Interesting insights with EEIO

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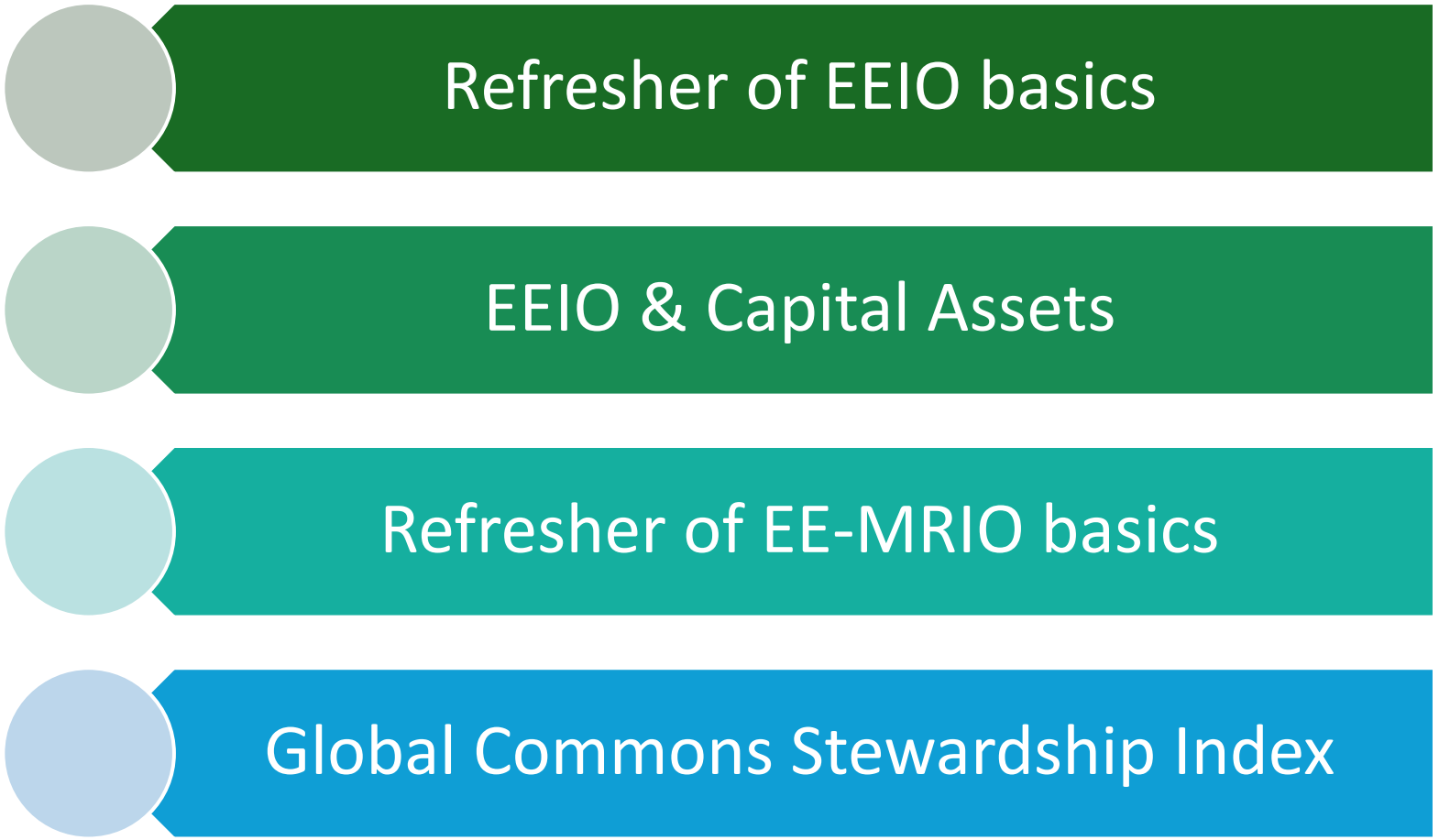
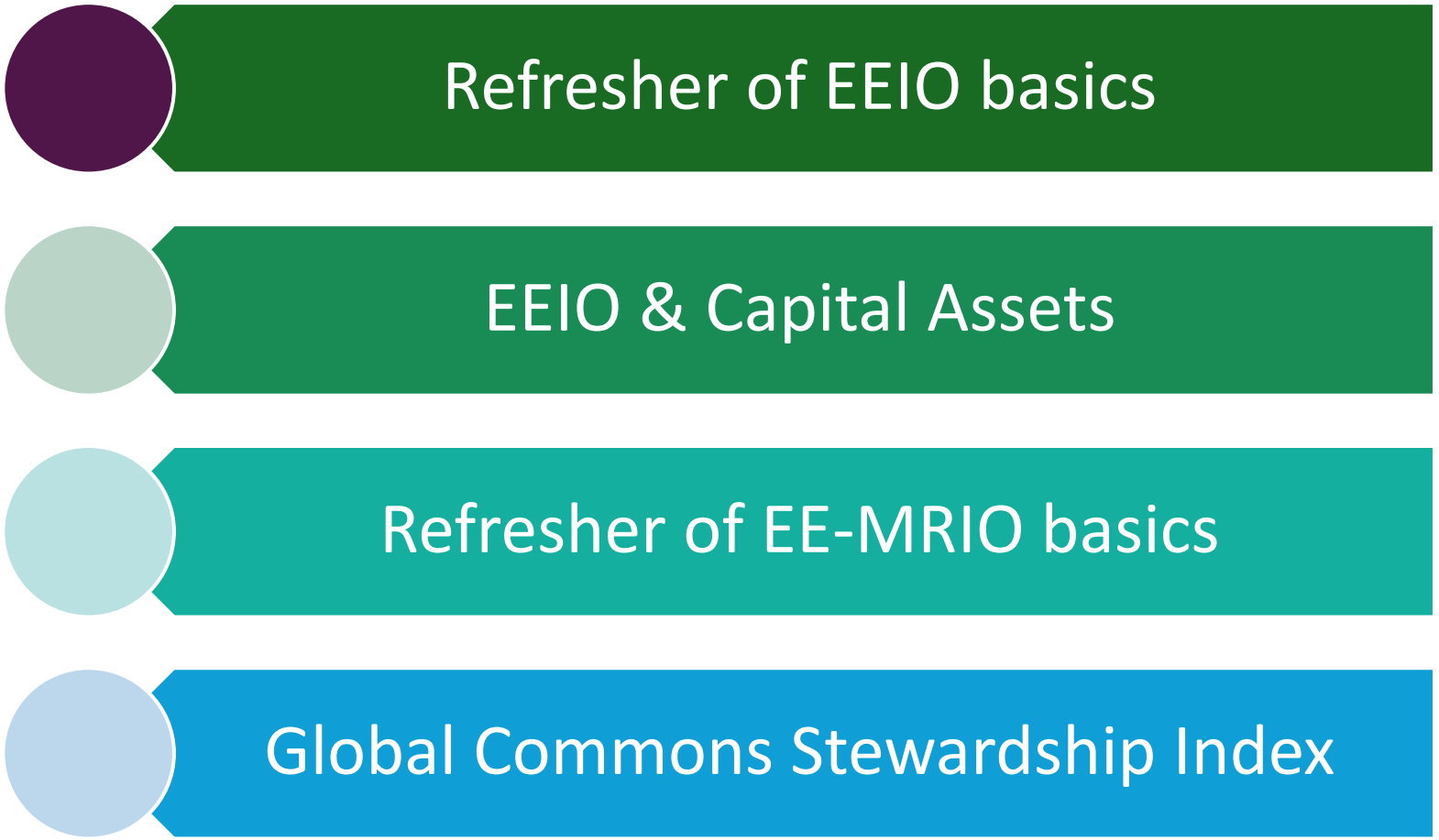
Overview


Refresher of EEIO basics
EEIO & Capital Assets
Refresher of EE-MRIO basics
Global Commons Stewardship Index

Overview


Refresher of EEIO basics
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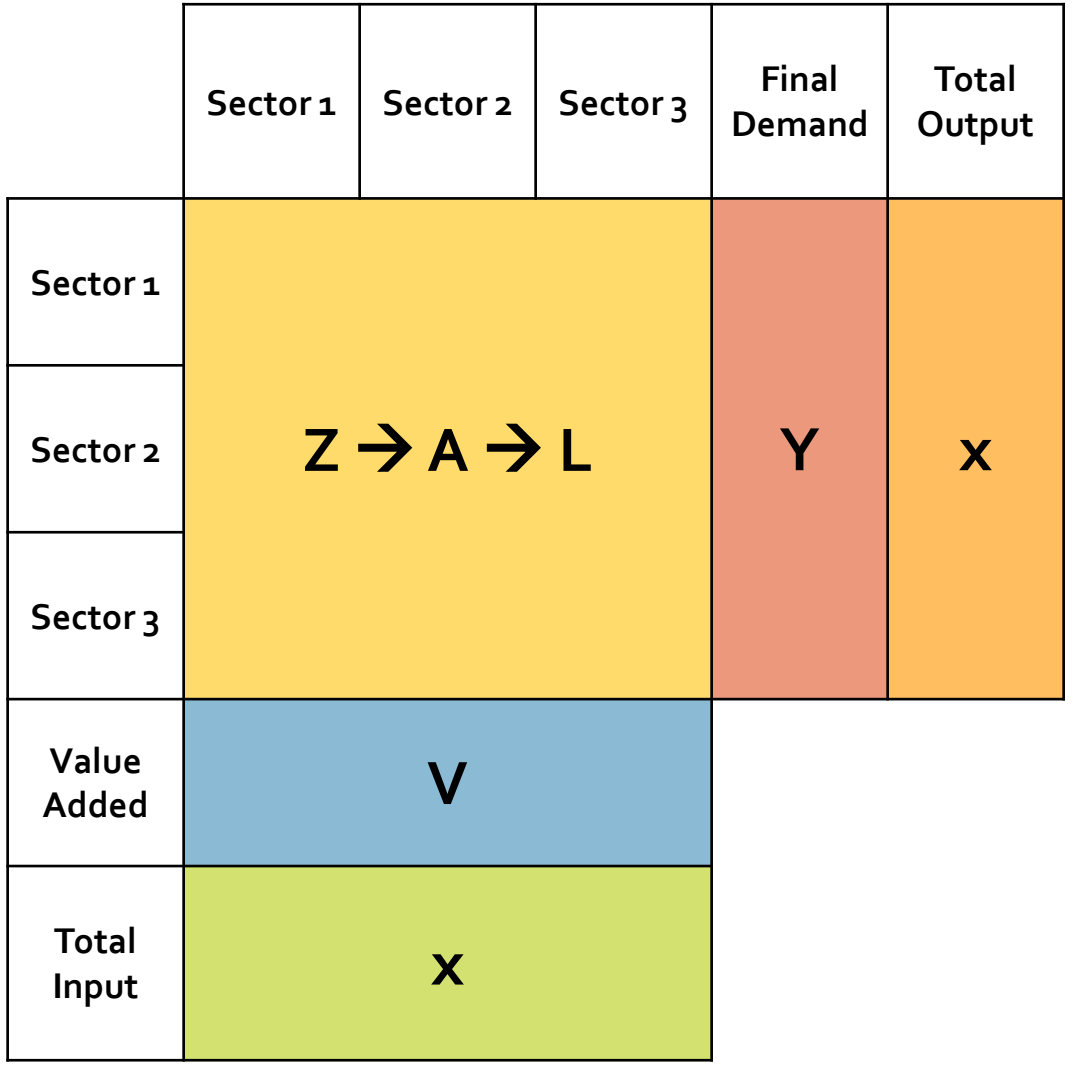
Refresher of EE-MRIO basics
Global Commons Stewardship Index

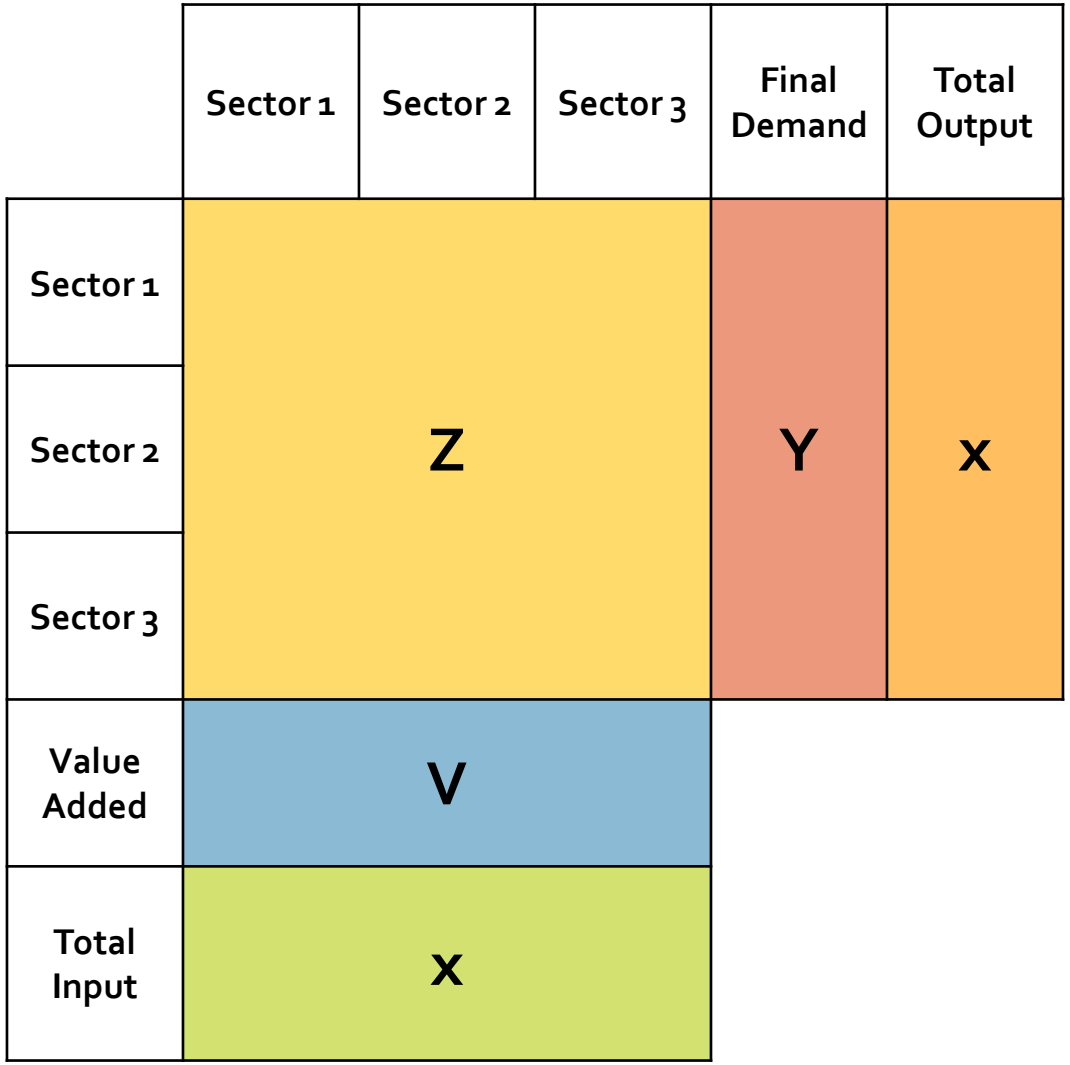
Let's review–where would each go?

1. Salaries of workers in the Indian mineral industry
2. Polish government purchased new trains
3. Electricity across supply chain to power Chinese electric bus
4. Portuguese farmers sold cork to Italian designers
5. I bought my cats food
6. Lumber bought per unit paper
7. Sum of sales of US cars



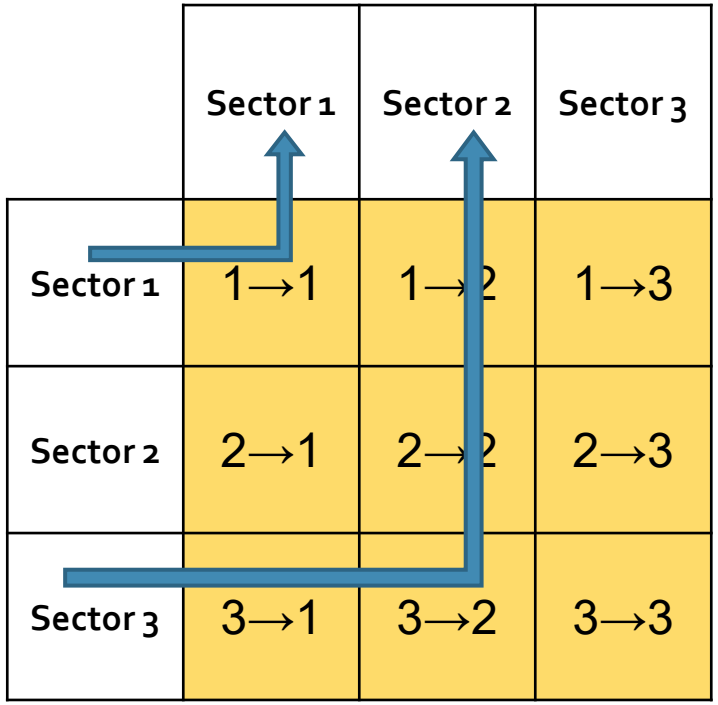
Overview of balanced Input-Output table

All tables are monetary
($, €, ¥, etc.)



Z: intermediate demand

- Transactions between pairs of sectors
  - (sometimes called **T** instead of **Z**)
- Goods and services consumed *within the year*
- 1⟶1 represents intra-industry trade
- 3⟶2 represents inter-industry trade



Z: intermediate demand
Dummy data

1. How much electricity and water did Agriculture use?
2. How much financial services did the arts use?
3. What was the total intermediate demand for education?

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government	SUM
Agriculture	127	117	27	67	37	34	3	12	12	436
Utilities	37	212	144	54	35	8	45	74	28	637
Construction	18	33	114	16	44	6	17	14	25	287
Retail & Wholesale	8	67	34	123	65	53	46	18	68	482
Transportation	5	34	14	47	162	12	17	15	38	344
Finance	44	56	34	78	57	315	7	72	36	699
Education	4	89	1	118	2	24	222	172	5	637
Arts	18	55	12	57	10	52	43	64	62	373
Government	2	16	8	5	4	16	23	73	42	189

Y: final demand

- Final purchases of final products

  What does that mean?

- Final purchases:
  - Expenditures
    - Households & Governments
  - Investments
    - Households, Governments, Businesses
- Adjustments
  - International trade
  - Change in valuables and inventories

	Final Demand
Sector 1	y_1
Sector 2	y_2
Sector 3	y_3

Y: final demand
Dummy data

1. Household expenditures on utilities?
2. Investments in transportation?
3. Total final demand for construction?

	Household Expend.	Government Expend.	Investments	Adjustments	SUM
Agriculture	49	5	21	8	83
Utilities	172	79	46	271	568
Construction	278	34	56	104	472
Retail & Wholesale	84	8	152	193	437
Transportation	94	18	182	198	492
Finance	15	2	50	111	178
Education	46	36	12	2	96
Arts	85	35	42	256	418
Government	57	16	15	275	363

x: total output

- **x** represents total value of goods and services produced by a sector
- $\sum \boldsymbol{Z} + \sum \boldsymbol{Y} = x_{output}$

Might this be a useful economic indicator?

	Sector 1	Sector 2	Sector 3	Final Demand	Total Output
Sector 1	$z_{1,1}$	$z_{1,2}$	$z_{1,3}$	y_1	x_1
Sector 2	$z_{2,1}$	$z_{2,2}$	$z_{2,3}$	y_2	x_2
Sector 3	$z_{3,1}$	$z_{3,2}$	$z_{3,3}$	y_3	x_3

x: total output
Dummy data

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government	SUM
Agriculture	127	117	27	67	37	34	3	12	12	436
Utilities	37	212	144	54	35	8	45	74	28	637
Construction	18	33	114	16	44	6	17	14	25	287
Retail & Wholesale	8	67	34	123	65	53	46	18	68	482
Transportation	5	34	14	47	162	12	17	15	38	344
Finance	44	56	34	[illegible]	[illegible]	315	7	72	36	699
Education	4	89	1	118	2	24	222	172	5	637
Arts	18	55	12	57	10	52	43	64	62	373
Government	2	16	8	5	4	16	23	73	42	189

Z

+

	Household Expend.	Government Expend.	Investments	Adjustments	SUM
Agriculture	49	5	21	8	83
Utilities	172	79	46	271	568
Construction	278	34	56	104	472
Retail & Wholesale	84	8	152	193	437
Transportation	94	8	182	198	492
Finance	15	[illegible]	50	111	178
Education	46	36	12	2	96
Arts	85	35	42	256	418
Government	57	16	15	275	363

Y

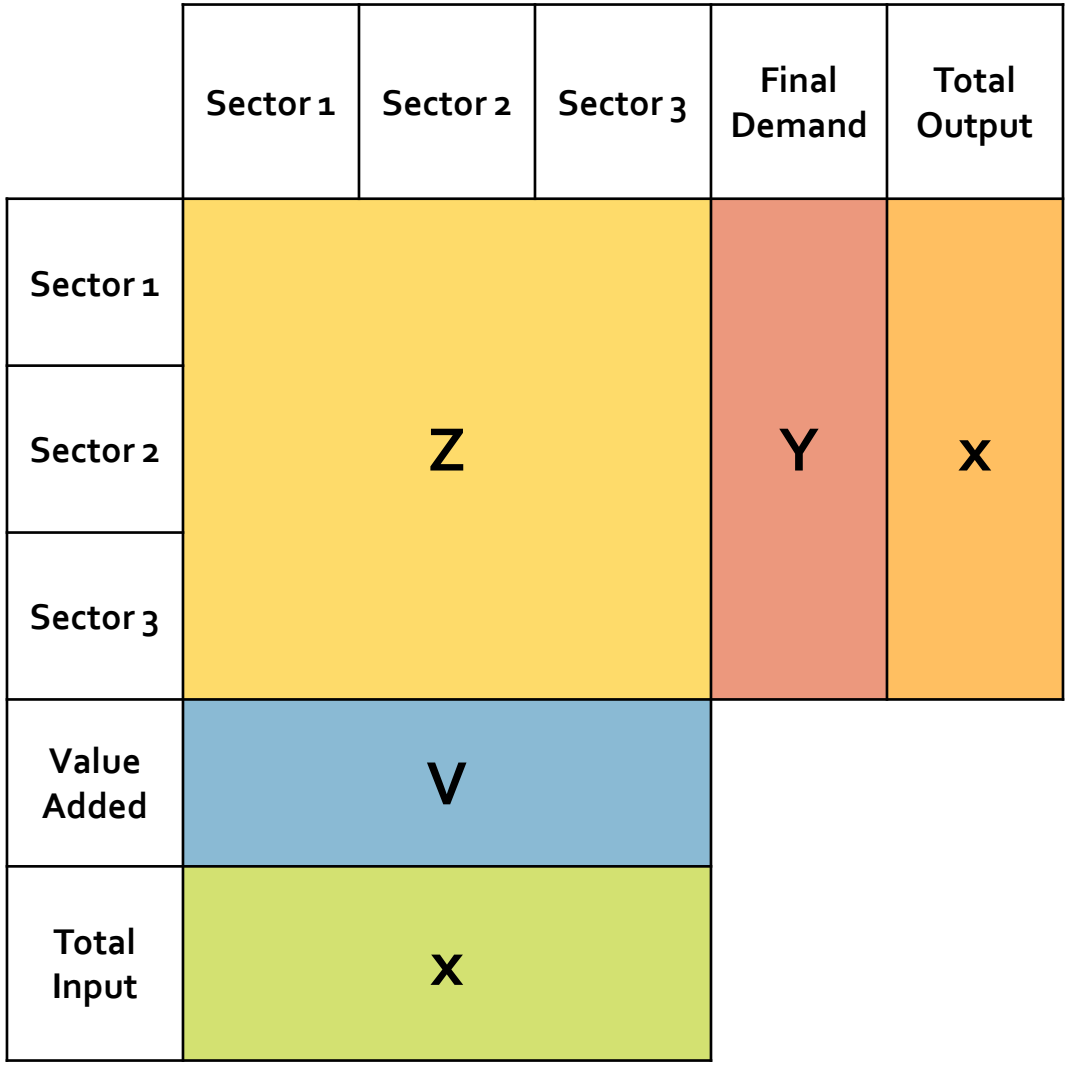
=

	TOTAL OUTPUT
Agriculture	519
Utilities	1205
Construction	759
Retail & Wholesale	919
Transportation	836
Finance	877
Education	733
Arts	791
Government	552

X

Overview of balanced Input-Output table

All tables are monetary
($, €, ¥, etc.)



V: value added

What business costs and earnings are missing from inputs to production in **Z**?

+ Compensation of employees

+ Taxes

- Subsidies

+ Gross operating surplus
  - (Balancing term)
  - + Corporate profits etc.
  - - Capital asset depreciation

	Sector 1	Sector 2	Sector 3
Sector 1	$z_{1,1}$	$z_{1,2}$	$z_{1,3}$
Sector 2	$z_{2,1}$	$z_{2,2}$	$z_{2,3}$
Sector 3	$z_{3,1}$	$z_{3,2}$	$z_{3,3}$
Value Added	v_1	v_2	v_3
Total Input	x_1	x_2	x_3

$$\sum \boldsymbol{Z} + \sum \boldsymbol{V} = x_{input}$$

Y, V, and GDP

- $\sum \boldsymbol{Z} + \sum \boldsymbol{Y} = x_{output}$
- $\sum \boldsymbol{Z} + \sum \boldsymbol{V} = x_{input}$
- $x'_{input} = x_{output}$
- What does that mean about $\sum \boldsymbol{V}$ & $\sum \boldsymbol{Y}$?
- $\sum \boldsymbol{V} = \sum \boldsymbol{Y} = \boldsymbol{GDP}$
  - *(when IO table is for a single country)*

What does gross domestic product (GDP) measure?

