Roundtable on Science and Technology for Sustainability
June 4-5, 2015

# Green Manufacturing and Social Sustainability Metrics

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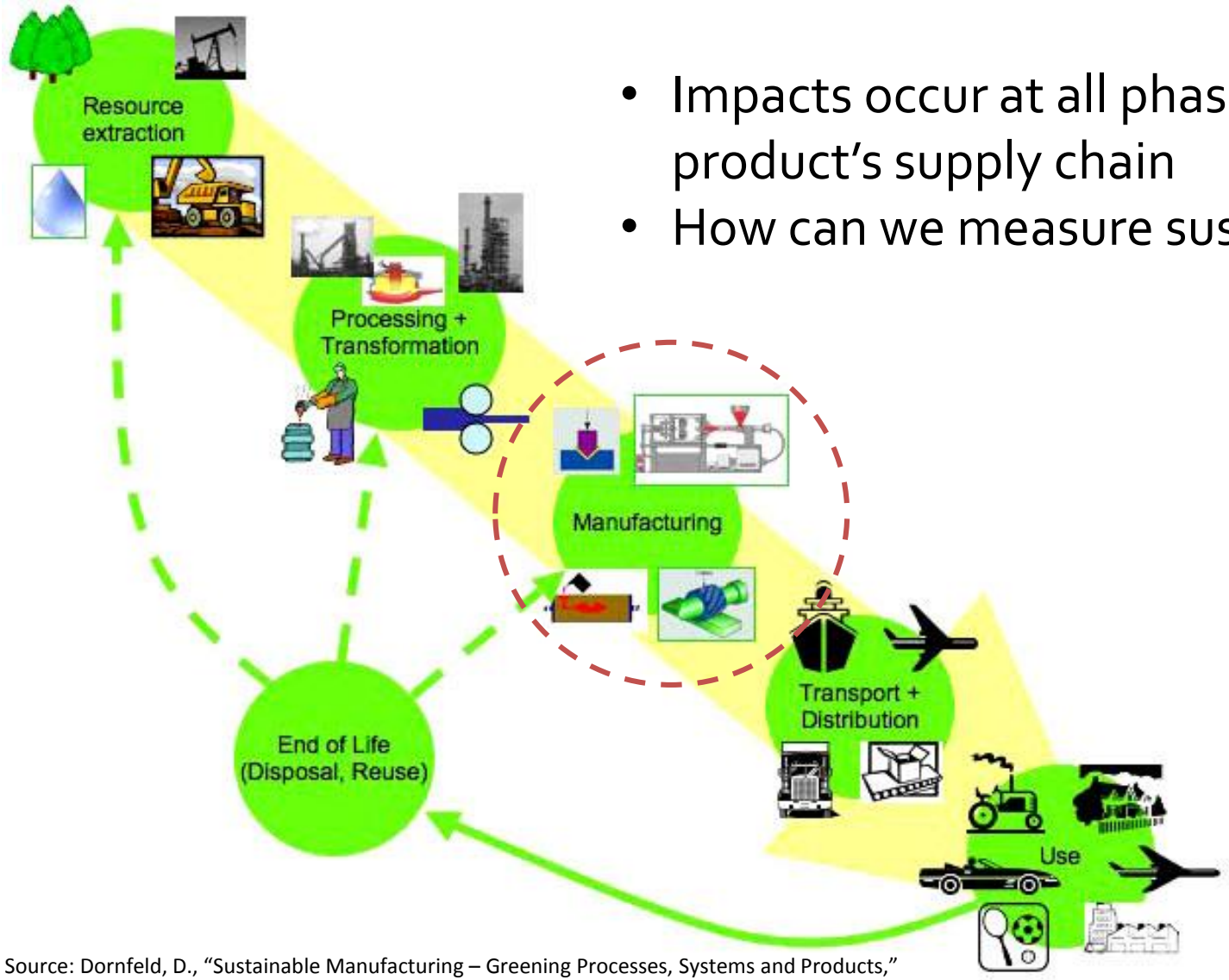
# Need to examine manufacturing efficiency (resource productivity) at multiple scales




- Impacts occur at all phases of a product's supply chain
- How can we measure sustainability?

