Circular urban economies: the case of waste to energy
Urban metabolism

Converting Solid Waste To Energy-Intensive Materials
ARPA-E November 7-8, 2019

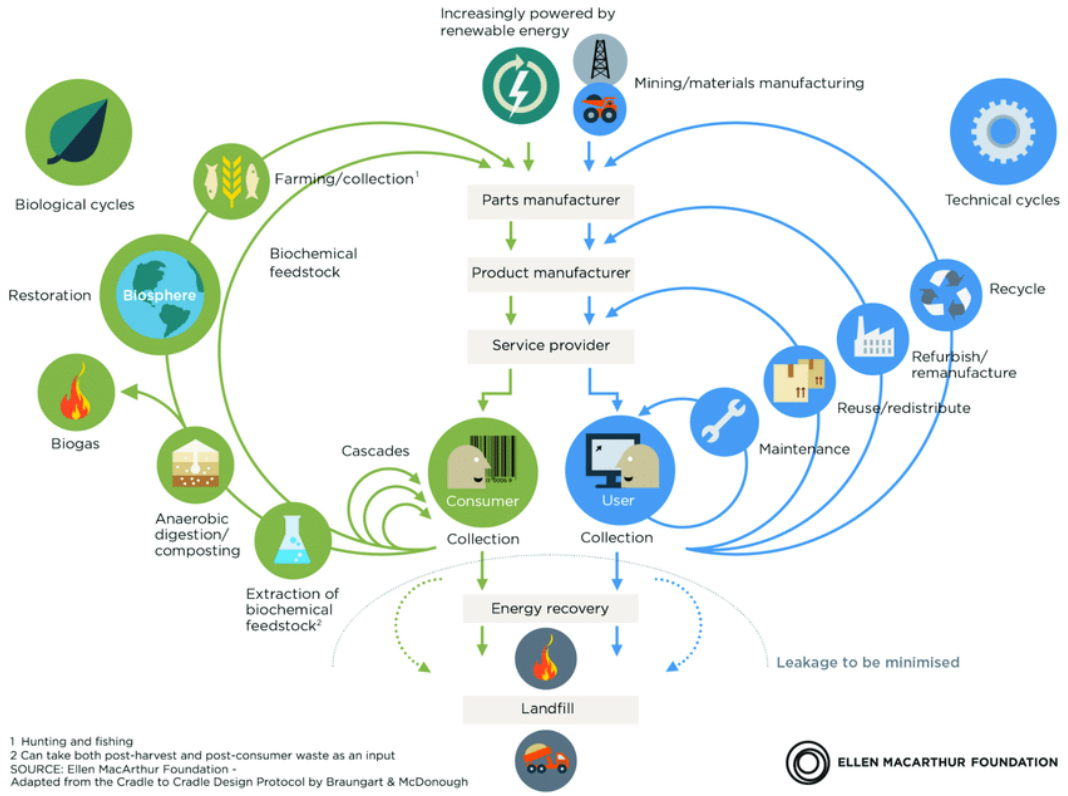
ENVIRONMENTAL SOLUTIONS INITIATIVE

John E. Fernández
Urban Metabolism Group
Massachusetts Institute of Technology

