# Natural resources

Topic 7 · SL and HL

# Capacity is not generated energy

## IEA report published 2024

China commissioned as much **solar** PV capacity in 2023 as the world did in 2022.

New capacity is not annual electricity generated.

## Resource choices change

Technology, cost, geography, policy and values shape use.

Sunlight supported human activities long before modern panels.

# Classify resources carefully

## Stocks and recurring flows

**Natural capital** supplies goods and services as **natural income**.

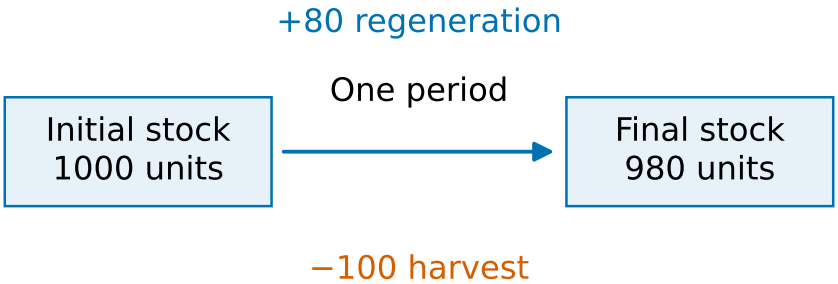
**Renewable** growth/recharge can be exceeded; sunlight/wind are finite-power flows.

## Timescales and losses

Soil formation and fossil groundwater can be effectively non-renewable.

Metals can be recycled, but collection, energy, contamination and losses matter.

# An invented stock budget




1000 + 80 − 100 = 980 units; use exceeds regeneration by 20 units.

# Goods, services and values

## Examples

Timber and fish are goods; flood regulation and nutrient removal are services.

Forests, rivers and wetlands support several functions at once.

## Different values

Aesthetic, cultural, economic, environmental, health, social, spiritual and technological.

Intrinsic worth is independent of human usefulness; a market price does not capture every value.

# Resource value and local choice

## Dynamic examples

Lithium demand changed with batteries; whale oil lost its lighting role to alternatives.

Lithium is not a rare earth; different materials serve different functions.

## Evaluate perspectives

Culture, history, cost, technology, policy and environmental concern.

Neutral voluntary surveys: willingness to pay also reflects income and access.

# Resource security: two water contexts

## Singapore

Four National Taps: catchments, imports, NEWater and desalination.

Diversity improves resilience but needs energy, finance and quality management.

## Jordan, 2023 strategy

About 61 $m^3$ **renewable** freshwater/person/year in the dated account.

Scarcity, demand, groundwater and unequal access; planned supply is not delivered capacity.

# Manage demand and ecological functions

## Strategies

Efficiency, durability, **substitution**, repair, reuse and suitable **recycling**.

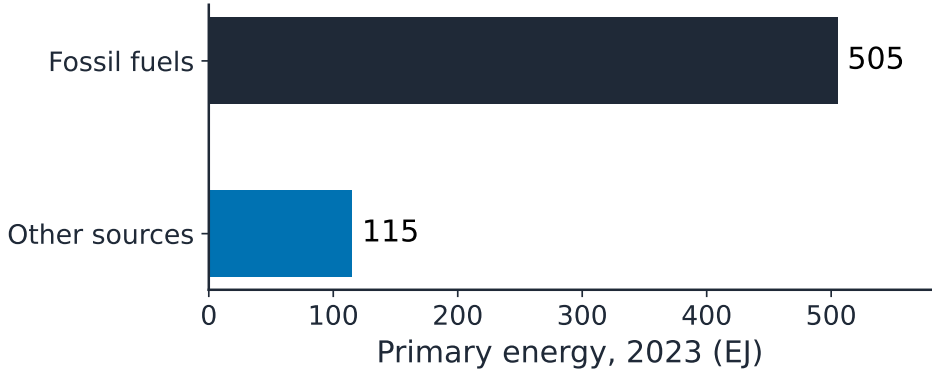
Diverse supply and trade can improve security.

