potential as a function of lithium requirement and size of the extractable amount available. Today; 1.2 billion cars globally									
URR million ton lithium	Recycling fraction of supply alternatives used								
	Alternative 1; 50%			Alternative 2; 65%			Alternative 3; 80%		
	Lithium requirement per battery unit, kg lithium contained								
	5	10	30	5	10	30	5	10	30
	Millions of electric battery units possible								
116	1,200	610	203	2,884	1,442	481	3,050	1,525	508
73	800	400	133	1,892	946	315	2,000	1,000	333
34	396	198	66	880	440	147	932	466	155

Assessing different sustainabiliy aspects of different energy production methods

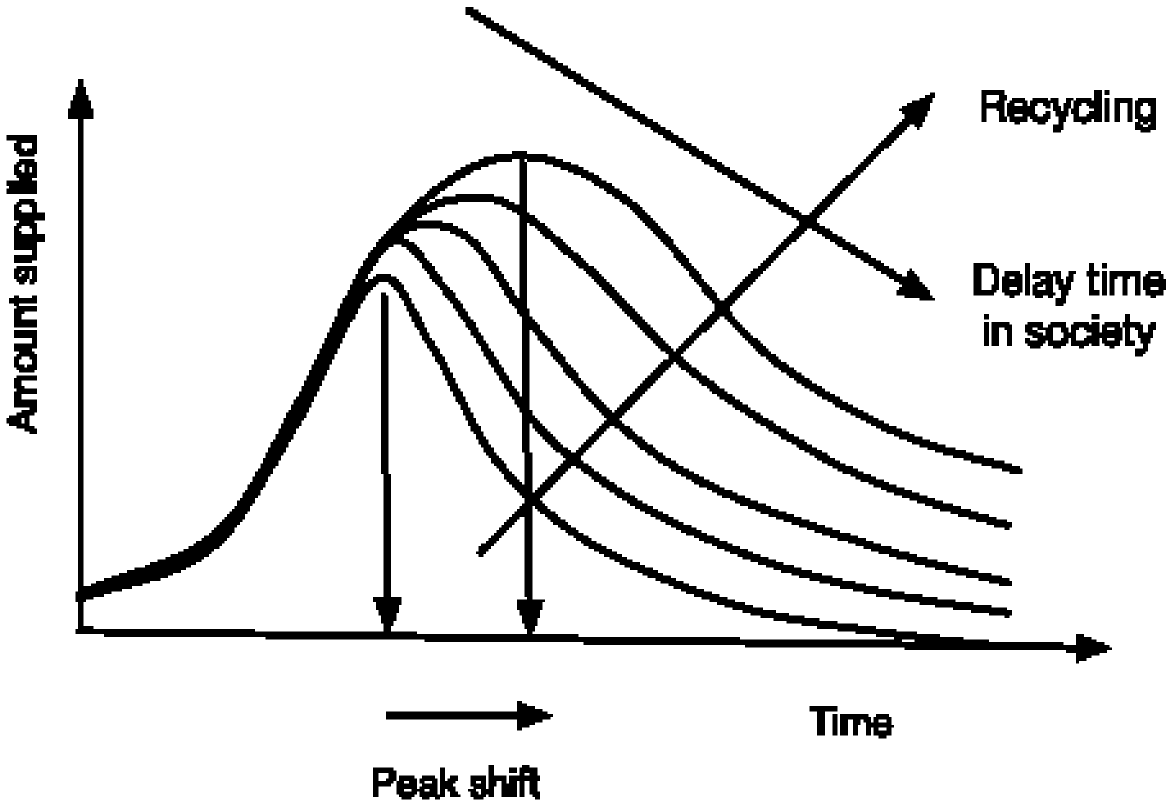
Extraction or production method	Energy source is sustainable?	Materials use is sustainable?	Environmentally sustainable?	Production and use is socially sustainable?	Totally sustainable?
Hydrocarbons	No	Yes	No	Yes	No
Biofuels	Can be by design	Yes	Can be by design	Can be by design	Can be by design
Wood	Yes	Yes	Can be by design	Yes	Can be by design
Wind energy	Yes	Limits	Can be by design	Can be by design	Limits
Photovoltaic	Yes	Limits	Yes	Yes	Limits
Uranium energy	No	No	No	No	No
Thorium energy	Partially	No	Partially	Partially	No
Fusion	Unknown	No	Unknown	Unknown	Unknown
Hydropower	Yes	Yes	Can be by design	Yes	Can be by design
Solar heat	Yes	Yes	Yes	Yes	Yes
Geothermal heat	Yes	Yes	Can be by design	Yes	Can be by design
Geothermal to electricity	No	Limits	No	Yes	No
Fuel cells	By design	No	Yes	Yes	No
Electric vehicles	By design	Limits	Yes	Yes	Yes

