TECHNOLOGIES AND MATERIALS FOR CIRCURAL CITIES

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CIRCURAL CITY

Maximize the lifecycle of raw materials and products, minimize the amount of waste, optimize energy and water use. Design infrastructure and services to minimize waste and pollution

SUSTAINABLE CITY

Balance environmental, social, and economic needs for long-term resilience. Renewable energy targets, equitable transport systems, and affordable housing alongside environmental protection

15-MINUTES CITY

Reduce commuting time, increase quality of life, and cut emissions from transport

Green, Carbon-Neutral, Resilient, Regenerative, Compact, Inclusive, Smart, Digital, Innovative City, ….

The Weight of Cities: Resource Requirements of Future Urbanization by Anu Ramaswami, director of the Sustainable Healthy Cities Network

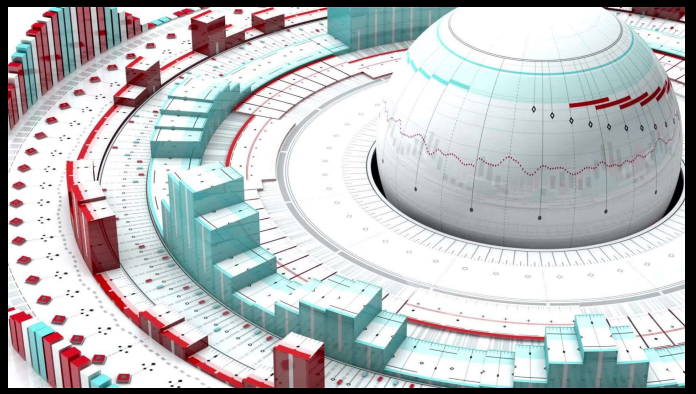
https://www.sustainablehealthycities.org/wp-content/uploads/2018/02/WoC-SPM-Web-Version_reduced.pdf

Sustainable Development Goal 11 - make cities and human settlements inclusive, safe, resilient and sustainable

Material consumption by the world's cities will grow from 40 bilion tonnes in 2010 to about 90 billion tonnes by 2050

Needs for various sustainability technology and materials

ISO 37120 - Indicators for Sustainable Cities,
ISO 37122 - Indicators for Smart Cities,
ISO 37123 - Indicators for Resilient Cities.



