Towards more effective residential retrofit interventions

Exploring an alternative monitoring approach to drive the effectiveness of residential energy efficiency retrofit interventions

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P5 | M.Sc. Graduation Thesis | BOLD Cities
University of Technology Delft

TU Delft

I am going to show…

it is important to **improve** our **understanding of the effects** of energy efficiency interventions

we could improve our understanding by **thinking in systems** and **using innovative technologies**

an **alternative thinking approach** could look like when applied to a specific showcase

BACKGROUND

(Why?)

Context

- Humanity is facing large scale **environmental challenges** emerging from anthropogenic **climate change**
- GHG emissions are considered to be the main driver of change
- EU Members States agreed on **significant reductions of GHG emissions** (based on Paris Climate Agreement)

Context

- Success of efforts depends to large parts on the **building sector** (responsible for about **40% of the final energy consumption**)
- Existing **residential housing stock** offers largest potential for reductions (**75%** of EU stock classified as **inefficient**)

European Residential Energy Transition

Objective	Cut GHG emissions of building sector by 90% until 2050	
Strategy	Reduction of final energy consumption and improved energy efficiency	Increased share of renewable energy sources in overall consumption
Interventions	**Policy** (e.g. EU and MS legislation and regulations)	
	Programme (e.g. subsidies, loans)	
	Project (e.g. building envelope, building services)	

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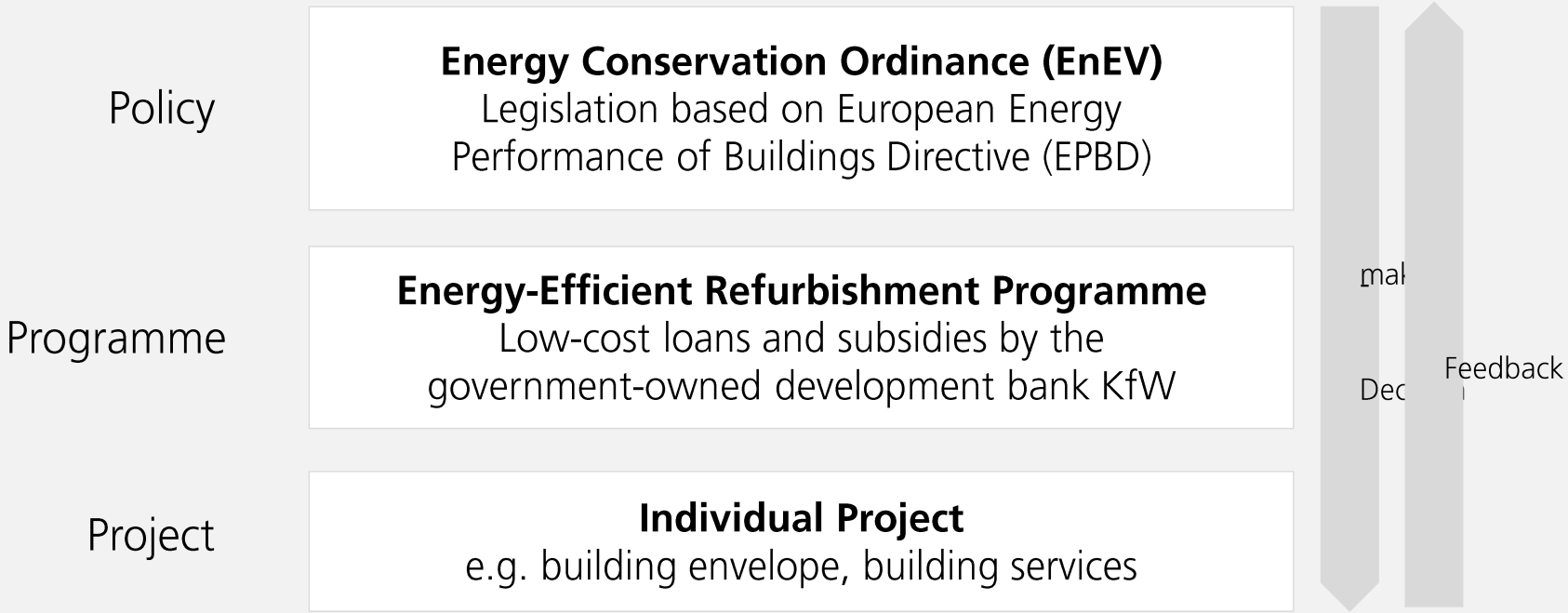
MS Energy Efficiency Interventions (Germany)



