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وزارة الصناعة والثروة المعدنية
Ministry of Industry and Mineral Resources
الأكاديمية الوطنية للصناعة
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Energy Efficiency and Carbon Management

Decarbonizing the future

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Your Facility's Biggest Energy Challenge?

Question:

"What is one energy or carbon challenge your facility faces?"

Examples:

- High electricity use, steam/boiler losses, compressed air leaks, fuel consumption, and/or lack of energy data.

Instructions:

1. One short sentence
2. 15 seconds each
3. No solutions yet

Training program objectives

Calculate carbon emissions for industrial operations

Interpret key energy performance indicators (SEC, EnPI)

Identify low-carbon and energy-efficient technologies

Understand carbon credits and reduction mechanisms

Develop a practical carbon-neutral action plan

Apply concepts through two hands-on workshops

Training agenda: day 1

Pre-Training short assessment

Module 1: Carbon footprint fundamentals

Module 2: Energy efficiency indicators

Workshop 1: Carbon footprint calculation

Module 3: Introduction to emission reduction measure

Training agenda: day 2

Module 4: Low-carbon and renewable technologies

Module 5: Carbon credits and incentives

Module 6: Carbon-neutral strategy design

Workshop 2: Carbon-neutral energy plan (10–15 year roadmap)

Carbon Footprint fundamentals

Module 1

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In this module we will cover:

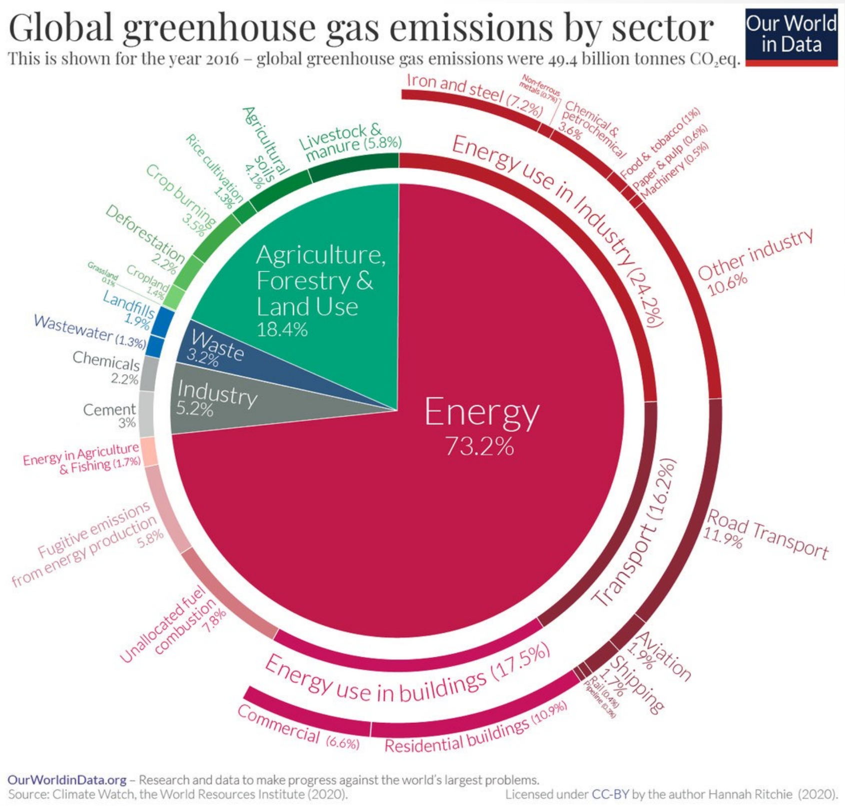
1. What a carbon footprint is
2. Scope 1, Scope 2, and Scope 3 emissions
3. Emission factors and activity data
4. Establishing baselines and boundaries
5. Calculating carbon intensity for industrial operations

What is a carbon footprint?

A **carbon footprint** is the total greenhouse gas emissions produced by a facility, process, or activity, expressed in **CO_2-equivalent (CO_2e)**.

Key points:

- Measured in **tons of CO_2e**
- Includes **direct and indirect** emissions
- Helps identify reduction opportunities



Why carbon footprinting matters?

Identify high-emission areas

Reduce energy use and operating costs

Support ESG compliance and reporting

Align with national frameworks (Vision 2030, SGI, SEEC, and/or 2060 national carbon naturality targets.)

Understanding scope 1, 2 and 3

Scope 1 — Direct emissions

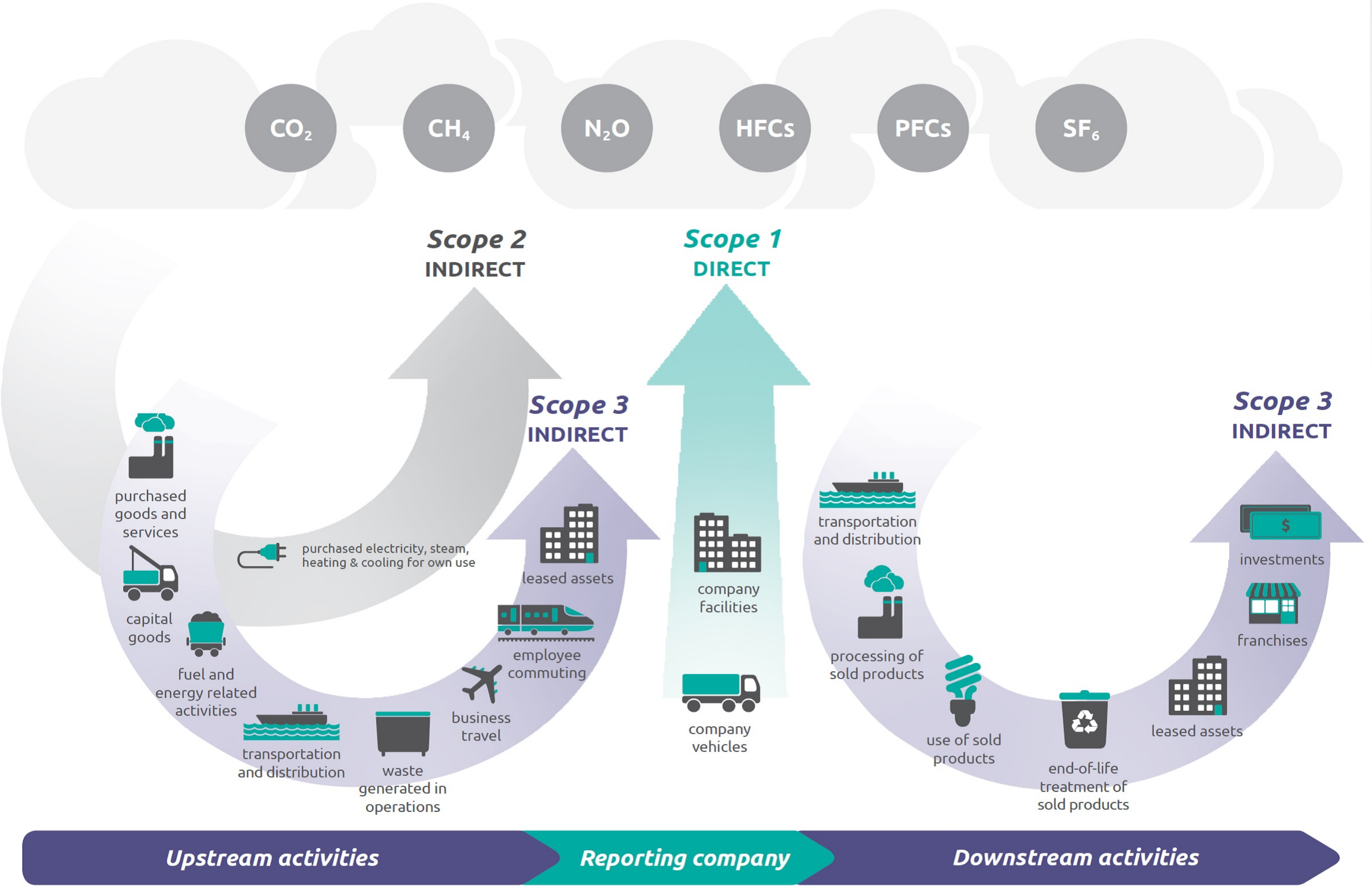
➢ Fuel combustion, boilers, furnaces, generators, company vehicles.

Scope 2 — Indirect emissions

➢ Purchased electricity, steam, chilled water.

Scope 3 — Value-chain emissions

➢ Materials, logistics, waste, commuting, suppliers.



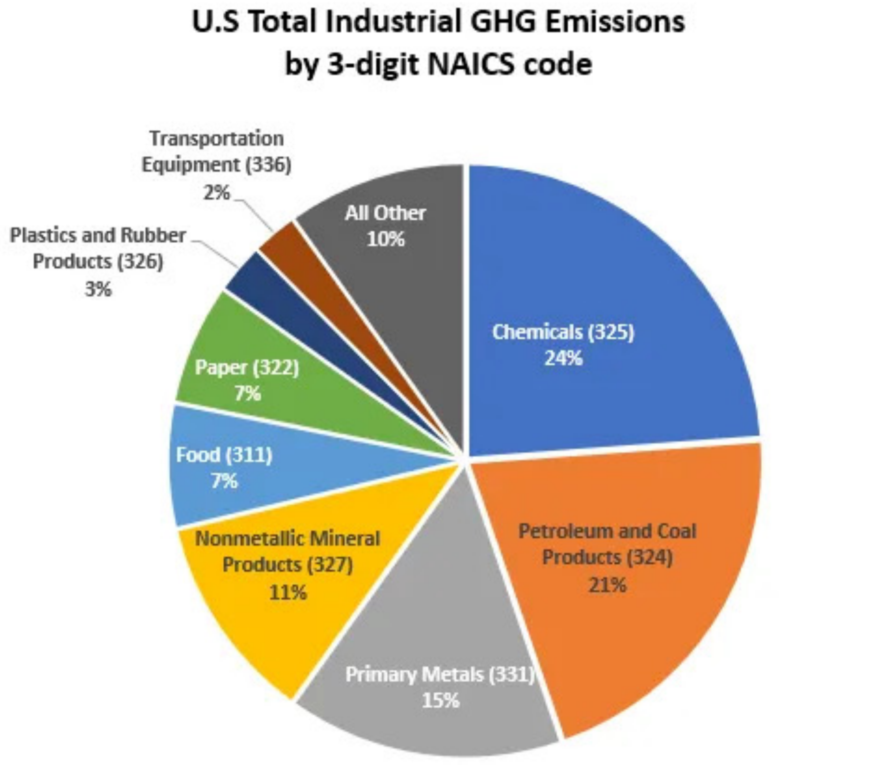
Common industrial emission sources

Manufacturing

- Furnaces and kilns
- Compressed air systems
- Motors and pumps
- Process heat

Mining

- Diesel for haul trucks
- Crushing & grinding
- Ventilation systems
- On-site generators



Note: Includes Direct, Indirect, and Process Emissions.
Source: ENERGY STAR Industrial Team Internal Energy & GHG Emission Analysis based on US GHG Inventory, EPA GHGRP, and EIA MECs

