OSU~EmEA 12:

Emergy Evaluation of Nations

Lecture Outline

- General overview
- Methodology and line item template
- Primary data needs
- Data sources
- Calculations & Transformities
- Summary flows and indices

Overview: National Evaluations

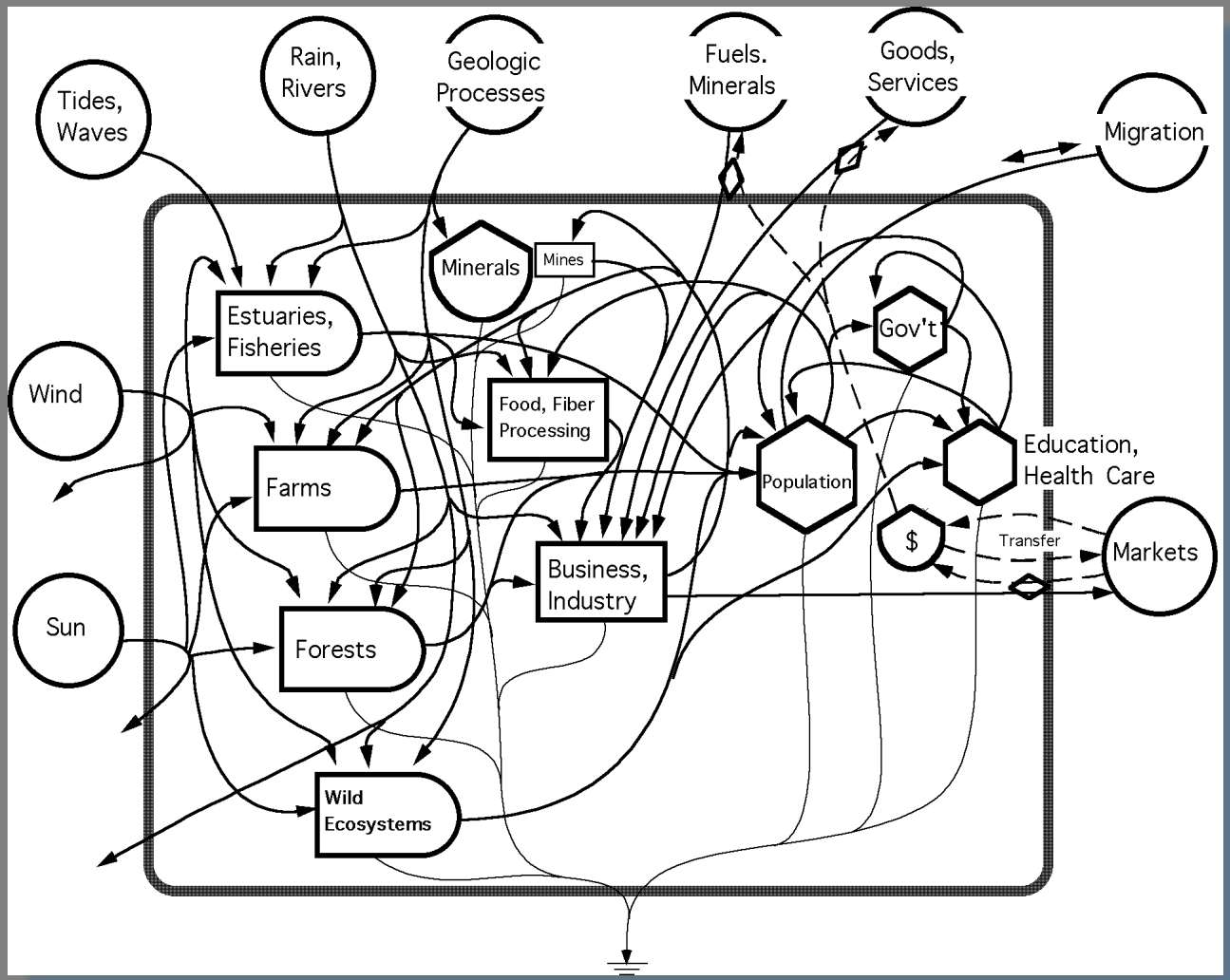
- Emergy evaluation of nations accounts for all major inflows and outflows crossing country boundaries, as well as internal production processes.

- Flows include diffuse flows from the environment (i.e., sun, wind, rain), concentrated flows from mined materials (i.e. metals, fuels, minerals), and purchased materials and services imported from other countries.

