

Physical Flow Accounts



System of
Environmental
Economic
Accounting

<http://www.unescap.org/our-work/statistics>

Outline

- Learning objectives
- Review of basics (10 min.)
- Level 1 What? Why? (compilers)
 - Concepts (25 min.)
 - Group exercise and discussion (30 min.)
- Level 2
 - Concepts (15 min)
 - Group discussion (10 min.)



Learning objectives

- **Level 1**
 - Understand what Physical Flows are and why they are important
 - Be familiar with the basic concepts
 - Understand how treated in the SEEA
 - Learn the steps of compiling Physical Flow Accounts

- **Level 2**
 - Understand further concepts required
 - Learn about data sources and measurement challenges

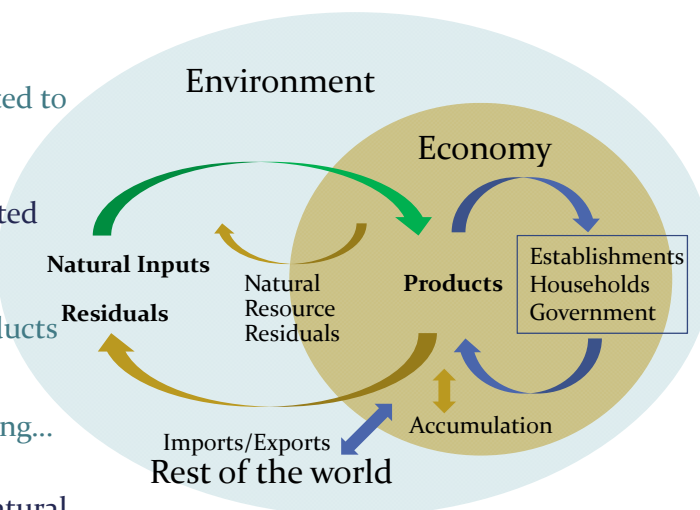
What is physical flow accounting?

Natural inputs are extracted and harvested to create...

Products, which are consumed, accumulated and discarded, in the process creating...

Residuals as by-products of production, consumption and accumulation including...

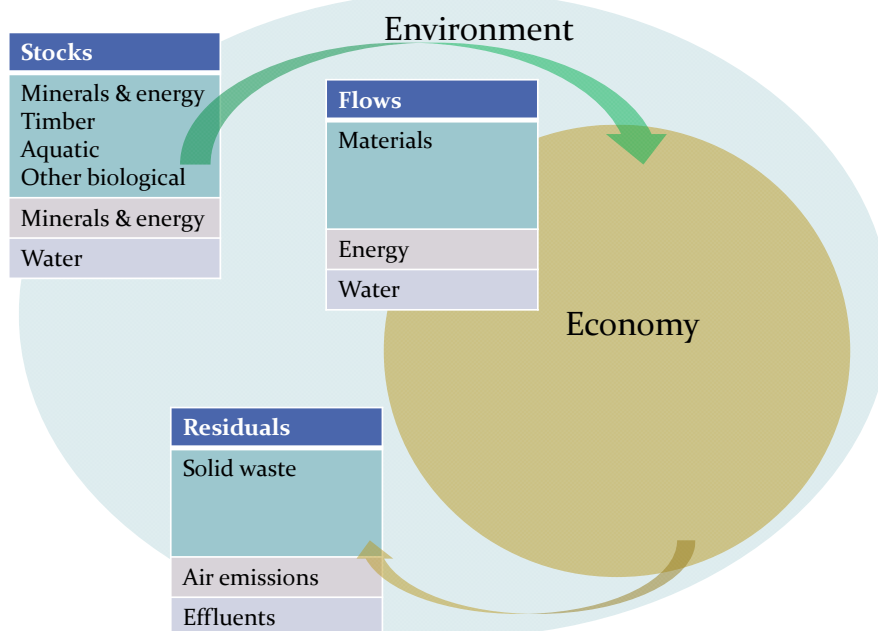
Natural resource residuals (unused natural inputs)



Environment accounts and statistics

SEEA-CF (Central Framework)	• Assets	• Minerals & Energy, Land, Timber, Soil, Water, Aquatic, Other Biological
	• Physical flows	• Materials, Energy, Water, Emissions, Effluents, Wastes
	• Monetary flows	• Protection expenditures, taxes & subsidies
SEEA Water; SEEA Energy; SEEA Agriculture, Forestry and Fisheries	Add sector detail	As above for <ul style="list-style-type: none"> • Water • Energy • Agricultural, Forestry and Fisheries
SEEA-EEA (Experimental Ecosystem Accounting)	Adds spatial detail and ecosystem perspective	Extent, Condition, Ecosystem Services, Carbon, Water, Biodiversity
FDES (Framework for the Development of Environment Statistics)	Basic statistics for above plus...	<ul style="list-style-type: none"> • Extreme events and disasters • Human settlements and health • Protection, management & engagement