Source: Dornfeld, D., "Sustainable Manufacturing – Greening Processes, Systems and Products," Proc. ICMC 2010 Sustainable Production for Resource Efficiency and Ecomobility, Chemnitz University of Technology, September, 2010

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# And across the enterprise

Enterprise
weeks - months

Country/Supply chain

Region

Community

Company

Suppliers/service

Employees

Technician EH&S

Social impacts

Facility
days - weeks

Data rates/actions

Line/system
hours - days

Machine
mins - hours

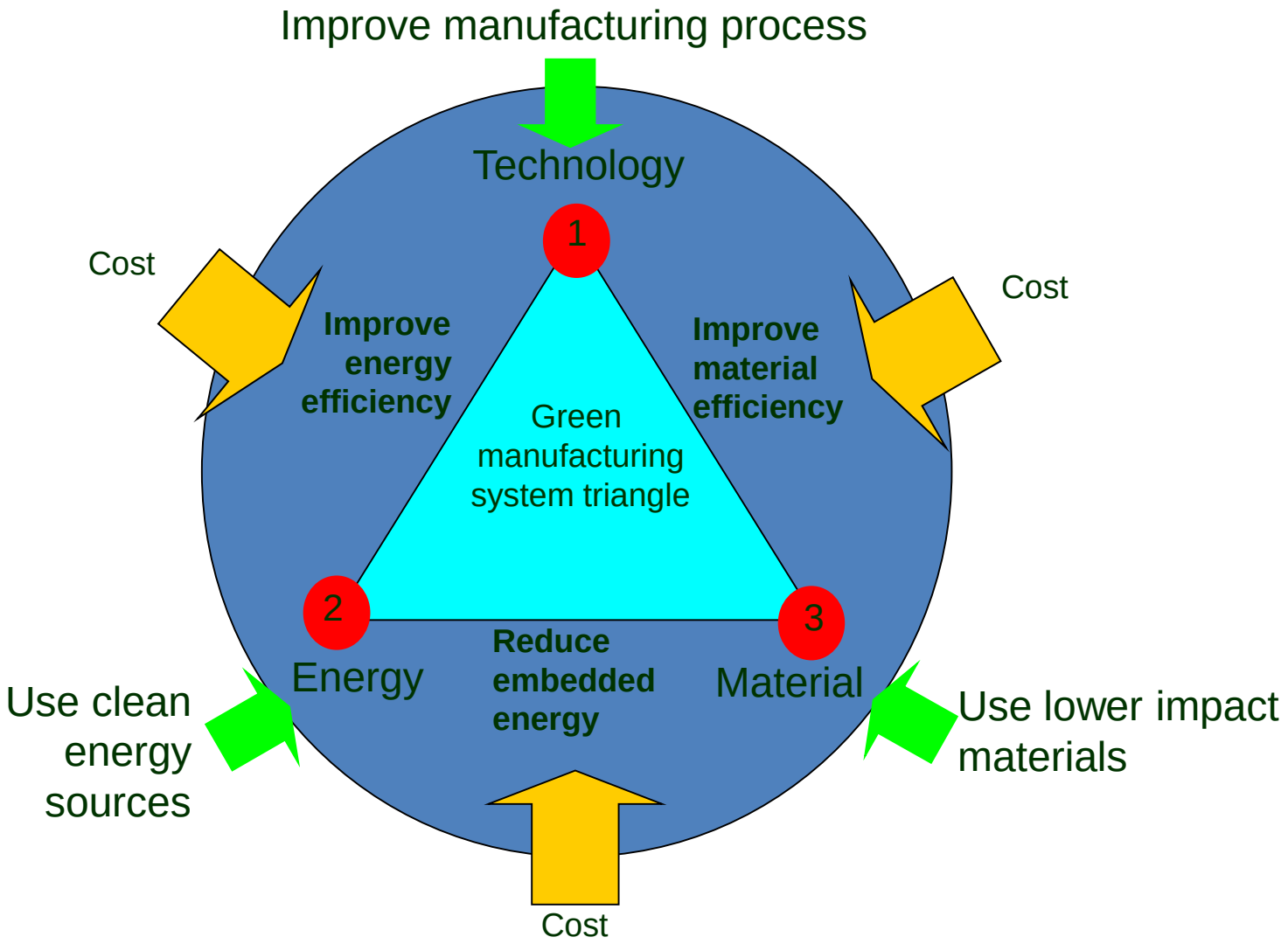
Tooling/setup
secs - mins

Process
msec - secs

µsec - msec

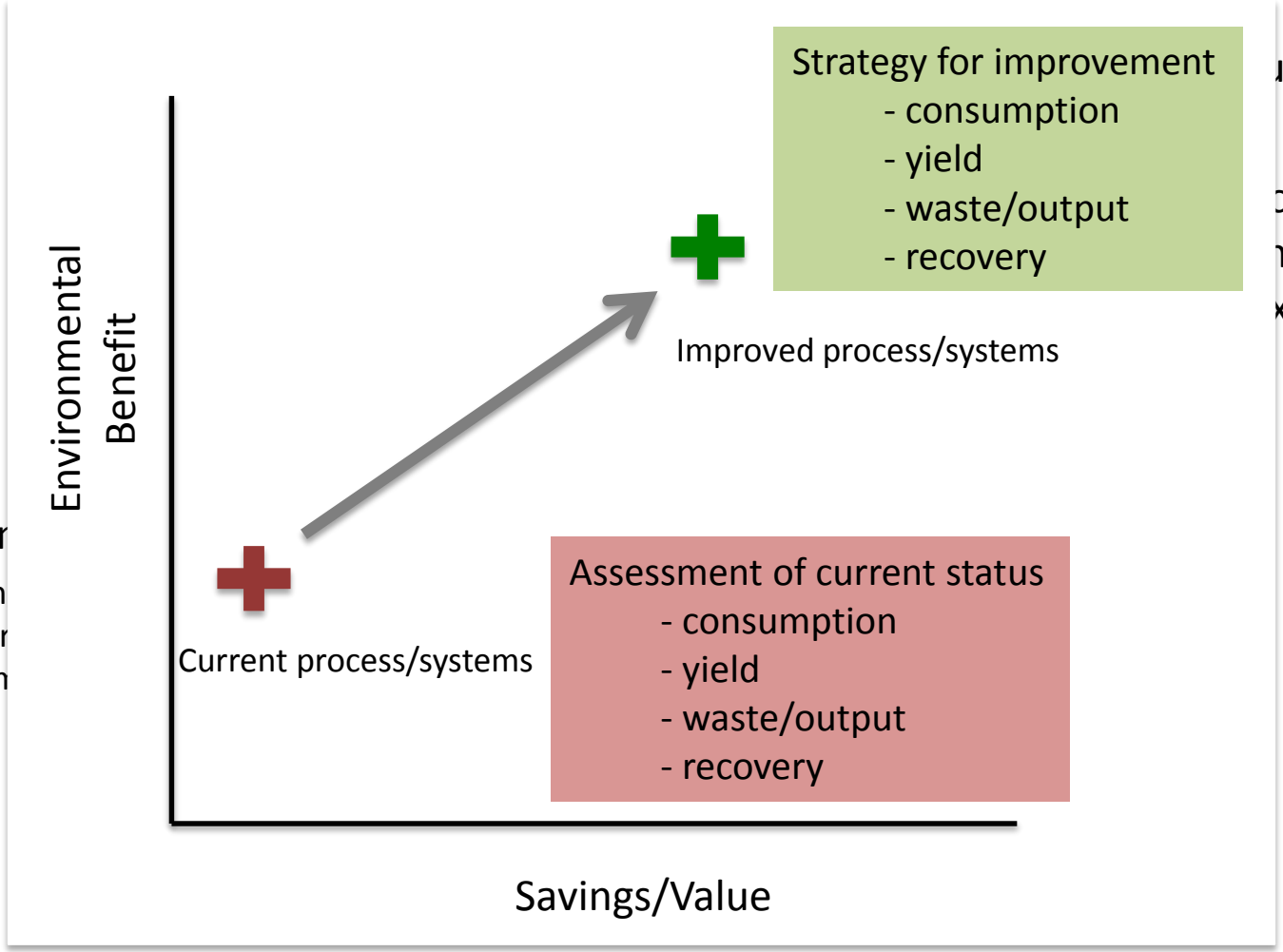
Source: Dornfeld, D., "Sustainable Manufacturing – Greening Processes, Systems and Products," Proc. ICMC 2010 Sustainable Production for Resource Efficiency and Ecomobility, Chemnitz University of Technology, September, 2010

