GREEN TECHNOLOGIES

MODULE N°07

Co-funded by the Erasmus+ Programme of the European Union

GREEN LABS

2026

★ Duration: 16 hours

TABLE OF TOPICS

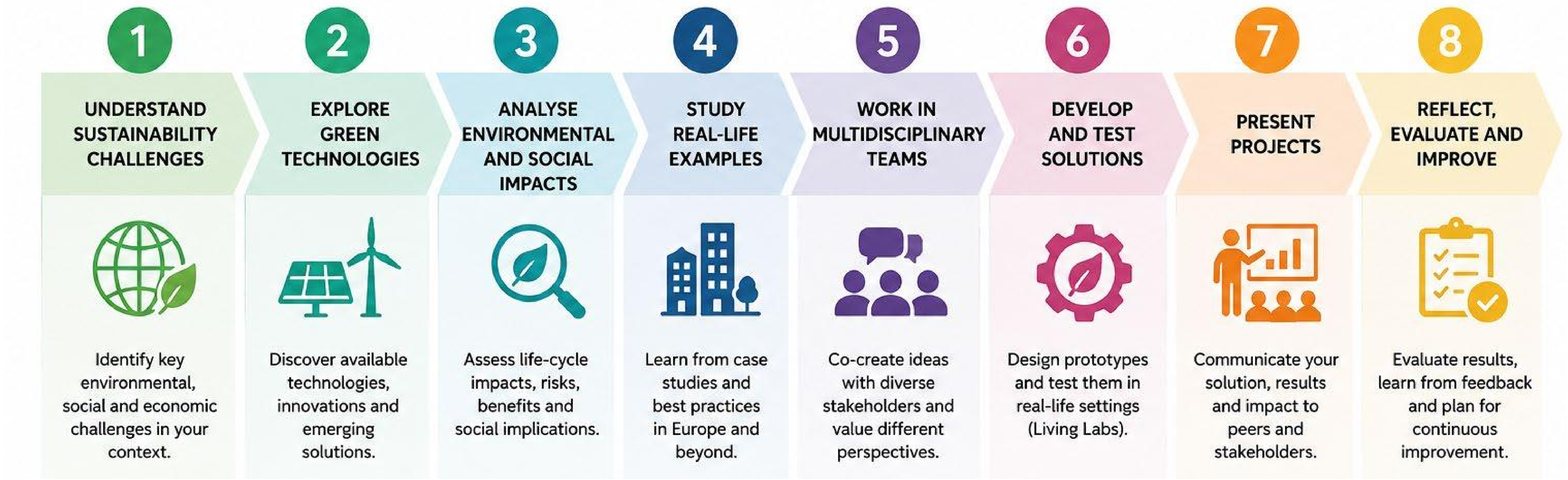
GREEN TECHNOLOGIES AND SUSTAINABLE DEVELOPMENT GOALS
RENEWABLE ENERGY TECHNOLOGIES
CIRCULAR ECONOMY TECHNOLOGIES
SUSTAINABLE BUILDINGS AND SMART CITIES
WASTE MANAGEMENT TECHNOLOGIES
SUSTAINABLE MOBILITY
DIGITAL TECHNOLOGIES FOR SUSTAINABILITY
GREEN TECHNOLOGIES IN AGRICULTURE
EUROPEAN CASE STUDIES
PRACTICAL EXERCISES
RECOMMENDED BOOKS
VIDEOS AND ONLINE RESOURCES
FINAL ASSIGNMENT

OBJECTIVES

By the end of the module, learners will be able to:

- Identify and explain major mature and emerging green technologies.
- Compare technological solutions using cost, performance, resource efficiency, lifecycle emissions, maturity and risk.
- Evaluate environmental impacts and possible unintended consequences.
- Connect green technologies with sustainable development goals six, seven, nine, eleven, twelve and thirteen.
- Use open datasets, maps and assessment tools to support evidence-based decisions.
- Co-create technology pilots with citizens, businesses, researchers, public authorities and civil-society organisations.
- Develop indicators for energy, emissions, materials, water, inclusion, resilience and financial viability.
- Design and present a green technology living lab for a city or territory.

LEARNING STEPS



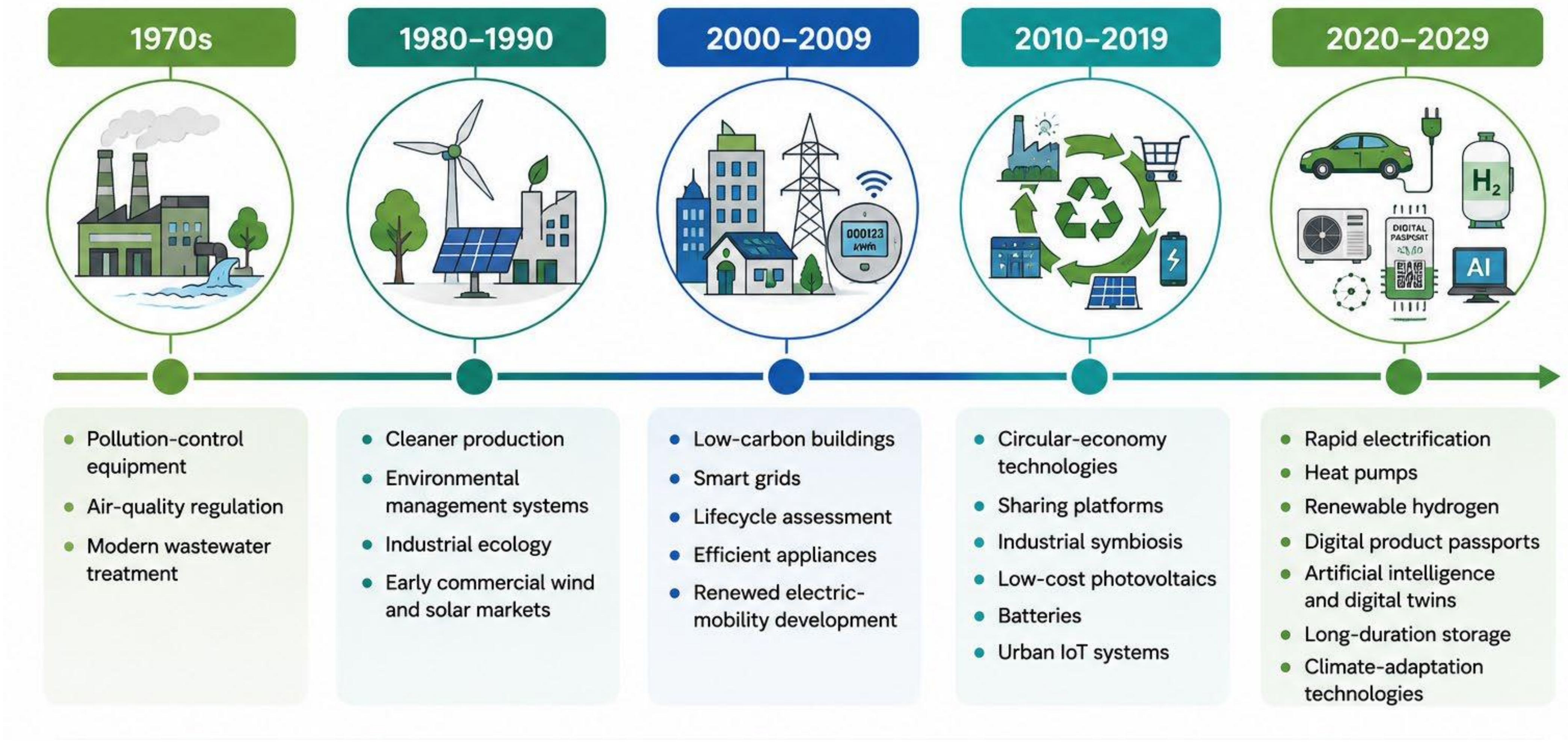
INTRODUCTION TO GREEN TECHNOLOGIES

Green technologies are products, processes, services and socio-technical systems designed to prevent, reduce or repair environmental harm while creating social and economic value. They include mature solutions such as energy efficiency, solar photovoltaics, heat pumps, wastewater treatment and mechanical recycling, as well as emerging applications such as renewable hydrogen, digital product passports, artificial-intelligence-assisted resource optimisation, digital twins and advanced materials recovery.

A technology is not automatically sustainable because it is labelled "green." Its full lifecycle must be assessed, including energy and material inputs, land and water use, emissions, toxicity, durability, repairability, data requirements, affordability and end-of-life management.

Name a technology that is beneficial in one context but potentially harmful or ineffective in another.