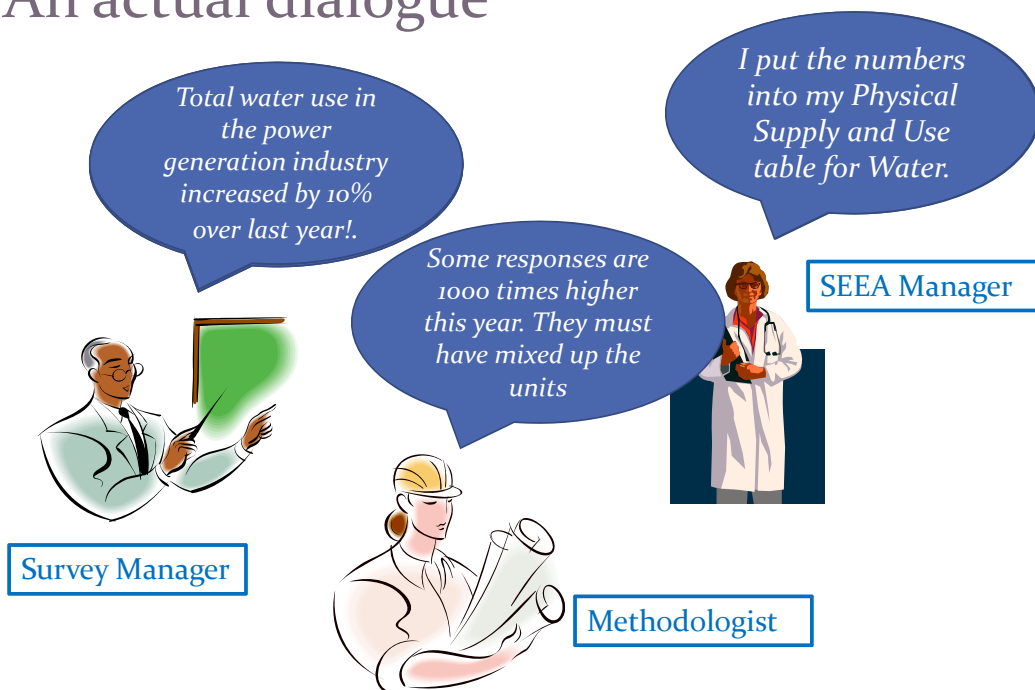
Physical flows in the SEEA (Ch. 3)



Accounts “balance the books”

- Source statistics, e.g.:
 - Water abstracted by municipal water supply
 - Water used for irrigation
- come from different sources & use different:
 - Methods, concepts and classifications
 - Units of measure
 - Accounting periods
- Accounts harmonize, integrate and improve source statistics
 - Show data gaps, duplication, inconsistencies
 - Fill data gaps (estimation)

An actual dialogue



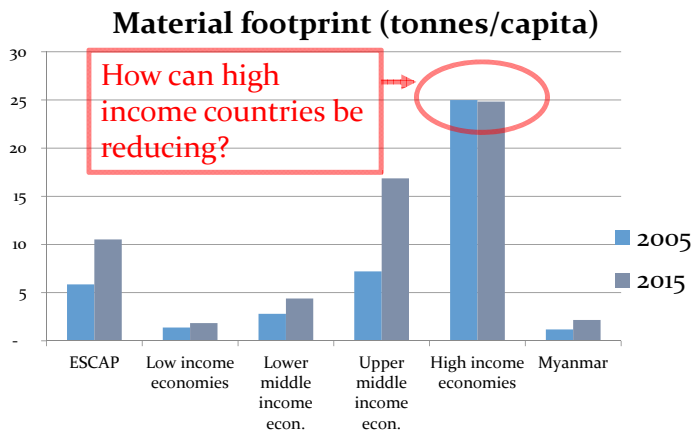


Uses of physical flow accounts

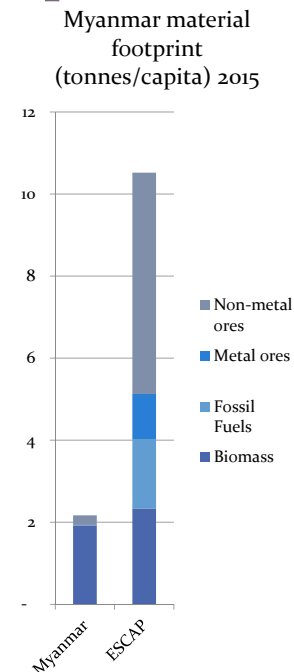
- **Natural inputs**
 - Sustainable consumption and production
 - Natural resource management (minerals, energy, water, food, timber)
 - Footprint calculations
- **Energy**
 - Analyse supply/use, distribution
- **Water**
 - Analyse supply/use, distribution
- **Residuals**
 - Analyse air emissions, wastewater, solid waste
 - Total quantities, main sources



One application: Material footprint



Material footprint: the total quantity of biomass, fossil fuels, metal ores and non-metal ores extracted globally and consumed in a country.