# We have three basic “levers” of influence




Ref: C. Yuan, A System Approach for Reducing the Environmental Impact of Manufacturing and Sustainability Improvement of Nano-scale Manufacturing, Ph. D. Thesis, LMAS, Univ. of California, Berkeley, 2009

# We can determine input/output




Input r
- Workin
- Auxiliar
- Consun
- Water

ure Impact?
warming
cation
n toxicity
xicity

And how do we track improvement?

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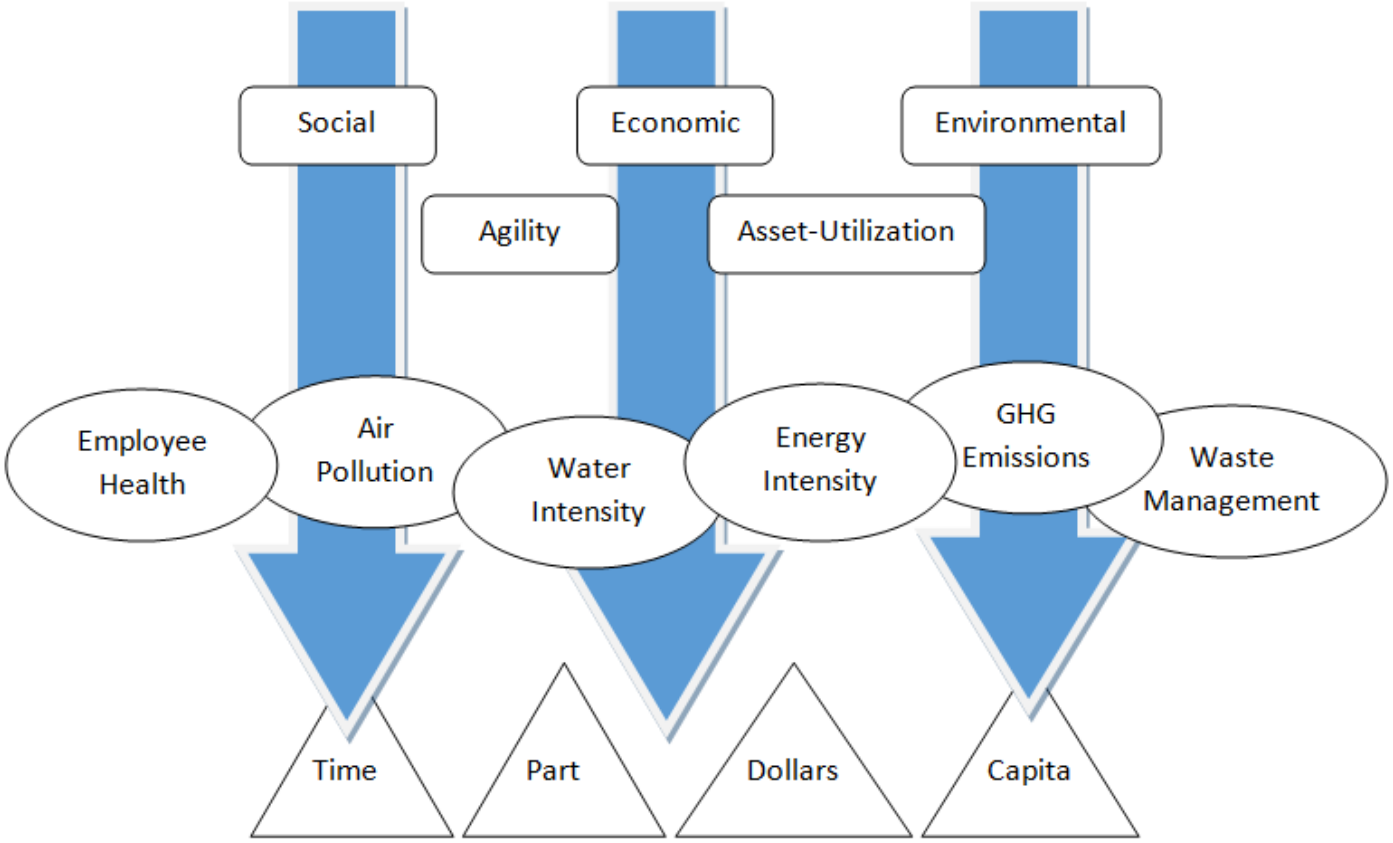
In a manufacturing context, key metrics include productivity, efficiency/effectiveness, energy consumption, resource productivity and capital investment.