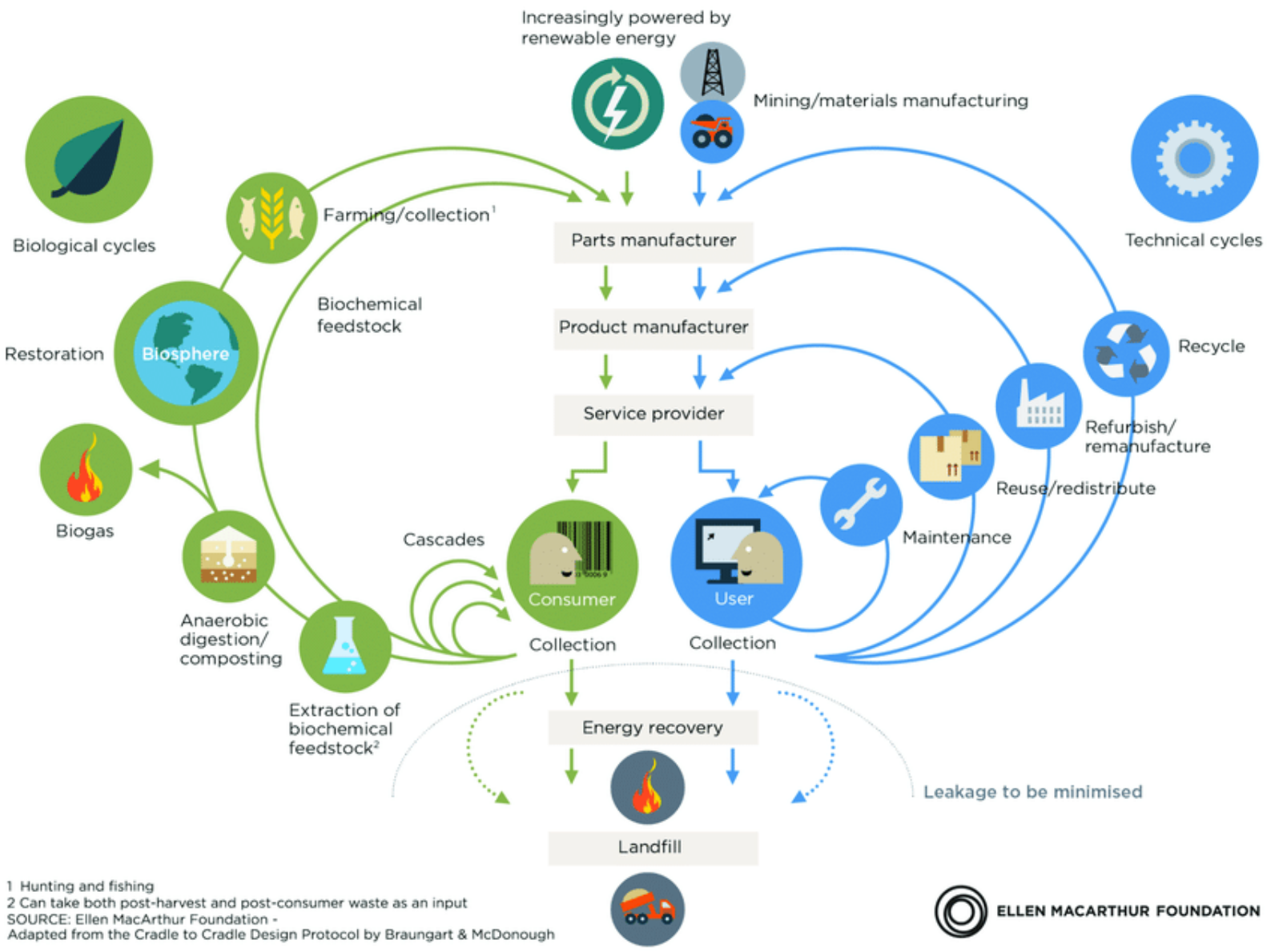
Meta-principles or “targets”

1. Circular economy
2. Zero waste
3. Low-carbon future (distributed heat)
4. Urban “mining”
5. Environmental protection
6. Environmental justice
7. Innovation for cities

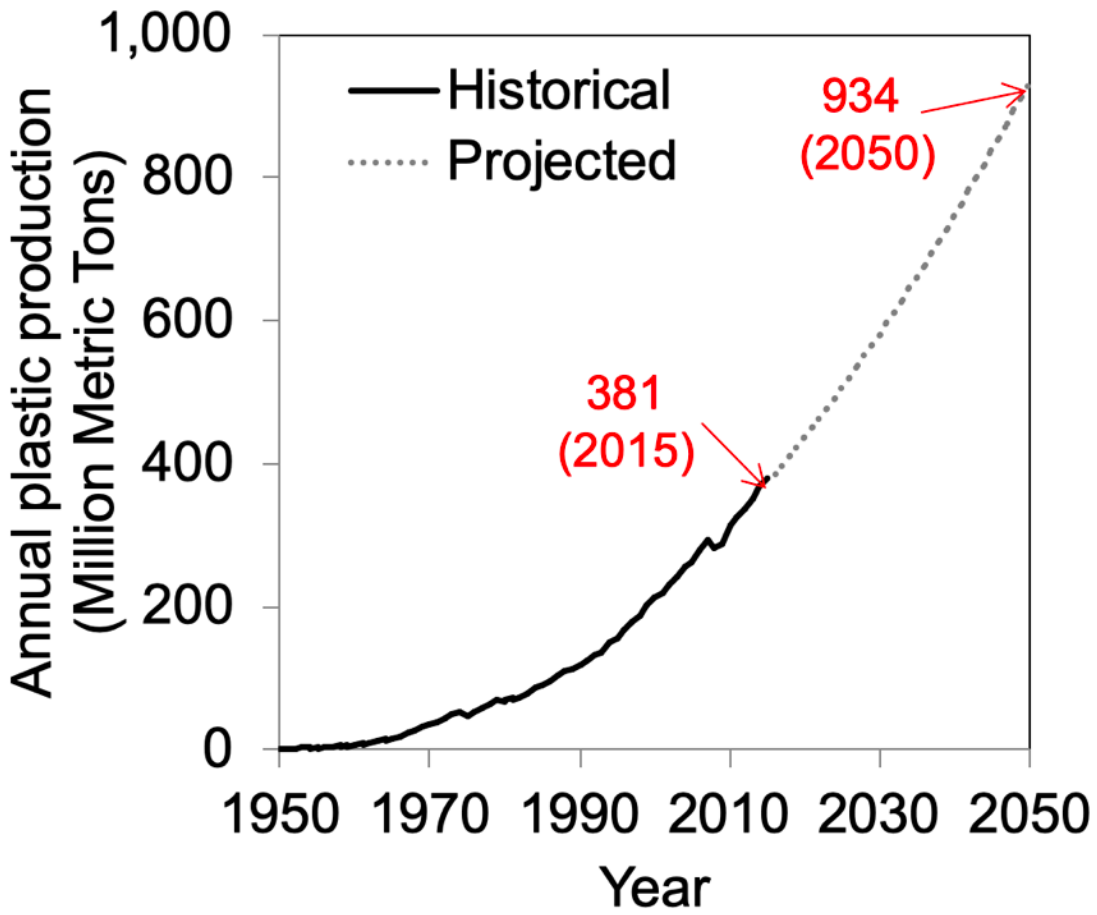
… does waste to energy offer multiple co-benefits?

