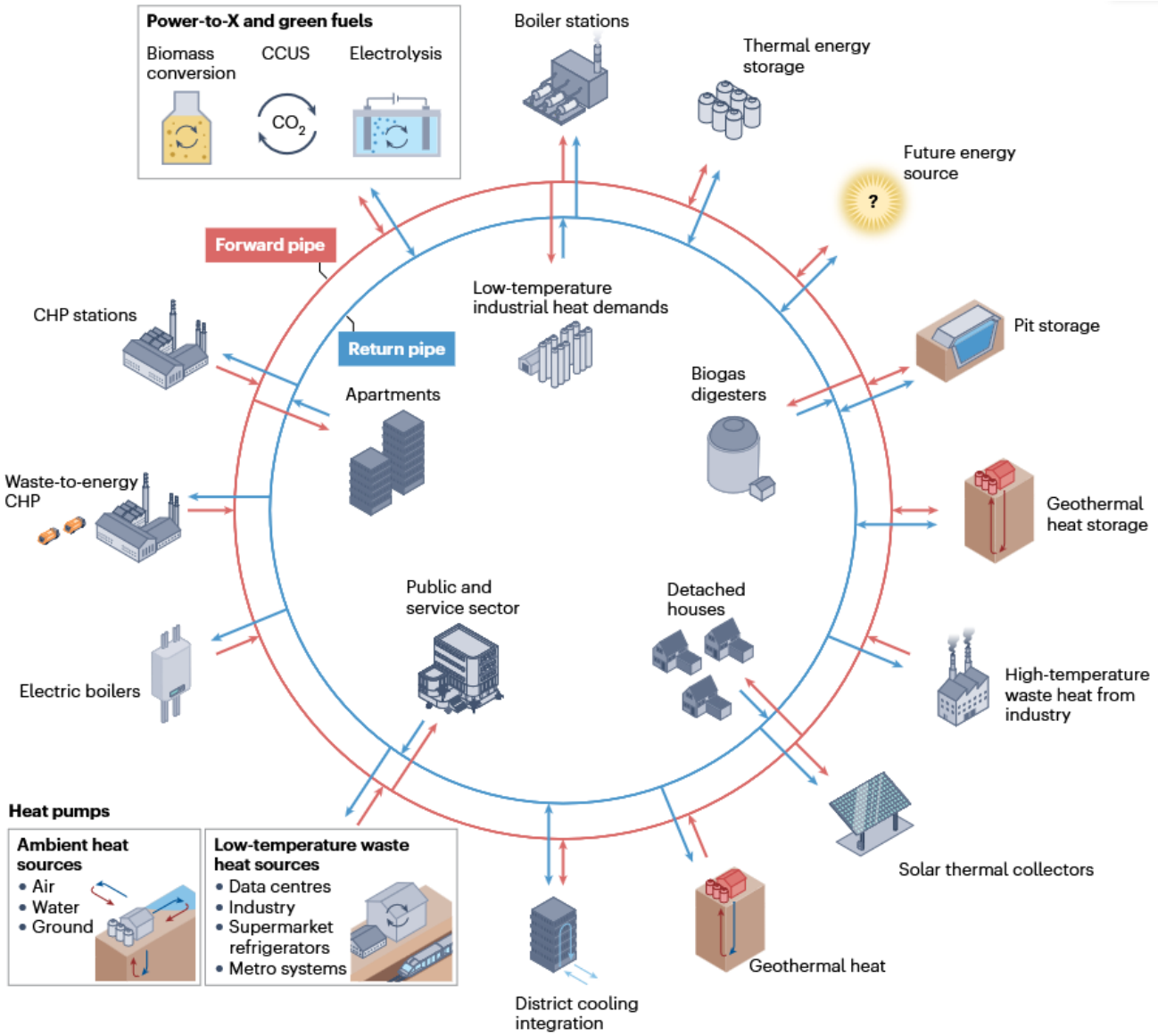
Modern district heating and cooling systems in the light of cross-sector integration

Andrej Kitanovski

University of Ljubljana, Faculty of Mechanical Engineering

SZE - Slovenian Energy Association

Coupling of energy sectors -example



Lund, Henrik (et al.) Nature Reviews Clean Technology, August 2025, Volume 1, Issue 8, pp 532 - 546