- Assumed boundaries:
  - edge of the submarine continental shelf (200m)
  - 1km above the earth and water surface
  - 1 km below the earth surface, or lake or sea floors

- Data are collected to calculate the flows in energy or weight units, transformities are used to convert flows to emergy units, and flows can then be summarized and aggregated into indices.

Systems Diagram: National Evaluations



Generic Table: National Evaluations

	Line Item (flows)	*Data*	*Units* J or g	*UEV* sej/J or sej/g	*Emergy* sej/yr
1.	First item	xx.x	J/yr	xxx.x sej/J	(data*UEV)
2.	Second item	xx.x	g/yr	xxx.x sej/g	(data*UEV)
3.	Third item	xx.x	$/yr	xxx.x sej/$	(data*UEV)
…					
…					
n.	n^{th} item	xx.x	J/yr	xxx.x	(data*UEV)

Foot notes

1. Notes and calculations for item #1
2. Notes and calculations for item #2

....

n. Notes and calculations for n^{th} item

National Evaluation Template:

National Emergy Accounting Database (NEAD)

- Line items for major flows are organized into a table with the following sections:
    1. *Renewable flows*
    2. *Internal Transformations*
    3. *Indigenous Nonrenewable Extraction*
    4. *Imports*
    5. *Exports*

National Evaluation Template:

Line Items – Renewable Flows

Biosphere inputs across Earth boundaries:

1. *Sunlight* – net radiation on land and water surfaces
2. *Deep heat* – heat rising from internal earth processes
3. *Tide* – tidal energy absorbed over continental shelf

Co-products produced within the biosphere that cross country boundaries:

4. *Wind* – kinetic wind energy
5. *Total water* – portion of rain and river inflow used
6. *Waves* – kinetic wave energy absorbed at coastline

National Evaluation Template:

RENEWABLE FLOWS:

1 Sunlight
2 Deep heat
3 Tide
4 Wind
5 Total water
6 Waves

INTERNAL TRANSFORMATIONS (ECONOMIC):

7 Agriculture Production
8 Livestock Production
9 Fisheries Production
10 Fuel wood Production
11 Industrial Round wood Production
12 Water extraction
13 Hydroelectricity
14 Total Electricity

INDIGENOUS NONRENEWABLE EXTRACTION:

15 Forestry
16 Fisheries
17 Water
18 Topsoil losses, organic matter
19 Coal
20 Natural Gas
21 Oil
22 Minerals
23 Metals

IMPORTS:

24 Fuels
25 Metals
26 Minerals
27 Food & agricultural products
28 Livestock, meat, fish
29 Plastics & synthetic rubber
30 Chemicals
31 Finished products
32 Machinery & transportation equipment
33 Other refined goods
34 Electricity
35 Service in imports

EXPORTS:

36 Tourism
37 Food & agricultural products
38 Livestock, meat, fish
39 Finished products
40 Fuels
41 Metals
42 Minerals
43 Plastics & synthetic rubber
44 Chemicals
45 Machinery & transportation equipment
46 Other refined goods
47 Electricity
48 Service in exports

National Evaluation Template:

Data transformation:

raw units > joules or grams > emergy (sej)

- After the primary data are collected, line items are converted into either energy units (joules) or weight units (g), using standardized equations (Odum, 1996, Appendix B).

Recap:

example: Sunlight requires net radiation, country area, and sec./yr.

Solar energy in Joules for "Sunlight"=

(Net radiation J/s/m^2) x (Area m^2) x (31,536,000 seconds/year)

- Once in units of energy or weight, *UEVs* are then used to convert the values to emergy units (sej).

National Emergy Evaluation, Line Item Table for USA 2015

- Primary data are converted to line item flows in energy or weight (J or g), with a detailed notes section documenting data sources and equations used
- Flows are converted to emergy (sej) using UEVs
- Flows in emergy can now be aggregated into *summary flows*

Table 1 is the Line Item Table of energy values, unit emergy values (UEV) and emergy values for all individual line item flows.

