How is South Africa utilizing its resources to drive development?

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Waste Research, Development and Innovation Roadmap

A waste R&D and innovation programme for South Africa
Innovation, and the development of new technologies, will improve waste management

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

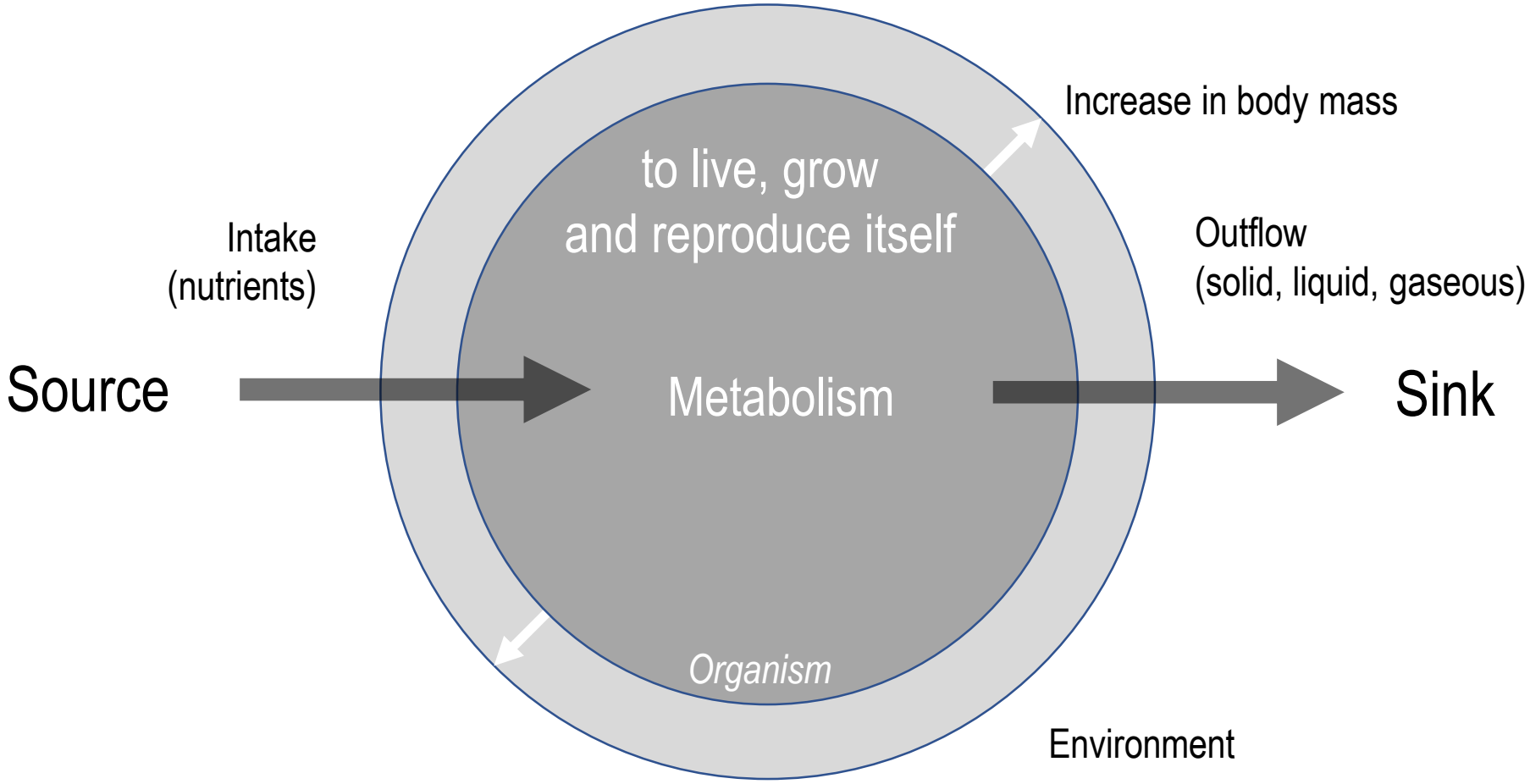
UNIVERSITY OF CAPE TOWN

CSIR
Touching lives through innovation

BOKU
University of Natural Resources and Life Sciences, Vienna

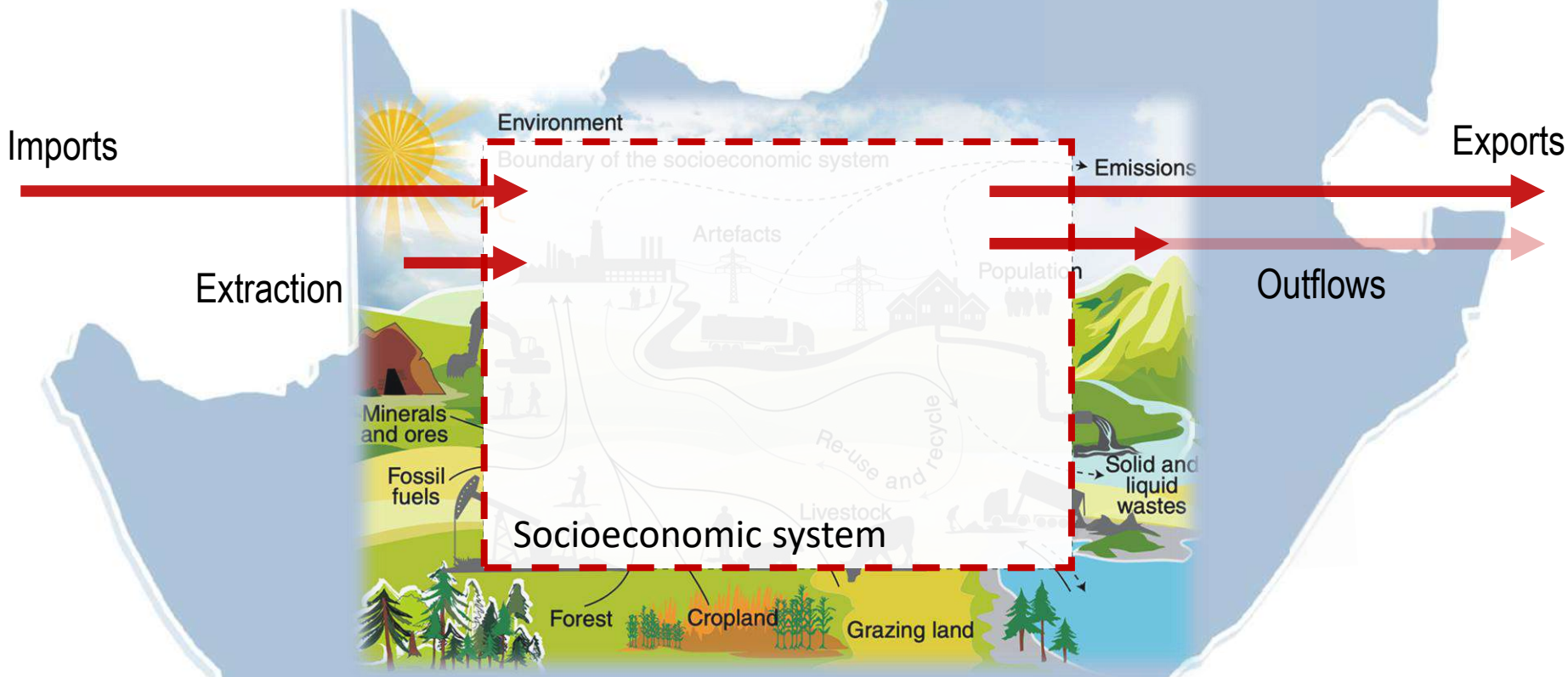
1. The methodological approach and overall results: Aggregated material flows through the economy
2. Biomass, metal, non-metallic minerals and fossil material flows and their reuse and recycling
3. State of circularity: indicators, key observations and conclusions

An organism has a metabolism



Mass balanced: intake = increase in body mass + outflow (law of conservation of mass)

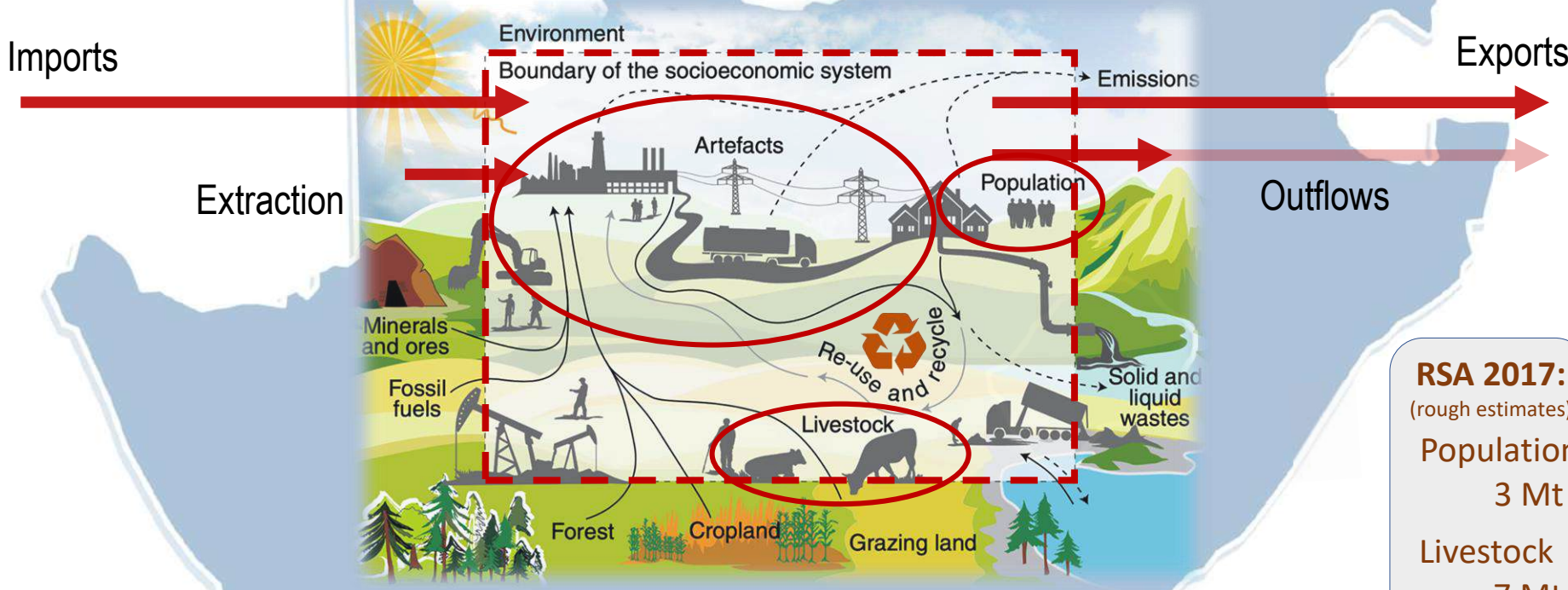
Economies have a social metabolism



Source of graph: Haberl, H., Wiedenhofer, D., Pauliuk, S., Krausmann, F., Müller, D. B., & Fischer-Kowalski, M. (2019). Contributions of sociometabolic research to sustainability science. *Nature Sustainability*, *2*(3), 173–184. https://doi.org/10.1038/s41893-019-0225-2

Economies have a social metabolism

Flows for operating, maintaining and extending stocks



RSA 2017:
(rough estimates)

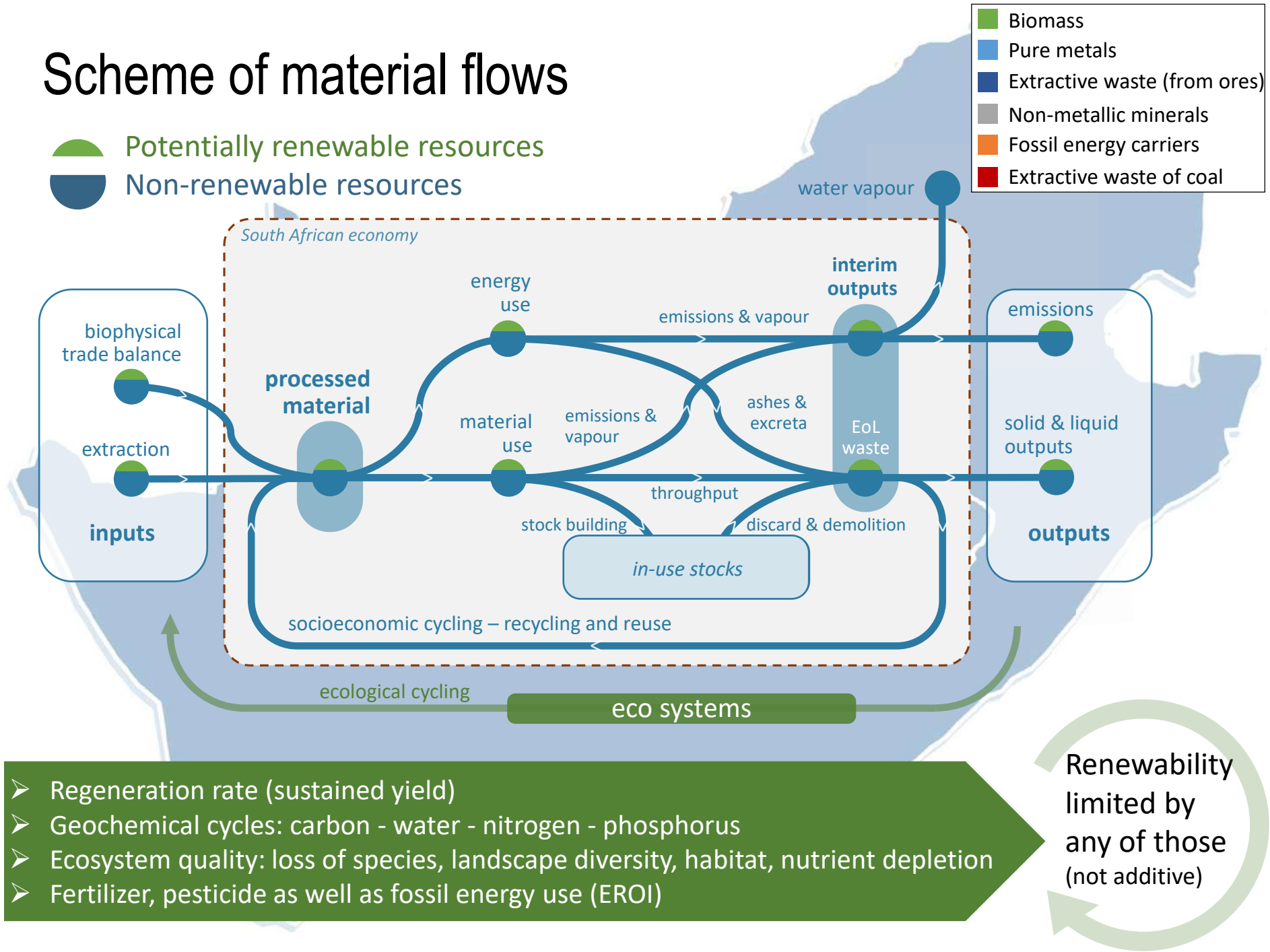
Population
3 Mt

Livestock
7 Mt

Artefacts
2 000 Mt

Mass balanced:
Inputs = Outflows + Net addition to stocks
(law of conservation of mass)