Efficiency Gains and Heat recovery

Renewable Integration

Defossilization

Flexibility Enhancement

Economic Resilience

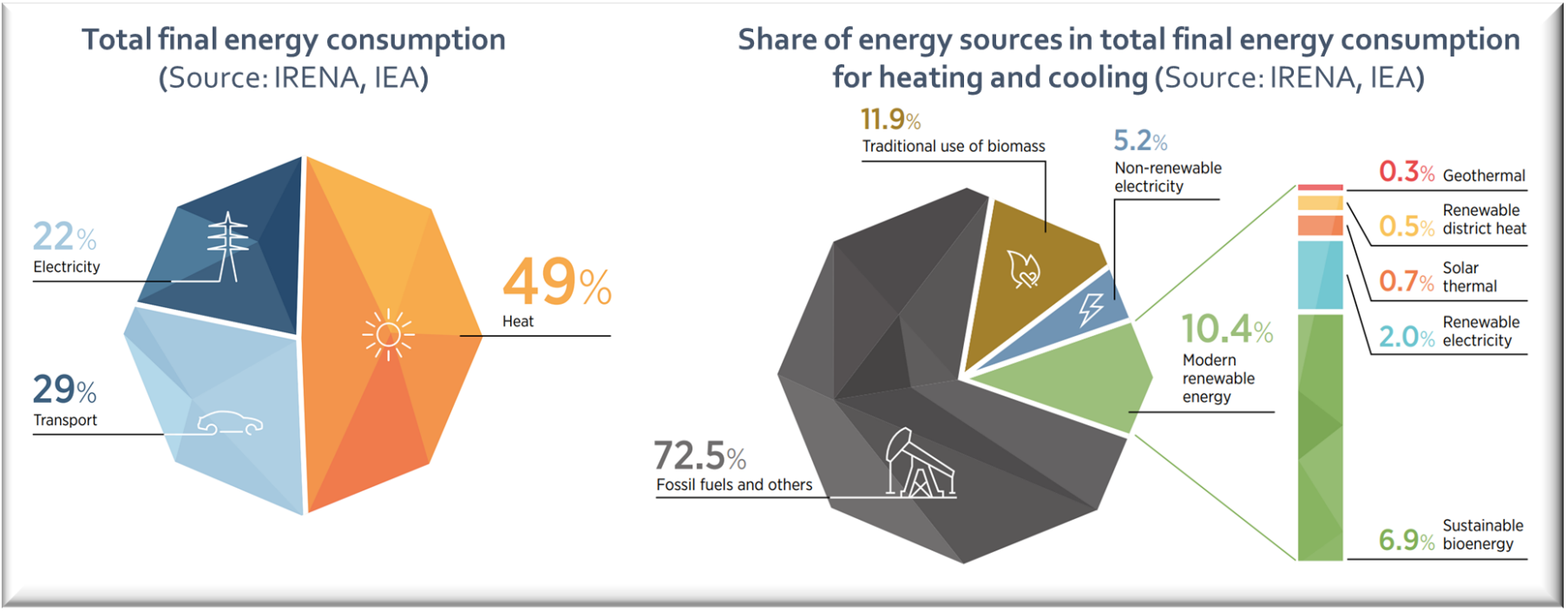
Cost Reduction

Energy Security

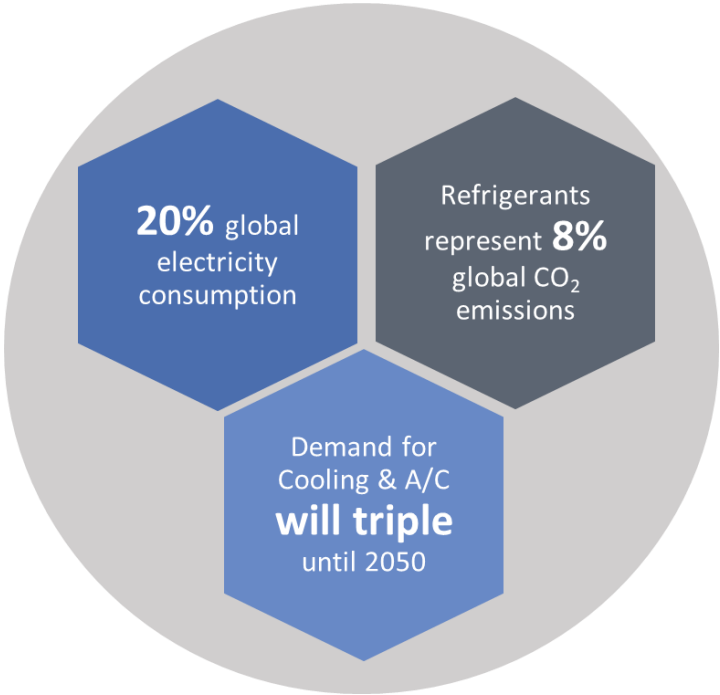
Social Equity

Environmental Protection and Public Health

Heating and cooling
FACTS - GLOBAL