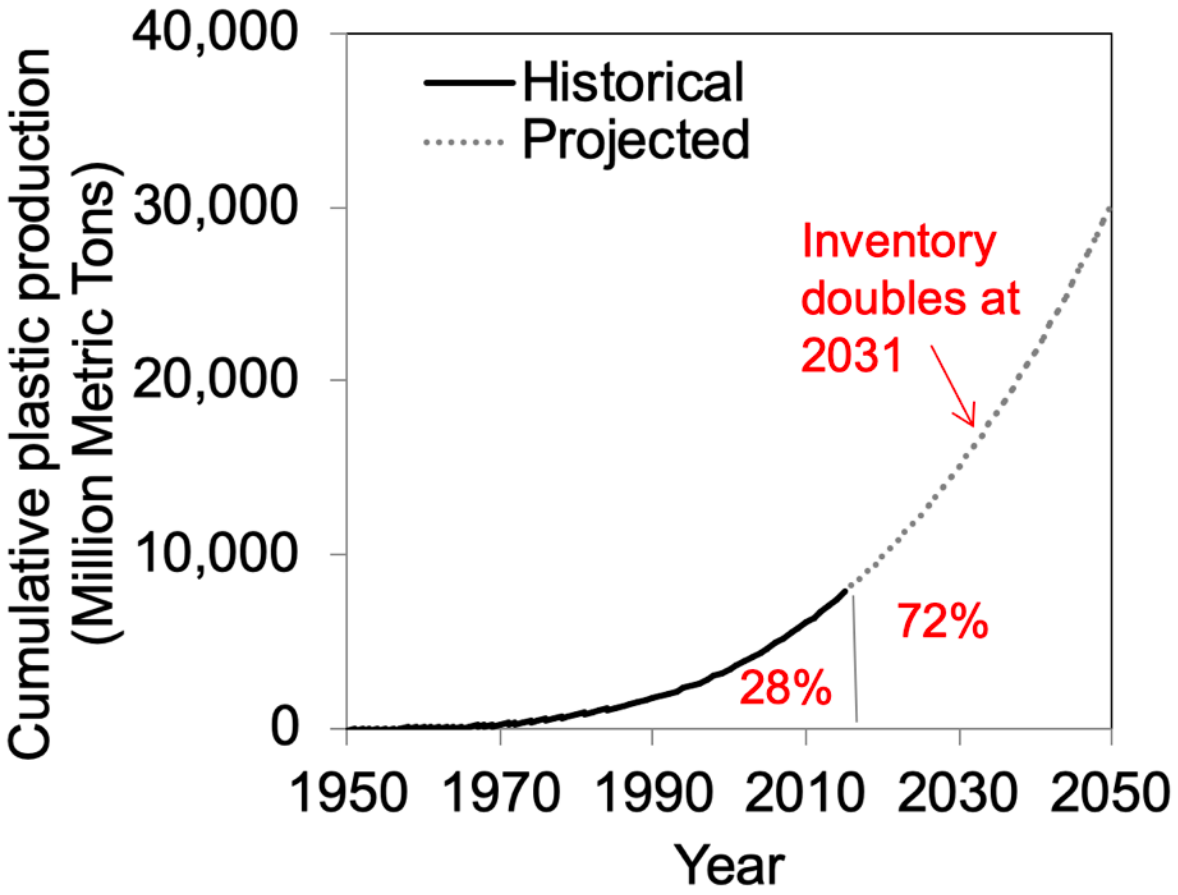


The circular economy: aspirational



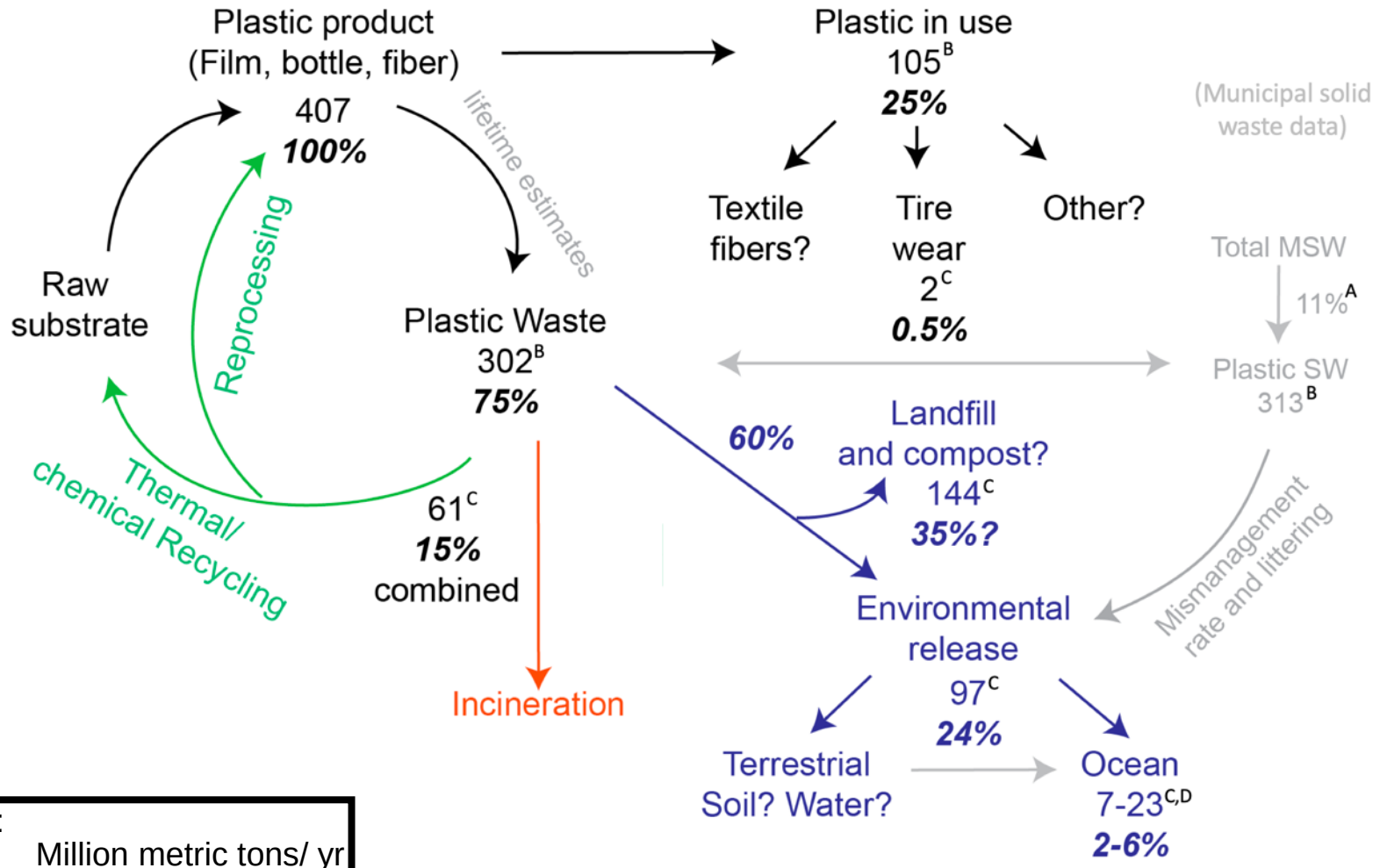
Plastics: annual and cumulative production





Data sources:
PlasticsEurope's Market Research and Statistics Group (PEMRG); Conversio Market & Strategy GmbH;
Geyer, R. and Law, K. L., Production, use, and fate of all plastics ever made. Science advances ***2017***
Compiled by Boya Xiong, PhD (Plata Lab)