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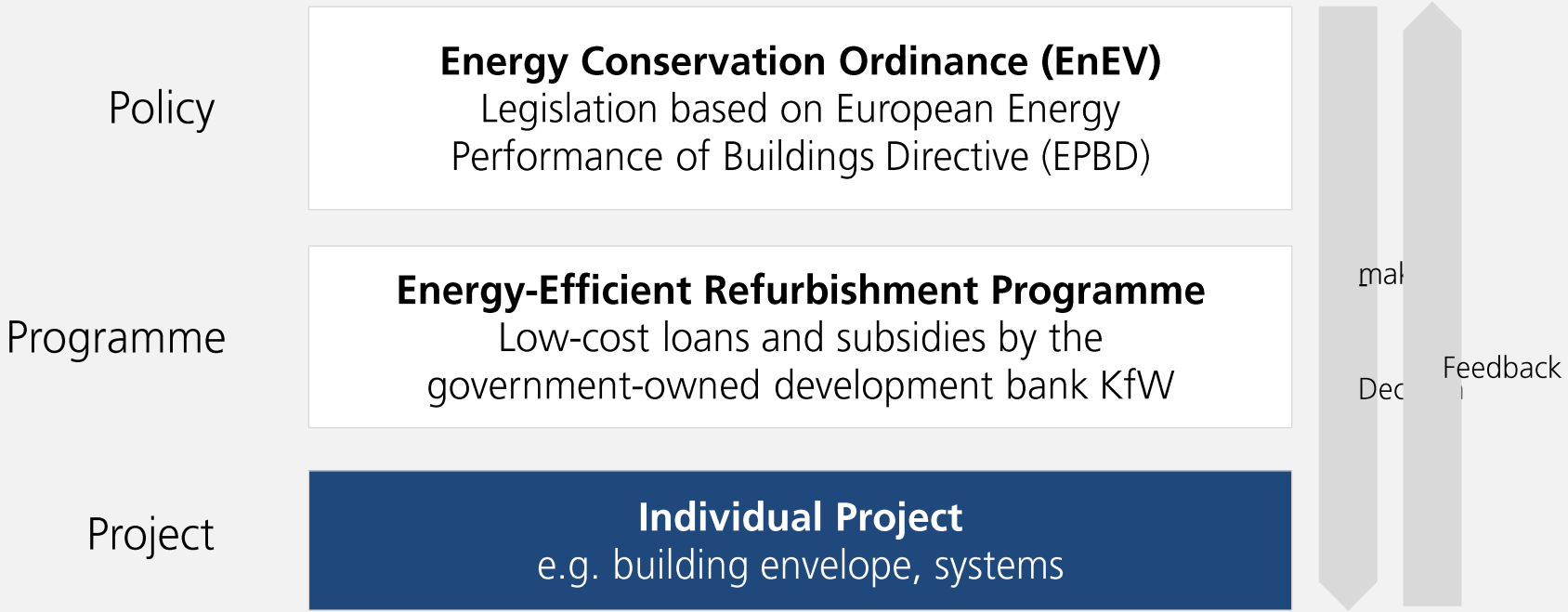


Individual Project Level Interventions

Physical
(building envelope)

- Insulating envelope
- Upgrading transparent components
- Adding sun protection
- Improving the use of daylight and natural ventilation

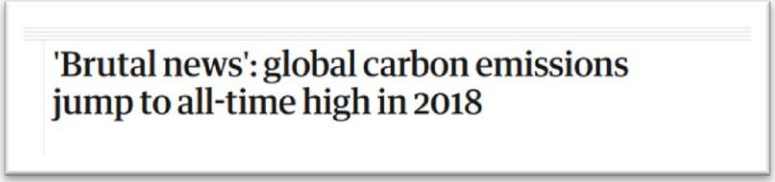
Service
(building services)

- Replacing inefficient heating, lighting and cooling appliances
- Installing energy management systems

UN Environment, 07.11.18

The Guardian, 27.11.18

New York Times, 07.12.18



The Guardian, 05.12.18

UN News, 27.11.18

Problem

Low take-up rate

Performance gap

Poor understanding of the underlying drivers and dynamics

Inability of the conventional monitoring approach to capture the bigger picture

Risk of ineffective resource allocations and missed opportunities to align goals

Goal

Develop an **alternative monitoring approach** for energy efficiency interventions to **improve the understanding** of their effects and dynamics

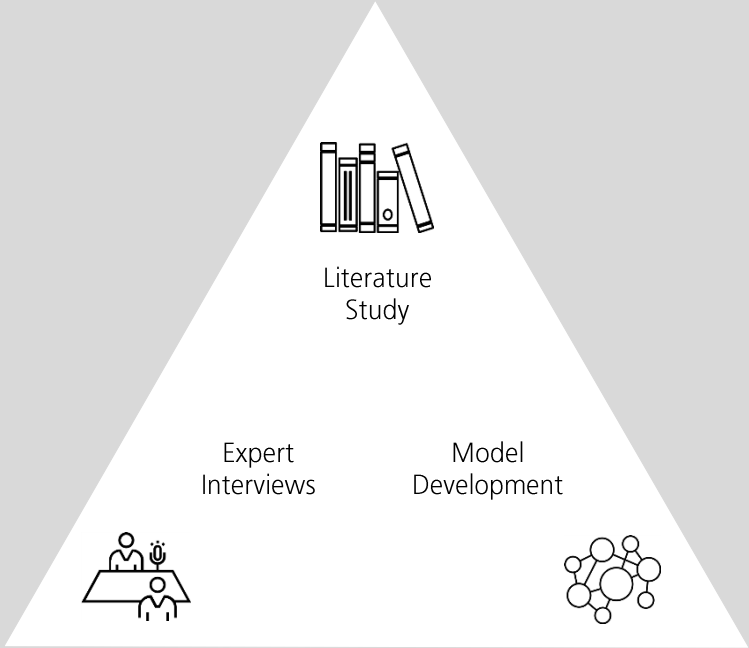
Thereby help to provide the evidence for more effective decision-making

Perspective: Policy-maker (achieve overall greatest benefit for society)

How can we monitor the performance of residential energy efficiency retrofit interventions more accurately to provide better evidence for decision-making?

Research Type, Design & Methods

- **Exploratory research:** Enable flexibility during the process and emphasise on the discovery if new ideas and insights
- **Multi-method design:** Enable exploration of the topic from different angles and increase reliability and robustness (data triangulation)



Research Process

Research Question(s)

Q1: DESIGN

Q2: DATA

How can we monitor the performance of residential energy efficiency retrofit interventions more accurately to provide better evidence for decision-making?