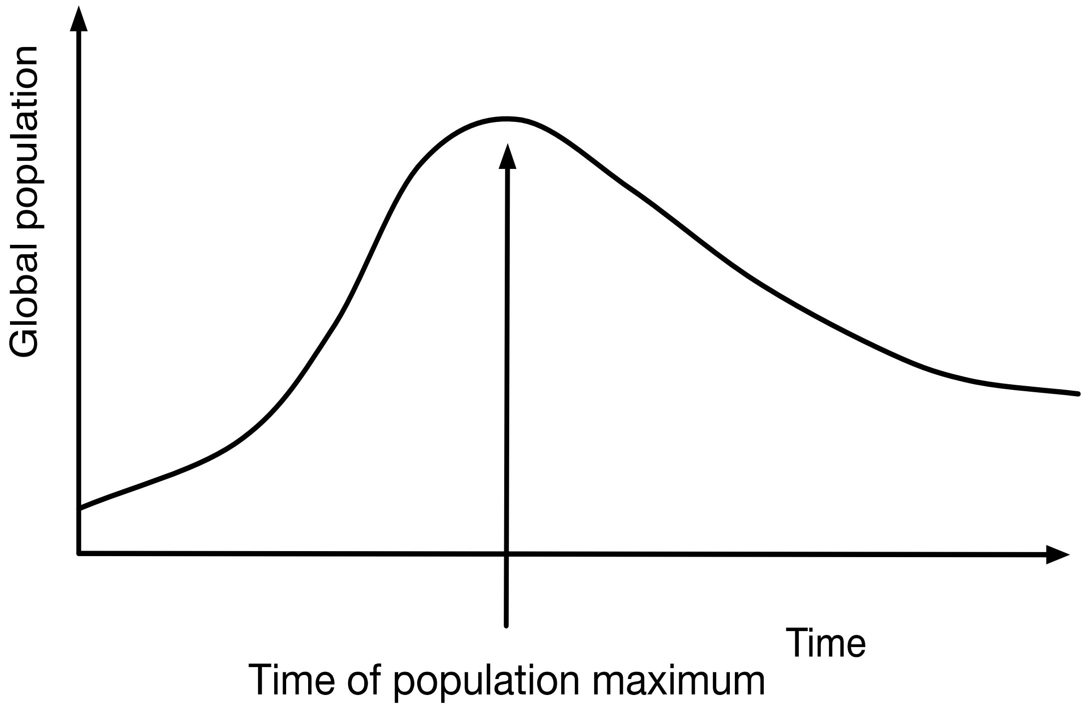
The fraction of all energy used for keeping the resource production going





What can we do?
Recycling and delay-times system dynamics of the supply maximum

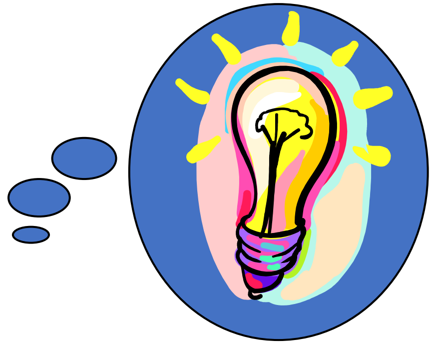




Scales matter

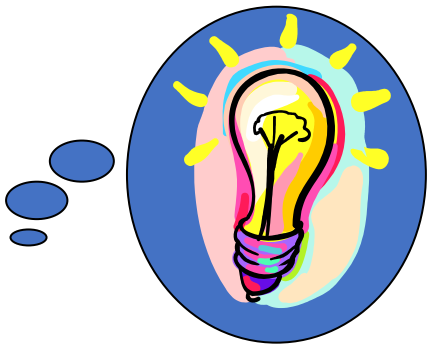
- Global scale
  - Sometimes challenging generalizations
  - Country boundaries cancel out
  - Many uncertainties cancel out
  - Many interregional issues cancel out
  - Policy relevant
- Regional scale
  - Import-export dynamics is challenging
  - Regional causality differences; differences in paradigms and causality parameterizations. Supply and value chain cascades and complex nestings
  - Very challenging parameterizations
  - Informal and criminal capital flows and decision networks are challenging but required
  - Policy relevant
- Business scale
  - Physical basis
  - Depends on larger scales for price mechanisms and policy inputs
  - Easy parameterization
  - Socially relevant

Insights



1. The economic system may have problems before the physical systems
2. All resources will get into soft scarcity (Price goes up). Key materials may get into physical scarcity (Limits to amounts)
3. Economic crisis cause risk for social stresses and problems for governance
4. Business-as-usual is a risky policy in some aspects
5. Business-as-**unusual** has large possibilities for change of trajectory by design

Insights II



1. Getting resources from recycling use 40-80% less energy than primary extraction from ore
2. Key technology elements required for new technologies (Antimony, cadmium, indium, gallium, germanium, silver, selenium, tellurium) are dependent on primary extraction of mother metals (Copper, zinc, lead, silver, nickel, aluminium)
3. Some key technology minerals (Rare Earth Elements, lithium) have major environmental issues with their extraction and refining
4. Some key technology minerals (tantalum, cobalt) have major social and environmental issues with extraction and refining

Conclusions

- A systemic approach is a condition for resolving the challenges and the potential goal conflicts
  - It is not only about adjusting the parameters of the present system;
  - Narrow sectorial appoaches are neither systemic, nor sufficient
- Systemic changes need to be multi-sectorial, causaly linked and pervasive
  - **Energiewende** is linked to a **Ressourcenwende**
  - Both are about rearranging the basic structure of the systems and resetting parameters; transformative changes; industrial dynamics, economic dynamics and social dynamics, innovation and technological development.
  - The successful change-makers are the new winners. Net gain of jobs, old jobs go away and new jobs take their place.
  - It may imply substaintial changes to existing power structures