What we currently know about the plastic lifecycle

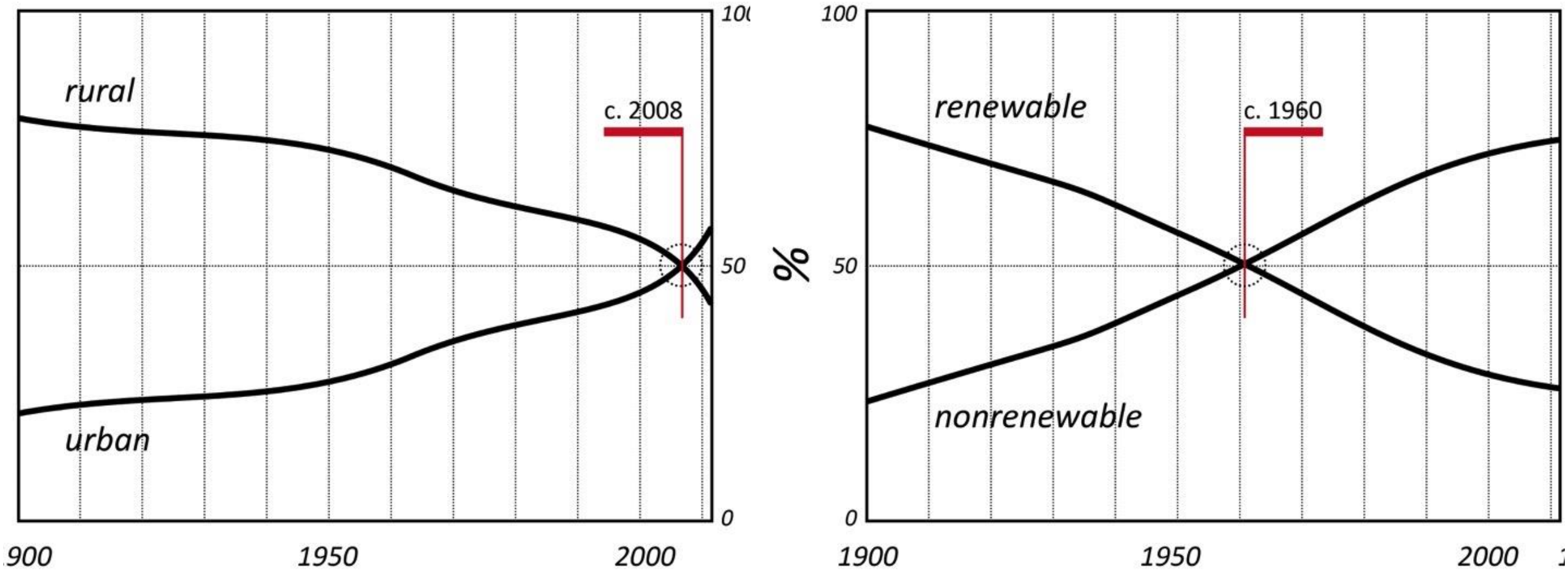


Units:
Million metric tons/ yr
% of total plastic products

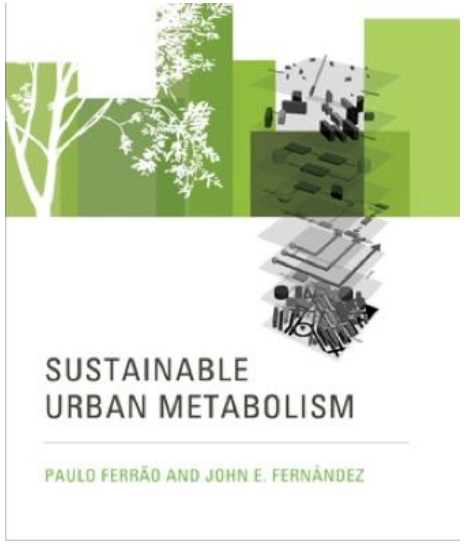
A= Direct measurement B= Calculated from mass balance
C= Assumed release rates D= Poor estimate

Xiong, Johnson, Olsen, Plata; unpublished

Global urban population and global resource extraction



Abe Wolman: The Metabolism of Cities (Sci. Am. 1965)