Emission factors

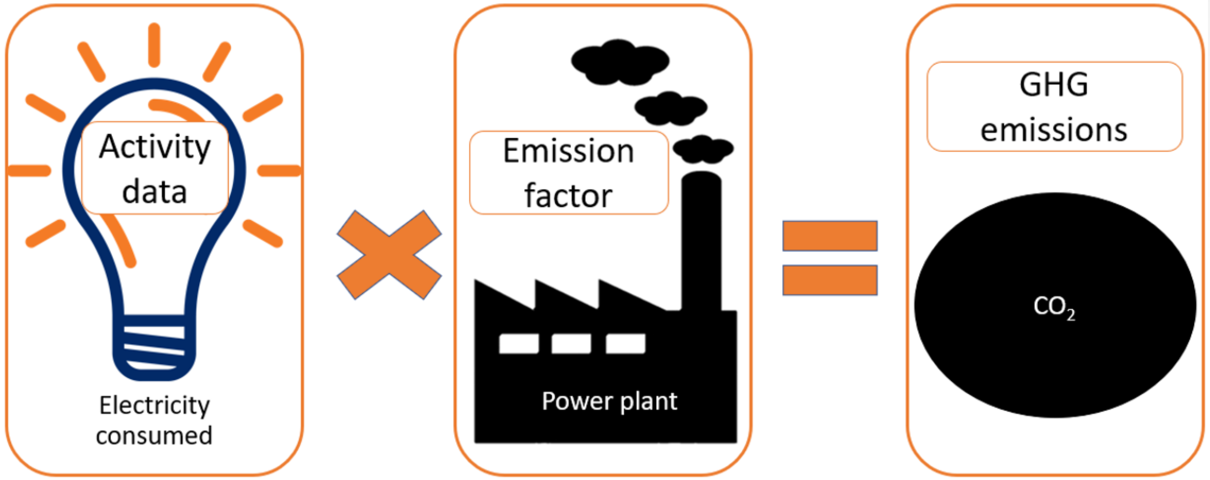
Emissions = **Activity data** × **Emission factor**

Examples

Diesel → ~2.68 kg CO_2 per liter

Natural gas → ~2.0 kg CO_2 per m³

Electricity (Saudi grid) → use latest SEEC factor



Activity data needed (1/2)

Scope 1 (direct emissions)

- Fuel consumption (diesel, gas, LPG)
- On-site combustion systems

Scope 2 (indirect energy emissions)

- Electricity (kWh)
- Purchased steam or chilled water

Activity data needed (2/2)

Scope 3 (value-chain emissions; increasingly required globally)

- Purchased materials
- Transport & logistics
- Waste treatment
- Business travel & commuting
- Upstream and downstream activities

CSRD
Corporate Sustainability Reporting Directive

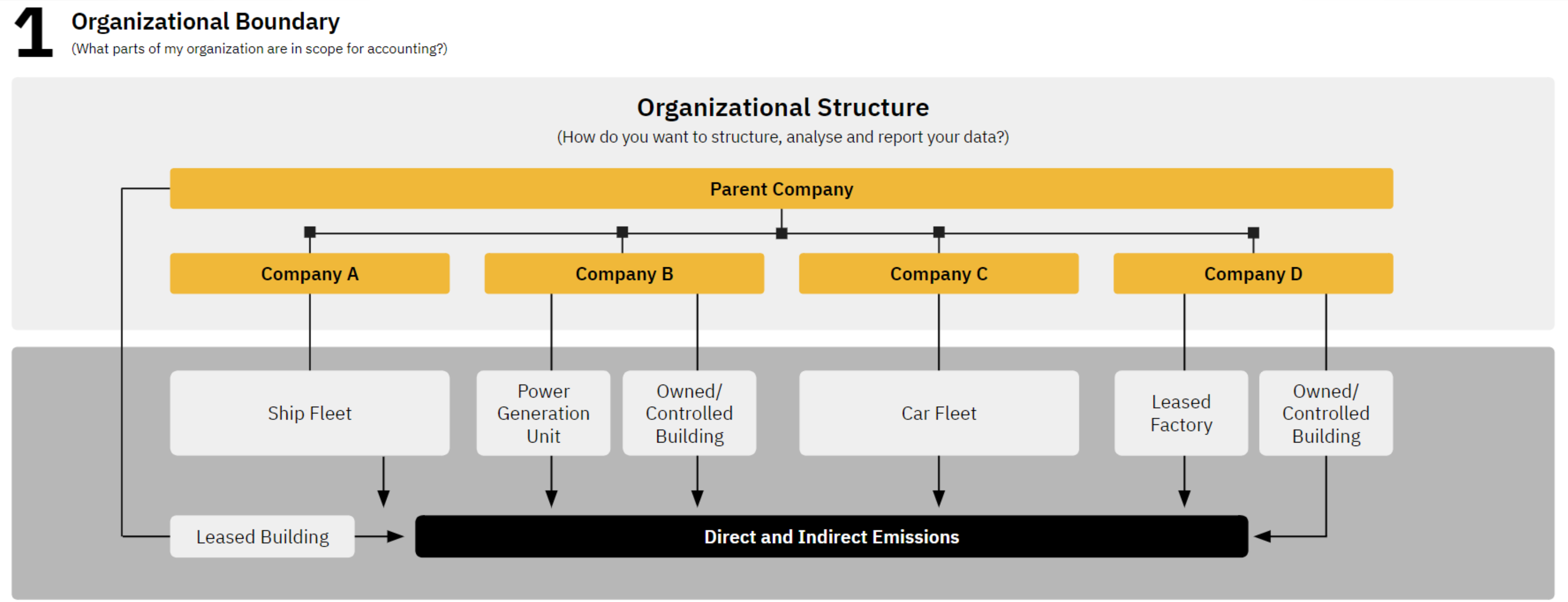
EU Directive on Corporate Sustainability Due Diligence

IFRS S2

Boundaries and baselines (1/2)

Organizational boundary

- Defines which sites, business units, or facilities are included.



Boundaries and baselines (2/2)

Operational boundary

- Defines which emission sources are included (Scope 1, Scope 2, Scope 3).

Baseline year

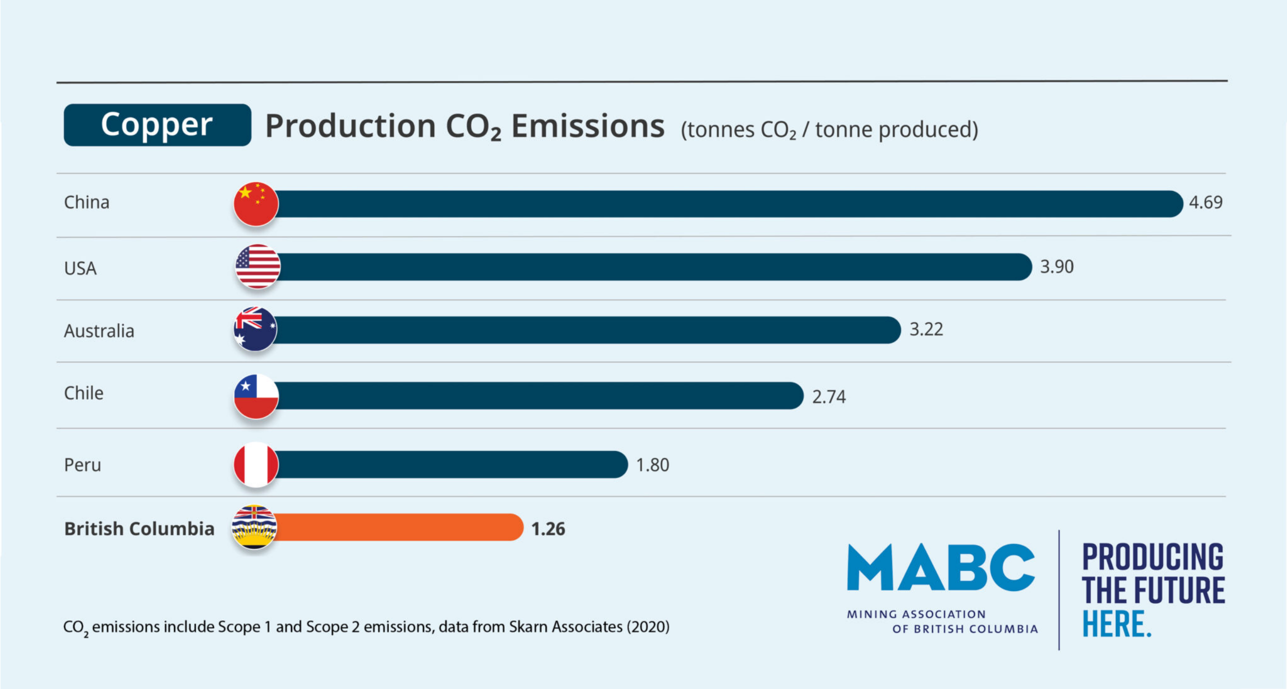
- The reference year used to measure improvement over time.

Calculating carbon intensity

Carbon intensity = Total CO_2e / Production output

Examples:

- Cement → tCO_2 per ton of clinker
- Mining → tCO_2 per ton of ore processed
- Manufacturing → tCO_2 per ton of product



Sample industrial carbon footprint

Activity data (example)

- **Diesel consumption:** 45,000 L/year
- **Electricity consumption:** 12,000,000 kWh/year
- **Natural gas consumption:** 500,000 m^3/year
- **Annual production:** 25,000 tons of product

What we calculate from this:

1. **Total CO_2e emissions**
   - Scope 1 → diesel + natural gas
   - Scope 2 → electricity
2. **Carbon intensity**
   - tCO_2e per ton of product
3. **Main emission drivers**
   - Which source contributes the most?
   - Typically electricity or fuel combustion

Module 1 summary

What we learned so :

- What a carbon footprint is
- Distinguish between Scope 1, Scope 2, and Scope 3
- Identify common industrial emission sources
- Use activity data and emission factors
- Establish boundaries and baselines
- Calculate basic carbon intensity (tCO_2/ton)

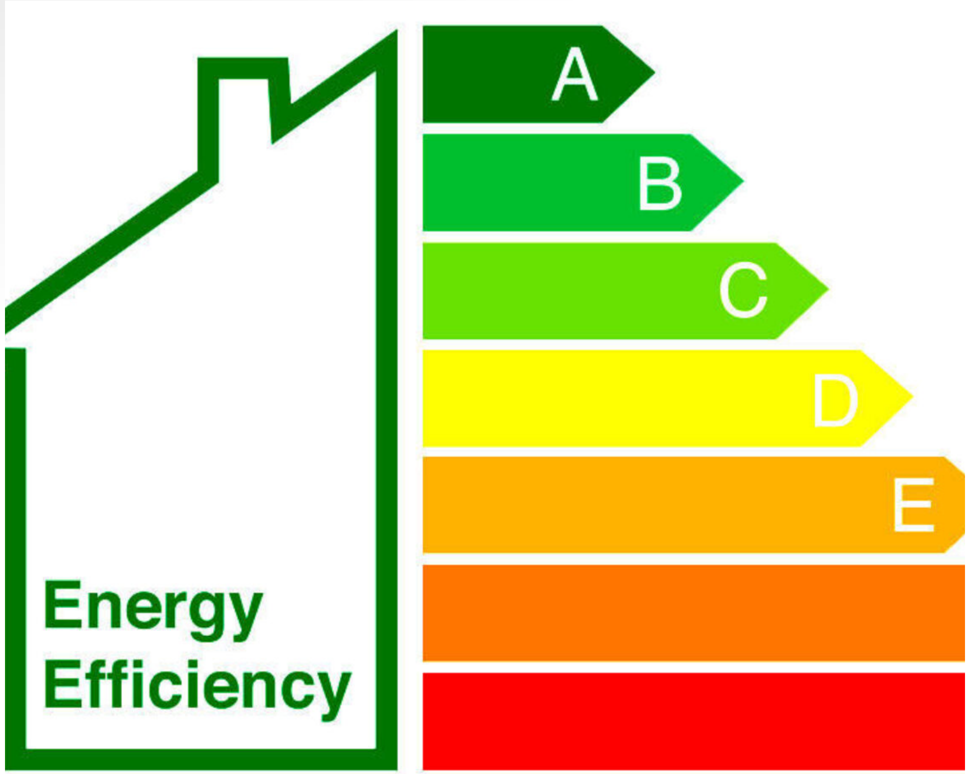
Energy Efficiency indicators

Module 2

In this module we will cover:

1. What energy intensity and SEC mean
2. How EnPIs are used in industry
3. How to identify significant energy uses (SEUs)
4. How indicators support carbon reduction

What is energy efficiency?



Energy efficiency means **using less energy to achieve the same output** or **producing more output with the same energy**.