Background (WHY?)

Literature study

Anthropogenic climate change

Residential energy transition

Energy efficiency

Systems thinking

Exploration (HOW?)

Expert Interviews

Centraal Bureau voor de Statistiek

BPIE

Maastricht University

iea International Energy Agency

Data innovation

Integration (WHAT?)

Model development

Conceptual model showcasing the alternative approach (exemplary focus on the intersections of energy efficiency, energy affordability and health and wellbeing)

EXPLORATION

(How?)

Research Approach

Conventional approach

Isolated and small

- Vague
- Simplified
- Fragmented
- Slow

Limitations to overcome

DESIGN: Isolated and narrow perspective on the physical intervention aspects

DATA: Availability gap, often time-delayed and inaccurate

Alternative approach

Connected and big

- Precise
- Real
- Holistic
- Timely

DESIGN

From isolated to connected

From Isolated to Connected

- Traditionally the effect o energy efficiency interventions is measured and assessed in terms of **units of reduced energy demand and GHG emissions**
- Research indicates that there is a **wide range of other factors** influenced that influence the actual net effect

	Intended effects	e.g. Units of reduced GHG emissions
+	Other positive effects	e.g. Health cost reductions due to healthier indoor environments
-	Other negative effects	e.g. Units of increased GHG emissions due to changing demand
=	Net effect	


Energy system security
Energy security
Energy delivery
Energy prices
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GHG emissions
Local air pollution
Resource management
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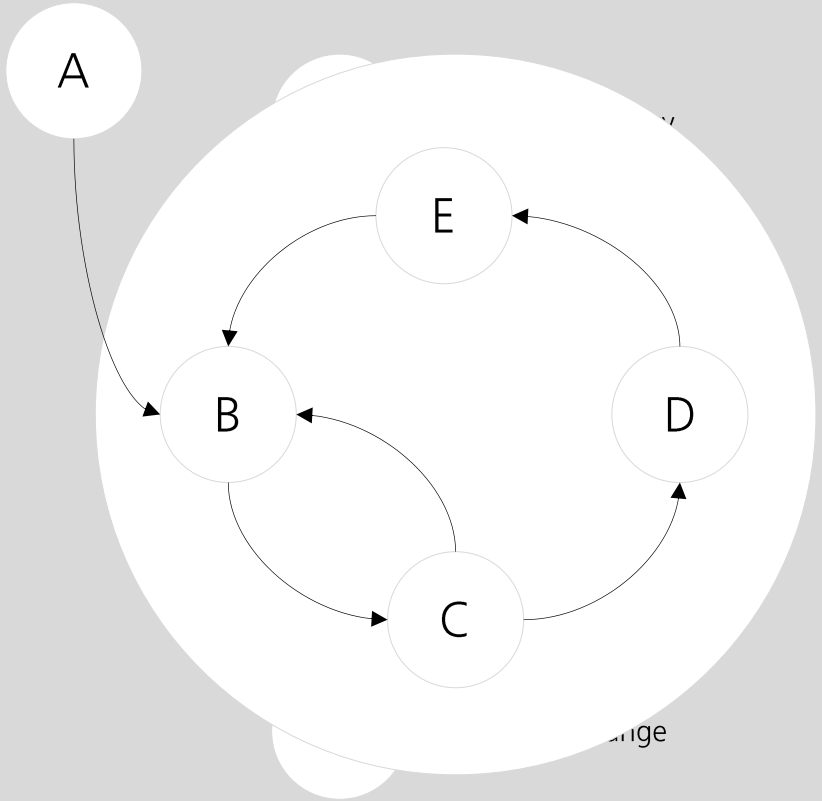
From Linear to Systems Thinking

- Conventional **linear thinking** approach **no longer adequate**
- **Systems thinking** is based on the idea that a system is more the sum of its parts
- Instead of looking at single factors (e.g. GHG emissions) in isolation the aim is to **understand relationships and dependencies** with other factors



DATA

From small to big

From Small to Big

SMALL	LARGE	BIG DATA REVOLUTION
• Local surveys • Qualitative interviews • Focus group • Mobile phone generated data (user)	• Census data • Surveys • Administrative reports • Monitoring data • Biometric and anthropometric data	An explosion in the **volume** of data, the **speed** with which data is produced, the **number of producers** of data, […] **new technologies** such as mobile phones […] (UN, 2014) 

DATA CONTINUUM

From Small to Big

SMALL	LARGE	BIG
• Local surveys • Qualitative interviews • Focus group • Mobile phone generated data (user)	• Census data • Surveys • Administrative reports • Monitoring data • Biometric and anthropometric data	• Electronic transactions • Social media • Automatic sensors • Satellite images • Text • Audio • Video • Phone records

DATA CONTINUUM

Exemplary Data Innovation Projects

- Common practise in the private sector (e.g. targeted marketing etc.)
- Remains **under-utilized in the public sector** and examples are scarce and in rather early stages

UN Global Pulse: Integration of Data innovation in global development interventions

