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Introduction

What are physical supply and use tables for energy?

- Compilation of all energy flows that enter, are used within and leave a country's economy

- Illustrates relationship between inputs to and outputs from energy transformation process

  > Assess how an economy supplies and uses energy products

  > Changes in production and consumption patterns over time

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Physical energy flow accounts

- Global Assessment 2022: 59 countries compile PEFA, including 11 in Asia

Central Asia	1
Eastern Asia	2
South-eastern Asia	3
Southern Asia	2
Western Asia	3

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Physical energy flow accounts in context

- Energy statistics and balances provide a wealth of information

- Some similarities between energy balances and accounts

- But accounts provide value added
  - > Coherence with SNA allows for economic analysis and expanded policy applications
  - > Can help improve data sources/quality
  - > Comprehensive (cover the entire economy)

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Physical energy flow accounts

Scope of the economy in SEEA-Energy and PEFA

- In accordance with the System of National Accounts and SEEA-CF, the scope of SEEA-Energy covers the economic activity of resident units

- Resident of a country = institutional unit with centre of economic interest in the economic territory of a country

- Resident units can operate inside or outside of the national territory

- Use of residence principle is in contrast to energy statistics and balances
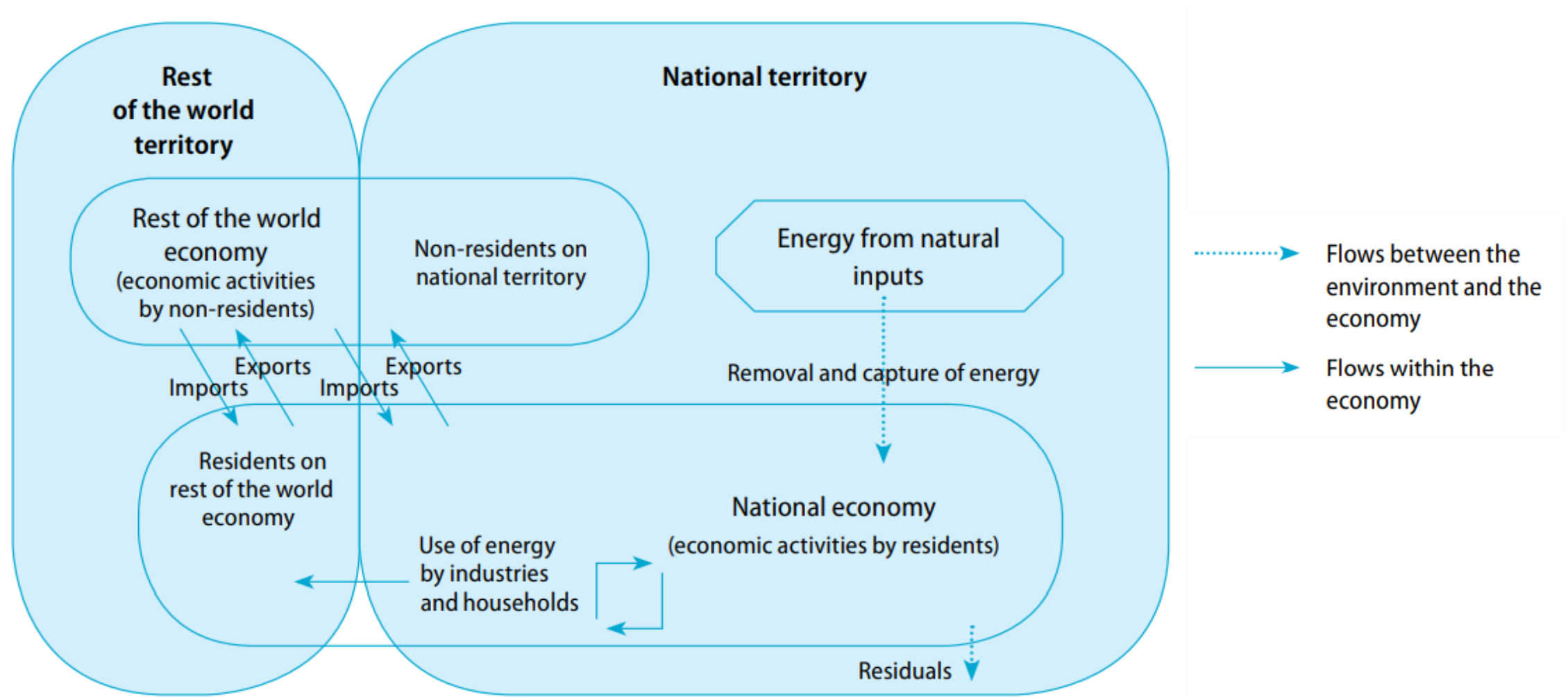
	Residents	Non-residents	
National territory	Sold on territory to resident units	Sold on territory to non-residents (foreign tourists, transport companies, embassies)	Energy statistics and balances
Rest of the world	Sold to residents operating abroad (tourists, transport companies, etc.)		
	SEEA-Energy		