EVOLUTION OF GREENTECHNOLOGIES



MAIN TECHNOLOGY CATEGORIES

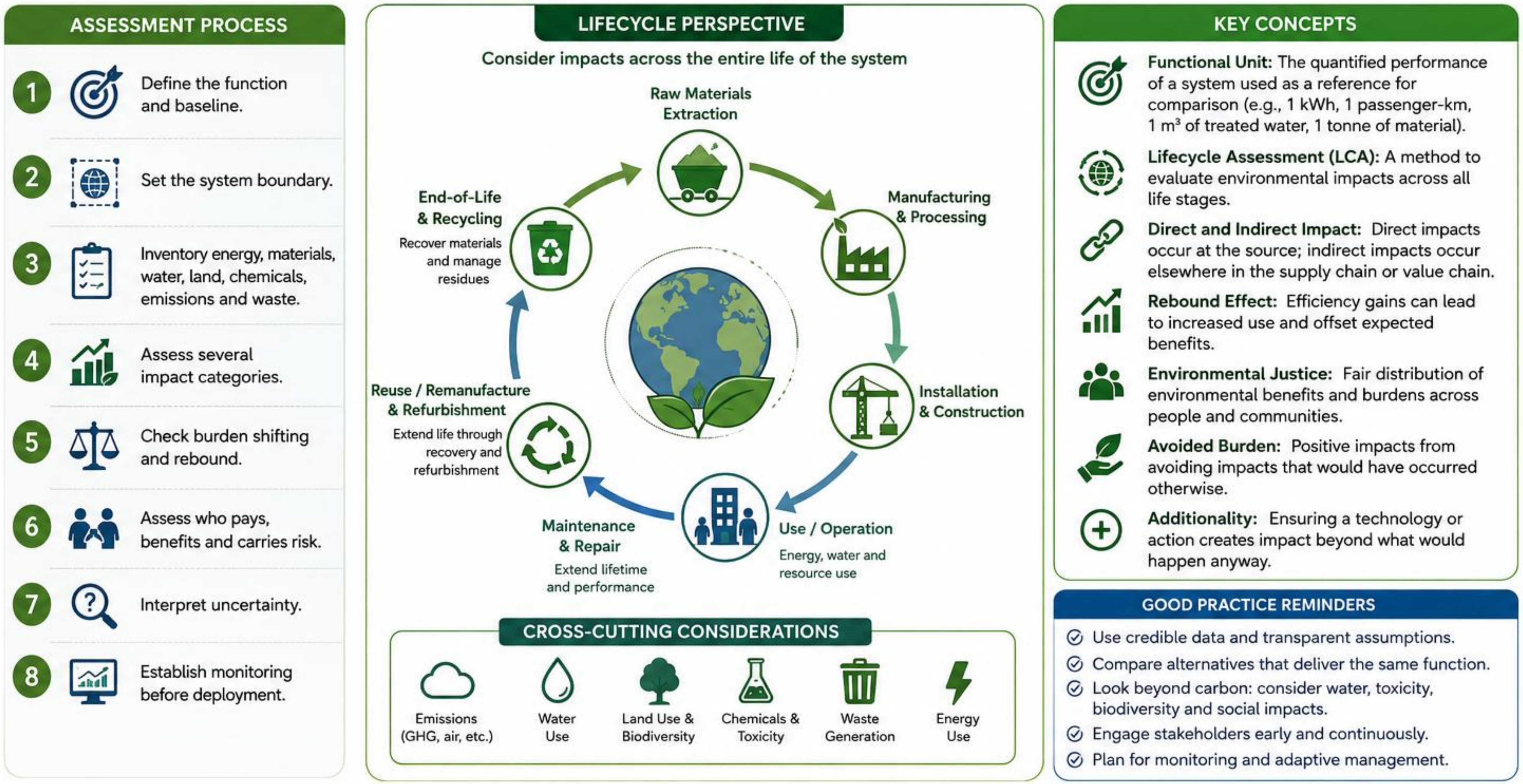
Category	Examples
Energy	Solar, wind, hydro, geothermal, storage, smart grids, hydrogen
Circular materials	Repair, remanufacturing, recycling, secondary materials, digital passports
Buildings	Passive design, heat pumps, controls, green roofs, district energy
Water	Reuse, purification, rainwater harvesting, desalination, leak detection
Waste	Sorting, composting, anaerobic digestion, recycling, residual energy recovery
Mobility	Active mobility, public transport, electric vehicles, charging, intelligent transport
Digital systems	Artificial intelligence, IoT, GIS, blockchain, digital twins, smart sensors
Agriculture	Precision agriculture, drones, irrigation, controlled environments, regenerative

MATURE, EMERGING AND SYSTEMIC INNOVATION

Innovation type	Characteristics	Examples	Management priority
Mature	Proven technology, standards and supply chains	LEDs, insulation, solar PV, mechanical recycling, heat pumps	Accelerate deployment, finance and skills
Emerging	Performance or business model still developing	Long-duration storage, green hydrogen, AI sorting, advanced recycling	Test assumptions and risks
Systemic	Requires coordinated change across actors and infrastructures	Positive-energy districts, circular construction, integrated mobility	Governance, collaboration and institutional change

What proportion of a municipal green-innovation budget should support proven deployment versus experimentation?

ENVIRONMENTAL-IMPACT ASSESSMENT



TECHNOLOGY READINESS AND DECISION GATES

Stage	Evidence	Green Manager question	Appropriate Living Lab action
Early research	Scientific principle or proof of concept	Is the mechanism plausible and relevant?	Observe and connect researchers with users
Prototype	Tested in controlled or relevant environment	Can it work safely in the local context?	Small, controlled co-designed pilot
Demonstration	Integrated system in an operational setting	Can maintenance, governance and users make it work?	Real-life demonstration
Proven solution	Repeated operational evidence	How can it be scaled equitably?	Deployment, monitoring and replication

REFLECTION

Assess four scenarios using lifecycle, rebound, equity, circularity and resilience criteria:

- An efficient appliance has a short life and cannot be repaired.
- An electric car is charged from a carbon-intensive grid and replaces public transport trips.
- A waste-to-energy plant reduces landfill but requires long-term waste-supply contracts.
- An AI irrigation system saves water but excludes small farms through proprietary equipment.

Can a solution be less harmful without being sustainable?

GREEN TECHNOLOGIES AND SUSTAINABLE DEVELOPMENT GOALS

A single technology may support several SDGs. It may also create trade-offs with affordability, biodiversity, labour rights or material security.

Technology–SDG nexus

SDG Six: water efficiency, reuse, sanitation, pollution monitoring.

SDG Seven: renewable energy, efficiency, storage and clean-energy access.

SDG Nine: resilient infrastructure, clean industry and innovation capability.

SDG Eleven: sustainable buildings, mobility, public space and urban resilience.

SDG Twelve: prevention, circular design, repair, traceability and resource productivity.

SDG Thirteen: mitigation, adaptation, climate-risk data and institutional capacity.

SYNERGIES AND TRADE-OFFS

Technology	Main contribution	Potential trade-off	Safeguard
Solar PV and batteries	Clean electricity and resilience	Mining and end-of-life waste	Responsible sourcing and recovery
Desalination	Drought-resilient supply	Electricity and brine	Renewables, efficiency and marine protection
Waste-to-energy	Residual treatment and heat	Emissions and lock-in	Strict hierarchy and limited capacity
Artificial intelligence	Better forecasting and control	Energy use, bias and lock-in	Proportional models and open standards
Precision agriculture	Lower inputs and adaptation	Digital divide	Cooperative services and farmer data rights

Which safeguard should be mandatory before a green technology receives public funding?

REFLECTION

- Choose one local challenge.
- Identify the relevant SDG targets.
- Develop three technology options and one non-technology option.
- Map direct benefits, co-benefits and potential harms.
- Select output, outcome and impact indicators.
- Assign data owners.
- Identify assumptions requiring Living Lab testing.

RENEWABLE ENERGY TECHNOLOGIES

Renewable energy technologies convert naturally replenished resources into electricity, heat and fuels. The transition is increasingly moving from individual technologies toward integrated energy systems that combine generation, storage, networks, digital control and flexible demand.

SOLAR

PV • Rooftop PV • Building-integrated PV • Solar thermal • Concentrated solar power

WIND

Onshore wind • Offshore wind

DISPATCHABLE RENEWABLES

Hydropower • Geothermal • Sustainable bioenergy

ENERGY STORAGE

Lithium-ion • Sodium-ion • Flow batteries • Pumped hydro • Thermal storage

RENEWABLE HYDROGEN

Electrolysis using renewable electricity • Industrial feedstock • Seasonal storage • E-fuels

SMART ENERGY SYSTEMS

Smart grids • Demand response • Energy communities • Aggregators • EV charging • Digital energy management

KEY STATISTIC

47.5% of EU gross electricity consumption came from renewable sources in 2024.

>90% of utility-scale renewable capacity commissioned globally in 2025 generated electricity more cheaply than the cheapest new fossil-fuel alternative.

USD 33/MWh global weighted-average LCOE of new onshore wind in 2025, compared with USD 44/MWh for solar PV and USD 78/MWh for offshore wind.

Technology	Global average LCOE
Onshore wind	**USD 33/MWh**
Solar PV	**USD 44/MWh**
Hydropower	USD 62/MWh
Offshore wind	USD 78/MWh
Bioenergy	USD 86/MWh
Geothermal	USD 89/MWh
Concentrated solar power	USD 115/MWh

What is currently the biggest constraint on renewable-energy deployment in your city or region: technology, grid capacity, finance, permitting, skills or public acceptance?