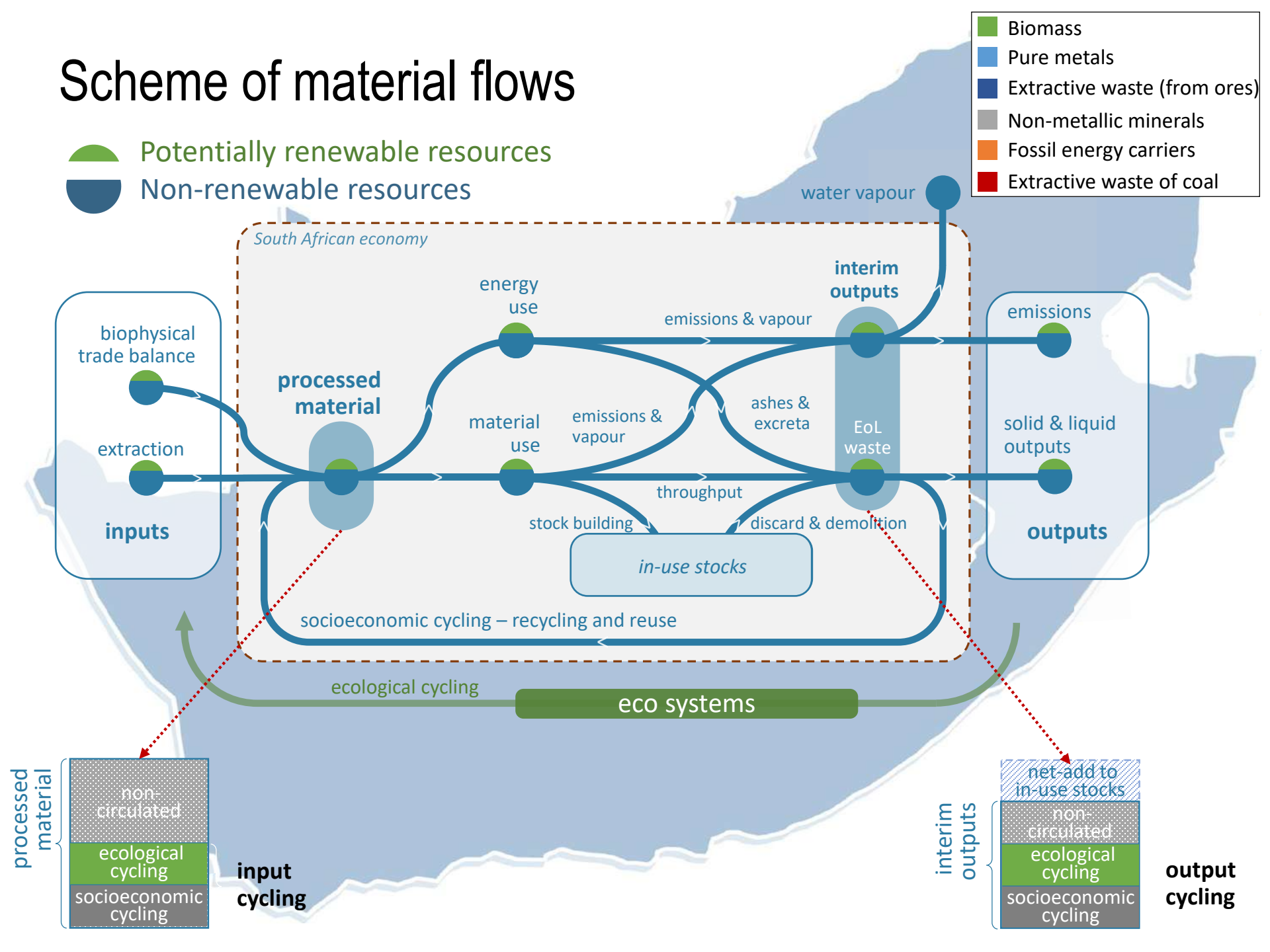
Scheme of material flows



- Regeneration rate (sustained yield)
- Geochemical cycles: carbon - water - nitrogen - phosphorus
- Ecosystem quality: loss of species, landscape diversity, habitat, nutrient depletion
- Fertilizer, pesticide as well as fossil energy use (EROI)

Renewability limited by any of those (not additive)

Scheme of material flows

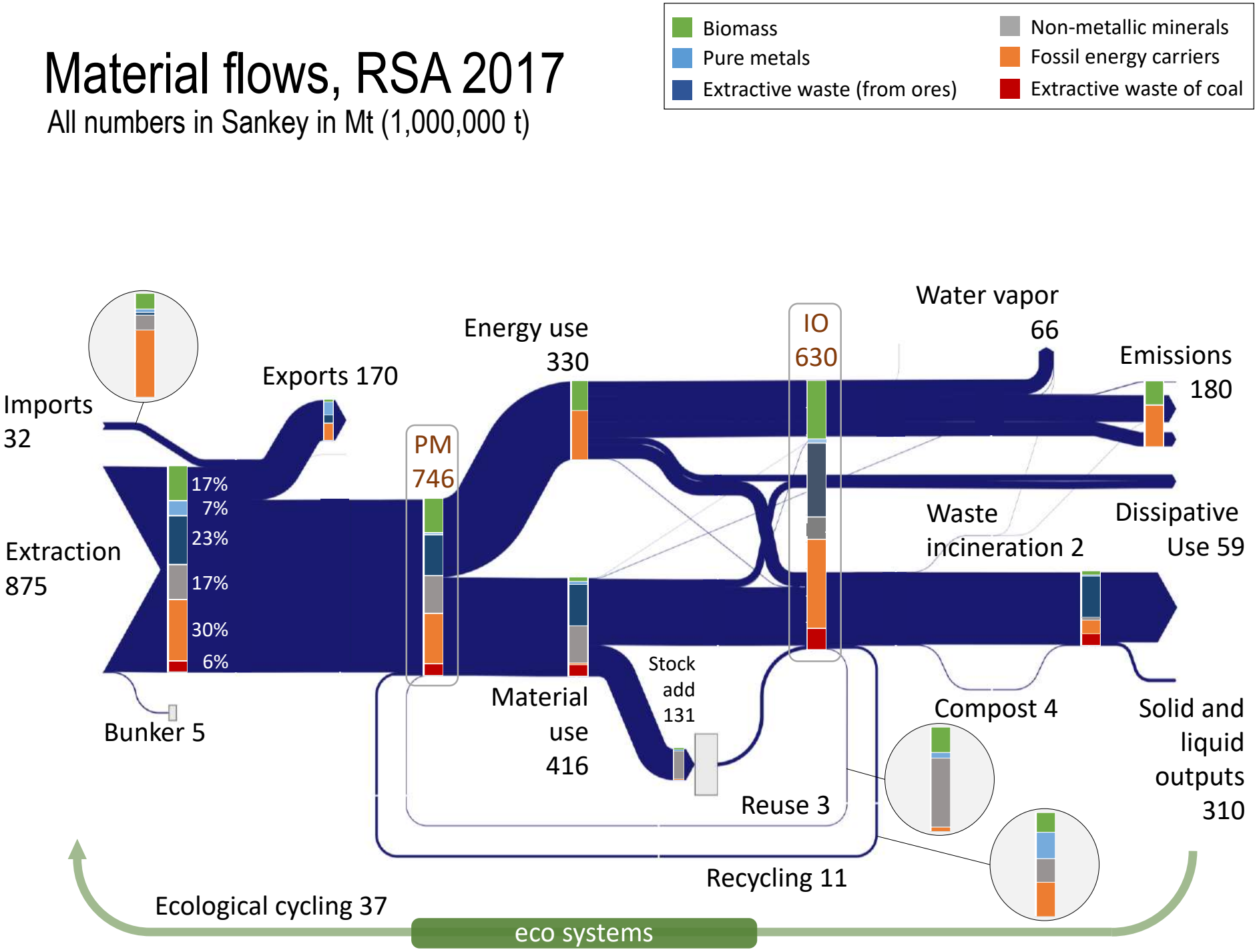


Some terminology

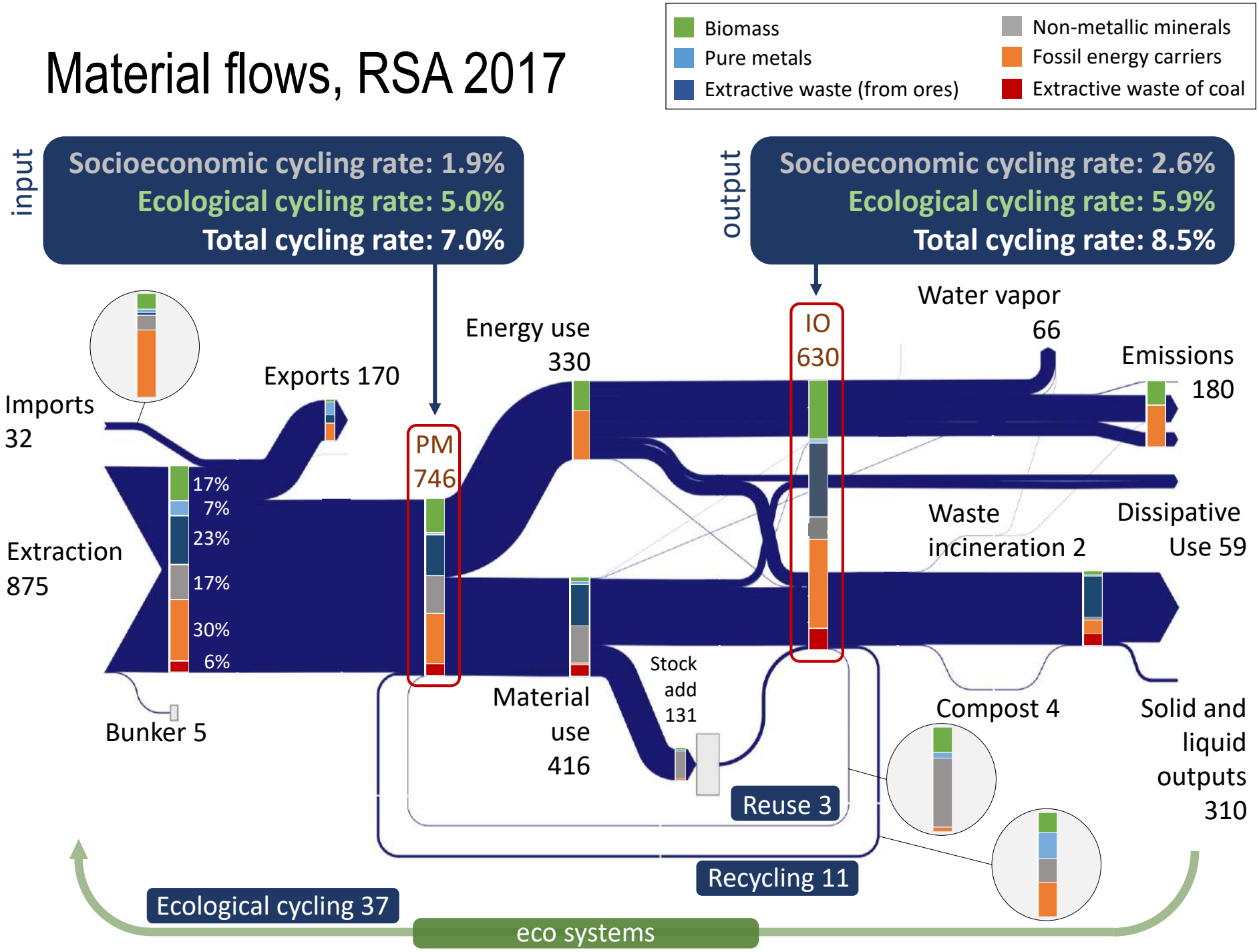
Term used in MFA	Meaning
Domestic extraction (DE)	From mining, farming, forestry, fishing within South Africa's borders; all harvested incl. residues and grazed (livestock are part of the socioeconomic system)
Extractive waste	Part of DE that becomes waste after some processing. Includes tailings, slags, bagasse etc.
Unused extraction	Material moved but not processed, incl. stover left on field, overburden, waste rock. Not counted.
Fresh weight	Weight of material incl. water
Dry weight	Weight of material excluding moisture content
Processed material	DE + imports – exports + recycling and reuse
Stock-building materials	Products that stay in use for > 1 year

Material flows, RSA 2017

All numbers in Sankey in Mt (1,000,000 t)