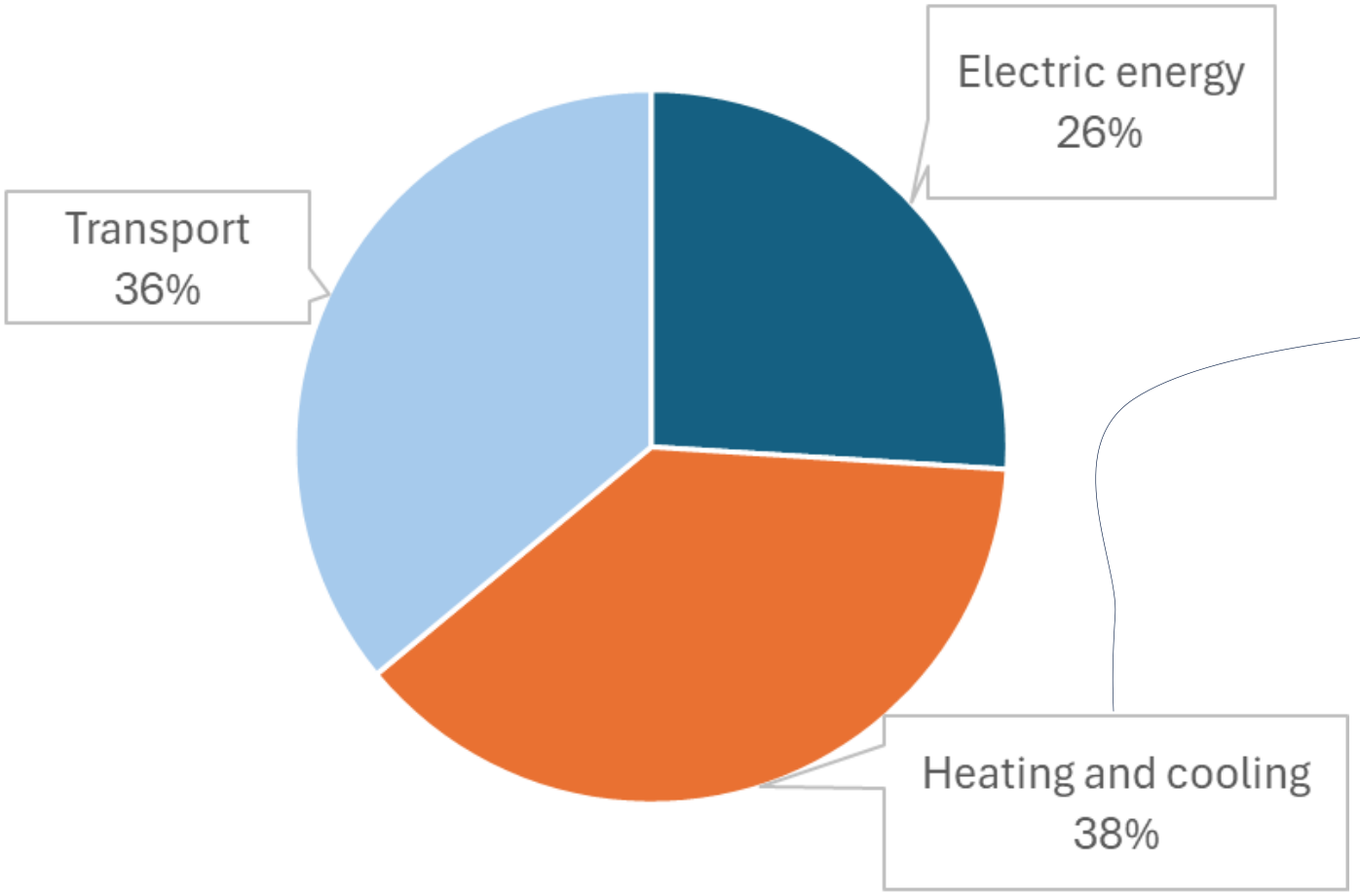


COOLING



Source: IEA, International Institute of Refrigeration

Heating and cooling
FACTS - SLOVENIA

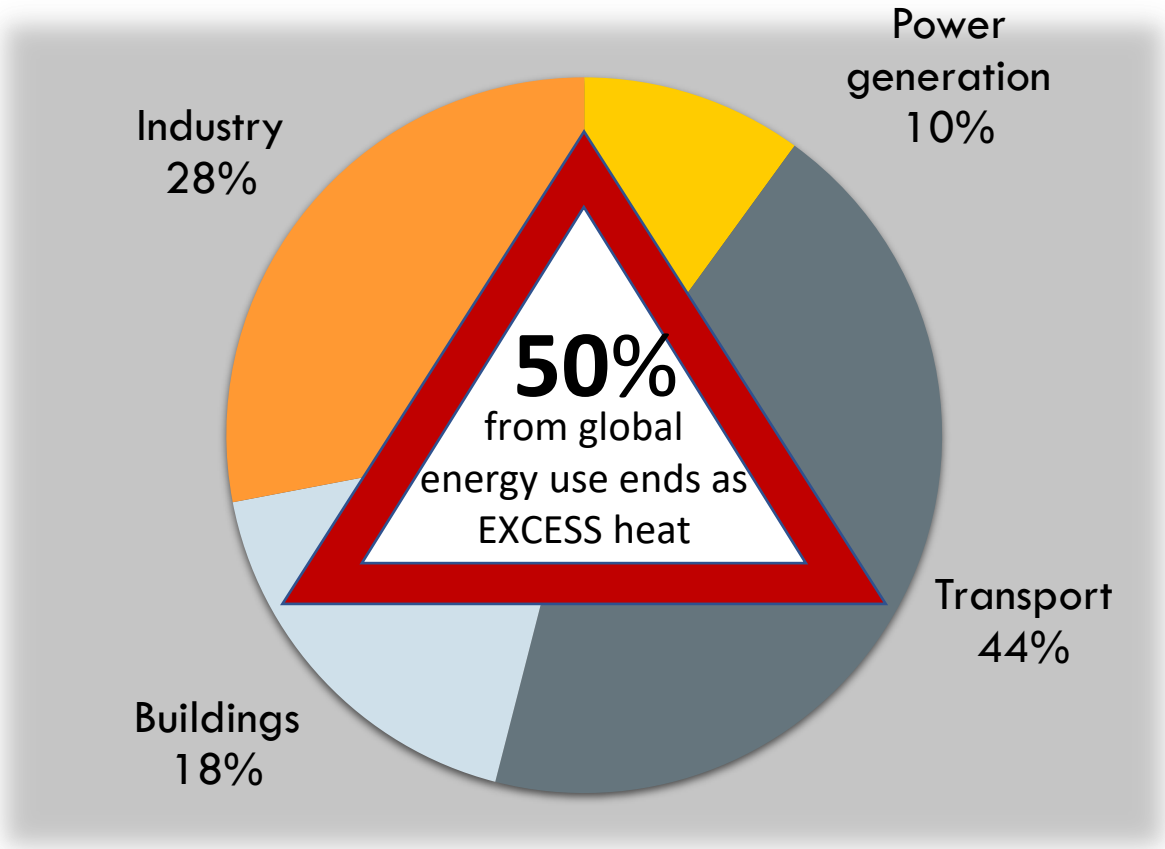


Cooling? Just a guess, no real data, no adequate policy

a critical gap we have persistently highlighted since the inception of SZE and its predecessor SDDE nearly three decades ago