REFLECTION

1. REDUCE Can demand be avoided or reduced first?

2. DEFINE What energy service is actually required?

3. MAP What are the hourly and seasonal electricity and heat profiles?

4. ASSESS Which local renewable resources and infrastructure are available?

5. INTEGRATE How will generation, grids, storage and demand flexibility work together?

6. TEST What are the lifecycle, environmental, social and resilience impacts?

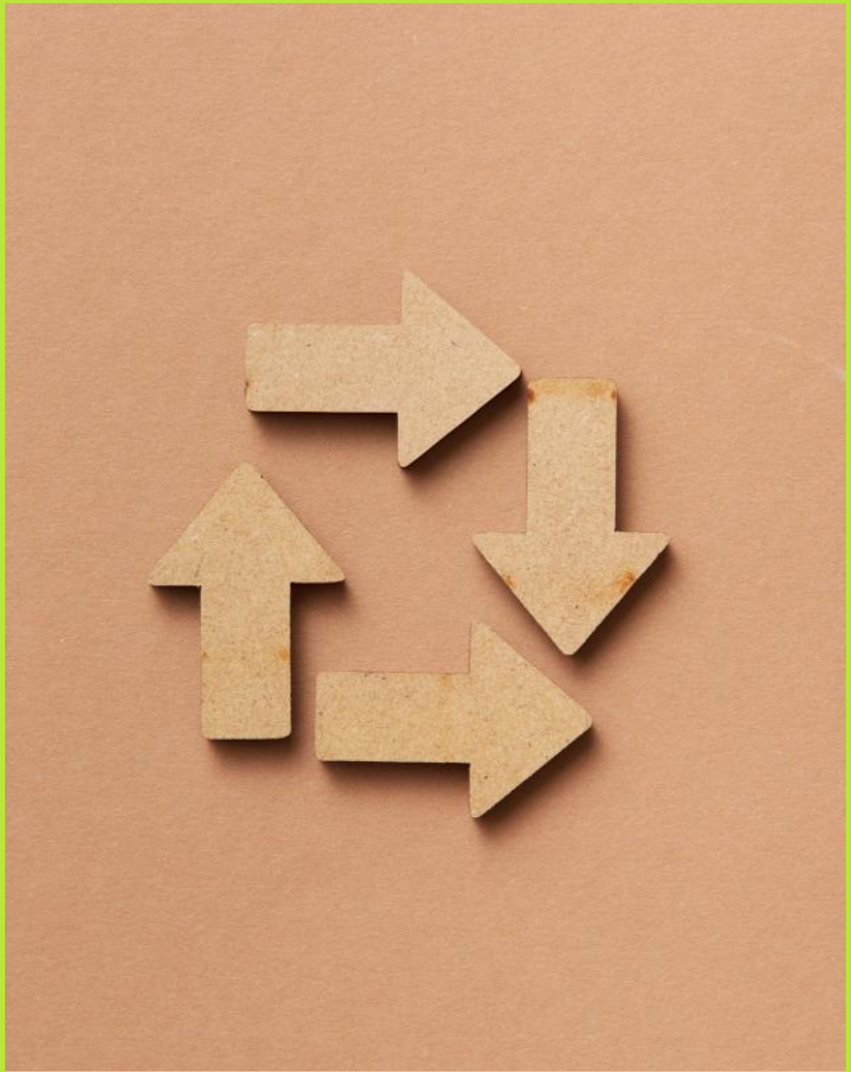
7. ENGAGE Who owns, pays, benefits and carries the risks?

8. MONITOR

Energy • CO_2e • Reliability • Curtailment • Affordability • Local value

« THE CHALLENGE IS NO LONGER SIMPLY HOW TO GENERATE RENEWABLE ELECTRICITY. THE TRANSITION DEPENDS ON INTEGRATING GENERATION, GRIDS, STORAGE, FLEXIBLE DEMAND, PERMITTING AND PEOPLE.
ALSO, THE "BEST" RENEWABLE TECHNOLOGY IS NOT NECESSARILY THE CHEAPEST TECHNOLOGY. IT IS THE SOLUTION THAT DELIVERS THE REQUIRED ENERGY SERVICE WITH THE STRONGEST OVERALL ENVIRONMENTAL, ECONOMIC AND SOCIAL PERFORMANCE. »

CIRCULAR ECONOMY TECHNOLOGIES



Circular economy technologies help **prevent waste, extend product life, retain embedded value and return materials to productive use**. Technology should support a hierarchy of actions rather than automatically directing materials toward recycling. Keeping a product or component functional generally retains more of its embedded **materials, energy, labour and knowledge** than breaking it down for recycling.

TECHNOLOGY ENABLES CIRCULARITY

Design → modularity, durability, repairability

Information → Digital Product Passports, material data

Operations → diagnostics, sorting, reverse logistics

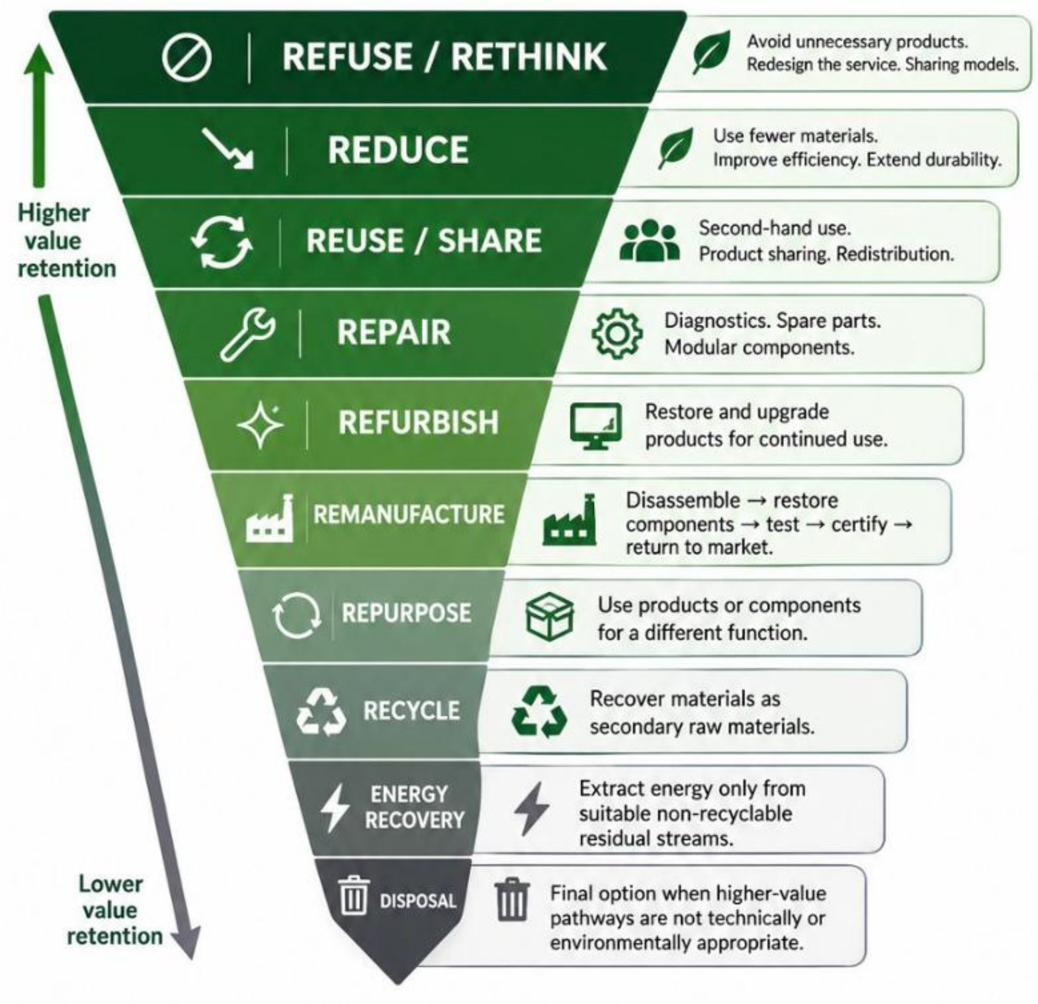
Recovery → repair, remanufacturing, recycling

Markets → quality assurance, certification, secondary materials

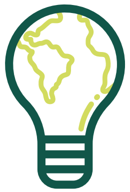
Collaboration → industrial symbiosis and shared infrastructure

TECHNOLOGY ALONE IS NOT ENOUGH

A technically sophisticated sorting plant can still produce low-value outputs if products were poorly designed, waste is contaminated or buyers do not trust secondary materials. Likewise, a Digital Product Passport creates little value unless the information can actually support repairers, recyclers, manufacturers, regulators and consumers.

