The tragedy of energy efficiency
An interdisciplinary analysis of rebound effects

Grégoire Wallenborn
Centre for Studies on Sustainable Development
Université Libre de Bruxelles

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Introduction

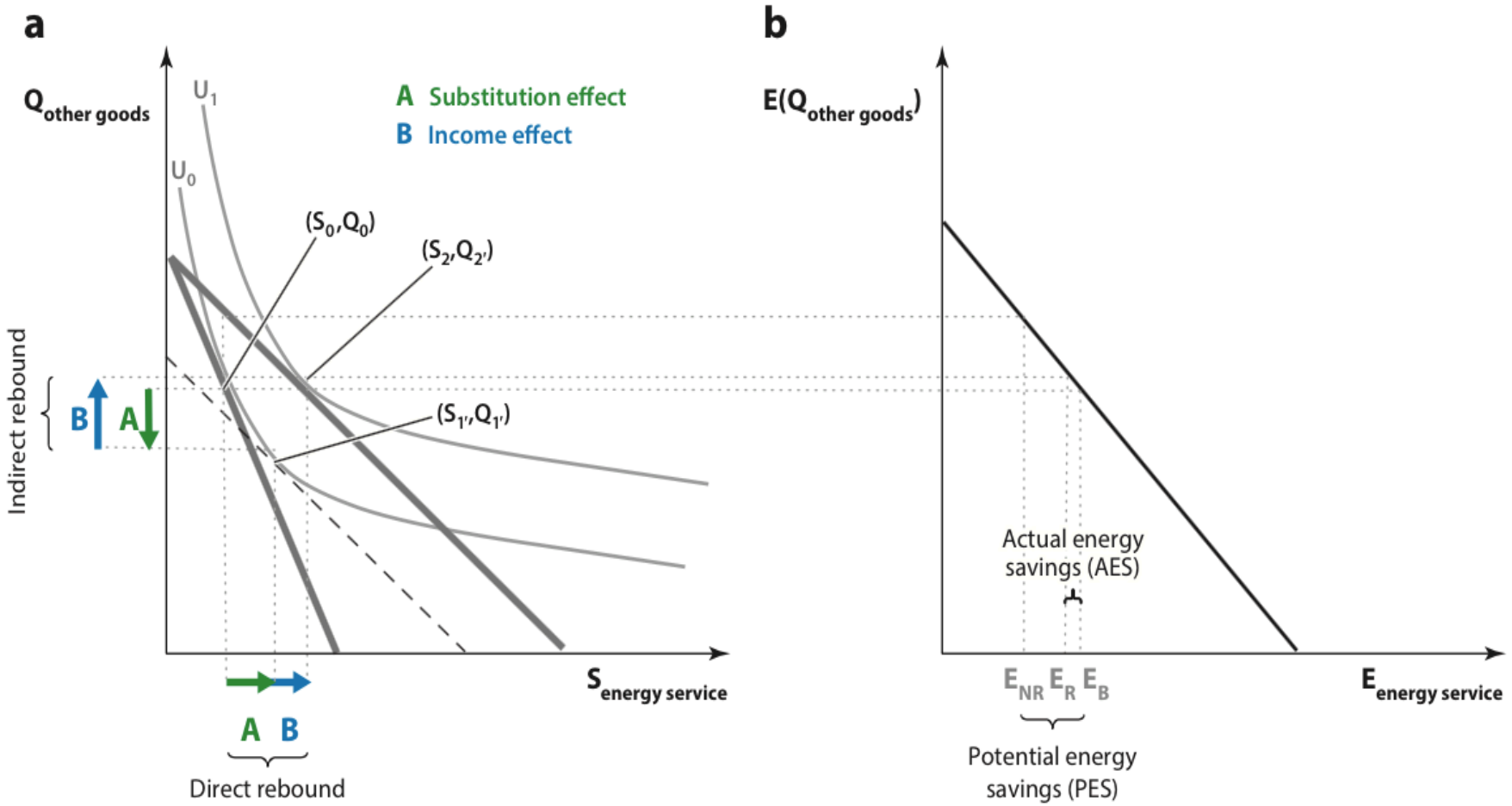
- Energy efficiency (EE) increases **and** energy consumption too.
- Is EE a solution or a problem to climate change ?
- Rebound: conserved energy will be used at another time, in another activity or elsewhere
- No satisfactory classification of rebounds
- Magnitude? Backfire? (i.e. rebound > 100%)
- Controversies: rebounds happens at various spatial and temporal scales → each discipline captures different mechanisms
- 4 « disciplinary framings » : neoclassical economics, ecology, technology, social practices

Energy efficiency or energy productivity?

- Definition of RE. Following the energy efficiency improvement of a technological system, energy consumption does not decrease (or even increase) as much as what is expected from an engineering model
- Efficiency : output/input
  - Input: energy, money, human work, time, materials, etc.
- Energy efficiency improvement: same output with less energy
- Energy productivity improvement : more output with same input

Neoclassical economics

- Micro level: utility function. Built to be derivable twice → use of lagrangian formalism (marginal utility = gradient of desire in the product space). Cf. Mirowski 1989.
- Direct micro rebounds:
  - Single service for an individual
  - 5 to 50% (10-30% as best guess)
- Indirect: difficult to be measured.