SMART, CIRCURAL AND SUSTAINABLE CITY STRATEGIES

EU projects and road map for smart city

The Smart Cities Marketplace

35 initiatives

Scalable Cities

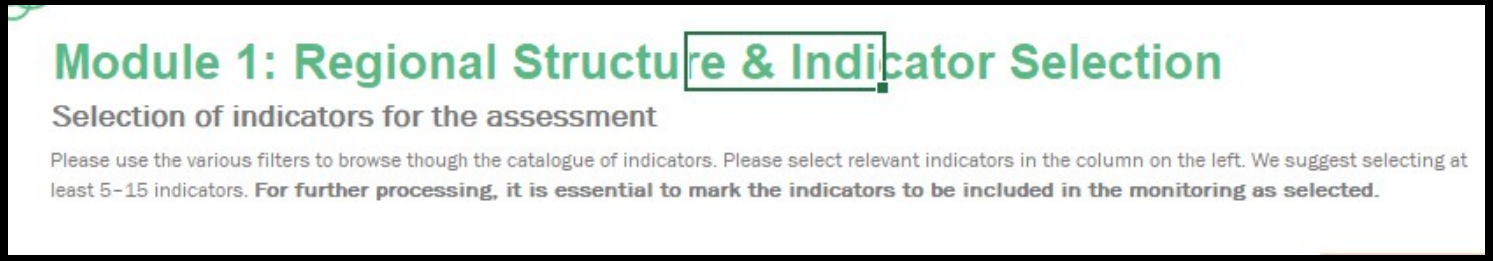
Urban Innovative Actions

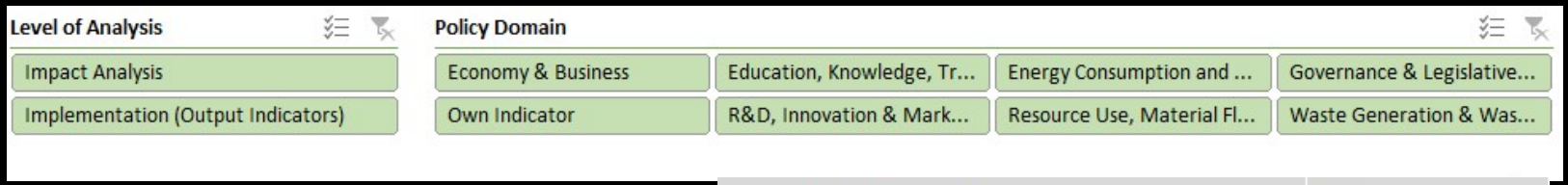
URBACT

The European Green Capital

The New European Bauhaus Award

2025 - EU Circular Cities and Regions Initiative with Self-Assessment Tool (SAT)





Carbon footprint of construction	kg CO2/square meter built	LCA/OEF
GHG-emissions from Waste	million tonnes GHGe	MFA/LCA
GHG-emissions by sector (to indicate in internal specification)	t CO2	MFA/LCA

Self-sufficiency in raw materials	Share
Tonnes of resources saved through circular economy actions (industrial symbiosis etc.)	tonnes
Regional Material Footprint	tonnes per capita
Resource productivity	€ GDP / tonne raw materials
Number of circular economy initiatives (hubs, platforms, hotspots etc.)	No.

https://smart-cities-marketplace.ec.europa.eu/

https://circular-cities-and-regions.ec.europa.eu/news/introducing-ccri-self-assessment-tool-supporting-cities-and-regions-tracking-their-circular

Indicators for circular & sustainable city

Project results will be of relevance for the Circular Cities and Regions Initiative (CCRI).

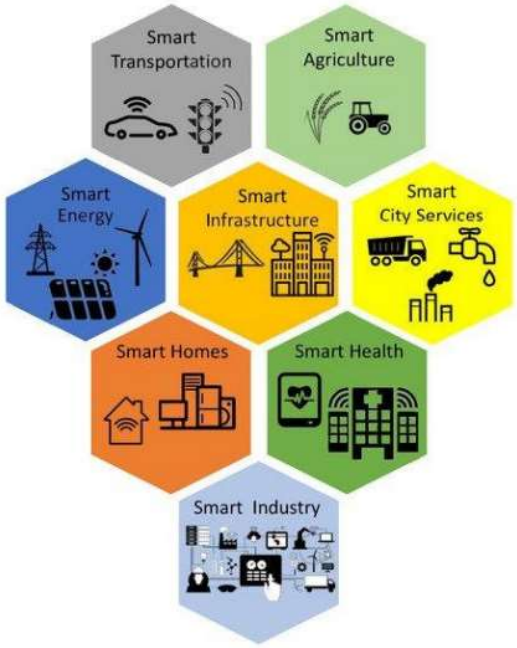


Figure 2. The main smart city issues (Syed et al. 2021).

https://www.enicbcmed.eu/sites/default/files/2024-01/D3.1.3-Indicators_for_Smart%20Buildings-Cities.pdf

INDICATORS FOR THE TRANSITION TO SUSTAINABLE AND CIRCULAR ECONOMY

FUNDING PROGRAM	Horizon Europe: Cluster 6 - Food, Bioeconomy, Natural Resources, Agriculture and Environment
CALL NUMBER	HORIZON-CL6-2025-01-CIRCBIO-06
DEADLINES	Opening 06.05.2025
	Deadline 17.09.2025 17:00

Figure 1. The CITYkeys indicator framework

People	Planet	Prosperity	Governance	Propagation
• Health	• Energy & mitigation	• Employment	• Organisation	• Scalability
• Safety	• Materials, water and land	• Equity	• Community involvement	• Replicability
• Access to (other) services	• Climate resilience	• Green economy	• Multi-level governance	
• Education	• Pollution and waste	• Economic performance		
• Diversity & social cohesion	• Ecosystem	• Innovation		
• Quality of housing and the built environment		• Attractiveness & competitiveness		

Source: Bosch et al. (2017), "CITYkeys indicator for smart city projects and smart cities," http://nws.eurocities.eu/MediaShell/media/CITYkeystheindicators.pdf

Milan Urban Food Policy Pack

International agreement among cities from all over the world - developing sustainable food systems that are inclusive, resilient, safe, and diverse.'