## Limits

Harvest at estimated growth does not alone conserve habitat or soil.

Pollutant loading must avoid harmful accumulation; security is not identical to sustainability.

# Dated world primary-energy quantities




EI 2024 edition: rounded 2023 total 620 EJ, with 505 EJ fossil and 115 EJ other sources.

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# Calculate a fossil-energy share

1. **Dated rounded values.** Fossil 505 EJ; total 620 EJ.
2. **Share.** $505/620 \times 100 = 81.45\%$, approximately 81.5%.
3. **Boundary.** Primary energy, under this report's accounting; not electricity shares.

## Decision

Do not splice datasets with different primary-energy methods or compare MW directly with MWh.

# Primary energy and industrial services

## Needs and change

Population and per-person demand influence totals.

Transport, heat, steel, cement and fertiliser need specific services.

## Carriers

Electricity and hydrogen are energy carriers.

Hydrogen production needs energy/feedstock; fuel cells are not a free primary source.

# Evaluate non-renewable sources

## Fossil fuels

Coal, oil and gas: useful energy and feedstocks, with emissions and extraction impacts.

Gas may lower direct $CO_2$ compared with coal, but upstream methane matters.

## Nuclear

Generally low lifecycle carbon; high availability and small fuel mass.

Mining, cooling, accidents, waste, financing and decommissioning need a full boundary.

# Renewables differ in constraints

## Solar and wind

PV needs sunlight; **wind** varies with weather.

Land, materials, construction, ecology and end-of-life management matter.

## Water, heat and biomass

Reservoir/run-of-river hydro differ; drought and ecology constrain both.

Geothermal is not only volcanic; tides are predictable, waves weather-dependent; **biomass** is not automatically carbon-neutral.

# Compare Norway and Japan

## Norway

Hydro-rich electricity, reservoirs and interconnections.

Geography, rainfall and existing infrastructure; ecological flows, drought and costs.

## Japan: IEA 2021 context

Import dependence and post-Fukushima supply disruption.

Diversification, efficiency, resilience, renewables and **nuclear** safety; dated context, not unchanged current shares.

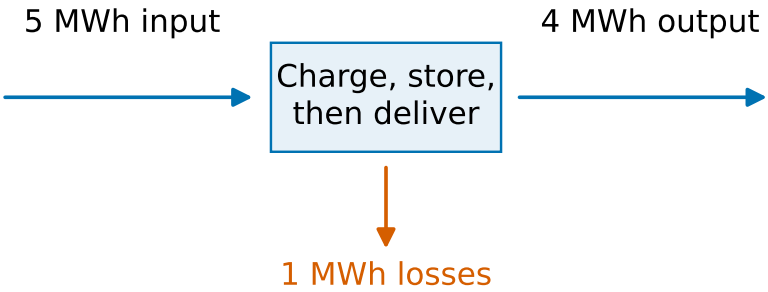
# Capacity factor is not efficiency

1. **Invented installation.** Rated power 50 MW; capacity factor 0.30; interval 8760 hours.
2. **Generated energy.** $50 \times 0.30 \times 8760 = 131400$ MWh$=131.4$ GWh.
3. **Interpret.** Ratio to continuous rated output, not thermodynamic conversion efficiency.

## Decision

Choose a power unit for rate and an energy unit for accumulated output.

# Storage shifts energy with losses




Invented round trip: 5 MWh input yields 4 MWh output and 1 MWh losses.

# Match storage power and duration

1. **Invented delivered energy.** 4 MWh at 1 MW can cover 4 hours.
2. **Round-trip efficiency.** $4/5 \times 100 = 80\%$.
3. **System choice.** Batteries, pumped hydro, thermal storage, grids and flexible demand serve different needs.

## Decision

Finite energy and power cannot guarantee unlimited backup through a long shortfall.

# Conservation, efficiency and rebound

## Two mechanisms

Behaviour can reduce service use; efficiency reduces input for comparable service.