	Sector 1	Sector 2	Sector 3	Final Demand	Total Output
Sector 1	$z_{1,1}$	$z_{1,2}$	$z_{1,3}$	y_1	x_1
Sector 2	$z_{2,1}$	$z_{2,2}$	$z_{2,3}$	y_2	x_2
Sector 3	$z_{3,1}$	$z_{3,2}$	$z_{3,3}$	y_3	x_3
Value Added	v_1	v_2	v_3	Σ = GDP	
Total Input	x_1	x_2	x_3		

V: value added
Dummy data

1. What is GDP?
2. $x'_{input} = x_{output}$?

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government	SUM
Agriculture	127	117	27	67	37	34	3	12	12	436
Utilities	37	212	144	54	35	8	45	74	28	637
Construction	18	33	114	16	44	6	17	14	25	287
Retail & Wholesale	8	67	34	123	65	53	46	18	68	482
Transportation	5	34	14	47	16	12	17	15	38	344
Finance	44	56	34	78	57	315	7	72	36	699
Education	4	89	1	118	2	24	222	172	5	637
Arts	18	55	12	57	10	52	43	64	62	373
Government	2	16	8	5	4	16	23	73	42	189
SUM	263	679	388	565	416	520	423	514	316	

Z

	Household Expend.	Government Expend.	Investments	Adjustments	SUM
	49	5	21	8	83
	172	79	46	271	568
	278	34	56	104	472
	84	8	152	193	437
	94	18	1[illegible]	198	492
	15	2	50	111	178
	46	36	12	2	96
	85	35	42	256	418
	57	16	15	275	363
	880	233	576	1418	3107

Y

TOTAL OUTPUT
519
1205
759
919
836
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733
791
552

X

Wages & Salaries	131	416	226	191	206	114	115	141	71	1611
Taxes less subsidies	26	68	37	67	7[illegible]	11	22	47	12	361
Gross operating surplus	99	42	108	9[illegible]	[illegible]	232	173	89	153	1135
SUM	256	526	37[illegible]	354	420	357	310	277	236	3107

V

Total Input	519	1205	759	919	836	877	733	791	552

X

$$\sum V = \sum Y = GDP$$

A: direct requirements
Recipes for production

- **A** normalizes **Z** by **x**, $A = Z\hat{x}^{-1}$, creating technical coefficients $a_{i,j}$
- Each row or column? represents a 'recipe' of inputs to production

Z

	Sector 1	Sector 2	Sector 3
Sector 1	$z_{1,1}$	$z_{1,2}$	$z_{1,3}$
Sector 2	$z_{2,1}$	$z_{2,2}$	$z_{2,3}$
Sector 3	$z_{3,1}$	$z_{3,2}$	$z_{3,3}$

divide columns by **x**

A

	Sector 1	Sector 2	Sector 3
Sector 1	$a_{1,1}$	$a_{1,2}$	$a_{1,3}$
Sector 2	$a_{2,1}$	$a_{2,2}$	$a_{2,3}$
Sector 3	$a_{3,1}$	$a_{3,2}$	$a_{3,3}$

A: direct requirements
Dummy data

1. What is the maximum that the sum of each column of **A** could be?
2. What does 0.06 Arts →Education mean?
3. Are relationships between inputs and outputs fixed?
4. Can agriculture produce more if only construction inputs are increased?

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government
Agriculture	0.24	0.10	0.04	0.07	0.04	0.04	0.00	0.02	0.02
Utilities	0.07	0.18	0.19	0.06	0.04	0.01	0.06	0.09	0.05
Construction	0.03	0.03	0.15	0.02	0.05	0.01	0.02	0.02	0.05
Retail & Wholesale	0.02	0.06	0.04	0.13	0.08	0.06	0.06	0.02	0.12
Transportation	0.01	0.03	0.02	0.05	0.19	0.01	0.02	0.02	0.07
Finance	0.08	0.05	0.04	0.08	0.07	0.36	0.01	0.09	0.07
Education	0.01	0.07	0.00	0.13	0.00	0.03	0.30	0.22	0.01
Arts	0.03	0.05	0.02	0.06	0.01	0.06	0.06	0.08	0.11
Government	0.00	0.01	0.01	0.01	0.00	0.02	0.03	0.09	0.08
SUM	**0.51**	**0.56**	**0.51**	**0.61**	**0.50**	**0.59**	**0.58**	**0.65**	**0.57**

L: Leontief Inverse
Total Requirements Matrix

We already know that:

- $\boldsymbol{Z + Y = x}$
- $\boldsymbol{A = Z\hat{x}^{-1}}$

So, let's combine and rearrange:

- $\boldsymbol{Ax = Z}$
- $\boldsymbol{Y = x - Z}$
- $\boldsymbol{Y = x - Ax}$
- $\boldsymbol{Y = (I - A)x}$
- $\boldsymbol{(I - A)^{-1}Y = x}$
- $\boldsymbol{L = (I - A)^{-1}}$
- $\boldsymbol{LY = x}$

$$\boldsymbol{Leontief\ Inverse}$$
$$\boldsymbol{L = (I - A)^{-1}}$$

For every unit of output, the total products required across the entire supply chain

L: Leontief inverse
Dummy data

1. How many units of Finance are needed across the supply chain to make one unit of Arts?
2. Why are elements on diagonal >1 ?
3. How much Utilities are needed *indirectly* across the supply chain to make one unit of Utilities as a final product?

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government
Agriculture	1.37	0.20	0.12	0.17	0.12	0.12	0.06	0.09	0.10
Utilities	0.16	1.29	0.32	0.16	0.12	0.08	0.17	0.21	0.15
Construction	0.07	0.07	1.20	0.06	0.10	0.04	0.06	0.06	0.09
Retail & Wholesale	0.07	0.13	0.11	1.23	0.15	0.15	0.15	0.12	0.22
Transportation	0.04	0.07	0.06	0.11	1.27	0.05	0.07	0.07	0.13
Finance	0.23	0.17	0.16	0.24	0.20	1.64	0.10	0.24	0.22
Education	0.08	0.21	0.09	0.30	0.07	0.15	1.53	0.42	0.14
Arts	0.09	0.11	0.07	0.14	0.06	0.14	0.14	1.17	0.19
Government	0.03	0.04	0.03	0.04	0.02	0.05	0.07	0.14	1.12

x: total output, production perspective
Dummy data (reminder)

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government	SUM
Agriculture	127	117	27	67	37	34	3	12	12	436
Utilities	37	212	144	54	35	8	45	74	28	637
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Retail & Wholesale	8	67	34	123	65	53	46	18	68	482
Transportation	5	34	14	47	162	12	17	15	38	344
Finance	44	56	34	[illegible]	[illegible]	315	7	72	36	699
Education	4	89	1	118	2	24	222	172	5	637
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Z

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Y

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Government	552

X

x: total output, consumption perspective
Dummy data

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government
Agriculture	1.37	0.20	0.12	0.17	0.12	0.12	0.06	0.09	0.10
Utilities	0.16	1.29	0.32	0.16	0.12	0.08	0.17	0.21	0.15
Construction	0.07	0.07	1.20	0.06	0.10	0.04	0.06	0.06	0.09
Retail & Wholesale	0.07	0.13	0.11	1.23	0.15	0.15	0.15	0.12	0.22
Transportation	0.04	0.07	0.06	0.11	1.27	0.05	0.07	0.07	0.13
Finance	0.23	0.17	0.16	0.24	0.20	1.64	0.10	0.24	0.22
Education	0.08	0.21	0.09	0.30	0.07	0.15	1.53	0.42	0.14
Arts	0.09	0.11	0.07	0.14	0.06	0.14	0.14	1.17	0.19
Government	0.03	0.04	0.03	0.04	0.02	0.05	0.07	0.14	1.12

L • Y = X

	SUM
Agriculture	83
Utilities	568
Construction	472
Retail & Wholesale	437
Transportation	492
Finance	178
Education	96
Arts	418
Government	363

	TOTAL OUTPUT
Agriculture	519
Utilities	1205
Construction	759
Retail & Wholesale	919
Transportation	836
Finance	877
Education	733
Arts	791
Government	552

x: total output, calculated with L
Dummy data

1. Where do you find the inputs to production?
2. What kind of products are represented in Y?

	SUM
Agriculture	83
Utilities	568
Construction	472
Retail & Wholesale	437
Transportation	492
Finance	178
Education	96
Arts	418
Government	363

Y

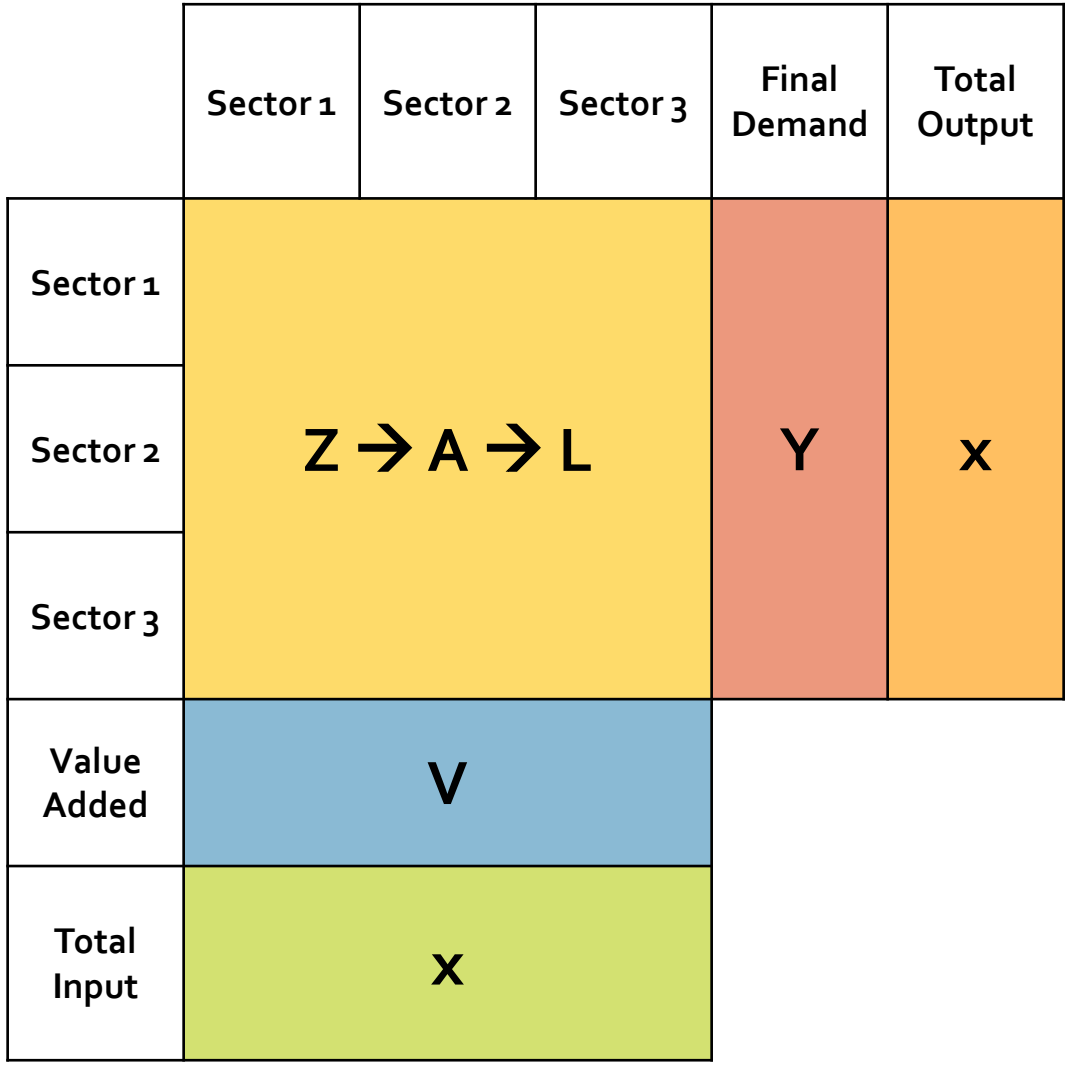
	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government	TOTAL OUTPUT
Agriculture	1.37	0.20	0.12	0.17	0.12	0.12	0.06	0.09	0.10	519
Utilities	0.16	1.29	0.32	0.16	0.12	0.08	0.17	0.21	0.15	1205
Construction	0.07	0.07	1.20	0.06	0.10	0.04	0.06	0.06	0.09	759
Retail & Wholesale	0.07	0.13	0.11	1.23	0.15	0.15	0.15	0.12	0.22	919
Transportation	0.04	0.07	0.06	0.11	1.27	0.05	0.07	0.07	0.13	836
Finance	0.23	0.17	0.16	0.24	0.20	1.64	0.10	0.24	0.22	877
Education	0.08	0.21	0.09	0.30	0.07	0.15	1.53	0.42	0.14	733
Arts	0.09	0.11	0.07	0.14	0.06	0.14	0.14	1.17	0.19	791
Government	0.03	0.04	0.03	0.04	0.02	0.05	0.07	0.14	1.12	552

L

X

Let's review–where would each go?

1. Salaries of workers in the Indian mineral industry
2. Polish government purchased new trains
3. Electricity across supply chain to power Chinese electric bus
4. Portuguese farmers sold cork to Italian designers
5. I bought my cats food
6. Lumber bought per unit paper
7. Sum of sales of US cars



EEIO

LCA

EEIO

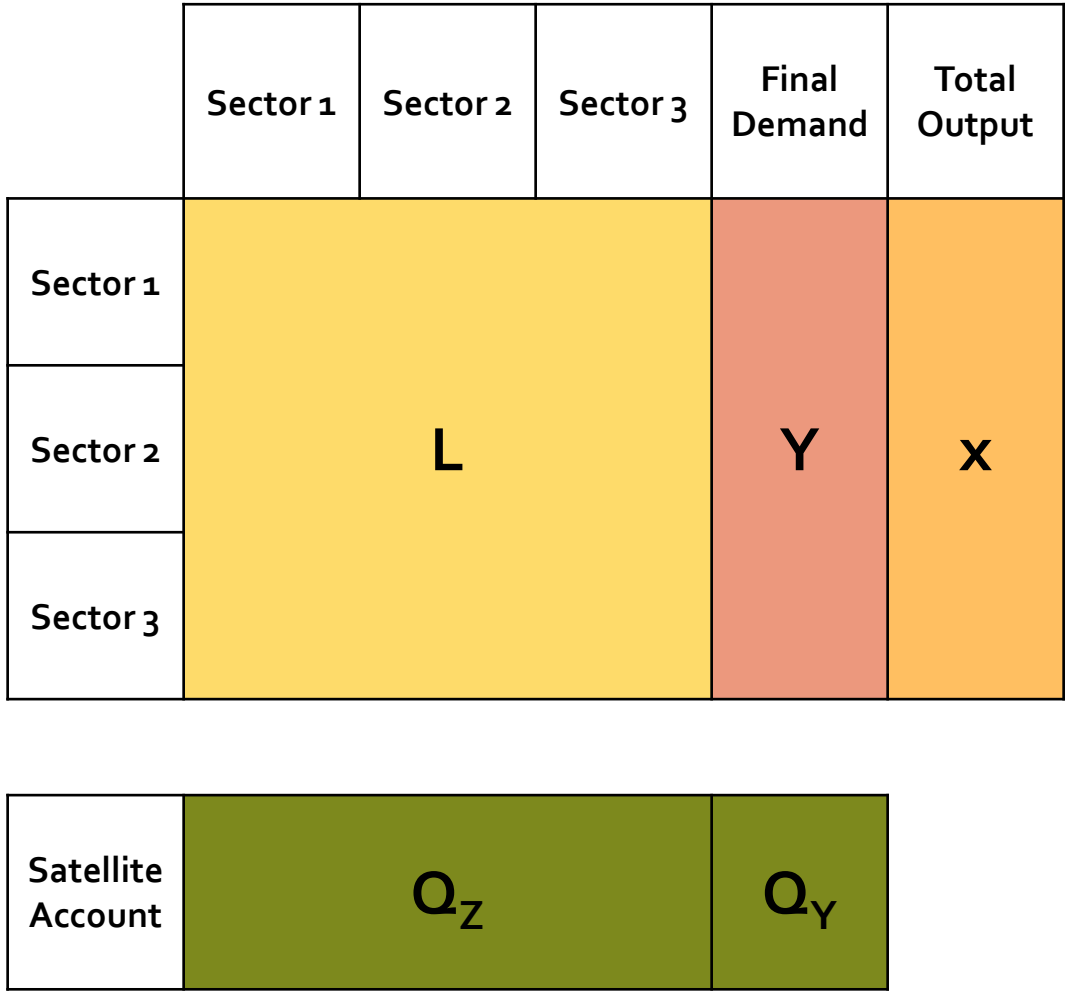
- Monetary transactions*
- Aggregated sectors
  - e.g. $1027 of non-ferrous metal
- Scope of assessment:
  Entire economy or sector
- Sector coverage:
  - Captures services (eg. financial)
  - Direct inputs based on IO table

Life Cycle Assessment

- Physical
- Detailed flows
  - e.g. 3.57 kg of triple-melt titanium
- Scope of assessment:
  Product or process
- Sector coverage:
  - Hard to capture non-physical services
  - Direct inputs manually added

Q: satellite account

- Inventory of *direct* environmental or social activities per sector
- Each row has different activity
- Absolute values
  - eg. tonnes of CH_4, m^3 of water
- Often 'raw' inventory
  - tonnes of CH_4, not tonnes of CO_2-eq.
- $\sum \boldsymbol{Q}$ is total of annual activity
- What is the difference between Q_Z & Q_Y?



Q: satellite account
Direct activities & Scope 1, 2, 3

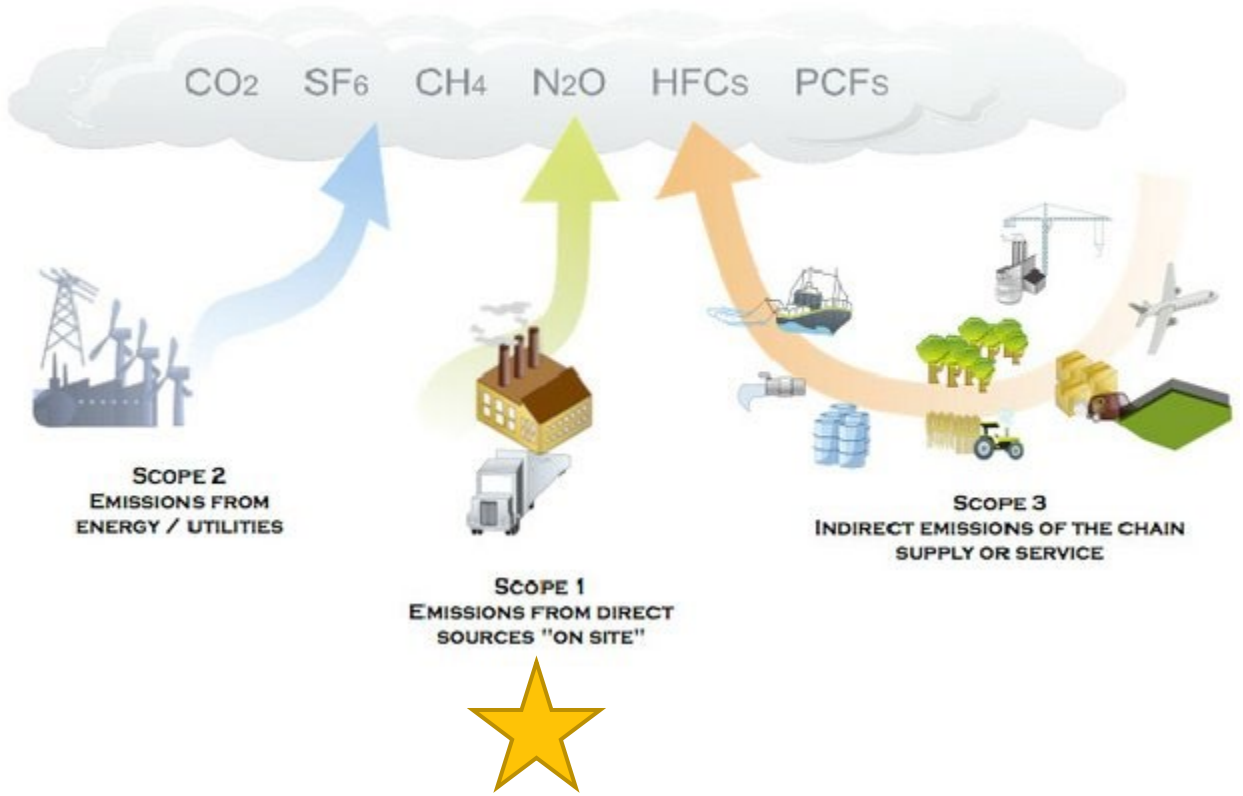


Figure: Villar, Juan & Hidalgo, Sebastián & Penela, Adolfo & Gómez Meijide, Breixo. (2012). A New Perspective for Labeling the Carbon Footprint Against Climate Change. 10.5772/48609.

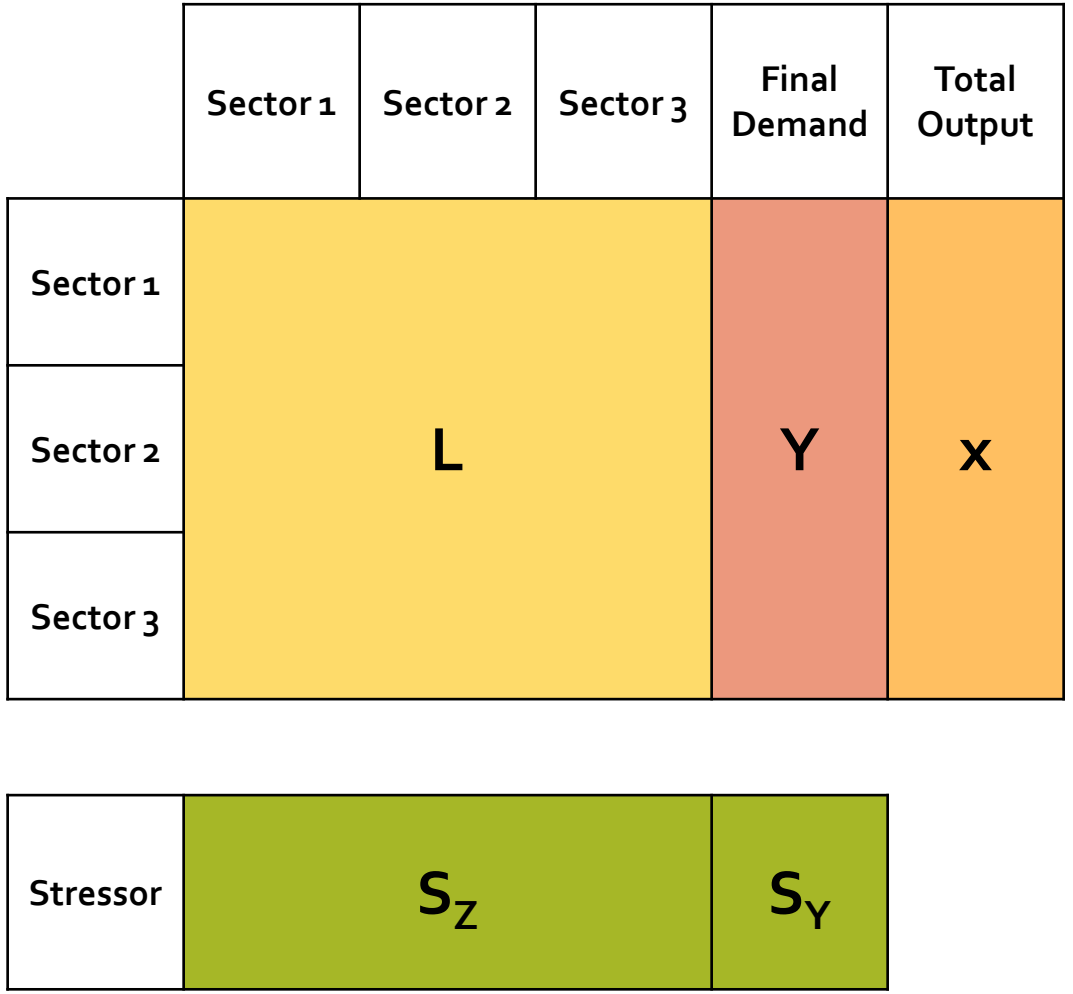
Q: satellite account
Direct or Indirect Activities?

1. Carbon dioxide emissions from a cement facility
2. Biodiversity loss due to Nike's purchase of rubber from Acme Rubber Inc.
3. Emissions from electricity use by Ford powering their factory
4. Particulate Matter emissions from Amazon's delivery vans

Figure: Villar, Juan & Hidalgo, Sebastián & Penela, Adolfo & Gómez Meijide, Breixo. (2012). A New Perspective for Labeling the Carbon Footprint Against Climate Change. 10.5772/48609.