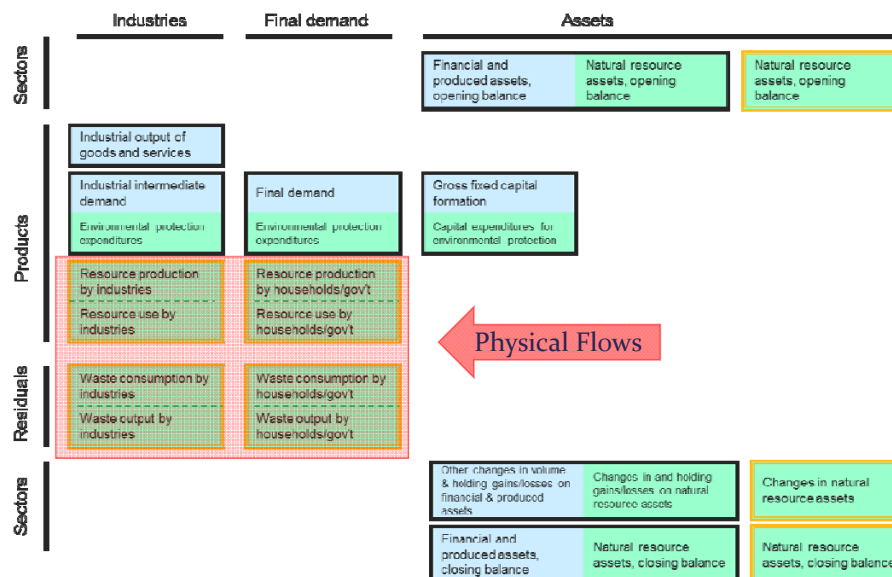


Basic concepts

- Physical flow accounting
- Physical supply and use tables
- The supply/use chain
- Accounting identities
- Definitions
 - Natural Inputs
 - Products
 - Residuals