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Physical flows of energy

- In accordance with the SEEA-CF, energy presents itself in three different ways in SEEA-Energy

- Natural inputs
  - > Energy resources in the environment which can be extracted/captured

- Energy products
  - > Products exclusively or mainly used as a source of energy
  - > Include fuels produced/generated, electricity and heat

- Energy residuals
  - > Flows of energy that are discarded, discharged or emitted by establishments and households

- Energy flows completely outside of the economy are not in scope

Physical flows of energy

Rest of the world territory

National territory

Rest of the world economy
(economic activities by non-residents)

Non-residents on national territory

Energy from natural inputs

Exports
Imports
Exports
Imports

Removal and capture of energy

Residents on rest of the world economy

National economy
(economic activities by residents)

Use of energy by industries and households

Residuals

- - - - - → Flows between the environment and the economy

——→ Flows within the economy

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Energy as natural inputs

- Classification of energy from natural inputs provides classification by type of resource and is based on the purpose of natural inputs

Energy natural resource inputs
Mineral and energy resources
Oil resources
Natural gas resources
Coal and peat resources
Uranium and other nuclear fuels
Natural timber resources
Inputs of energy from renewable sources
Solar
Hydro
Wind
Wave and tidal
Geothermal
Other electricity and heat
Other natural inputs
Energy inputs to cultivated biomass

Energy as products

- Energy statistics usually classify products according to the Standard International Energy Product (SIEC) classification—can also be used for the SEEA

- But in national accounts, energy products are classified according to Central Product Classification (CPC)

- May need to utilize a cross-walk, though it should be noted that there is not always a 1:1 relationship between CPC and SIEC

0	Coal
1	Peat and peat products
2	Oil shale/oil sands
3	Natural gas
4	Oil
5	Biofuels
6	Waste
7	Electricity
8	Heat
9	Nuclear fuels and other fuels not elsewhere classified

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Energy as residuals

- Energy losses as well as other energy residuals

- Energy residuals are grouped into five groups:

  > Losses during extraction, e.g. flaring of natural gas during extraction

  > Losses during distribution, e.g. oil tanker spill

  > Losses during storage, e.g. petrol leaks from a tank

  > Losses during transformation, e.g. heat losses when coal is used for production of electricity

  > Other energy residuals, primarily dissipative heat generated through the end use of energy products, e.g. fuel combustion for vehicles or electricity for heating

- Other residual flows

  > Residuals from end use for non-energy purposes, e.g. naptha for plastics

Physical supply and use tables

SUPPLY TABLE	Industries	Households	Accumulation	Rest of the World	Environment	Totals
Energy from natural inputs					Energy inputs from the environment	Total supply of energy from natural inputs
Energy products	Output			Imports		Total supply of energy products
Energy Residuals	Energy residuals generated by industry	Energy residuals generated by household consumption	Energy residuals from accumulation	Energy residuals received from the rest of the world	Energy residuals recovered from the environment	Total supply of energy residuals