Source: SOH, IJS, 2023

Surplus heat
FACTS - GLOBAL

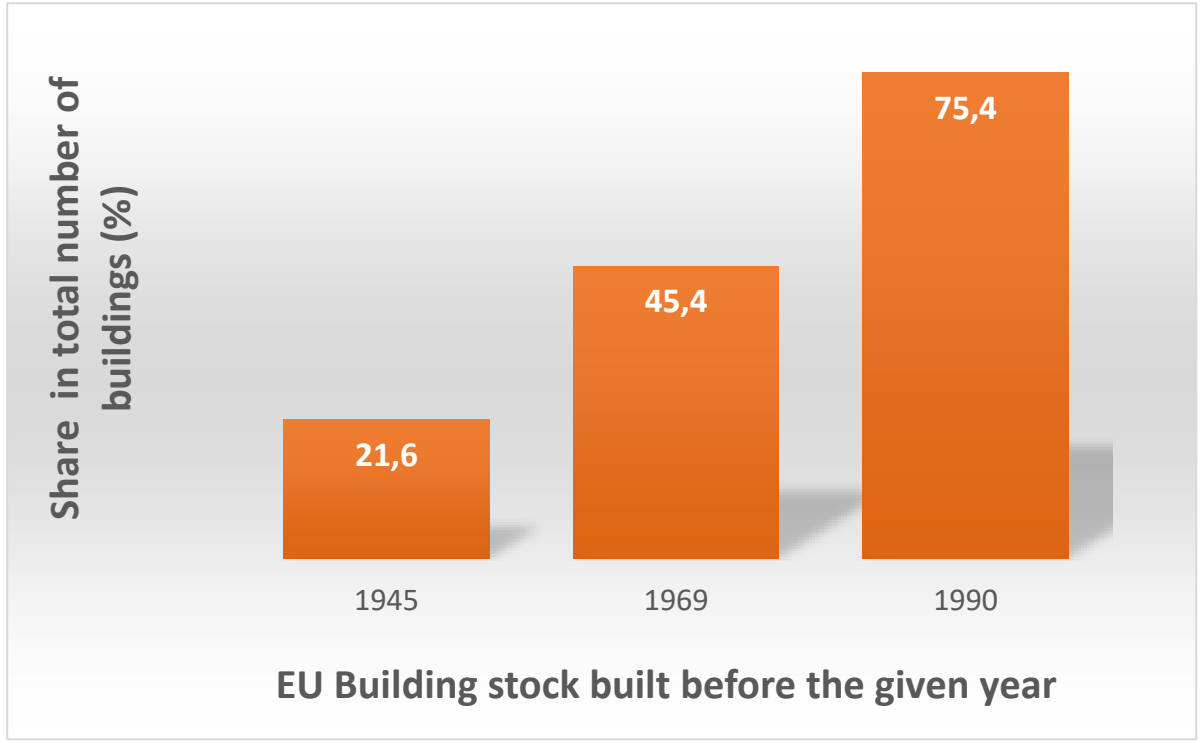


A. Firth, et al, Applied Energy, Volume 235, 2019, Pages 1314-1334.

SLOVENIA

Up-to-date, no HQ systematic evaluation has been conducted by the responsible Slovenian authorities