Food waste is responsible for approximately 10 % of GHG

Technology

- Smart packaging technologies -inform about food quality.
- “Too Good To Go” create a direct connection between businesses and consumers seeking discounted products.
- Food-sharing platforms - Olio - offer promising solutions by connecting consumers with surplus food

Olio

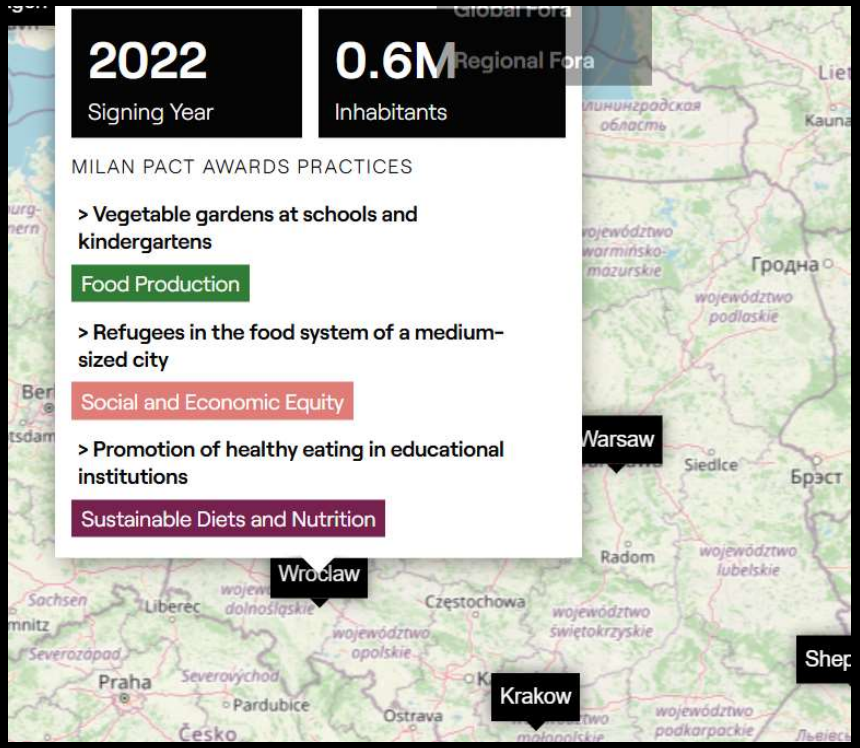
Too Good To Go

Flashfood - Grocery deals

FoodHero – Save on Groceries

Ecosia

NoWaste - Food Inventory List



SMART, CIRCURAL & SUSTAINABLE CITY TECHNOLOGIES & MATERIALS

TECHNOLOGIES FOR MONITORING RESOURCE FLOWS

Information systems and sensors

- Smart utility metering - automatic reading and remote monitoring of water, electricity, and gas consumption at building or district level.
- Waste tracking systems - sensors in waste bins signal when collection is needed, and tracking platforms trace waste from source to recycler or landfill.

Analysis of raw material consumption

- Integrated data platforms - urban dashboards aggregate resource data citywide and support decision-making for sustainability targets.

Identification of opportunities to close loops

- Blockchain for material traceability - secure, tamper-proof records of materials as they move through supply chains and recycling processes.
- Digital twins - Virtual representations of city infrastructure enabling real-time simulation, scenario planning, and prediction of resource flows.