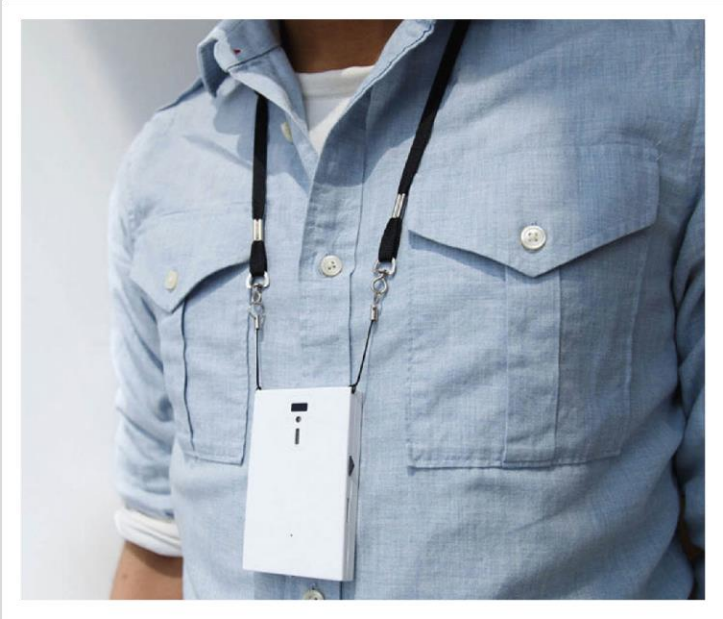
MIT Media Lab (Human Dynamics): Using data innovation to capture human behaviour

CBS Center for Big Data Statistics: Using data innovation to provide more nuanced information about policy interventions

Basic Data Collection Badge

- Collection of large data sets and real-time feedback on the **individual communication behaviours** of people
- Based on location sensors, accelerometers, proximity sensors and a microphone

Possible application: Technological basis to collect behavioural and environmental data (e.g. through additional sensors)



Universal Sensing Platform

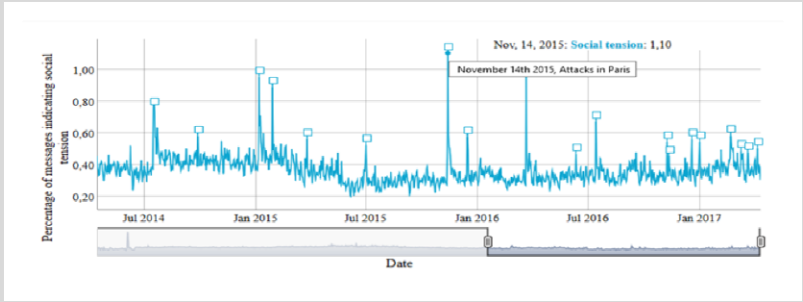
- Open-source sensing framework using **mobile phones** for the continuous collection of data on **social and behavioral activity**
- Location data, credit card data, social media and daily polling of moods, stresses, sleep etc.)

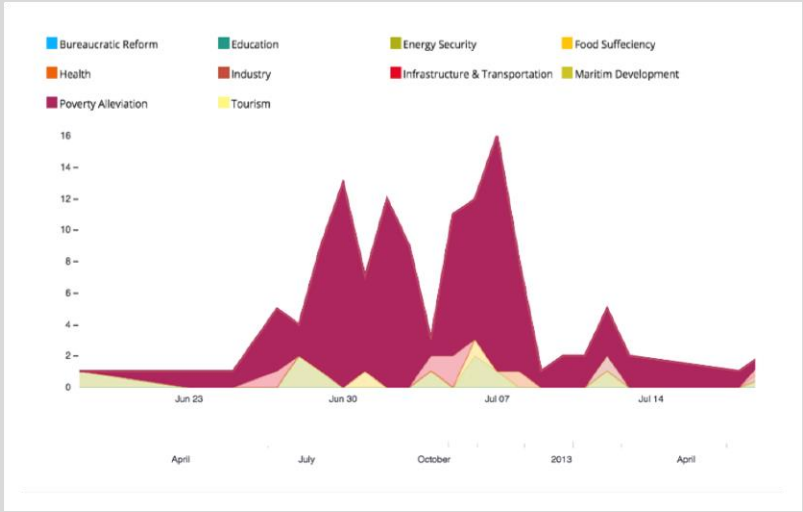
Possible application: Technological basis to collect e.g. perceptions data (daily polls) and behavioural data

Public Policy Opinion & Sentiment

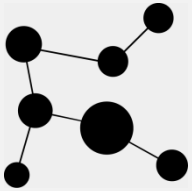
- Tools to measure the **public opinion** and thereby providing real-time feedback about policy interventions (throughout the policy cycle)
- Based on **social media data** (Twitter, Facebook etc.)

Possible application: Technological basis to collect citizen opinions data on policy and programme interventions





Major Challenges of Data Innovation

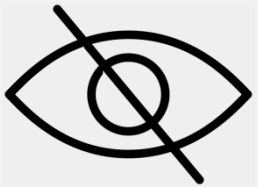


Causality and Theory

- Correlation does not imply causality which requires alternative to identify causal relationships

Privacy

- Ensure personal privacy and freedom while enabling the use of data for the benefit of the whole society



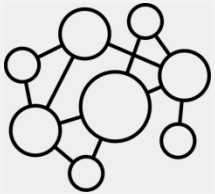
Accessibility

- Most data today remains in silos of private companies which requires new ways of sharing

INTEGRATION

(What?)