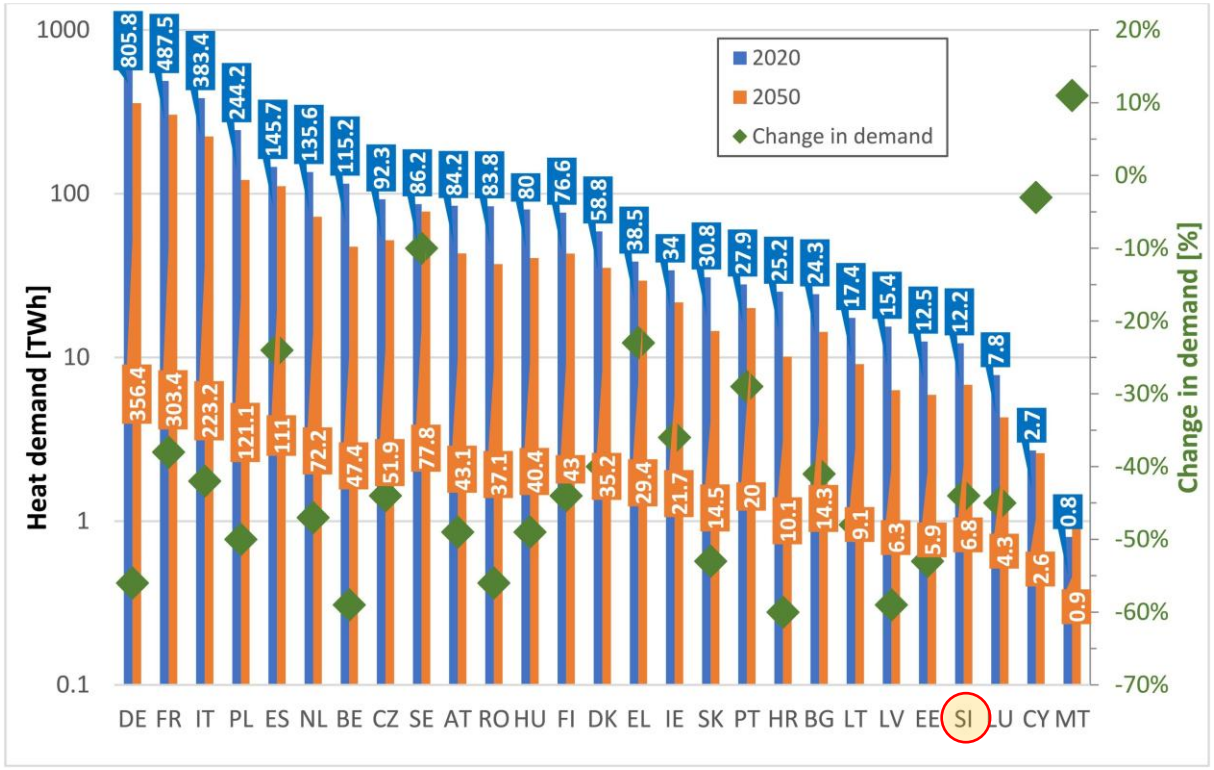
Building stock
FACTS - EUROPE



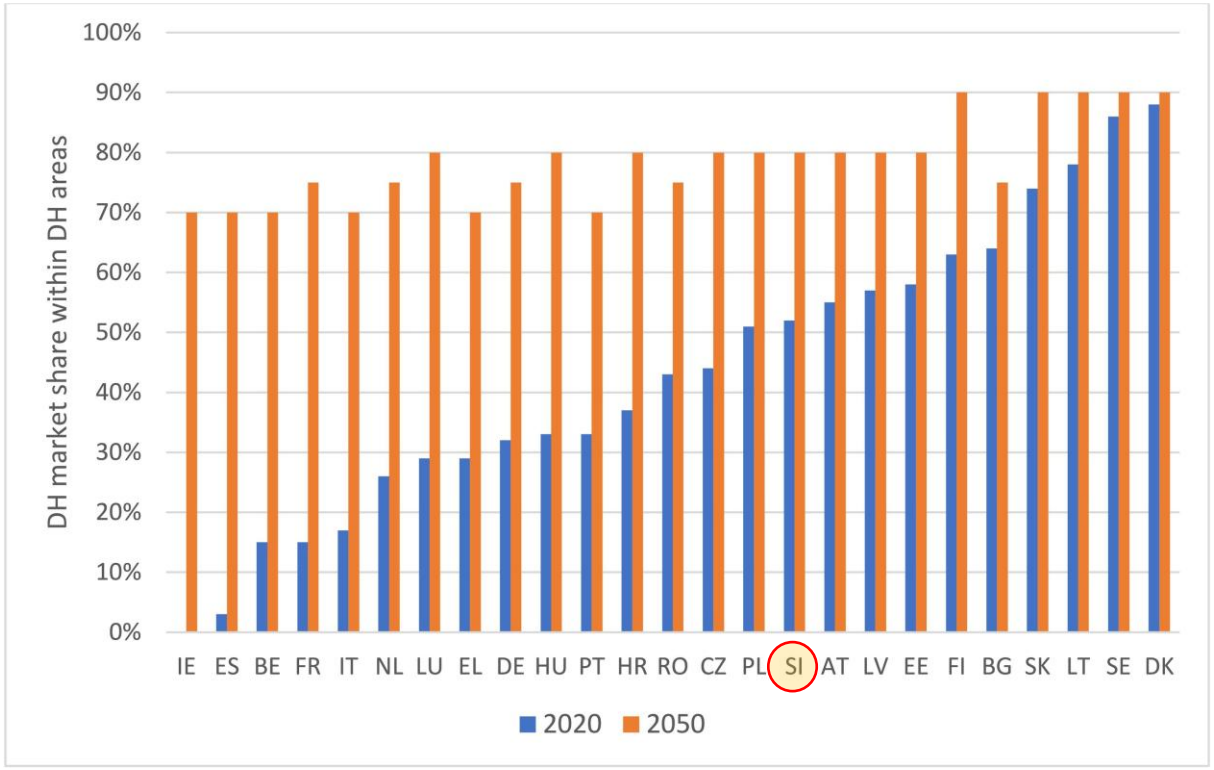
https://build-up.ec.europa.eu/

Image by Mojca-Peter from Pixabay

District heating and cooling FUTURE - EUROPE



Useful heat demand levels (TWh) in 2020 and 2050, and the relative changes in residential and tertiary sectors (secondary Y-axis) based on the best-case scenario.



DH market shares within DH areas used as inputs for the base year (2020) and target year (2050)

Fallahnejad, M. "District heating potential in the EU-27: Evaluating the impacts of heat demand reduction and market share growth." Applied Energy, vol. 353, 2024

HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED

DEMAND AND DISTRIBUTION
REDEFINE USERS/PROSUMERS
BUILDING ENVELOPES
BUILDING INTERNAL ENERGY SYSTEM
DHC SUBSTATIONS
DHC PIPELINES
MESHED DECENTRALIZED NETWORKS

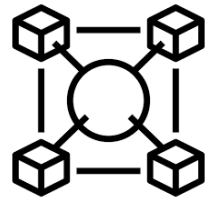
EXCESS/SURPLUS HEAT FIRST
HEAT FROM POWER PLANTS
INDUSTRIAL HEAT
DATABANKS
WASTE AIR
DIFFERENT COOLING/ AC SYSTEMS
SEWAGE, WATER TREATMENT PLANT

THERMAL STORAGE ALWAYS
BUILDING INTEGRATED
DIURNAL, SEASONAL

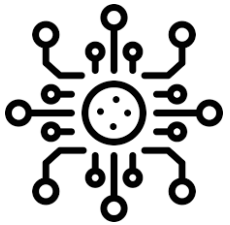
RES HEAT SECOND
SOLAR PVT, T
GROUND SOURCE HP
WATER SOURCE HP
SHALLOW GEOTHERMAL HP
DEEP GEOTHERMAL
BIOFUELS ONLY COGENERATION

OTHER HEAT LAST
LARGE SCALE ELECTRIC BOILERS
GAS BACKUP BOILERS

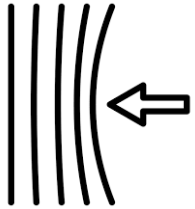
ENERGY



INTEROPERABILITY



BIG DATA, AI, AUTOMATION, SMART METERS, ADVANCED SIMULATIONS AND PREDICTIVE MODELS, GIS, DIGITAL TWINS AND DIGITAL TRIPLETS



RESILIENCE

HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED

URBAN ENVIRONMENT

ENVIRONMENT WITHOUT DHC → Basis for 4th gen. first, then other activities (tech, ownerships, refurbishment)

ENVIRONMENT WITH OLD DHC → Extension of old system technology must by prohibited

GREENFIELD → NEVER do the urban development plan for old gens of DHC

RURAL ENVIRONMENT

ENVIRONMENT WITHOUT DHC → **New system design and integration approaches are required**
If yes, then basis for 4th generation DHC first, then other activities (tech, ownerships, refurbishment)
If no, then basis for: energy efficiency and environmental pollution first, integration of RES, coupling with electricity or **defossilize**d gas sector

ENVIRONMENT WITH OLD DHC → Extension of old system technology must by prohibited.
Feasibility of DHC must be re-evaluated.