(Azevedo 2014)

Neoclassical economics

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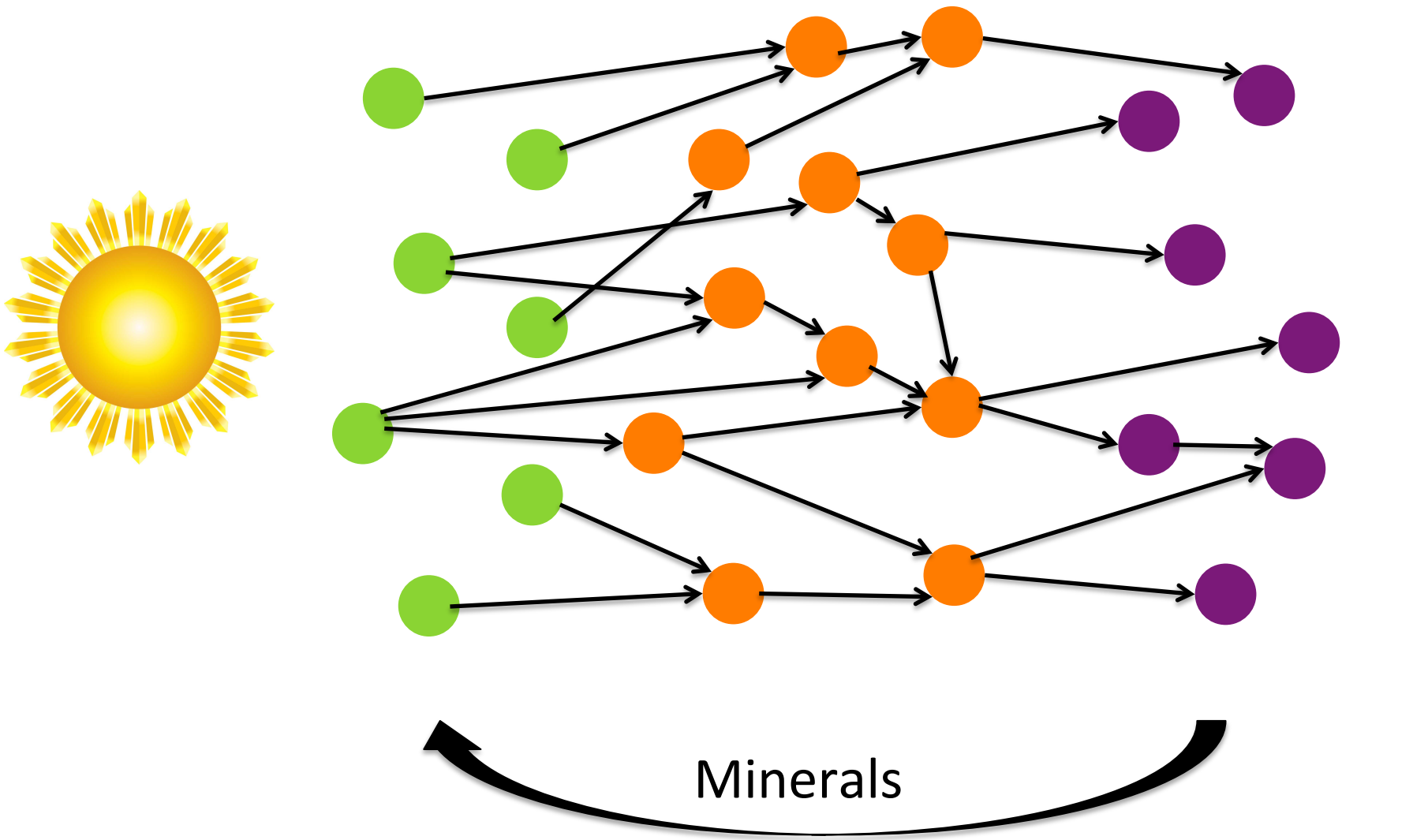
- Direct micro rebounds:
  - Single service
  - 5 to 50% (10-30% as best guess)
- Indirect: difficult to be measured.
- Macro level: depends on assumption about elasticities of substitution between energy, labour, capital and materials.
  - Production (Computable General Equilibrium models)
  - 0-200% (40-70% as best guess)
- Conclusion:
  - No dynamics
  - Assume independant variables, which are linked.

Ecology

- Relations and processes: energy and material flows
  - Trophic chains: producers (plants), consumers and decomposers.