USE TABLE	Industries	Households	Accumulation	Rest of the World	Environment	Totals
Energy from natural inputs	Extraction of energy from natural inputs					Total use of energy from natural inputs
Energy products	Intermediate consumption	Household consumption	Changes in inventories	Exports		Total use of energy products
Energy residuals	Collection & treatment of energy residuals		Accumulation of energy residuals	Energy residuals sent to the rest of the world	Energy residual flows direct to environment	Total use of energy residuals

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Supply

PHYSICAL SUPPLY TABLE (unit:PJ)	Production (incl. household own account) & generation of residuals								Accumulation	Flows from the rest of the World (Imports)	Flows from the environment	TOTAL
	Industries (by ISIC)							Households				
	Agriculture Forestry & Fishery	Mining & Quarrying	Manufacturing	Electricity, gas, steam & air condition-ing supply	Transport-ation & Storage	Other Industries	Total Industry					
	(ISIC A)	(ISIC B)	(ISIC C)	(ISIC D)	(ISIC H)							
1. Energy from natural inputs:												
Natural resource inputs											1166	1166
Inputs of energy from renewable sources											124	124
Other natural inputs											2	2
2. Energy Products:												
Production of energy products by SIEC class:												
Coal										225		225
Peat and peat products												
Oil shale / oil sands												
Natural gas		395		369			764					764
Oil		721	347				1068			930		1998
Biofuels	5			2			7					7
Waste	39		55				94			17		111
Electricity				212			212			22		234
Heat				79			79					79
Nuclear fuels and other fuels												
3. Energy Residuals:												
Total energy residuals	50	48	432	307	632	96	1565	240				1805
4. Other Residual Flows:												
Residuals from end-use for non-energy purposes			51									51
Energy from solid waste										94		94
5. TOTAL SUPPLY	94	1164	885	969	632	96	3840	240		94	1194	1292	6660

Use

PHYSICAL USE TABLE (unit: PJ)	Agriculture Forestry & Fishery (ISIC A)	Mining & Quarrying (ISIC B)	Manufacturing (ISIC C)	Electricity, gas, steam & air conditioning supply (ISIC D)	Transportation & Storage (ISIC H)	Other Industries	Total Industry	Final Consumption Households	Accumulation	Flows to the rest of the World (Exports)	Flows to the environment	TOTAL
1. Energy from natural inputs:												
Natural resource inputs	5	1161										1166
Inputs of energy from renewable sources				124								124
Other natural inputs				2								2
2. Energy Products:												
Transformation of energy products by SIEC class:												
Coal				223			223					223
Peat and peat products												
Oil shale / oil sands												
Natural gas				482			482					482
Oil			360	16			376					376
Biofuels												
Waste				31			31					31
Electricity												
Heat												
Nuclear fuels and other fuels												
End-use of energy products by SIEC class:												
Coal	2		17				19		1	-21	2	1
Peat and peat products												
Oil shale / oil sands												
Natural gas	2		39			12	53	26	2	201		282
Oil	34	2	326		621	49	1032	102	-3	441		1572
Biofuels				2			2	5				7
Waste	3		4	37		1	45	33			1	79
Electricity	7	1	22	50	10	15	105	29		100		234
Heat	2		11	2	1	19	35	44				79
Nuclear fuels and other fuels												
End-use of energy products for non-energy purposes			51				51					51
3. Energy Residuals:												
Total energy residuals											1805	1805
4. Other residual flows:												
Residuals from end-use or non-energy purposes									51			51
Energy from solid waste	39		55									94
5. TOTAL USE	94	1164	885	969	632	96	3840	240	29	745	1805	6659

Accounting rules and principles

- Supply and use identity

  > Total supply of each product = output + imports

  is equal to

  Total use of each product= Intermediate consumption + final consumption

  + changes in inventories + exports

- Input-output identity

  > Identity regarding flows between environment and economy

  > Total inputs into the economy: product inputs + resource inputs + imports

  is equal to

  Total outputs from the economy = production outputs + residuals + net additions to stock

  + exports

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Compilation of supply and use tables

- Identify source data, usually from various places (basic energy statistics, energy balances, national accounts data, traffic and transport data, etc)