Concept of Exemplary Showcase

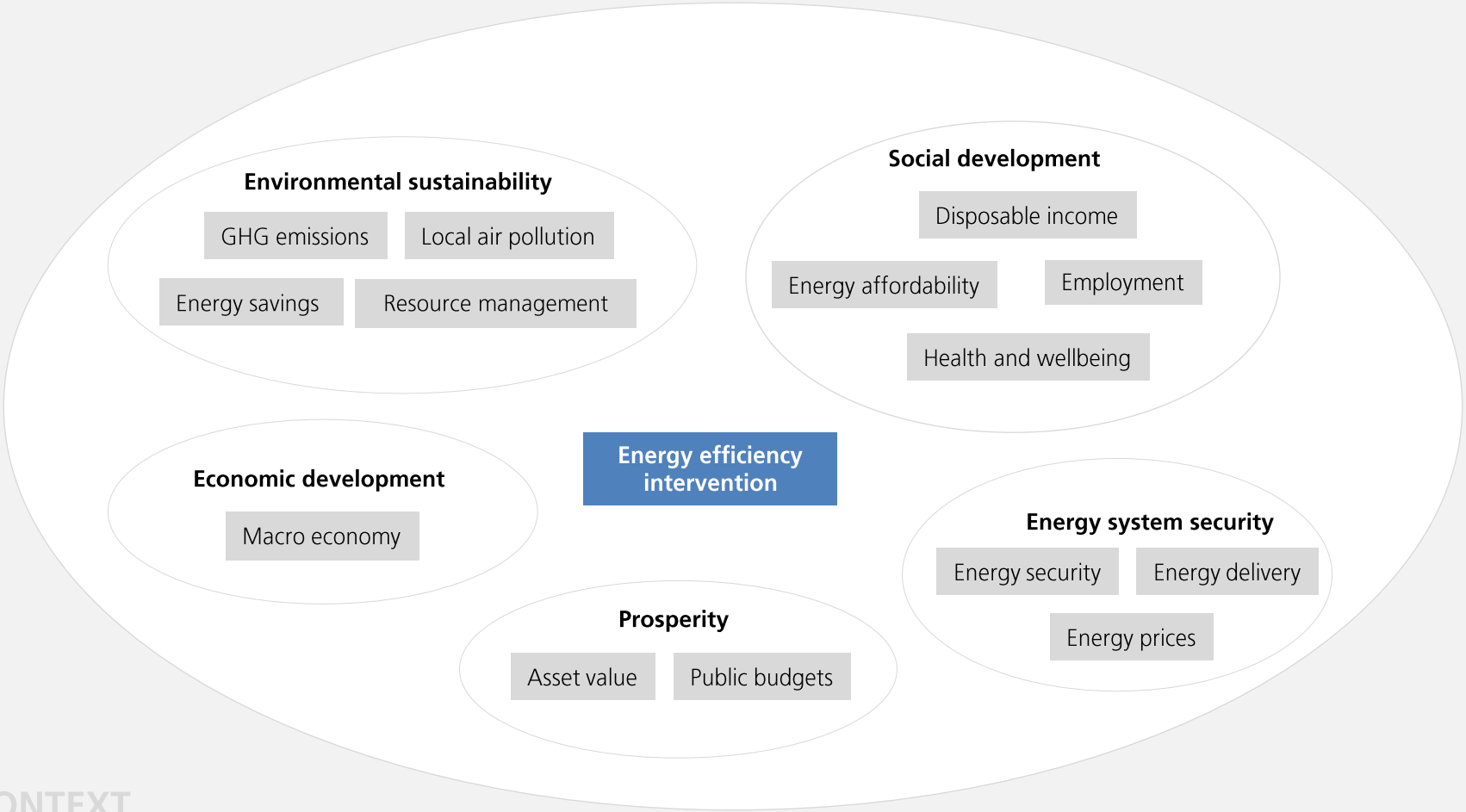


Connected systems thinking approach

Mixed methods (conventional + innovative data sources)