Examples:

- Efficient motors
- Optimized compressed air systems
- Improved process heating

Understanding SEC

SEC (Specific Energy Consumption)

- **Process- or product-specific metric**
- Measures **energy used per unit of production**
- Always tied to a *specific product, process, or equipment*

Examples:

- kWh/ton of cement, GJ/ton of clinker, kWh/m³ of compressed air

Used for:

- Benchmarking process lines
- Monitoring specific systems
- Comparing performance across shifts or machines

Energy intensity

Energy used **per unit of total output or activity at the facility level**.

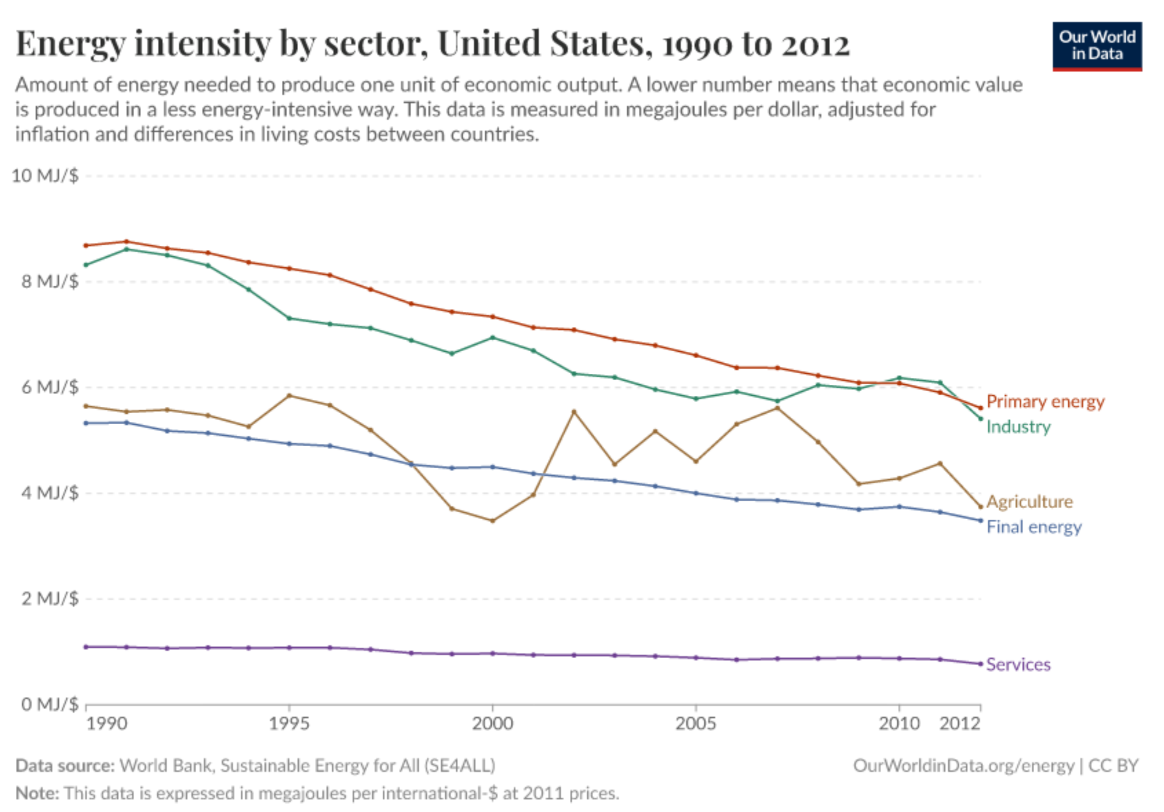
Broader indicator than SEC

Example:

- kWh/ton of *total plant output*, MJ per SAR/$ of revenue (Economic intensity)

Used for:

- Whole-facility performance assessment, High-level corporate energy reporting, cross-site comparisons



What are EnPIs?

EnPIs (Energy Performance Indicators) are metrics used to **measure, monitor, and improve energy performance** at process or facility level.

Examples of EnPIs:

- SEC (kWh/ton of product), Facility energy intensity (kWh/ton of total output), Motor system efficiency (%)

Why EnPIs matter:

- Track performance over time
- Compare against targets or baselines
- Identify abnormal or inefficient operations
- Required under **ISO 50001:2018 Energy management systems**

Identifying significant energy uses (SEUs)

SEUs = Processes, systems, or equipment that consume the largest share of energy.

- They are the **priority areas** for improving efficiency and reducing emissions.

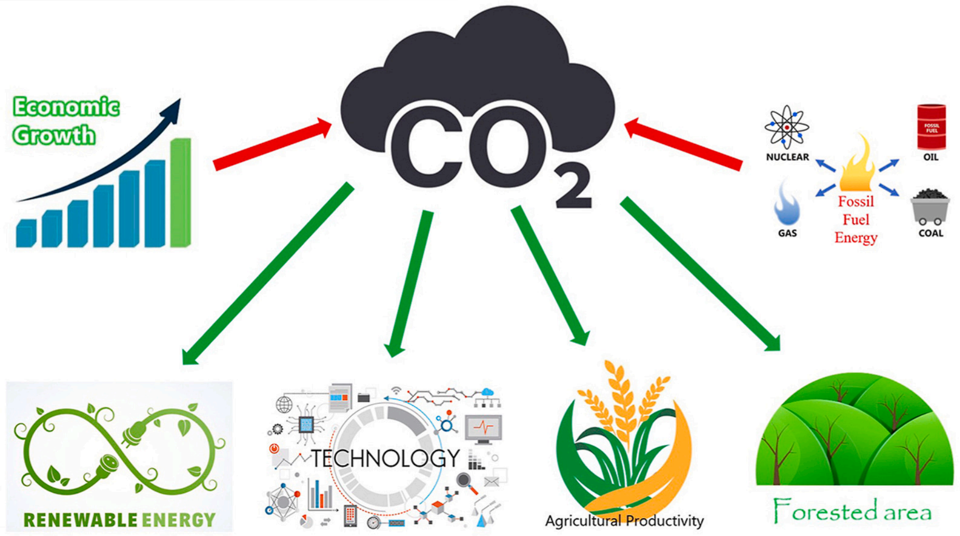
Common SEUs in industry:

- Motors and pumps, compressed air systems, furnaces and boilers, HVAC and process cooling, crushing & grinding (mining), ventilation systems (mining)

Why SEUs matter:

- They use the most energy
- Small improvements give big savings
- Focuses efforts where impact is highest

How indicators support carbon reduction



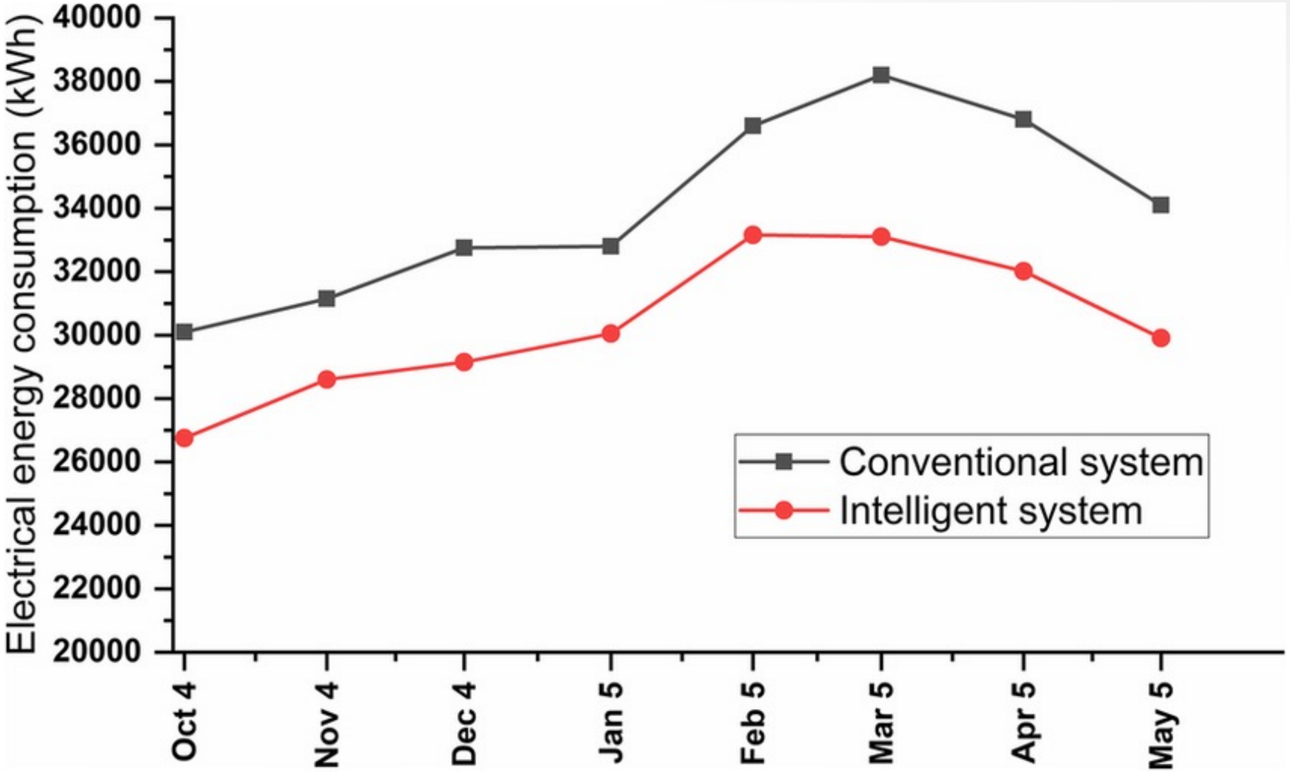
Energy indicators help you:

- Track efficiency over time
- Spot abnormal or wasted energy use
- Identify improvement opportunities
- Link energy use directly to CO_2 emissions
- Support low-carbon planning and decision-making

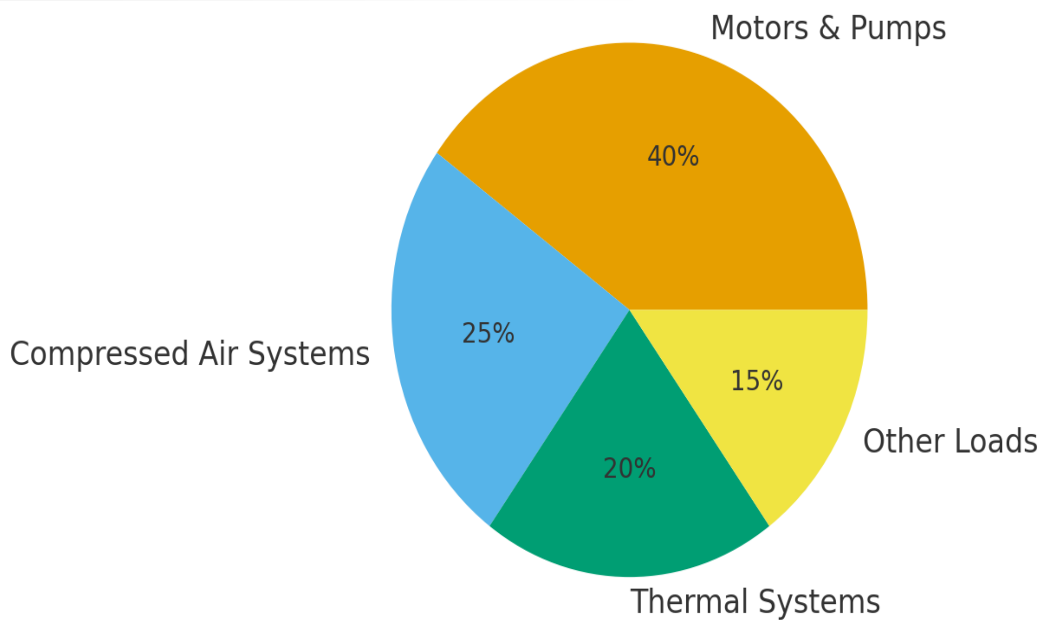
Example: SEC trend

Tracking SEC over time helps identify:

- Seasonal variations
- Equipment degradation
- Process inefficiencies
- Opportunities for improvement



Example: SEU analysis



What this chart tells us:

- Motors/pumps are the top priority
- Compressed air is a major opportunity
- Thermal systems also require attention

Module 2 summary

What we learned in module 2:

- What are SEC and energy intensity measure
- Use EnPIs to track energy performance
- Identify significant energy uses (SEUs)
- Interpret trends and spot inefficiencies
- Understand how energy indicators support carbon reduction

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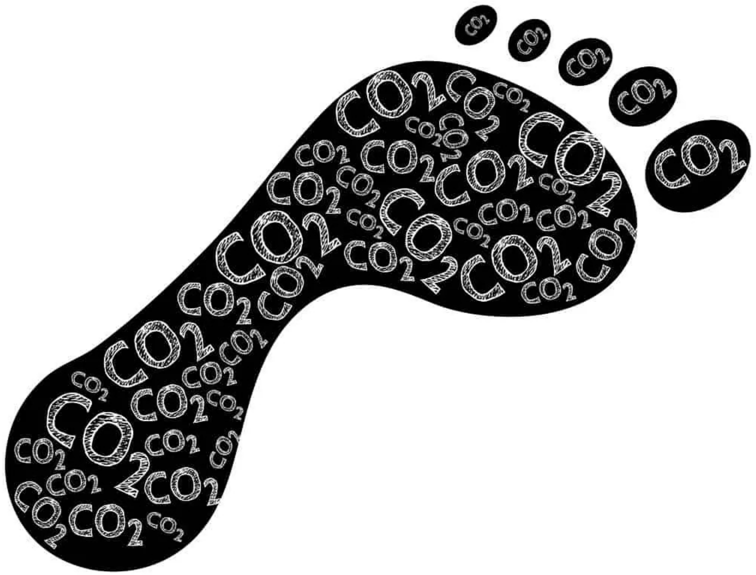
Carbon footprint calculation

Workshop 1

Workshop 1: Carbon footprint calculation



In this workshop, you will:

- Use activity data (fuel + electricity)
- Apply emission factors
- Calculate Scope 1 and Scope 2 emissions
- Compute carbon intensity
- Identify main emission sources

Dataset for calculation

Activity data (example facility):

- Diesel consumption: **45,000 L/year**
- Natural gas: **500,000 m³/year**
- Electricity: **12,000,000 kWh/year**
- Production output: **25,000 tons/year**

Emission factors (provided):

- Diesel: **2.68 kg CO_2/L**
- Natural gas: **2.0 kg CO_2/m³**
- Electricity (KSA grid, example): **0.63 kg CO_2/kWh**

Step 1: Calculate Scope 1 emissions

Scope 1 = Emissions from diesel + natural gas:

- *Diesel CO_2e = Diesel (L) × EF*
- *Natural gas CO_2e = Gas (m^3) × EF*

We will compute:

- Total diesel CO_2e
- Total natural gas CO_2e
- Scope 1 total

Step 2: Calculate Scope 2 emissions

Scope 1 = Emission from electricity use

- *Electricity CO_2e = kWh × EF (grid)*

We will compute:

- Total electricity CO_2e
- Scope 2 total

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Step 3: Total emissions & intensity

Total emissions = Scope 1 + Scope 2

Carbon intensity = Total CO_2e / Production output

What should we determine:

- Facility's annual CO_2e
- tCO_2 per ton of product
- Percentage contribution of fuel vs electricity

Step 4: Identify main emission sources

Using your results, please determine:

1. Which source contributes the most?
   - Diesel?
   - Natural gas?
   - Electricity?
2. What percentage each source contributes?
3. Where reduction efforts should start?

Group discussion questions

1. Which emission source was the largest?
2. What quick improvements could reduce energy use in that area?
3. How does this compare to the challenges you shared earlier?
4. Is your facility’s main source likely similar?

Workshop 1 summary

We have now practiced:

- Scope 1 & 2 calculations
- Using emission factors
- Finding total CO_2e
- Calculating carbon intensity
- Identifying major emission drivers

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Introduction to emission reduction measures

Module 3

In this module we will cover:

1. How to link emissions to energy use
2. Short-term and low-cost reduction measures
3. Medium- and long-term improvement options
4. How facilities typically sequence reduction actions
5. Preparing for the carbon-neutral planning workshop

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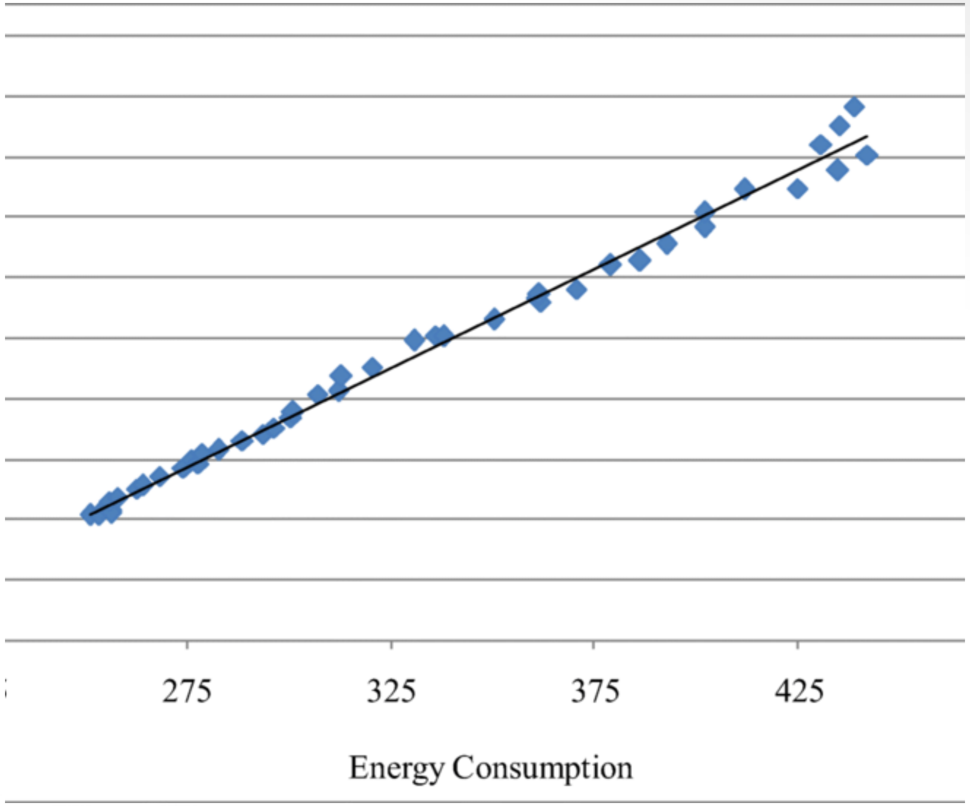
The link between energy and emissions

Key point:

Reducing energy use = reducing carbon emissions

Why:

- Most industrial emissions come from fuel and electricity use
- Lower energy consumption directly reduces CO_2
- Efficiency improvements are usually the fastest, cheapest way to cut emissions



Types of emission reduction measures (1/2)

1. Operational improvements

- Fix leaks (compressed air, steam)
- Optimize setpoints
- Reduce idling and no-load running
- Improve maintenance routines

2. Energy efficiency upgrades

- High-efficiency motors
- VFDs
- Heat recovery
- Efficient lighting and HVAC

Types of emission reduction measures (2/2)

3. Fuel switching

Diesel → natural gas

Fuel oil → gas

Thermal oil → electric heating (where feasible)

4. Renewable energy

Solar PV

Solar thermal

Hybrid systems for remote sites

Short-term, low-cost measures ("quick wins")

Examples:

- Fix leaks and insulation issues
- Optimize equipment scheduling
- Improve combustion efficiency
- Switch off non-essential loads
- Tune compressed air pressures

Impact:

- Low or zero CAPEX
- Immediate savings
- Strong payback

Medium-term measures

Examples:

- Motor replacement (IE3/IE4)
- Installing VFDs
- Upgrading boilers and burners
- Waste heat recovery systems
- Process optimization projects

Impact:

- Moderate CAPEX
- Significant long-term savings

Long-term measures

Examples:

- Electrification of high-temperature processes
- Green hydrogen (future pathway)
- Carbon Capture, Utilization, & Storage (CCUS)
- Major plant redesign or modernization

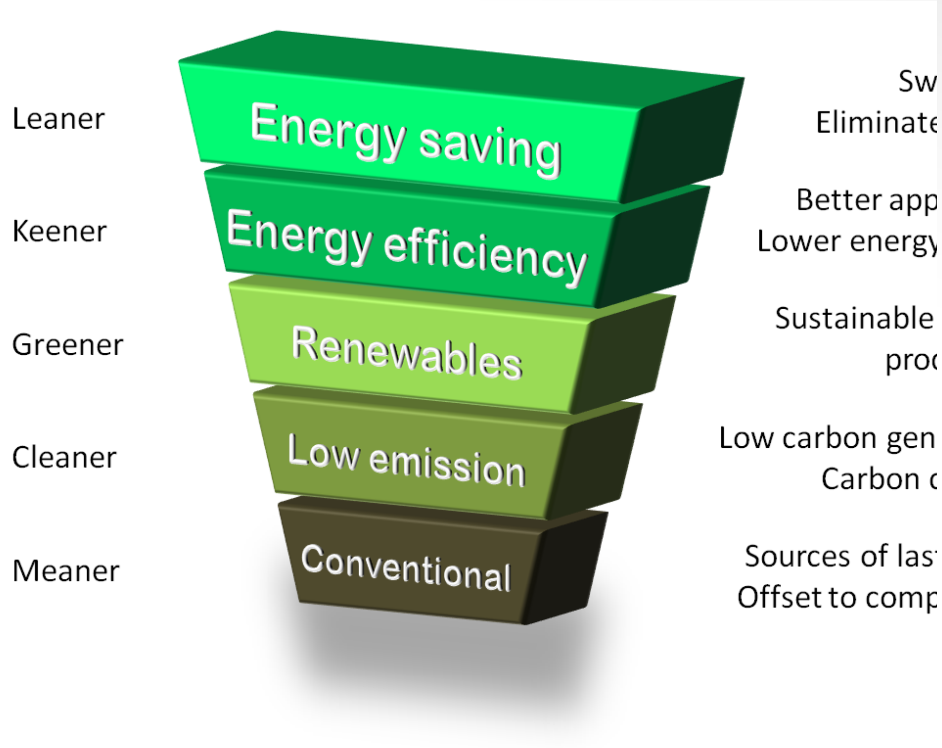
Impact:

- High CAPEX
- Long payback
- Required for deep decarbonization

Sequencing carbon reduction actions

Typical reduction sequence:

1. **Quick wins** (no/low cost)
2. **Efficiency upgrades** (medium CAPEX)
3. **Fuel switching**
4. **Renewable integration**
5. **Long-term deep decarbonization**
6. **Managing residual emissions** (offsets/credits)



Preparing for the workshop

Your tasks in the next workshop will be to:

- Identify key emission sources
- Select suitable reduction options
- Prioritize actions by cost and impact
- Start building a long-term reduction pathway

Module 3 summary

What we learned in module 3:

- Why reducing energy reduces emissions
- The main types of reduction measures
- Differences between short-, medium-, and long-term emission reduction options
- How to sequence actions logically
- What they will apply in the next workshop