#	Line item	Flow	Flow units	UEV	UEV units	Emergy E20 sej/yr	Em$ E6 $/yr
RENEWABLE FLOWS:							
1	Sunlight	1.19e+23	J	1.00E+00	sej/J	1.19e+3	6.40e+4
2	Deep heat	2.84e+19	J	4.90E+03	sej/J	1.39e+3	7.47e+4
3	Tide	5.37e+18	J	3.09E+04	sej/J	1.66e+3	8.92e+4
4	Wind	9.88e+20	J	5.20E+02	sej/J	5.14e+3	2.76e+5
5	Total water	varies	J	varies	sej/J	6.50e+3	3.49e+5
6	Waves	5.75e+18	J	4.13E+03	sej/J	2.38e+2	1.28e+4
INTERNAL TRANSFORMATIONS (ECONOMIC):							
7	Agriculture Production	8.82e+18	J	varies	sej/J	1.19e+4	6.40e+5
8	Livestock Production	6.66e+17	J	varies	sej/J	8.15e+3	4.38e+5
9	Fisheries Production	5.04e+13	J	1.01E+07	sej/J	5.07e+0	2.73e+2
10	Fuelwood Production	2.79e+17	J	varies	sej/J	8.91e+1	4.79e+3
11	Industrial Roundwood Production	2.21e+18	J	varies	sej/J	8.53e+2	4.59e+4
12	Water extraction	2.40e+18	J	1.85E+05	sej/J	4.44e+3	2.39e+5
13	Hydroelectricity	8.97e+17	J	3.52E+05	sej/J	3.16e+3	1.70e+5
14	Total Electricity	1.40e+19	J	2.21E+05	sej/J	3.11e+4	1.67e+6
INDIGENOUS NONRENEWABLE EXTRACTION:							
15	Forestry	-	J	3.83E+04	sej/J	0	-
16	Fisheries	1.85e+13	J	1.01E+07	sej/J	1.85e+0	9.95e+1
17	Water	-	J	2.11E+05	sej/J	0	-
18	Topsoil loss, organic matter	0	J	varies	sej/J	8.65e+3	4.65e+5
19	Coal	1.99e+19	J	6.70E+04	sej/J	1.34e+4	7.20e+5
20	Natural Gas	2.93e+19	J	1.40E+05	sej/J	4.11e+4	2.21e+6
21	Oil	3.38e+19	J	1.32E+05	sej/J	4.47e+4	2.40e+6
22	Minerals	3.47e+14	g	varies	sej/g	8.90e+2	4.78e+4
23	Metals	1.60e+14	g	varies	sej/g	1.28e+3	6.88e+4
IMPORTS:							
24	Fuels	varies	J	varies	sej/J	3.66e+4	1.97e+6
25	Metals	varies	g	varies	sej/g	1.03e+4	5.54e+5
26	Minerals	varies	g	varies	sej/g	1.17e+3	6.29e+4
27	Food & agriculture products	varies	J	varies	sej/J	1.43e+3	7.69e+4
28	Livestock, meat, fish	varies	J	varies	sej/J	5.43e+2	2.92e+4
29	Plastics & synthetic rubber	varies	g	varies	sej/g	5.36e+3	2.88e+5
30	Chemicals	varies	J	varies	varies	1.44e+3	7.74e+4
31	Finished products	varies	J	varies	varies	1.43e+3	7.69e+4
32	Mach. & trans equip.	varies	J	varies	varies	1.04e+5	5.59e+6
33	Other refined goods	varies	$	1.33e+12	sej/$	7.72e+1	4.15e+3
34	Electricity	2.73e+8	J	2.21E+05	sej/J	6.03e+2	3.24e+4
35	Service in imports	2.31e+12	$	1.33e+12	sej/$	3.08e+4	1.66e+6
EXPORTS:							
36	Fuels	varies	J	varies	sej/J	3.49e+4	1.88e+6
37	Metals	varies	g	varies	sej/g	4.66e+3	2.51e+5
38	Minerals	varies	g	varies	sej/g	3.64e+2	1.96e+4
39	Food & ag. products	varies	J	varies	sej/J	4.03e+3	2.17e+5
40	Livestock, meat, fish	varies	J	varies	sej/J	1.43e+3	7.69e+4
41	Plastics & synthetic rubber	varies	g	varies	sej/g	1.08e+4	5.81e+5
42	Chemicals	varies	J	varies	varies	1.73e+3	9.30e+4
43	Finished products	varies	J	varies	varies	1.77e+3	9.52e+4
44	Mach. & trans equip.	varies	J	varies	varies	7.39e+4	3.97e+6
45	Other refined goods	varies	$	1.86e+12	sej/$	8.54e+1	4.59e+3
46	Electricity	3.28e+7	J	2.21E+05	sej/J	7.25e+1	3.90e+3
47	Service in exports	1.50e+12	$	1.86e+12	sej/$	2.80e+4	1.51e+6
48	Tourism	2.46e+11	$	1.86e+12	sej/$	4.58e+3	2.46e+5

National Evaluation Template:

Aggregated Summary Flows, USA 2015

Table 2 is the Summary Flow Table of emergy flows aggregated from the individual line item flows.

