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Organic materials for construction: questioning the concept of feedstock energy

Ventura A.(1), Santero N.(2)

(1) IFSTTAR
(2) PE International

Organic materials in LCA

- Organic materials contain energy: feedstock energy
  - i.e. bitumen contains ~ 40 MJ/kg
- Accounted in LCA
  - Contained in Total Primary Energy (TPE)
  - Although small quantities, they have a large influence on TPE results
- A source of ambiguity

Two different points of view

- Materials producers:
  - « double counting » both in kg and in MJ
  - Materials are not used for energy so why accounting energy ?
  - Materials are not only energy stocks, they also contain non emitted pollutants (emissions from combustion: CO_2, NOx, VOC…)
  - The energy is stocked, not used

- LCA methodology:
  - All what is extracted from ecosphere must be accounted: the global stock is depleted

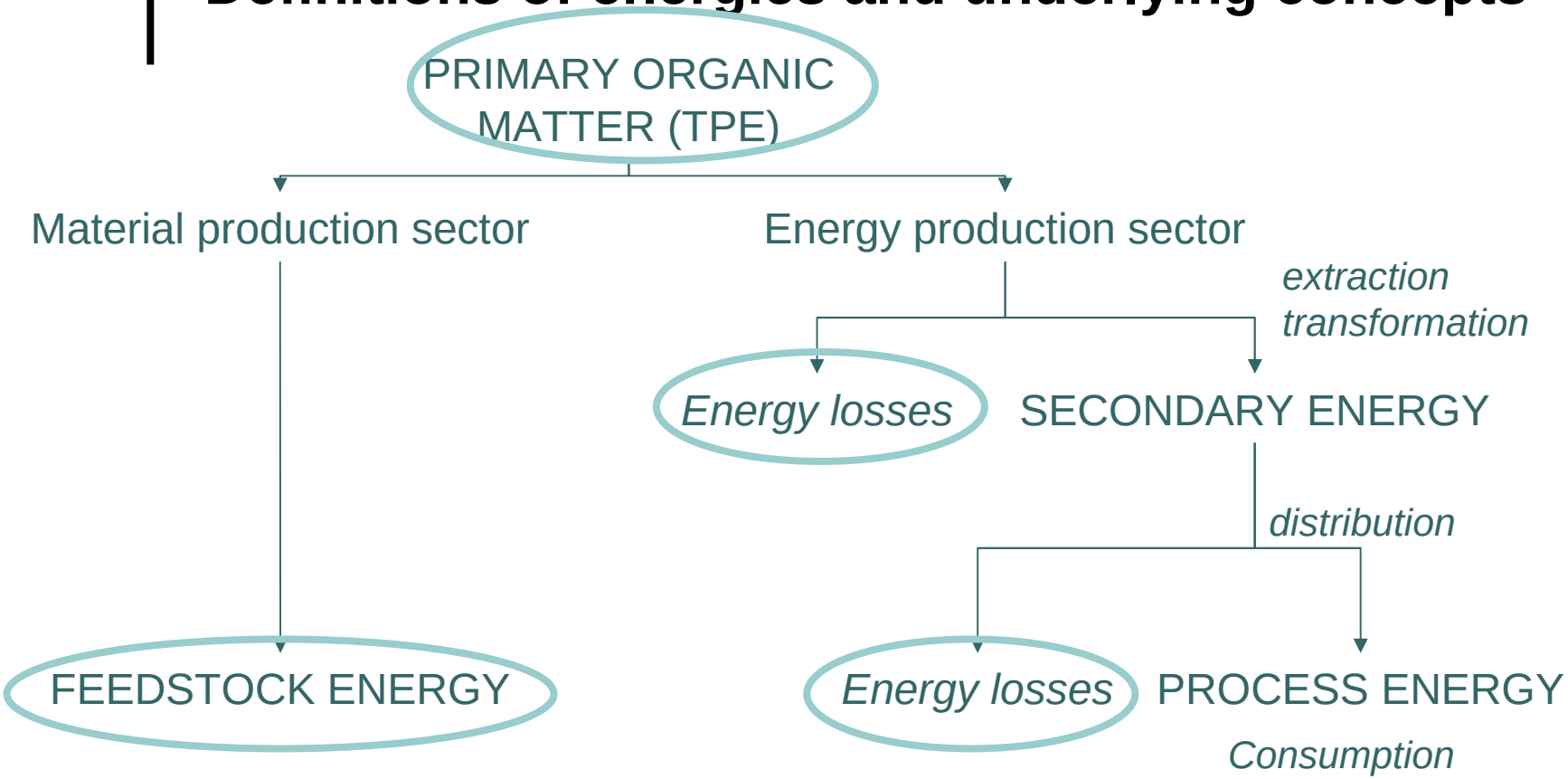
Feedstock energy: "when organics are used as materials, the energy associated with much of this input remains incorporated in the product"