Material flows, RSA 2017



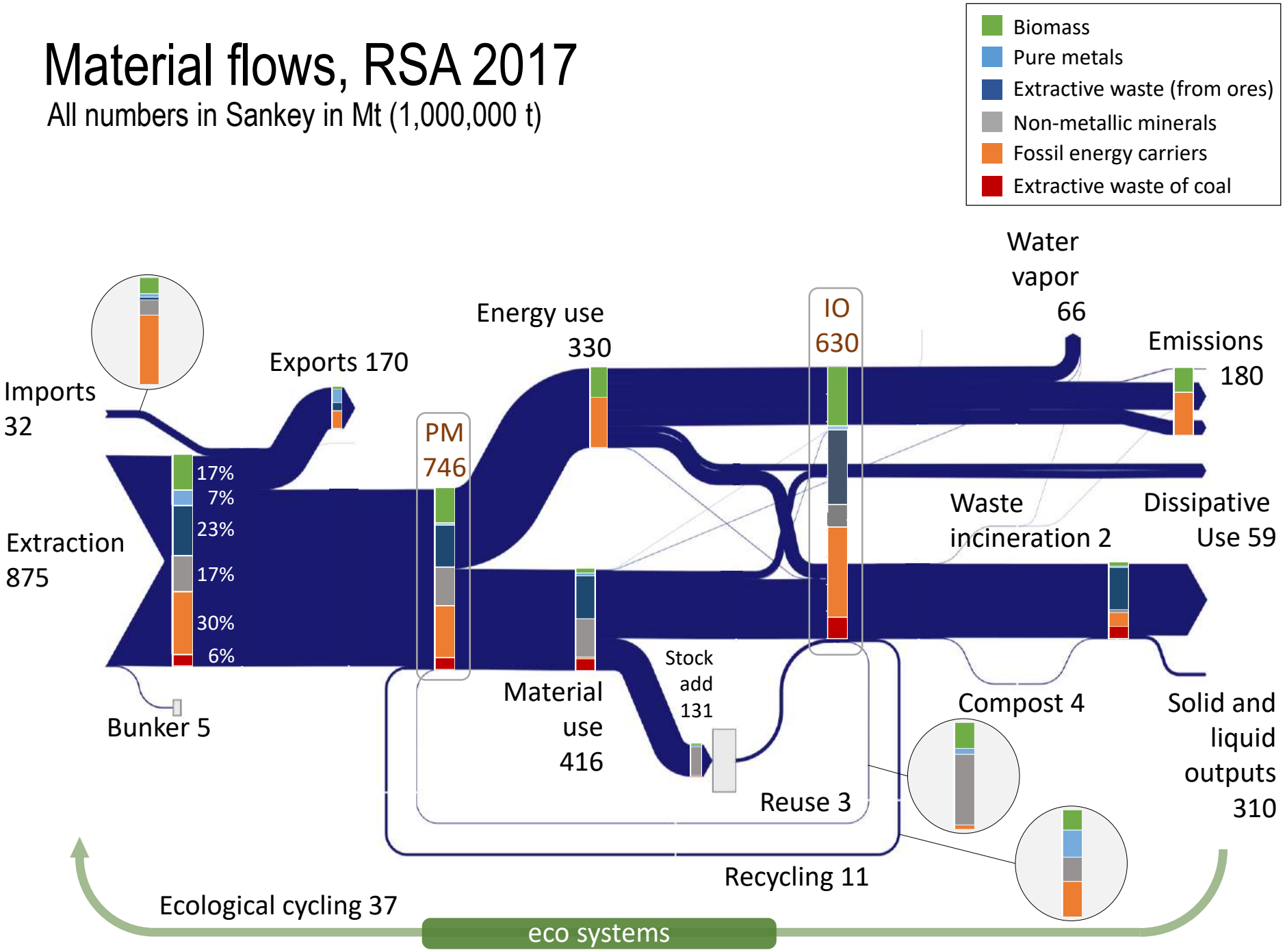
Breakdown of results

Biomass, metal, non-metallic minerals and fossil material flows and their reuse and recycling

RSA 2017

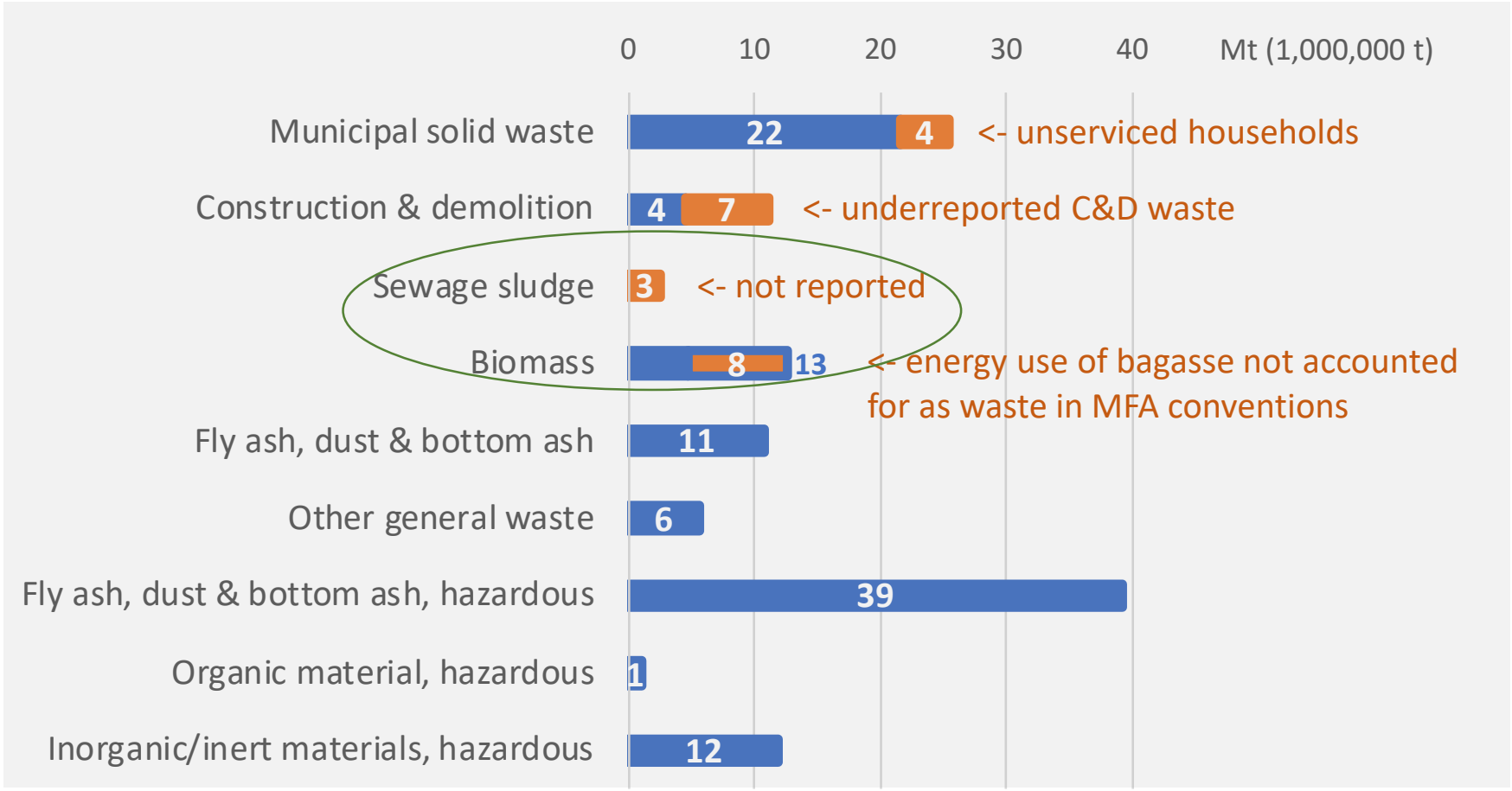
Material flows, RSA 2017

All numbers in Sankey in Mt (1,000,000 t)



How much waste is there?

1) SASoW
2) deviating estimates
3) mass-balanced add.



1) SASoW **107 Mt Sum**

deviations of our study **111 Mt Sum**

2)

Sum EoL ≈ 330 Mt

plus extra flows

+ 170 Mt extractive waste metal mining

+ 50 Mt extractive waste coal mining

3)

Method for estimating C&D waste and its informal reuse

Method 1: Stock life of construction materials

Assumptions:

- 3% annual growth rate in construction material
- All stock-add of 1 life-time ago demolished in 2017 = D
- 1% of new construction materials become waste directly = C

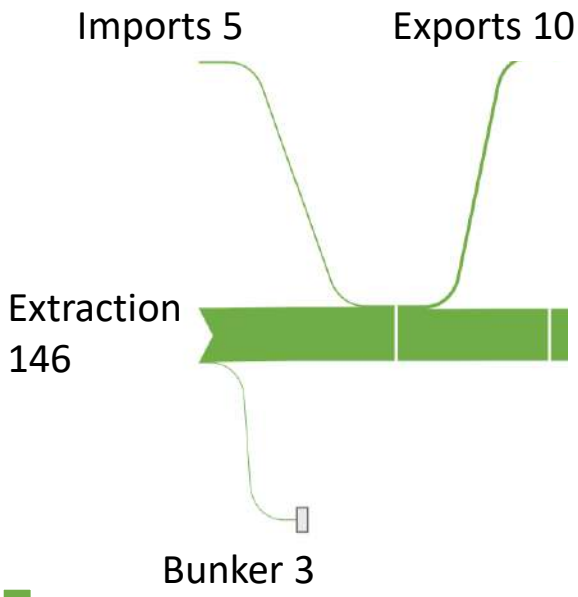
- **Result 17,2 Mt**
  - But some EoL stocks hibernate?

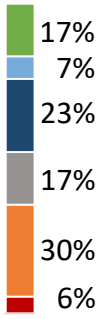
Method 2: Scale-up from Cape Town data

- C&D waste generation in Cape Town reported as 1,09 Mt
- Population:
  - Cape Town 3,8 million
  - national 57 million
  - 60% urban and 40% rural
- Assumed C&D waste per capita
  - Urban same as Cape Town
  - Rural 20% of urban
- **Result: 11,1 Mt**

Biomass flows, 2017

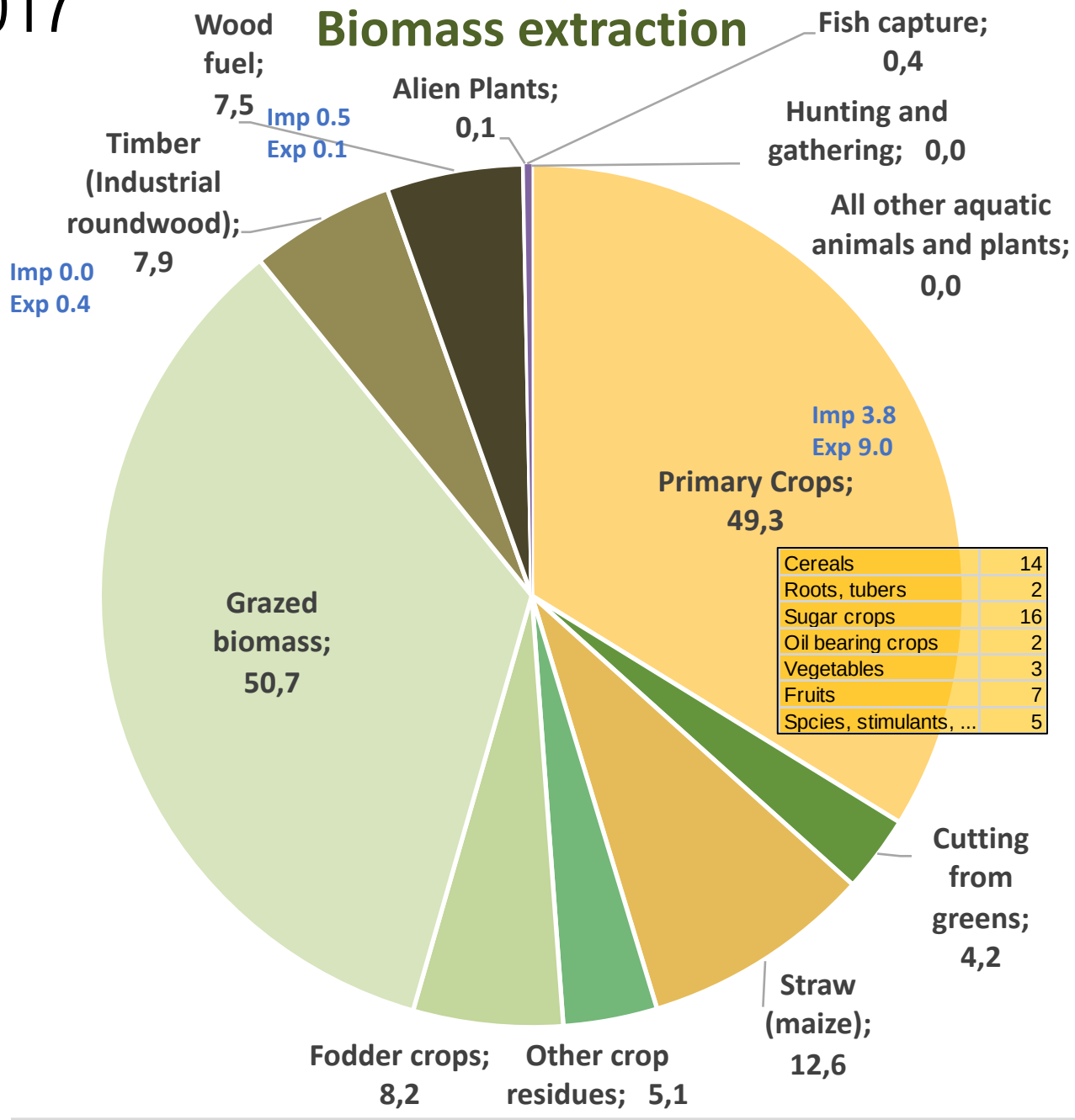
All numbers in Mt (1,000,000 t)