Insulation and efficient lighting need measured comfort/illumination comparisons.

## Invented conversion

30 MJ useful from 100 MJ input gives 30% efficiency.

Rebound can offset engineering savings; a lower impact per service need not lower total use.

# Classify waste by source and type

## Source

Domestic, industrial and agricultural.

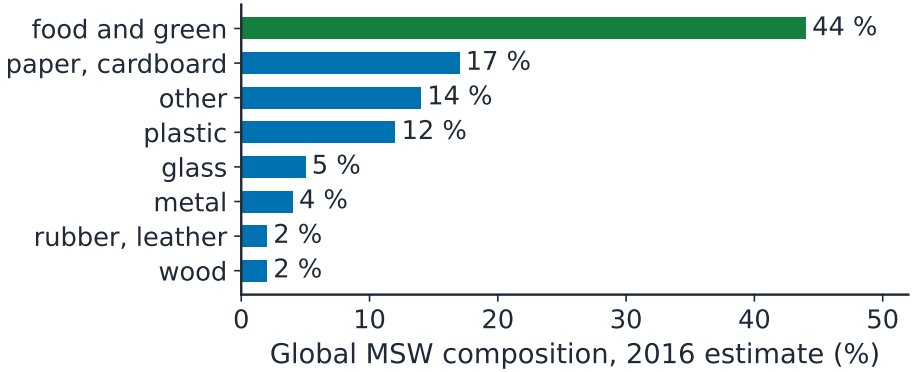
Municipal definitions and collection coverage vary.

## Type and measure

Food, e-waste, biohazardous materials, paper, plastic, metals and others.

Categories overlap; mass, volume, moisture basis and per-person rates differ.

# A dated global waste composition




World Bank 2018 report: approximate 2016 composition, not every city or a current measurement.

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# Trends are conditional and unequal

## World Bank 2018 report

2016 estimate 2.01 billion tonnes MSW; conditional 2050 projection 3.40 billion.

Not a current annual count.

## Society and time

Income, diet, policy, technology, packaging, season and collection matter.

Do not treat all higher- or lower-income households as identical.

# Plastic persistence and exposure

## Physical effects

Entanglement, ingestion, habitat effects and fragmentation.

No universal lifetime; a garbage patch is not a solid island.

## Read the denominator

OECD: 9% of 2019 plastic waste ultimately recycled after losses.

Microplastic detection establishes exposure, not by itself a particular disease.

# Half-life is a conditional model

1. **Invented assumptions.** 80 g substance; fixed 10-year half-life.
2. **After one and two half-lives.** 40 g after 10 years; 20 g after 20 years.
3. **Limits.** Not a universal model for weathering, every polymer or elemental metals.

**Decision**

Biodegradable does not guarantee rapid harmless breakdown in every environment.

# Waste can transfer social costs

## Exposure

**Leachate**, uncontrolled smoke and unsafe recovery affect workers and neighbours.

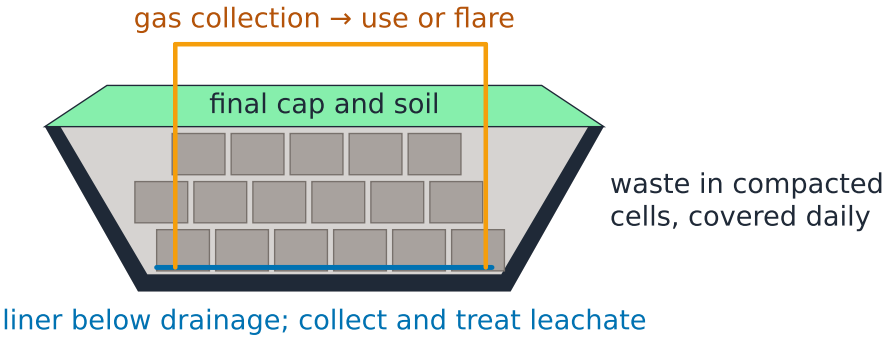
Export may provide materials/income while moving environmental risks.