- Put the data into the accounting format

- Allocate supply and use to ISIC

- Make corrections for residence principle

- Ensure accounting identities are met

- Quality assurance

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Compilation of supply and use tables - demo

- Extraction of crude oil by mining industry (1500 PJ) // Loss of 100 PJ during extraction

- Supply of crude oil to refinery (1400 PJ)

- Refining of crude oil to diesel (1200 PJ, 200 lost during transformation)

- Use of diesel by transport industry (600 PJ) and households (600 PJ)

- Based on Statistics Netherlands example

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Extraction of oil resources

- Extraction of crude oil by mining industry (1500 PJ)

- Environment supplies crude; crude is used/extracted by ISIC B

Supply		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources							1500	1500
Energy products	Crude								
	Petrol								
	Losses during extraction								
	Losses during transformation								
Residuals	Other energy residuals								
	Total							1500	1500

Use		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources	1500							1500
Energy products	Crude								
	Petrol								
	Losses during extraction								
	Losses during transformation								
Residuals	Other energy residuals								
	Total	1500							1500

From natural input to product

- 100 PJ of crude is lost during extraction, and only 1400 PJ of crude is supplied to the refinery

Supply		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources							1500	1500
	Crude	1400							1400
Energy products	Petrol								
	Losses during extraction	100							100
	Losses during transformation								
Residuals	Other energy residuals								
	Total	1500						1500	3000

Use		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources	1500							1500
	Crude		1400						1400
Energy products	Petrol								
	Losses during extraction							100	100
	Losses during transformation								
Residuals	Other energy residuals								
	Total	1500	1400					100	3000

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Supply and use of energy products

- Refinery refines all crude (1400PJ) into diesel, but 200 is lost during transformation

- Use of diesel by transport industry (600 PJ) and households (600 PJ)

Supply		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources							1500	1500
	Crude	1400							1400
Energy products	Petrol		1200						1200
	Losses during extraction	100							100
	Losses during transformation		200						200
Residuals	Other energy residuals								
	Total	1500	1400					1500	4400

Use		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources	1500							1500
	Crude		1400						1400
Energy products	Petrol			600	600				
	Losses during extraction							100	100
	Losses during transformation							200	200
Residuals	Other energy residuals								
	Total	1500	1400	600	600			300	3200

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Balancing

- Dissipative heat following combustion of petrol by ISIC H and Households is recorded as "other energy residuals"

Supply		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources							1500	1500
Energy products	Crude	1400							1400
	Petrol		1200						1200
	Losses during extraction	100							100
	Losses during transformation		200						200
Residuals	Other energy residuals			600	600				
	Total	1500	1400	600	600			1500	4400

Use		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources	1500							1500
Energy products	Crude		1400						1400
	Petrol			600	600				
	Losses during extraction							100	100
	Losses during transformation							200	200
Residuals	Other energy residuals							1200	1200
	Total	1500	1400	600	600			1500	4400

Supply = use

- Supply now equals use for final total and row/column totals
- Note that we double record the energy content

Supply		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources							1500	1500
	Crude	1400							1400
Energy products	Petrol		1200						1200
	Losses during extraction	100							100
	Losses during transformation		200						200
Residuals	Other energy residuals			600	600				
	Total	1500	1400	600	600			1500	4400

Use		ISIC B Mining	ISIC C Manufacturing	ISIC H Transportation	Households	Accumulation	Imports	Flows from Environment	Total
Natural inputs	Oil resources	1500							1500
	Crude		1400						1400
Energy products	Petrol			600	600				
	Losses during extraction							100	100
	Losses during transformation							200	200
Residuals	Other energy residuals							1200	1200
	Total	1500	1400	600	600			1500	4400

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Indicators and applications

- Indicators
  - > SDG target 7.3: By 2030, double the global rate of improvement in energy efficiency
    - Indicator 7.3.1: Energy intensity → energy use / value added
  - > Net domestic energy use: End use of energy products (including changes in inventories) less exports of energy products plus all losses of energy
  - > Gross energy input: Energy from natural inputs plus imports of energy products plus energy from waste

- Decoupling GDP from energy use
  - > Growth rate of an environmental pressure is less than that of its economic driving force
  - > i.e. growth in energy use is less than that of GDP

- Input-Output modelling

- Calculation of air emission accounts

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Questions?