MIT Urban Metabolism Workshop 2006

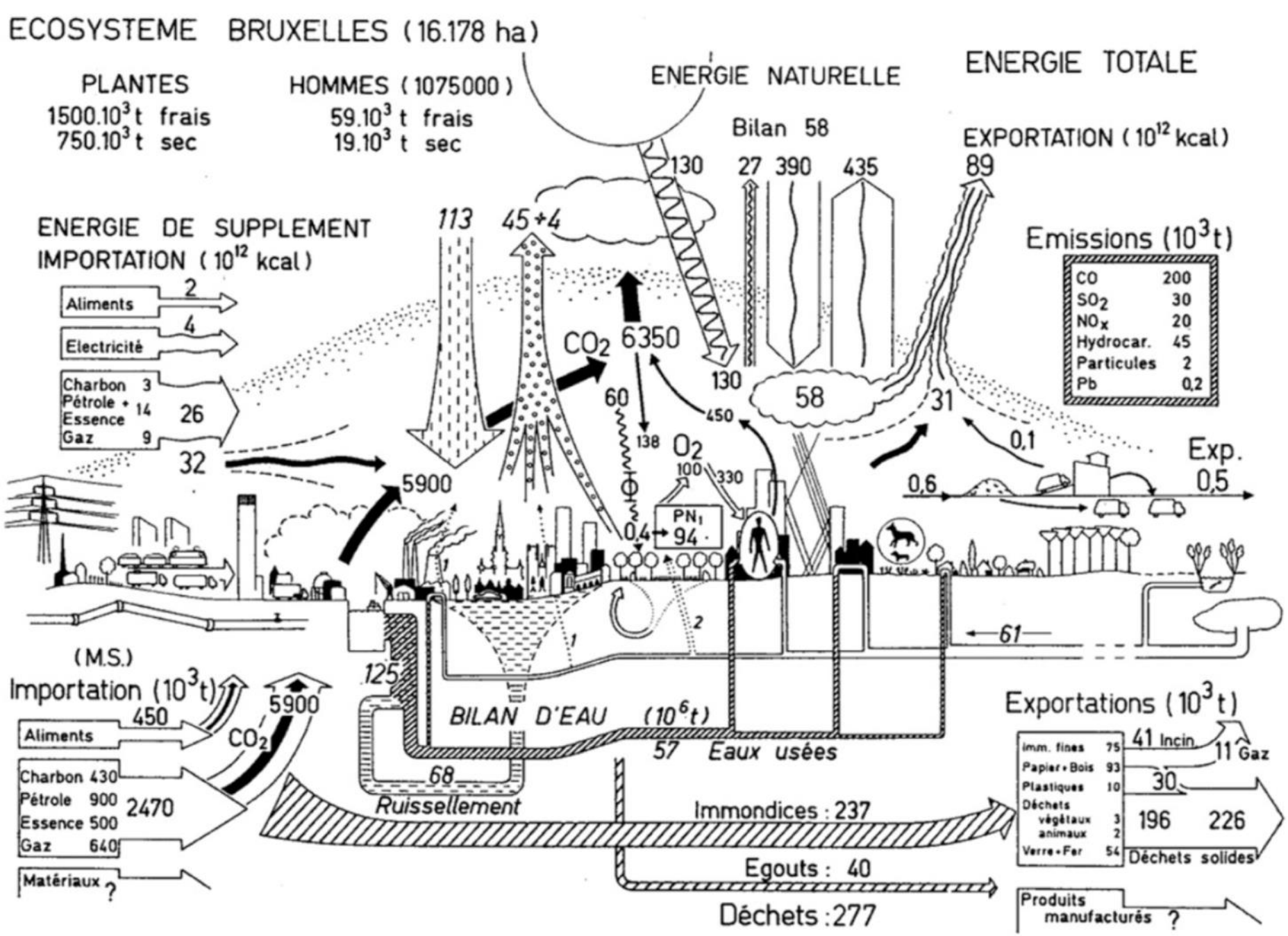
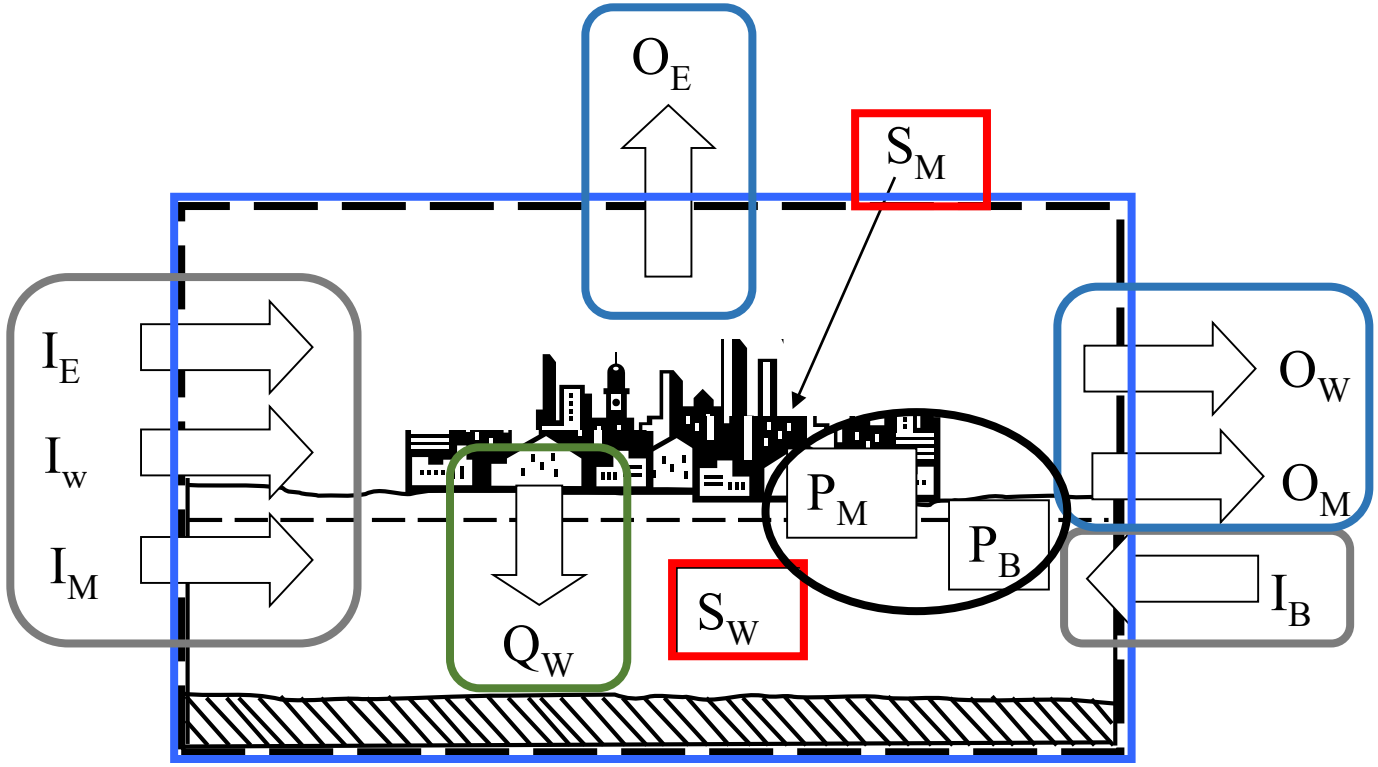


Fig. 1. The urban metabolism of Brussels, Belgium in the early 1970s (Duvigneaud and Denayeyer-De Smet, 1977).