S: stressor matrix

- How did we convert **Z → A?**
- **S** is **Q** normalized by **x**, $S = Q\hat{x}^{-1}$
- What does **S** represent?
- How can we calculate the total annual activity from **S ?**



Q → S: satellite account & stressor matrices
Dummy data

Q

X

S

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government
kg CO2	40	59	55	49	59	70	72	74	95
kg CH4	22	16	25	23	22	25	1	6	11
kg N20	1	3	3	5	13	25	12	15	21
kg HCFC-22	3	4	3	3	1	4	2	2	1
m3 blue water	126	15	35	5	22	2	8	4	15
m3 green water	320	-	-	-	-	-	-	-	-
km2 crop land	247	-	-	-	-	-	-	-	-
km2 forest land	524	-	-	-	-	-	-	-	-

÷

	Household Expend.	Government Expend.	Investments	Adjustments
kg CO2	12	-	-	-
kg CH4	3	-	-	-
kg N20	1	-	-	-
kg HCFC-22	1	-	-	-
m3 blue water	52	-	-	-
m3 green water	13	-	-	-
km2 crop land	-	-	-	-
km2 forest land	-	-	-	-

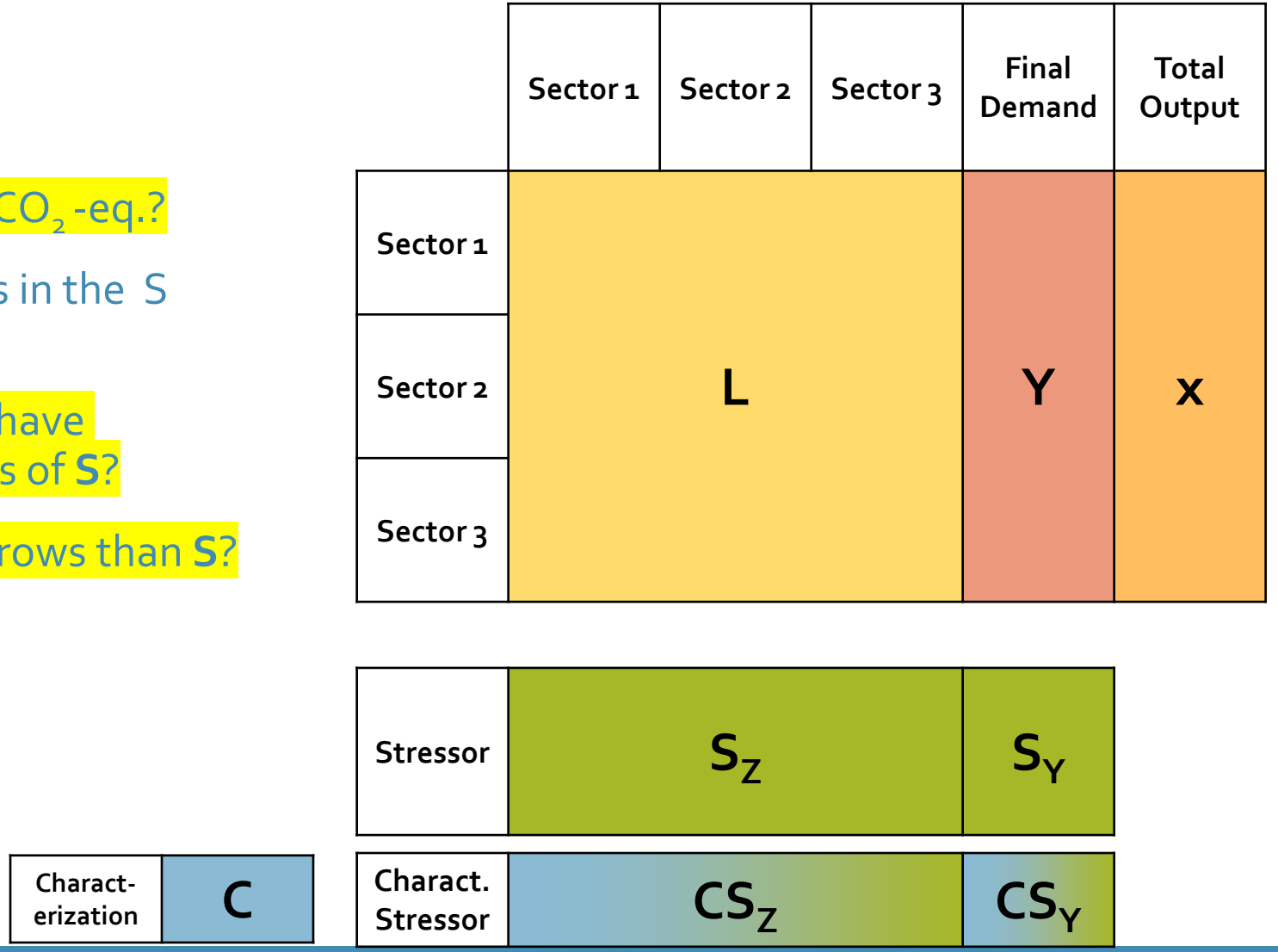
Total Output	519	1205	759	919	836	877	733	791	552

=

kg CO2/$ output	0.077	0.049	0.072	0.053	0.071	0.080	0.098	0.094	0.172
kg CH4/$ output	0.042	0.013	0.033	0.025	0.026	0.029	0.001	0.008	0.020
kg N20/$ output	0.002	0.002	0.004	0.005	0.016	0.029	0.016	0.019	0.038
kg HCFC-22/$ output	0.006	0.003	0.004	0.003	0.001	0.005	0.003	0.003	0.002
m3 blue water/$ output	0.243	0.012	0.046	0.005	0.026	0.002	0.011	0.005	0.027
m3 green water/$ output	0.617	-	-	-	-	-	-	-	-
km2 crop land/$ output	0.476	-	-	-	-	-	-	-	-
km2 forest land/$ output	1.010	-	-	-	-	-	-	-	-

C: characterization matrix

- How do we convert from tonnes of CH_4 → tonnes of CO_2-eq.?
- The C matrix combines rows in the S matrix into common units
- How many columns does **C** have compared to the dimensions of **S**?
- Does **C** have fewer or more rows than **S**?



CS: characterized stressor matrix
Dummy data

S_Z

	Agriculture	Utilities	Construction	Retail & Wholesale	Transportation	Finance	Education	Arts	Government
kg CO2/$ output	0.077	0.049	0.072	0.053	0.071	0.080	0.098	0.094	0.172
kg CH4/$ output	0.042	0.013	0.033	0.025	0.026	0.029	0.001	0.008	0.020
kg N20/$ output	0.002	0.002	0.004	0.005	0.016	0.029	0.016	0.019	0.038
kg HCFC-22/$ output	0.006	0.003	0.004	0.003	0.001	0.005	0.003	0.003	0.002
m3 blue water/$ output	0.243	0.012	0.046	0.005	0.026	0.002	0.011	0.005	0.027
m3 green water/$ output	0.617	-	-	-	-	-	-	-	-
km2 crop land/$ output	0.476	-	-	-	-	-	-	-	-
km2 forest land/$ output	1.010	-	-	-	-	-	-	-	-

GWP

	kg CO2	kg CH4	kg N20	kg HCFC-22	m3 blue water	m3 green water	km2 crop land	km2 forest land
kg CO2eq/kg	1	25	298	14,800	-	-	-	-
m3 water/m3	-	-	-	-	1	1	-	-
km2 land/km2	-	-	-	-	-	-	1	1

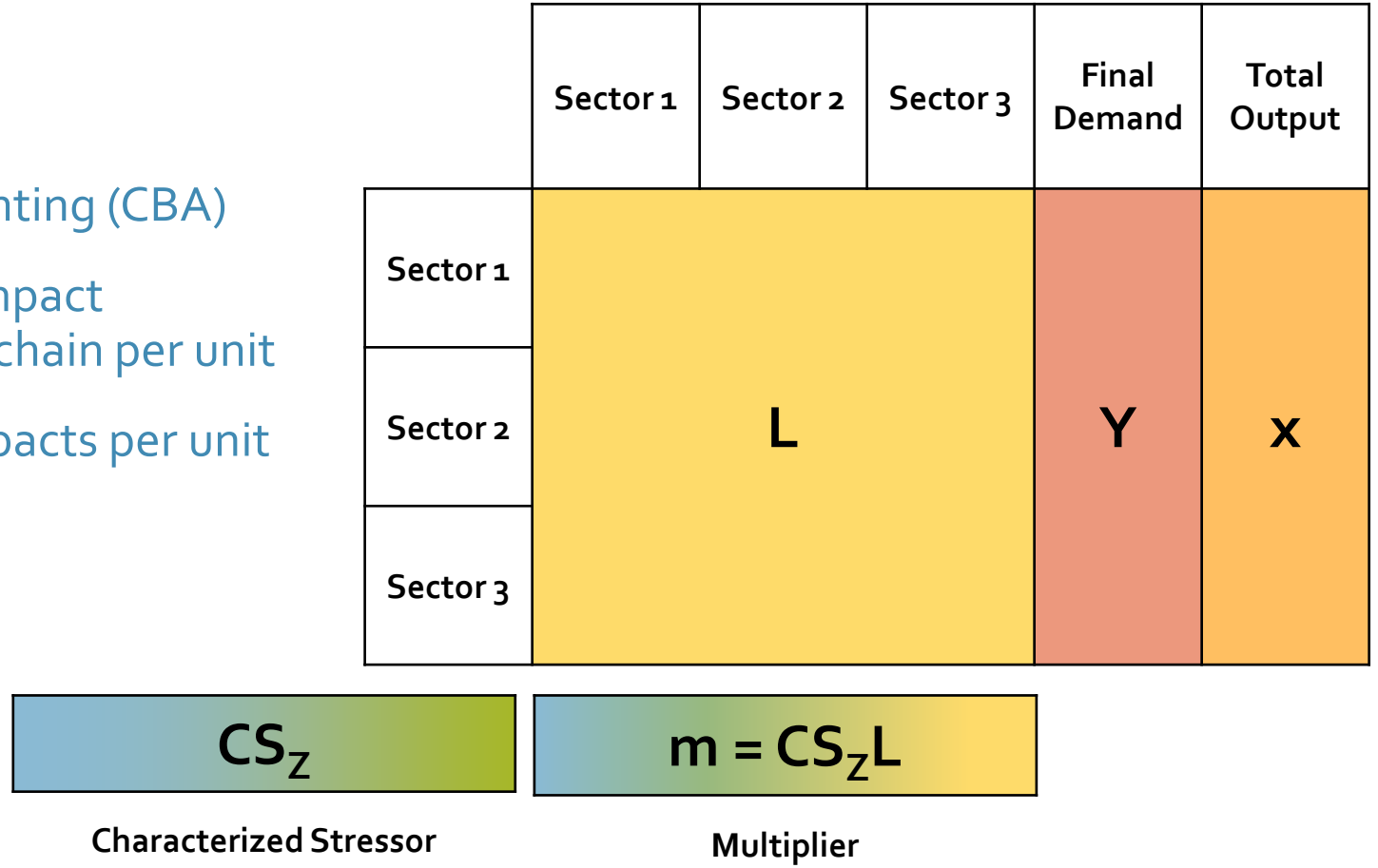
C

87.26	50.25	60.57	50.61	23.07	76.79	45.39	43.36	38.82
0.86	0.01	0.05	0.01	0.03	0.00	0.01	0.01	0.03
1.49	-	-	-	-	-	-	-	-

CS_Z

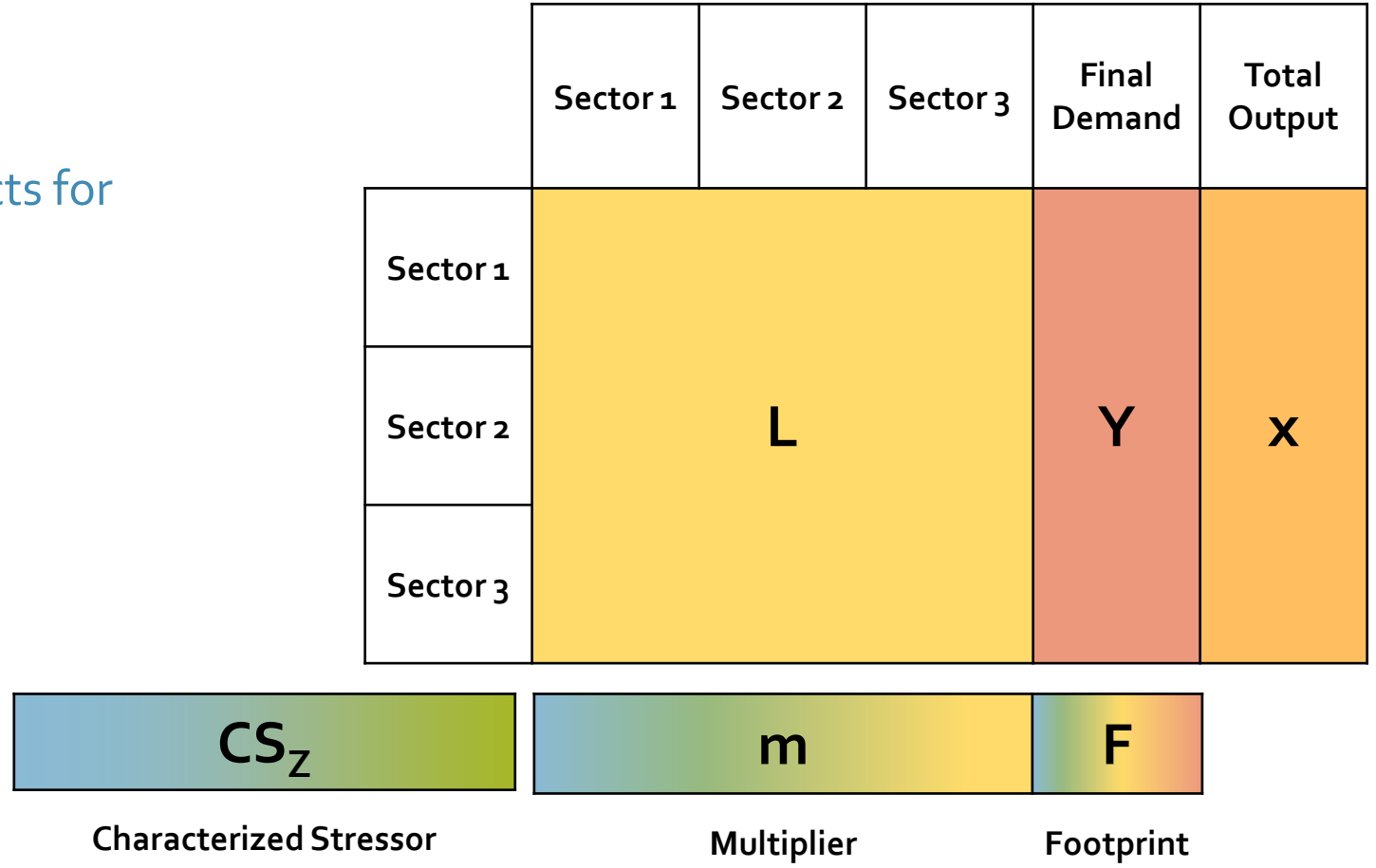
m: multiplier matrix

- Consumption-Based Accounting (CBA)
- **m** reflects environmental impact accumulated across supply chain per unit
- **m** represents embodied impacts per unit of final product
- $m = CS_Z L$
- Why is **L** involved?



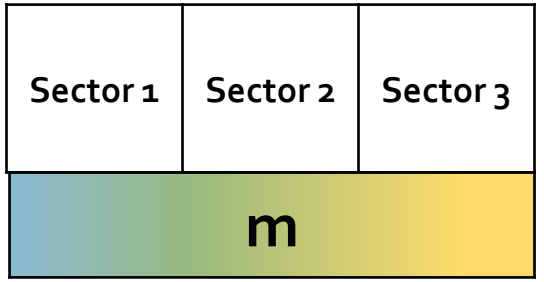
F: footprint matrix

- **F** represents total embodied impacts for all final demand
- reflects environmental impact accumulated across supply chain
- $\boldsymbol{F = mY = CS_Z LY}$
- Why do we use **L** here?
- Can you calculate **F** with **x**?
- $\boldsymbol{F = CS_Z x}$
- So why did we bother with **L**??

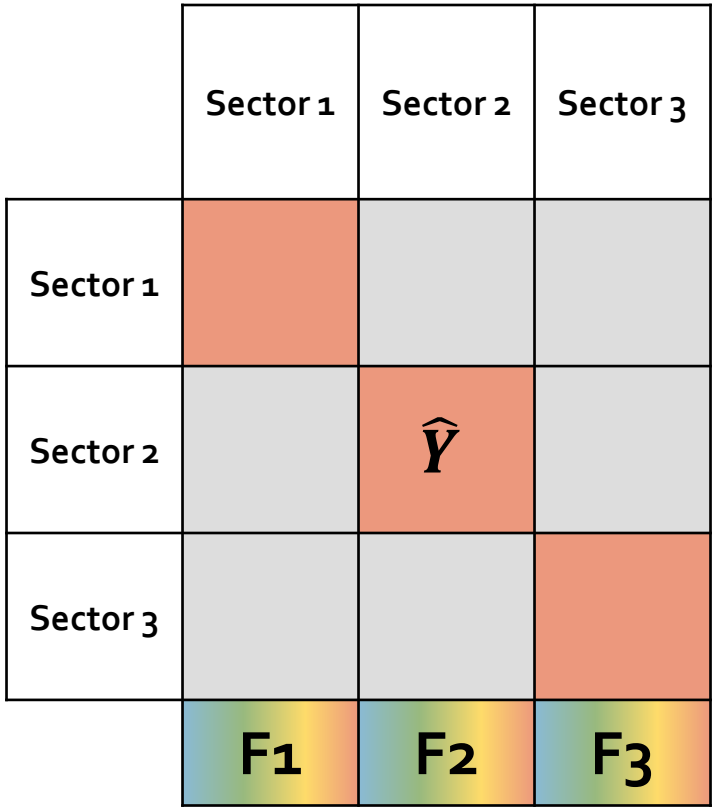


F: detailed footprint

- How could you find out the embodied impact from final demand per sector?
- $\boldsymbol{F = m\widehat{Y}}$
- What is another way to do this math?
- $\boldsymbol{F = m\#Y = m \circ Y}$
  - one row of **m** at a time
- We can also separate types of **Y**



Multiplier



Detailed Footprint

Overview

- Refresher of EEIO basics
- EEIO & Capital Assets
- Refresher of EE-MRIO basics
- Global Commons Stewardship Index

IMPACT OF CAPITAL ON THE AMERICAN CARBON, ENERGY, AND MATERIAL FOOTPRINT

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Yookyung Kim, Xinzhu Zheng, Edgar G. Hertwich

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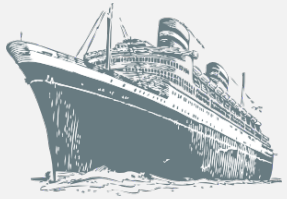
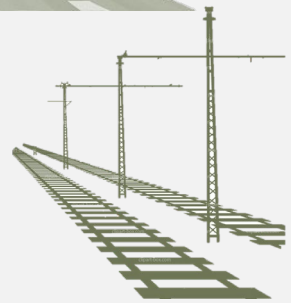
IMPORTANCE OF CAPITAL ASSETS

WHAT ARE CAPITAL ASSETS? TRANSPORTATION-RELATED

EQUIPMENT



STRUCTURES

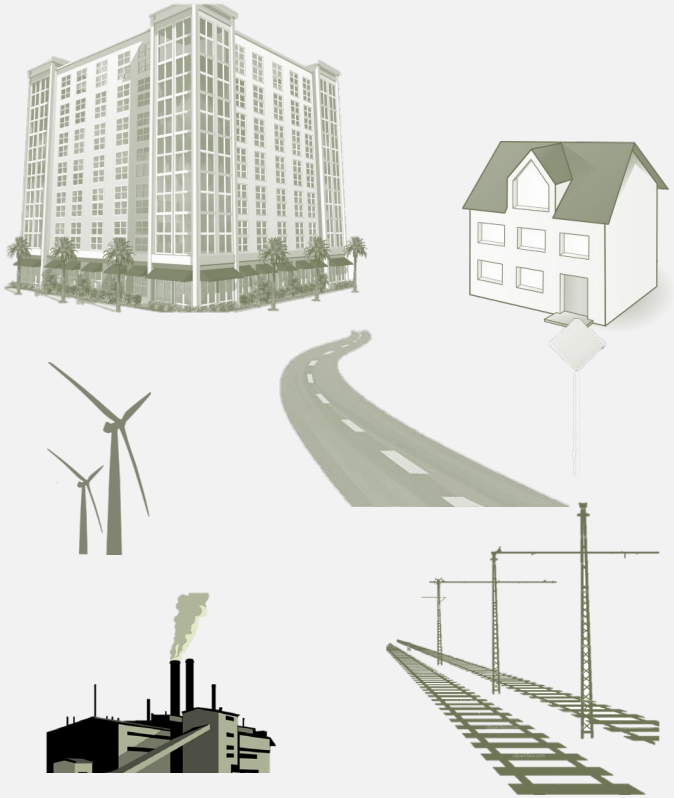


INTELLECTUAL PROPERTY PRODUCTS (IPP)

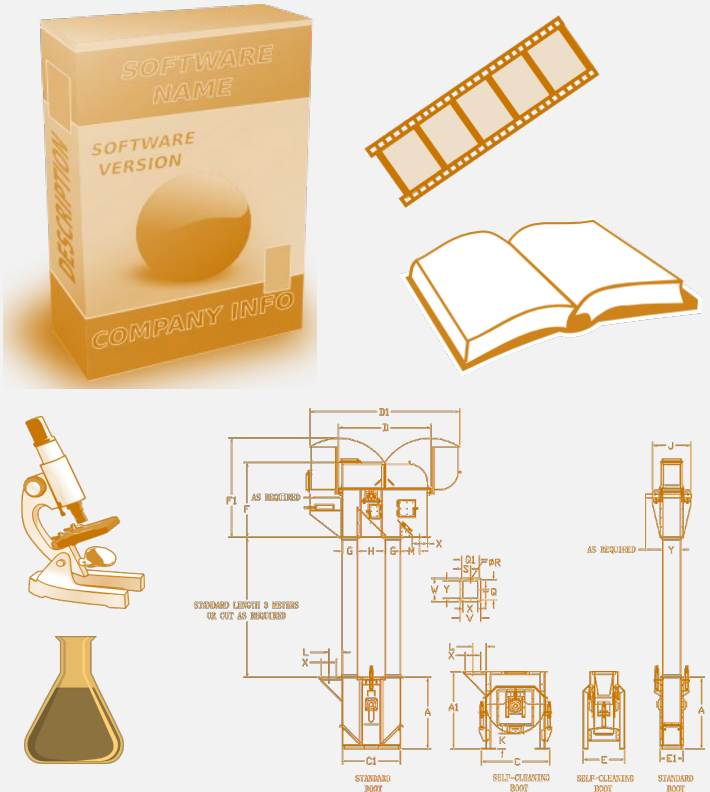
WHAT ARE CAPITAL ASSETS?
ENTIRE SUPPLY CHAIN