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PEFA exercise

- Can you compile a supply and use table for the hypothetical scenario provided?

- In this scenario, the country uses both renewable and non-renewable natural energy inputs

- The country also supplies/uses a variety of energy products and exports energy products

- Based on ESCAP exercise

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Indicator exercise

- Can you calculate the following:

  > Net domestic energy use?

  - End use of energy products (including changes in inventories) less exports of energy products plus all losses of energy

  > Energy intensity of each industry?

  - Energy use / value added

  > Gross energy input?

  - Energy from natural inputs plus imports of energy products plus energy from waste

- How would you interpret or explain these indicators? How could they be used to inform climate change policies?

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PEFA solution

SUPPLY TABLE

UNIT: Petajoule (10¹⁵)		ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Imports	Environment	Total
Natural energy inputs	Fossil non-renewable natural energy inputs									**1** 150	150
	Wind based renewable natural energy inputs										0
	Solar based renewable natural energy inputs										0
	Biomass based renewable natural inputs										0
Energy products	Hard coal		**3** 140								140
Energy and other residuals	Energy losses during extraction and distribution		**3** 10								10
	Total supply of energy	0	150	0	0	0	0	0	0	150	300

USE TABLE

UNIT: Petajoule (10¹⁵)		ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Exports	Environment	Total
Natural energy inputs	Fossil non-renewable natural energy inputs		**2** 150								150
	Wind based renewable natural energy inputs										0
	Solar based renewable natural energy inputs										0
	Biomass based renewable natural inputs										0
Energy products	Hard coal				**5** 112				**6** 28		140
Energy and other residuals	Energy losses during extraction and distribution									**4** 10	10
	Total use of energy	0	150	0	112	0	0	0	28	10	300

1. The mining industry extracts 150 PJ of coal.
2. The mining industry loses 10 PJ of coal during extraction and transportation *(140 remains, 10 goes to losses)*.
3. Eighty percent of the remaining coal is used by coal power plants *(112)*;
4. Twenty percent of the remaining coal is exported *(28)*.

SUPPLY TABLE

UNIT: Petajoule (10^{15})	ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Imports	Environment	Total
Natural energy inputs										
Fossil non-renewable natural energy inputs									150	150
Wind based renewable natural energy inputs									**2** 30	30
Solar based renewable natural energy inputs									**2** 30	30
Biomass based renewable natural inputs										0
Energy products Including non-energy use										
Hard coal		140								140
Electrical energy			**1 (75PJ)**	135 **4 (60PJ)**						135
Heat				**1** 25						25
Energy and other residuals										
Energy losses during extraction and distribution		10								10
Energy losses during transformation				**1** 12						12
Energy losses from end use	**7** 38	**7** 18	**7** 20	**7** 34		**7** 50				160
Total supply of energy	38	168	20	206	0	50	0	0	210	692

USE TABLE

UNIT: Petajoule (10^{15})	ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Exports	Environment	Total
Natural energy inputs										
Fossil non-renewable natural energy inputs		150								150
Wind based renewable natural energy inputs				**3** 30						30
Solar based renewable natural energy inputs				**3** 30						30
Biomass based renewable natural inputs										0
Energy products Including non-energy use										
Hard coal				112					28	140
Electrical energy	**5** 38	**5** 15	**5** 20	**5** 32		**5** 30				135
Heat		**6** 3		**6** 2		**6** 20				25
Energy and other residuals										
Energy losses during extraction and distribution									10	10
Energy losses during transformation									12	12
Energy losses from end use									160	160
Total use of energy	38	168	20	206	0	50	0	28	182	692