City	Infrastructure	Infrastructure	Market	Index Score
Atlanta	87.8	66.0	82.0	79.4
Boston	85.1	68.7	80.0	78.7
San Francisco	81.3	75.3	75.0	78.5
Washington	75.6	69.0	96.0	75.6
Chicago	76.9	68.7	48.0	70.6

City	Connectivity & Infrastructure	Green Infrastructure	Tech Job Market	Index Score
Paris	78.8	75.9	62.2	75.8
Stockholm	89.6	59.3	22.2	71.0
Amsterdam	64.9	72.2	68.9	68.0
Munich	63.2	65.6	92.2	67.5
Lisbon	69.9	54.4	86.7	66.4

- **Cities best prepared for a smart city future in US and Europe based on** OECD's guidelines for smart cities. https://proptechos.com/smart-city-index/

Smart transportation - Smart home

Various policies to reduce the use of cars (e.g. building cycling ways), and adopting Intelligent Transport Systems projects to improve users' mobility experience

- App-based ride services and shared mobility
- Vehicular Ad-hoc Networks - real-time traffic monitoring and route optimization.
- Intelligent and autonomous transportation - Vehicle-to-Everything (V2X)
- Land and Transport Singapore (LTSG) datasets
- UBER and BOLD… ?

SOCIAL ASPECT

- Free public transport – Luxemburg, Since 2020, public transport has been free for everybody, residents as well as tourists, Poland i some cities and for person >70 years
- Intelligent transportation not only enhances driving experiences, road safety, and traffic management but also yields significant sustainability benefits by reducing CO2 emissions and other harmful pollutants

https://www.sciencedirect.com/science/article/pii/S2666691X24000277

- EU Mission of 100 Climate-Neutral and Smart Cities – 5 Polish cities - Kraków, Łódź, Rzeszów, Warsaw, Wrocław - https://netzerocities.eu/

- Poland - households are one of the largest energy consumers - nearly 1/3 of final energy consumption, even the average domestic households in 2021 24.6 GJ of energy per capita, is at the European average level - in 2021 about 21% of households were heated with coal,

Green ICT and Smart Metering	% of households and buildings with reduced water consumption as a consequence of installing smart water meters	% of households
Green ICT and Smart Metering	% of municipal buildings equipped with building energy management systems	% of public buildings
EGovernment	% of city services available online	% increase of total services
Access to information	Business-to-Government (B2G) data sharing	# of Private Datasets Shared with the City/Local Authority
Urban Data Platforms	Usage of Urban Data Platforms	# Active Users / Day

https://unfccc.int/sites/default/files/resource/BTR1_Poland_31Dec2024.pdf

Zero-Emission and Circular Mobility

- Reducing greenhouse gas emissions
- Lowering dependence on fossil fuels
- Electric public transport
- Urban bike-sharing programs
- Electric car-sharing schemes
- Infrastructure for electric mobility
- Promoting shared modes of transport

EU Sustainable Urban Mobility Plan - Over 70% of EU citizens live in urban areas (cities, towns and suburbs) that generate 23% of all transport GHG.

Name of city: Wrocław
Number of inhabitants (urban centre): 674,312
Part of the EU Mission on Climate-Neutral and Smart Cities: Yes

2020 - Wrocław was one of the finalists of the 8th Award for Sustainable Urban Mobility Planning (SUMP Award), which focused on the theme of safe walking and cycling.

In 2023 13 electric buses eCitaro, and planned next 21 - thanks to EU FEnIKS programme

Clean Transport Area ?

https://transport.ec.europa.eu/transport-themes/urban-transport/sustainable-urban-mobility_en