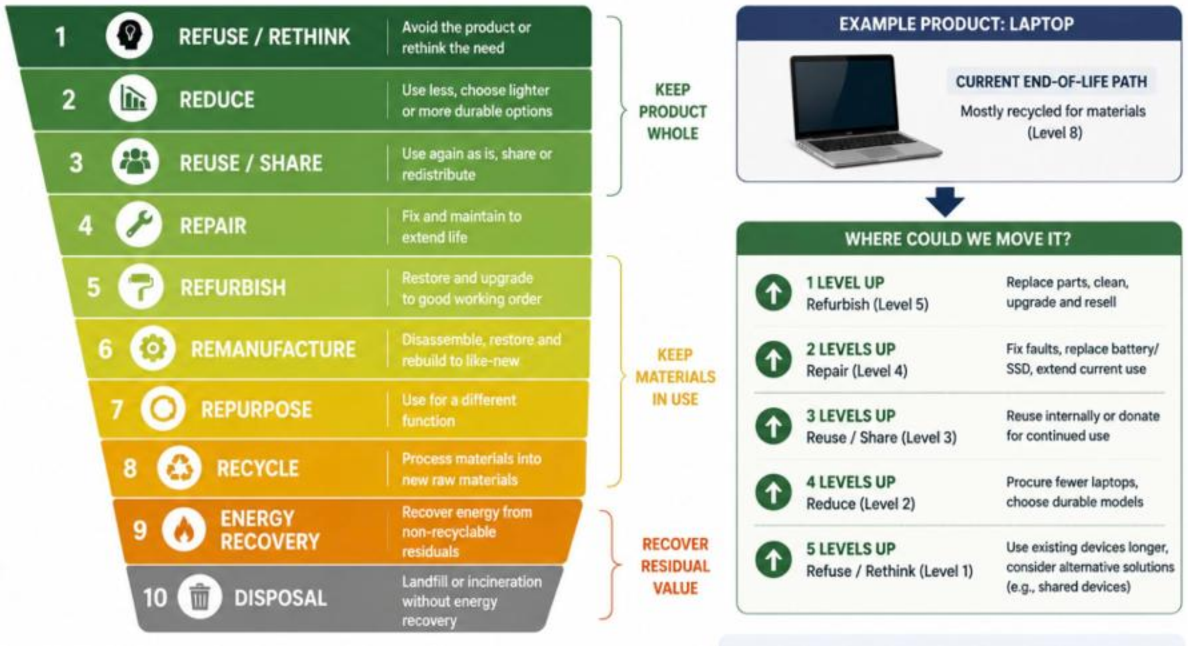


Which is currently the weakest link in your local circular system: technology, information, logistics, skills, regulation or market demand?



REFLECTION

Take one product used by your organisation. How many levels up the circular hierarchy could it realistically move?



SMART BUILDINGS

Buildings should be treated as integrated energy, comfort and material systems. The most effective strategy is to reduce demand first, then meet the remaining demand efficiently and with low-carbon energy.

Buildings account for roughly one-third of EU energy-related greenhouse-gas emissions. The revised Energy Performance of Buildings Directive establishes the zero-emission building as the standard for new public buildings from 2028 and all new buildings from 2030.

What data should a building collect, and what data should it deliberately avoid collecting?

BUILDING-PERFORMANCE HIERARCHY

TECHNOLOGY DECISION GUIDE

Measure	Capital need	Complexity	Main KPI
Façade renovation	Medium–High	Low	kWh/m² + comfort
Heat pump	Medium	Medium	Seasonal performance
Building controls	Low–Medium	Medium	Verified energy savings
Green roof	Medium	Medium	Water retained + surface temperature
Smart lighting	Low–Medium	Low	Energy + maintenance savings
District energy	High	High	Carbon intensity + affordability

FROM SMART BUILDING TO SMART DISTRICT

A smart energy district combines efficient buildings, flexible infrastructure and fair governance.

District systems can integrate:

Large heat pumps

Geothermal energy

Industrial waste heat

Solar thermal

Sustainable biomass

Thermal storage

Low-temperature heat networks

REFLECTION

Technology does not determine how benefits are distributed.

Who owns the infrastructure?

Who finances investment?

Who sets tariffs?

Who carries performance risk?

Who receives financial savings?

How are vulnerable consumers protected?

SMART CITIES: FROM SENSORS TO PUBLIC VALUE

A smart city is not defined by the number of sensors, dashboards or connected devices it owns.

Technology becomes valuable when it helps cities deliver better environmental, social and economic outcomes while remaining transparent, secure and accountable.

SMART-CITY ARCHITECTURE

1 – PHYSICAL ASSETS
Buildings • Roads • Lighting • Energy networks • Water systems • Green infrastructure • Public transport
↓
2 – SENSORS & DEVICES
Energy meters • Air-quality sensors • Traffic counters • Water sensors • Weather stations
↓
3 – CONNECTIVITY
Fibre • Wi-Fi • 5G • LPWAN • IoT networks
↓
4 – DATA PLATFORM
Integration • Storage • Interoperability • APIs • Data quality
↓
5 – ANALYTICS & DIGITAL TWINS
AI • GIS • Forecasting • Scenario modelling • Optimisation
↓
6 – DECISION INTERFACES
Dashboards • Alerts • Operational systems • Citizen interfaces
↓
7 – GOVERNANCE
Privacy • Cybersecurity • Procurement • Accountability • Ethics • Open standards

TECHNOLOGY DECISION GUIDE

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REFLECTION

Before deploying smart-city technology, ask:

PROBLEM – What public problem are we solving?

EVIDENCE – What evidence shows that technology is required?

DATA – What data is genuinely necessary?

ALTERNATIVES – Is there a simpler non-digital solution?

RIGHTS – What privacy, cybersecurity or equity risks arise?

VALUE – Who benefits and who pays?

KPI – How will success be measured?

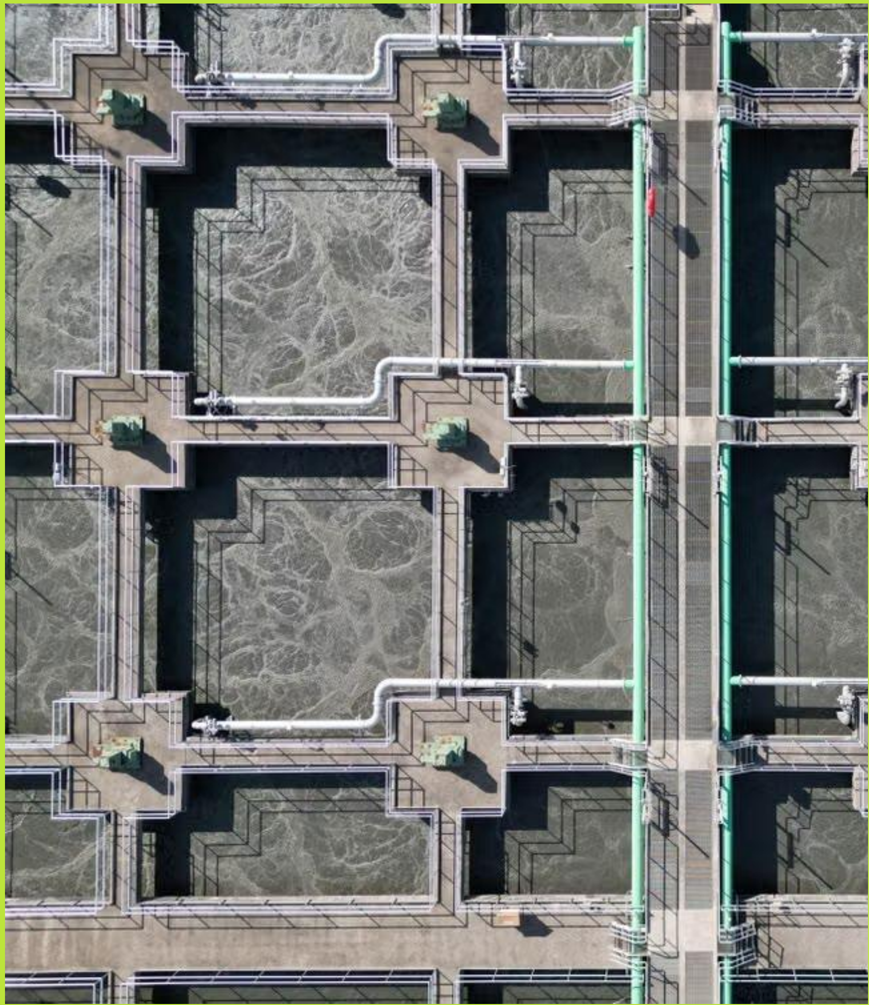
EXIT – What happens if the technology does not work?

«

SMART CITY ≠ MORE TECHNOLOGY
SMART CITY = BETTER PUBLIC OUTCOMES ENABLED BY APPROPRIATE TECHNOLOGY

»

WATER TECHNOLOGIES



Water technology should be selected according to a circular water hierarchy. **The priority is to protect existing resources and reduce unnecessary demand before developing new water supplies.**

Technology selection should not begin with the most sophisticated supply technology. Start with source protection, demand reduction, leakage management and reuse. Introduce the fit-for-purpose principle: treatment should achieve the quality required for the intended application while protecting human health and the environment. Applying drinking-water treatment standards to every non-potable application can unnecessarily increase energy, chemicals and costs.

Water reuse requires multiple barriers: source control, appropriate treatment, safe storage and distribution, clear labelling, monitoring, maintenance and incident-response procedures.

CIRCULAR WATER HIERARCHY

Examples:

Reclaimed wastewater → irrigation / industry / cleaning

Rainwater → toilets / irrigation / cooling

Greywater → selected non-potable applications

THE MOST SUSTAINABLE LITRE OF WATER IS OFTEN THE LITRE THAT DOES NOT NEED TO BE EXTRACTED, TREATED AND TRANSPORTED.

WASTE MANAGEMENT TECHNOLOGIES

Waste management technology begins before waste reaches the treatment facility. Product design, procurement choices, consumer behaviour and collection systems determine the quality of waste streams and strongly influence what can be recovered downstream.

For example, clean, separately collected cardboard can become a valuable secondary material, while cardboard contaminated with food, glass and residual waste may lose much of its recycling potential.