## Governance

Basel e-waste amendments effective January 2025 extend prior-informed-consent controls.

Not proof that illegal movement ended or a universal ban on every working used device.

# Engineered landfill reduces rather than eliminates risk




Drainage sits above the liner; treat **leachate**, manage gas and monitor during and after operation.

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# Compare treatment pathways

## Landfill and incineration

Engineered **landfill** needs containment, gas and long-term monitoring.

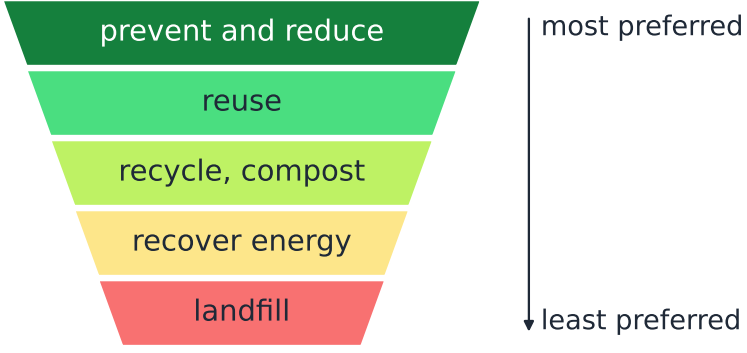
**Incineration** may recover energy but needs emissions control and ash management.

## Biological and material routes

Compost needs sorted organics, oxygen and quality control.

Digestion yields biogas/digestate; **recycling** needs collection, clean streams, energy and markets.

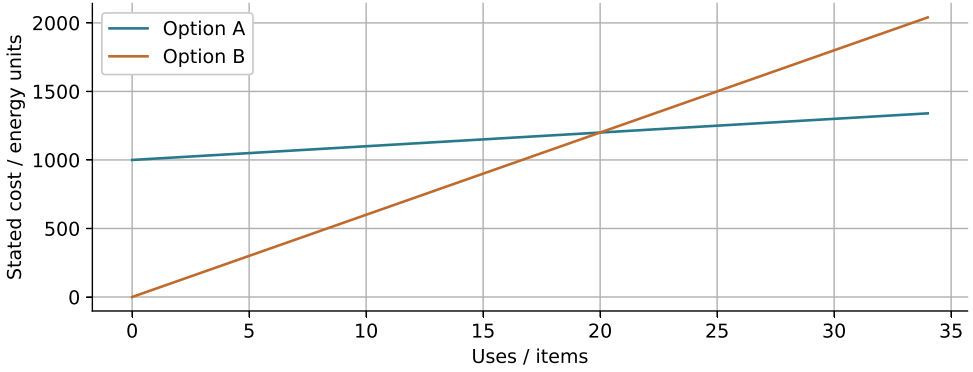
# Prefer prevention with safe residual treatment




Avoid upstream demand where possible; hazardous contamination can limit safe recovery.

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# A matched-service lifecycle model




Invented energy boundary: reusable $1000 + 10n$, disposable $60n$; equality at 20 uses.

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# Use an inequality for lower energy

1. **Invented bottle.** Reusable: $1500+15n$ kJ; disposable: $90n$ kJ.
2. **Lower energy.** $1500+15n<90n \rightarrow n>20$.
3. **First whole-number use.** 21; equality at 20 is not a saving.

## Decision

One wash per use is assumed; water, transport, detergent, breakage and other impacts remain outside the model.

# Shanghai sorting: stages need evidence

## Regulation effective July 2019

Recyclables, hazardous, wet/food and dry/residual streams.

Labels, facilities, education, monitoring and penalties can support behaviour.

## Evaluate downstream

Track contamination, processing, recovered output and residues.

Before/after sorted collection alone does not prove causation or complete **recycling**.