Source: D. Jagger & D. Dornfeld, 2014

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The IPAT equation connects environmental and social measurements with economic outcomes.

$$\text{Impact} = \text{Population} \times \frac{\text{GDP}}{\text{person}} \times \frac{\text{Impact}}{\text{unit GDP}}$$

*(Affluence) per capita* GDP

*Technology*, unit GDP → manufactured product (e.g. unit of consumption)

(Sum total of all activities required to make, use and dispose of a product - say an automobile)

Source: P. Ehrlich and J. Holdren, Impact of Population Growth, *Science* (171), 1971, 1212-1217.

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But … what's "impact" and how to define and measure "unit of consumption"?

$$\frac{\text{Impact}}{\text{per unit of GDP (consumption)}}$$

- $\frac{\text{Energy (or water) used}}{\text{Value of fixed assets}}$
- $\frac{\text{Life cycle GHG emission}}{\text{Product unit}}$
- $\frac{\text{Embedded energy}}{\text{Product value (\$)}}$
- •
- •
- •

Over what geography/region? Over what time? What part of the life cycle?

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3 main assessment mechanisms are used by companies: Supply Chain Analysis, Risk Assessment, and LCA

**Examples**

Cummins: Remanufacturing
Unilever: Studying Product Use Phase
Healthy Building Network:  Assessing Substitutes
Apple / Google: Analyzing Multi-tiered Supply Chain
Intel: Semiconductor fab water consumption

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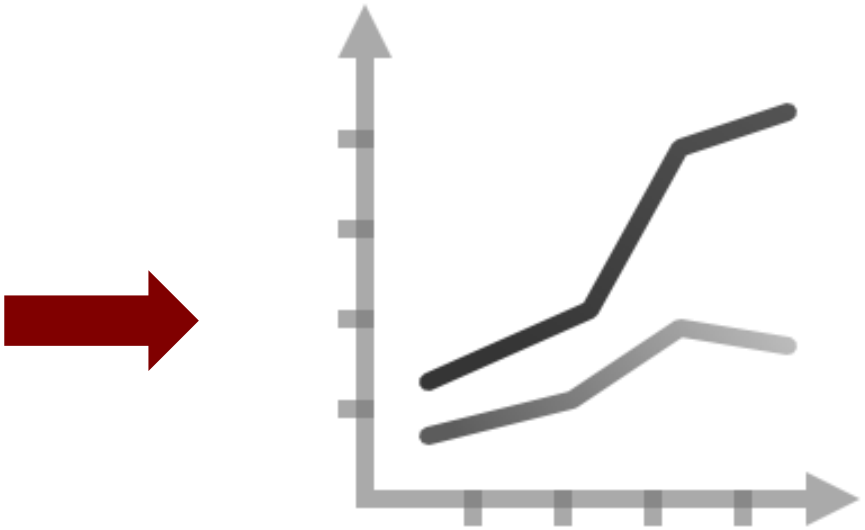
Social metrics remain perplexing for most. Companies are often either not measuring social impacts or measuring the wrong things at the wrong resolution.