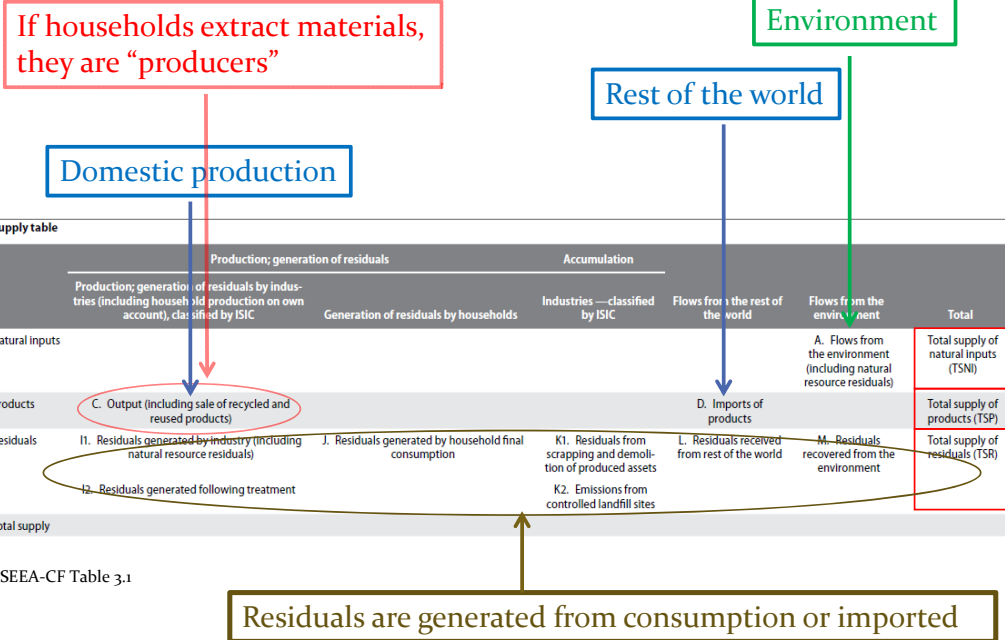


Physical flows in the SEEA

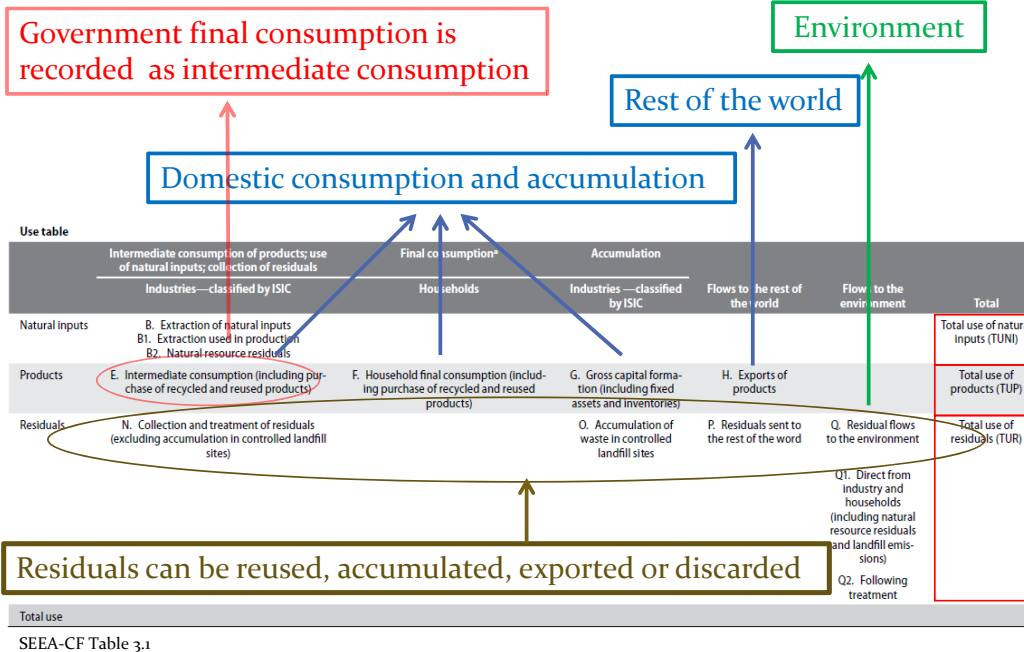




Physical supply table



Physical use table



The supply/use chains



Natural inputs **supplied** by environment → **used** by extraction, harvesting, capture industries

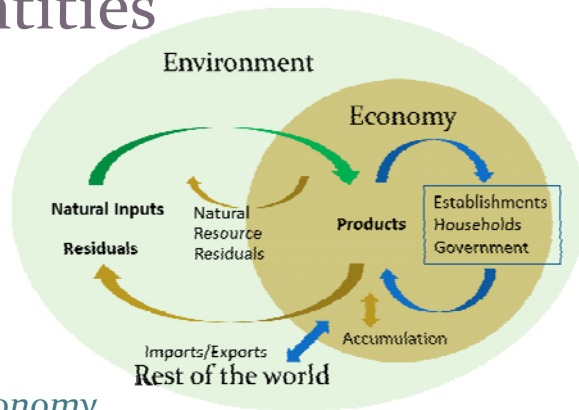
Products **supplied** by production and imports → **used** by intermediate consumption, households, accumulation and exports

Residuals **supplied** (generated) by all → **used** by collection & treatment, accumulation, export and environment

Table 3.1
General physical supply and use table

Supply table		Production: generation of residuals		Accumulation			Total
		Production: generation of residuals by industries (including household production on own accounts), classified by ISIC	Generation of residuals by households	Industries—classified by ISIC	Flows from the rest of the world	Flows from the environment	
Natural inputs						A. Flows from the environment (including natural resource residuals)	Total supply of natural inputs (TSNI)
Products	C. Output (including sale of recycled and reused products)				D. Imports of products		Total supply of products (TSP)
Residuals	I1. Residuals generated by industry (including natural resource residuals) I2. Residuals generated following treatment	J. Residuals generated by household final consumption	K1. Residuals from scraping and dismantling of packaged assets K2. Emissions from controlled landfill sites	L. Residuals received from rest of the world	M. Residuals recovered from the environment		Total supply of residuals (TSR)
Total supply							
Use table		Intermediate consumption of products; use of natural inputs; collection of residuals		Final consumption		Accumulation	
		Industries—classified by ISIC	Households	Industries—classified by ISIC	Flows to the rest of the world	Flows to the environment	Total
Natural inputs	B. Extraction of natural inputs B1. Extraction used in production B2. Natural resource residuals						Total use of natural inputs (TUNI)
Products	E. Intermediate consumption (including purchase of recycled and reused products)	F. Household final consumption (including purchase of recycled and reused products)	G. Gross capital formation (including fixed assets and inventories)	H. Exports of products			Total use of products (TUP)
Residuals	N. Collection and treatment of residuals (excluding accumulation in controlled landfill sites)		O. Accumulation of waste in controlled landfill sites	P. Residuals sent to the rest of the world	Q. Residual flow to the environment	Q1. Direct from industry and households (including natural resource residuals and landfill emissions) Q2. Following treatment	Total use of residuals (TUR)
Total use							