Technology investment must also avoid infrastructure lock-in. Large treatment facilities that depend on guaranteed waste volumes can create economic pressure to maintain waste generation, even when policies aim to prevent waste and increase reuse and recycling.

Which waste stream in your organisation could be prevented entirely before considering better treatment?

WASTE HIERARCHY

«

WASTE-TREATMENT CAPACITY SHOULD RESPOND TO RESIDUAL WASTE–NOT CREATE A LONG-TERM DEMAND FOR WASTE.

»

SUSTAINABLE MOBILITY

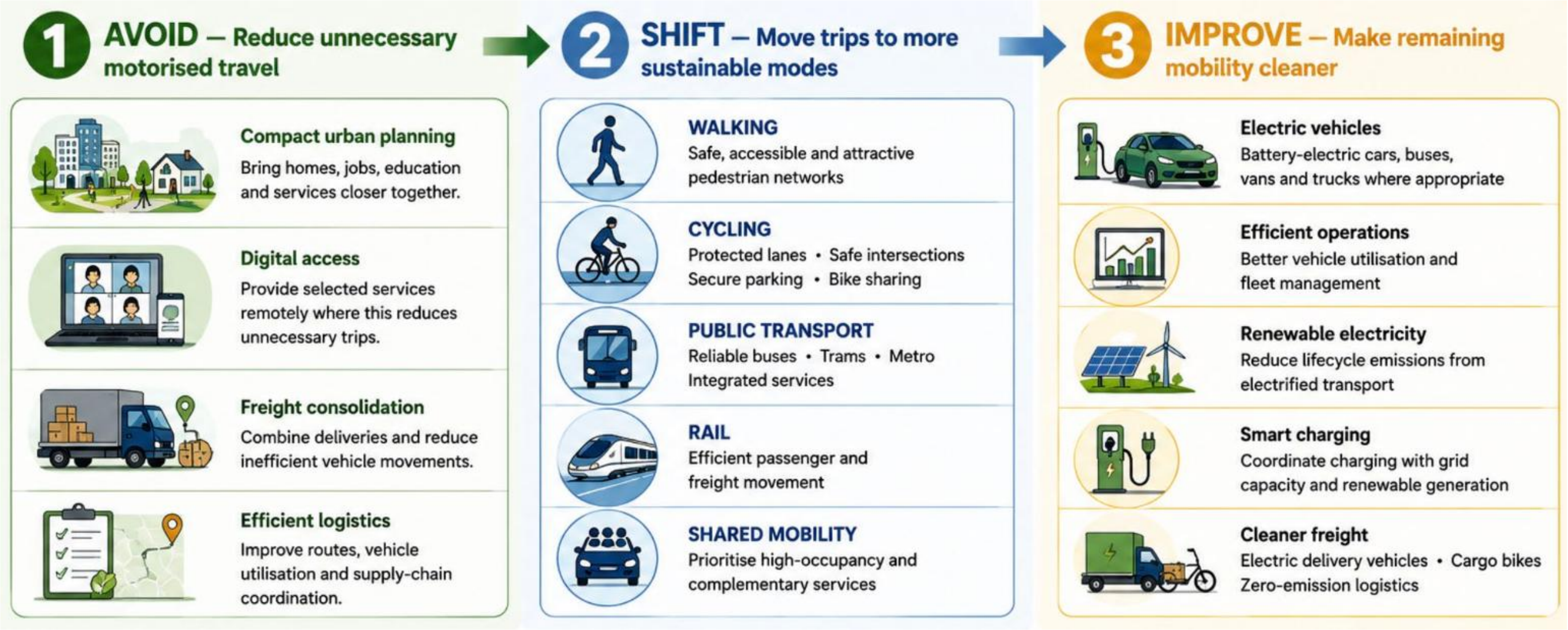
Sustainable mobility is not simply about replacing fossil-fuel vehicles with electric ones. It starts by asking **how much travel is necessary, which modes should carry that travel, and how remaining transport can be made cleaner and more efficient.**

Mobility focuses on movement – how people travel and how efficiently they can move from one place to another. Accessibility focuses on opportunities – how easily people can reach employment, education, healthcare, culture, public services, shops and recreation.

A sustainable city therefore aims to bring people and essential services closer together, while providing safe, affordable and low-carbon transport options when travel is necessary.

Choose one common trip in your city. What could be avoided, what could shift to another mode, and what should be electrified?

AVOID–SHIFT–IMPROV



Why the hierarchy matters
Replacing every conventional vehicle with an EV can reduce emissions and urban air pollution, but it does not automatically solve important meetire in mobily.

«

SMART MOBILITY ≠ FASTER TRAFFIC
SMART MOBILITY = BETTER ACCESS WITH LESS ENVIRONMENTAL AND SOCIAL COST

»

DIGITAL TECHNOLOGIES

Digital technologies can support sustainability by turning **physical and environmental data into better decisions, operations and investments**.

Digitalisation should begin with the decision or environmental problem, not with the technology.

For example, installing hundreds of air-quality sensors has little environmental value if nobody is responsible for responding when pollution levels increase.

The same applies to energy, water, mobility and waste systems. Data creates value only when there is a clear pathway from measurement to action.

Is AI necessary - or could a rule, spreadsheet or conventional model solve the problem?

DIGITAL SUSTAINABILITY STACK

Governance surrounds every stage

PURPOSE – Why is the data needed?

QUALITY – Is it accurate enough?

CONSENT & ACCESS – Who can collect and use it?

SECURITY – How is it protected?

INTEROPERABILITY – Can systems work together?

ACCOUNTABILITY – Who is responsible?

INCLUSION – Who may be excluded?

FOOTPRINT – What environmental impact does the digital system itself create?

« ENVIRONMENTAL VALUE APPEARS ONLY WHEN INFORMATION CHANGES A REAL DECISION, OPERATION, INVESTMENT OR BEHAVIOUR. »

AGRICULTURE TECHNOLOGIES

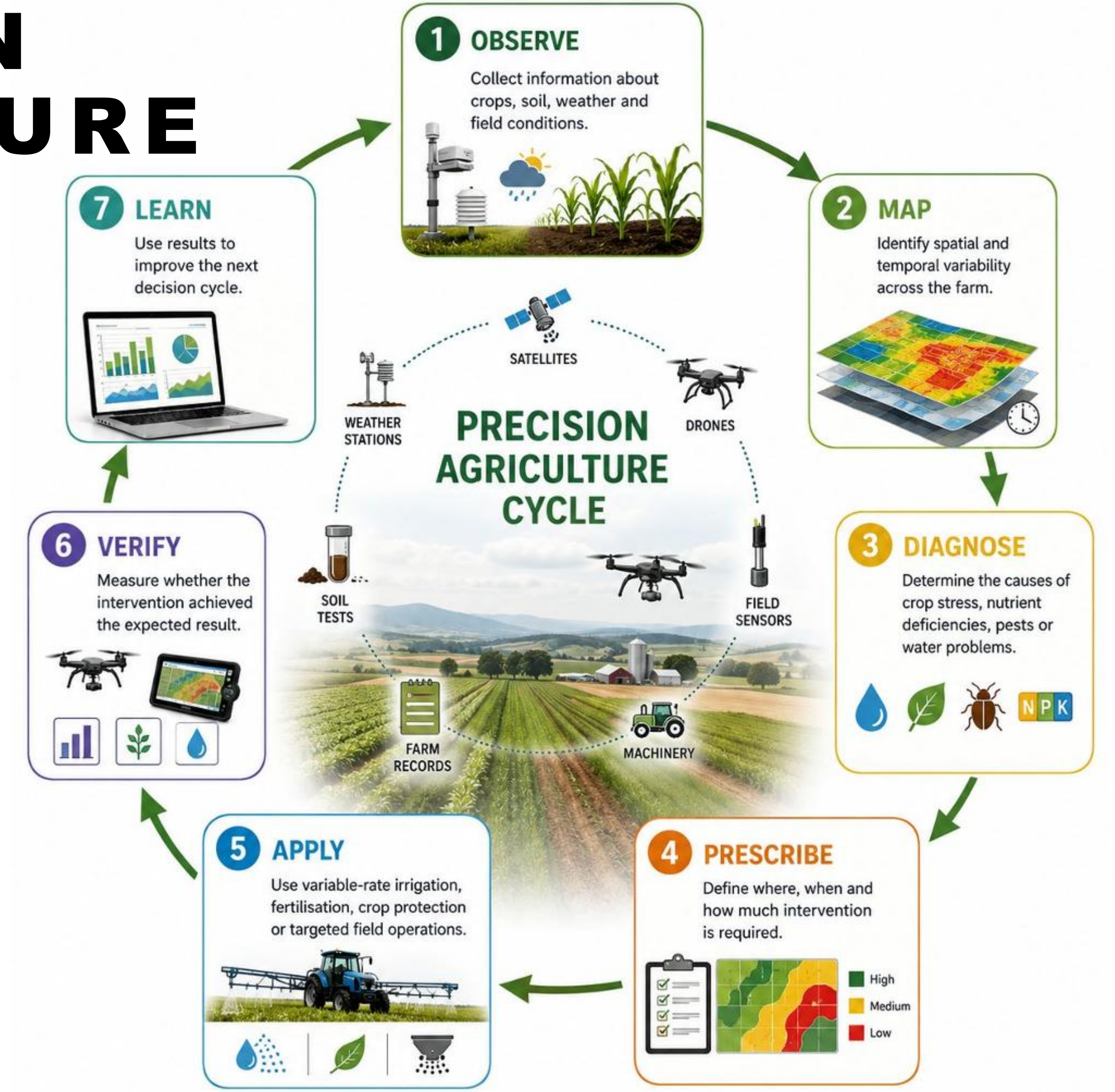
Precision agriculture uses **data, monitoring and targeted interventions** to apply the right input, in the right place, at the right time.