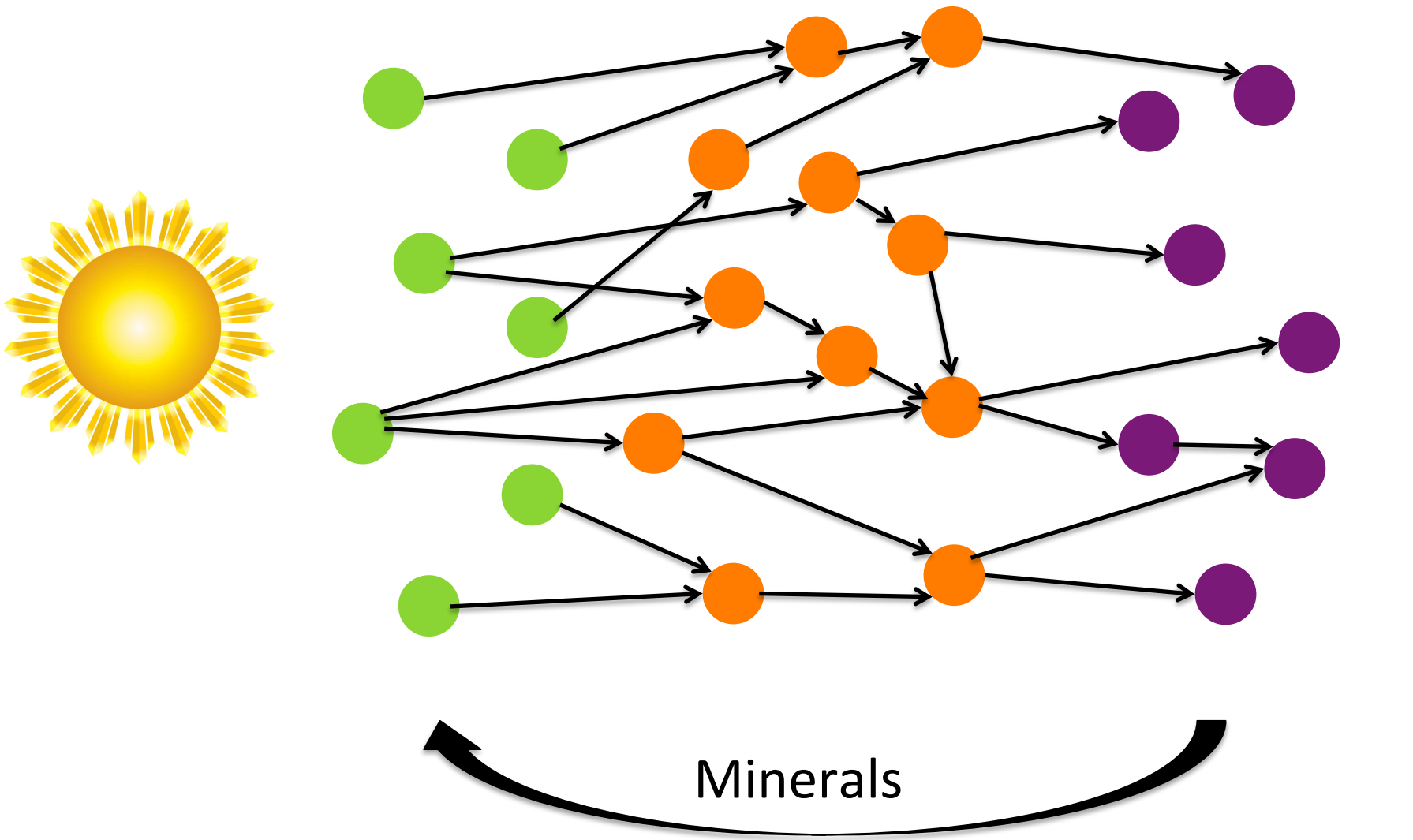
Trophic chains



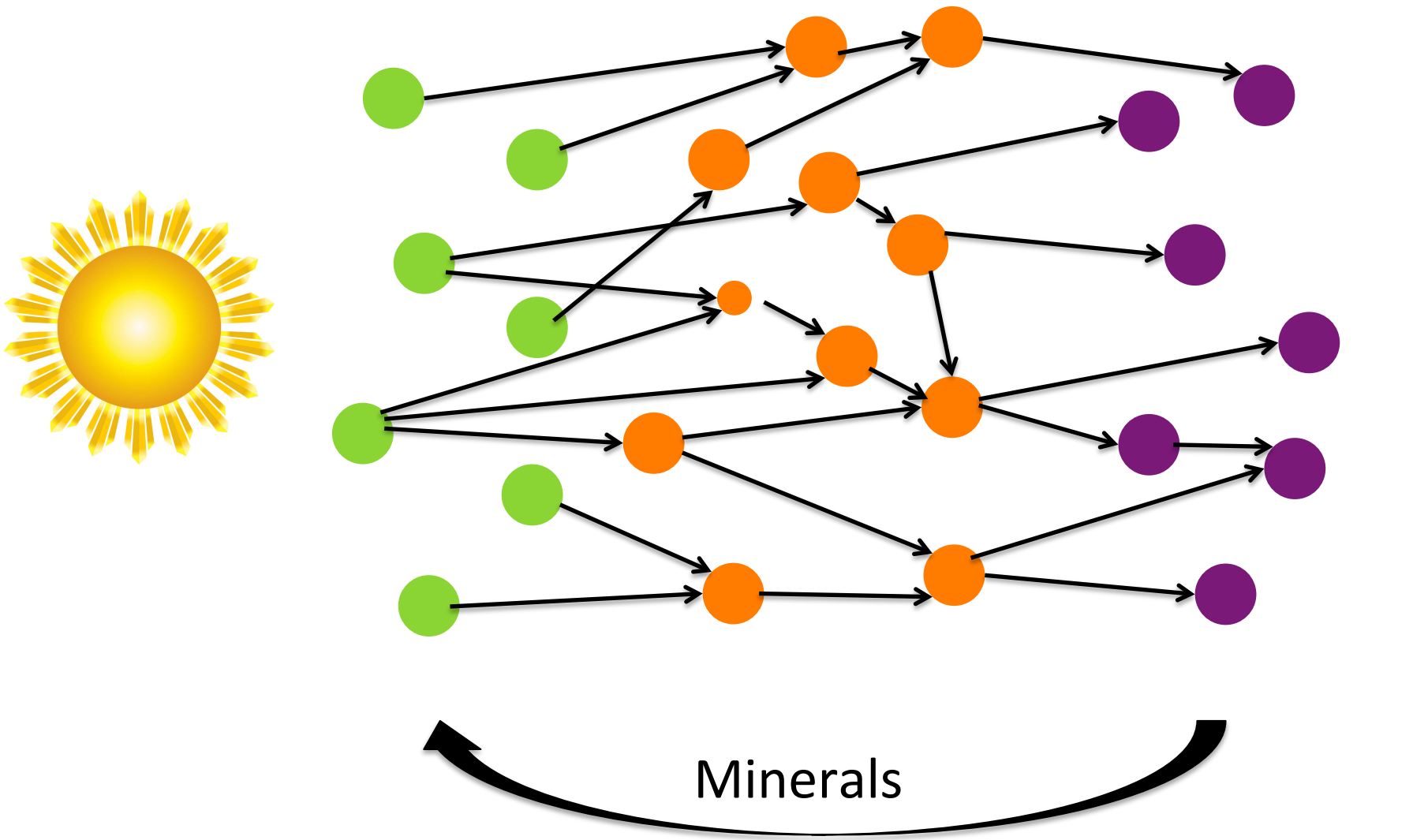
Ecology

- Relations and processes: energy and material flows
  - Trophic chains: producers (plants), consumers and decomposers.
- Reproduction of life
  - Every day
  - Through generations: darwinian evolution
- First mechanism:
  - Minimisation of entropy production: consumption efficiency