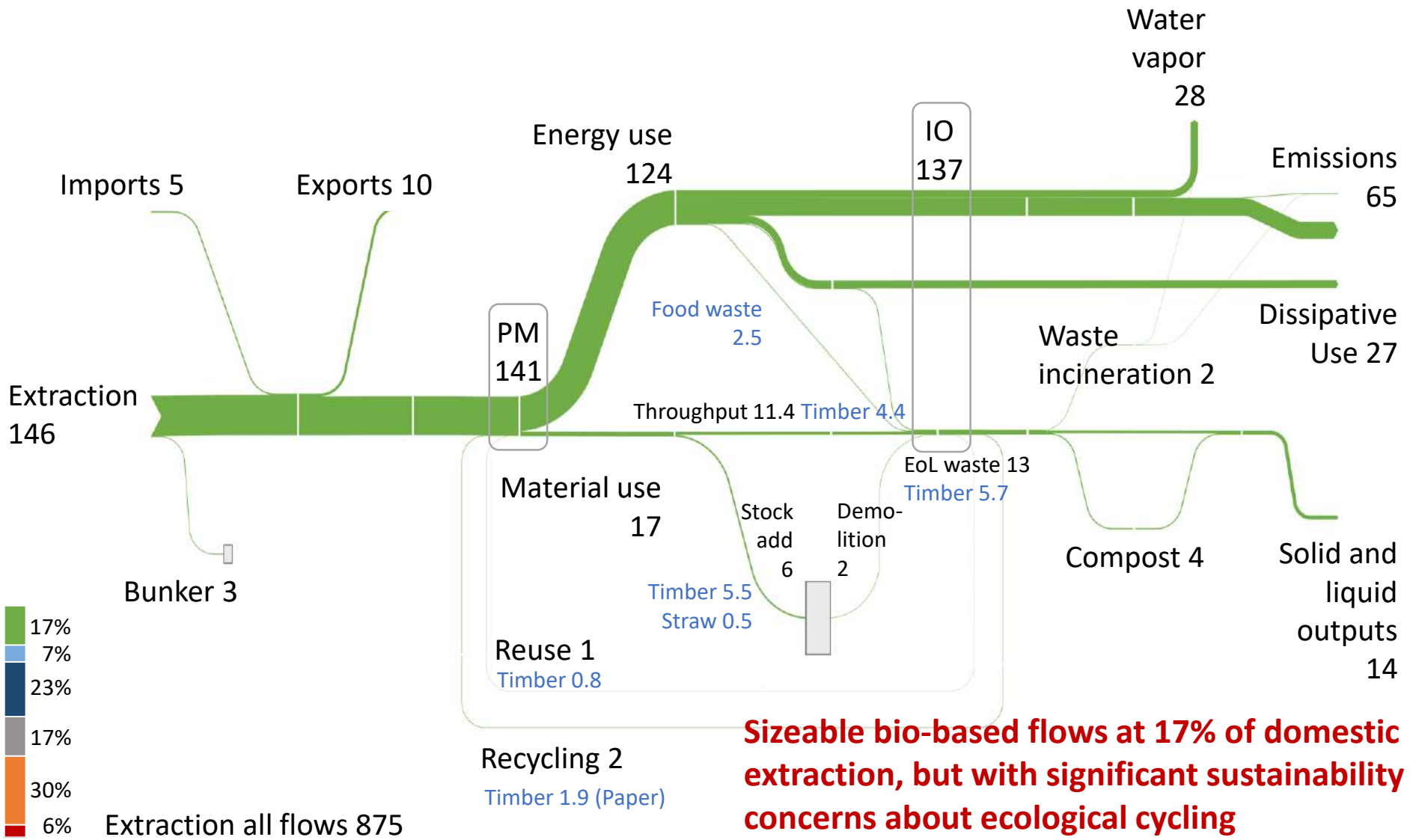
Extraction all flows 875

Biomass extraction



Biomass flows, 2017

All numbers in Mt (1,000,000 t)



Sizeable bio-based flows at 17% of domestic extraction, but with significant sustainability concerns about ecological cycling

Potentials to increase ecological circularity

olute			DE	Imp	Exp	Interim Outputs	sustainable fraction in % of DE	sustainable fraction absolut
A.1.1	Primary Crops		49,3	3,8	9,0	41,5	20%	9,9
A.1.1a	Cutting from greens		4,2	-	-	4,2	100%	4,2
A.1.2	Crop residues							-
		Straw (maize)	12,6	0,0	0,0	12,1	20%	2,5
		Other crop residues	5,1	0,0	0,0	5,1	20%	1,0
		Fodder crops	8,2	-	-	8,2	20%	1,6
		Grazed biomass	50,7	-	-	50,7	10%	5,1
A.1.3	Wood							
		Timber (Industrial roundwood)	7,9	0,0	0,4	6,7	80%	6,3
		Wood fuel	7,5	0,5	0,1	7,9	80%	6,0
		Alien Plants	0,1	-	-	0,1	100%	0,1
A.1.4	Wild fish catch, aquatic plants/animals, hunting and gathering							
		Fish capture	0,4	0,3	0,4	0,4	76%	0,3
		All other aquatic animals and plants	0,0	0,0	0,0	0,0	76%	0,0
		Hunting and gathering	0,0	-	-	0,0	100%	0,0
Total biomass			145,9	4,7	9,9	136,8	27%	37,0

Conservation agriculture

Expert judgment

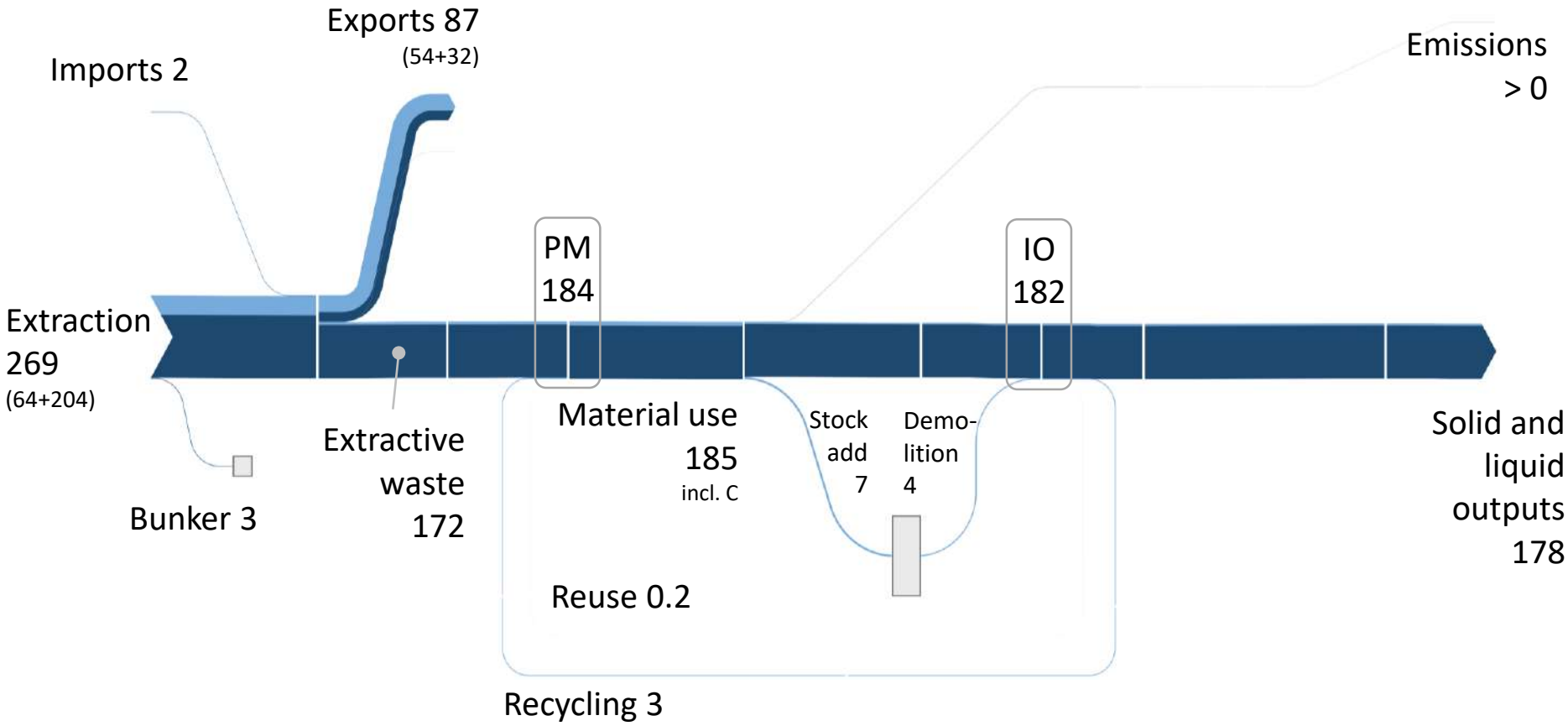
FSC

- Global level: biogeochemical nutrient cycle (N, P) has transgressed planetary boundaries caused by industrial and agricultural processes.
- South Africa: The Natural Capital Accounts initiative is extremely important and other scientific assessments should help generate evidence for tailor-made strategies.
- Attention needs to be paid to sustainable farming practices especially for grasslands, livestock and primary crop farming.

Metal flows, RSA 2017

All numbers in Sankey in Mt (1,000,000 t)

Including extractive waste (dark)



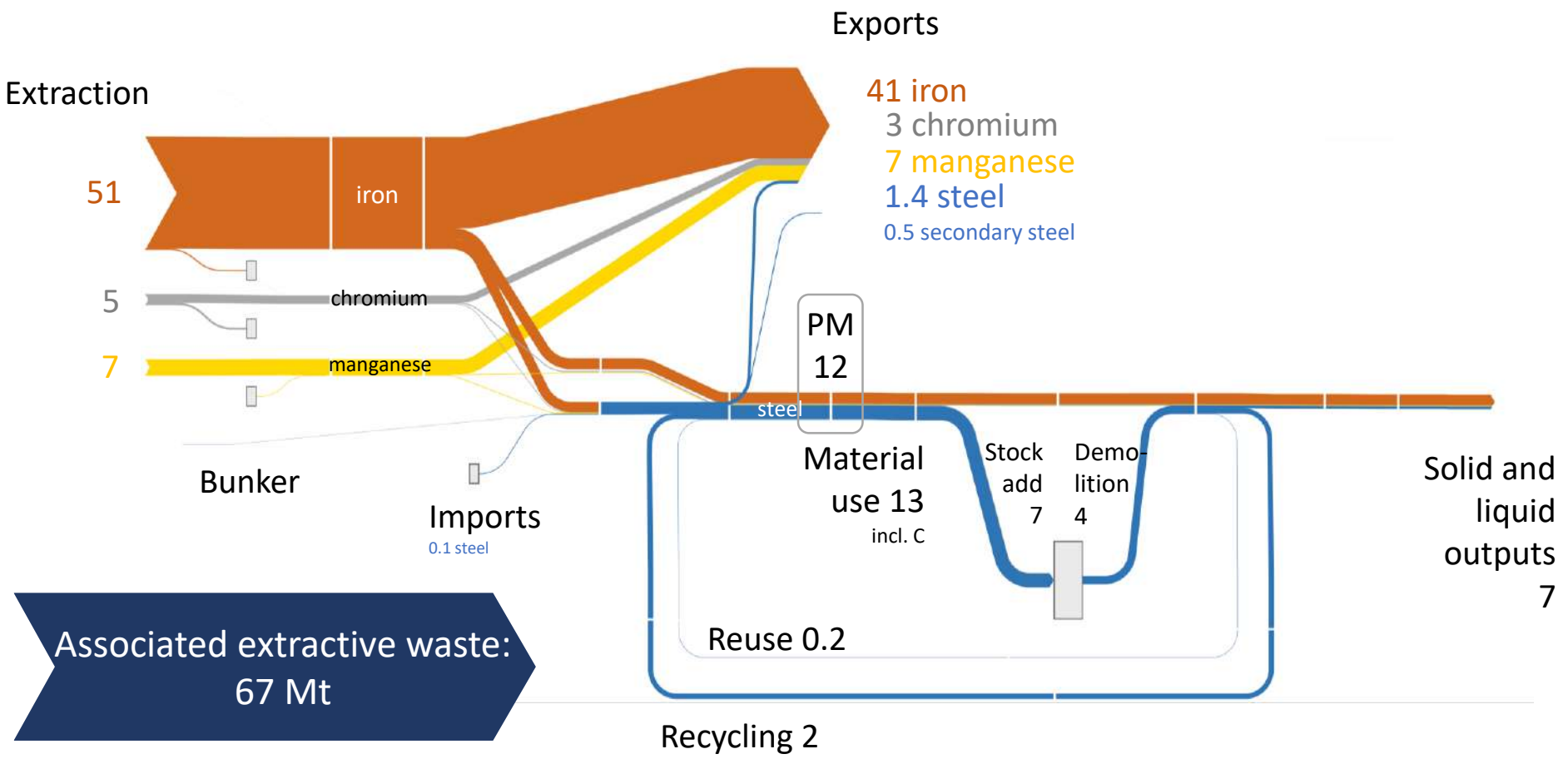
Interlinkages amongst mining sub-sectors

Mining sector	Key metals	Intermediates	Metal products	Extractive waste
Iron Ore	Fe	Pig iron	Iron	Oxygen, Silicon +
		(Pig iron from other sectors)	**Steel**	
Manganese	Mn, Fe	Ferro-Manganese		Oxygen, Silicon +
Chromium	Cr, Fe	Ferro-Chromium		Oxygen, Silicon +
PGM	Fe, Cr	Chromite concentrate		
	Pt, Pd, Rh, Au	Precious metal concentrate	Pt, Pd, Rh	Sulphur +
	Cu, Co, Ni	Base metal concentrate	Nickel, Cobalt	Sulphur +
Copper	Cu, Fe		Copper	Sulphur, Iron, Silicon +

Flows of iron, chromium, manganese and steel RSA 2017

All numbers in Sankey in kt (1,000 t)