Focus on intersections of health and wellbeing + energy affordability

Aim: Illustrate alternative approach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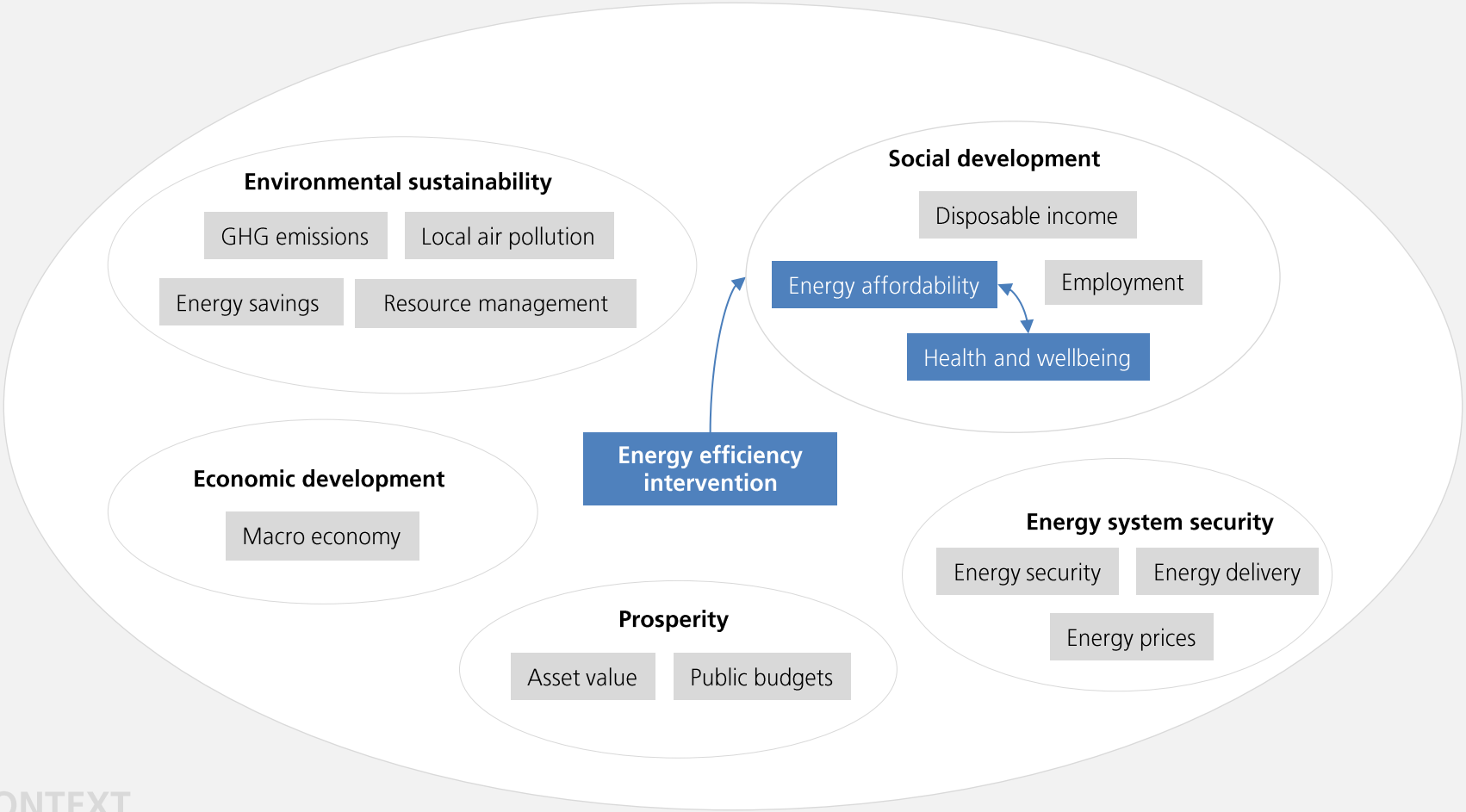
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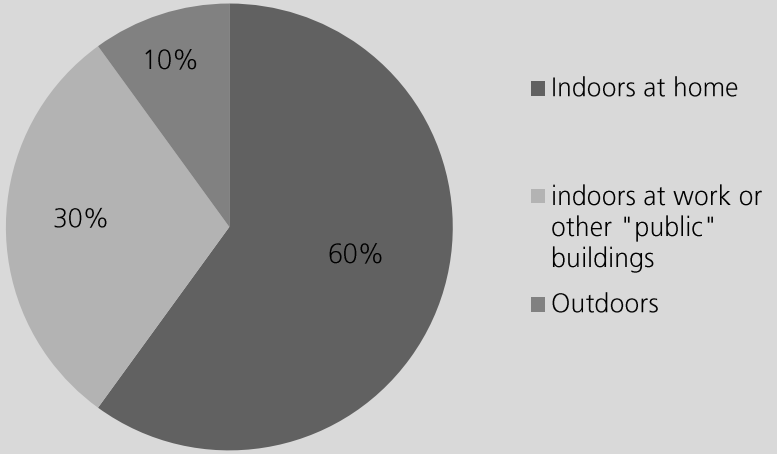
Concept A: Health and Wellbeing

- Improved energy efficiency can support good health by **creating healthy indoor environments** (e.g. air quality, temperature, humidity level)
- **Mental health:** Anxiety, Stress and depression
- **Physical health:** Respiratory or cardiovascular conditions, rheumatism, allergies, winter mortality, risk of dehydration



Concept B: Energy Affordability

- Caused by a combination of low income, poor housing quality and high energy costs
- Associated with sub-optimal physical and mental health
- About 50 million households in the EU live in energy poverty (Major synergies with other policy areas possible)

Indicators and Data Sources

	Indicator	Source	Accessibility (Stakeholder)
Energy affordability	Energy demand and costs	Smart meter	Private (provider, household)
	Household income	Administrative data (tax statement)	Public
Health and wellbeing	Indoor environmental parameters	Non-wearable indoor ambient sensors	Private (household)
	Morbidity and mortality rate	Administrative data (register)	Private (insurance)
	Health parameters	Wearable physiological sensors	Private (household)
	Psychosocial wellbeing	Mobile phone digital survey	Private (household)
Energy efficiency	Intervention type and costs	Administrative data (report)	Public (programme coordinator)

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Data Collection (non-wearable)

Smart meter

Detailed data on consumption patterns (electricity, gas)