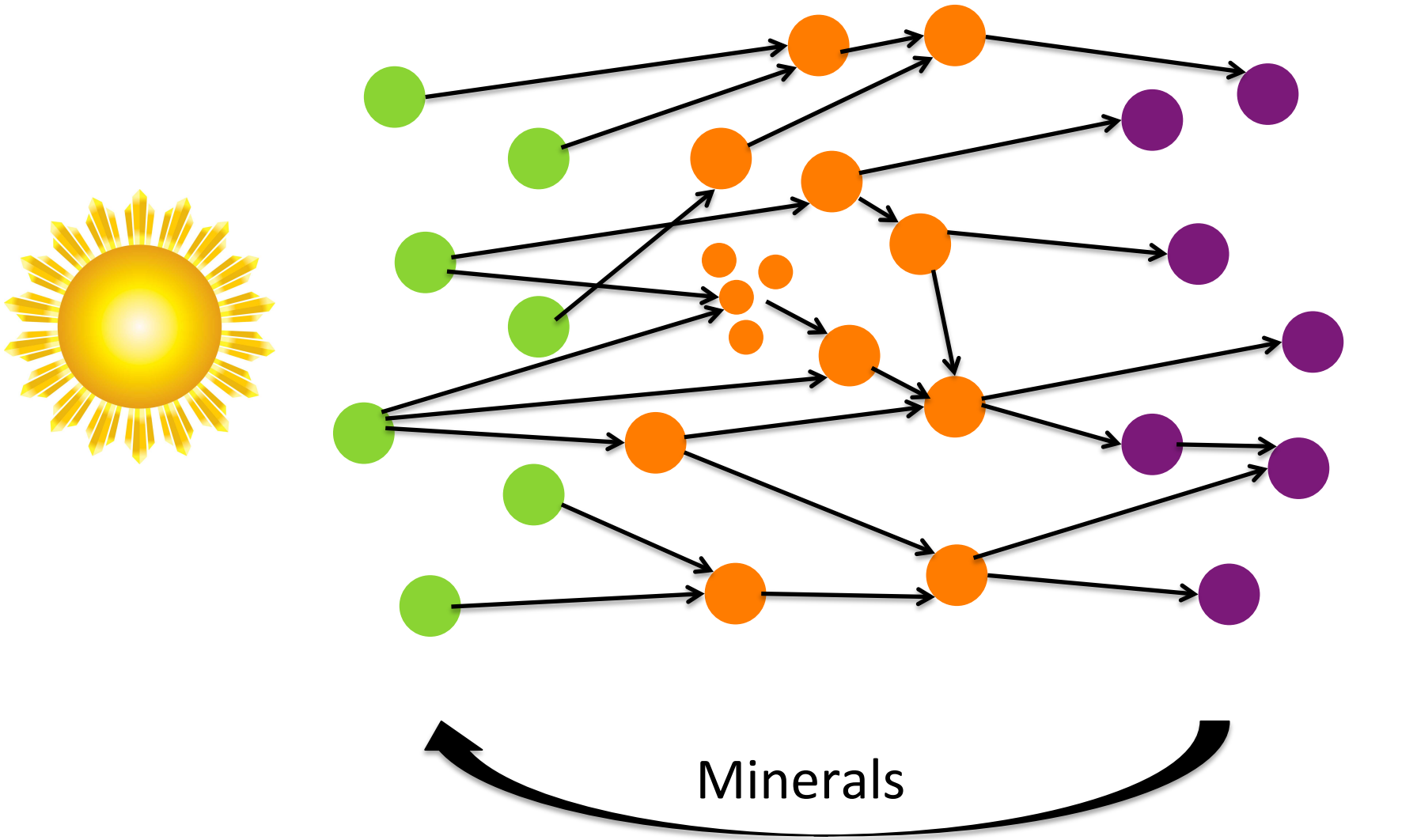
Trophic chains



Trophic chains



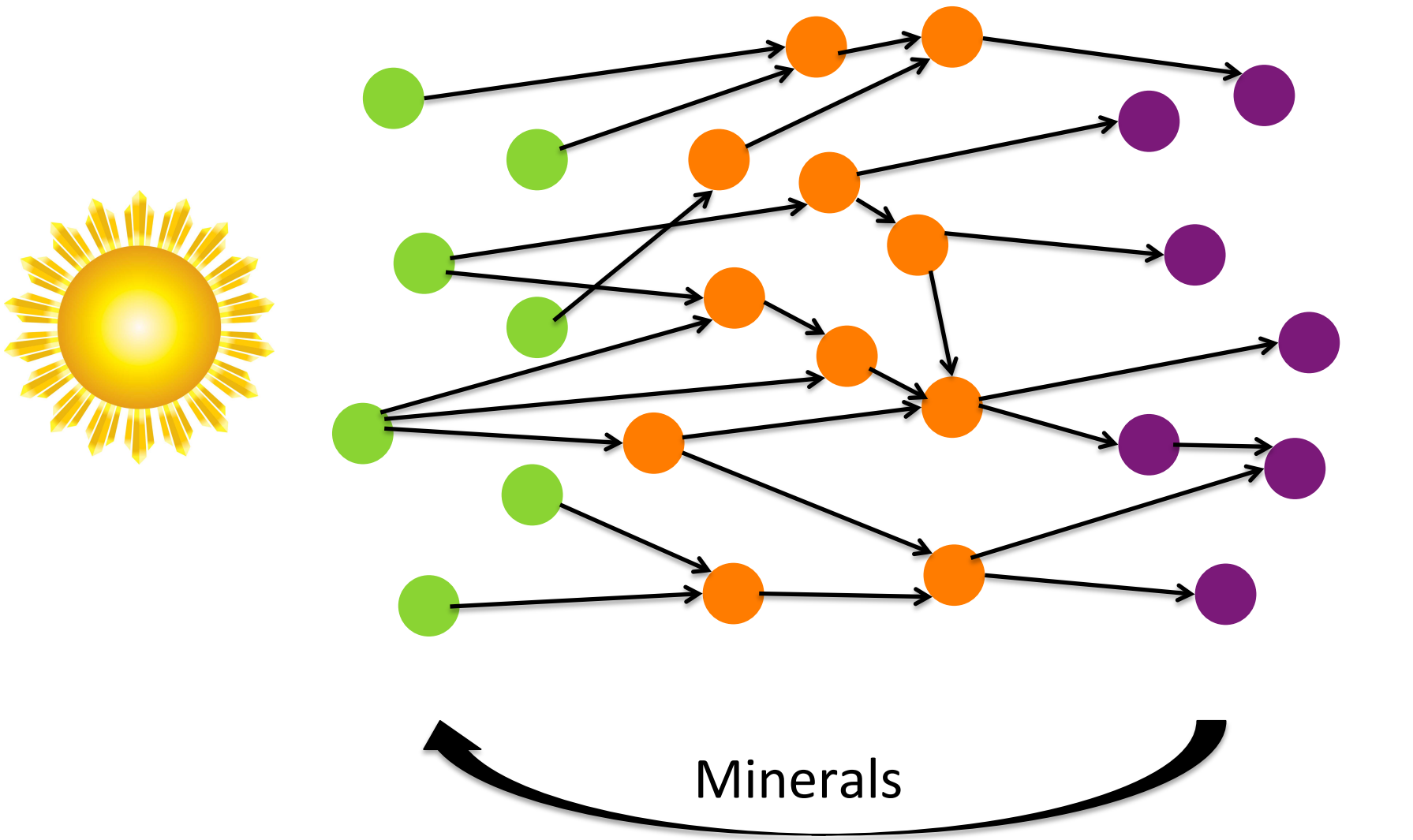
Trophic chains



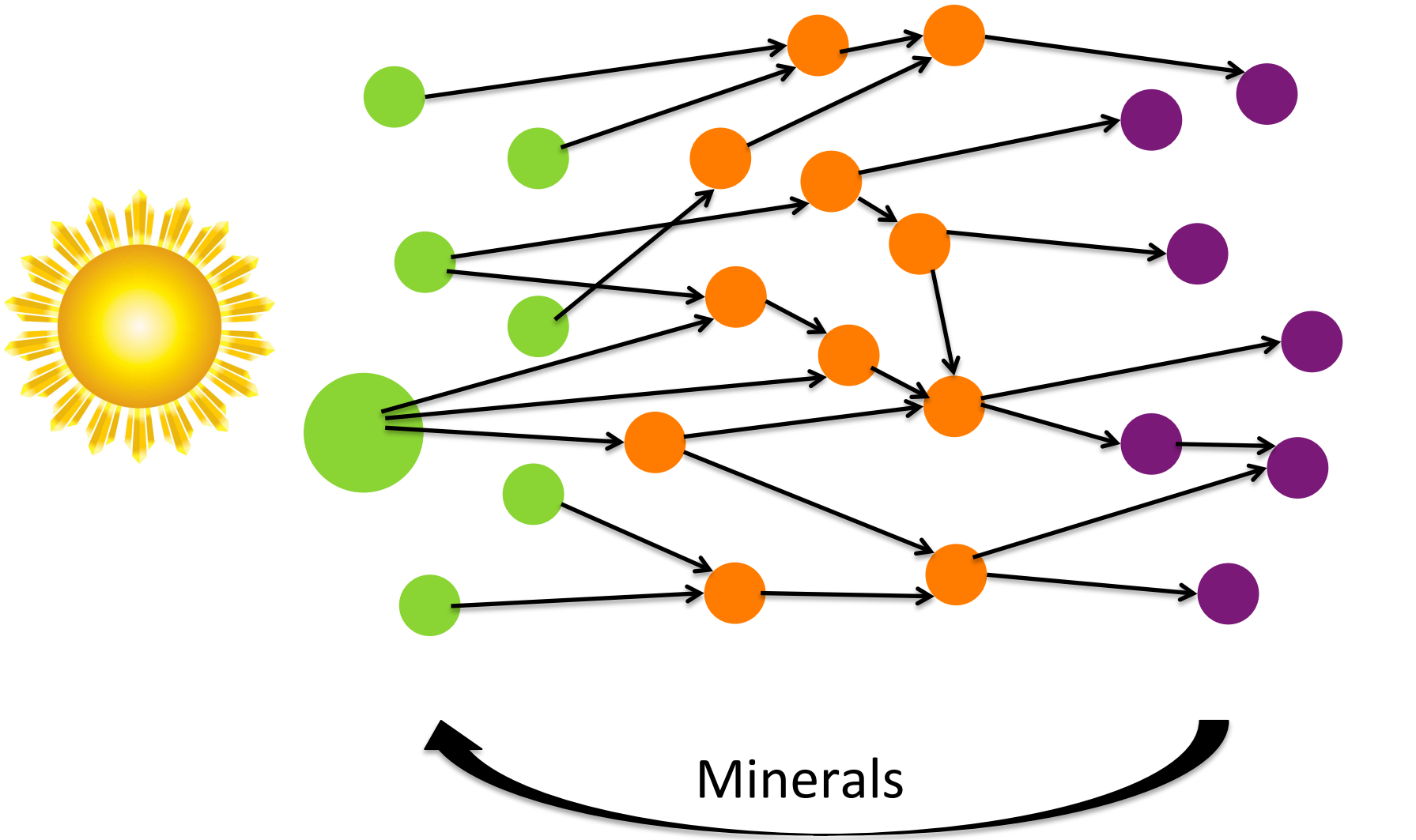
Power maximisation

- "the advantage must go to the organisms whose energy-capturing devices are most efficient in directing available energy into channels favourable to the preservation of the species" (Lotka 1922)
  - If material resources are available → total mass increases, and energy and material flows increase
  - If material resources are limited → energy is used to accelerate material cycles
- Application to human societies?
  - Odum: applicable if human groups struggle to acquire energy