Accounting identities



Input-output identity

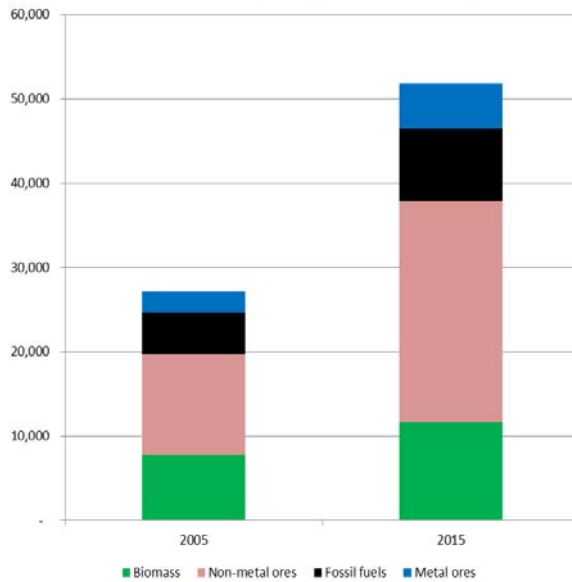
- Over an accounting period:

flows of materials **into** an economy
= flows of materials **out** of an economy
+ any **net additions** to stock in the economy
(**accumulation**)

Accumulation can be big

ESCAP

Material footprint (million tonnes)



What are all the non-metal ores being used for?

Accounting identities

Supply and use identity (double entry accounting)

- Total **Supply** (including imports) = Total **Use** (including exports)

Total Supply of	= Total Use of
Natural Resource Inputs (TSNI)	= Natural Resource Inputs (TUNI)
Products (TSP)	= Products (TUP)
Residuals (TSR)	= Residuals (TUR)

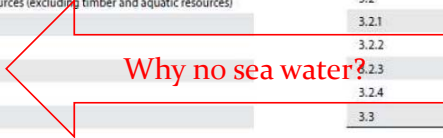
Definitions: Natural inputs

3.45 ... all physical inputs that are **moved** from their location in the environment as a part of economic production processes or are **directly used** in production.



Table 3.2
Classes of natural inputs

1		2	
Natural resource inputs		Inputs of energy from renewable sources	
1.1	Extraction used in production	2.1	Solar
1.1.1	Mineral and energy resources	2.2	Hydro
1.1.1.1	Oil resources	2.3	Wind
1.1.1.2	Natural gas resources	2.4	Wave and tidal
1.1.1.3	Coal and peat resources	2.5	Geothermal
1.1.1.4	Non-metallic mineral resources (excluding coal and peat resources)	2.6	Other electricity and heat
1.1.1.5	Metallic mineral resources	3 Other natural inputs	
1.1.2	Soil resources (excavated)	3.1	Inputs from soil
1.1.3	Natural timber resources	3.1.1	Soil nutrients
1.1.4	Natural aquatic resources	3.1.2	Soil carbon
1.1.5	Other natural biological resources (excluding timber and aquatic resources)	3.1.3	Other inputs from soil
1.1.6	Water resources	3.2	Inputs from air
1.1.6.1	Surface water	3.2.1	Nitrogen
1.1.6.2	Groundwater	3.2.2	Oxygen
1.1.6.3	Soil water	3.2.3	Carbon dioxide
1.2	Natural resource residuals	3.2.4	Other inputs from air
		3.3	Other natural inputs n.e.c.



Definitions: Products

3.64 ...goods and services that result from a process of production in the economy (same as SNA)

CPC Ver. 2

(Central Product Classification, Ver.2)

Click on any code to see more detail. Click [here](#) for top level only.