Consoli et al., SETAC ed., 1993

Objectives

- Re-explore the energy concepts related to feedstock energy
  - Types of energy and underlying concepts
  - Possible reasons for ambiguous meanings
  - Re-express the feedstock problematic
- Propose a new framework
  - The stock inventory
  - Discussion for applications

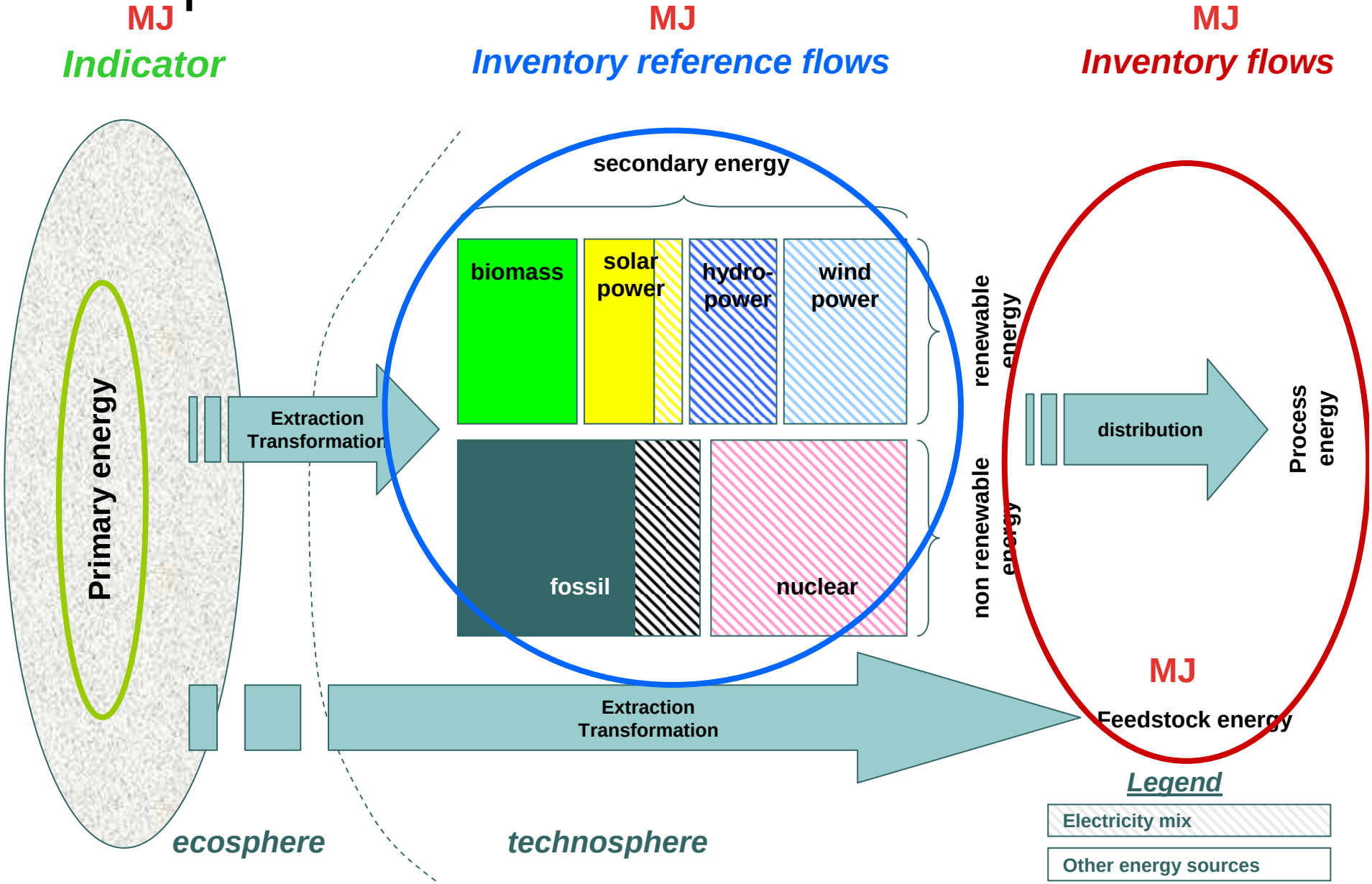
Definitions of energies and underlying concepts