Precision agriculture should begin with the **management decision**, not with buying sensors or drones. For example, before installing soil-moisture sensors, determine what irrigation decision the measurements will change, what accuracy is required and how much spatial variability exists.

More sensors do not automatically produce better decisions. Poorly positioned or poorly maintained sensors can generate misleading information.

How many sensors are enough—and where should they be located to support a real farming decision?

PRECISION AGRICULTURE CYCLE



AGRICULTURAL TECHNOLOGY SELECTION

Technology	Main value	Main risk	Inclusion response
Soil-moisture sensor	Better irrigation decisions	Poor placement	Shared advice and training
Drone service	Rapid field diagnosis	Cost and data overload	Cooperative service
Variable-rate inputs	Lower input use	Complexity and rebound	Open formats and independent advice
Vertical farm	Controlled local output	Energy and capital	Renewable power and credible crop choice
Carbon-farming monitoring	Evidence and finance	Permanence and claim uncertainty	Conservative accounting

« TECHNOLOGY CAN SUPPORT MEASUREMENT, PLANNING AND VERIFICATION BUT CANNOT REPLACE FARMER KNOWLEDGE AND ECOLOGICAL UNDERSTANDING. »

EUROPEAN CASE STUDIES

KALUNDBORG INDUSTRIAL SYMBIOSIS

COUNTRY: DENMARK

TECHNOLOGY: INDUSTRIAL SYMBIOSIS AND RESOURCE EXCHANGE

CHALLENGE: LARGE INDUSTRIAL FACILITIES GENERATED SURPLUS HEAT, STEAM, WATER AND RESIDUAL MATERIALS WHILE NEIGHBOURING ORGANISATIONS REQUIRED SIMILAR RESOURCES.

IMPLEMENTED SOLUTION: PARTNERS DEVELOPED BILATERAL EXCHANGES OF WATER, ENERGY AND MATERIALS. THE NETWORK EVOLVED INCREMENTALLY THROUGH COMMERCIALLY USEFUL PROJECTS, CONTRACTS, PROXIMITY, TRUST AND A DEDICATED SYMBIOSIS ORGANISATION.

RESULTS: REPORTED ANNUAL BENEFITS INCLUDE APPROXIMATELY FOUR MILLION CUBIC METRES OF GROUNDWATER SAVED, 586,000 TONNES OF CO_2 AVOIDED AND 62,000 TONNES OF RESIDUAL MATERIALS RECYCLED.

LINKS

HTTPS://WWW.SYMBIOSIS.DK/EN/

HTTPS://WWW.KALUNDBORGREFINERY.COM/ENERGY-ENVIRONMENT-AND-QUALITY/

COPENHAGEN CYCLING AND SMART MOBILITY

COUNTRY: DENMARK

TECHNOLOGY: PROTECTED CYCLING NETWORKS, BRIDGES, TRAFFIC MANAGEMENT AND MOBILITY DATA

CHALLENGE: CONGESTION, EMISSIONS, HEALTH IMPACTS AND LIMITED URBAN SPACE REQUIRED A MORE EFFICIENT MOBILITY SYSTEM. IMPLEMENTED SOLUTION COPENHAGEN DEVELOPED CONNECTED CYCLING INFRASTRUCTURE, SAFE INTERSECTIONS, BICYCLE BRIDGES, PARKING, TRAFFIC COUNTING, WINTER MAINTENANCE AND INTEGRATION WITH PUBLIC TRANSPORT.

RESULTS: AROUND HALF OF COMMUTING AND EDUCATION TRIPS HAVE BEEN MADE BY BICYCLE IN RECENT YEARS; THE CITY HAS HUNDREDS OF KILOMETRES OF CYCLING INFRASTRUCTURE AND SUSTAINED LONG-TERM INVESTMENT.

AMSTERDAM CIRCULAR ECONOMY STRATEGY

COUNTRY: NETHERLANDS

TECHNOLOGY: CIRCULAR PROCUREMENT, MATERIAL-FLOW INTELLIGENCE, REUSE AND URBAN EXPERIMENTATION

CHALLENGE: THE CITY DEPENDED ON VIRGIN MATERIALS AND LINEAR CONSTRUCTION, CONSUMPTION AND FOOD SYSTEMS. IMPLEMENTED SOLUTION AMSTERDAM ADOPTED A CIRCULAR STRATEGY FOCUSING ON FOOD AND ORGANIC STREAMS, CONSUMER GOODS AND THE BUILT ENVIRONMENT. IT USES PROCUREMENT, PILOTS, MONITORING AND PUBLIC-PRIVATE COLLABORATION.

RESULTS: THE CITY TARGETS A 50% REDUCTION IN VIRGIN RAW-MATERIAL USE BY 2030 RELATIVE TO 2016 AND A FULLY CIRCULAR ECONOMY BY 2050.

FREIBURG GREEN CITY

COUNTRY: GERMANY

TECHNOLOGY: SOLAR ENERGY, EFFICIENT DISTRICTS AND SUSTAINABLE MOBILITY

CHALLENGE: FREIBURG SOUGHT CLEANER ENERGY, LIVEABLE NEIGHBOURHOODS AND A STRONG LOCAL GREEN ECONOMY. IMPLEMENTED SOLUTION THE CITY COMBINED SOLAR DEPLOYMENT, RESEARCH INSTITUTIONS, LOW-ENERGY BUILDINGS, TRAMS, CYCLING AND CAR-LIGHT DISTRICTS INCLUDING VAUBAN.

RESULTS: EXAMPLES INCLUDE MAJOR SOLAR ROOFS AND A 2.6 MWP FORMER-LANDFILL SOLAR INSTALLATION REPORTED TO SUPPLY ROUGHLY ONE THOUSAND HOUSEHOLDS AND AVOID APPROXIMATELY 2,500 TONNES OF CO_2 ANNUALLY.

BARCELONA SENTILO AND SMART CITIZEN

COUNTRY: SPAIN

TECHNOLOGY: OPEN-SOURCE URBAN IOT AND PARTICIPATORY ENVIRONMENTAL SENSING CHALLENGE CITY DEPARTMENTS AND COMMUNITY INITIATIVES REQUIRED INTEROPERABLE SENSOR DATA WITHOUT REPEATEDLY PROCURING ISOLATED PROPRIETARY SYSTEMS.

IMPLEMENTED SOLUTION: BARCELONA DEVELOPED SENTILO, AN OPEN-SOURCE SENSOR AND ACTUATOR PLATFORM. FAB LAB BARCELONA AND SMART CITIZEN INITIATIVES EXPANDED CITIZEN SENSING AND ENVIRONMENTAL-DATA LITERACY.

RESULTS: SENTILO HAS SUPPORTED MUNICIPAL-BUILDING ENERGY MONITORING, NOISE MEASUREMENT AND URBAN-LABORATORY ACTIVITIES AND IS REUSABLE BY OTHER MUNICIPALITIES.

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ESTONIA X-ROAD

COUNTRY: ESTONIA

TECHNOLOGY: SECURE, INTEROPERABLE PUBLIC-SECTOR DATA EXCHANGE CHALLENGE FRAGMENTED DATABASES GENERATED REPEATED PAPERWORK AND INEFFICIENT PUBLIC SERVICES.

IMPLEMENTED SOLUTION: X-ROAD LINKS PUBLIC AND PRIVATE INFORMATION SYSTEMS THROUGH AN OPEN-SOURCE, DISTRIBUTED AND SECURE DATA-EXCHANGE LAYER WHILE INFORMATION REMAINS WITH ITS RESPONSIBLE OWNER.

RESULTS: OFFICIAL E-ESTONIA REPORTING STATES THAT X-ROAD SAVES MORE THAN 1,345 WORKING YEARS ANNUALLY THROUGH REDUCED PAPERWORK AND FASTER INFORMATION ACCESS.

LJUBLJANA ZERO WASTE

COUNTRY: SLOVENIA

TECHNOLOGY: DOOR-TO-DOOR SEPARATION, COLLECTION CENTRES, REUSE AND RECYCLING CHALLENGE THE CITY BEGAN WITH LIMITED SEPARATE COLLECTION AND FACED PRESSURE TO RELY ON DISPOSAL OR INCINERATION.

IMPLEMENTED SOLUTION: LJUBLJANA EXPANDED SEPARATE COLLECTION OF RECYCLABLES AND BIOWASTE, PREVENTION, REUSE FACILITIES, COLLECTION CENTRES AND PUBLIC COMMUNICATION WHILE AVOIDING INCINERATOR LOCK-IN.