Circular Water and Food Management

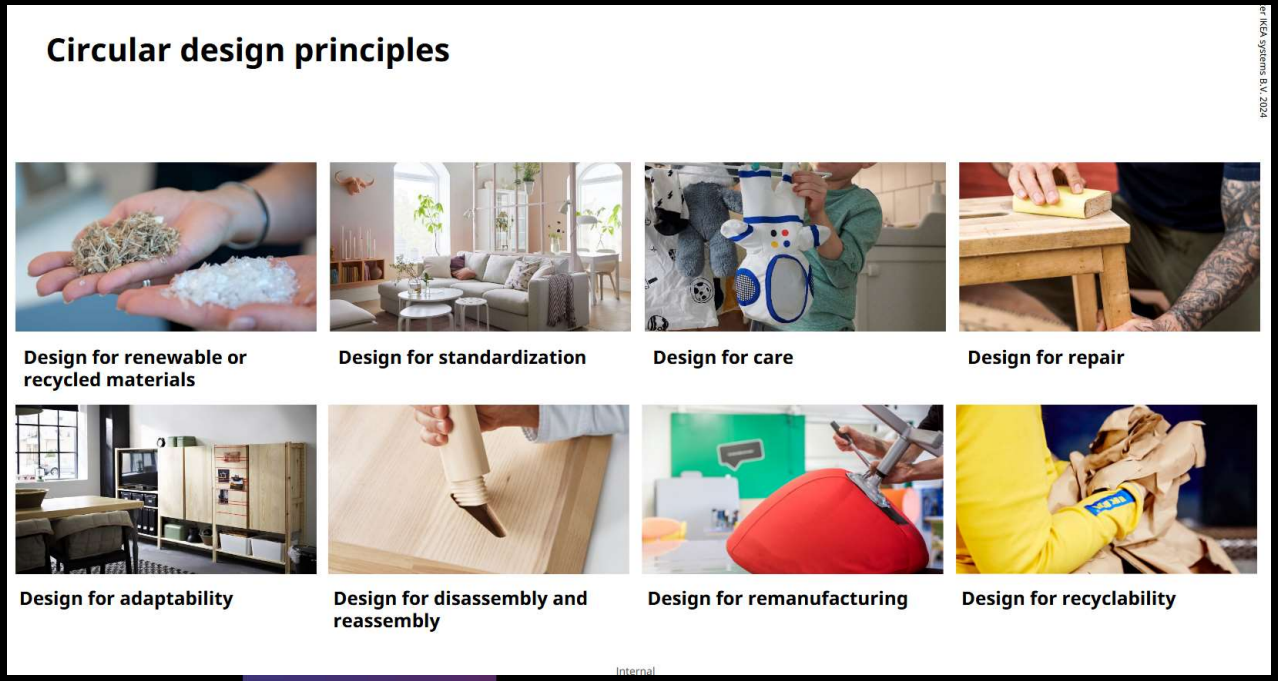
- Technologies for recycling and purifying rainwater and greywater
- Use advanced systems to recover valuable resources (e.g., phosphorus) from wastewater sludge for reuse as fertilizer.
- Compost biodegradable organic waste from households
- Promote urban and vertical farming systems reducing transportation
- Integrate greenhouses, hydroponics, and vertical gardens within city
- Close resource loops in water and food sectors to conserve resources, reduce emissions and waste, and build resilient local food systems.

Struvite

https://magazin.tu-braunschweig.de/en/pi-post/phosphorus-recycling-from-sewage-sludge-to-plant-fertilise/

https://thecircularwaterco.com/

Circular design and materials



- Certified Wood
- Natural Composites - Flax and Hemp
- Bioplastics and Biodegradable Materials
- Straw, cork, and bamboo for insulation or structural applications
- Sheep's wool or flax wool for natural, breathable insulation.
- Clay and clay-based plasters for walls and finishes.
- Recycled paper or cardboard-based building boards.

Barriers?

https://www.ikea.com/global/en/images/IKEA_Circular_product_design_guide_2024_0925_f56183ff98.pdf

Circular technology and city in Poland

GREENEVO
TECHNOLOGY ACCELERATOR

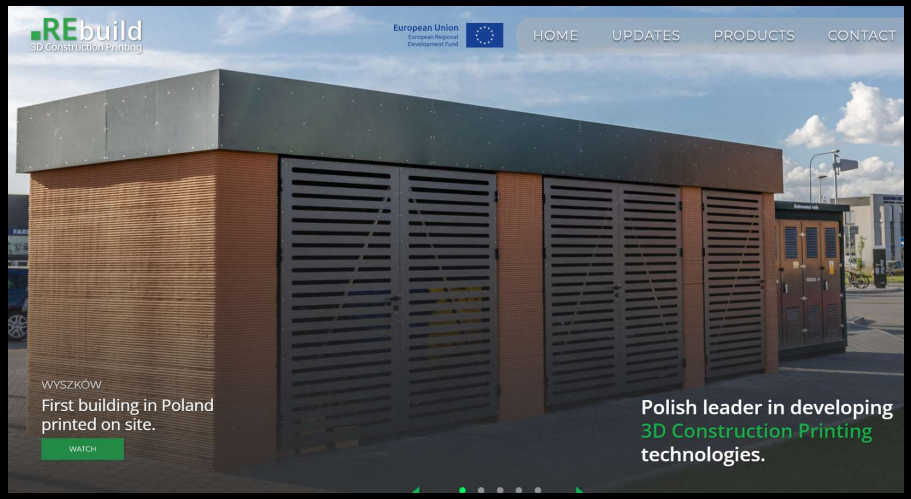
- **EasySolar** - ability to design photovoltaic systems on photos, drone photos, google maps, any other maps, building visualizations, schemes or on a sketch.
- **¡Charge station** for on-grid small electromobility devices for modern and eco-friendly cities is designed to provide charging facilities in public spaces for **electric scooters and bicycles.**