Environmental Sensors

Detailed data collection on indoor air quality, temperatures and humidity

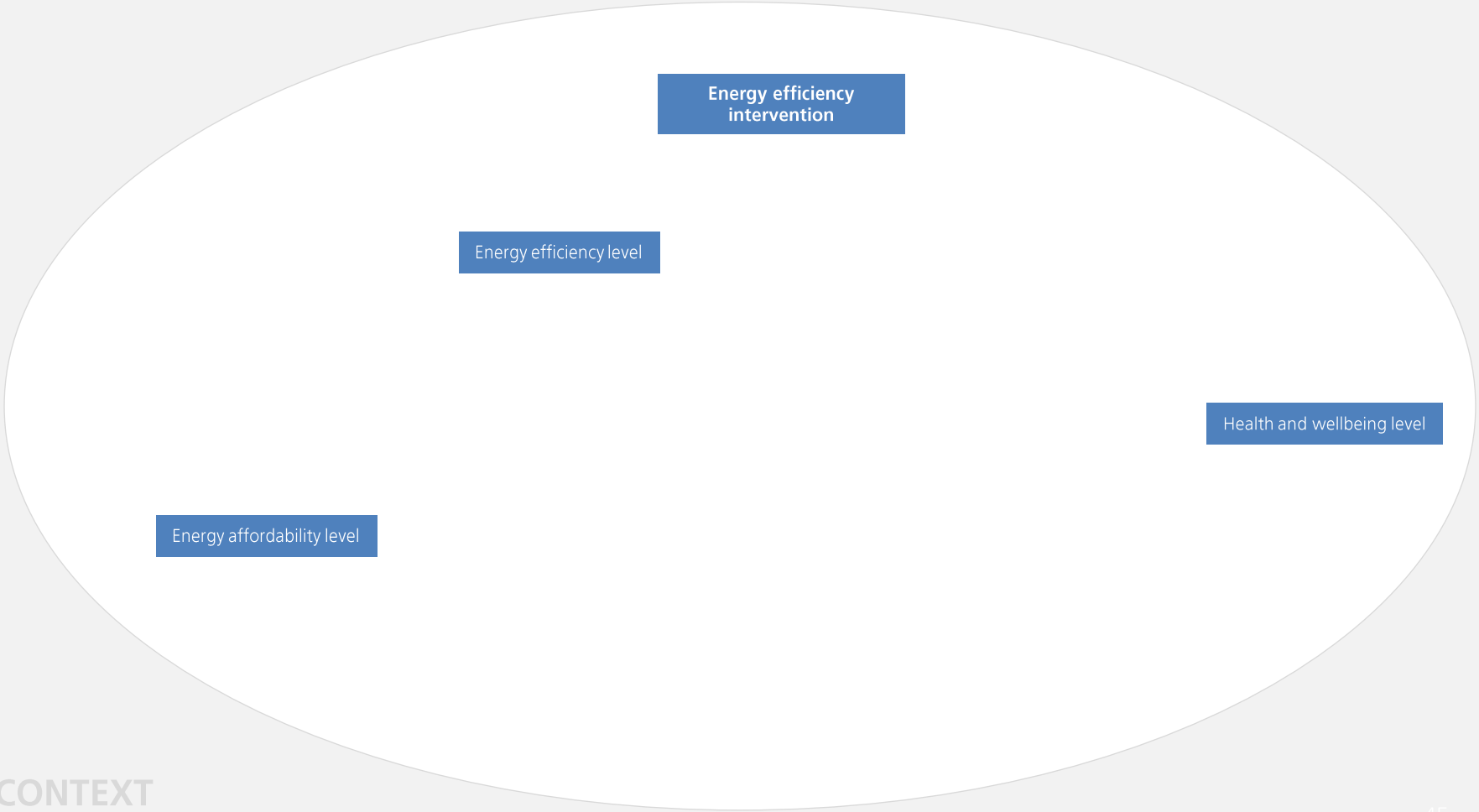
Data Collection (wearable)

Fitness tracker

Physiological parameters (body temperature and heartbeat, sleep, activity)