EQUIPMENT

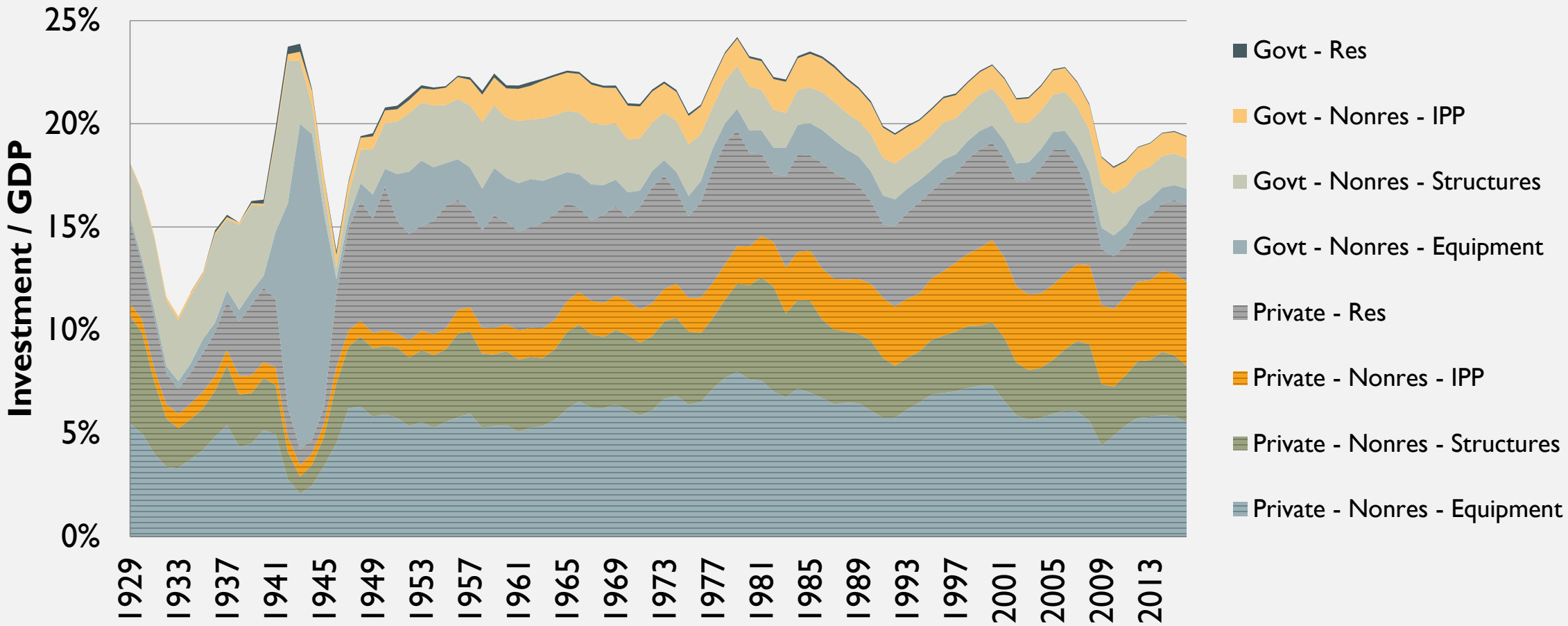
STRUCTURES



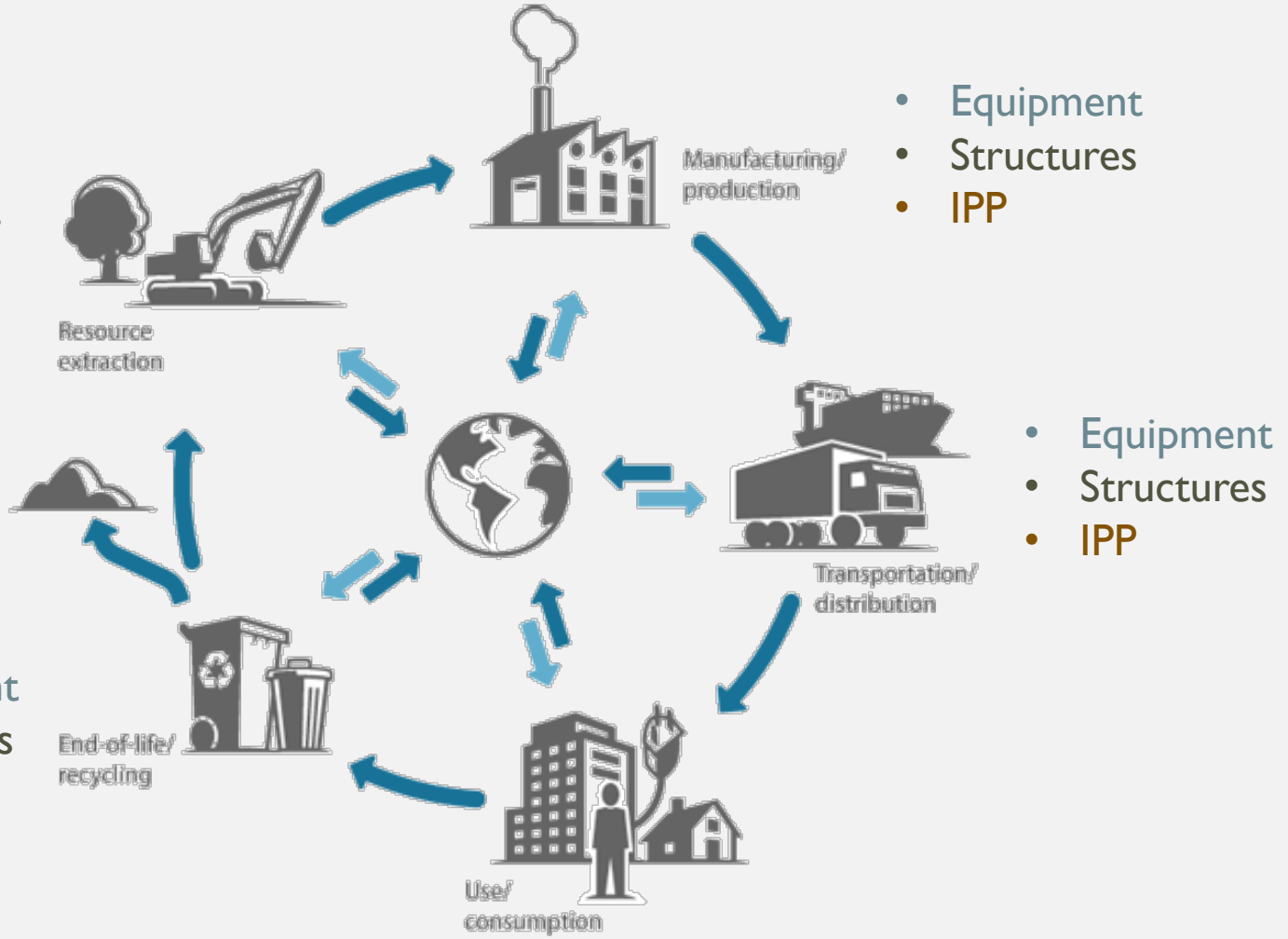
INTELLECTUAL PROPERTY PRODUCTS (IPP)



US INVESTMENT IN CAPITAL ASSETS AS % OF GDP



USE OF CAPITAL OVER THE LIFE CYCLE



- Equipment
- Structures
- IPP

- Equipment
- Structures
- IPP

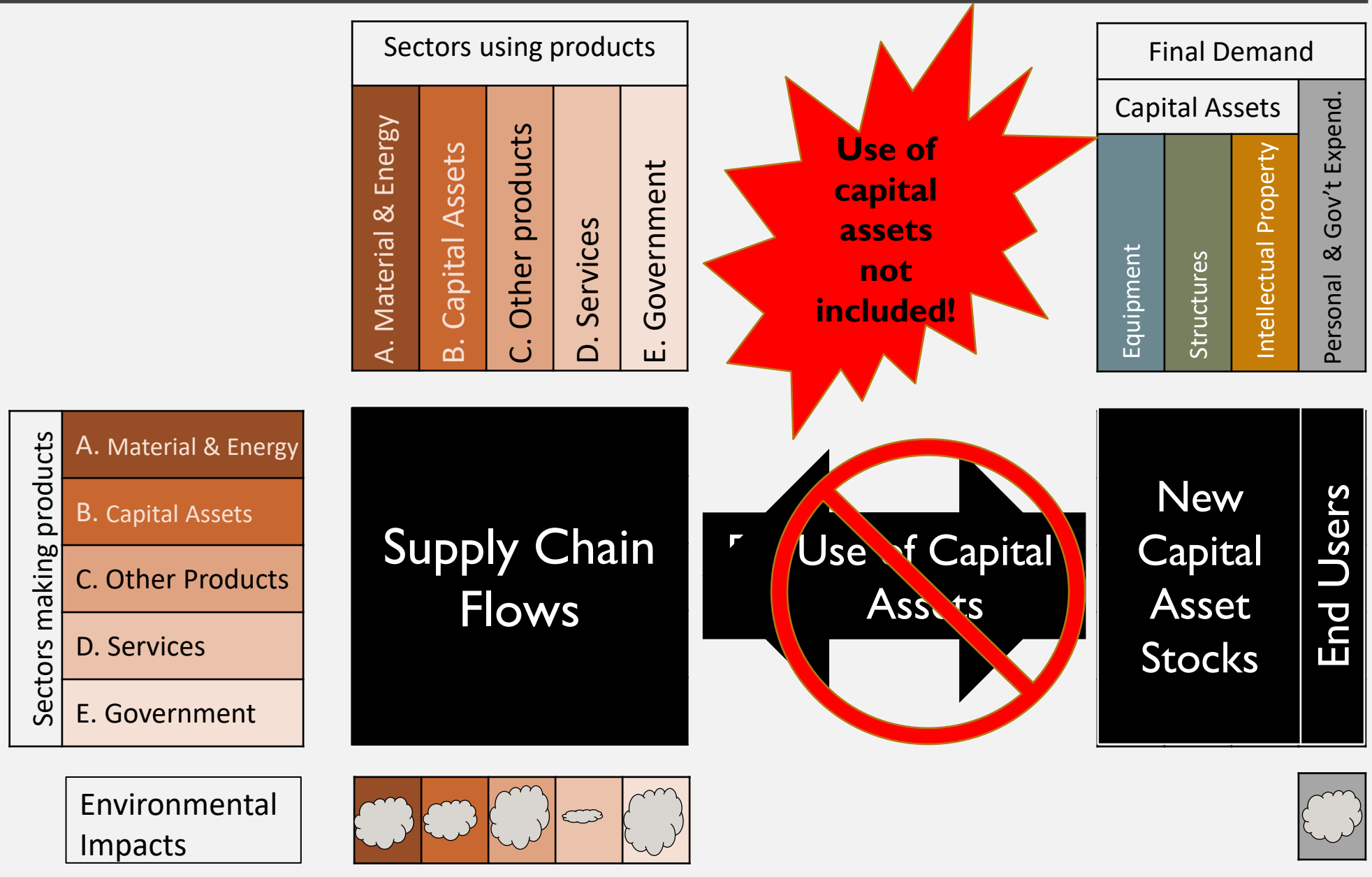
- Equipment
- Structures
- IPP

- Equipment
- Structures
- IPP

Image: http://www.hydroquebec.com/sustainable-development/documentation-center/life-cycle-analysis.html

REPRESENTING TRANSPORTATION IN EEIO

CAPITAL ASSETS IN EEIO



OBJECTIVES

‘Endogenize’ capital in USEEIO

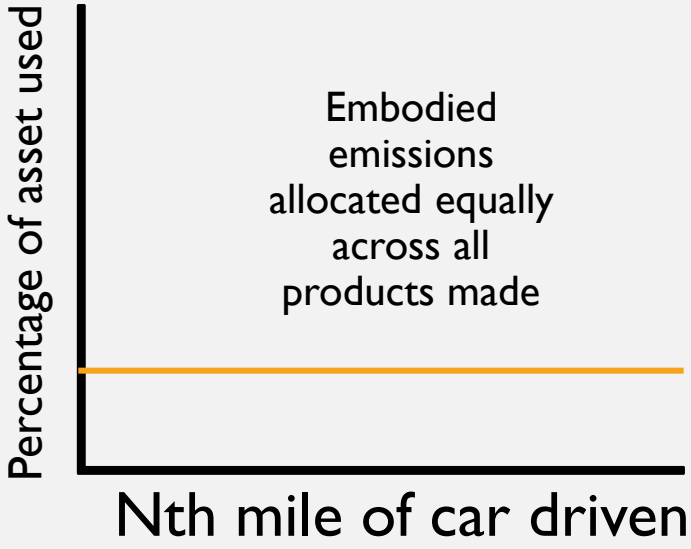
Contribution of capital to footprints

Importance to different products

CONCEPTUALIZING USE OF CAPITAL ASSETS

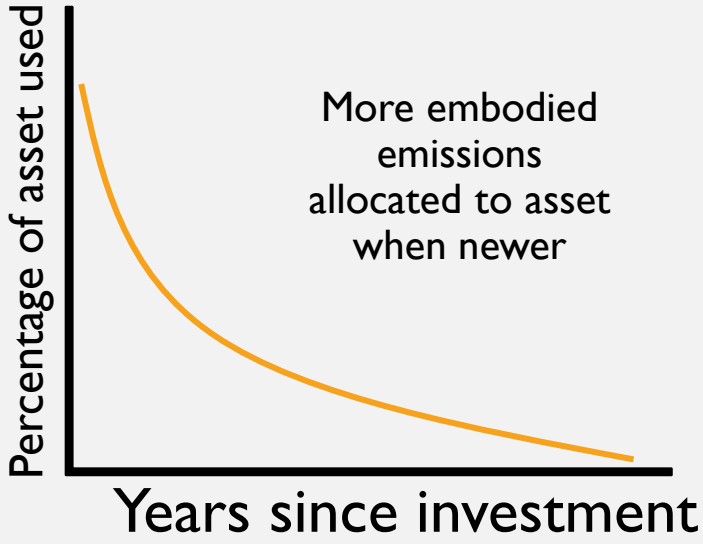
Approach for LCA

- Estimate lifetime use of capital asset:
  - Car driven 200,000 miles over lifetime
  - Each mile driven assigned 1/200,000 car

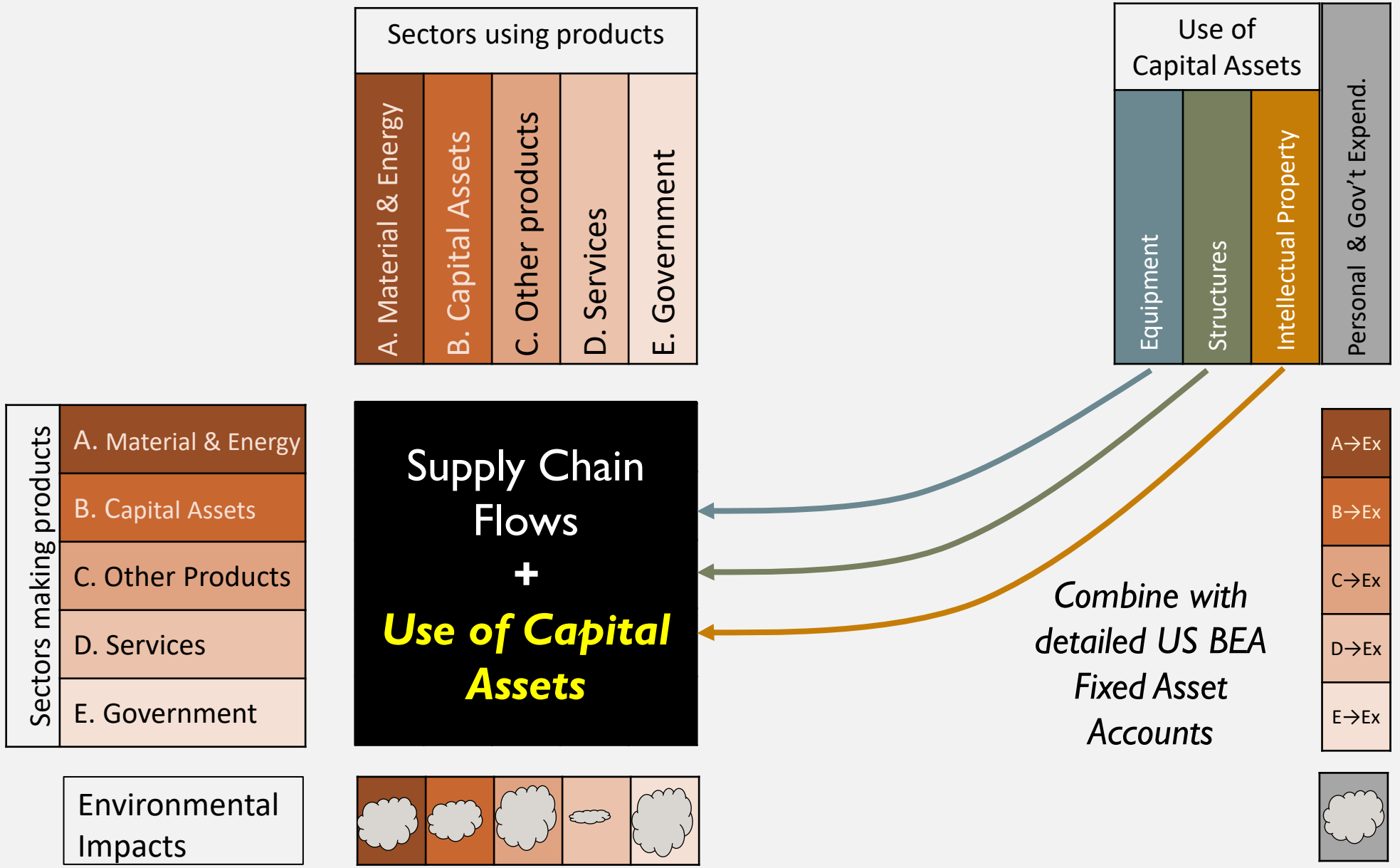


Approach for EEIO

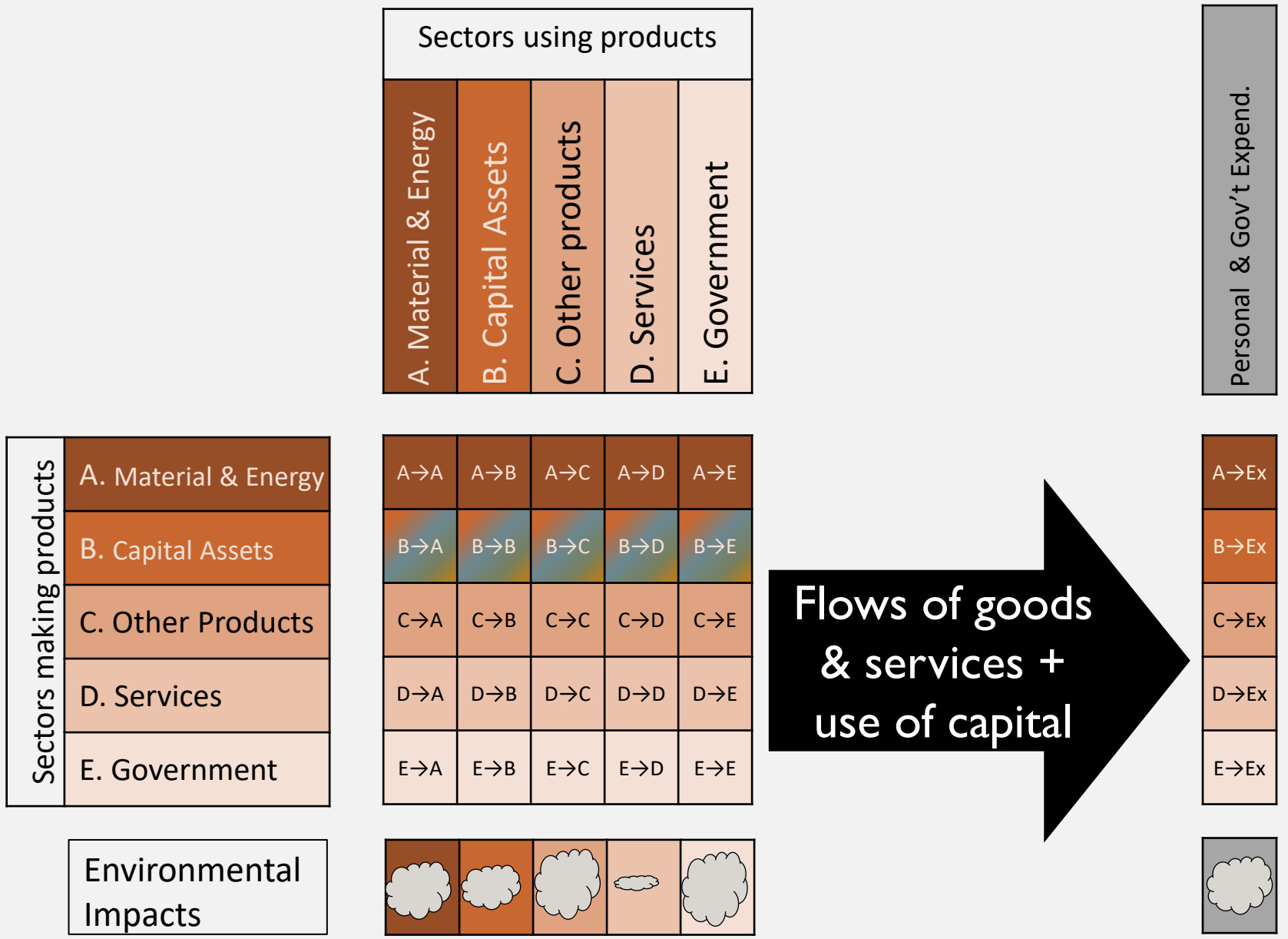
- Estimate service life and **depreciation rate** of capital asset, apply to annual investment
  - Autos: 19% geometric depreciation rate