GREENFIELD → **New system design and integration approaches are required**
If yes, then basis for 4th generation DHC first, then other activities (tech, ownerships, urban development plan)
If no, then basis for: energy efficiency and environmental pollution first, integration of RES, coupling with electricity or **defossilized** gas sector

ENERGY

HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED

Cost-effective infrastructure and capital structure

How to finance upfront grid upgrades (e.g., via public–private partnerships, green bonds, or regulated tariffs) while keeping connection and heat prices acceptable for customers.

Long-term price stability and risk sharing

Designing contracts and tariffs that share price-risk between utilities, energy-producers, and consumers (e.g., long-term heat-purchase agreements, indexed tariffs, or fixed-price blocks).

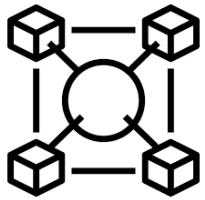
Revenue diversification and flexibility markets

New DHC gens can diversify revenue by monetising ancillary grid services (via demand-side flexibility and thermal storage) and integrated multi-energy services, shifting the business model from pure heat-volume sales to one that captures value from flexibility, peak-shaving, and sector-coupling.

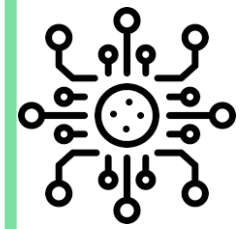
Supportive regulatory and institutional framework

Supportive regulatory and institutional framework—including carbon pricing, renewable-heat support, connection obligations, and clear rules for prosumers and bidirectional flows and shared infrastructure, high taxes for wasted heat to the environment

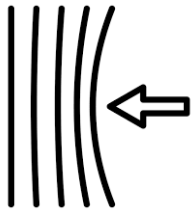
ECONOMY



INTEROPERABILITY



BIG DATA, AI, AUTOMATION, SMART METERS, ADVANCED SIMULATIONS AND PREDICTIVE MODELS, GIS, DIGITAL TWINS AND DIGITAL TRIPLETS



RESILIENCE

HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED

Climate Protection

Eliminate greenhouse gas emissions by replacing fossil fuels with carbon-neutral sources, preventing global warming contributions from heating and cooling sectors.

Surplus Heat Valorization

Prevent thermal pollution of rivers, air, and soils by capturing and reusing industrial/urban surplus heat.

Resource Conservation

Reduce primary energy extraction and habitat disruption by prioritizing ambient and low-grade heat sources over intensive fuel production..

Circular Economy

Minimize environmental degradation through closed-loop heat cycles that preserve water quality, cut air emissions, and protect biodiversity from overexploitation. biofuels must derive from byproducts and waste streams only—not from cutting trees or dedicating crops to fuel production—to avoid deforestation, soil depletion, and competition with food security

ENVIRONMENT

HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED

Energy Affordability

Ensure stable, lower heating costs for households for reducing energy poverty in vulnerable communities..

Public Health Protection

Eliminate emissions, improving local air quality and cutting respiratory illnesses

Economic stimulation for benefit of local, regional, and national communities in Slovenia

Do not import. Promote domestic innovation and businesses in manufacturing energy devices and systems, providing services, and utilizing heat- or cold-intensive products (e.g., agriculture, food processing, chemicals, pharmaceuticals, logistics). We possess all the required knowledge and knowhow in Slovenia.