Flow	Description	Units	Calculation	Value
R	Renewable Emergy Flow	sej	largest land flow + largest continental shelf flow	8.46e+23
N	Total Nonrenewable Emergy Flow	sej	sum of line items 15 to 23	1.10e+25
N0	Dispersed Nonrenewable Production	sej	sum of line items 15 to 18	8.65e+23
N1+N2	Concentrated Nonrenewable Production	sej	sum of line items 19 to 23	1.01e+25
N1	Concentrated Nonrenewable Use	sej	(N1+N2)-N2	9.93e+24
N2	Nonrenewable Flow - Exported without Use	sej	N2(f) - N2(m)	1.99e+23
N2(f)	Fuels Exported Without Use	sej	unrefined portion of line item 36	1.57e+23
N2(m)	Mineral & Metal Exported Without Use	sej	unrefined portion of line items 37 and 38	4.15e+22
F(i)	Fuels, Metals and Minerals Imports	sej	sum of line items 24 to 26	4.81e+24
G(i)	Goods and Electricity Imports	sej	sum of line items 27 to 34	1.15e+25
I	Money ($) for Imports	$	line item 35	2.31e+12
P2I	Imported Services	sej	line item 35	3.08e+24
F(e)	Fuels, Metals and Minerals Exports	sej	sum of line items 36 to 38	3.99e+24
G(e)	Goods and Electricity Exports	sej	sum of line items 39 to 46	9.39e+24
E	Money ($) for Exports	$	line item 47	1.50e+12
P1E	Exported Services	sej	line item 47	2.80e+24
X	Gross Domestic Product (GDP)	$	Reported Data	1.67e+13
P2	World Emergy Money Ratio (EMR)	sej/$	(biosphere inputs + global N1)	1.33e+12
P1	National Emergy Money Ratio (EMR)	sej/$	Total Emergy Used / GDP	1.86e+12
AREA	Total Land Area	sq. meters	Reported Data	9.16e+12
POP	Total Population	#	Reported Data	3.21e+8

National Evaluation Template:

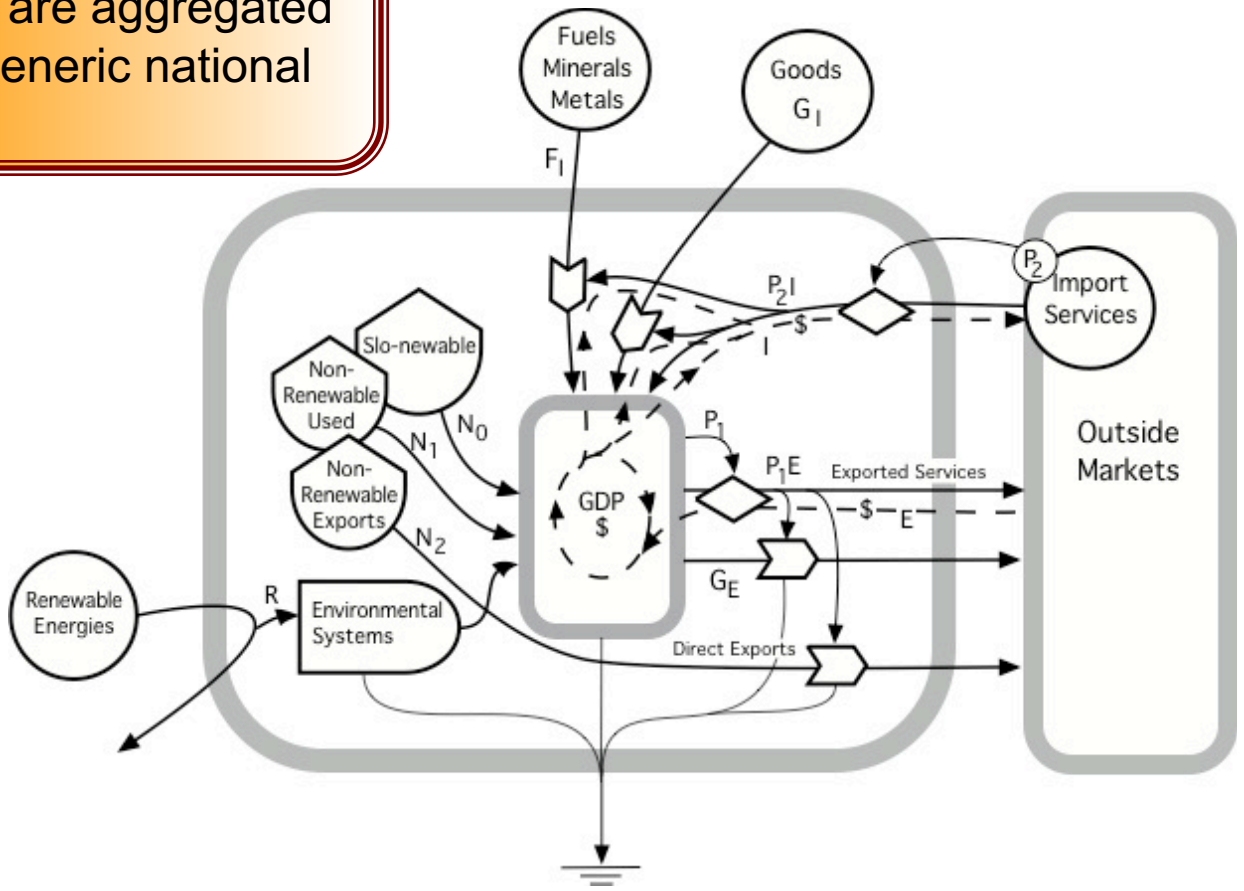
Emergy indices, USA 2015

Table 3 is the Emergy Indices Table, containing indices respresenting various aspects of system condition

Item	Index Name	Units	Calculation*	Value
1	Total Emergy Used (U)	sej	R + N0 + N1 + IMP	3.10e+25
2	Total Imported Emergy (IMP)	sej	F(i) + G(i) + modified P2I	1.94e+25
3	Total Exported Emergy (EXP)	sej	F(e) + G(e) + modified P1E + tourism	1.62e+25
4	Imports minus Exports	sej	IMP - EXP	2.91e+24
5	Imports to Exports	-	IMP / EXP	1.18e+0
6	Imports to Exports (excl. services)	-	[F(i) + G(i)] / [F(e) + G(e)]	1.22e+0
7	Empower Density (Use per Area)	sej/m^2	U / Area	3.39e+12
8	Use per Capita	sej/capita	U / Population	9.66e+16
9	Renewable Flow per Capita	sej/capita	R /Population	2.63e+15
10	Non-Renewable Flow per Capita	sej/capita	N'/Population (N'=N1+Soil Loss)	3.36e+16
11	Total Fuel Use	sej	Production + Imports - Exported without Use	1.34e+25
12	Fuel Use per Capita	sej/capita	Total Fuel Use/Population	4.17e+16
13	Emergy Investment Ratio (EIR)	-	IMP / (R+N0+N1)	1.67e+0
14	Environmental Loading Ratio (ELR)	-	(IMP+N0+N1) / R	3.57e+1
15	Emergy Yield Ratio (EYR)	-	Total Use / (N0+N1+IMP)	1.60e+0
16	Emergy Sustainability Index (ESI)	-	EYR / ELR	4.48e-2
17	Exported without Use fraction	-	N2 / EXP	1.49e-2
18	Indigenous fraction	-	(N0 + N1+ R) / Total Use	3.75e-1
19	Renewable fraction	-	R / Total Use	2.73e-2
20	Purchased fraction	-	IMP / Total Use	6.25e-1
21	Imported Service fraction	-	P2I / Total Use	9.91e-2
22	Concentrated:Rural Emergy Use	-	(IMP+N1) / (R+N0)	1.71e+1
23	Electricity fraction	-	Electricity / Total Use	1.00e-1
24	Soil Loss per Area	sej/m^2	Soil loss / Area	9.44e+10
25	Soil Loss fraction	-	Soil loss / Total Use	2.79e-2
26	Water Overuse fraction	-	Water Overuse / Total Use	-
27	Fish Overuse fraction	-	Fish Overuse / Total Use	6.00e-6
28	Deforestation fraction	-	Deforestation / Total Use	-
29	Natural Capital Depletion fraction	-	Total Natural Capital / Total Use	2.79e-2
30	Emergy footprint	-	(1+ELR)*AREA	3.36e+14