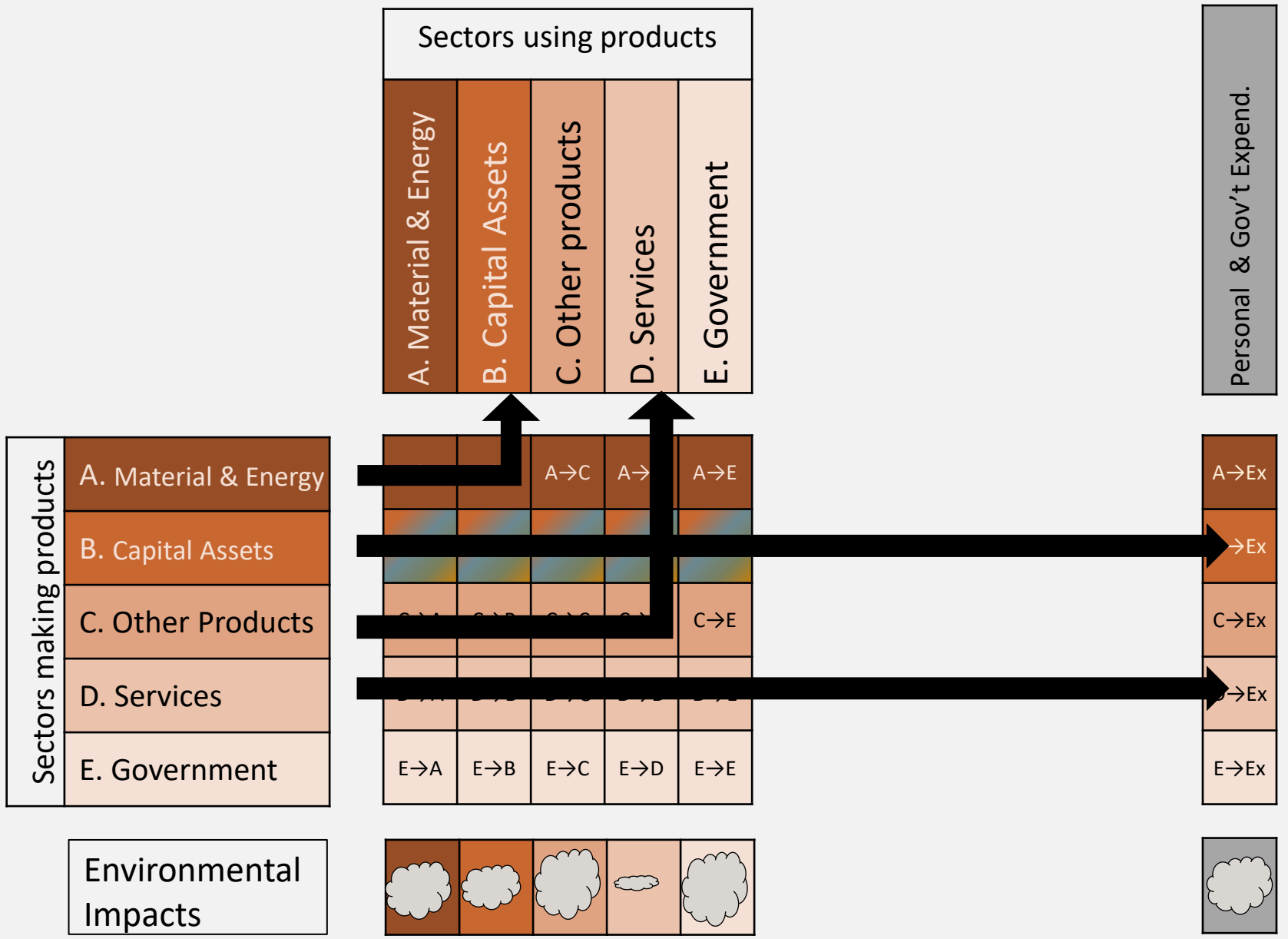
CAPITAL ASSETS IN EEIO



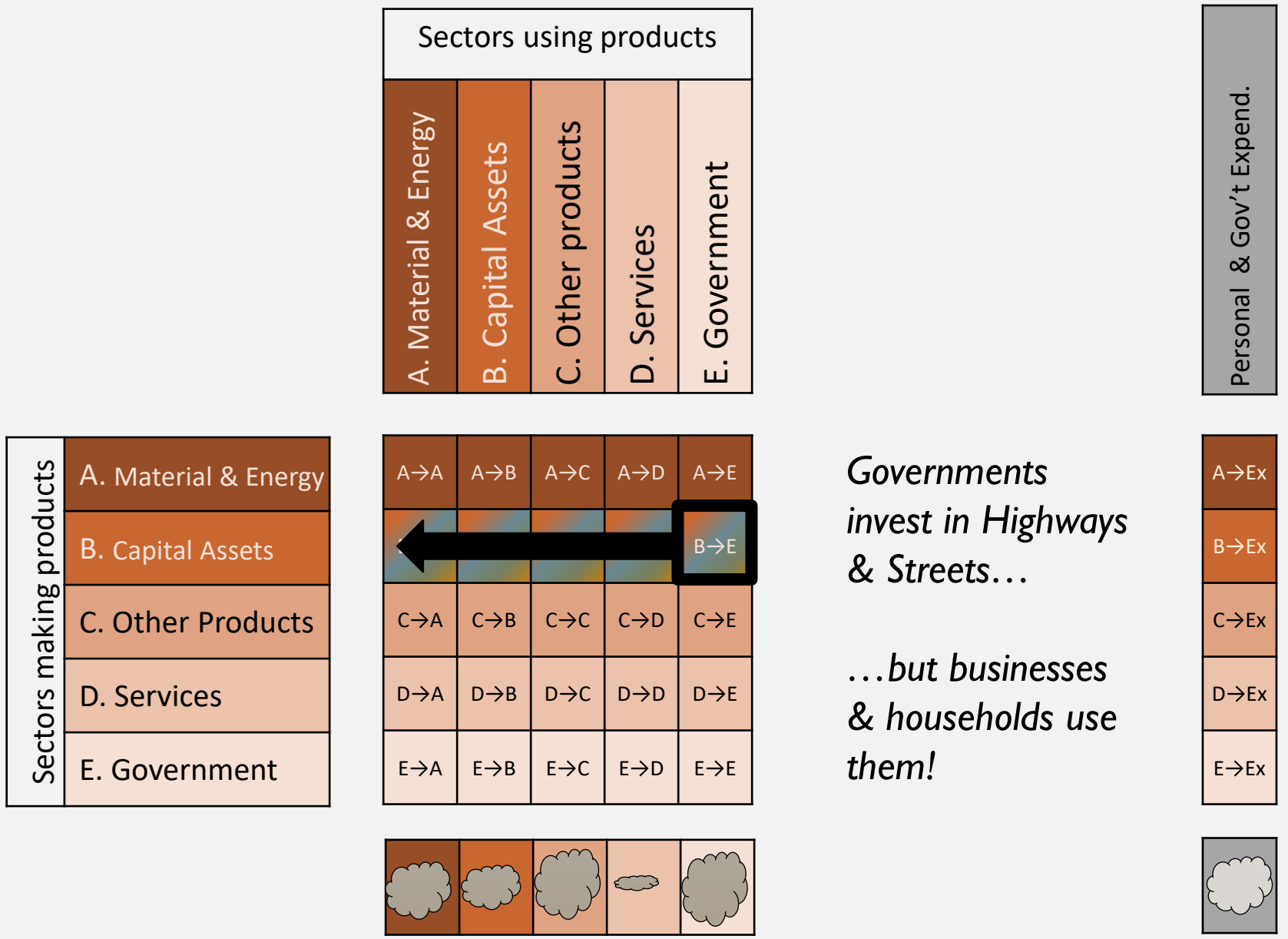
CAPITAL ASSETS IN EEIO



CAPITAL ASSETS IN EEIO

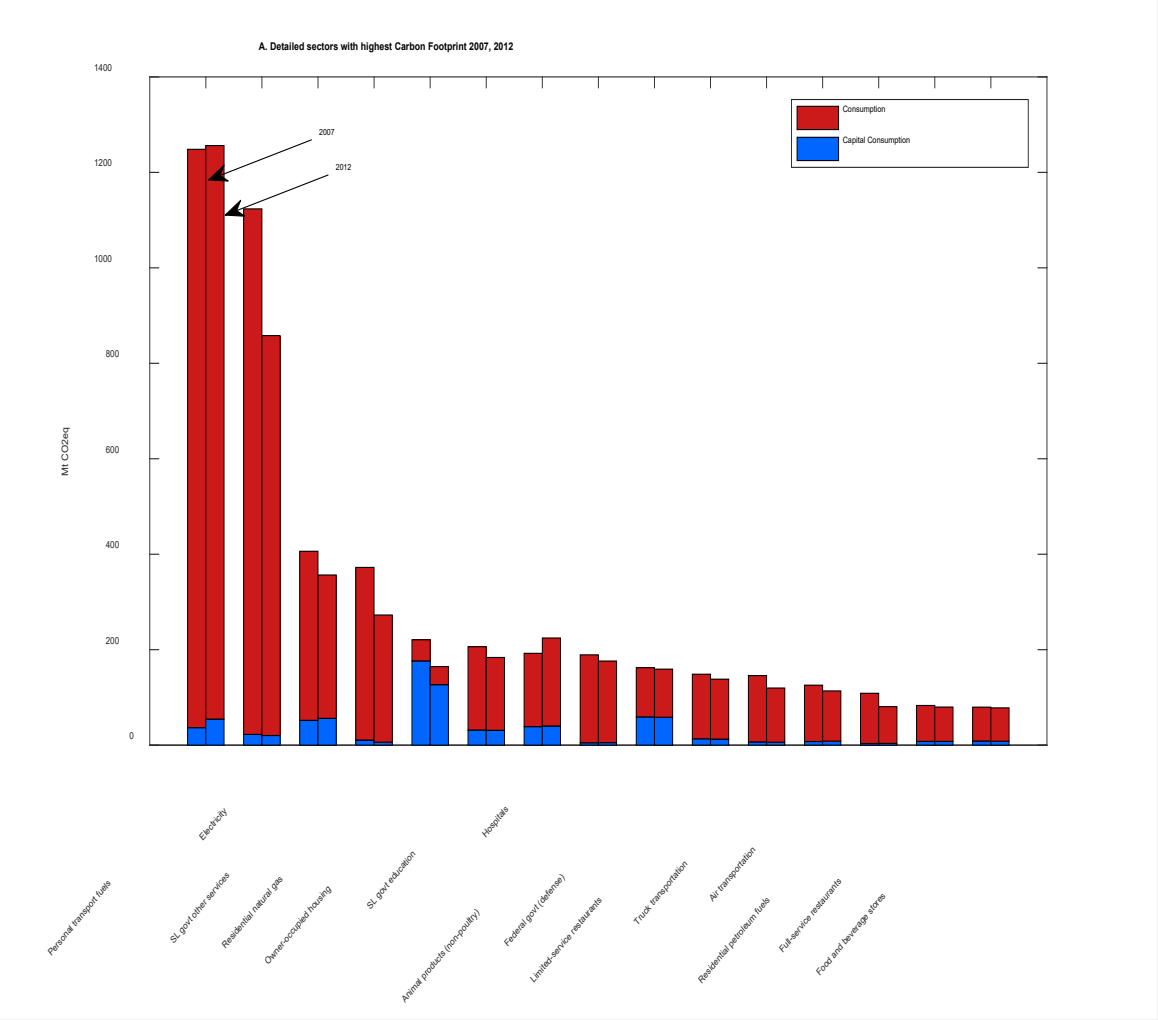


HIGHWAYS & STREETS CAPITAL ASSETS IN EEIO



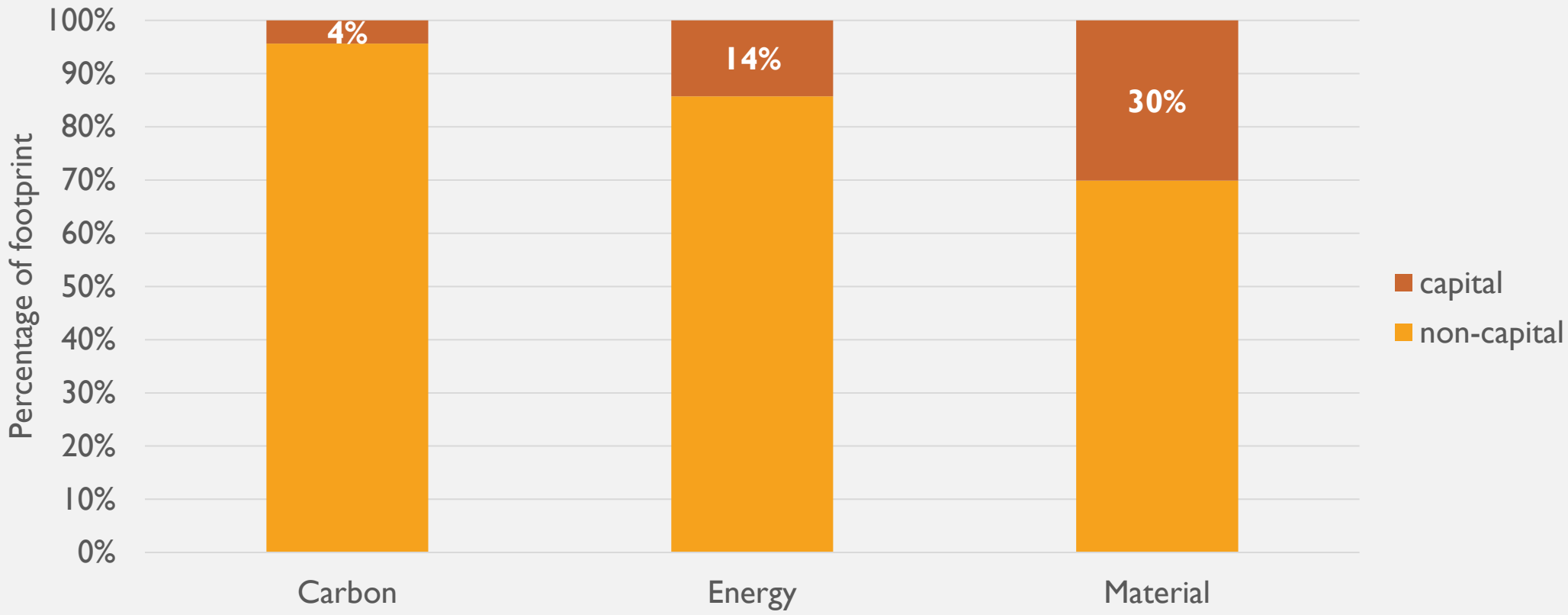
RESULTS: CAPITAL IN TRANSPORTATION FOOTPRINTS

PERSONAL TRANSPORT FUELS

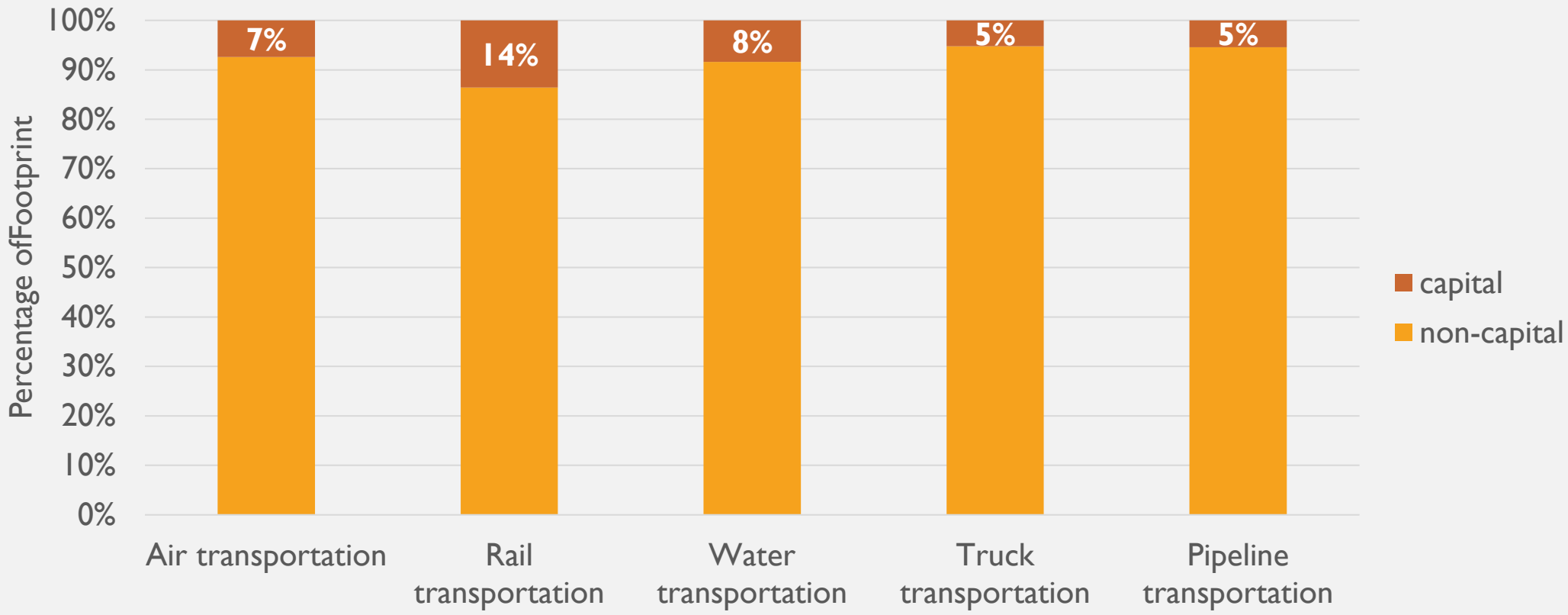


- We added 'Personal Transport Fuels' sector to original detailed sectors
- Combustion of transport fuels by households & fuel supply chains
- **Highest overall carbon footprint**

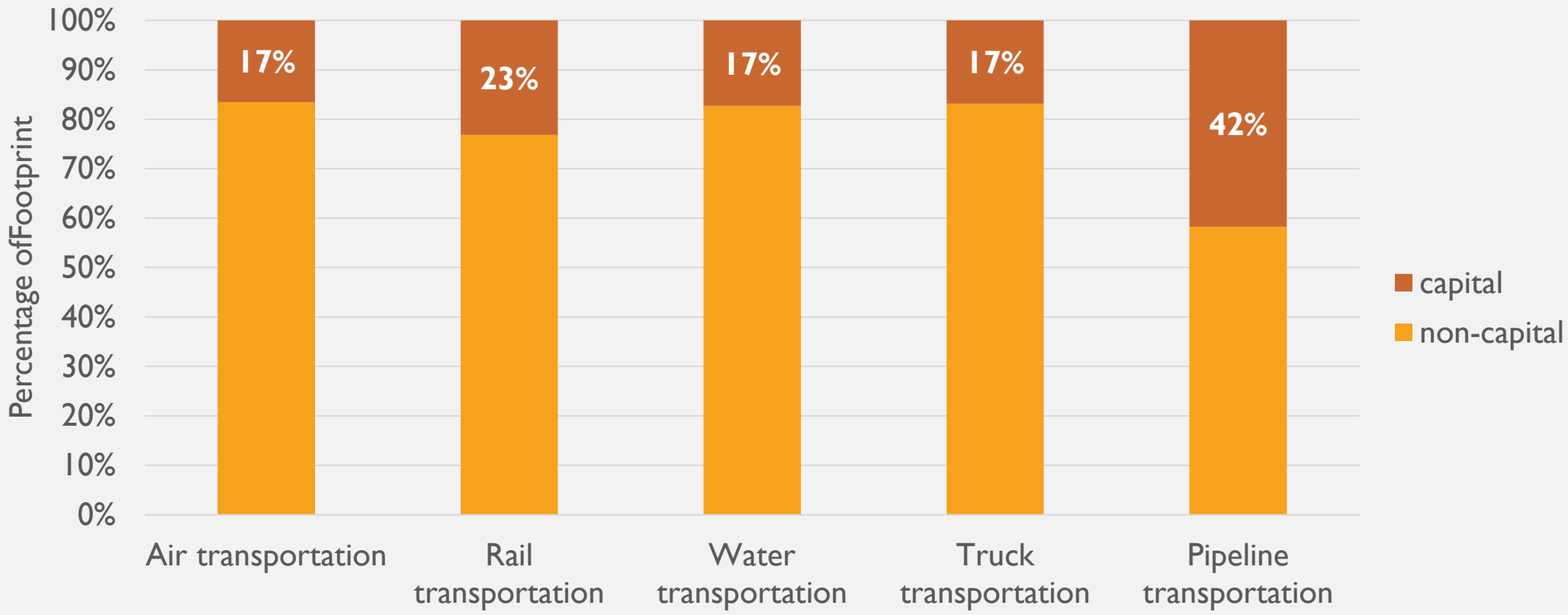
CAPITAL ASSETS IN PERSONAL TRANSPORT FUELS



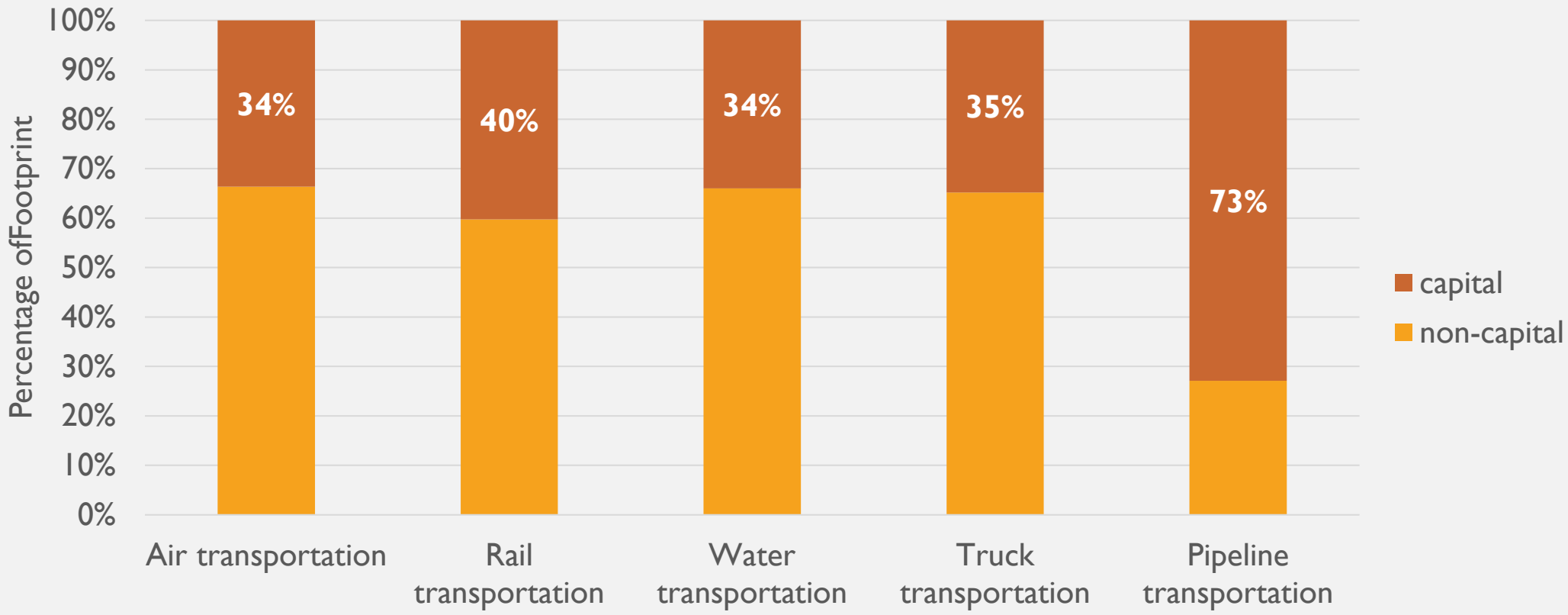
CAPITAL ASSETS % OF CARBON FOOTPRINT



CAPITAL ASSETS % OF ENERGY FOOTPRINT



CAPITAL ASSETS % OF MATERIAL FOOTPRINT



KEY TAKEAWAYS

- Capital assets can be important to include in EEIO
- Simple & detailed Methods have been developed to 'endogenize capital'
- Room to improve model:
  - Detailed multi-region model
  - Include trends in environmental impacts based on year the capital is created

TWO PAPERS IN JIE

- Miller TR, Berrill P, Wolfram P, et al. **Method for endogenizing capital in the United States Environmentally-Extended Input-Output Model** . *J Ind Ecol*. 2019.
- Berrill P, Miller TR, Kondo T, Hertwich E. **Capital in the American Carbon, Energy, and Material Footprint** . *J Ind Ecol*. 2019.

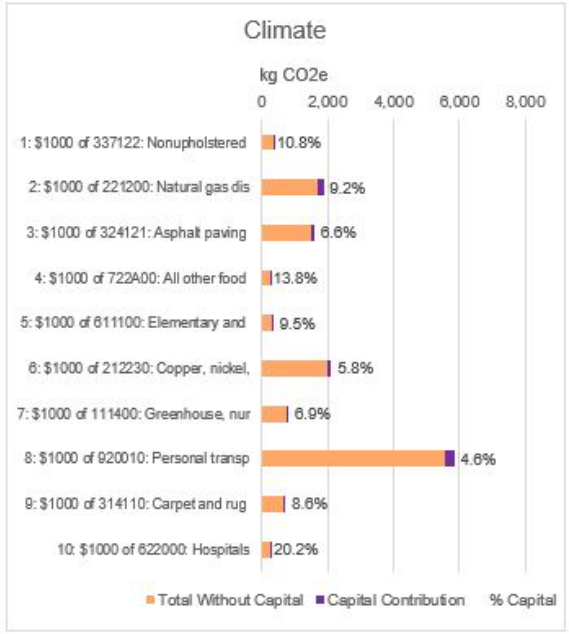
CIFT-US: CAPITAL-INCLUSIVE FOOTPRINT TOOL FOR UNITED STATES

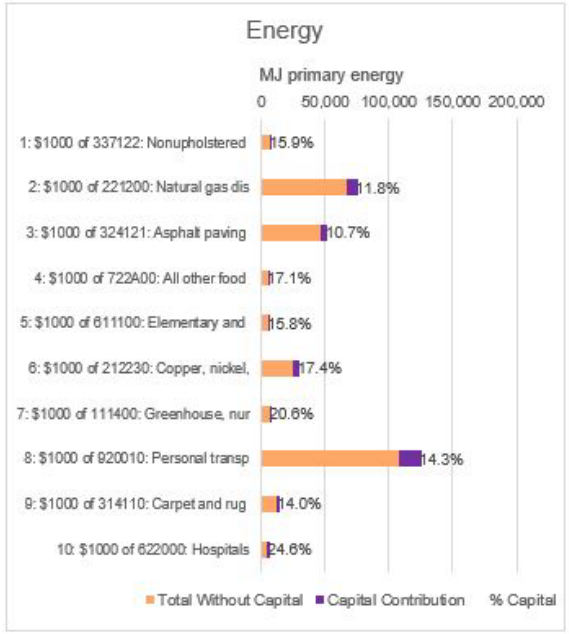
Overall Footprint Results

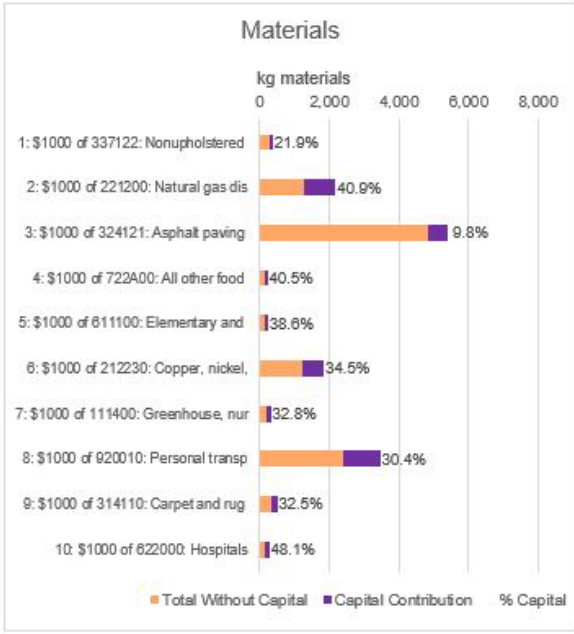
Select units here →	kg CO2e				
	Climate				
Case Names (hide row to hide case from chart)	Case	Total Without Capital	Capital Contribution	Total With Capital	% Capital
1: $1000 of 337122: Nonupholstered	1	356.9	43.2	400.1	10.8%
2: $1000 of 221200: Natural gas dis	2	1,700.2	173.3	1,873.5	9.2%
3: $1000 of 324121: Asphalt paving	3	1,497.7	105.7	1,603.4	6.6%
4: $1000 of 722A00: All other food	4	249.1	39.9	289.0	13.8%
5: $1000 of 611100: Elementary and	5	319.8	33.7	353.6	9.5%
6: $1000 of 212230: Copper, nickel,	6	1,995.9	122.3	2,118.2	5.8%
7: $1000 of 111400: Greenhouse, nur	7	760.7	56.8	817.5	6.9%
8: $1000 of 920010: Personal transp	8	5,570.9	268.0	5,838.9	4.6%
9: $1000 of 314110: Carpet and rug	9	666.4	62.3	728.7	8.6%
10: $1000 of 622000: Hospitals	10	251.4	63.6	314.9	20.2%

MJ primary energy				
Energy				
Case	Total Without Capital	Capital Contribution	Total With Capital	% Capital
1	6,686.3	1,268.7	7,955.0	15.9%
2	66,401.3	8,870.7	75,272.0	11.8%
3	46,564.3	5,557.9	52,122.2	10.7%
4	4,943.8	1,016.7	5,960.5	17.1%
5	5,235.1	982.1	6,217.2	15.8%
6	24,726.1	5,198.3	29,924.4	17.4%
7	6,333.2	1,641.5	7,974.7	20.6%
8	107,351.4	17,959.9	125,311.3	14.3%
9	11,992.6	1,945.0	13,937.6	14.0%
10	4,803.9	1,565.4	6,369.3	24.6%

kg materials				
Materials				
Case	Total Without Capital	Capital Contribution	Total With Capital	% Capital
1	297.4	83.5	380.9	21.9%
2	1,291.4	893.0	2,184.4	40.9%
3	4,858.4	526.3	5,384.7	9.8%
4	133.0	90.4	223.4	40.5%
5	147.3	92.5	239.8	38.6%
6	1,210.3	638.1	1,848.3	34.5%
7	213.0	104.0	317.0	32.8%
8	2,414.4	1,052.4	3,466.8	30.4%
9	339.7	163.5	503.2	32.5%
10	142.6	132.0	274.5	48.1%







https://cie.research.yale.edu/research/incorporating-capital-american-carbon-energy-and-material-footprints