Counting factory accidents



Understanding patterns behind accidents

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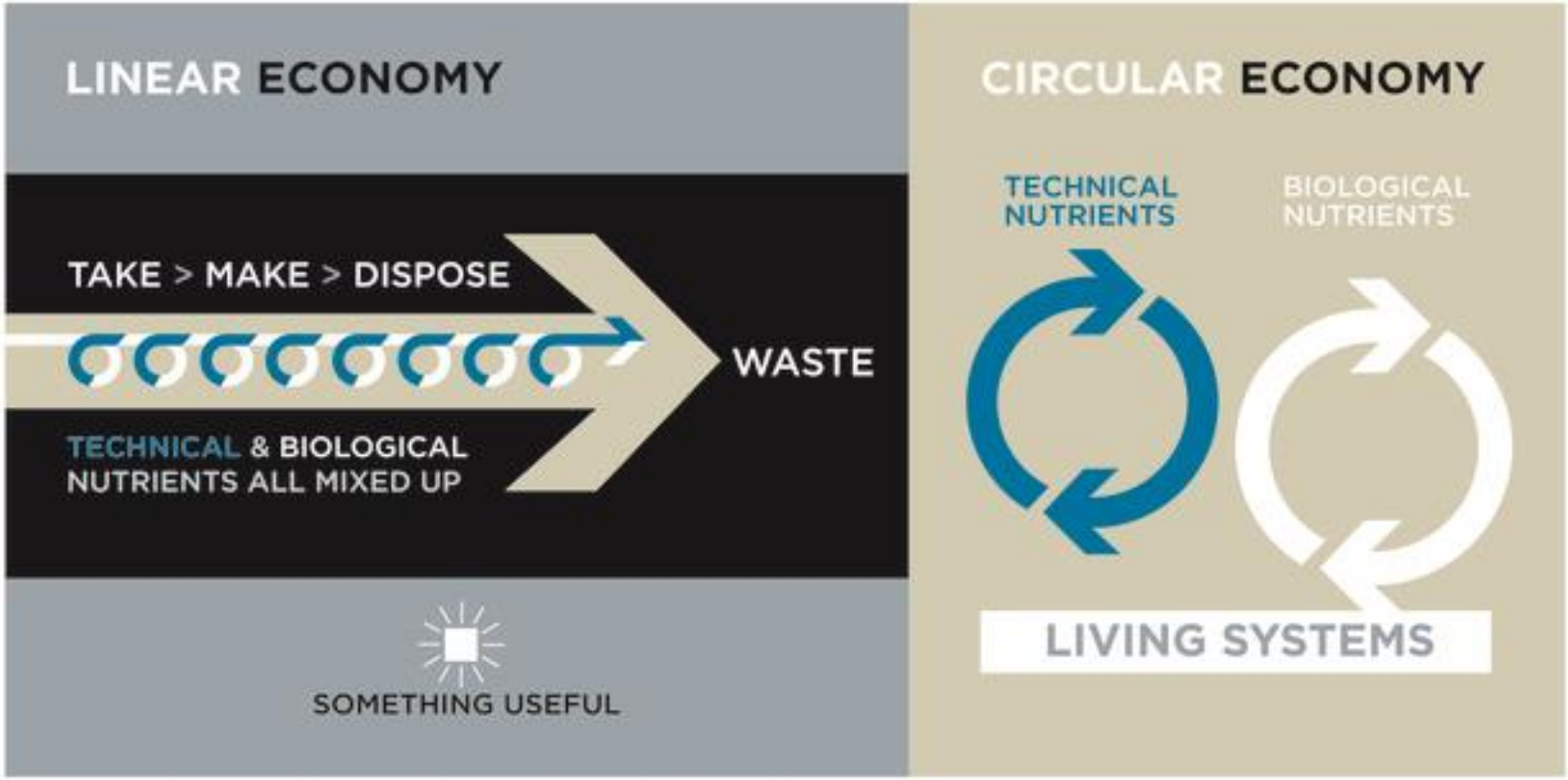
LCA metrics don't cover circularity. Need to better develop metrics that assess production and consumption systems and the linkages.




Thank you