Pure metals only

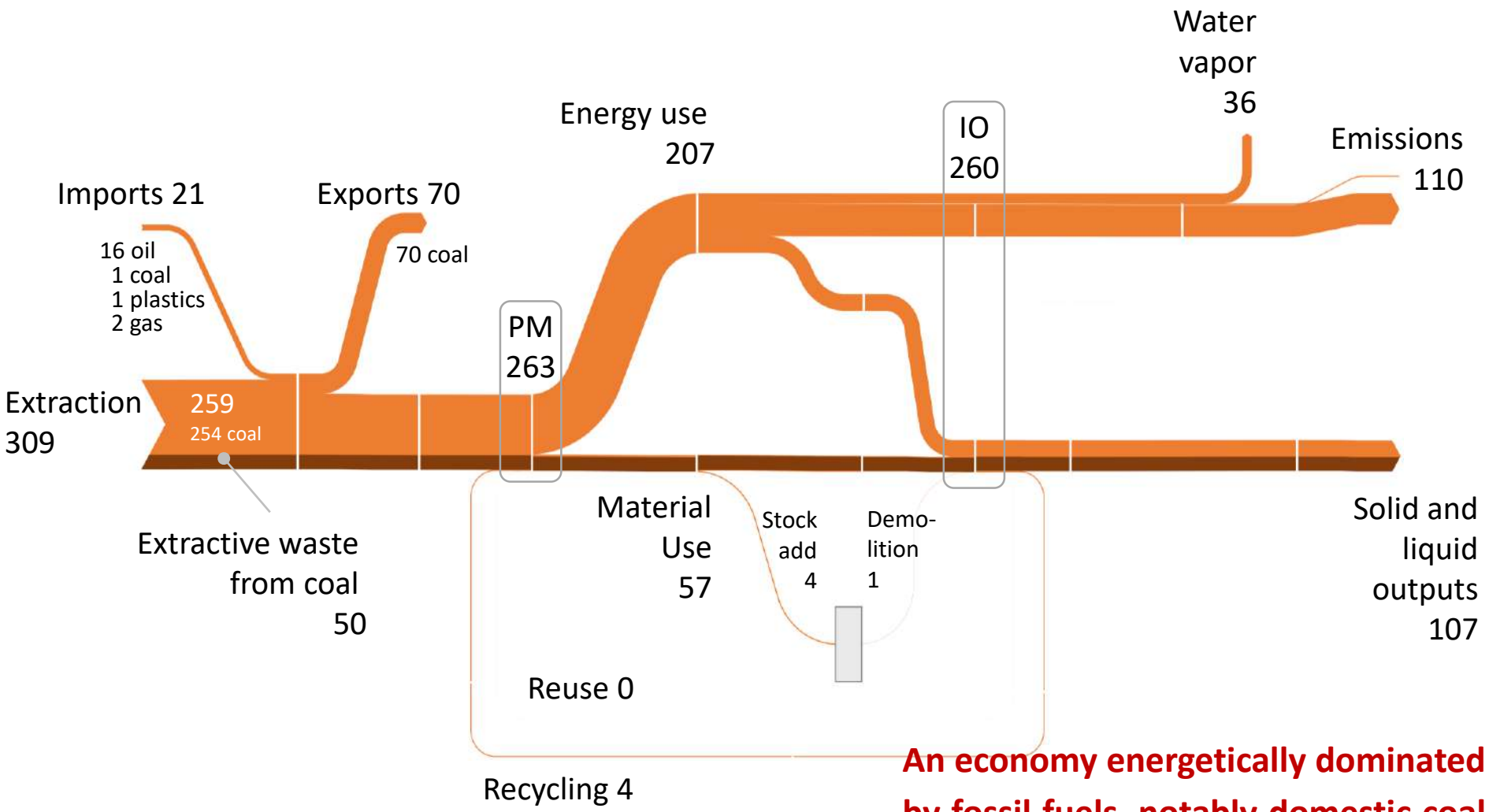


Associated extractive waste: 67 Mt

An economy materially dominated by export-oriented extractives

Fossil-based material flows, RSA 2017

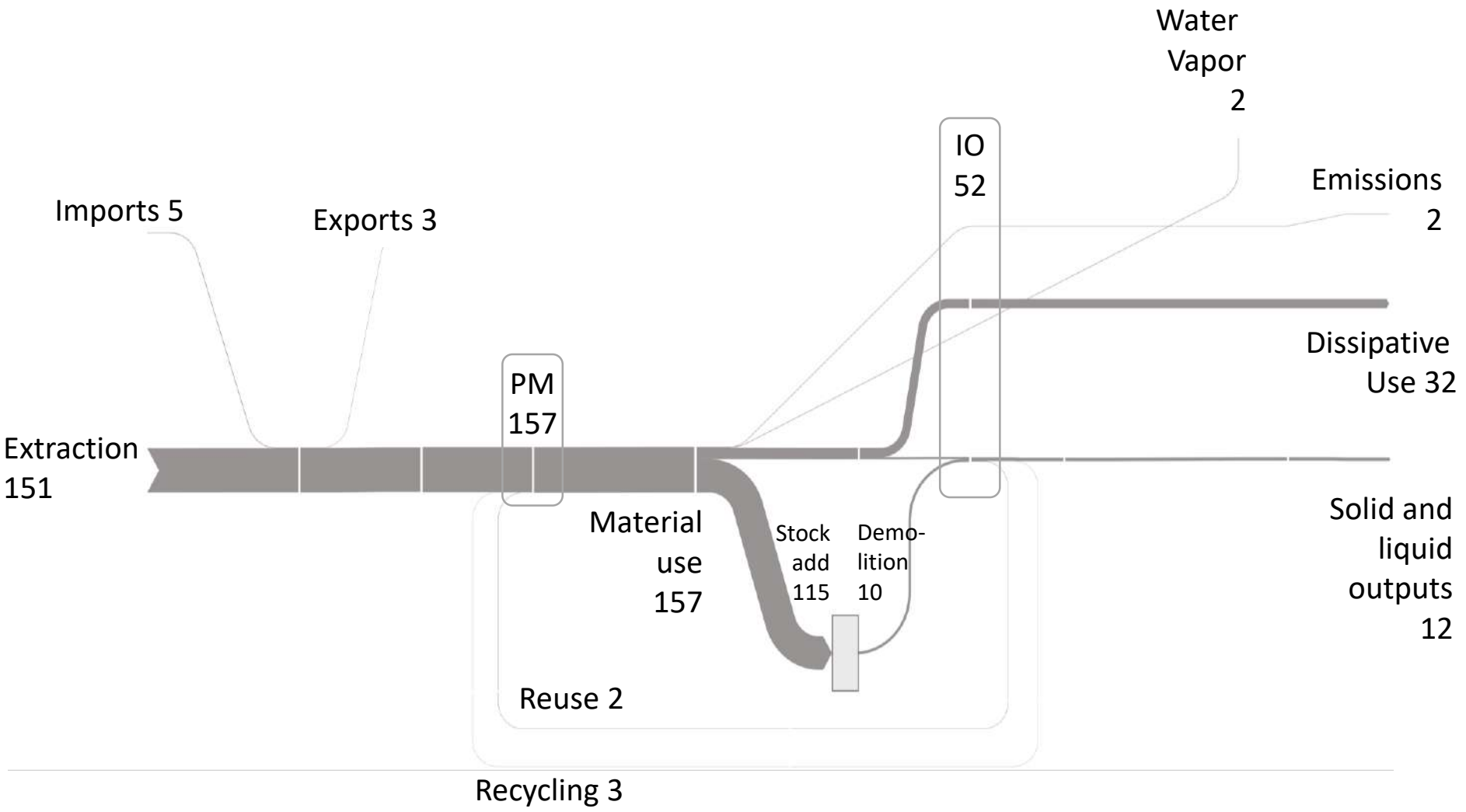
All numbers in Sankey in Mt (1,000,000 t)
Including extractive waste from coal (dark)

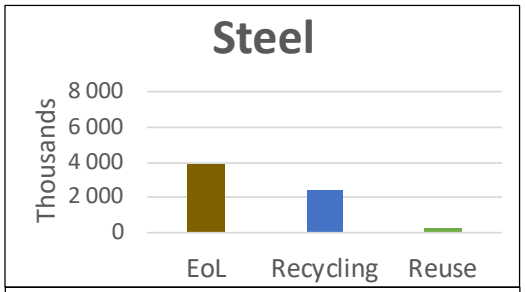


An economy energetically dominated by fossil fuels, notably domestic coal supported by imported oil

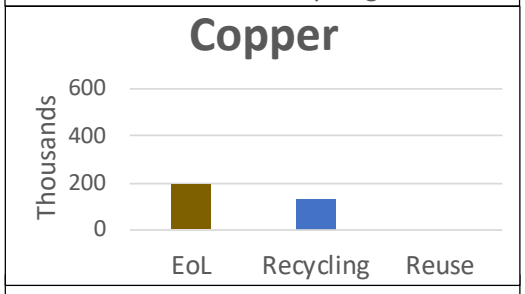
Non-metallic minerals flows, RSA 2017

All numbers in Sankey in Mt (1,000,000 t)

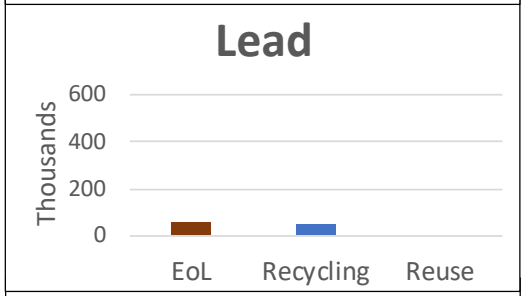




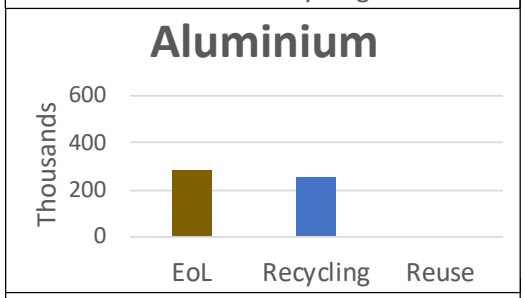
Recycling already a routine reuse of metal frames



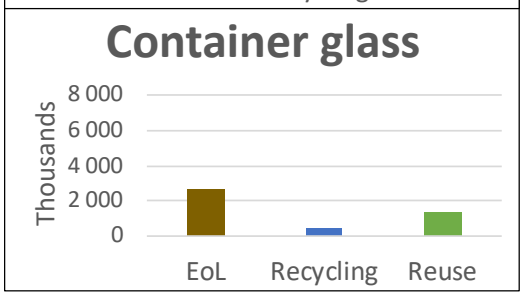
Recycling already a routine



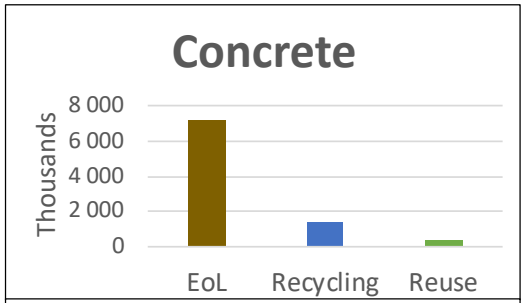
High recycling rates



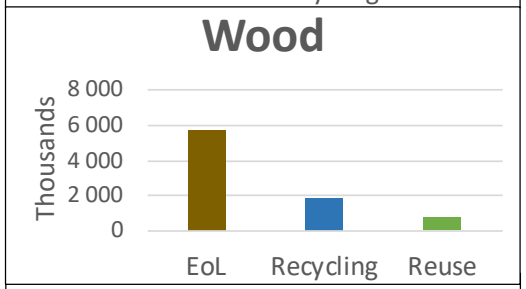
High recycling rates, though uncertain



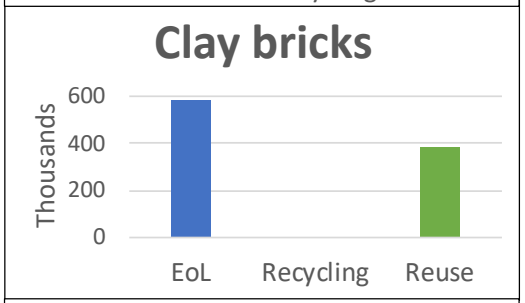
Successful reuse



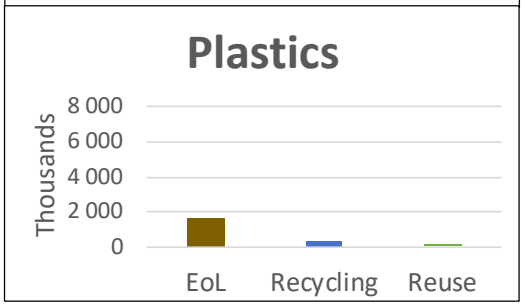
Recycling challenging



Recycling of paper and reuse of wood products



High informal reuse?