3 underlying concepts:

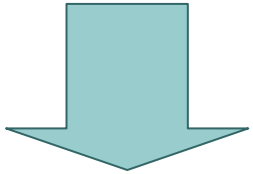
- Necessity to account for the « loss of energy »
- Necessity to valuate energy taken from the environment (extractible energy)
- Necessity to account for the energy stock contained into primary matter

Reasons for ambiguity



To resume

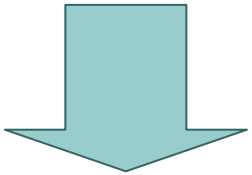
- Important concepts behind different types of energy
  - The value of extracted energy from the ecosphere
  - The « loss » of energy
  - The energy stock in primary matter and materials



- Current practices are source of ambiguity
  - Different types of concepts
  - Different types of LCA methodological status: inventory flows, reference flows, indicators
  - But same units
  - But all in the inventory table

The value of energy extracted from ecosphere

- A non-renewable energy resource indicator
- Current resource depletion indicators include the primary energy concept, i.e.
  - ADP (Abiotic resource DePletion): material's upper heating value is the characterization factor
  - CEENE (Cumulative Exergy Extraction): chemical exergy includes upper heating value of organic materials



Total Primary Energy should be removed from inventory tables and accounted as an impact assessment result (by itself or inside resource depletion indicators)

The “loss” of energy

Primary energy: “the most meaningful parameter in judging the energy efficiency of systems since losses due to transformation and transport are fully taken into account”

Klöpffer, J. LCA 2(2) 61, 1997

Thermodynamics (first law): energy is never lost (destroyed), but changed from one form to another

Exergy concept:

- Defined as “*the maximum useful work possible during a process that brings the system into equilibrium with a heat reservoir*”
- Represents the maximum usable energy

Energy efficiency

$$\eta_{system} = \frac{Exergy_{system,real}}{Exergy_{system,ideal}}$$

Effective exergy balance of the technological system (MJ)

Ideal exergy balance of the technological system, reversible, no entropy production (MJ)

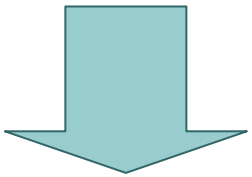
TPE: yes! But as an indicator

Exergetic Life Cycle Assessment

Rendon et al, Int. J. Applied Thermodynamics 2 (3), 115-123, 1999

The energy stock

- Feedstock energy is not consumed
  - The assumption that it will eventually be combusted is not certain nor verifiable
- Feedstock is not only energy
  - Feedstock also contains emissions that are not emitted
  - “stocked” environmental impacts



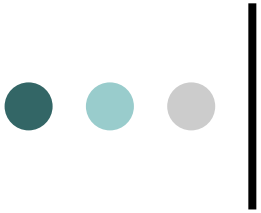
- The stock inventory
  - Contains the process energy generated by the material
  - Contains stocked emissions
  - Separated from the main inventory

The stock inventory

- One stock inventory for one organic materials
- Stock inventory are additive
- Default values of the stock inventory
  - potential energy and emissions associated to the combustion of the material
  - Can be refined when end of life scenarios are defined
    - i.e. technological improvements can enhance energy production and reduce emissions
- Separate tables in “cradle to gate” systems
- Inventory and stock inventory can be added if end of life scenarios consider that the stocked energy an emissions are effectively consumed or release

Conclusion - discussion

- Renewing the frame of feedstock energy by the stock inventory table
  - Avoids the ambiguity amongst various types of energies
  - Respects the important underlying concepts of LCA
- Has other consequences
  - Environmental impacts of end of life scenarios are allocated to the initial product (underlying end of life allocation)
  - The stock inventory could be interpreted as “avoided impacts”
    - Should we use flows of the “best available technology” (in favor of a future combustion)
    - Should we use flows of the “worst existing technology” (in favor of a future reuse as a material)



Thanks for your attention