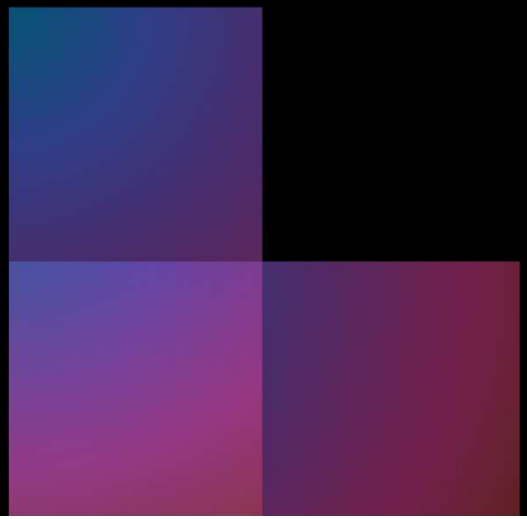
The Eco-Miasto program is a joint initiative of UNEP/GRID-Warsaw, an organization that has been carrying out the mission of the United Nations Environment Programme (UNEP) in Poland since 1991, and the Embassy of France in Poland.

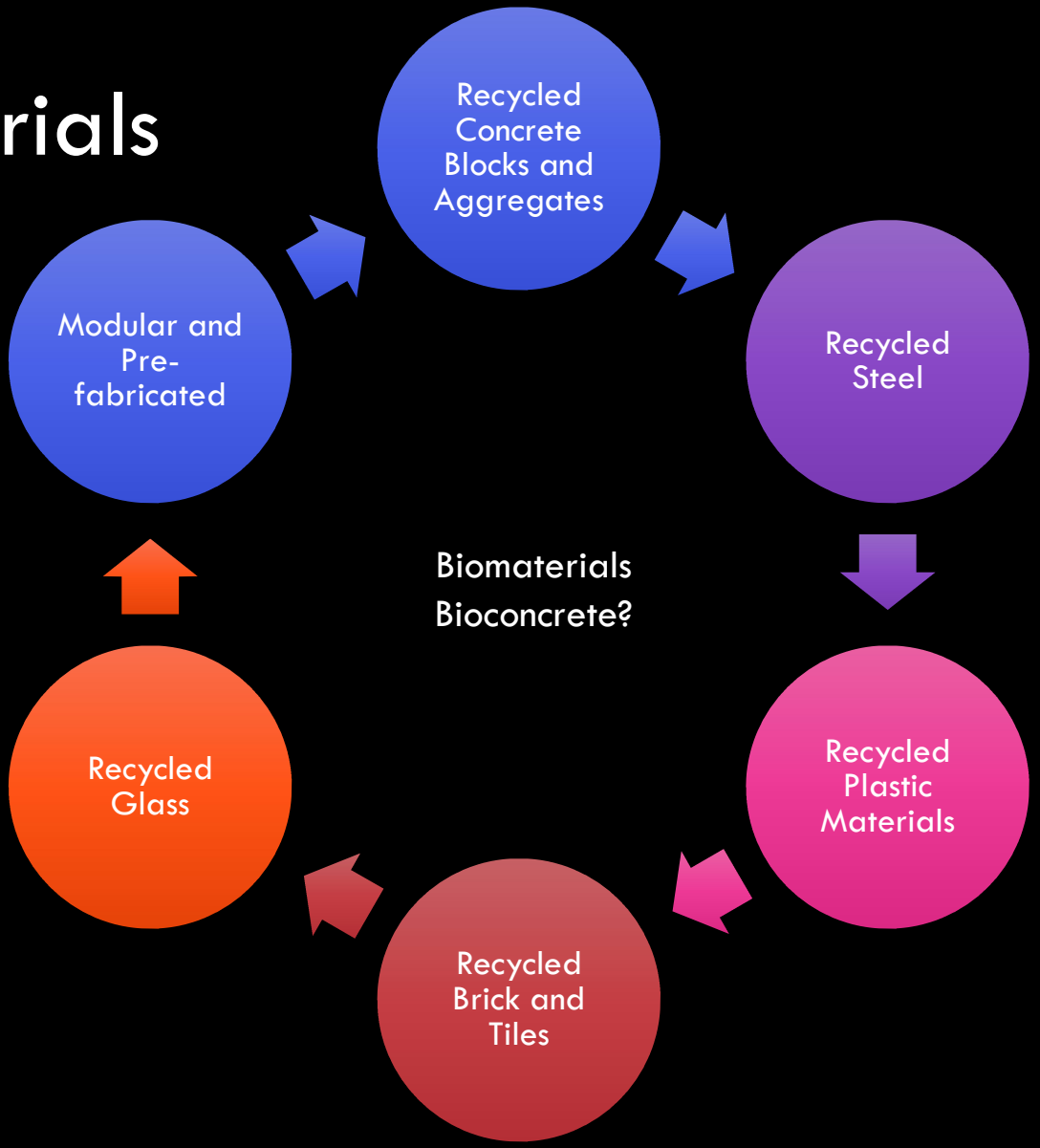
Circular city in Poland:
Kępno (Klamotowisko and education) , Poznań (Gratowisko – reuse)