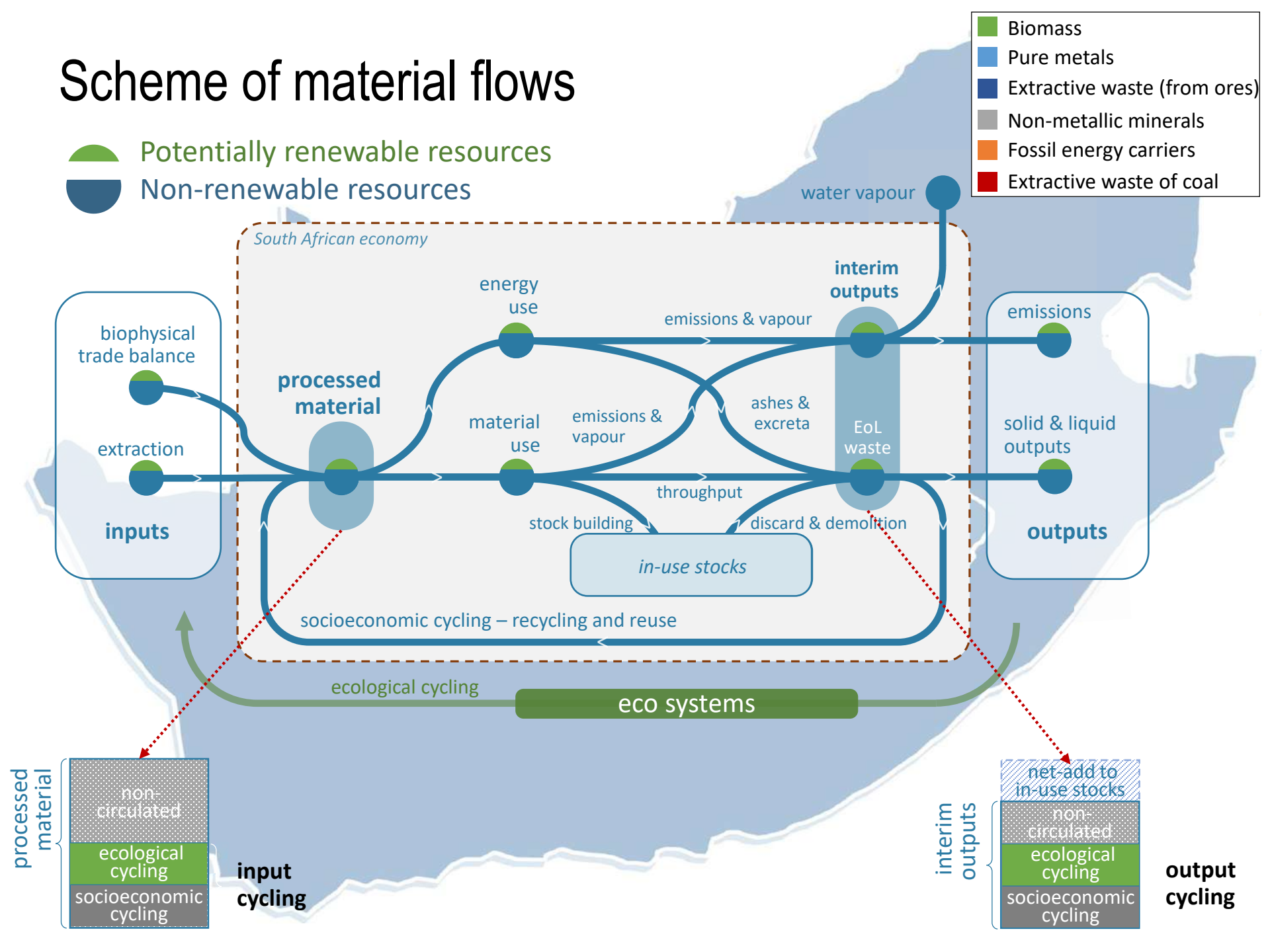
Challenging and work in progress

Pockets of high circularity in the domestic economy and significant informal activity around cascade use, reuse and recycling

State of circularity

Indicators, key observations and conclusions

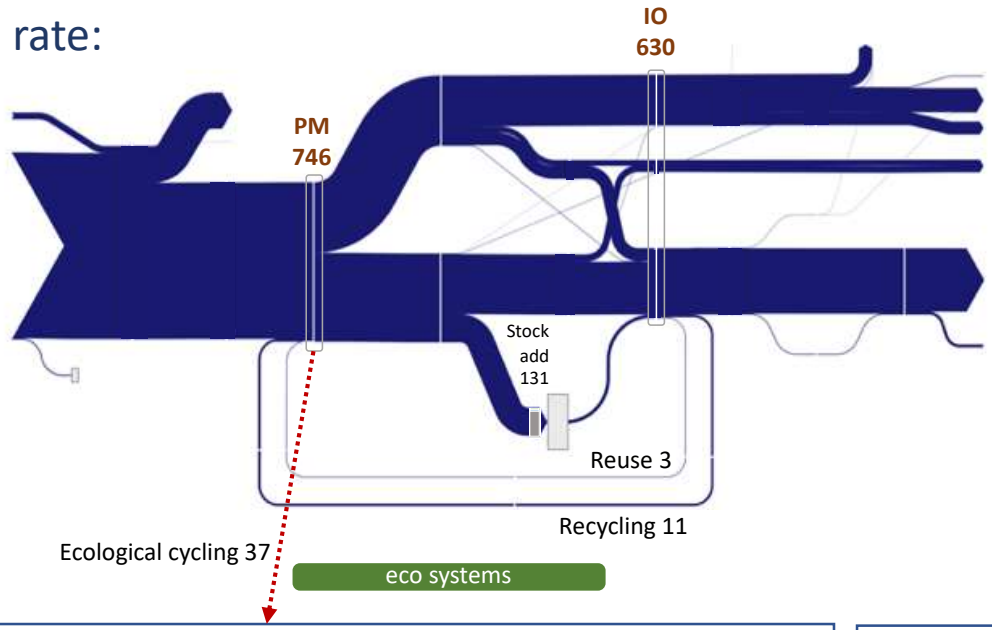
Scheme of material flows

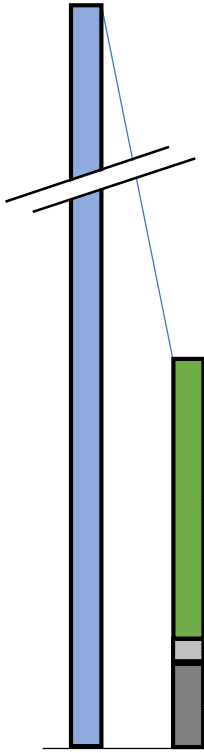


Socioeconomic cycling rate:
1.9%

Ecological cycling rate:
5.0%

Total cycling rate:
7.0%





Processed Material (PM): 746 Mt = 100%

Total cycled material: 52 Mt = 7.0% of PM

Ecological cycling
Cycled biomass: **37 Mt = 5.0% of PM**

Socioeconomic cycling: 14 Mt = 1.9% of PM
Reused: 3 Mt = 0.4% of PM
Recycled: 11 Mt = 1.5% of PM

Differences in sums due to rounding

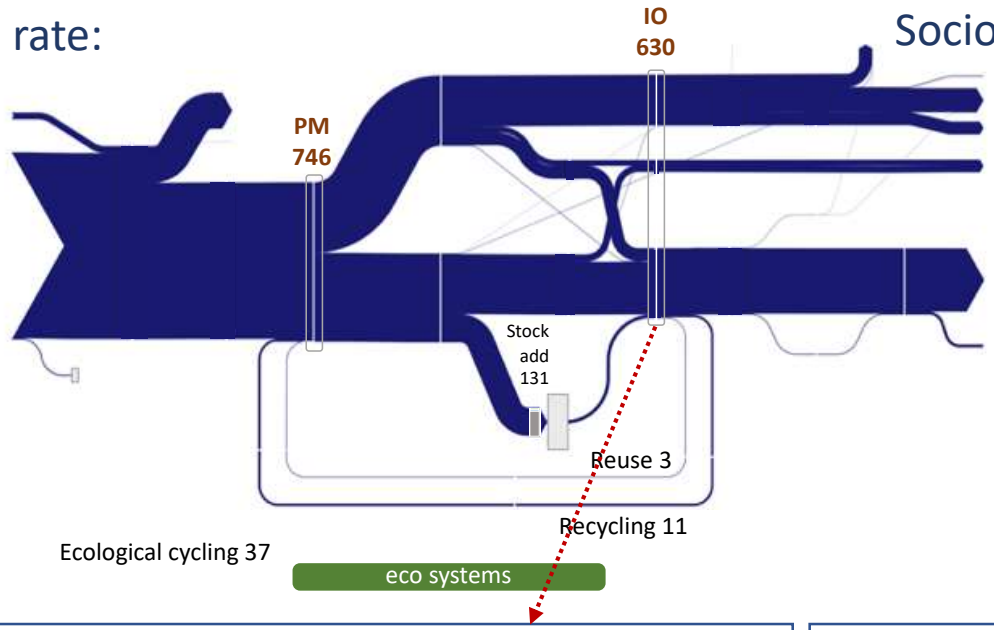
Uncertainty estimate

	Low range	High range
PM (Mt)	671	895
Total cycling	6.5%	14.6%
Eco-cycling	5.0%	11.3%
Socio-economic cycling	1.5%	3.3%
Reuse	0.4%	1.4%
Recycling	1.1%	1.9%

Socioeconomic cycling rate:
1.9%

Ecological cycling rate:
5.0%

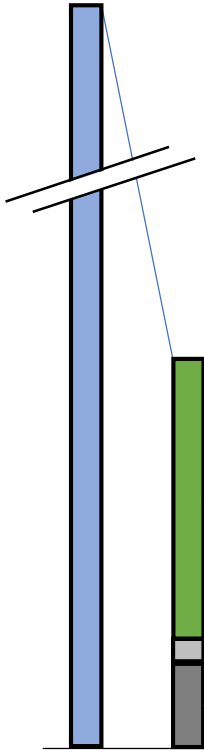
Total cycling rate:
7.0%



Socioeconomic cycling rate:
2.6%

Ecological cycling rate:
5.9%

Total cycling rate:
8.5%



Interim Output (IO): 630 Mt = 100%

Total cycled material: 52 Mt = 8.5% of PM

Ecological cycling

Cycled biomass: **37 Mt = 5.9% of PM**

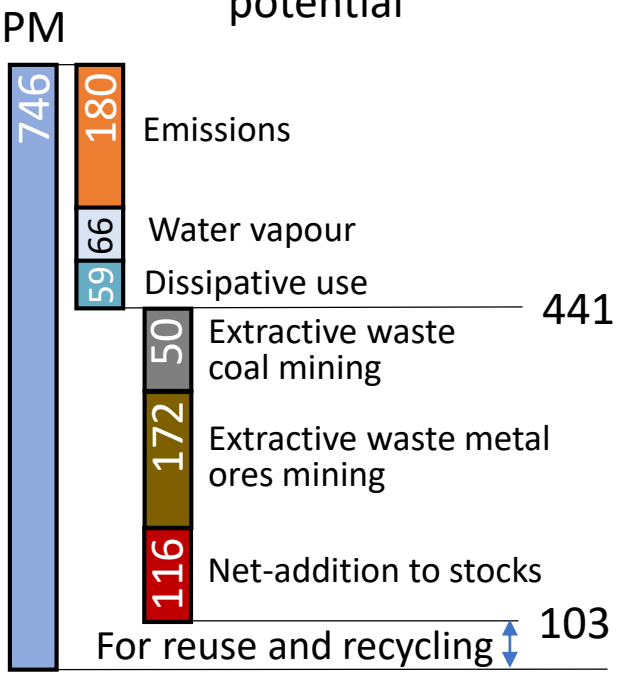
Socioeconomic cycling: 14 Mt = 2.6% of PM