- 0 - Agriculture, forestry and fishery products
 - 01 - Products of agriculture, horticulture and market gardening
 - 02 - Live animals and animal products (excluding meat)
 - 03 - Forestry and logging products
 - 04 - Fish and other fishing products
- 1 - Ores and minerals; electricity, gas and water
 - 11 - Coal and lignite; peat
 - 12 - Crude petroleum and natural gas
 - 13 - Limestone and thorium ores and concentrates
 - 14 - Metal ores
 - 15 - Stone, sand and clay
 - 16 - Other minerals
 - 17 - Electricity, town gas, steam and hot water
 - 18 - Natural water
- 2 - Food products, beverages and tobacco; textiles, apparel and leather products
 - 21 - Meat, fish, fruit, vegetables, oils and fats
 - 22 - Dairy products and egg products
 - 23 - Grain mill products, starches and starch products; other food products
 - 24 - Beverages
 - 25 - Tobacco products
 - 26 - Yarn and thread; woven and tufted textile fabrics
 - 27 - Textile articles other than apparel
 - 28 - Knitted or crocheted fabrics; wearing apparel
 - 29 - Leather and leather products; footwear
- 3 - Other transportable goods, except metal products, machinery and equipment
 - 31 - Products of wood, cork, straw and plaiting materials
 - 32 - Pulp, paper and paper products; printed matter and related articles
 - 33 - Coke oven products; refined petroleum products; nuclear fuel
 - 34 - Basic chemicals
 - 35 - Other chemical products; man-made fibres
 - 36 - Rubber and plastics products
 - 37 - Glass and glass products and other non-metallic products n.e.c.
 - 38 - Furnitures; other transportable goods n.e.c.
 - 39 - Wastes or scraps
- 4 - Metal products, machinery and equipment
 - 41 - Basic metals
 - 42 - Fabricated metal products, except machinery and equipment
 - 43 - General-purpose machinery
 - 44 - Special-purpose machinery
 - 45 - Office, accounting and computing machinery
 - 46 - Electrical machinery and apparatus
 - 47 - Radio, television and communication equipment and apparatus
 - 48 - Medical appliances, precision and optical instruments, watches and clocks
 - 49 - Transport equipment
- 5 - Constructions and construction services
 - 51 - Constructions
 - 52 - Construction services
- 6 - Distributive trade services; accommodation, food and beverage serving services; transport services; and electricity, gas and water distribution services
 - 61 - Wholesale trade services
 - 62 - Retail trade services
 - 63 - Accommodation, food and beverage services
 - 64 - Passenger transport services
 - 65 - Freight transport services
 - 66 - Rental services of transport vehicles with operators
 - 67 - Supporting transport services
 - 68 - Postal and courier services
 - 69 - Electricity, gas and water distribution (on own account)
- 7 - Financial and related services; real estate services; and rental and leasing services
 - 71 - Financial and related services
 - 72 - Real estate services
 - 73 - Leasing or rental services without operator
- 8 - Business and production services
 - 81 - Research and development services
 - 82 - Legal and accounting services
 - 83 - Other professional, technical and business services
 - 84 - Telecommunications, broadcasting and information supply services
 - 85 - Support services
 - 86 - Support services to agriculture, hunting, forestry, fishing, mining and utilities
 - 87 - Maintenance, repair and installation (except construction) services
 - 88 - Manufacturing services on physical inputs owned by others
 - 89 - Other manufacturing services; publishing, printing and reproduction services; materials recovery services
- 9 - Community, social and personal services
 - 91 - Public administration and other services provided to the community as a whole; compulsory social security services
 - 92 - Education services
 - 93 - Human health and social care services
 - 94 - Sewage and waste collection, treatment and disposal and other environmental protection services
 - 95 - Services of membership organizations
 - 96 - Recreational, cultural and sporting services
 - 97 - Other services
 - 98 - Domestic services
 - 99 - Services provided by extraterritorial organizations and bodies

Definitions: Residuals

2.92 ... flows of **solid, liquid and gaseous materials, and energy, that are**

- **discarded, discharged or emitted by establishments and households**
- **through processes of production, consumption or accumulation**

Table 3.4

Typical components for groups of residuals

Group	Typical components
Solid waste (includes recovered materials) ^a	Chemical and health-care waste, radioactive waste, metallic waste, other recyclables, discarded equipment and vehicles, animal and vegetal wastes, mixed residential and commercial waste, mineral wastes and soil, combustion wastes, other wastes
Wastewater ^a	Water for treatment and disposal, return flows, reused water
Emissions to air	Carbon dioxide, methane, dinitrogen oxide, nitrous oxides, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride, carbon monoxide, non-methane volatile organic compounds, sulphur dioxide, ammonia, heavy metals, persistent organic pollutants, particulates (e.g., PM10 dust)
Emissions to water	Nitrogen compounds, phosphorus compounds, heavy metals, other substances and (organic) compounds
Emissions to soil	Leaks from pipelines, chemical spills
Residuals from dissipative use of products	Unabsorbed nutrients from fertilizers, salt spread on roads
Dissipative losses	Abrasion (tyres/brakes), erosion/corrosion of infrastructure (roads, etc.)
Natural resource residuals	Mining overburden, felling residues, discarded catch

^a This list of typical components for groups of residuals can also be applied to certain flows defined as products.

Compilation exercise

Compile a physical supply and use table for oil resources:

- Oil resources extracted by **Mining** (100 mln kg)
- **Mining** supplies 100 mln kg crude oil to **Refining**
- **Refining** produces 80 mln kg petrol
 - **Exports** 50 mln kg petrol
 - Supplies 30 mln kg petrol to **Households** (all is burned)
 - Burns 20 mln kg crude oil for own consumption
- **Burning (combustion):**
 - **Uses** 3 units oxygen (O₂) per unit crude oil or petrol
 - **Creates** 4 units of CO₂ per unit of crude oil or petrol



Complete the table

How?

A. Follow the supply/use chain

B. Calculate column and row totals and check accounting identities (supply = use)

C. Burning 1 kg crude oil and petrol uses 3 kg O₂ to create 4 kg CO₂

D. Questions:

- Total natural inputs?
- Total products?
- Total residuals?
- Total materials?