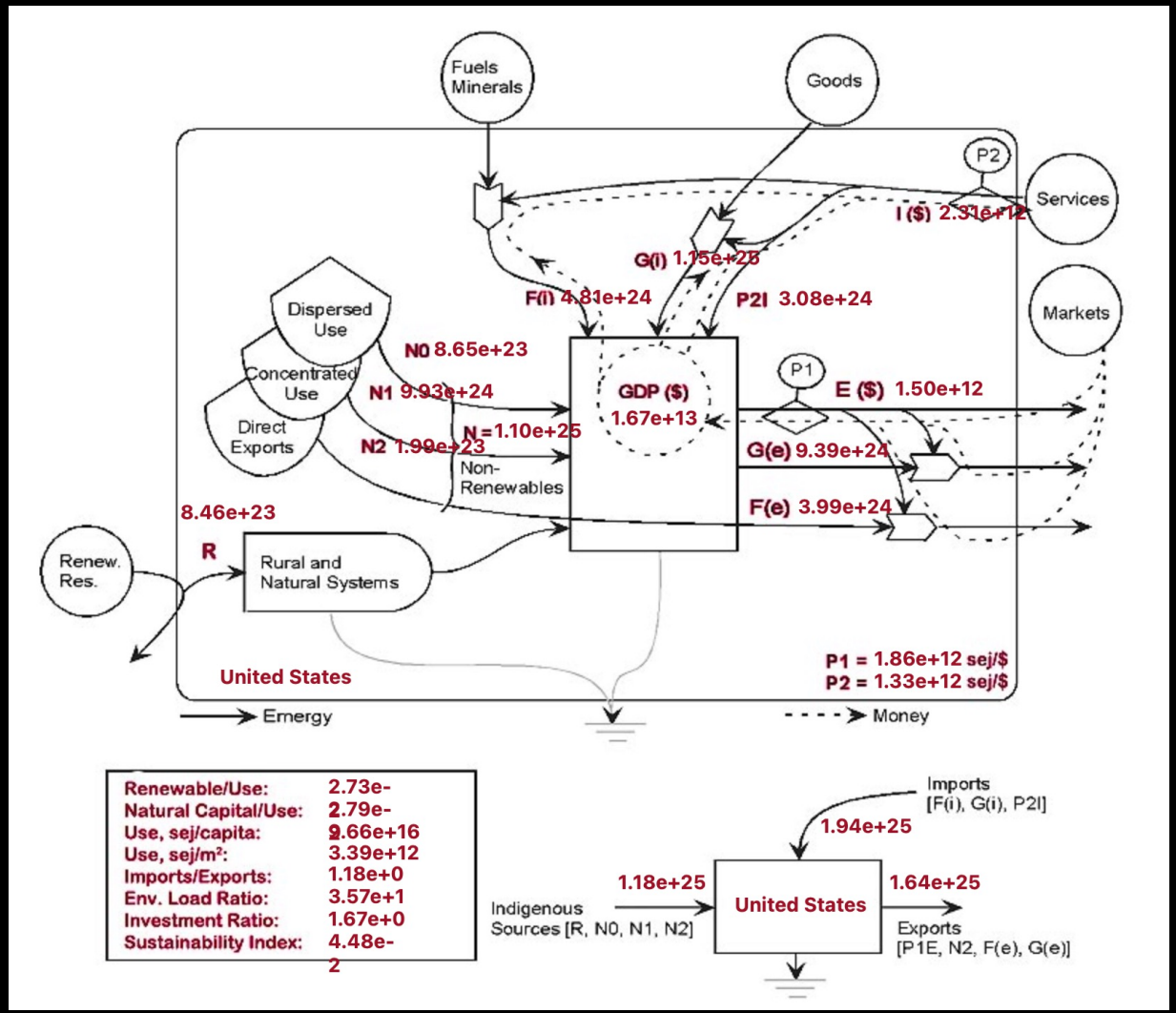
National Evaluation Template:

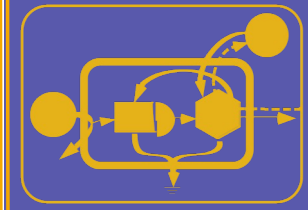
The emergy flows support the country are aggregated using this generic national diagram.



National Evaluation Template:

Summary Diagram, USA 2015





Questions?

Comments?

Concerns?