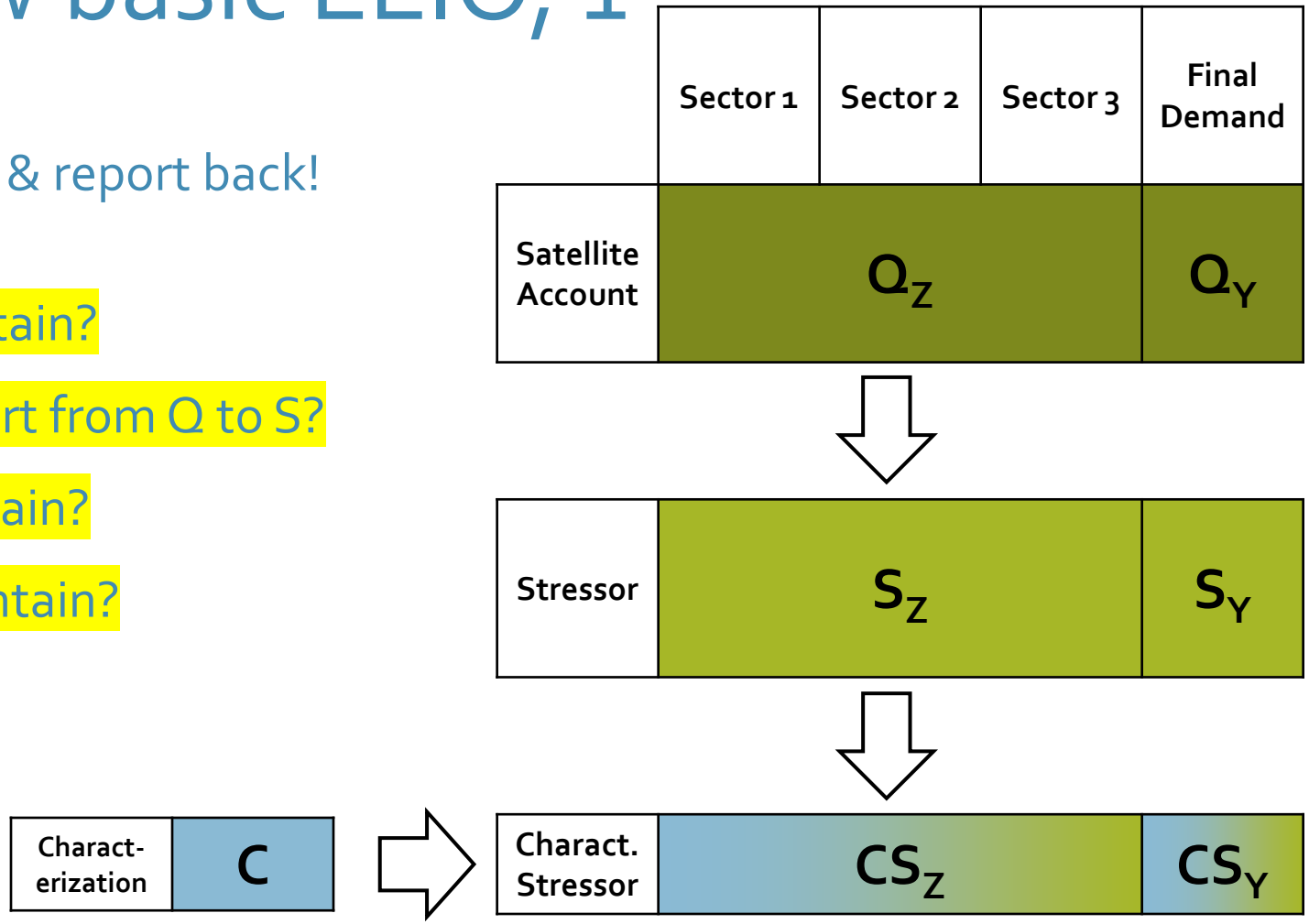
Overview

- Refresher of EEIO basics
- EEIO & Capital Assets
- Refresher of EE-MRIO basics
- Global Commons Stewardship Index

Let's review basic EEIO, 1

Talk to your neighbor & report back!
(3 min)

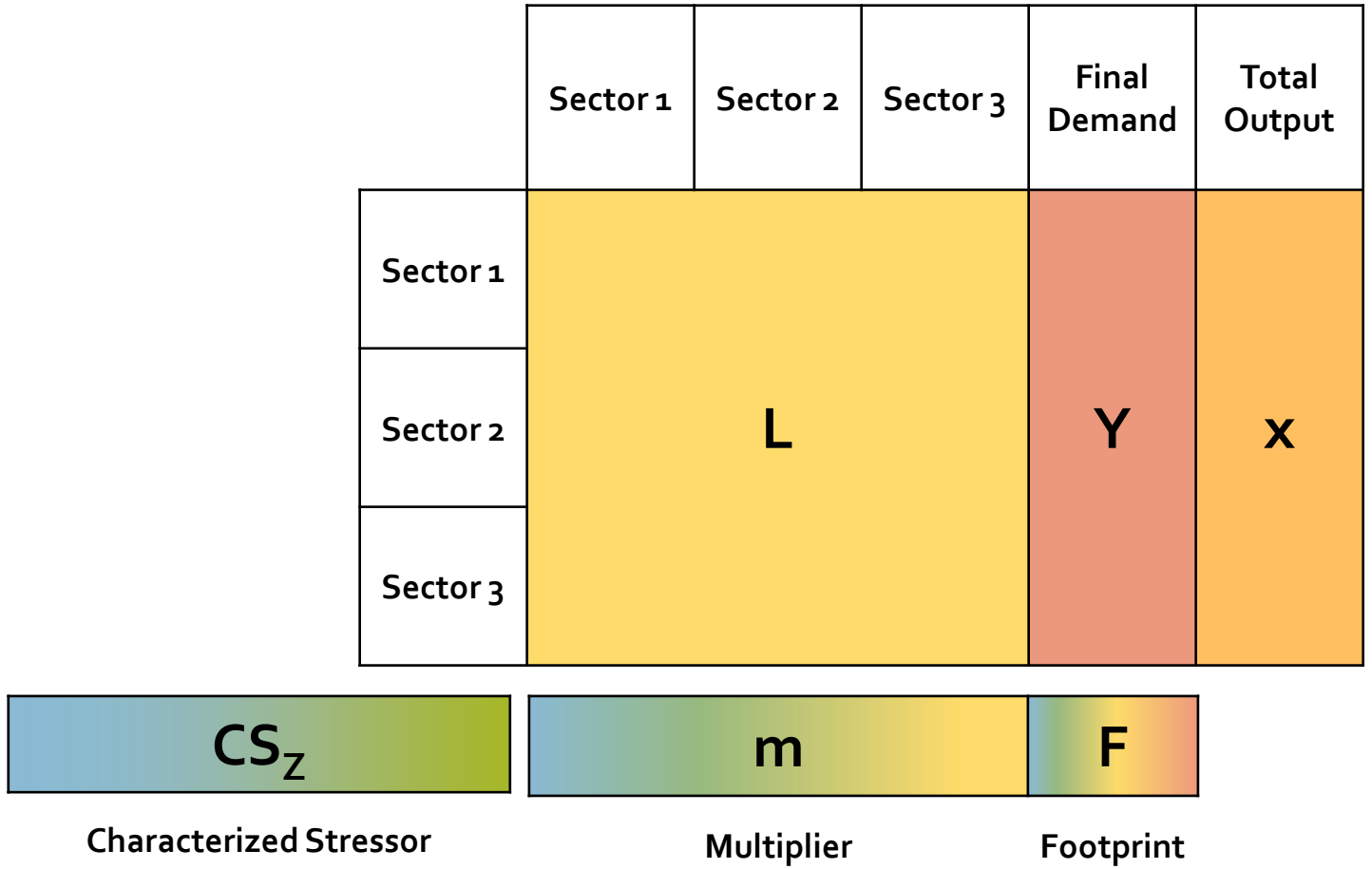
1. What does Q contain?
2. How do we convert from Q to S?
3. What does C contain?
4. What does CS contain?



Let's review basic EEIO, 2

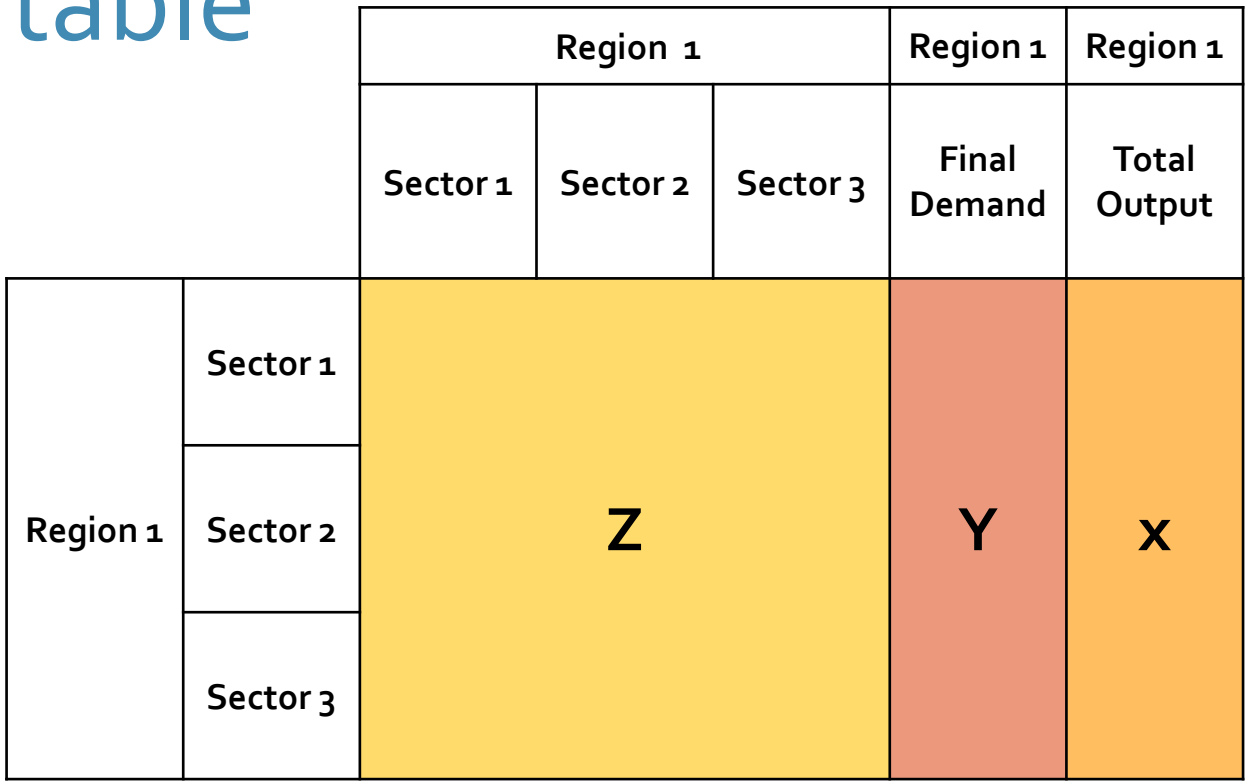
All together now!

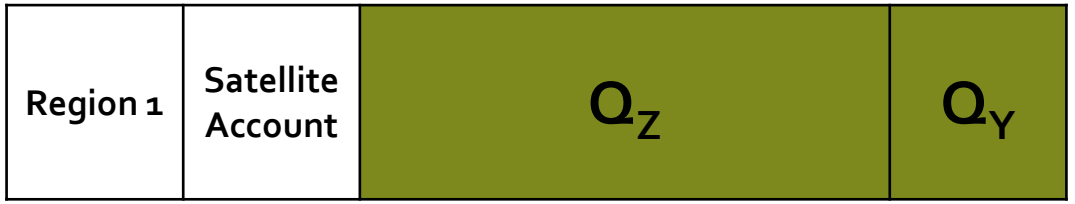
1. How are these calculated & what do they represent:
   - **m**
   - **F**
2. Where are imports & exports balanced?



Single-Region EEIO table

- So far, have looked at SR-EEIO
- Prepared by each country
- Transactions within one region
- Balance trade in **Y**
  - + Exports, - Imports
- Domestic technology assumption: Assumes all products made using that region's technology





Overview of Multi-Region EEIO table

- The matrices are expanded to have multiple regions
- EEIO algebra is the same
  - $\boldsymbol{Z} + \boldsymbol{Y} = \boldsymbol{x}$
  - $\boldsymbol{A} = \boldsymbol{Z}\hat{\boldsymbol{x}}^{-1}$
  - $\boldsymbol{L} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$
  - etc.
- Do we need a different **C** than used in SR-EEIO?

	Region 1	Region 2	Region 3	Final Demand Region 1	Final Demand Region 2	Final Demand Region 3	Total Output
Region 1	$\boldsymbol{z_{1,1}}$	$z_{1,2}$	$z_{1,3}$	$y_{1,1}$	$y_{1,2}$	$y_{1,3}$	x_1
Region 2	$z_{2,1}$	$\boldsymbol{z_{2,2}}$	$z_{2,3}$	$y_{2,1}$	$y_{2,2}$	$y_{2,3}$	x_2
Region 3	$z_{3,1}$	$z_{3,2}$	$\boldsymbol{z_{3,3}}$	$y_{3,1}$	$y_{3,2}$	$y_{3,3}$	x_3
Satellite Account	Qz_1	Qz_2	Qz_3	Qy_1	Qy_2	Qy_3	

Overview of Multi-Region EEIO table

Each block is comprised of many rows & columns

- Z1,1:
  - sectors in rows
  - sectors in columns
- Qz1
  - satellites in rows
  - sectors in columns
- What does Y1,1 have in rows & columns?

	Region 1	Region 2	Region 3	Final Demand Region 1	Final Demand Region 2	Final Demand Region 3	Total Output
Region 1	$\boldsymbol{z_{1,1}}$	$z_{1,2}$	$z_{1,3}$	$y_{1,1}$	$y_{1,2}$	$y_{1,3}$	x_1
Region 2	$z_{2,1}$	$\boldsymbol{z_{2,2}}$	$z_{2,3}$	$y_{2,1}$	$y_{2,2}$	$y_{2,3}$	x_2
Region 3	$z_{3,1}$	$z_{3,2}$	$\boldsymbol{z_{3,3}}$	$y_{3,1}$	$y_{3,2}$	$y_{3,3}$	x_3
Satellite Account	Qz_1	Qz_2	Qz_3	Qy_1	Qy_2	Qy_3	

Multi-Region EEIO table *Dummy Data*

		Atlantis			Laputa			Zembla			Atlantis		Laputa		Zembla		TOTAL OUTPUT
		Agriculture	Goods	Services	Agriculture	Goods	Services	Agriculture	Goods	Services	Expenditures	Investmentss	Expenditures	Investmentss	Expenditures	Investmentss	
Atlantis	Agriculture	127	117	27	67	37	34	3	12	12	49	0	26	0	8	0	519
	Goods	37	212	144	54	35	8	45	74	28	172	79	46	98	57	116	1205
	Services	18	33	114	16	44	6	17	14	25	278	34	56	12	78	14	759
Laputa	Agriculture	8	67	34	[illegible]	[illegible]	53	46	18	68	84	8	152	[illegible]	150	16	919
	Goods	5	34	14	47	162	12	17	15	38	94	18	[illegible]	18	154	26	836
	Services	44	56	34	[illegible]	[illegible]	315	7	72	36	15	0	[illegible]	0	111	0	877
Zembla	Agriculture	4	89	1	118	2	24	222	172	5	0	0	0	0	0	96	733
	Goods	18	55	12	57	10	52	43	64	62	85	35	42	22	198	36	791
	Services	2	16	8	5	4	16	23	73	42	57	16	15	4	225	46	552
	kg CO2	40	59	55	49	59	70	72	74	95	12	-	[illegible]	[illegible]	-	-	
	kg CH4	22	16	25	[illegible]	[illegible]	25	1	6	11	3	-	[illegible]	[illegible]	-	-	
	kg N20	1	3	3	[illegible]	13	25	12	15	21	1	-	[illegible]	[illegible]	-	-	
	kg HCFC-22	3	4	3	3	1	4	2	2	1	1	-	[illegible]	[illegible]	-	-	
	m3 blue water	126	15	35	5	22	2	8	4	15	52	-	[illegible]	[illegible]	-	-	
	m3 green water	320	-	-	[illegible]	-	-	-	-	-	13	-	[illegible]	[illegible]	-	-	
	km2 crop land	247	-	-	-	[illegible]	-	-	-	-	-	-	[illegible]	[illegible]	-	-	
	km2 forest land	524	-	-	-	-	-	-	-	-	-	-	[illegible]	[illegible]	-	-	

Z

Y

X

Q_z

Q_y

Multi-Region EEIO table *Dummy Data* **Z**

Z

		Atlantis			Laputa			Zembla		
		Agriculture	Goods	Services	Agriculture	Goods	Services	Agriculture	Goods	Services
Atlantis	Agriculture	127	117	27	67	37	34	3	12	12
	Goods	37	212	144	54	35	8	45	74	28
	Services	18	33	114	16	44	6	17	14	25
Laputa	Agriculture	8	67	34	123	65	53	46	18	68
	Goods	5	34	14	47	162	12	17	15	38
	Services	44	56	34	78	57	315	7	72	36
Zembla	Agriculture	4	89	1	118	2	24	222	172	5
	Goods	18	55	12	57	10	52	43	64	62
	Services	2	16	8	5	4	16	23	73	42

- How much **Atlantis Goods** were needed to make **Atlantis Goods**?
- How much **Zembla Goods** were input to make **Laputa Agriculture**?

Multi-Region EEIO table *Dummy Data* ***Y***

Y

		Atlantis		Laputa		Zembla	
		Expenditures	Investmentss	Expenditures	Investmentss	Expenditures	Investmentss
Atlantis	Agriculture	49	0	26	0	8	0
	Goods	172	79	46	98	57	116
	Services	278	34	56	12	78	14
Laputa	Agriculture	84	8	152	27	150	16
	Goods	94	18	182	18	154	26
	Services	15	0	52	0	111	0
Zembla	Agriculture	0	0	0	0	0	96
	Goods	85	35	42	22	198	36
	Services	57	16	15	4	225	46

- How much **Zembla Expenditures** on **Atlantis Services**
- How much **Laputa Investments** in **Laputa Goods?**

Multi-Region EEIO table *Dummy Data Q*

Q_Z

	Atlantis			Laputa			Zembla		
	Agriculture	Goods	Services	Agriculture	Goods	Services	Agriculture	Goods	Services
kg CO2	40	59	55	49	59	70	72	74	95
kg CH4	22	16	25	23	22	25	1	6	11
kg N2O	1	3	3	5	13	25	12	15	21
kg HCFC-22	3	4	3	3	1	4	2	2	1
m3 blue water	126	15	35	5	22	2	8	4	15
m3 green water	320	-	-	-	-	-	-	-	-
km2 crop land	247	-	-	-	-	-	-	-	-
km2 forest land	524	-	-	-	-	-	-	-	-

- **kg CO2** from **Laputa Goods?**
- **m3 blue water** for **Zembla Services?**

Single Region vs Multi Region EEIO

Single Region EEIO (EE-SRIO)

- One country/region
- Imports & Exports balanced in **Y** columns
- Some Pros & Cons:
  - -Domestic technology assumption: Assumes all products made using that region's technology
  - + Often have detailed sectors
  - + Often detailed environmental data
  - - Environmental data from national reporting

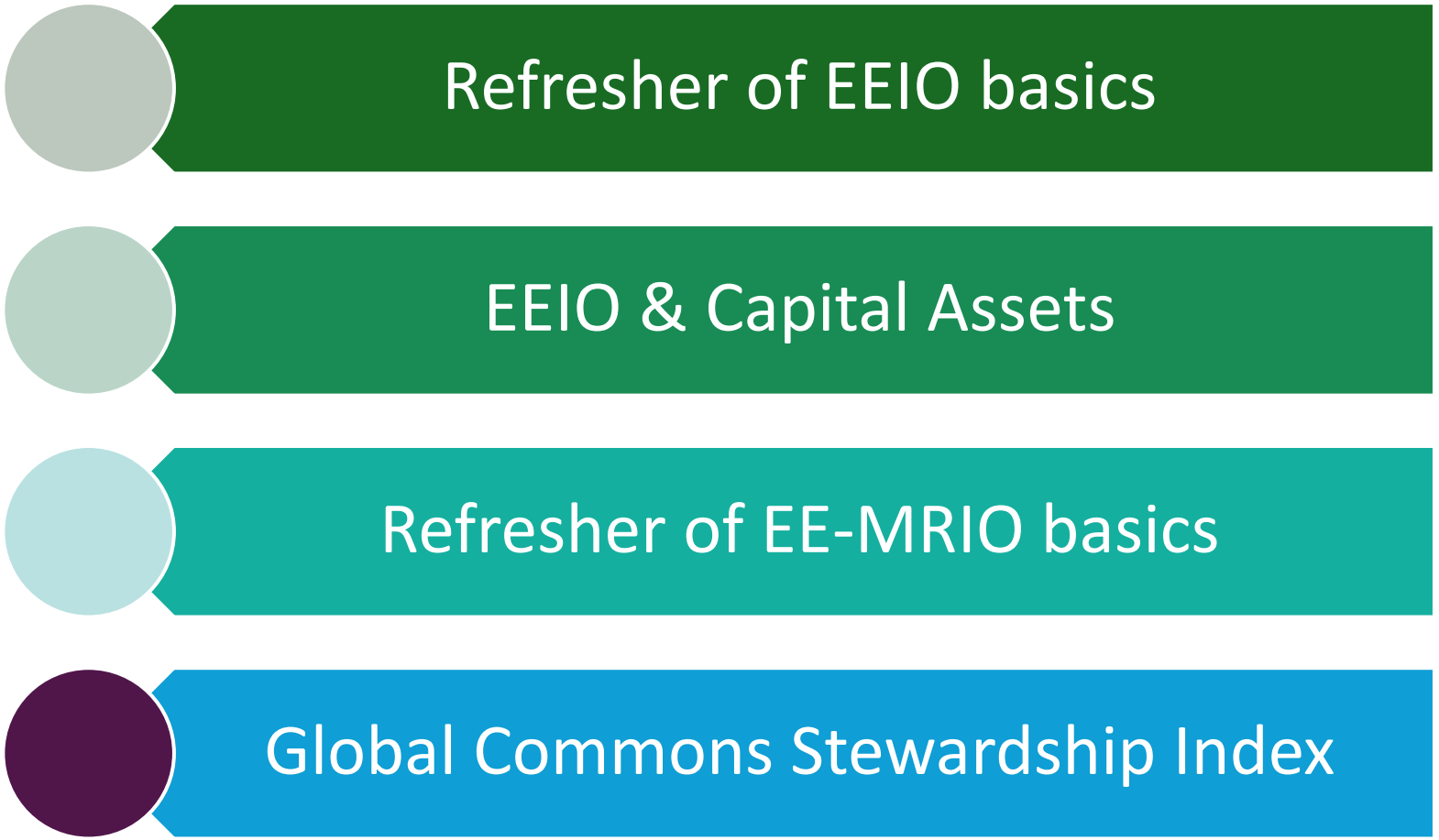
Multi Region EEIO (EE-MRIO)

- Multiple countries/regions
- Imports & Exports represented as trade between country-sectors
- Some Pros & Cons
  - + Trace along global supply chains
  - + Assumes products made with the technology in each region
  - ~ Sector detail varies with model
  - ~ Environmental data modeled with multi-regional datasets

Comparison of available EE-MRIO models

	EXIOBASE v3	GLORIA	EORA	WIOD	GTAP 10
# Sectors	**200 common**	97 common	• 26 common • 26 – 511	56 common	65 common
# Regions	**44 countries + 5 RoW**	160 countries + 4 RoW	189 countries	43 countries + 1 RoW	121 countries + 20 RoW
Environmental Satellites	**Many**	Several	Many through 2016	Several	Several
Years	**1995-2022**	1990-2021	1990-2021	2000-2014 (closed)	2004, 2007 , 2011, 2014
Provided by	**NTNU, free**	IELab, license	KGM Assoc., $	Univ. of Groningen	Purdue, $
Site	**exiobase.eu**	ielab.info/ analyse	worldmrio.com	wiod.org	gtap.agecon. purdue.edu

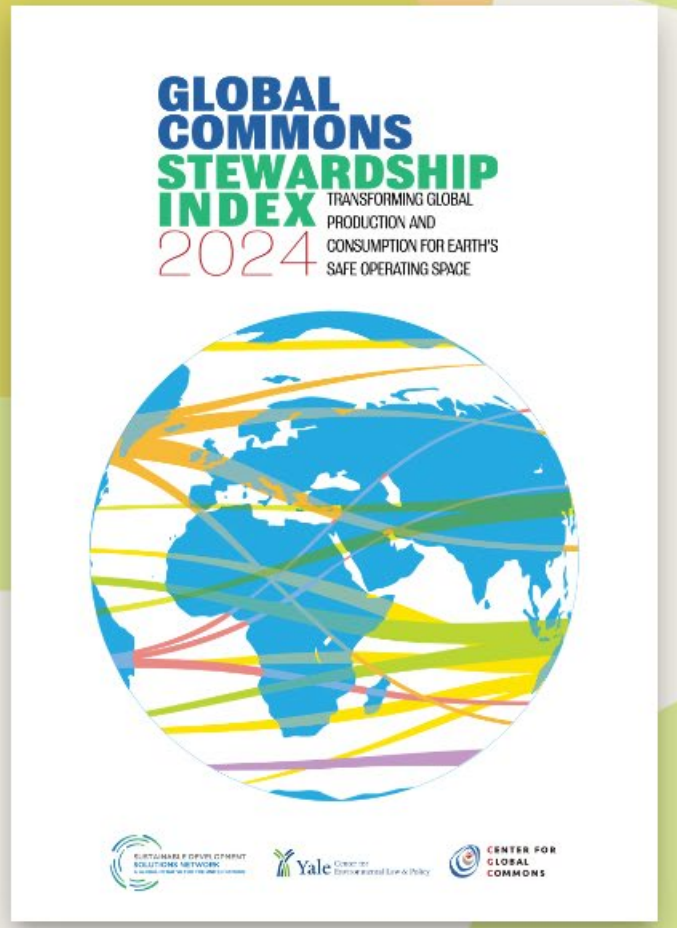
Overview


Refresher of EEIO basics
EEIO & Capital Assets
Refresher of EE-MRIO basics
Global Commons Stewardship Index

GLOBAL COMMONS STEWARDSHIP INDEX 2024

Executive Summary | Map | Profiles | Rankings | Downloads

gcsi.unsdsn.org



Global Commons Stewardship Index 2024

Transforming global production and consumption for earth's safe operating space

READ REPORT | EXPLORE DATA

GCS INDEX 2024

Proportional Overall score

Legend

Click on a country to see its performance.