RESULTS: OVER APPROXIMATELY A DECADE, TOTAL WASTE GENERATION REPORTEDLY DECLINED BY 15%, RECYCLING OR COMPOSTING REACHED AROUND 61%, LANDFILL FELL BY 59%, AND RECOVERED MATERIALS ROSE FROM 16 TO 220 KG PER PERSON.

SWEDISH WASTE-TO-ENERGY AND DISTRICT HEATING

COUNTRY: SWEDEN

TECHNOLOGY: COMBINED HEAT-AND-POWER WASTE INCINERATION LINKED TO DISTRICT HEATING CHALLENGE RESIDUAL WASTE REQUIRED TREATMENT, WHILE URBAN AREAS NEEDED DEPENDABLE HEAT.

IMPLEMENTED SOLUTION: SWEDEN LINKED MODERN INCINERATION WITH DISTRICT-HEATING SYSTEMS, EMISSIONS CONTROLS, COMBINED HEAT AND POWER, AND SELECTED METAL RECOVERY FROM ASH.

RESULTS: NORDIC DATA REPORT 17.9 TWH OF HEAT AND 3 TWH OF ELECTRICITY FROM WASTE INCINERATION IN 2022, SUPPLYING ROUGHLY ONE QUARTER OF SWEDISH DISTRICT HEATING.

PRACTICAL EXERCISES

TECHNOLOGY ASSESSMENT MATRIX

Objective: Compare four technology options using weighted criteria.

Duration: Sixty minutes

Instructions: Define the decision and minimum requirements. Select eight to ten criteria. Assign weights totalling 100%. Score each option from one to five with supporting evidence. Change two weights and assess ranking sensitivity.

Materials: Matrix template, evidence pack and spreadsheet.

Expected output: Completed matrix, sensitivity analysis and short recommendation.

External materials

JRC Knowledge for Policy: https://knowledge4policy.ec.europa.eu/

IEA Data and Statistics: https://www.iea.org/data-and-statistics

OpenLCA: https://www.openlca.org/

EU Taxonomy Compass: https://ec.europa.eu/sustainable-finance-taxonomy/

CIRCULAR ECONOMY MAP

Objective: Map material flows and identify a high-value circular intervention.

Duration: Seventy-five minutes

Instructions: Define a system boundary and product or material stream. Map suppliers, users, collection, treatment and disposal. Estimate quantities and value losses. Identify higher-value loops. Select one loop and identify its technology, actors, buyer and pilot.

Materials: Material-flow template, stakeholder cards and waste data.

Expected output: Sankey-style map, selected loop, value proposition and KPIs.

External materials

Flows: https://ec.europa.eu/eurostat/web/environment/information-data/material-flows-resource-productivity
Circularity Gap: https://www.circularity-gap.world/
Eurostat Waste Database: https://ec.europa.eu/eurostat/web/waste/database
Material Circularity Indicator: https://ellenmacarthurfoundation.org/material-circularity-indicator

SUSTAINABLE MOBILITY PACKAGE

Objective: Develop an avoid–shift–improve package for a corridor or neighbourhood.

Duration: Seventy-five minutes

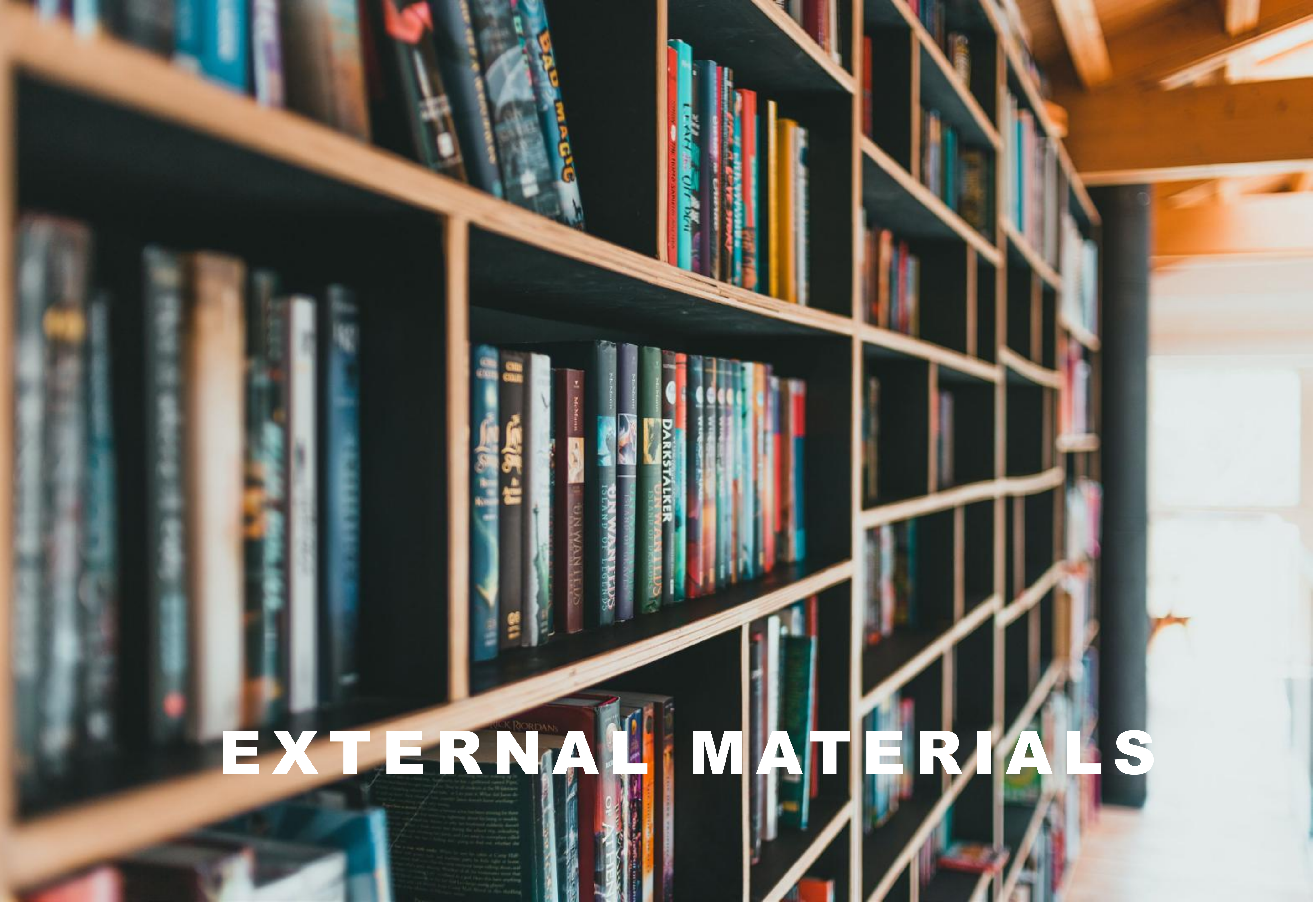
Instructions: Map origins, destinations, barriers and mode share. Identify avoid, shift and improve measures. Estimate changes in trips, vehicle-km and access. Allocate street space and budget. Assess effects on disabled users, low-income residents and businesses.

Materials: Street map, travel data, stakeholder personas and mode-share worksheet.

Expected output: Before-and-after map, package, impact estimate and equity statement.

External materials

EU Urban Mobility Observatory: https://urban-mobility-observatory.transport.ec.europa.eu/
OpenStreetMap: https://www.openstreetmap.org/
Eurostat Transport: https://ec.europa.eu/eurostat/web/transport/database
OpenRouteService: https://openrouteservice.org/



EXTERNAL MATERIALS

RECOMMENDED BOOKS

Book	Author	Year and publisher	Level	Description
The Circular Economy: A Wealth of Flows	Ken Webster	2017, Ellen MacArthur Foundation	Intermediate	Systems perspective on circularity
Cradle to Cradle	William McDonough and Michael Braungart	2002, North Point Press	Beginner	Foundational circular-design philosophy
Thinking in Systems	Donella Meadows	2008, Chelsea Green	Beginner	Feedback, leverage points and system behaviour
Doughnut Economics	Kate Raworth	2017, Random House Business	Beginner	Social foundations and ecological ceilings
Drawdown	Paul Hawken, editor	2017, Penguin	Beginner	Portfolio of climate solutions

RECOMMENDED BOOKS

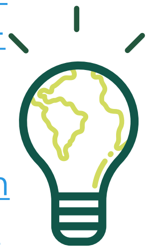
Book	Author	Year and publisher	Level	Description
Regeneration	Paul Hawken	2021, Penguin	Beginner	Climate action and ecological restoration
How to Avoid a Climate Disaster	Bill Gates	2021, Knopf	Beginner	Technology pathways and innovation gaps
There Is No Planet B	Mike Berners-Lee	2019, Cambridge University Press	Beginner	Evidence-based sustainability guide
How the World Really Works	Vaclav Smil	2022, Viking	Intermediate	Material and energy realities of modern society
Smart Cities	Anthony M. Townsend	2013, W. W. Norton	Intermediate	Critical history of urban digital systems

RECOMMENDED BOOKS

Book	Author	Year and publisher	Level	Description
Green Building Illustrated	Francis D. K. Ching and Ian M. Shapiro	2014, Wiley	Intermediate	Visual guide to sustainable building systems
Resilient Cities	Peter Newman, Timothy Beatley and Heather Boyer	2017, Island Press	Intermediate	Urban resilience, mobility and planning
Water 4.0	David Sedlak	2014, Yale University Press	Intermediate	History and future of urban water technology
The Vertical Farm	Dickson Despommier	2010, Thomas Dunne Books	Beginner	Controlled-environment urban agriculture
The Fifth Discipline	Peter M. Senge	2006, Currency	Advanced	Learning organisations and systems thinking