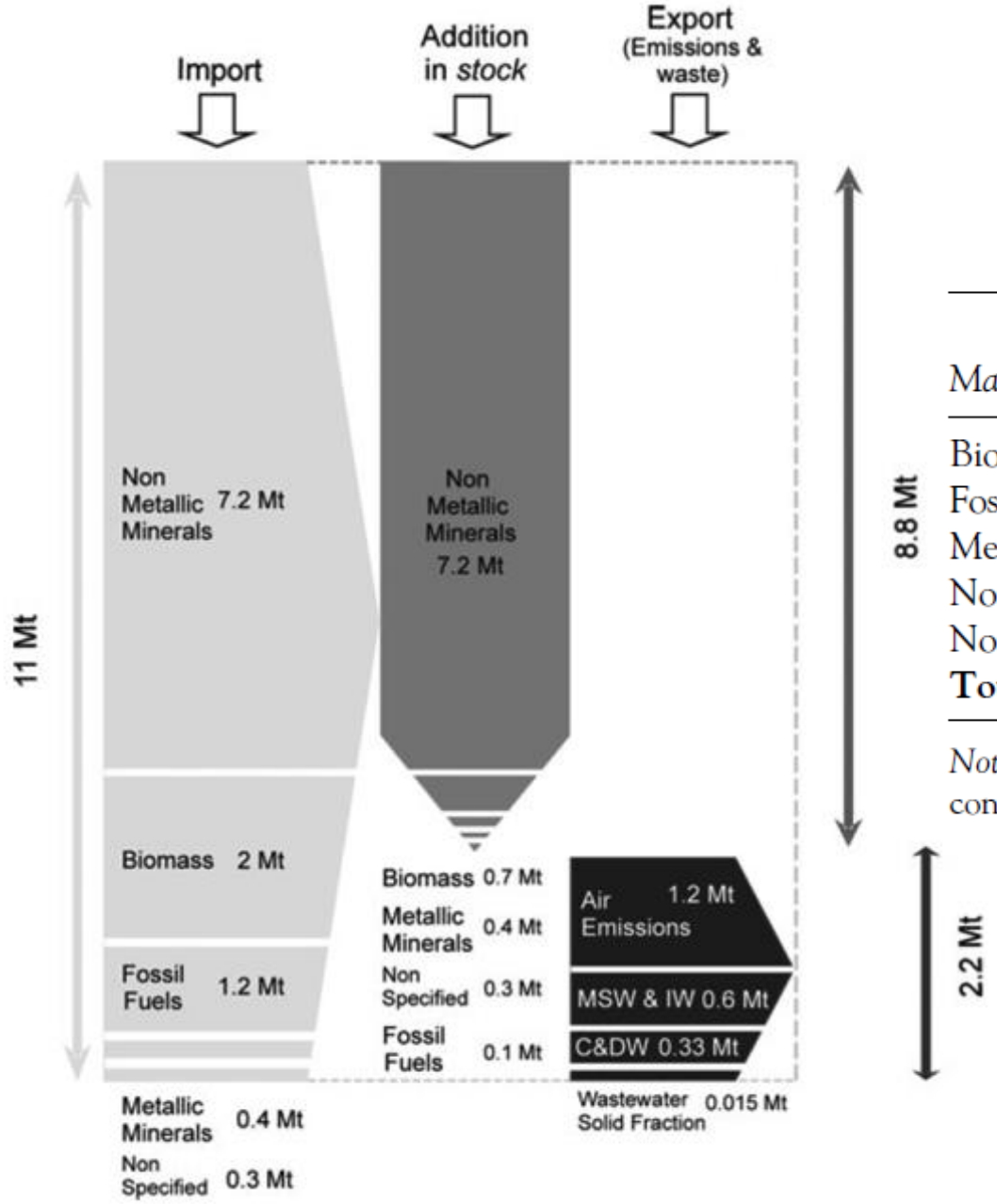
UM framework



Urban systems boundary broadly showing inflows (I), outflows (O), internal flows (Q), storage (S) and production (P) of biomass (B), minerals (M), water (W), and energy (E).