Community Resilience

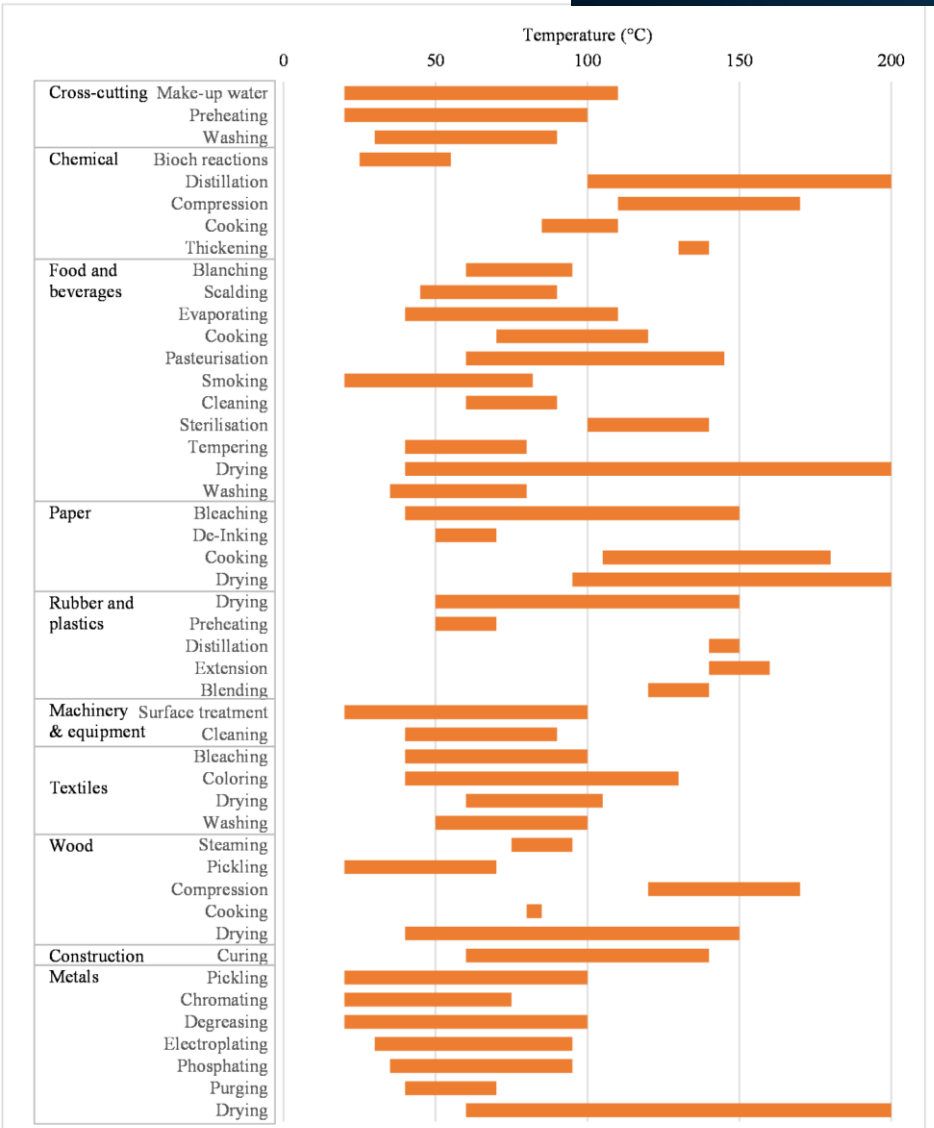
Build reliable, decentralized heat/cold supplies that withstand energy crises, extreme weather, and supply disruptions for greater social security

SOCIETY

HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED

Heating and cooling serve purposes beyond just buildings

Never design a power plant or DHC system without accounting for these factors—not solely with respect to local community demands and priorities



A Delcea and I Bitir-Istrate 2021 IOP Conf. Ser.: Earth Environ. Sci. 664 012031

Coupling of energy sectors
Example for Slovenia

Principles

Energy efficiency first = provide basis for low energy consumption

Redefine users/prosumers

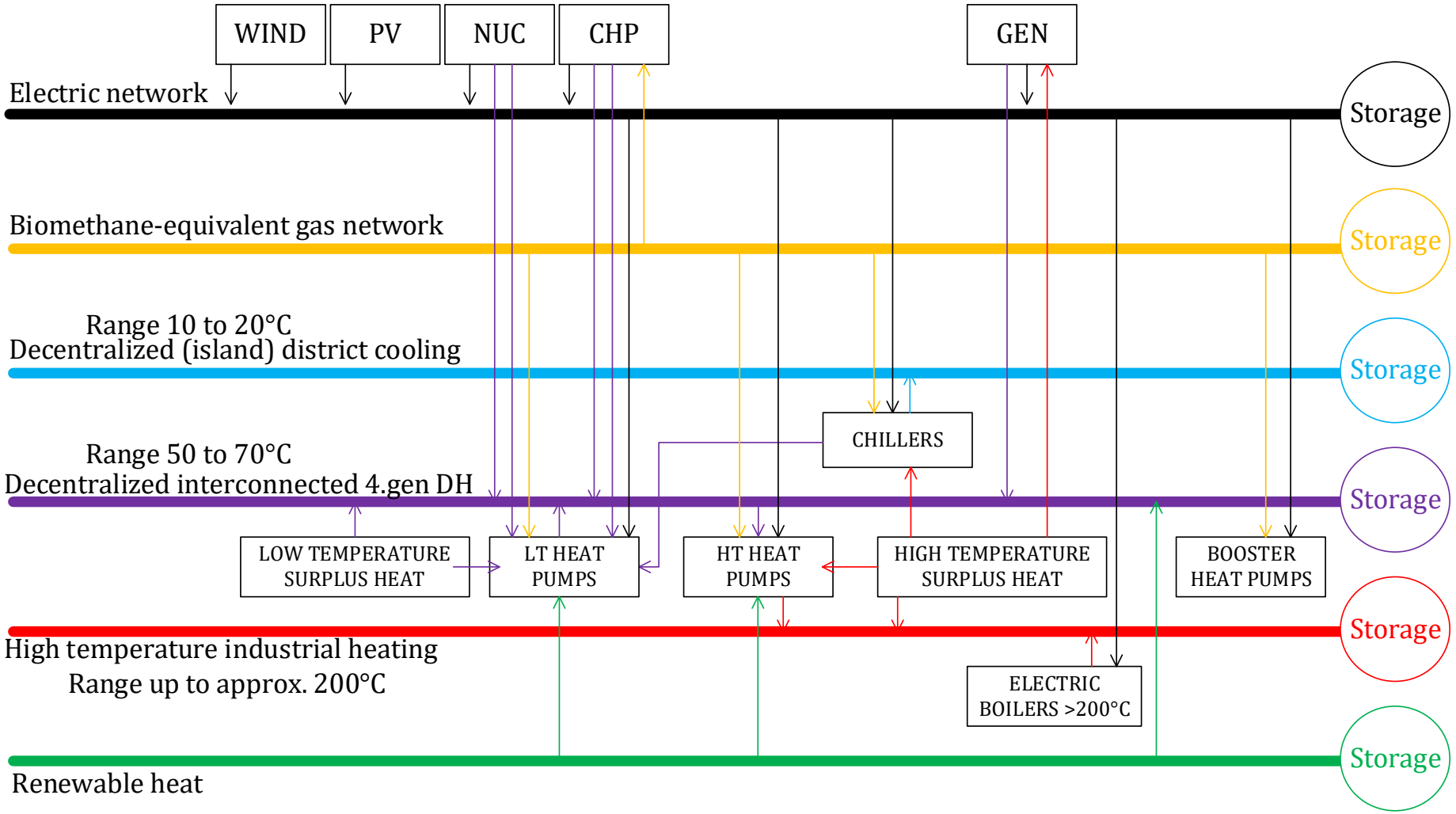
Energy efficiency first = do not use boilers for any heating below 200°C