- 95 - 100
- 90 - 95
- 80 - 90
- 70 - 80
- 50 - 70
- 30 - 50
- 0 - 30
- Information unavailable

Displaying Proportional Scores

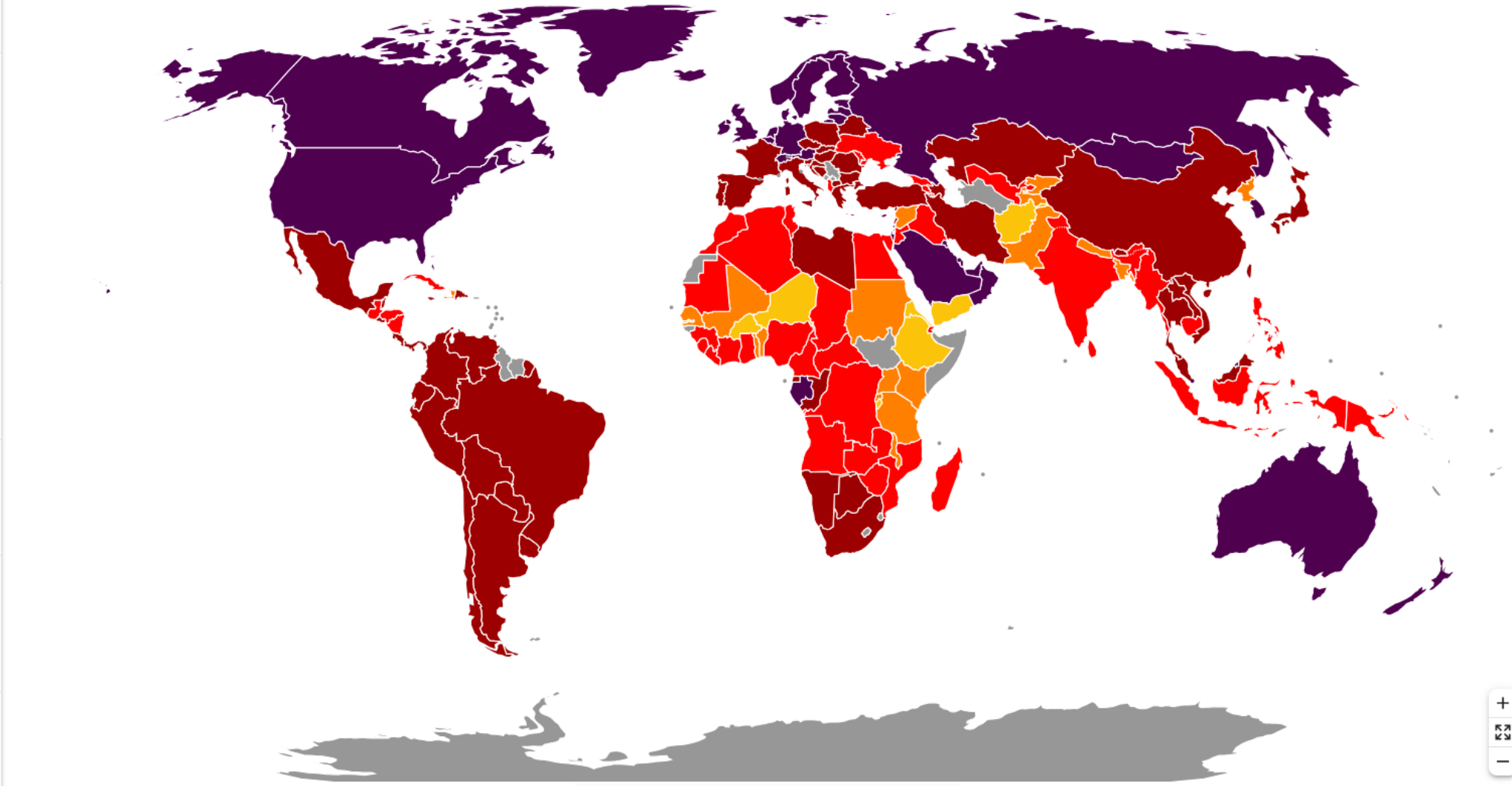
These scores are calculated using indicators that are standardized to allow cross-country comparison, regardless of country size. Some impacts are directly measured in proportional terms, and others are denominated by population size.

Displaying Ratings

Each score is classified with a color that communicates on an ordinal scale the extent to which a country is impacting the Global Commons, from "none or limited" to "extreme."

Description

These scores combine the impacts of each country on the Global Commons resulting from activities within their territorial borders (Domestic) and embodied in imports for final consumption (Spillover).



Canada

OECD member

OVERVIEW | INDICATORS

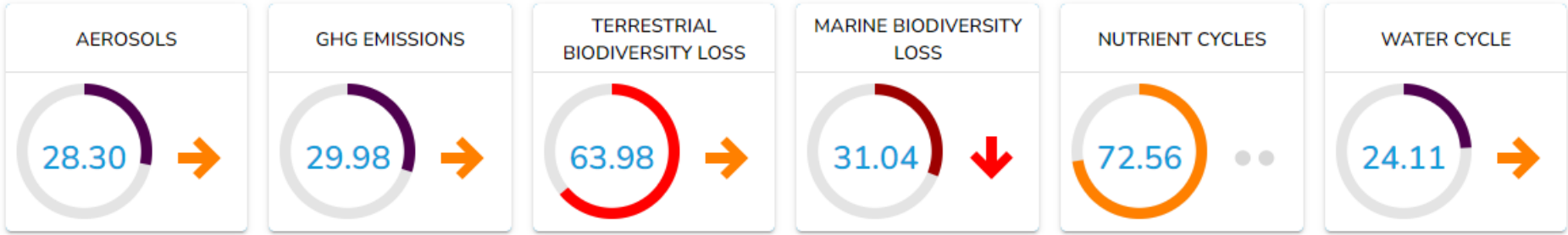
Overall

OVERALL ABSOLUTE SCORE	OVERALL PROPORTIONAL SCORE
22.77 →	13.74 →

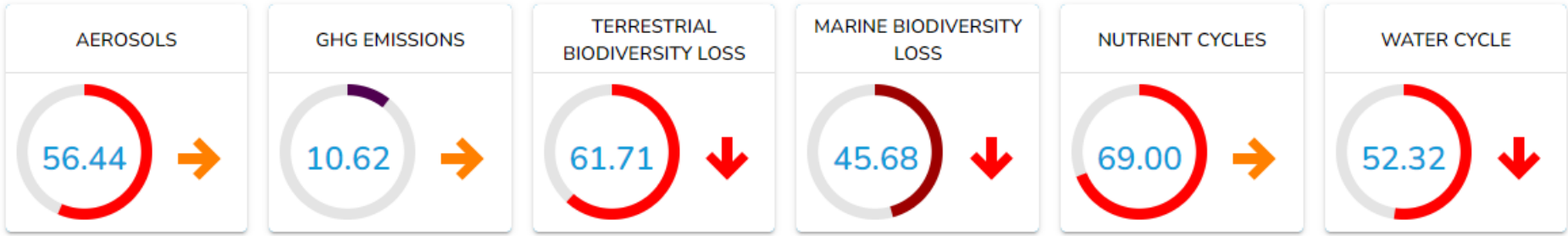
Pillars

PILLAR ABSOLUTE SPILLOVER SCORE	PILLAR PROPORTIONAL SPILLOVER SCORE	PILLAR ABSOLUTE DOMESTIC SCORE	PILLAR PROPORTIONAL DOMESTIC SCORE
32.15 →	22.08 →	16.13 →	8.55 →

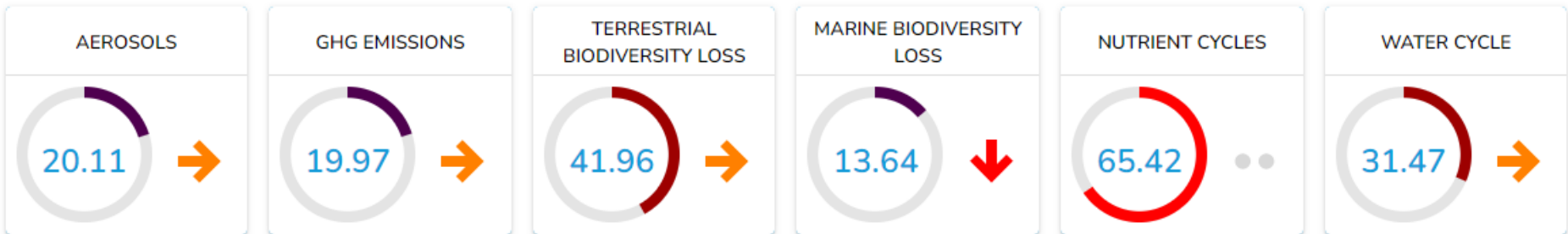
Absolute Spillover Parameters



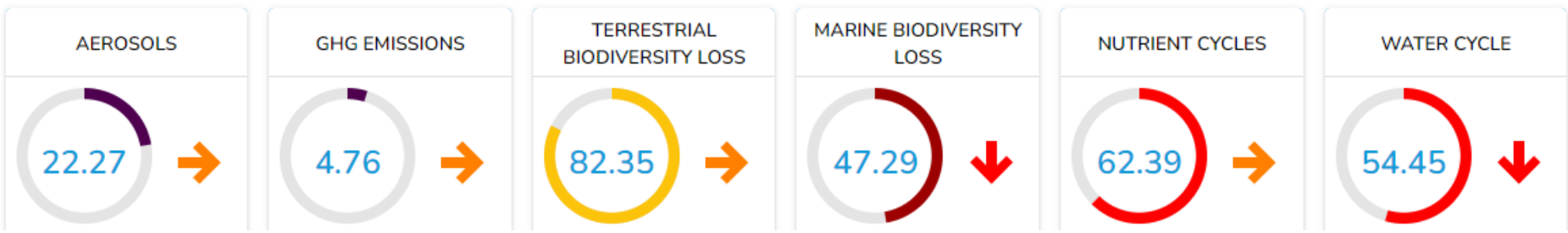
Absolute Domestic Parameters



Proportional Spillover Parameters



Proportional Domestic Parameters



GCS Index

Reed Miller

EcoBalance 2022

Yale Center for Environmental Law & Policy

envirocenter.yale.edu/our-work/projects/global-commons-stewardship-index

Overview

Purpose of composite environmental indices

Structure of GCS Index

Excerpt of GCS Index 2021 Results

Updates for GCS Index 2022

GCSI is latest in evolution of environmental indices

Indices influence nations to improve policies

THE JORDAN TIMES

Home | Local | Region | World | Business | Sports | Features | Opinion

Home » Local » Jordan ranks 3rd in region on Yale Environmental Performance Index

Jordan ranks 3rd in region on Yale Environmental Performance Index

By Rana Tayseer - Sep 06,2022 - Last updated at Sep 06,2022

THE HINDU

MENU TODAY'S PAPER | NEWS | OPINION | BUSINESS | SPORT | ENTERTAINMENT | CROSSWORD+

SCI-TECH | SCIENCE | TECHNOLOGY | HEALTH | AGRICULTURE | ENVIRONMENT | GADGETS

SCI-TECH > ENVIRONMENT

ENVIRONMENT

Explained | Why is India ranked at the bottom of the 2022 Environmental Performance Index?

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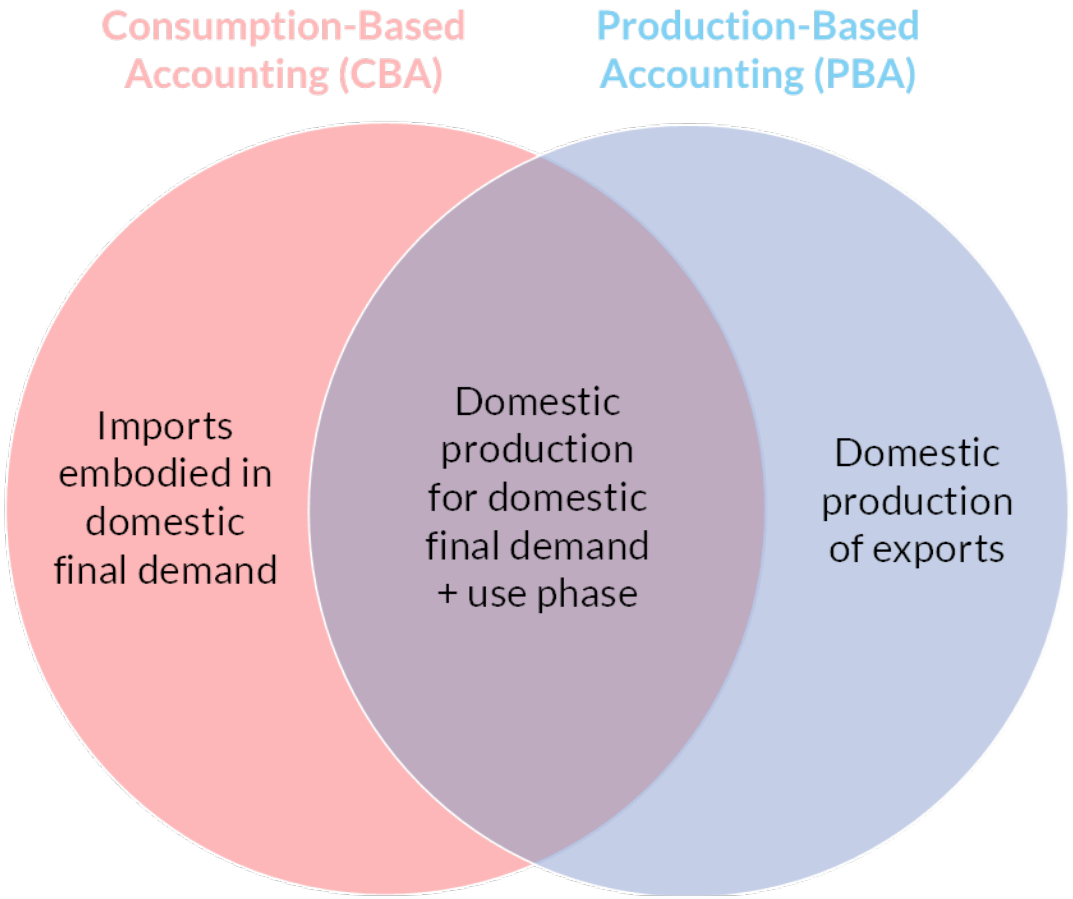
Index accounts for consumption *and* production

- Countries are rated on:
  - Impacts along global supply chain
  - What happens inside their country
- Spillover Pillar comes from consumption-based accounting
- Domestic Pillar based on production-based accounting



Index accounts for consumption *and* production

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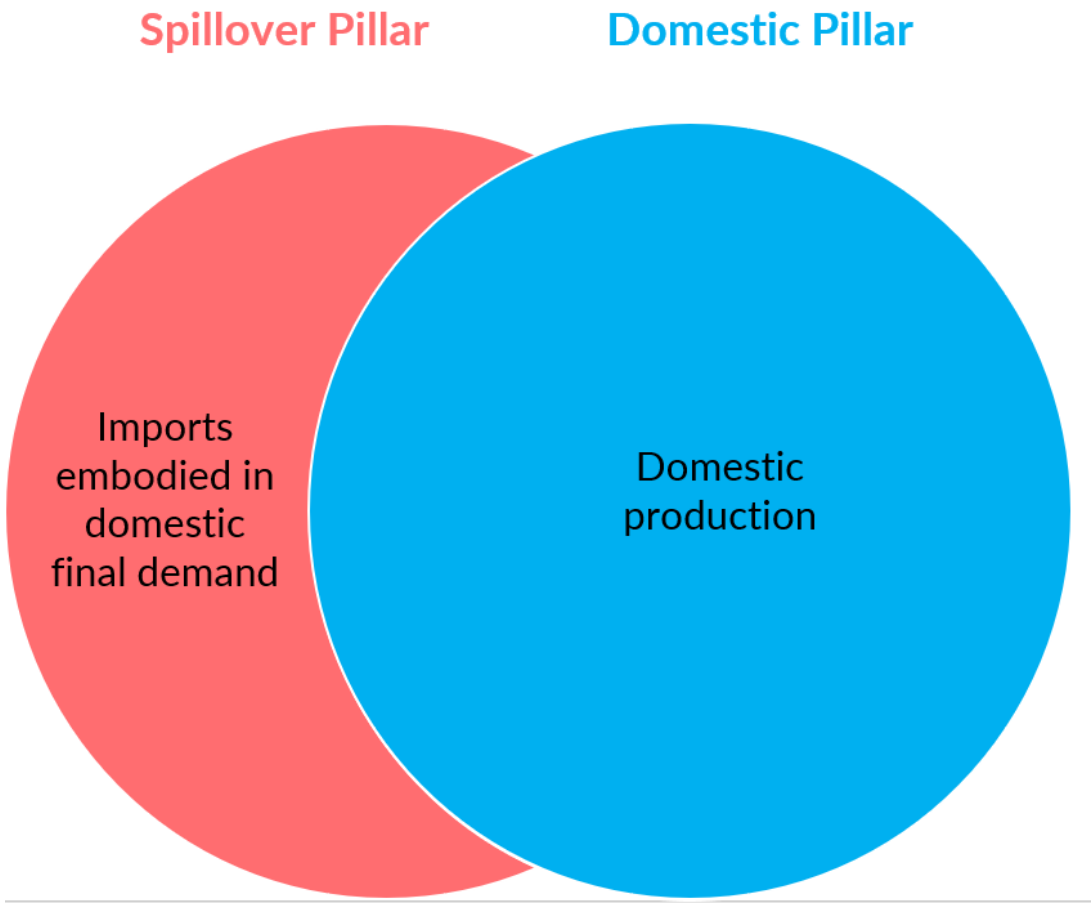
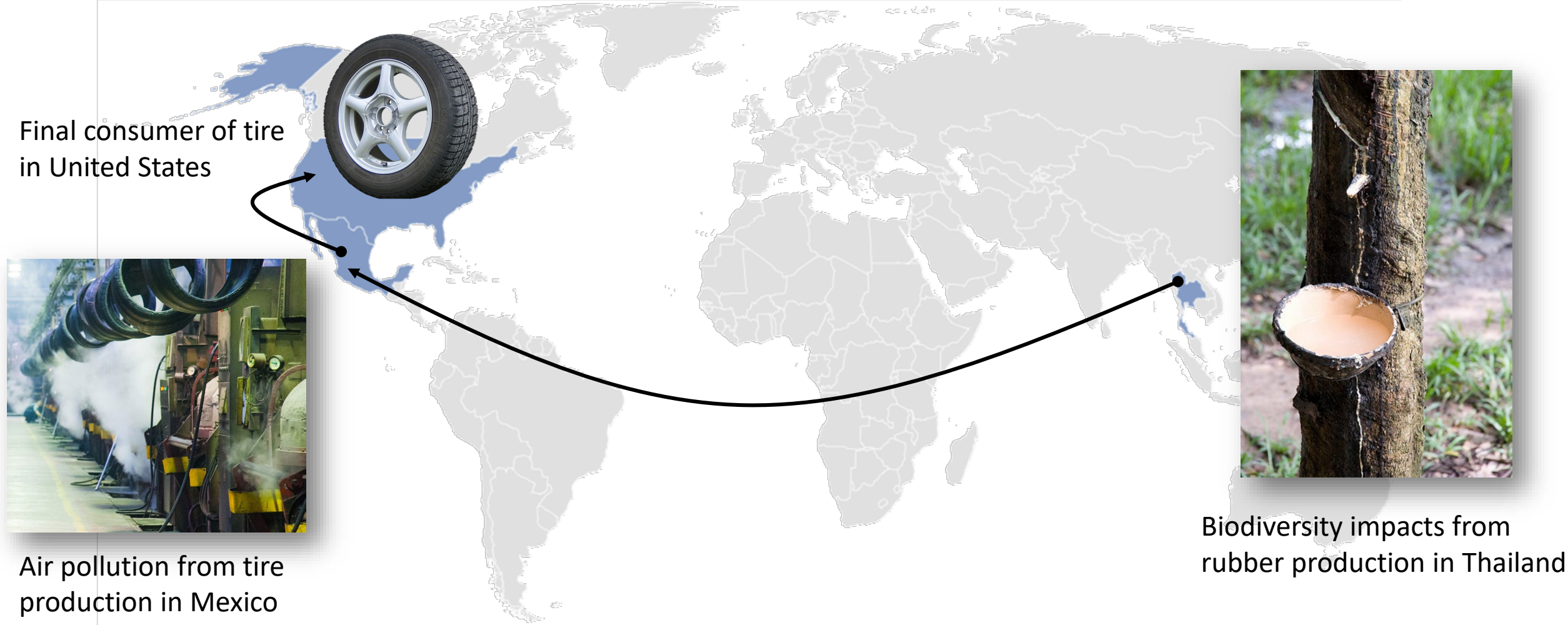


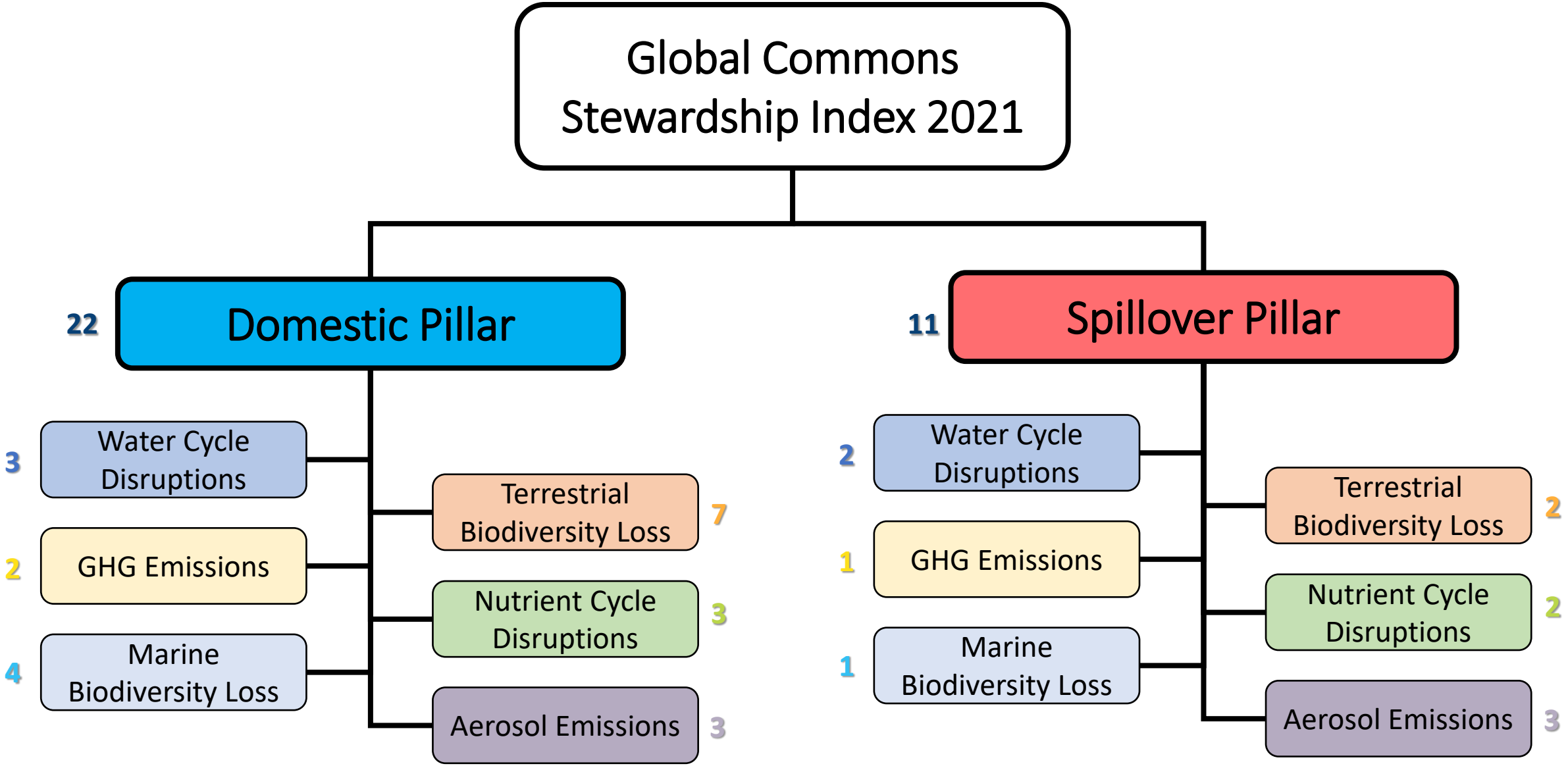
Example of Transboundary Spillover



Final consumer of tire in United States

Air pollution from tire production in Mexico

Biodiversity impacts from rubber production in Thailand


Global Commons Stewardship Index 2021
22
Domestic Pillar
11
Spillover Pillar
3
Water Cycle Disruptions
2
GHG Emissions
4
Marine Biodiversity Loss
Terrestrial Biodiversity Loss
7
Nutrient Cycle Disruptions
3
Aerosol Emissions
3
2
Water Cycle Disruptions
1
GHG Emissions
1
Marine Biodiversity Loss
Terrestrial Biodiversity Loss
2
Nutrient Cycle Disruptions
2
Aerosol Emissions
3