Supply (mln kg)		Industry		Households	Import	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources					1	
	O ₂						
Products	Crude oil	3					
	Petrol		5				
Residuals	CO ₂						
Total							

Use (mln kg)		Industry		Households	Export	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources	2					
	O ₂						
Products	Crude oil		4				
	Crude oil (own consumption)						
	Petrol			6			
Residuals	CO ₂						
Total							

The supply/use chain

Supplier

- 1 Environment
- 3 Mining & imports
- 5 Refining

User

- 2 Mining
- 4 Refining
- 6 Households & Exports



Answers

Total natural inputs = 250

Total products = 180

Total residuals = 200

Total materials = 630

Supply (mln kg)		Industry		Households	Import	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources					100	100
	O ₂					150	150
Products	Crude oil	100					100
	Petrol		80				80
Residuals	CO ₂		80	120			200
Total		100	160	120	0	250	630

Use (mln kg)		Industry		Households	Export	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources	100					100
	O ₂		60	90			150
Products	Crude oil		80				80
	Crude oil (own consumption)		20				20
	Petrol			30	50		80
Residuals	CO ₂					200	200
Total		100	160	120	50	200	630

Answers: Why?

Data sources:

- Corporate reports
- Agencies: Mining
- Taxes, concessions

Environment supplies 100 mln kg oil resources to **Mining**

Supply (mln kg)		Industry		Households	Import	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources					100	100
	O ₂					150	150
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Total		100	160	120	50	200	630

Answers: Why?

Data sources:

- Corporate reports
- Agencies: Energy, Customs
- Taxes, surveys (\$\$\$)

Mining supplies 100 mln kg crude oil to **Refining**

Refining consumes 20 mln kg crude oil

Supply (mln kg)		Industry		Households	Import	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources					100	100
	O ₂					150	150
Products	Crude oil	100					100
	Petrol		80				80
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Use (mln kg)		Industry		Households	Export	Environment	Total
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Natural Inputs	Oil resources	100					100
	O ₂		60	90			150
Products	Crude oil		80				80
	Crude oil (own consumption)		20				20
	Petrol			30	50		80
Residuals	CO ₂					200	200
Total		100	160	120	50	200	630



Answers: Why?

Refining supplies 30 mln kg petrol to **Households** and 50 mln kg to **Exports**

Data sources:
Household, business surveys
Agencies: Transport, Customs
Retail trade

Supply (mln kg)		Industry		Households	Import	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources					100	100
	O ₂					150	150
Products	Crude oil	100					100
	Petrol		80				80
Residuals	CO ₂		80	120			200
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		Mining	Refining				
Natural Inputs	Oil resources	100					100
	O ₂		60	90			150
Products	Crude oil		80				80
	Crude oil (own consumption)		20				20
	Petrol			30	50		80
Residuals	CO ₂					200	200
Total		100	160	120	50	200	630



Answers: Why?

Refining burns 20 mln kg crude oil, **environment** supplies 60 mln kg O₂ to supply 80 mln kg CO₂
Households burn 30 mln kg petrol, **environment** supplies 90 mln kg O₂ to supply 120 mln kg CO₂

Data sources:
Calculated

Supply (mln kg)		Industry		Households	Import	Environment	Total
		Mining	Refining				
Natural Inputs	Oil resources					100	100
	O ₂					150	150
Products	Crude oil	100					100
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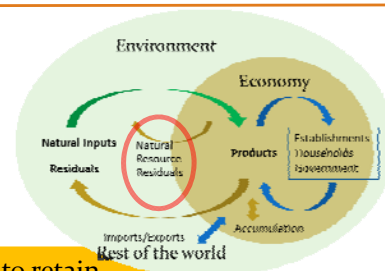
200 mln kg CO₂ are used by the environment

Welcome to Level 2!

- A few more concepts
 - Types of natural resource residuals
 - Is it a product or a residual?
 - Transboundary flows
 - How to account for losses
- Data sources
- Compilation challenges
- Discussion on country priorities

Concepts

- Types of natural resource residuals



Losses during extraction

Resources the extractor would prefer to retain.

Example: Losses of natural gas through flaring and venting

Unused extraction

Resources in which the extractor has no ongoing interest.

Example: Mining overburden; mine de-watering; discarded fish catch

Reinjections

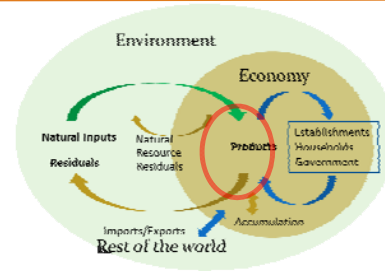
Natural resources extracted but immediately returned to the deposit and may be re-extracted at a later time.

Example: Water injected into aquifer; natural gas reinjection

Concepts

• Product or residual?