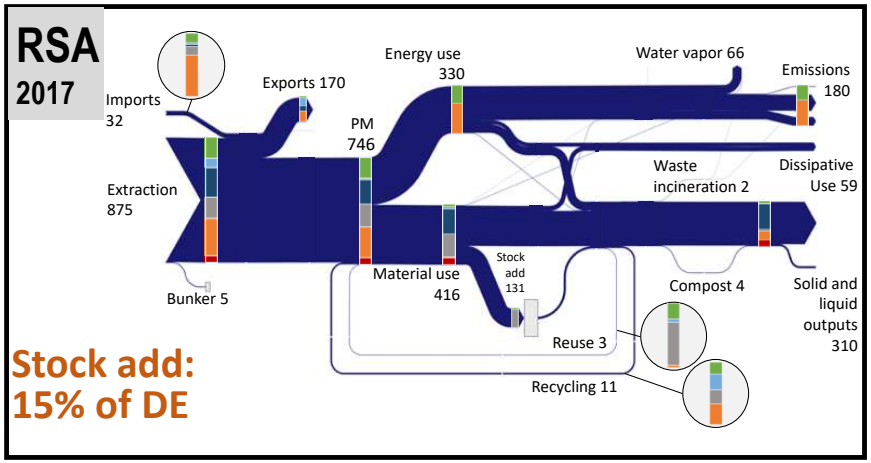
Reuse: 3 Mt = 0.6% of PM

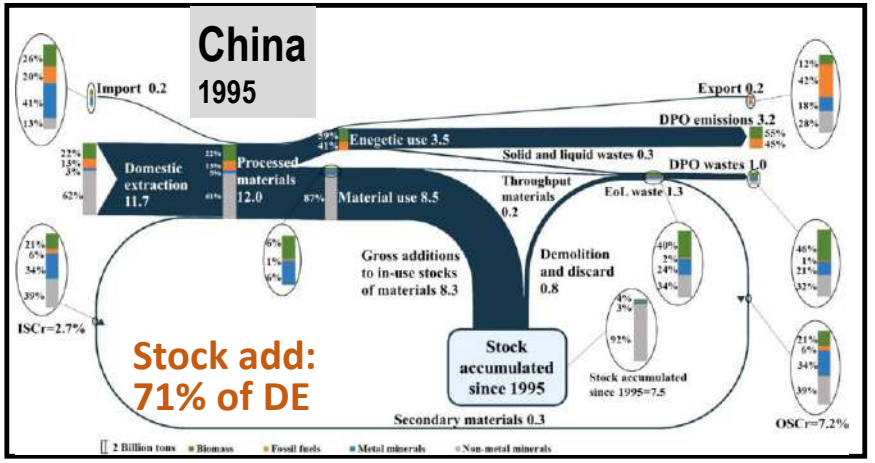
Recycling: 11 Mt = 2.0% of PM

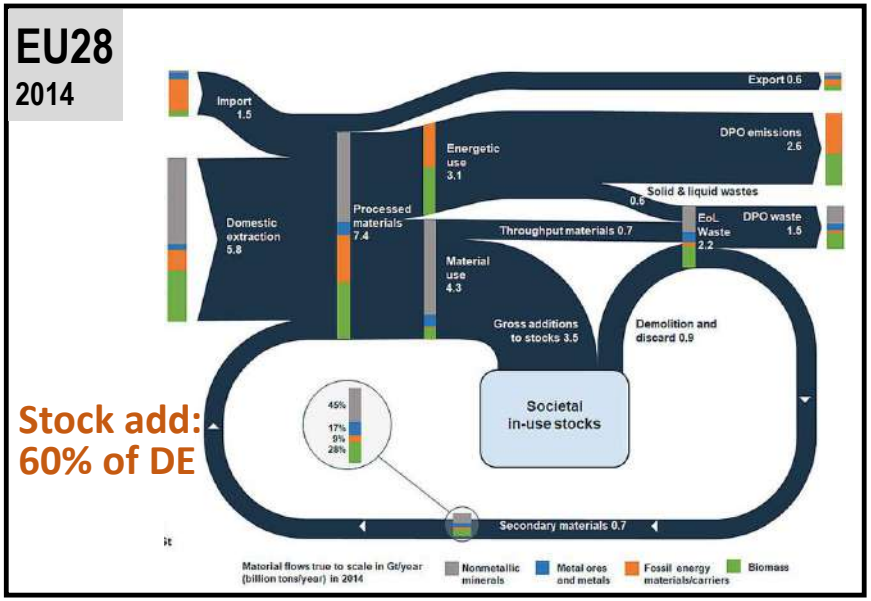
Differences in sums due to rounding

Theoretical recycling potential









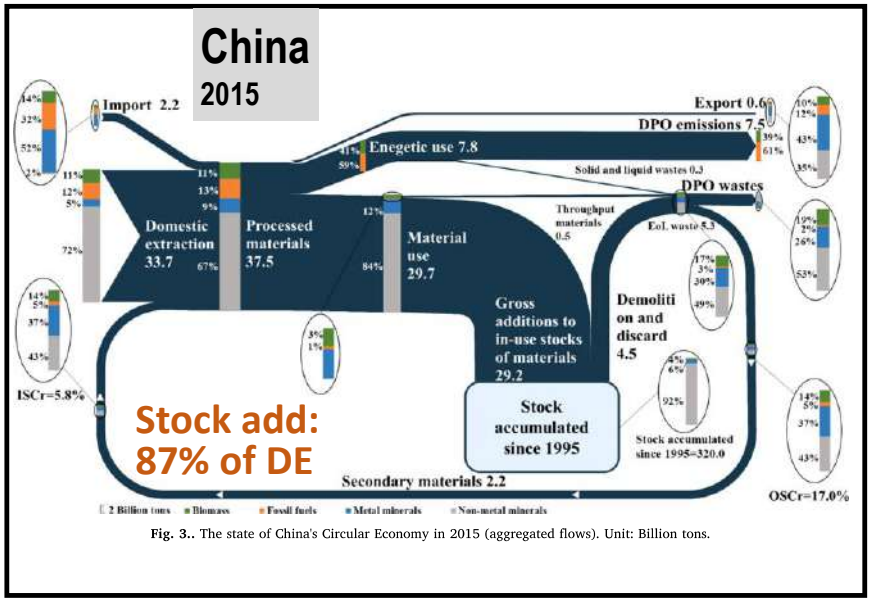
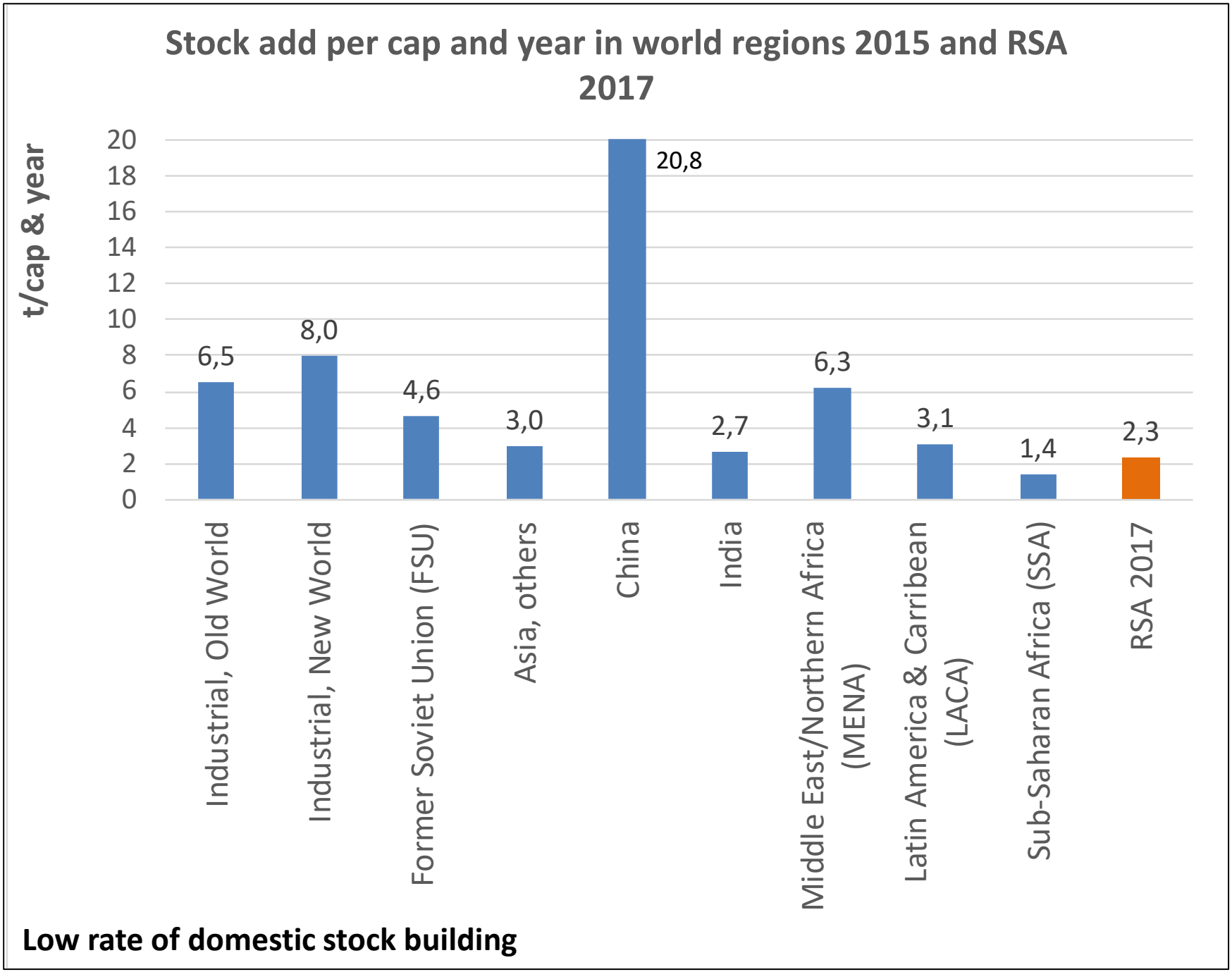


Fig. 3.. The state of China's Circular Economy in 2015 (aggregated flows). Unit: Billion tons.

Low rate of domestic stock building

RSA (2017): 2.3 t stock add/cap
EU28 (2014): 8.0 t stock add/cap
China (1995): 6.7 t stock add/cap
China (2015): 20.8 t stock add/cap

Source of Chinese results: Wang, H., Schandl, H., Wang, X., Ma, F., Yue, Q., Wang, G., Wang, Y., Wei, Y., Zhang, Z., & Zheng, R. (2020). Measuring progress of China's circular economy. *Resources, Conservation and Recycling*, *163*, 105070. https://doi.org/10.1016/j.resconrec.2020.105070



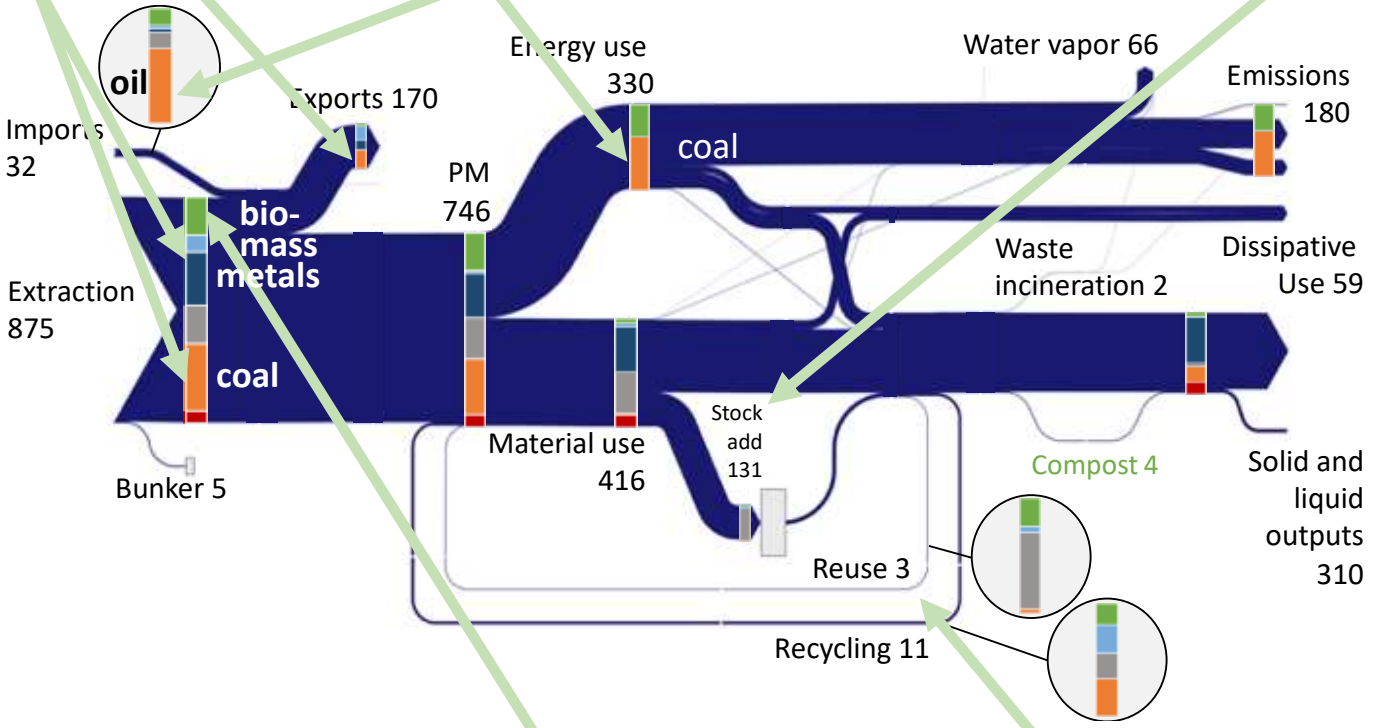
Low rate of domestic stock building

Summarizing our findings

Finding 1:
An economy materially dominated by export-oriented extractives

Finding 2:
An economy energetically dominated by fossil fuels, notably domestic coal supported by imported oil

Finding 4:
Low rate of domestic stock building

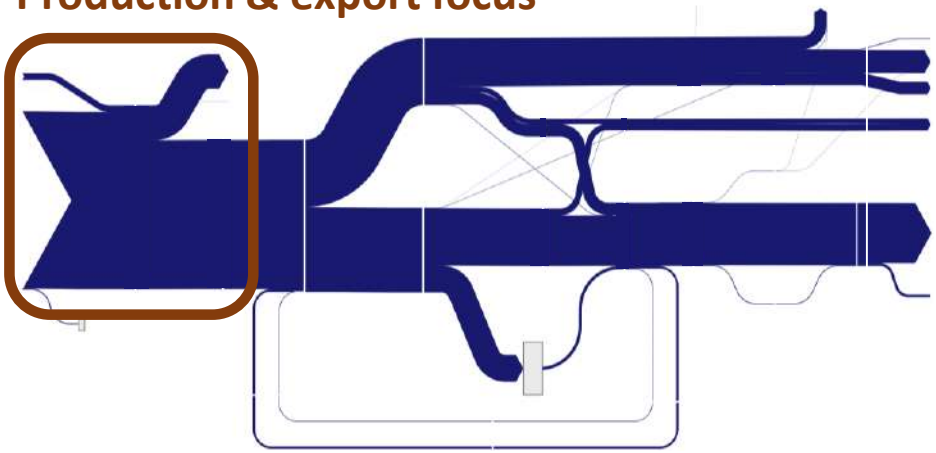


Finding 3:
A sizeable footprint of bio-based activities, with some attention to ecological cycling but also with significant concerns

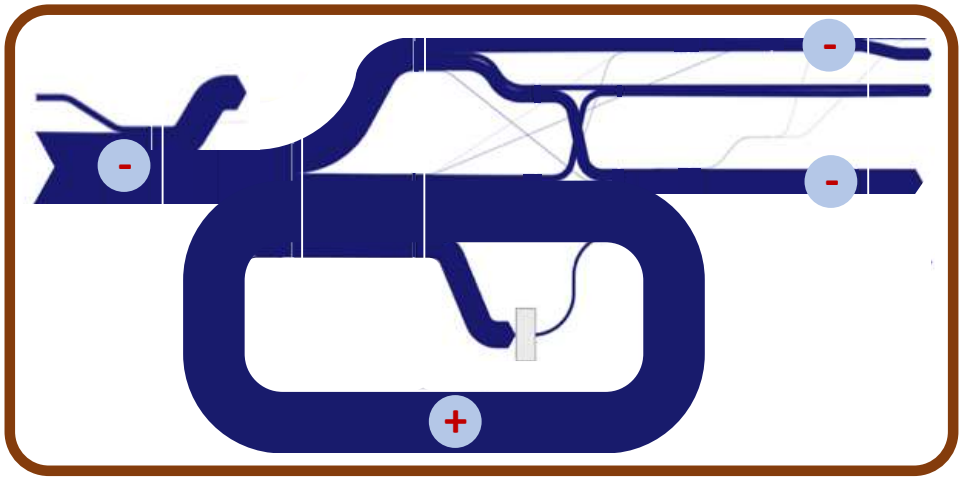
Finding 5:
Pockets of high circularity and significant informal activity around cascade use, reuse and recycling

Shifting priorities in the national development model

Production & export focus



System focus



Thank you for your interest

Sooner or later international climate and circularity policies will change the global policy and business environment for SA.

- SA exports non-renewable metals and coal
- Power generation depends on coal
- Both highly vulnerable to future changes
- Related extractive wastes and coal-related emissions are > 50% of outputs to nature

A pro-active strategy enables SA to seize the opportunities a CE potentially offers:

- new businesses in the service sector,
- decent jobs for all skill levels directed at a stronger domestic economy and
- lower environmental impacts.

A substantial change mainly in mining, agriculture, transport, urban planning, the power sector and small services.
Research and innovation for change will demand a systems focus.