https://www.eco-miasto.pl/pl/

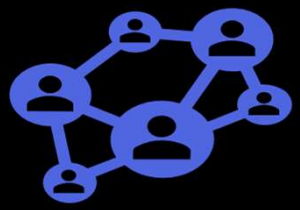
Recycled Building Materials







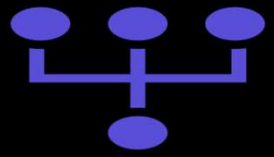
Collaboration and Social Education



active participation and awareness of local residents.

Educational campaigns and outreach activities

the public about sustainable practices, resource efficiency, and the benefits.



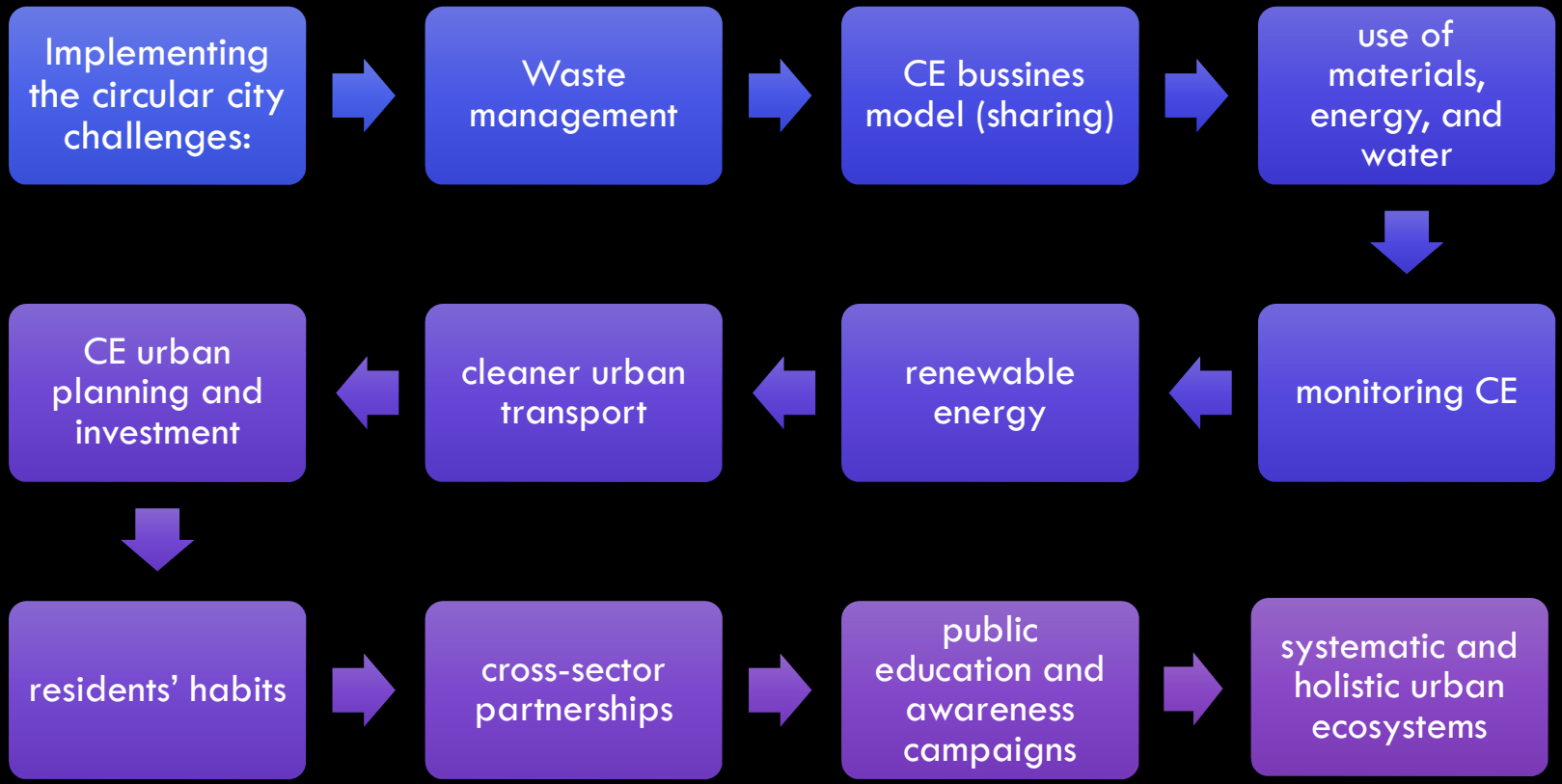
workshops, exchange events, and sharing platforms

To reduce waste and strengthen community bonds and foster a culture of sustainability.

local initiatives, encouraging eco-friendly behaviors and providing practical education, cities help empower citizens to make better environmental choices.

collaboration among local authorities, NGOs, businesses, and citizens is key to building a circular urban ecosystem. social campaigns, community-led projects.

Key Challenges for Circular Cities



Krakow – case study

- Krakow is one of three Polish cities actively involved in the international Circular Cities Poland project. This initiative focuses on implementing innovative solutions and tools for managing resource cycles, integrating the efforts of local government, businesses, academia, and the local community. As part of the project, Krakow tests and adapts best practices from the circular economy and shares experiences with other cities.
- Some of the ways Krakow advances circularity include:
  - Piloting modular construction methods that facilitate the reuse of building components and reduce construction waste.
  - Promoting urban agriculture and community composting, closing organic resource loops within city neighborhoods.
  - Expanding green infrastructure, such as green roofs and pocket parks, which both retain rainwater and support biodiversity.
  - Rolling out digital platforms for sharing, repair, and exchange—empowering residents to extend the life of goods and reduce consumption.
  - Investing in smart waste collection and recycling systems, including sensor-based monitoring and advanced sorting facilities.
  - Collaborating on educational campaigns and public workshops to foster circular behaviors among citizens.

http://circularhotspot.pl/userfiles/baza-wiedzy/CircularCitiesProgram_Krakow_Final%20Report.pdf

Summary

Technologies used in circular cities, such as Krakow, enable effective closure of material loops, optimization of energy and water use, and minimization of waste. Intelligent monitoring systems, renewable energy sources, digital sharing platforms, and the use of recycled materials and biomaterials all help create an integrated, sustainable urban environment—one that is resilient to future challenges and friendly to its residents. It is in line with Małopolska region CE programme.

Kraków in 2018

https://www.krakow.pl/aktualnosci/224282,1912,komunikat,pierwsza_stacja_do_ladowania_samochodow_elektrycznych_.html

Thank you

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