Low-Carbon technologies and renewable energy options

Module 4

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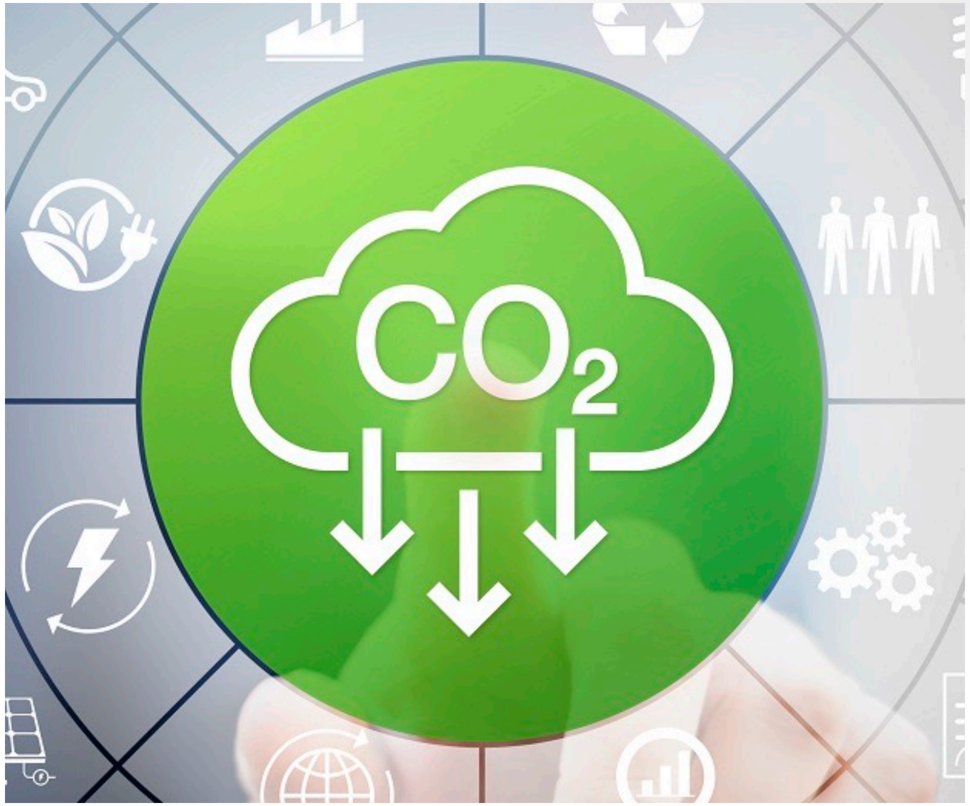
In this module we will cover:

1. Key low-carbon technologies for industry
2. Renewable energy options
3. Electrification pathways
4. How to evaluate suitability for your facility
5. Role of these technologies in long-term decarbonization

What is a low-carbon technology? (1/2)

A **low-carbon technology** reduces emissions by:

- Using less energy
- Using cleaner energy
- Avoiding fossil-fuel combustion
- Replacing high-carbon processes



What is a low-carbon technology? (2/2)

Examples:

- High-efficiency motors
- VFDs
- Heat pumps
- Solar PV / solar thermal
- Waste-heat recovery

High-efficiency motors (1/2)

Why motors matter:

Motive power = **60–70%** of electricity use in many factories

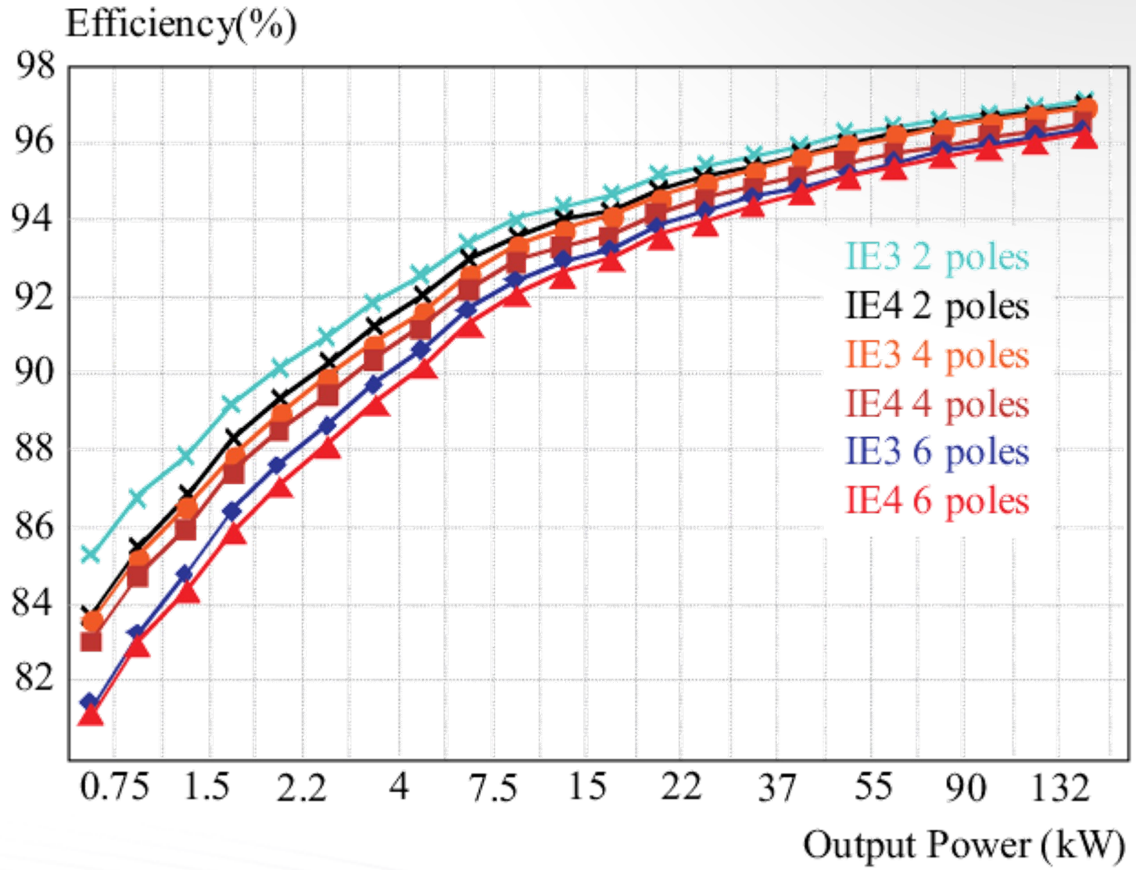
Motors and pumps are often top SEUs

Upgrading to IE3/IE4 motors cuts energy significantly

High-efficiency motors (2/2)

Benefits:

- 2–8% efficiency gain
- Lower heat and maintenance
- Works well with VFDs



Variable frequency drives (VFDs)

What VFDs do:

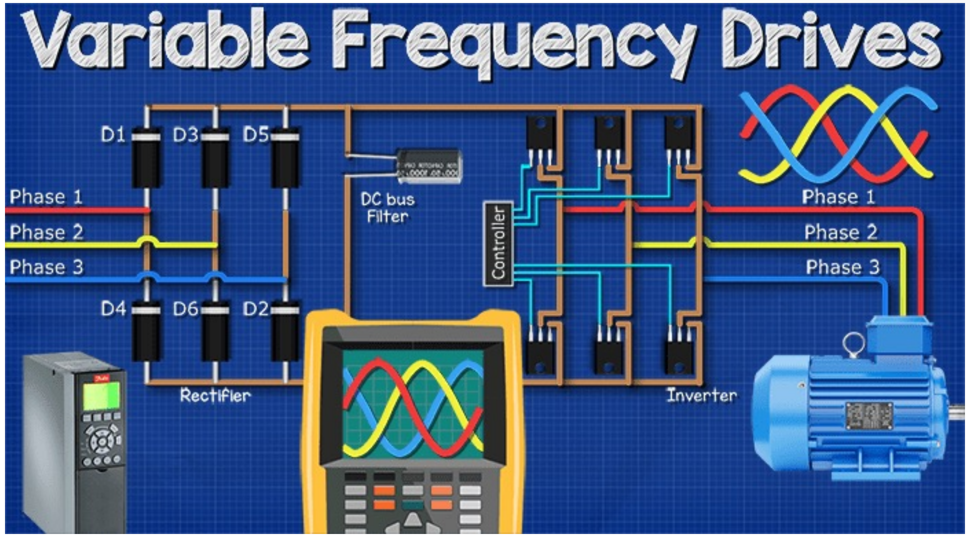
- Control **speed and torque** of motors
- Match motor speed to actual load
- Reduce energy use dramatically

Typical savings:

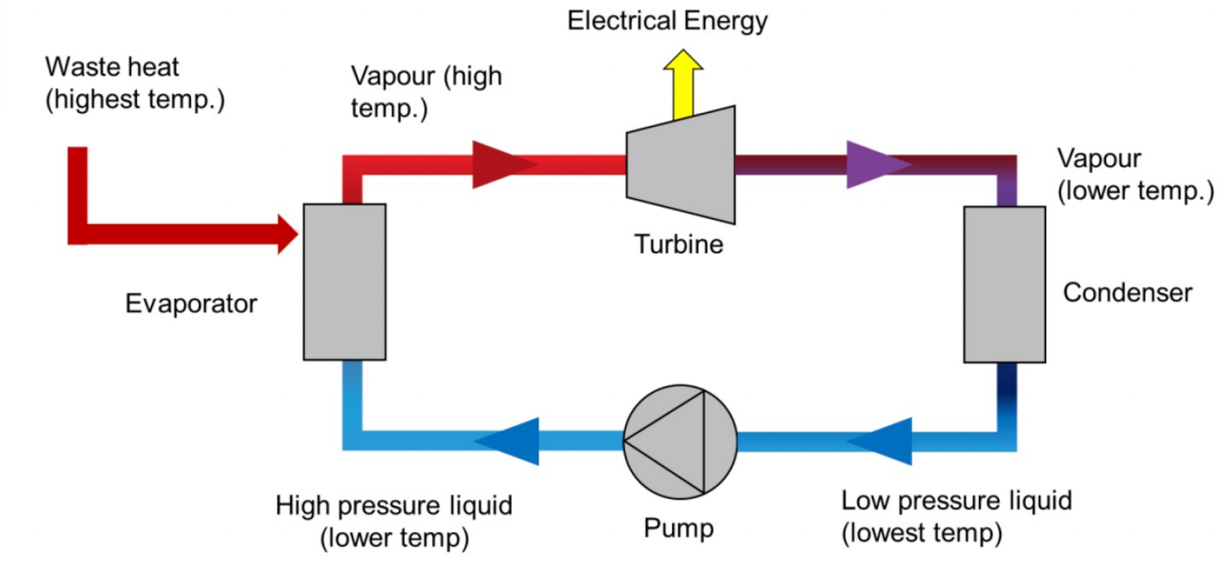
- **20–60%** for pumps, fans, blowers

Common applications:

- Pumps, fans, HVAC, conveyors



Waste-heat recovery



What it does:

Captures heat from flue gases, kilns, compressors, or exhaust and **reuses it** for:

- Pre-heating air or fuel
- Process heating
- Steam generation

Benefits:

- Reduces fuel use
- Improves thermal efficiency
- Cuts Scope 1 emissions

Electrification pathways

What electrification replaces:

- Fossil-fuel combustion in heating
- Diesel-powered equipment
- Boilers and burners

Examples:

- Electric boilers
- Electric furnaces (low-temp)
- Battery-electric mobile equipment
- Electrified mining fleets (haul trucks, loaders)

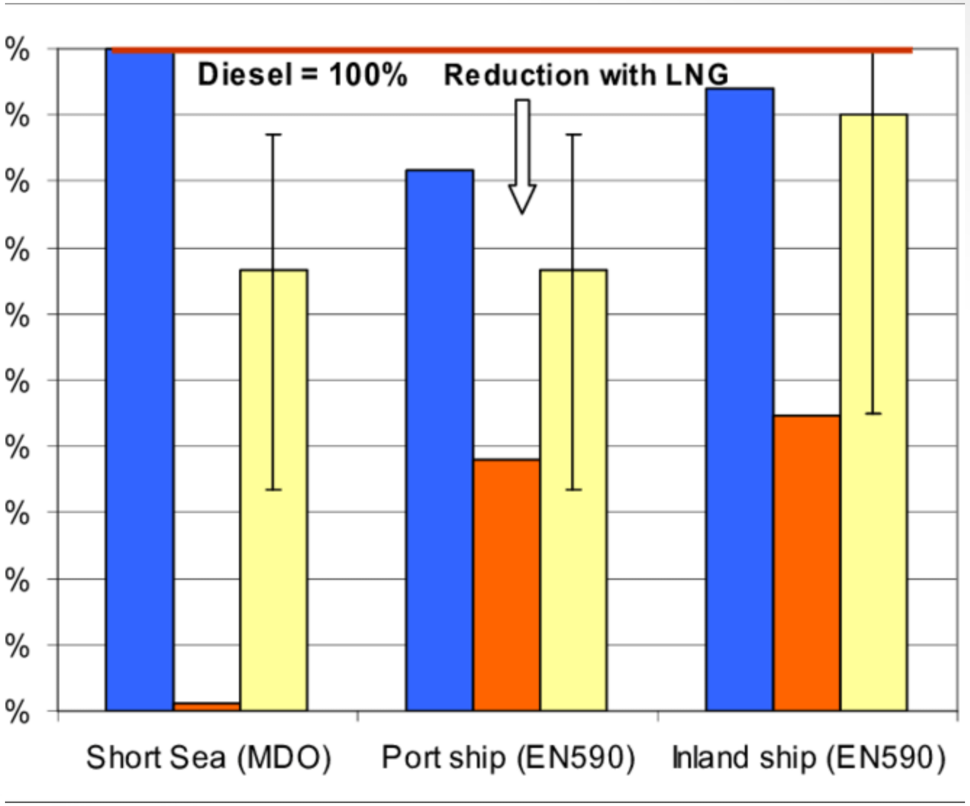
Fuel switching

Cleaner fuels reduce Scope 1 emissions:

- Diesel → natural gas
- Heavy fuel oil → gas
- Fossil heat → electric heat

When to consider fuel switching:

- Fuel availability
- Boiler/burner compatibility
- Safety and infrastructure



How to evaluate a low-carbon technology?