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- Mr Bruno Merven, Energy Systems Research Group, UCT

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- Ms Anel Blignaut, Blue North Consultants
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Waste & recyclables with additional focus on construction material stocks and flows:

- Prof Cristina Trois, SA Research Chair Waste & Climate Change, UKZN
- Mr Saliem Haider, GreenCape
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- Mr Katlego Letsoalo, Minerals Council of South Africa

Supplementary slides

Main sources

Table 1: South African data sources used to complement international data sets

Material flow	Nature of uncertainty	Sources used	Resolution
Mining	For several metals, combination of USGS data for extraction and Comtrade for imports and exports yielded negative DMC	MCSA 2018, SAMI (2017)	Comparison of combination of local vs. International data sources for extraction and trade on a metal by metal basis to determine arrive at positive DMC
Construction minerals	Official and industry sector national estimates lower than in UNEP	SAMI 2017 MCSA 2018	Stayed with higher UNEP estimate; an earlier industry claim was found that official statistics under-report; could not balance construction materials recipes with lower sand & gravel.
Energy	Some flows in international sources questionable or disaggregation missing	DMRE Energy Balance 2017	Big discrepancies in domestic fuel use required attention
Polymers and chemicals from coal	A uniquely South African practice	Own plastics MFA	Inserted a line in the calculations for plastics from coal, equivalent to plastics from oil
IPPU emissions	Not immediately available from international sources	SA GHGI 2017	Used for cement sector

Main sources for information on biomass

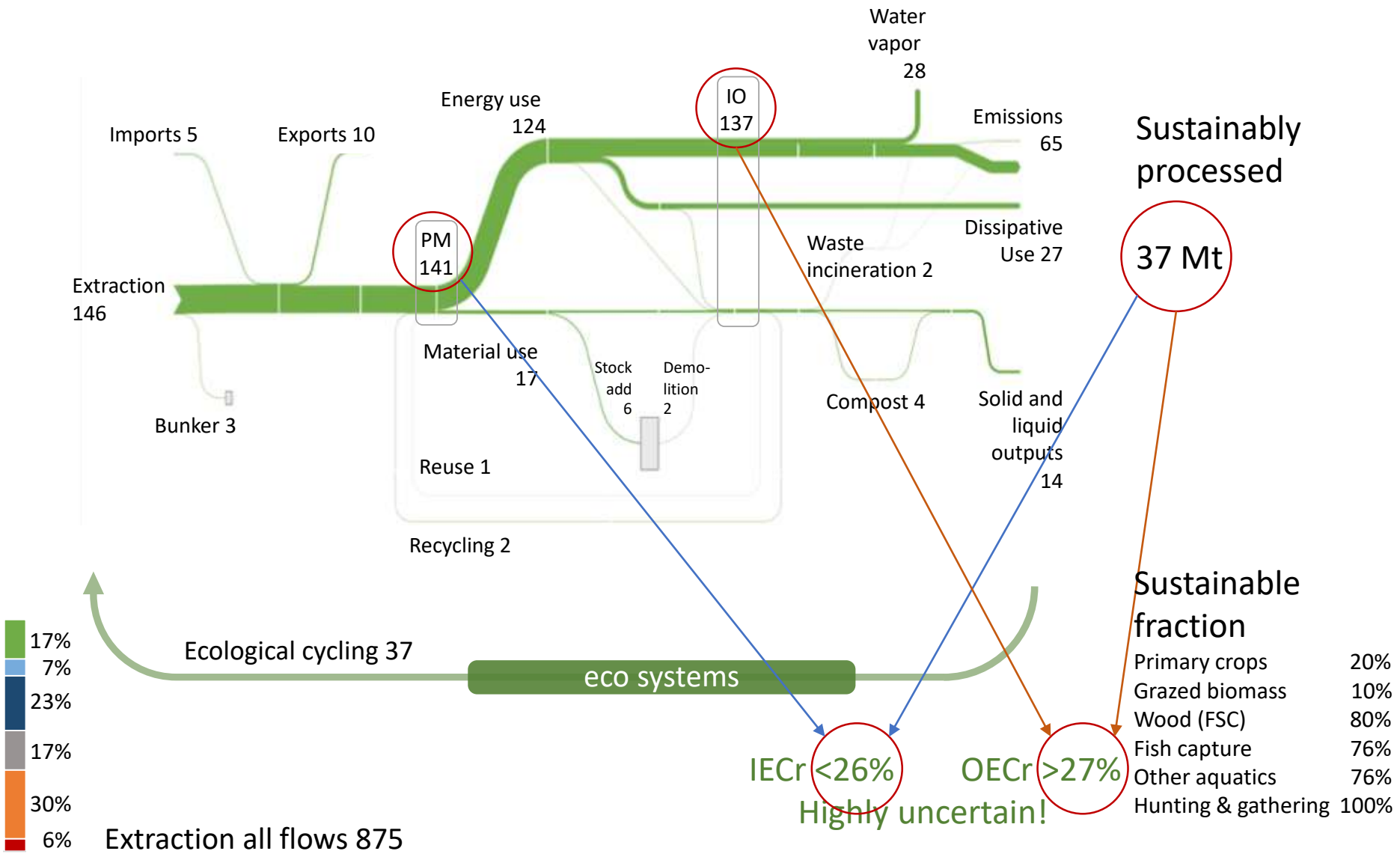
Material flow	Nature of uncertainty	Sources used	Resolution
Primary crops	Fraction produced sustainably	FAO statistics	Estimated 20 % grown by Conservation Agriculture (highly uncertain)
Maize straw	Amounts and Fates	Tongwane et al. (2016)	Half used, half unused extraction
Bagasse	Not waste in MFA	Own calculation	Only ash is Interim Output
Wood products	Fraction produced sustainably	FSC Southern Africa (2018)	80% is FSC certified
Mill residues	Not waste in MFA	SASOW (2018)	Only ash is Interim Output
Fish	Fraction harvested sustainably	FAO Statistics	Rely on SASSI (green), 75%
Animal feed	Amount grazed (livestock populations); fraction managed sustainably	Du Toit et al. (2014) Expert estimate	Management of grasslands highly concerning (Blignaut, 2021)
Manures	Amounts (livestock populations) and Fates	Abstract of Agricultural Statistics (2019)	Sources differ. Between 47% and 80% of manures left in pastures/veld. Mostly not cycled ecologically.
Sewage sludge	SA State of Waste only covers sludge from WWTWs	SASOW (2018)	Use data as is
Non-sewered	Fraction of population not connected to sewer or without basic sanitation	Water & sanitation Masterplan	Only 29% of households sewer-connected; 29% of population without access to basic sanitation
OFMSW	None	SASOW (2018)	Use reported data for food and garden waste

Biomass containing wastes

Type	Amount	Data source / Notes
Garden and food wastes	6,7 Mt	SASOW (2018), part of MSW
Human excreta (not to sewer)	1,9 Mt	Own estimate, based on water and sanitation masterplan
Sewage sludge	0,8 Mt	SASOW (2018)
Industrial biomass wastes	3,2 Mt	14,4 Mt before energetic use
Animal manures	21,2 Mt	MFA calculations, checked against own calculations
Crop residues	17,8 Mt	Tongwane et al. (2016), own calculations

Biomass flows, RSA 2017

All numbers in Sankey in Mt (1,000,000 t)



Will it be salvaged and re-used?

Material group	Attractiveness for informal reuse or recycling	informal reuse
Wood products & offcuts	High	0,8
Flat glass	Low (mostly broken)	0,1
Metal frames, furnishings	High	0,5
Concrete	Very unlikely (difficult to separate)	0
Bricks, mortar, paving, tiling	Medium to high for clay, low for cement	0,143
Plastic pipes, frames, furnishings	Medium to high	0,500
Gypsum	Low	0,1
Asphalt	Very unlikely	0
Miscellaneous	medium	0,333

All numbers are educated guesses. Does anyone have better sources?

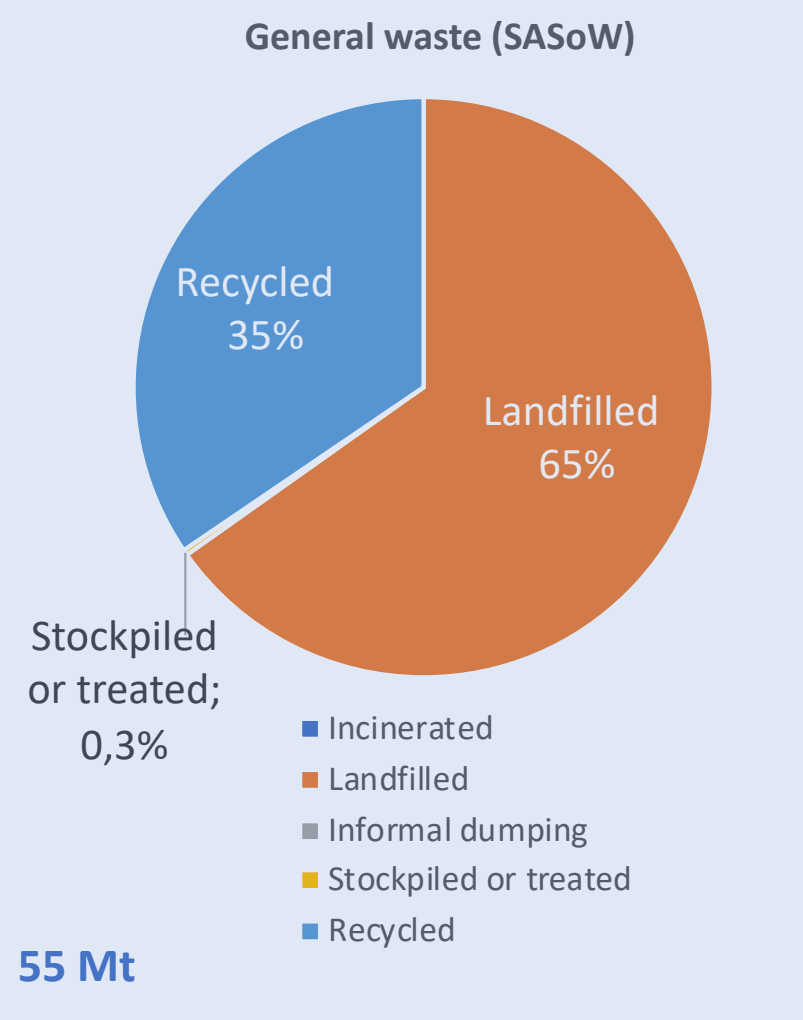
Is this plausible?

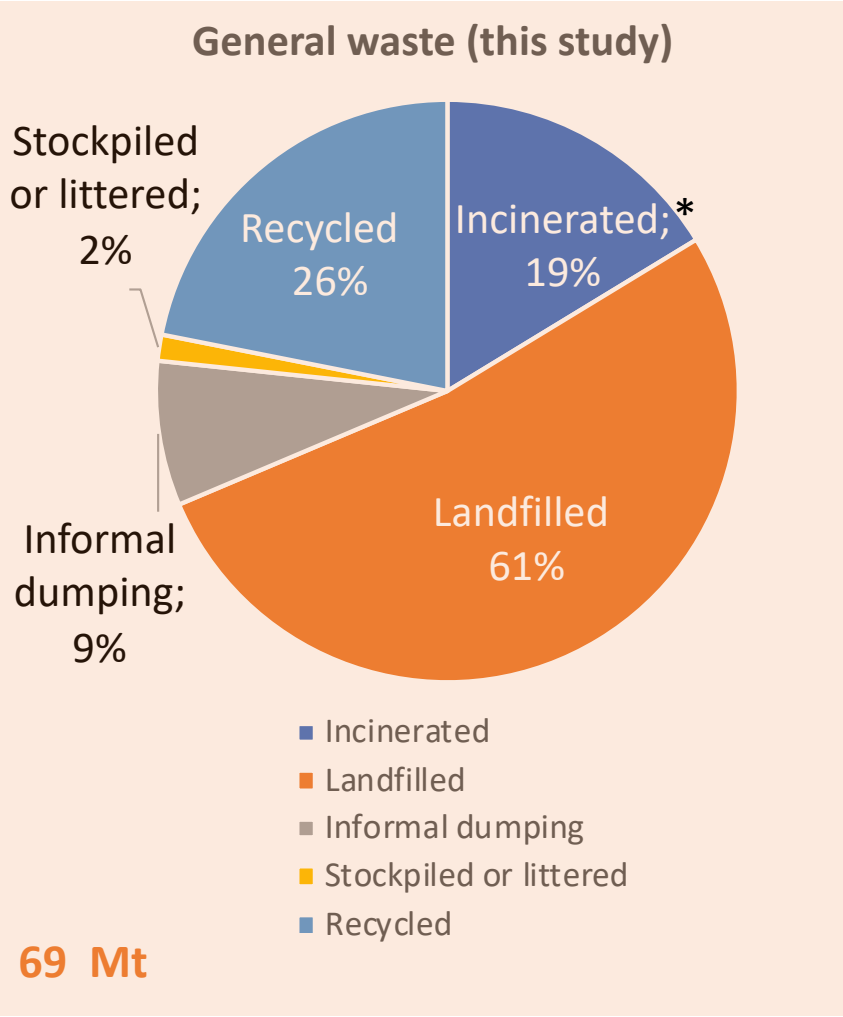
Estimated fates of C&D waste in South Africa (2017, in kilo-tonnes)

	informally reused	formal recycling	cover material	informal dumping	landfill	Total
Wood products & offcuts	391	24	0	24	49	489
Flat glass	5	5	10	10	20	50
Metal frames, furnishings	112	67	0	0	45	225
Concrete	0	1422	1422	853	569	4266
Bricks, mortar, paving, tiling	533	0	1225	746	1225	3728
Plastic pipes, frames, furnishings	57	19	0	19	19	113
Gypsum	5	0	22	0	27	54
Asphalt	0	227	562	112	223	1125
Miscellaneous	359	180	180	180	180	1078
TOTAL	1462	1944	3421	1944	2356	11128

Refinement and verification subject of an ongoing Masters dissertation

Adding some detail to fate of wastes





* bagasse still included