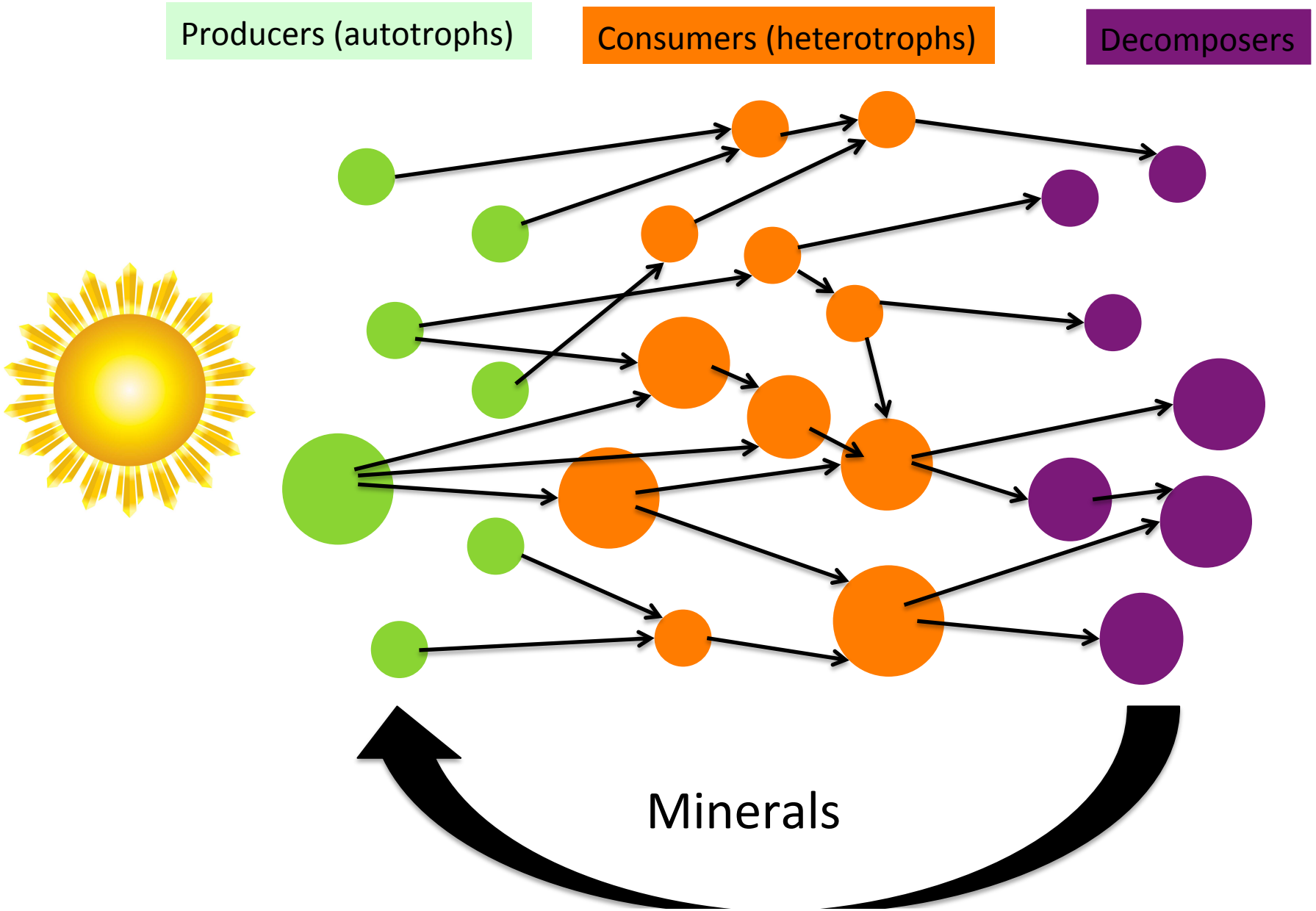
Trophic chains



Trophic chains



Trophic chains

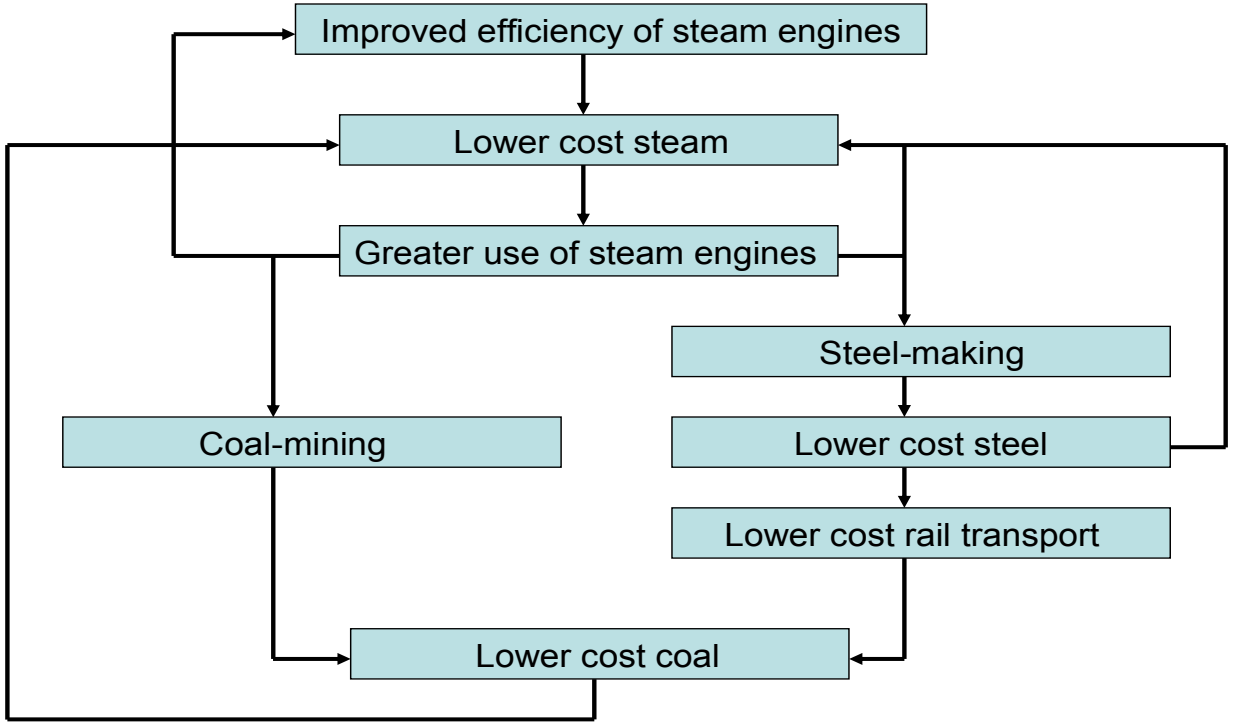


Technology (engineering)

- Machines: use external source of energy
- Infrastructures: connect machines together
- Energy consumption supposes at least two networks:
  - Energy provision (electricity, oil, gas, …)
  - Machine distribution
- Efficiency can apply to:
  - Extraction
  - Transformation
  - Distribution
  - Consumption