Key questions:

- What problem does it solve?
- What is the expected CO_2 reduction?
- What is the CAPEX / payback period?
- Is the technology proven in similar industries?
- Is the required expertise available?

Module 4 summary

What we learned in module 4:

- Major low-carbon technologies
- Renewable options for industry
- Electrification pathways
- Fuel switching opportunities
- How to evaluate technology suitability

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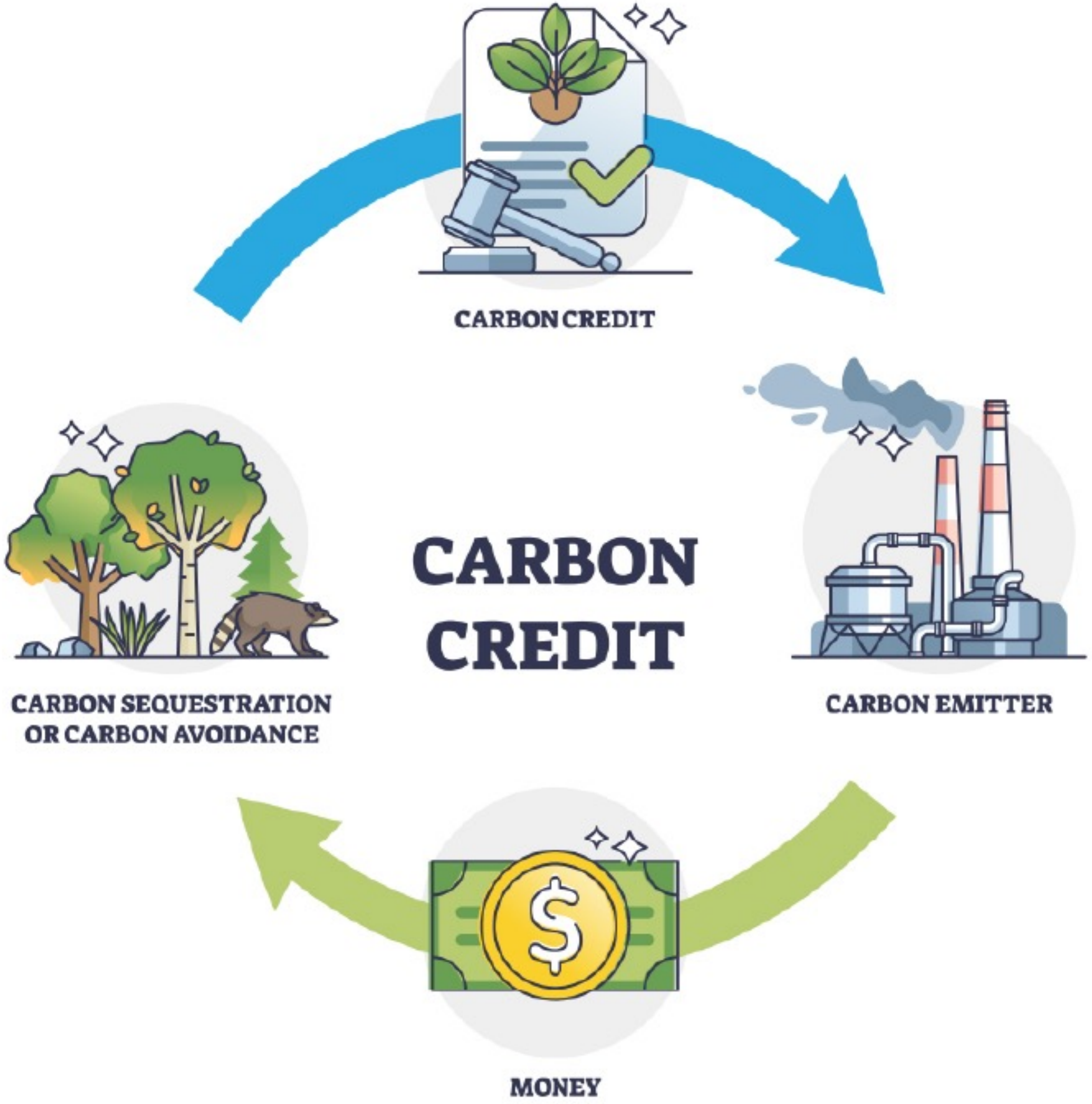
Carbon credits and incentives

Module 5



In this module we will cover:

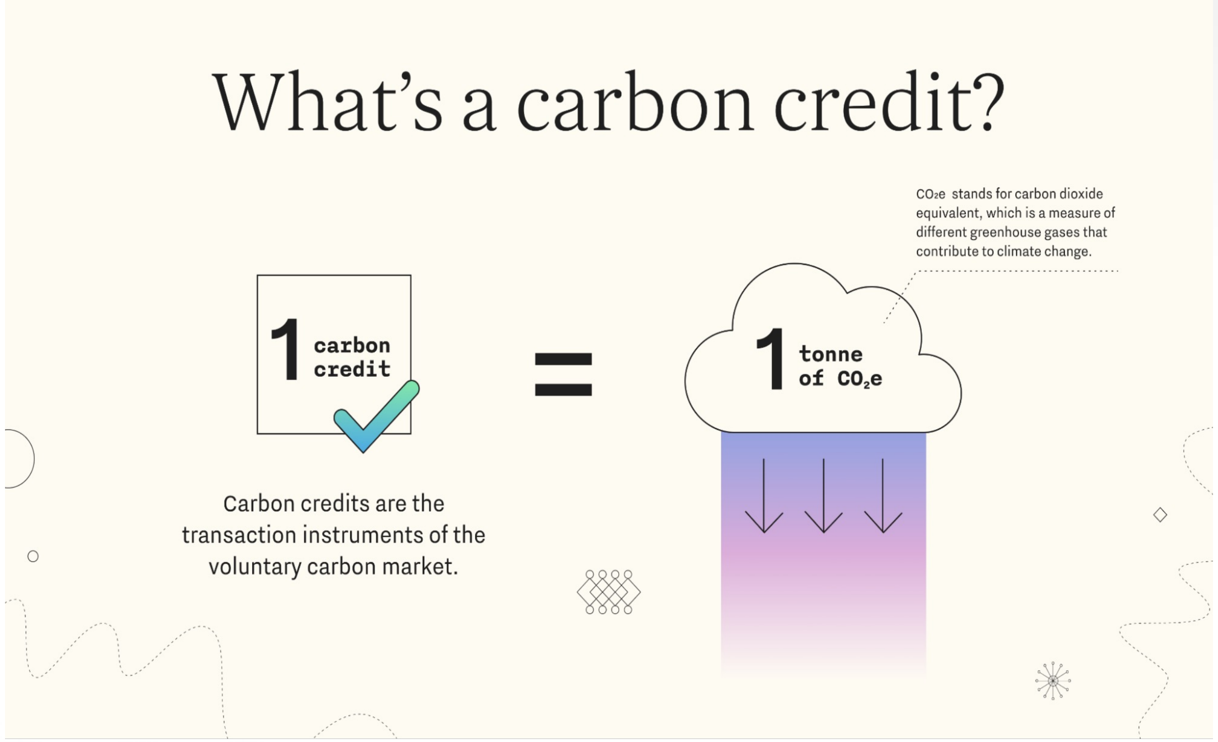
1. What carbon credits are
2. How carbon markets work
3. Difference between compliance and voluntary markets
4. Financial incentives for emission reduction
5. Role of credits in carbon-neutral strategies

What is a carbon credit?

A **carbon credit** represents **1 ton of CO_2e reduced or removed** from the atmosphere.

Credits can come from:

- Renewable energy projects
- Efficiency projects
- Reforestation
- Methane capture
- Carbon removal technologies



Compliance vs voluntary markets

Compliance markets

- ➤Government-regulated
- ➤Examples: EU ETS, California Cap-and-Trade
- ➤Mandatory for certain sectors

Voluntary markets

- ➤Companies buy credits voluntarily
- ➤Used for carbon neutrality
- ➤Wide range of project types

How carbon credits support industry

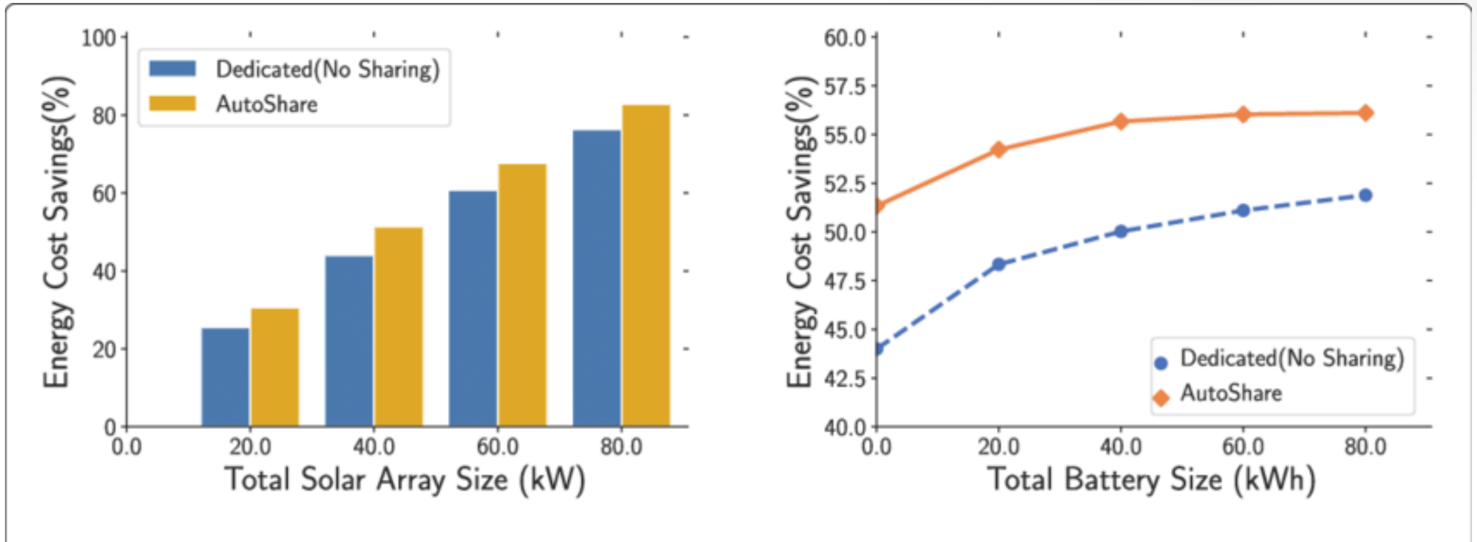
Carbon credits help organizations:

- Neutralize **residual emissions**
- Meet corporate climate targets
- Improve ESG ratings
- Access certain export markets
- Support long-term net-zero commitments

Financial incentives for reducing emissions

Companies can benefit from:

- ➢ Lower energy costs
- ➢ Lower carbon risk exposure
- ➢ Access to green financing
- ➢ Alignment with investor requirements
- ➢ Improved market competitiveness



(a) Savings with Solar (b) Savings with Battery

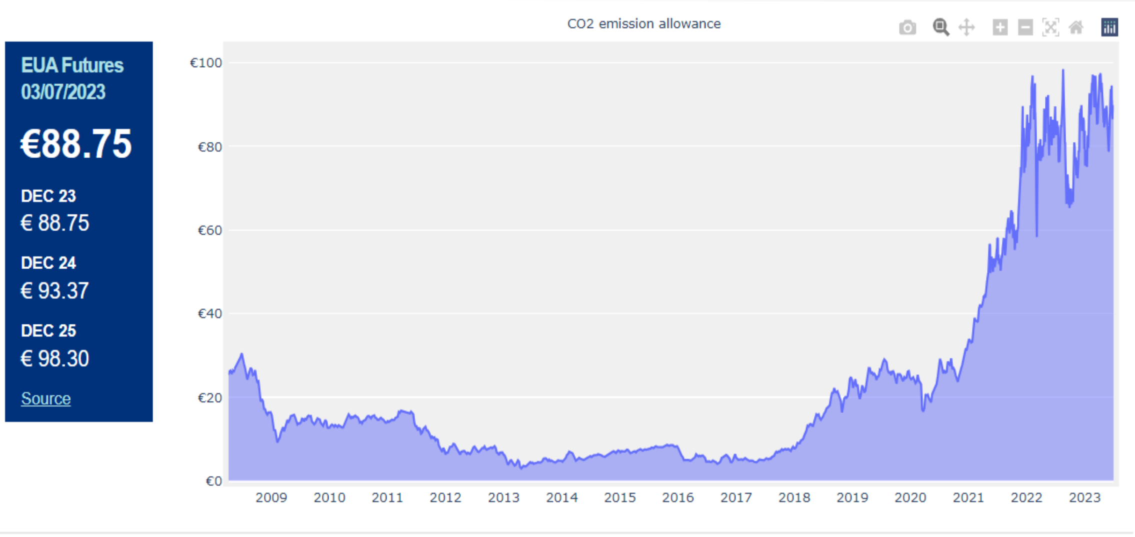
How carbon pricing works

Carbon pricing mechanisms:

- ➢**Carbon taxes**
- ➢**Cap-and-trade systems**
- ➢**Internal carbon pricing** (used by companies)

Prices can range from:

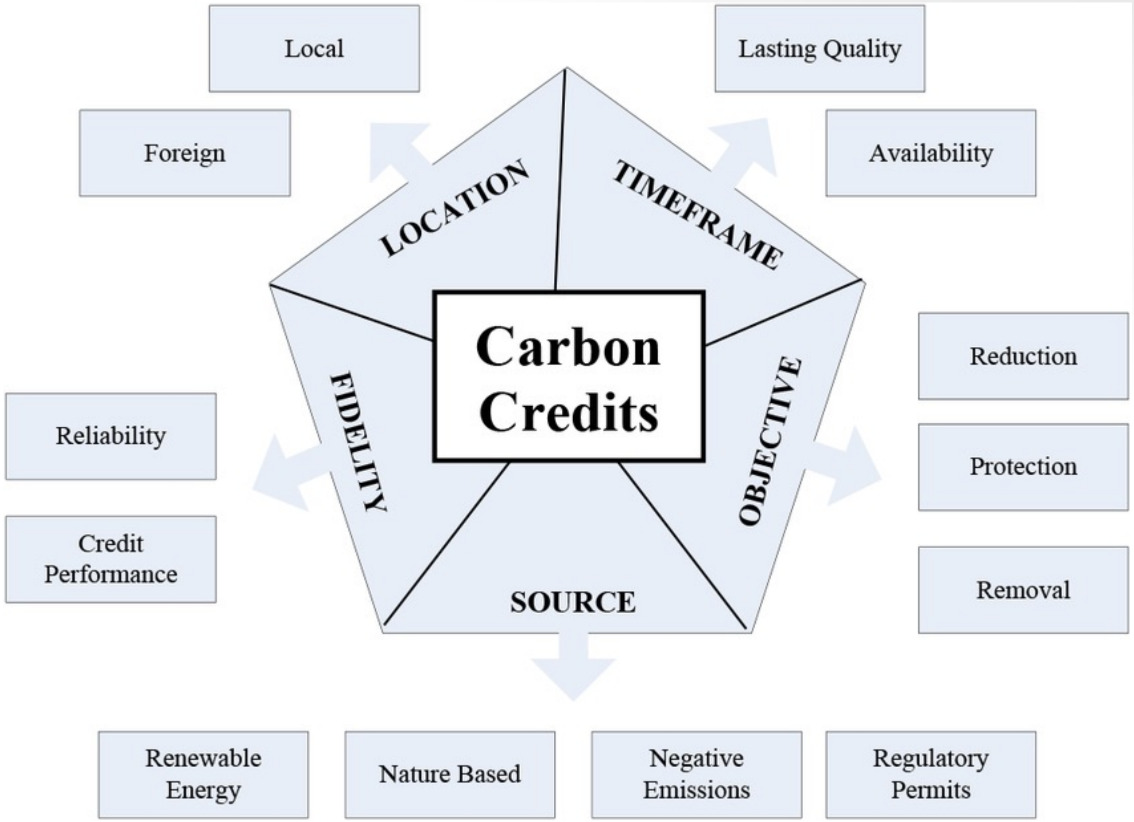
- ➢**$5–$10/ton** (voluntary markets)
- ➢**$50–$100+/ton** (regulated markets)



Carbon credit quality

High-quality carbon credits must be:

- **Real** — actual, measurable emission reductions
- **Additional** — would not happen without the project
- **Verifiable** — independently audited
- **Permanent** — reductions/removals last over time
- **No leakage** — emissions aren't shifted elsewhere



When carbon credits should be used

Carbon credits are appropriate when:

- Emissions **cannot** be reduced technologically
- Electrification or fuel switching is not feasible
- Only **residual emissions** remain after reductions
- Achieving carbon neutrality requires a final step
- Reduction measures are too costly or disruptive to implement immediately

Example: Combining reductions and credits

A typical carbon-neutral pathway includes:

- **60–70%** reduction from efficiency, optimization, and renewables
- **10–20%** reduction from fuel switching or electrification
- **10–20%** neutralized using carbon credits (residual emissions)

- **Key message:**

Most emissions must be reduced internally — credits cover only the last portion.

Module 5 summary

What we learned in module 5:

- What carbon credits represent
- How carbon markets function
- The difference between compliance and voluntary markets
- Financial incentives for reducing emissions
- How credits support carbon-neutral strategies
- When credits should—and should not—be used

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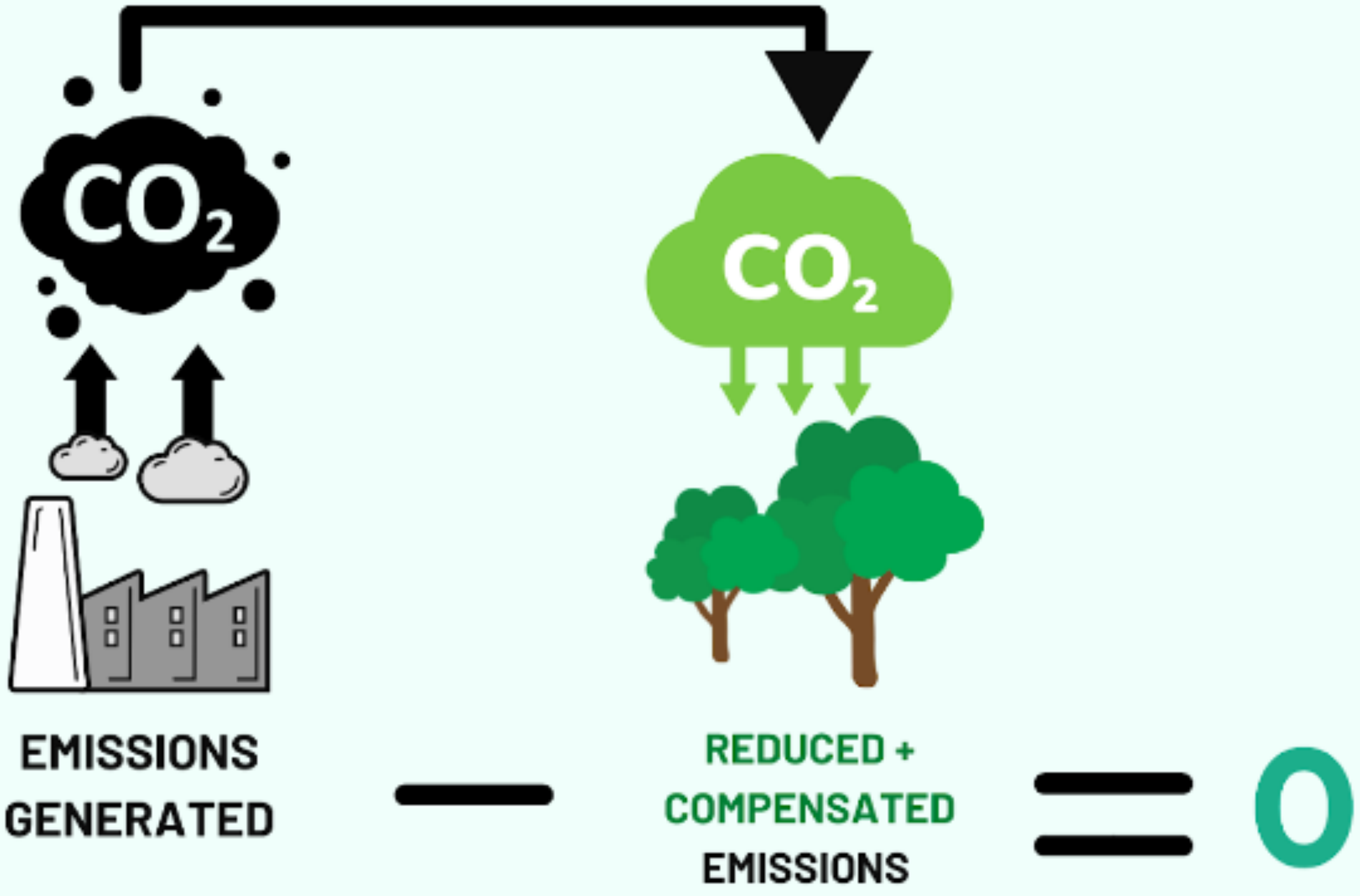
Designing a carbon-neutral strategy

Module 6



In this module we will cover:

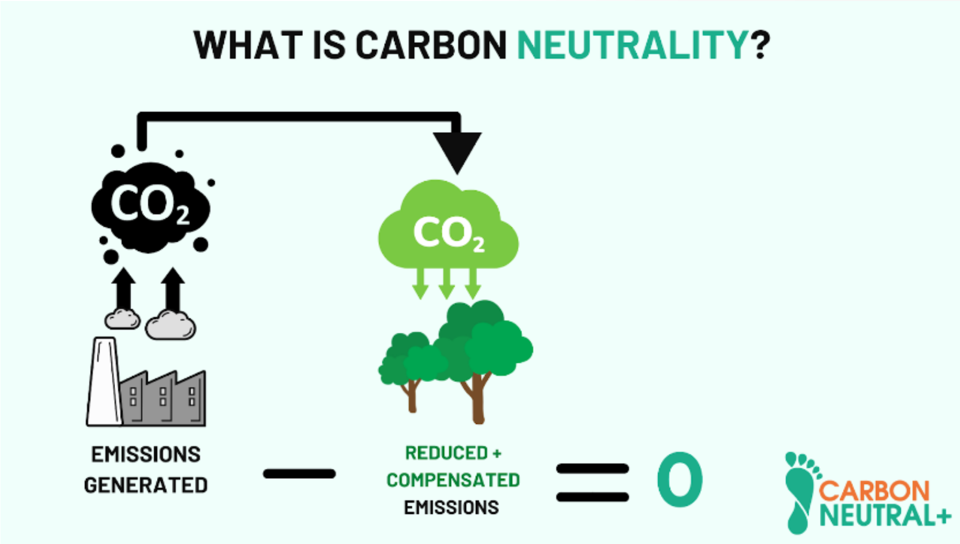
1. What carbon neutrality means
2. How to build a long-term reduction pathway
3. How to prioritize actions (cost vs. impact)
4. How to sequence low-carbon technologies
5. How credits fit into neutrality plans

What is carbon neutrality?