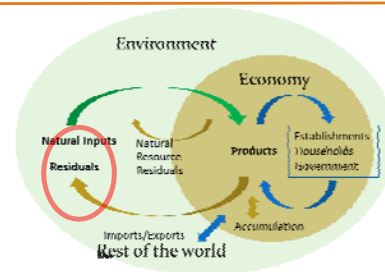
- If *payment* made = solid waste **product**
- Example: recycled materials
 - Household
 - Newspapers = whether recycling bin or garbage → residual
 - Recycling industry: **recovers** residual → product
 - Waste management industry → solid waste → residual
 - Business
 - Newspapers = in recycling bin
 - **Sell** to Recycling industry → product



Concepts

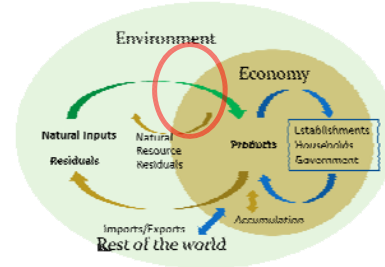
• Transboundary flows of residuals

- Only **products** are imported and exported (includes solid waste “products” such as scrap metal)
- **Residuals** (e.g. wastewater, air emissions, solid wastes) flow within the environment
- Water asset accounts do track inflows & outflows



Concepts

“Losses” are residuals the supplier would prefer to retain



Losses during extraction	...occur during extraction before processing...
Losses during distribution	...between abstraction, extraction or supply and point of use...
Losses during storage	...energy products and materials...
Losses during transformation	...heat energy...

Data sources

- **Industry & household surveys**
 - Inputs/outputs of materials, energy, water, residuals
 - Government/private waste management
- **Administrative & regulatory data**
 - Imports, exports, consumption
 - Pollutant release and transfer register
- **Field measurement**
 - Waste, water, energy, materials audits
 - Engineering design factors (estimate losses...)
- **Existing statistics**
 - National Accounts (\$ supply/use to estimate physical)
 - Energy balances
 - Company reports

Data sources

UN Environment: *Indicators for a Resource Efficient and Green Asia and the Pacific: Toolkit Page*

- National and international sources
- Visualize data
- Download data



<http://web.unep.org/asiapacific/regional-initiatives/resource-efficiency>

Compilation challenges

- Correcting for **residence principle**
 - Tourists, foreign airplanes \neq consumers
- Disaggregating & linking information to ISIC
 - Details, details, details (material type...)
 - Data may be on “activity” (fuel used for transport)
 - Household “sector” engaged in productive activity
- Consistency with National Accounts concepts
 - Within enterprise flows in SEEA (not in SNA) ←
- Compiling time series
 - Sources and detail change over time (e.g., industry surveys include quantities or \$ value)
 - Prices change over time (price \times volume = value)

Remember example: Refining consumes crude oil.

Documentation challenges



- There are some inconsistencies between SEEA-CF and SEEA-Water
 - SEEA-Water is based on SEEA-2003
 - e.g., “Supply” / “Use”
 - e.g., “Consumption” = “Use”
 - Extraction/abstraction = Supply
- SEEA-Energy is based on SEEA-CF 2012
- Suggest using SEEA-CF (2012) as the primary guidance and sub-components for details

Discussion

- Which physical flow accounts could be a priority in your country?
 - Materials, Water, Energy
 - Solid Wastes, Air emissions, Wastewater
- What sources of data do you have?
- What are the gaps?
- What would be the next steps:
 - New data?
 - Collaborate with data sources? Stakeholders? Funding?
 - Learn how to create accounts?

References

- SEEA-CF:
http://unstats.un.org/unsd/envaccounting/seeaRev/SEEA_CF_Final_en.pdf
- SEEA-Energy:
<http://unstats.un.org/unsd/envaccounting/seeae/chapterList.asp>
- SEEA-Water:
<http://unstats.un.org/unsd/envaccounting/seeaw/seeawaterwebversion.pdf>
- SEEA-Agriculture, Forestry and Fisheries:
http://unstats.un.org/unsd/envaccounting/aff/2GC_Draft.pdf
- OECD PRTR (Pollutant release and transfer registry):
<http://www.oecd.org/chemicalsafety/pollutant-release-transfer-register/>
- UNEP: Indicators for a Resource Efficient and Green Asia and the Pacific: Toolkit Page
<http://www.unep.org/roap/Activities/ResourceEfficiency/IndicatorsforaResourceEfficient/tabid/1060186/Default.aspx>

Acknowledgements

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- Materials adapted from:
 - Joe St. Lawrence (Statistics Canada; Chiba, Japan; Feb. 23, 2016)
 - Julian Chow (UNSD; Malaysia; Sept. 23, 2013)
 - Ole Gravgård (Statistics Denmark; Addis Ababa, Ethiopia; Feb. 2, 2015)