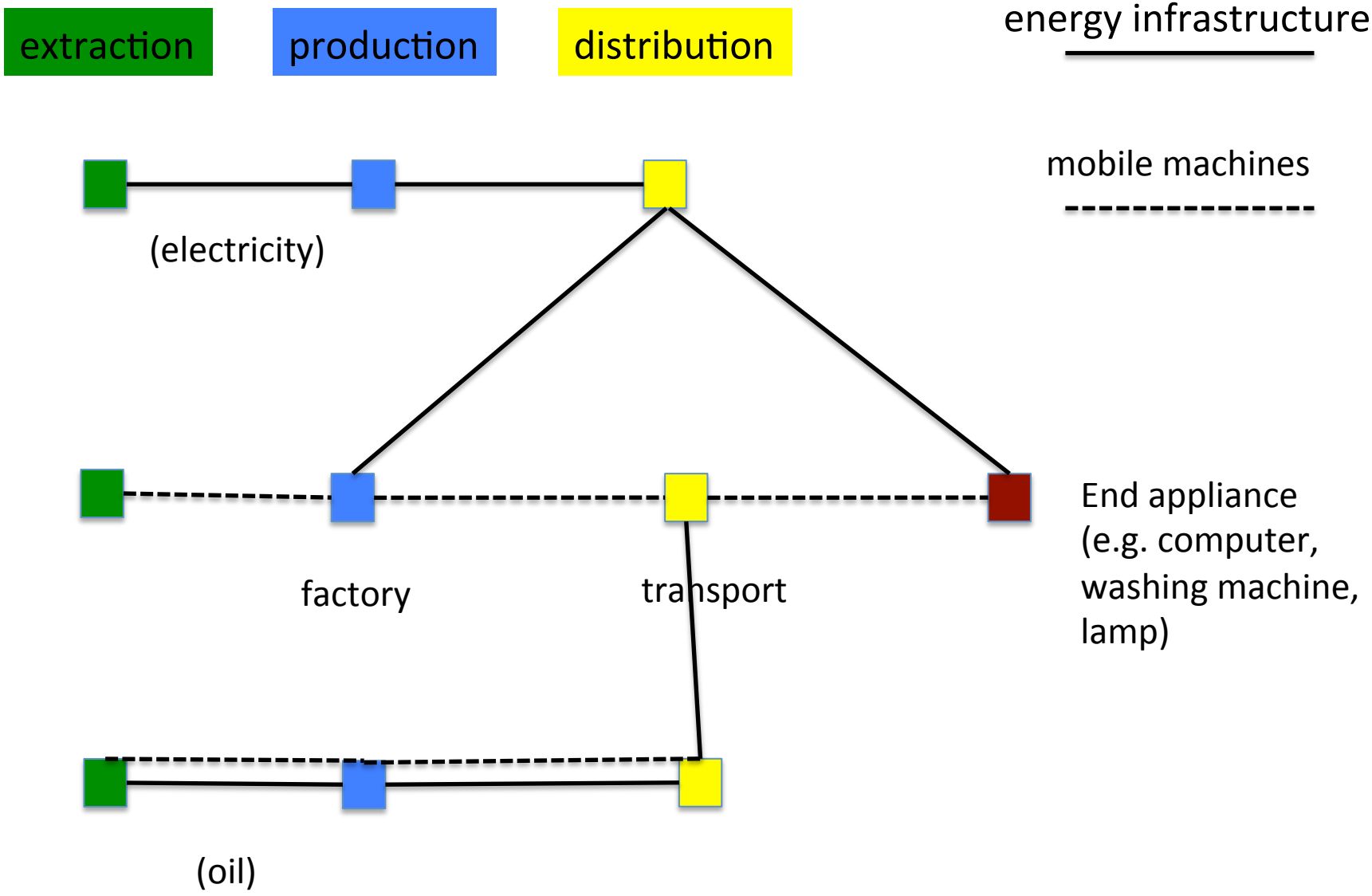
Positive feedback loops

Example: coal, steel and steam in the 19th century (Sorrel 2010)



Positive feedback loops

- « Lamarckian » evolution: steered by experience, including efficiency improvement
  - Genealogy of machines
- Efficiency helps to :
  - Extract more energy and materials
  - Build infrastructures
  - Circulate more efficient machines
- Examples: train and telegraph, electricity and lighting, cars and roads, electronics and ICT.