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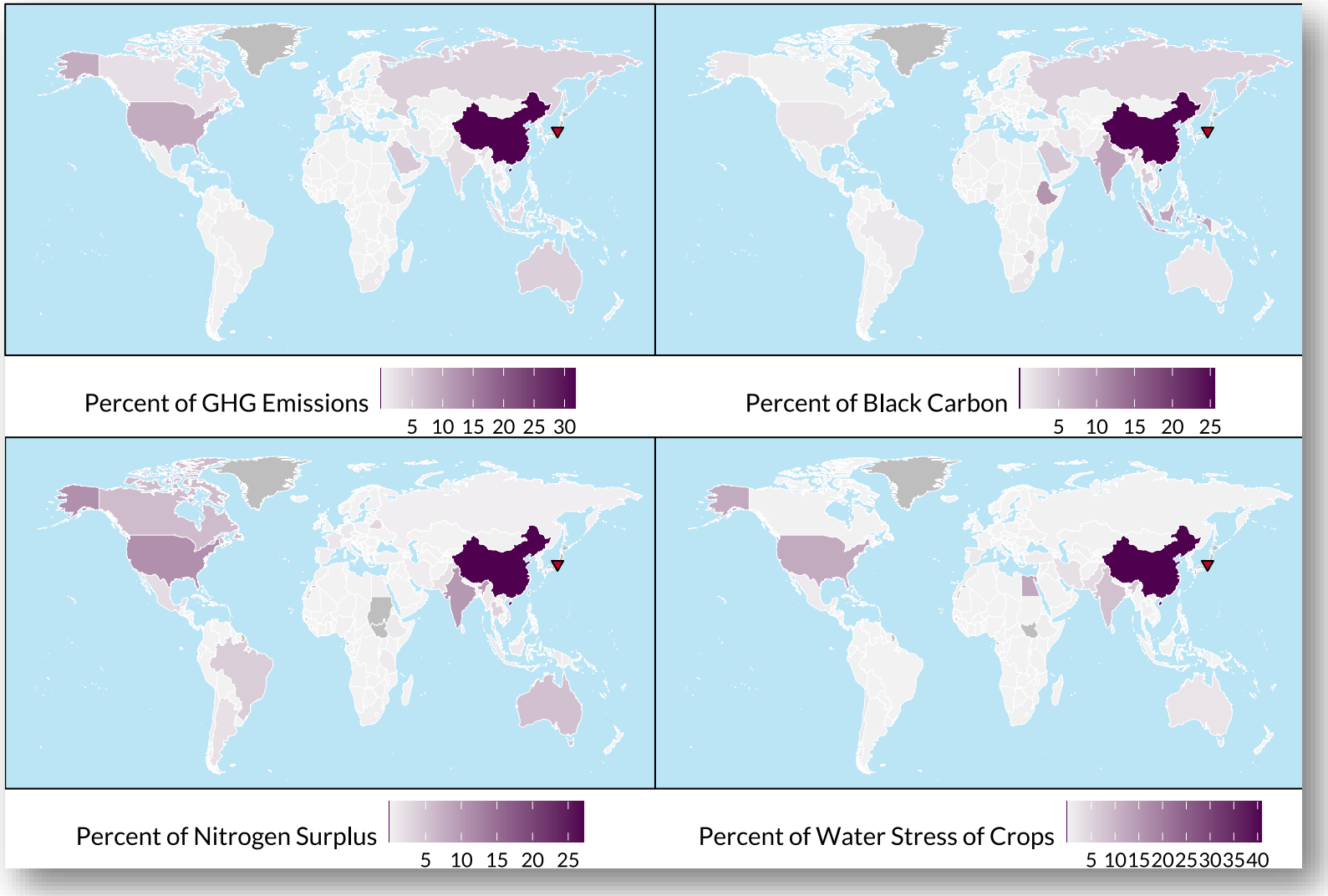
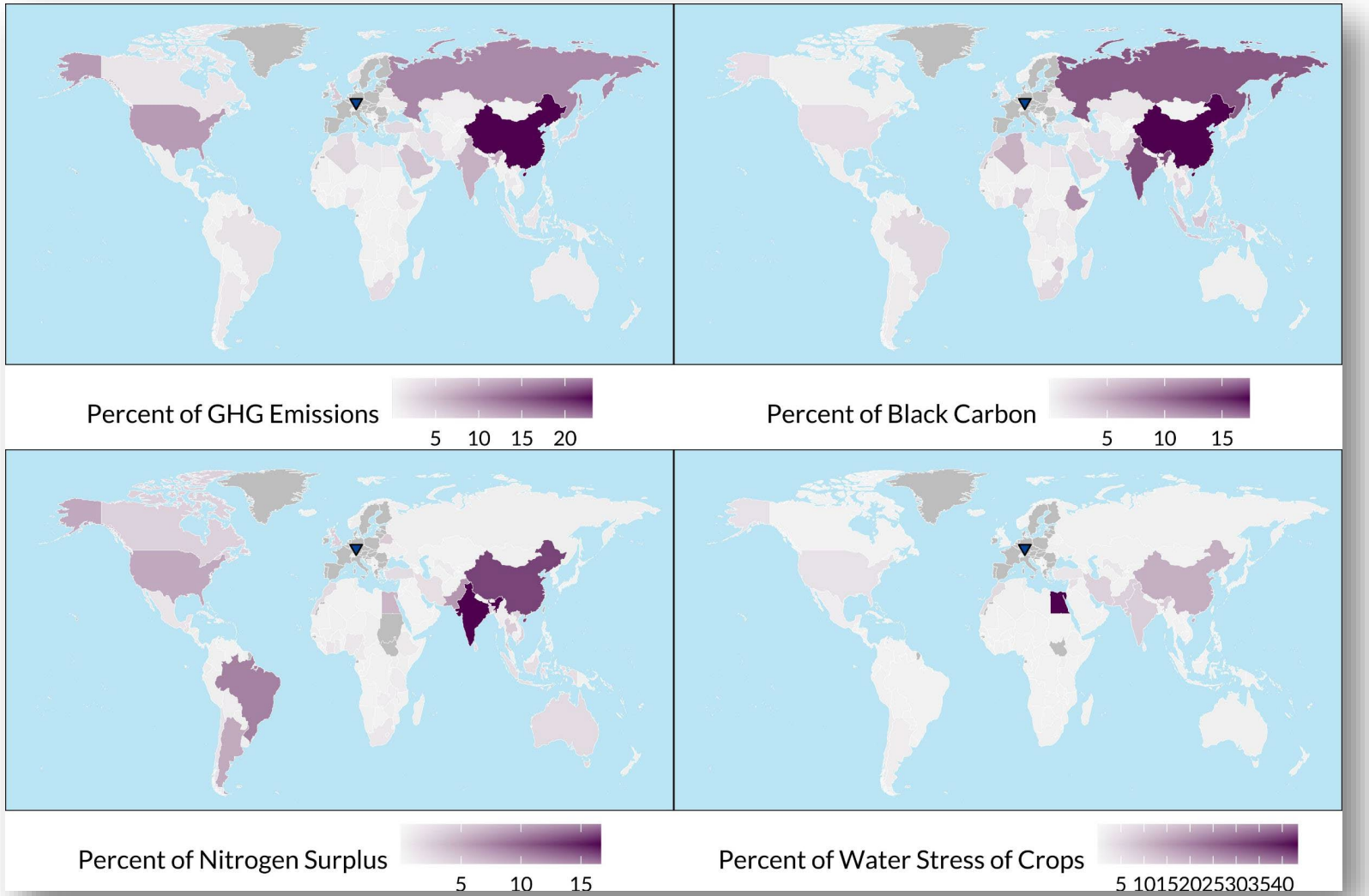
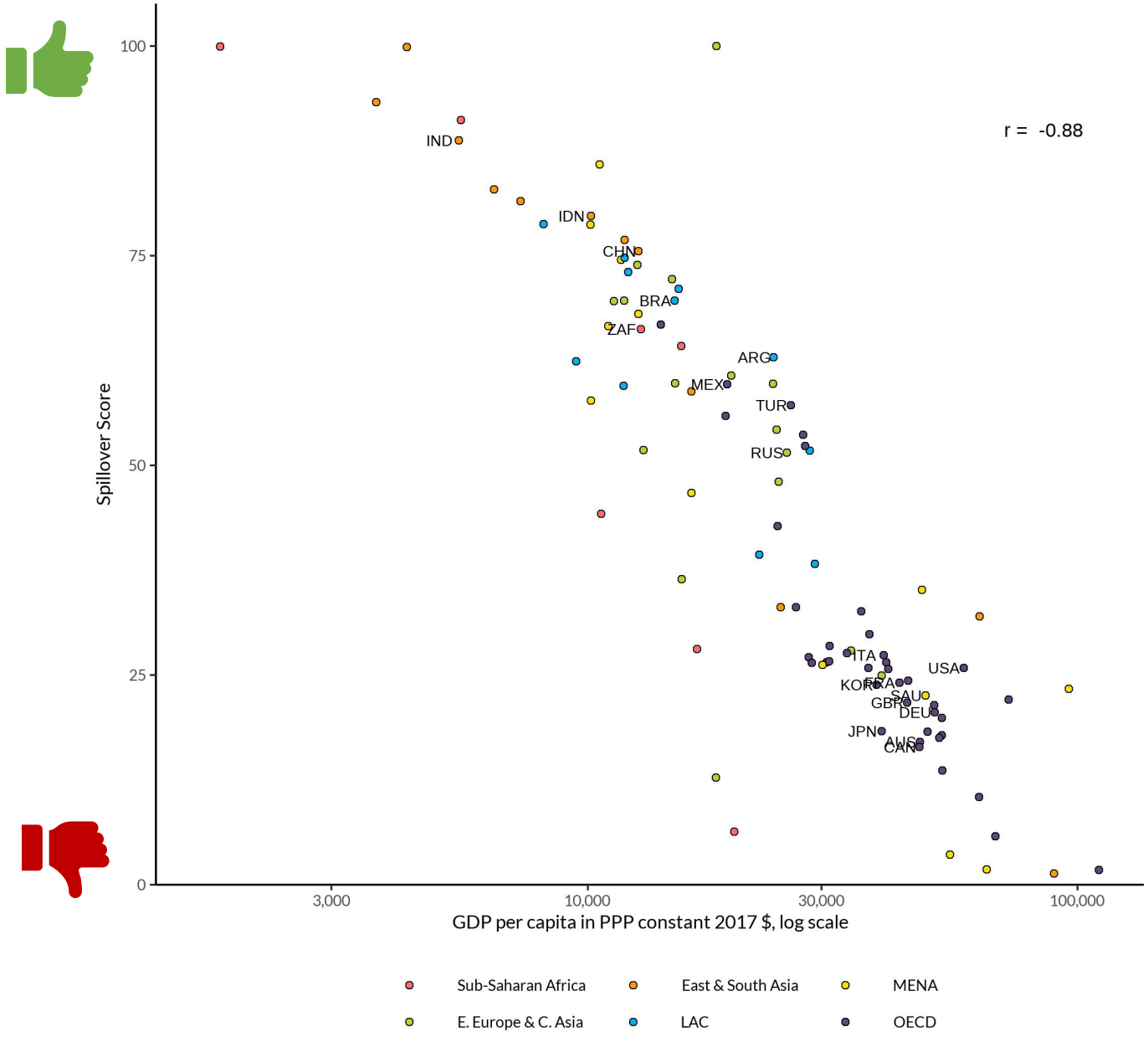
Japan Spillovers



EU27 Spillovers

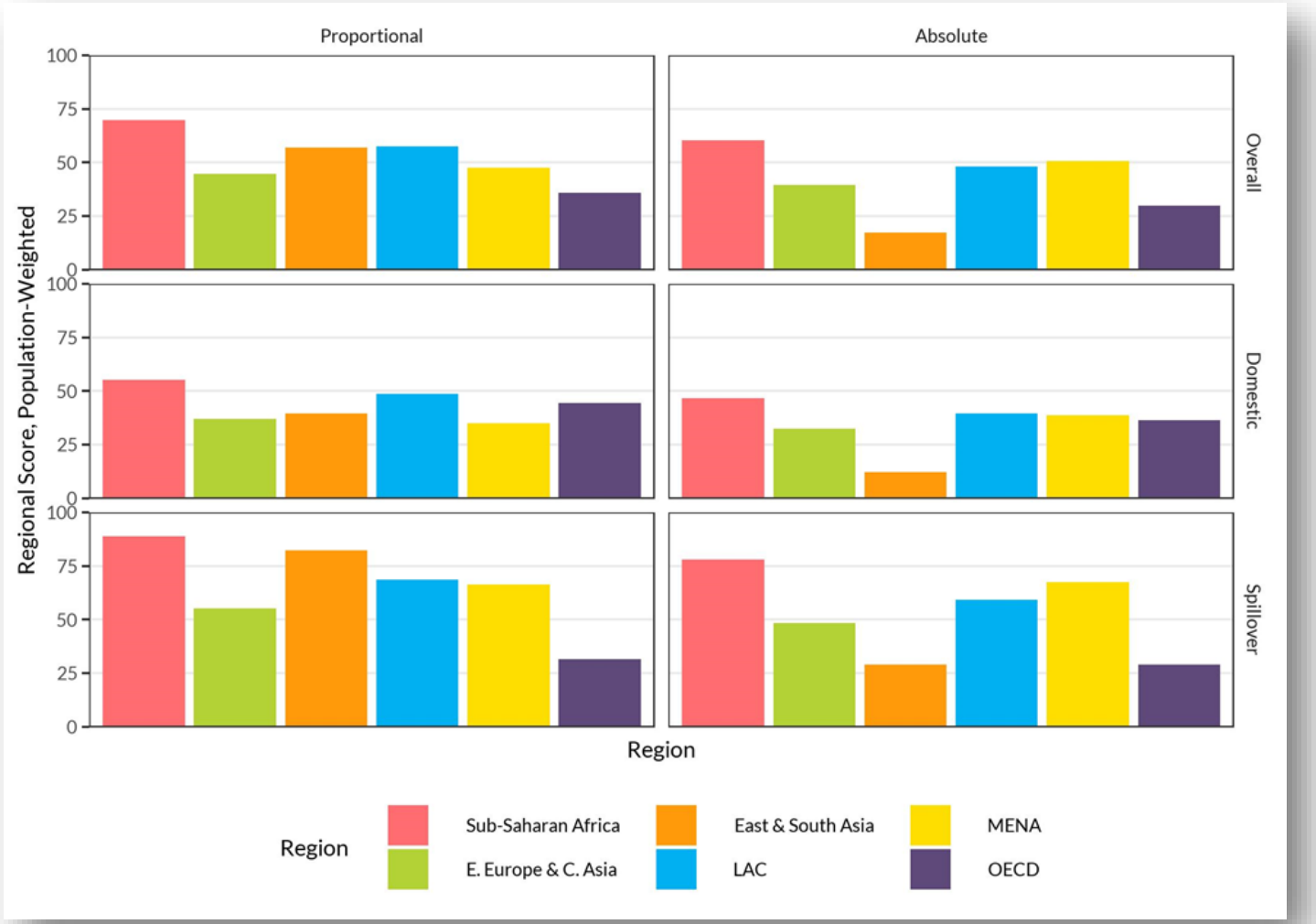


Spillover Score versus GDP per Capita



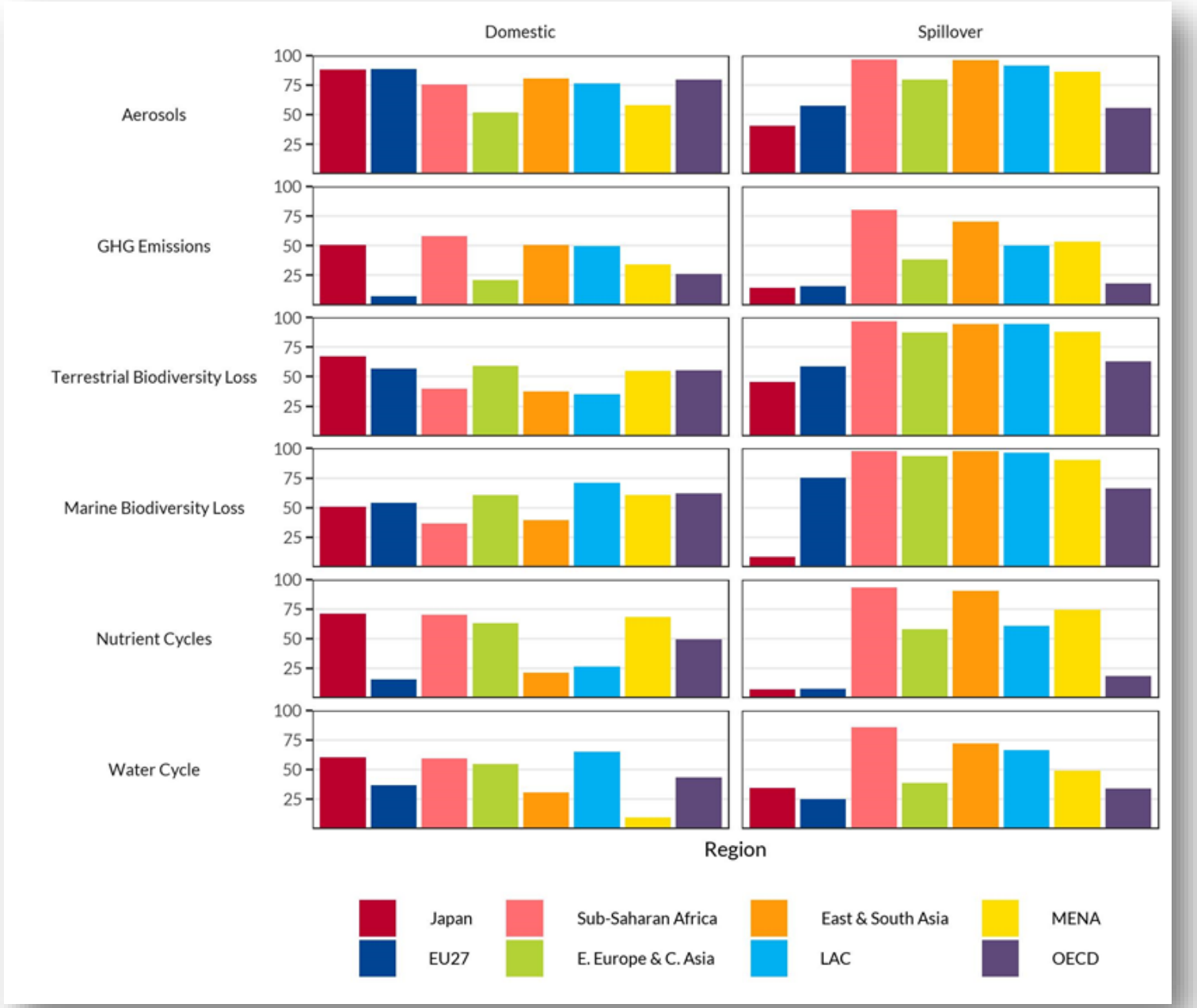
Regional Scores: Pillar

- Lower scores = Worse
- OECD performs poorly
- East & South Asia poor absolute, decent per capita



Regional Scores: Pillar + Subpillar

- Regional Scores vary widely across Pillar and Subpillar
- Regions need to focus effort on different areas for improvement



Country Scores Comparison

Table 4. Bottom 20 countries in the 2021 GCS Index in absolute terms.

Country	Overall		Domestic		Spillover	
Iran		→	33.4	→	58.7	→
Turkey		→	36.1	→	47.8	→
Spain		→	44.0	→	37.6	→
Korea, Rep.		→	49.3	→	32.5	→
Italy		→	48.2	→	31.2	→
France		→	55.5	→	25.6	→
Mexico		→	29.6	→	47.1	→
Saudi Arabia		→	34.4	→	38.5	→
Canada		→	36.7	→	35.1	→
Australia		→	23.0	→	50.6	→
United Kingdom		→	48.7	→	23.0	→
Brazil		→	24.1	→	43.2	→
Indonesia		→	12.1	↓	52.8	→
Germany		→	45.4	→	11.6	→
Russian Federation		→	16.3	→	26.3	→
India		→	4.4	↓	30.6	→
Japan		→	46.2	→	1.3	→
European Union		→	9.1	↓	1.0	→
United States		→	7.8	→	1.0	→
China		↓	4.5	↓	1.0	↓

- Scores based on distance to target
- Scores combined per Subpillar, then per Pillar
- Arrows indicate trajectory

Country Profiles

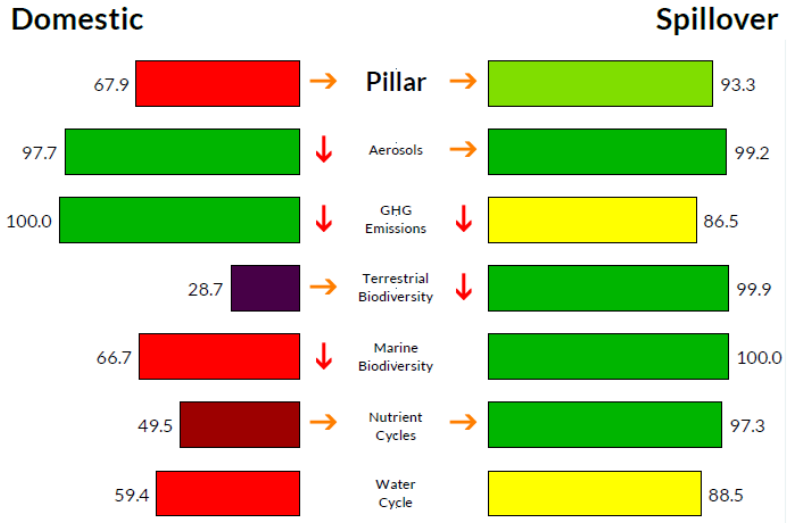
Bangladesh

East & South Asia

Population [millions]	164.7	**GDP** [$, billions]	793.0
Land area [km^2, thousands]	14,030.3	**GDP** per capita	4,815

Overall impact on the Global Commons and trajectory: **Medium-high** →

Impacts and trajectory by pillar and sub-pillar:



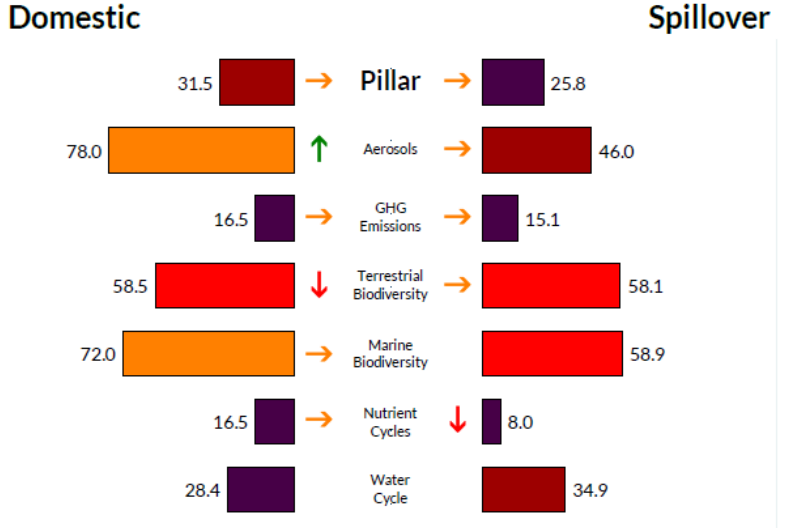
United States

OECD

Population [millions]	333.1	**GDP** [$, billions]	20,000.0
Land area [km^2, thousands]	949,857.1	**GDP** per capita	60,048

Overall impact on the Global Commons and trajectory: **Extreme** →

Impacts and trajectory by pillar and sub-pillar:



Some Key Takeaways

Major transformations are urgently needed in all countries to address negative impacts on the Global Commons generated by unsustainable production and consumption

Rich countries generate the largest share of the international spillovers

Further efforts needed to **decouple socio-economic progress from the negative impacts of the current trading system** on the Global Commons

Persistent **data gaps and limitations** should be addressed for more real-time and forward-looking monitoring of countries' impacts on the Global Commons.

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Updates to GCS Index Features

GCS Index 2021

- 2 pillars
- 33 indicators, year 2015
- 99 countries + EU
- 282 page report
- Launched at Tokyo Forum

GCS Index 2022

- 2 pillars
- 44 indicators, year 2018/2019
- 145 countries + EU
- Special focus on G7
- Product-level results
- Creating data visualization

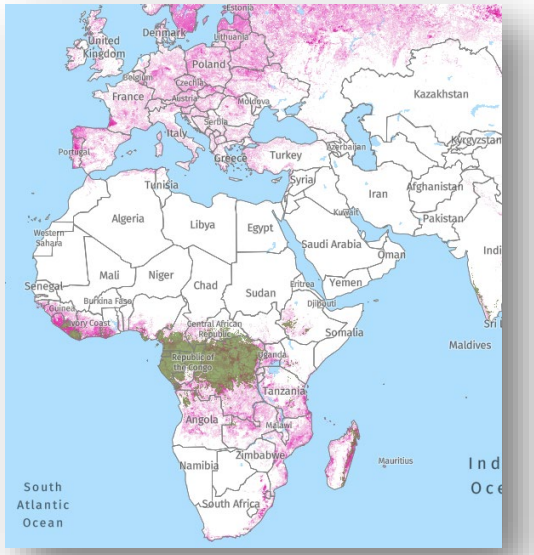
GCSI 2022: New Spillover Indicators

Terrestrial Biodiversity Loss

Marine Biodiversity Loss

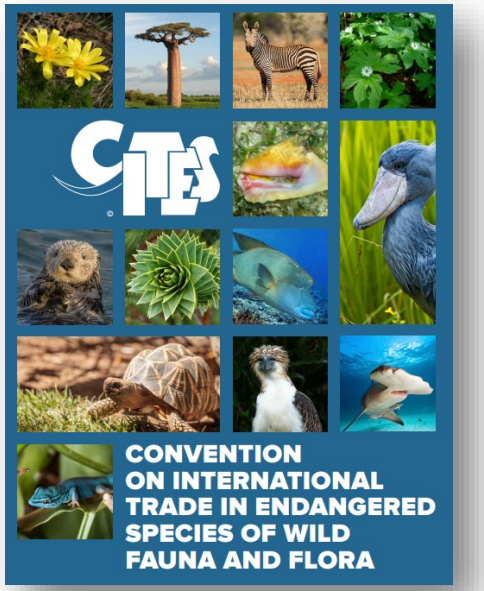
Deforestation

Partnering with WRI Global Forest Watch



Trade in Endangered Species

Trade data from CITES



Marine Fisheries Vulnerability

Partnering with Sea Around US