urban economy

Lisbon, Portugal



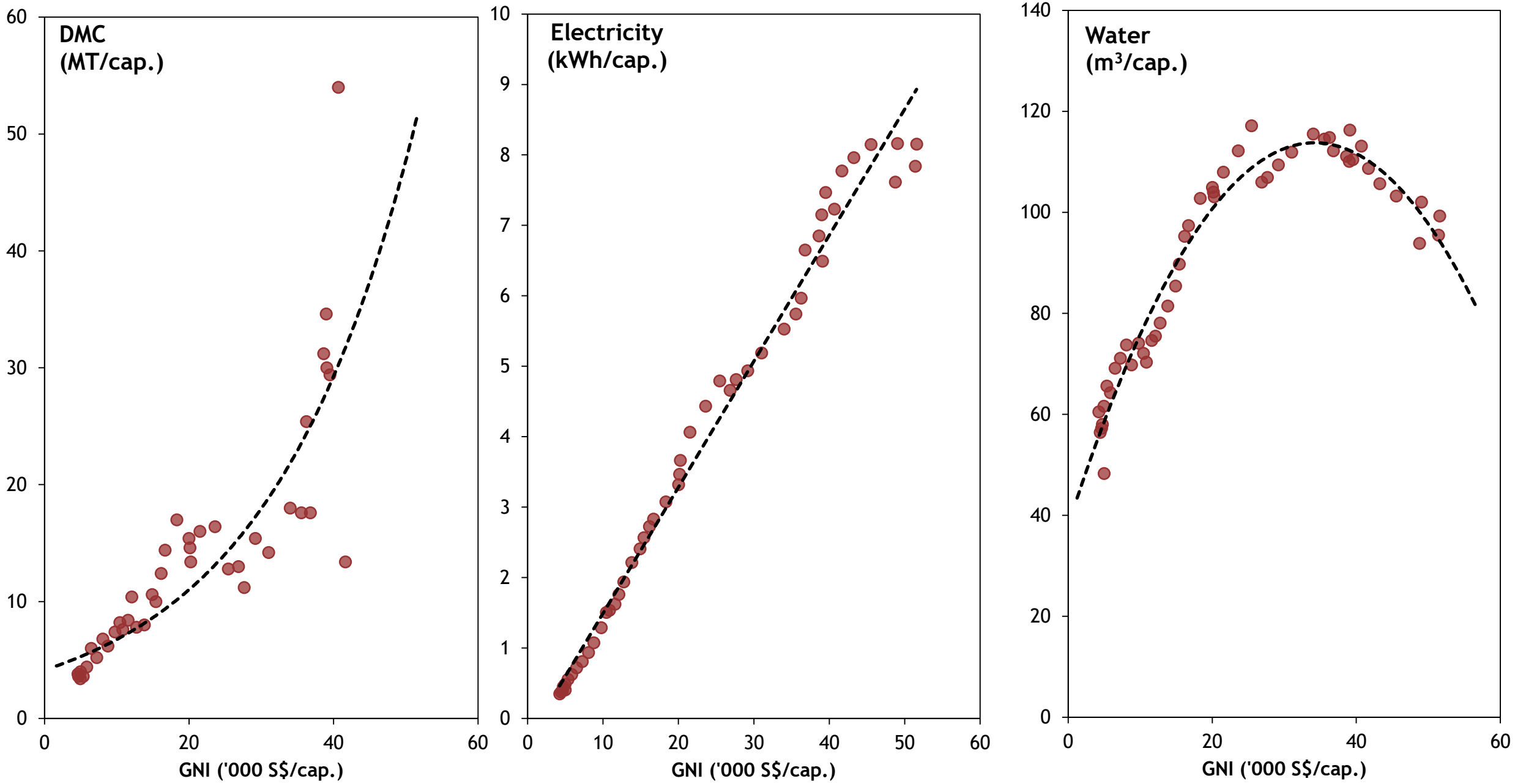
Material category	*Lisbon (DMC 2004)*	*Portugal (DMC 2000)*
Biomass	3.67	4.23
Fossil fuels	2.13	2.24
Metallic minerals	0.78	9.19
Nonmetallic minerals	12.99	
Nonspecified	0.52	-
Total	**20.08**	**15.66**

Note: t/cap = tonnes per capita; DMC = domestic material consumption.

pre-fossil fuel urban economy: ~1 ton per capita

transition urban economy: 12-30 tons per capita

fully developed urban economy: 30-100+ tons per capita


DMC
(MT/cap.)
GNI ('000 S$/cap.)
Electricity
(kWh/cap.)
GNI ('000 S$/cap.)
Water
(m³/cap.)
GNI ('000 S$/cap.)

Shenzhen, China: Waste to energy plant

Copenhagen, Denmark: Copenhill Power Plant

COPENHILL.DK
Mashable
77

John E. Fernández
fernande@mit.edu
Director, Environmental Solutions Initiative

urbanmetabolism.org
MIT Urban Metabolism Group

David Quinn, Jonathan Krones, Zak Accuardi, Karen Noiva, Nourhan Bayomi, Rachel Perlman, Kyoung Sun Moon, Harnwei Kua, Phebe Dudek, and many dozens of UROPs.

environmentalsolutions.mit.edu
MIT Environmental Solutions Initiative

URBAN METABOLISM GROUP