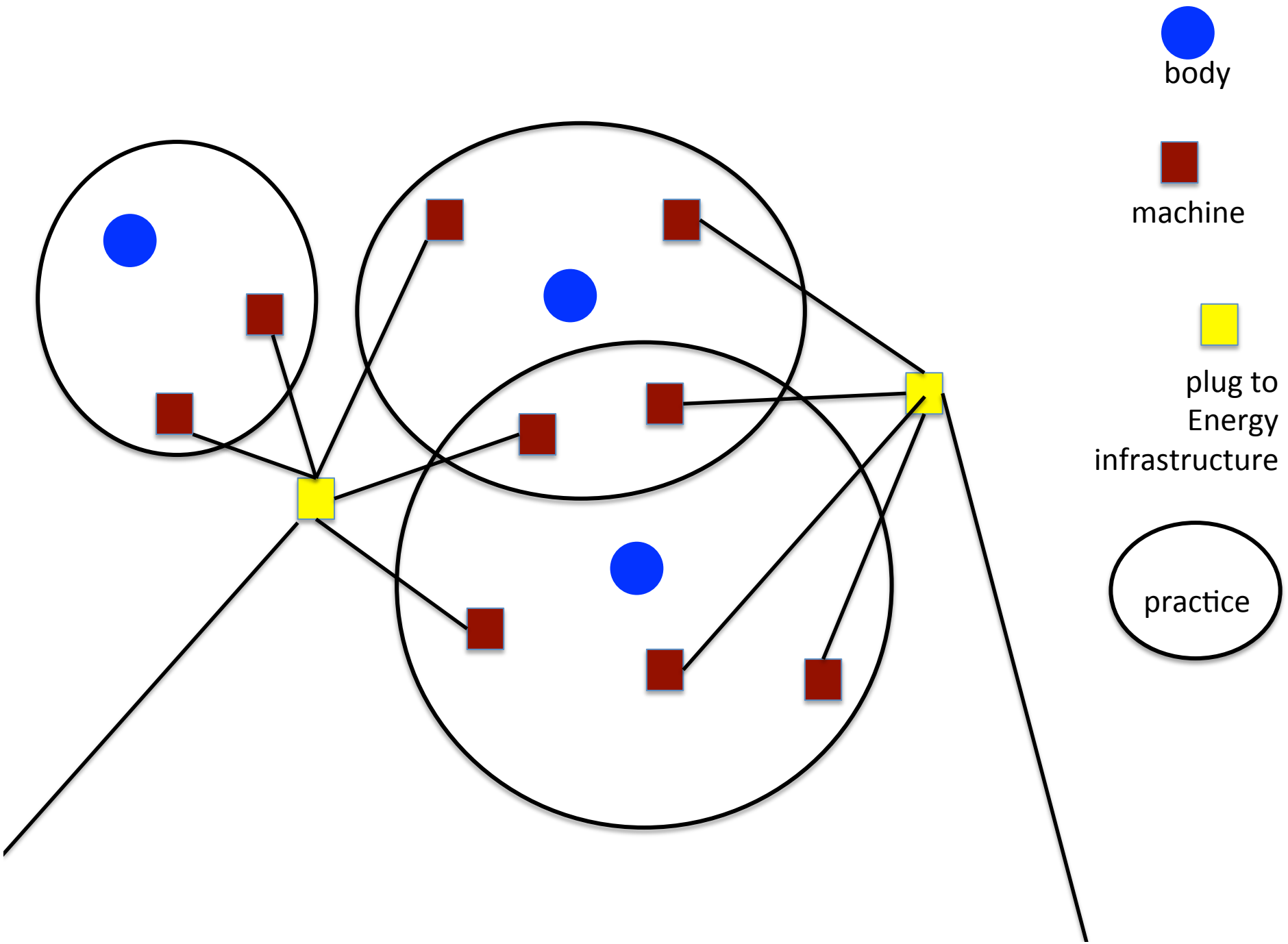

extraction
production
distribution
energy infrastructure
mobile machines
(electricity)
factory
transport
End appliance
(e.g. computer,
washing machine,
lamp)
(oil)

Social practices

- Dispersive rebounds:
  - Coal stove (less efficient): cooking, dining, bathing, dishwashing

  →Central heating + other efficient appliances (more efficient) dispersed in different rooms
- Integrative rebounds:
  - Commuting, shopping, driving children, leisure trips

  → Integrated in the use of the car
- Delegation of tasks to machines
- Time efficiency (number of practices/unit of time) is central


body
machine
plug to
Energy
infrastructure
practice

Renewed description of rebounds

- When energy is “saved”: where and when will it be consumed?
- Rebounds: link EE improvement and number of activities increase (efficient living beings, more machines, more practices).
- Occur when consumptive entities are in competition to access to energy or to save time. These entities can agregate and organise themselves to increase their total productivity.
- Are accelerated when infrastructure can redistribute quickly energy.

Conclusion

- Dynamics and time: activity as the unit of analysis
- The system evolution is non-linear and fed with positive feedback loops of energy efficiency
- Efficiency applies to all stage of energy “life cycle”
- Development of infrastructures: importance of connections between entities (bodies and machines)
- Limitation of rebounds = limitation of access to energy (including infrastructures).

Thanks for your attention!

gregoire.wallenborn@ulb.ac.be