VIDEO RESOURCES

Title	Channel	Duration	Topic and link
The Most Important Thing You Can Do to Fight Climate Change: Talk About It	TED, Katharine Hayhoe	17 min	Climate communication: https://www.youtube.com/results?search_query=TED+Katharine+Hayhoe+talk+about+climate
The Surprising Thing I Learned Sailing Solo Around the World	TED, Ellen MacArthur	18 min	Circular economy: https://www.youtube.com/results?search_query=TED+Ellen+MacArthur+sailing+solo
A Climate Solution Where All Sides Can Win	TED, Ted Halstead	13 min	Climate policy: https://www.youtube.com/results?search_query=TED+Ted+Halstead+climate+solution
The Case for Optimism on Climate Change	TED, Al Gore	25 min	Energy transition: https://www.youtube.com/results?search_query=TED+Al+Gore+climate+optimism
How We Can Turn the Tide on Climate	TED, Christiana Figueres	15 min	Systems change: https://www.youtube.com/results?search_query=TED+Christiana+Figueres+climate



VIDEO RESOURCES

Title	Channel	Duration	Topic and link
Explaining the Circular Economy and How Society Can Re-think Progress	Ellen MacArthur Foundation	4 min	https://www.youtube.com/results?search_query=Ellen+MacArthur+Foundation+rethink+progress
Circular Economy Systems Diagram	Ellen MacArthur Foundation	3 min	https://www.youtube.com/results?search_query=Ellen+MacArthur+Foundation+systems+diagram
What Is a Circular Economy?	Ellen MacArthur Foundation	4 min	https://www.youtube.com/results?search_query=Ellen+MacArthur+Foundation+what+is+circular+economy
Introduction to Sustainable Energy	MIT OpenCourseWare	50–60 min	https://www.youtube.com/results?search_query=MIT+OpenCourseWare+Introduction+Sustainable+Energy
Solar Energy Lecture	MIT OpenCourseWare	50–60 min	https://www.youtube.com/results?search_query=MIT+OpenCourseWare+solar+energy+lecture

VIDEO RESOURCES

Title	Channel	Duration	Topic and link
Wind Energy Lecture	MIT OpenCourseWare	50–60 min	https://www.youtube.com/results?search_query=MIT+OpenCourseWare+wind+energy
Energy Storage Lecture	MIT OpenCourseWare	50–60 min	https://www.youtube.com/results?search_query=MIT+OpenCourseWare+energy+storage
Energy Innovation and Emerging Technologies	Stanford Online	60 min	https://www.youtube.com/results?search_query=Stanford+energy+innovation+emerging+technologies
The Future of Energy Storage	Stanford Energy	60 min	https://www.youtube.com/results?search_query=Stanford+future+energy+storage

OPEN DATA AND ONLINE TOOLS

Resource	Use	Link
Eurostat Data Browser	European energy, waste, transport and materials data	https://ec.europa.eu/eurostat/databrowser/
EEA Datahub	Environmental indicators and maps	https://www.eea.europa.eu/en/datahub
IEA Data Explorer	Energy-system data	https://www.iea.org/data-and-statistics/data-tools
Global Solar Atlas	Solar-resource assessment	https://globalsolaratlas.info/
Global Wind Atlas	Wind-resource assessment	https://globalwindatlas.info/
PVGIS	PV yield and solar-radiation estimates	https://re.jrc.ec.europa.eu/pvg_tools/en/
Copernicus Browser	Satellite imagery	https://browser.dataspace.copernicus.eu/
OpenStreetMap	Participatory and infrastructure mapping	https://www.openstreetmap.org/
Climate Watch	Climate targets and emissions	https://www.climatewatchdata.org/

CIRCULARITY AND LIVING LAB TOOLS

Resource	Use	Link
OpenLCA	Lifecycle assessment	https://www.openlca.org/
Level(s)	Sustainable-building assessment	https://environment.ec.europa.eu/topics/circular-economy/levels_en
Circularity Gap	Material circularity evidence	https://www.circularity-gap.world/
Climate-ADAPT	Climate-adaptation data and cases	https://climate-adapt.eea.europa.eu/
NetZeroCities	Climate-neutral city tools	https://netzerocities.eu/
ENoLL	Living Lab principles and network	https://enoll.org/
EU Funding and Tenders	Funding opportunities	https://ec.europa.eu/info/funding-tenders/opportunities/portal/
EU Urban Mobility Observatory	Mobility planning and cases	https://urban-mobility-observatory.transport.ec.europa.eu/

END-OF-TRAINING ASSESSMENT

https://forms.gle/bXEoYPxDfDKFxJUL8

Quiz: GREEN TECHNOLOGIES

Q1 What is the most appropriate way to determine whether a technology is genuinely sustainable?

A) Check whether it is marketed as a green technology

B) Consider only its operational energy consumption

C) Assess its full lifecycle, including resource use, emissions, durability, repairability and end-of-life management

D) Compare its purchase price with conventional alternatives

Click any answer to see if you got it right.

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Next Question →

Quiz: GREEN TECHNOLOGIES

Q2 Which approach best reflects an integrated renewable-energy system?

A) Installing renewable generation without considering the electricity grid

B) Combining renewable generation, storage, networks, digital control and flexible demand

C) Replacing all energy sources with solar PV

D) Prioritising the renewable technology with the lowest initial investment cost

Click any answer to see if you got it right.

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Quiz: GREEN TECHNOLOGIES

Q3 According to circular-economy principles, which option generally retains the greatest embedded value?

A) Energy recovery

B) Recycling materials into new products

C) Keeping products or components functional through repair and reuse

D) Disposal in a controlled landfill

Click any answer to see if you got it right.

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Quiz: GREEN TECHNOLOGIES

Q4 What should generally be the first priority when improving the environmental performance of a building?

A) Install renewable-energy generation

B) Install more sensors

C) Reduce unnecessary energy demand

D) Replace all appliances with smart devices

Click any answer to see if you got it right.

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Quiz: GREEN TECHNOLOGIES

Q5 What best describes a genuinely "smart" city?*

A) A city with the largest possible number of sensors and connected devices

B) A city where all public services use artificial intelligence

C) A city that uses appropriate technology to improve environmental, social and economic outcomes while maintaining transparency and accountability

D) A city that collects as much data as possible

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Quiz: GREEN TECHNOLOGIES

Q6 Which sequence best represents a sustainable approach to water management?

A) Desalination → treatment → leakage management → demand reduction

B) Source protection → demand reduction → leakage management → reuse → additional supply where necessary

C) New supply → treatment → monitoring → conservation

D) Drinking-water treatment standards for all water applications

Click any answer to see if you got it right.

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Next Question →

Quiz: GREEN TECHNOLOGIES

Q7 Which option has the highest priority in the waste hierarchy?*

A) Recycling

B) Energy recovery

C) Waste prevention

D) Disposal

Click any answer to see if you got it right.

Quiz: GREEN TECHNOLOGIES

Q7 Which option has the highest priority in the waste hierarchy?*

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B) Energy recovery

C) Waste prevention

D) Disposal

Next Question →

Quiz: GREEN TECHNOLOGIES

Q8 What does the Avoid–Shift–Improve approach to sustainable mobility mean?

A) Avoid electric vehicles, shift to conventional vehicles and improve roads

B) Reduce unnecessary travel, make remaining transport cleaner and more efficient

C) Avoid public transport, shift toward private mobility and improve vehicle efficiency

D) Reduce walking distances, increase traffic speeds and electrify all vehicles

Click any answer to see if you got it right.

Quiz: GREEN TECHNOLOGIES

Q8 What does the Avoid–Shift–Improve approach to sustainable mobility mean?

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Next Question →

Quiz: GREEN TECHNOLOGIES

Q9 When should digital technologies such as AI, IoT or digital twins be introduced into a sustainability project?

A) Whenever sufficient funding is available

B) Whenever the technology is innovative

C) After defining the environmental or operational problem and determining that digital technology can improve the decision or action

D) Before defining indicators, so that the technology can determine what should be measured

Click any answer to see if you got it right.

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Next Question →

Quiz: GREEN TECHNOLOGIES

Q10 A Green Innovation Manager is preparing a Living Lab pilot for a new green technology. Which approach is most appropriate?

A) Select the most advanced technology and deploy it immediately at full scale

B) Let technology providers make all implementation decisions

C) Co-create the pilot with relevant stakeholders, test assumptions and impacts, define measurable indicators, monitor results and adapt the solution

D) Focus exclusively on technical performance and evaluate social and economic impacts after implementation

Click any answer to see if you got it right.

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End of quizz

THANK YOU FOR YOUR PARTICIPATION!

GREEN LABS PROJECT

The GREEN LABS project aims to support and stimulate the green transition by promoting innovation and greening of VET systems through internationalization, exchange of practices, and knowledge sharing among partners, in accordance with the Osnabrück Declaration of 2020 on vocational education and training for sustainable competitiveness, social fairness and resilience.

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