Carbon neutrality =
Reducing emissions as much as possible **+**
Neutralizing remaining (residual) emissions through credible carbon credits.

Key points:

- Internal reductions come first
- Credits only cover unavoidable emissions
- Targets are usually 10–15 years



The components of a carbon-neutral plan

A complete strategy includes:

1. **Baseline emissions**
2. **Forecasted growth**
3. **Reduction measures** (efficiency, fuel switching, electrification, renewables)
4. **Residual emissions** after reductions
5. **Neutralization** through high-quality credits

Typical industrial decarbonization pathway

- **Years 1–3: Quick wins**
- Operational improvements
- Leak repairs
- Basic optimization

- **Years 3–7: Efficiency upgrades**
- ➢ Motors, VFDs, boilers
- ➢ Process optimization
- ➢ Waste-heat recovery

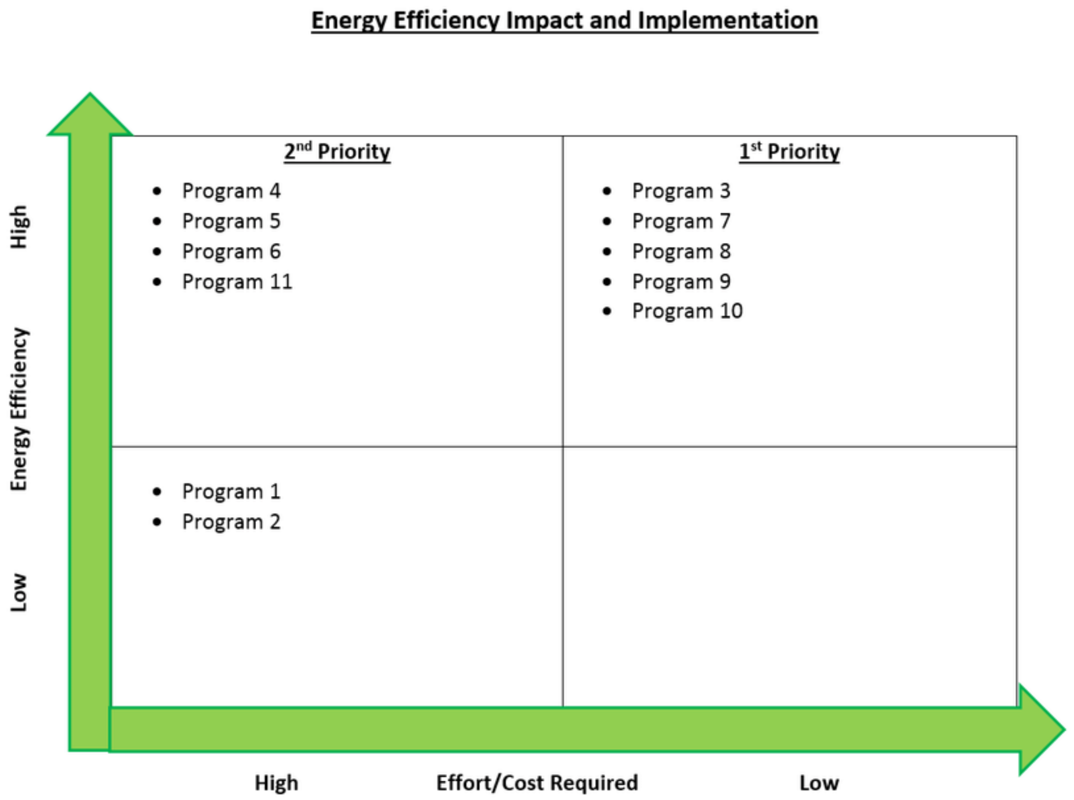
- **Years 7–15: Deep decarbonization**
- ➢ Electrification
- ➢ Renewables (PV/thermal)
- ➢ Fuel switching
- ➢ CCUS (where relevant)

- **Final step: Neutralization**
- ➢ Carbon credits for residual emissions

Prioritizing actions (cost vs. impact)

Plan actions based on:

1. **Low cost + high impact** → do first
2. **Medium cost + high impact** → plan in next phase
3. **High cost + high impact** → long-term
4. **Low impact** → deprioritize



Selecting reduction measures

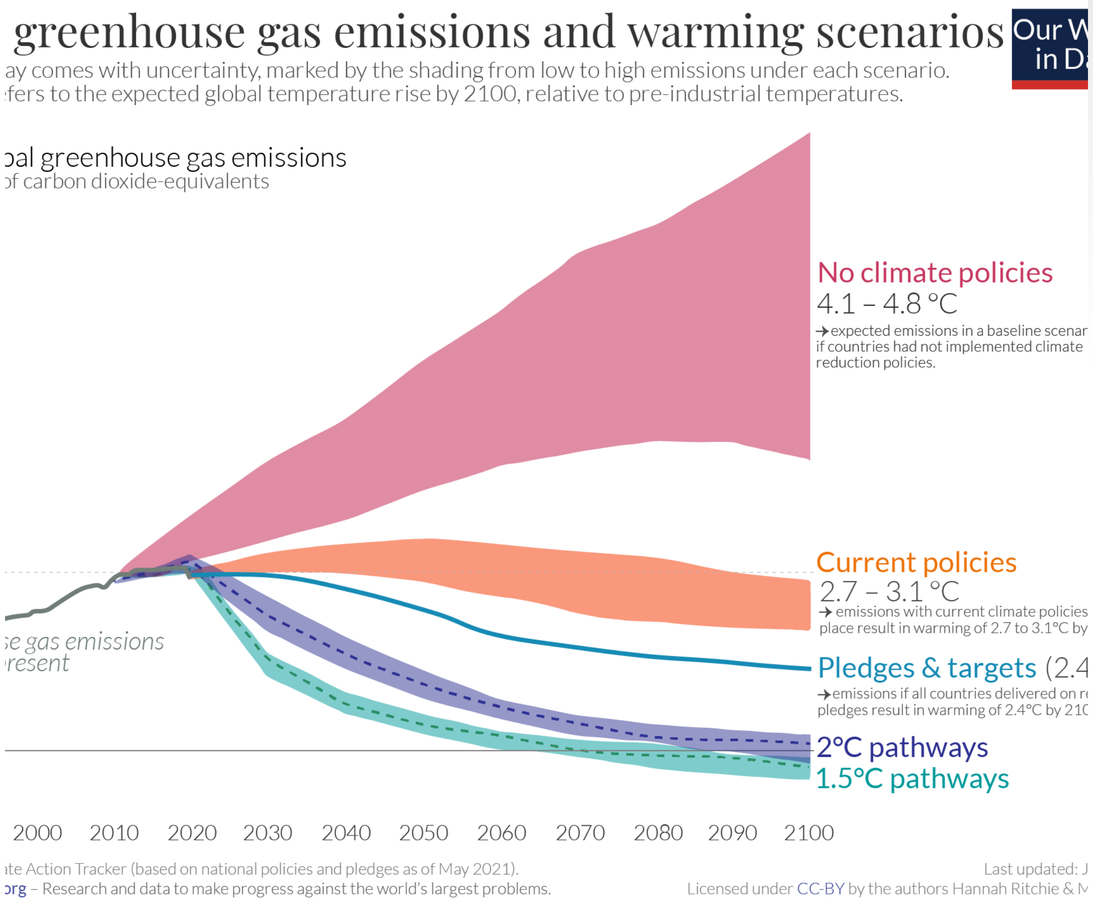
Considerations:

- Technical feasibility
- Past performance of similar sites
- CAPEX and payback
- Downtime requirements
- Skill availability
- Fuel and electricity outlook

Estimating future emissions

Steps:

1. Start from baseline
2. Add production growth
3. Apply efficiency improvements
4. Apply fuel switching / electrification
5. Apply renewables
6. Calculate remaining emissions



Identifying residual emissions

Residual emissions typically include:

- High-temperature processes
- Chemical process emissions
- Hard-to-electrify equipment
- Intermittent loads
- Remote operations

Neutralization with carbon credits

High-quality credits can cover:

- Remaining Scope 1 emissions
- Remaining Scope 2 emissions
- Relevant Scope 3 emissions

Timing:

- Credits should be used **after** reductions are **maximized**.

Module 6 summary

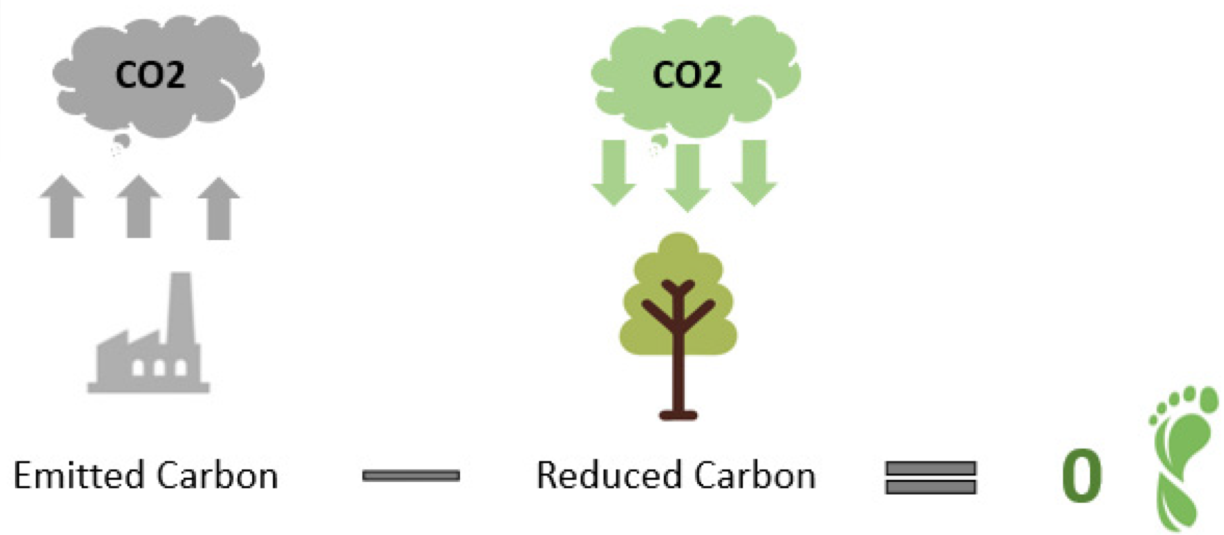
What we learned in module 6:

- What carbon neutrality means
- How to build a long-term reduction plan
- How to prioritize and sequence actions
- What residual emissions are
- How to use credits to neutralize them

Carbon-neutral energy plan design

Workshop 2

Workshop 2: Carbon-neutral energy plan design



In this workshop, you will:

- Identify main emission sources
- Assess emission sources for a sample facility
- Select suitable reduction measures
- Build a 10–15 year decarbonization pathway
- Identify residual emissions
- Decide where carbon credits are needed
- Present your plan in groups

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