1. The coal power plant *(112)* converts the coal from the mining industries to energy and heat, producing 75 PJ of electricity and 25 PJ of heat. Losses during transformation account for the rest of the coal supply *(12 PJ lost)*.
2. 60 PJ of electricity are generated from renewable sources (50% from wind, 50% from solar).
3. The resulting electricity from solar and coal is used as follows *(60 from renewable; 75 from coal, total 135)*:
   Agriculture 38 PJ; Mining 15 PJ; Manufacturing 20 PJ; Electricity 32 PJ; Households consume the rest of the electricity (30 PJ)

4. For heating (25 PJ) Households use 20 PJ of heat; Electricity sector uses 2 PJ; the rest is used by mining (3).

SUPPLY TABLE

UNIT: Petajoule (10^{15})	ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Imports	Environment
Natural energy inputs									
Fossil non-renewable natural energy inputs								**1**	150+500
Energy products, including non-energy									
Hard coal		140							
Crude oil, NGL, and other hydrocarbons (excl. bio)		**3** 450							
Kerosenes and jet fuels (without bio)			**5** 360						
Naptha			**9** 90						
Energy and other residuals									
Energy losses during extraction and distribution		**3** 10+50							
Energy losses during transformation				12					
Energy losses from end use	38	18	20	34	**7** 50+360				
Energy incorporated in products for non-energy use			**11** 90						

USE TABLE

UNIT: Petajoule (10^{15})	ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Exports	Environment
Natural energy inputs									
Fossil non-renewable natural energy inputs		**2** 150+500							
Energy products									
Hard coal				112				28	
Crude oil, NGL, and other hydrocarbons (excl. bio)			**4** 450						
Kerosenes and jet fuels (without bio)						**6** 360			
Naptha			**10** 90						
Energy and other residuals									
Energy losses during extraction and distribution									**4** 10+50
Energy losses during transformation									12
Energy losses from end use									**8** 160+360
Energy incorporated in products for non-energy use						**12** 90			

1. In addition to coal, 500 PJ of crude is extracted from domestic deposits. 10 percent of crude is lost for various reasons during its extraction *(50 PJ lost, 450 remaining)*.

2. Crude is transformed into naptha (for plastics) and kerosene. Eighty percent of the remaining crude is transformed by refineries into kerosene for use by households *(360)*. Twenty percent of the remaining crude is transformed into naptha for plastics *(90)*.

SUPPLY TABLE

UNIT: Petajoule (10^{15})	ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Imports	Environment
Natural energy inputs									
Fossil non-renewable natural energy inputs									650
Biomass based renewable natural inputs									**1** 100
Energy products, including non-energy									
Hard coal		140							
Wood, wood waste and other solid biomass, charcoal	**3** 100								
Electrical energy				135					
Heat				25					
Energy and other residuals									
Energy losses during extraction and distribution		60							
Energy losses from end use	38	18	20	34		410+100 **5**			

USE TABLE

UNIT: Petajoule (10^{15})	ISIC A: Agriculture and forestry	ISIC B: Mining	ISIC C: Manufacturing	ISIC D: Electricity supply	Other industries	Households	Inventories	Exports	Environment
Natural energy inputs									
Fossil non-renewable natural energy inputs		650							
Biomass based renewable natural inputs	**2** 100								
Energy products									
Hard coal				112				28	
Wood, wood waste and other solid biomass, charcoal						**4** 100			
Electrical energy	38	15	20	32		30			
Heat		3		2		20			
Energy and other residuals									
Energy losses during extraction and distribution									60
Energy losses from end use								**6**	520+100

1. Logging companies cut down 50 PJ of fuel wood; households also cut down 50 PJ of fuel wood.

2. Households use this fuel wood for cooking

Indicator exercise solutions

- Gross energy input (PJ)
    - > Energy from natural inputs plus imports of energy products plus energy from waste
    - > 810 PJ

- Net domestic energy use (PJ)
    - > End use of energy products (including changes in inventories) less exports of energy

ISIC A	ISIC B	ISIC C	ISIC D	Country
38	78	110	46	782

- Energy intensity (MJ/$)

ISIC A	ISIC B	ISIC C	ISIC D
10.56	12.45	8.29	11.07

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