Energy efficiency first = do not use any type of boilers for district heating

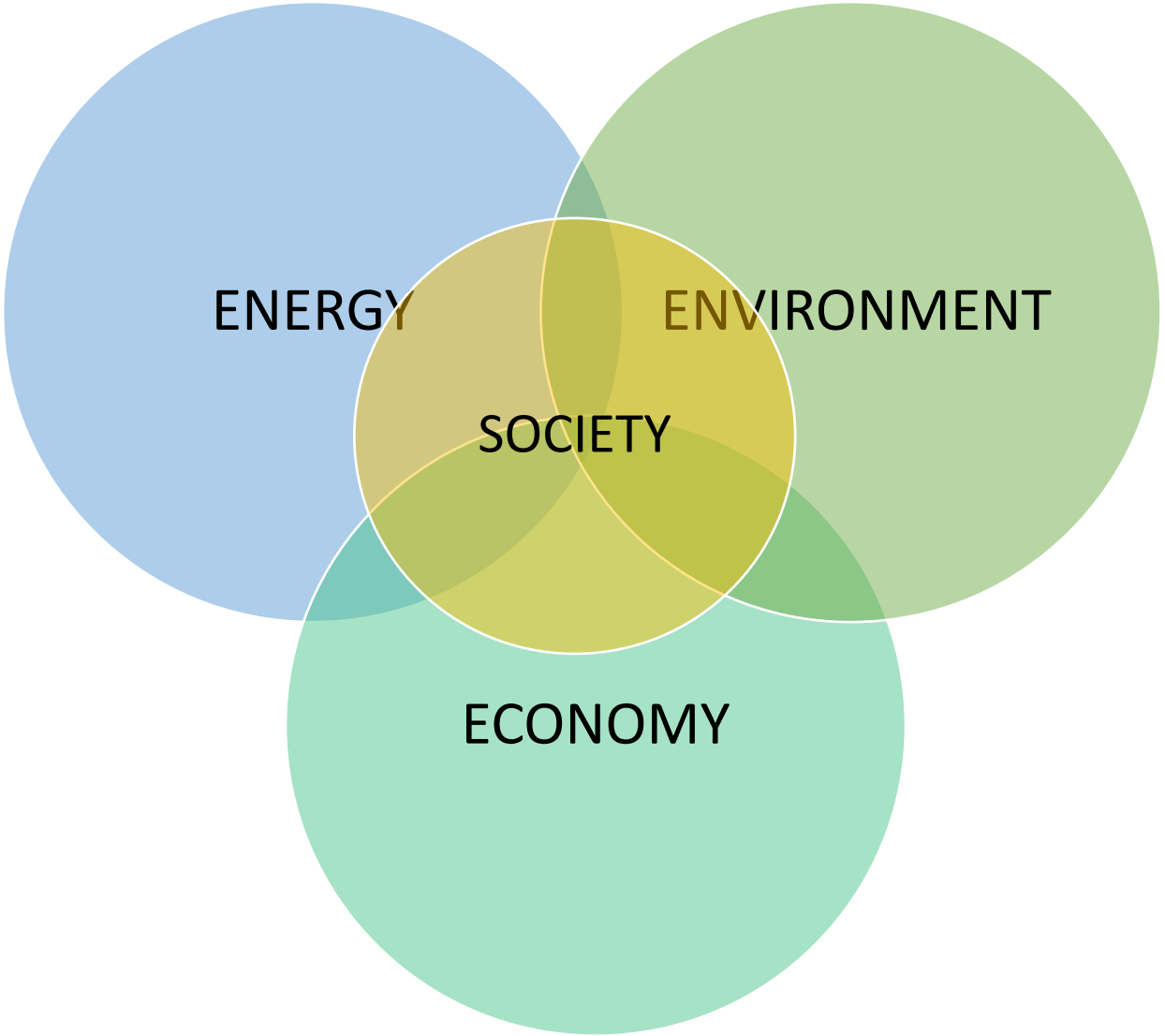
Surplus heat first
Renewable heat second

Diurnal and seasonal storage is a must

Natural (pre)cooling first



HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED



SHOULD REPRESENT STATE'S STRATEGIC INVESTMENT and STATE'S SYSTEM INTEGRATION

REQUIRE HOLISTIC APPROACH OF PLANNING

PROVIDE SOLUTIONS FOR ALL OTHER HEATING AND COOLING systems, not only DHC

MUST DEMONSTRATE MULTIPLICATIVE POSITIVE IMPACT in ALL PILLARS

HOW FUTURE DHC SYSTEMS SHOULD BE DESIGNED OR MODERNIZED

We do not need to import knowledge and expertise—we already have this.

What **we urgently need is government support for a strategic and operational program**, led by an interdisciplinary, apolitical team of high-level, globally recognized Slovenian experts and their affiliated groups from industry and different well-recognized public research institutions. The programme would comprehensively address technology, finance, environment, society, implementation, and monitoring.