# Follow a material through circular recovery

1. **Pathway.** Ore $\rightarrow$ refining $\rightarrow$ aluminium can manufacture $\rightarrow$ use $\rightarrow$ collection $\rightarrow$ sorting/remelting.
2. **Invented efficiencies.** 100 units $\times$80% collected $\times$90% recovered $=$72 units returned.
3. **Loss.** 28 units uncollected or lost; prevention/reuse can reduce primary demand earlier.

## Decision

Technical recyclability differs from observed recovery; growth in demand can outweigh lower use per item.

# AHL: Incentives and SDGs

## Intervention

Taxes, limits, bonds, penalties; procurement, subsidies, research and standards.

NGOs and communities can monitor and organise action.

## Two linked goals

SDG 6 water and SDG 12 consumption/production.

Water reuse can support both, with energy, access and treatment safeguards.

# AHL: Renewable does not prove sustainable extraction

## Timber supply chain

Roads, habitat fragmentation, soil loss and transport emissions.

Volume replacement alone does not protect all services.

## Incentives and claims

Short-term income may undermine long-term renewal.

Biological nitrogen fixation is not an established replacement for every industrial ammonia need.

# AHL: Assess a proposed reservoir

## EIA sequence

Define alternatives/no project; baseline; predict; avoid/mitigate; evaluate residuals.

Requirements vary by jurisdiction.

## Follow-up

Seasonal flow, sediment, fish, water quality, rights and livelihoods.

Indicators, triggers, independent scrutiny, actions and accountable funding.

# AHL: Participation and resource security

## Public evidence

Accessible information, local knowledge, documented disagreement and rights.

A late meeting does not automatically establish informed consent.

## Trade and resilience

Demand reduction, supply and technology choices in food, water and energy.

Trade can spread risk but dependence on narrow suppliers/routes can create vulnerability.

# AHL: Rank association does not prove causation

1. **Invented matched observations.** A: 2,4,6,8; B: 3,5,7,9 units/person.
2. **Rank differences.** Both rank 1,2,3,4; every d=0, so Spearman r=1.
3. **Interpret.** Amounts differ; annual observations may not be independent.

## Decision

Real secondary-data studies need matched units/periods, metadata, sample-size justification and uncertainty.

# AHL: Reserves-to-production is conditional

1. **Invented snapshot.** Reserves 120 units; extraction 3/year $\rightarrow$ R/P=40 years.
2. **Change assumptions.** Extraction 4 $\rightarrow$30 years; reserves 150 at extraction 3 $\rightarrow$50 years.
3. **Limits.** Discovery, prices, technology, policy and demand change values.

## Decision

Climate constraints can limit burning before physical exhaustion; R/P is not a guaranteed countdown.

# AHL: Nuclear costs, wastes and safety

## Full lifecycle

Fission heat $\rightarrow$ steam $\rightarrow$ electricity; fuel **non-renewable**, lifecycle carbon generally low.

Mining, cooling, financing, construction and decommissioning.

## Different hazards

Waste heat, shielding, containment and long-term management have distinct roles.

Availability is not absolute and low operating fuel cost does not guarantee a cheap new project.

# AHL: Battery chemistry and supply chains

## Materials

Lithium: alkali metal. Cobalt: transition metal. Neither is a rare earth.

Some lithium-ion cathodes contain cobalt; LFP contains none.

## Stages and outcomes

Mining/brine extraction, refining, cell manufacture, use and recovery.

Water, tailings, energy, rights and safety; mining and processing concentration differ.

# Exam tips

## State the quantity

Stock/flow; MW/MWh; primary energy/electricity; capacity factor/efficiency.

Collection versus actual recovery; mass versus volume.

## Evaluate

Named context, full boundary, equity and evidence.

**Renewable**/recyclable labels are not outcomes; equality is not a strict saving.

# Check yourself

## Your turn

A reusable item matches disposable energy at 20 uses and grows more slowly thereafter. At which whole-number use does it first use less?

A. 21 uses.

B. 20 uses.

C. 19 uses.