Mobile phone

Digital survey personal perception data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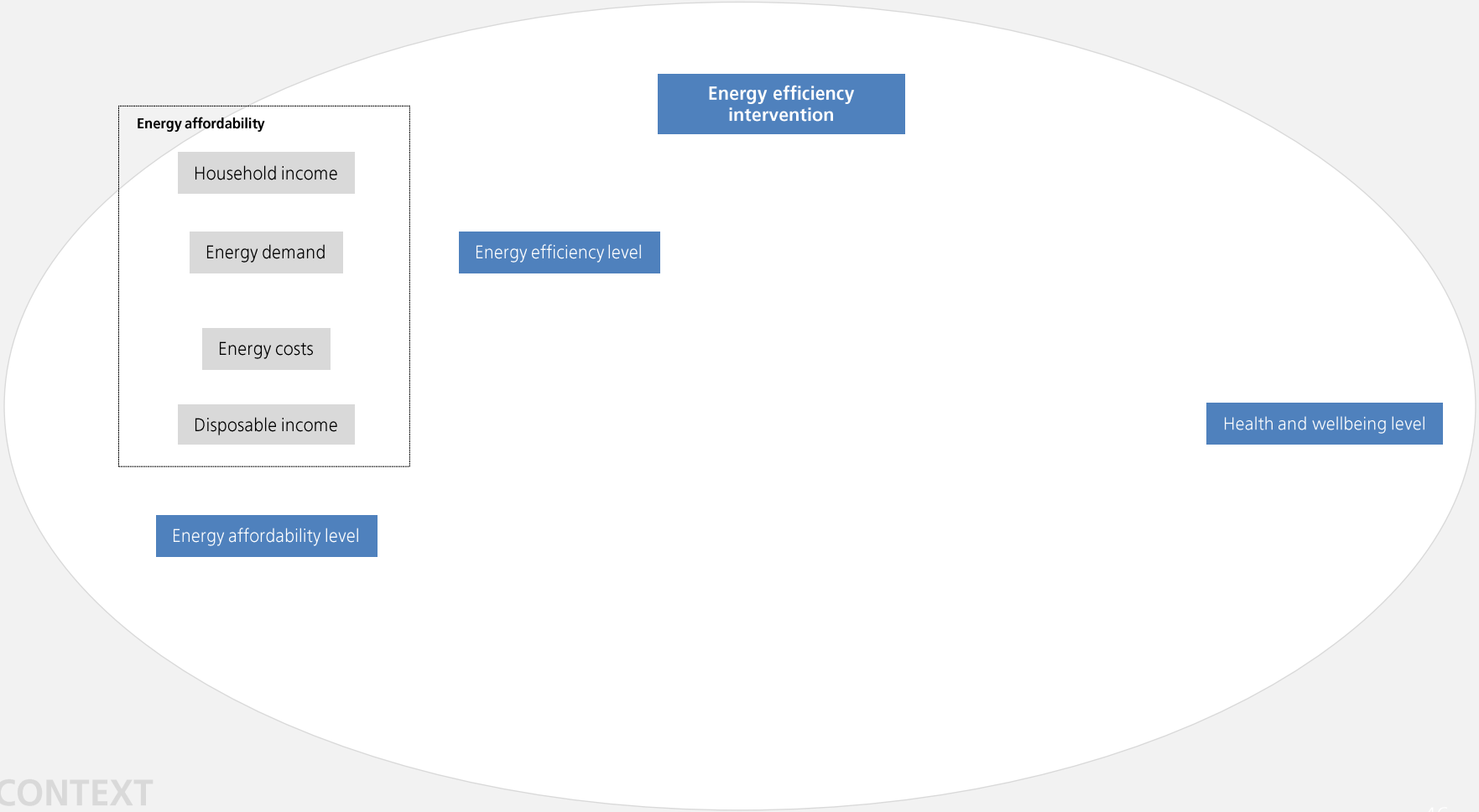
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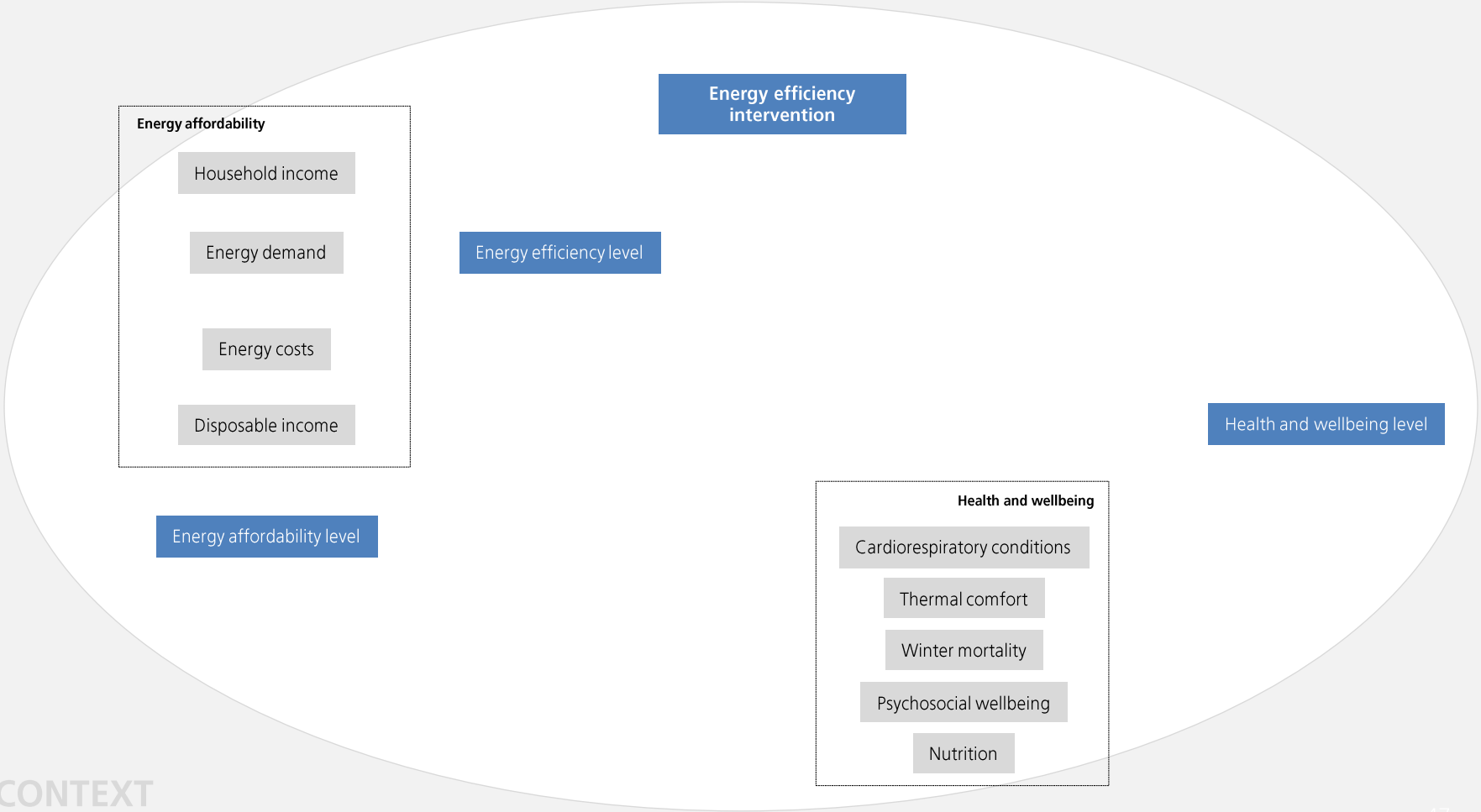
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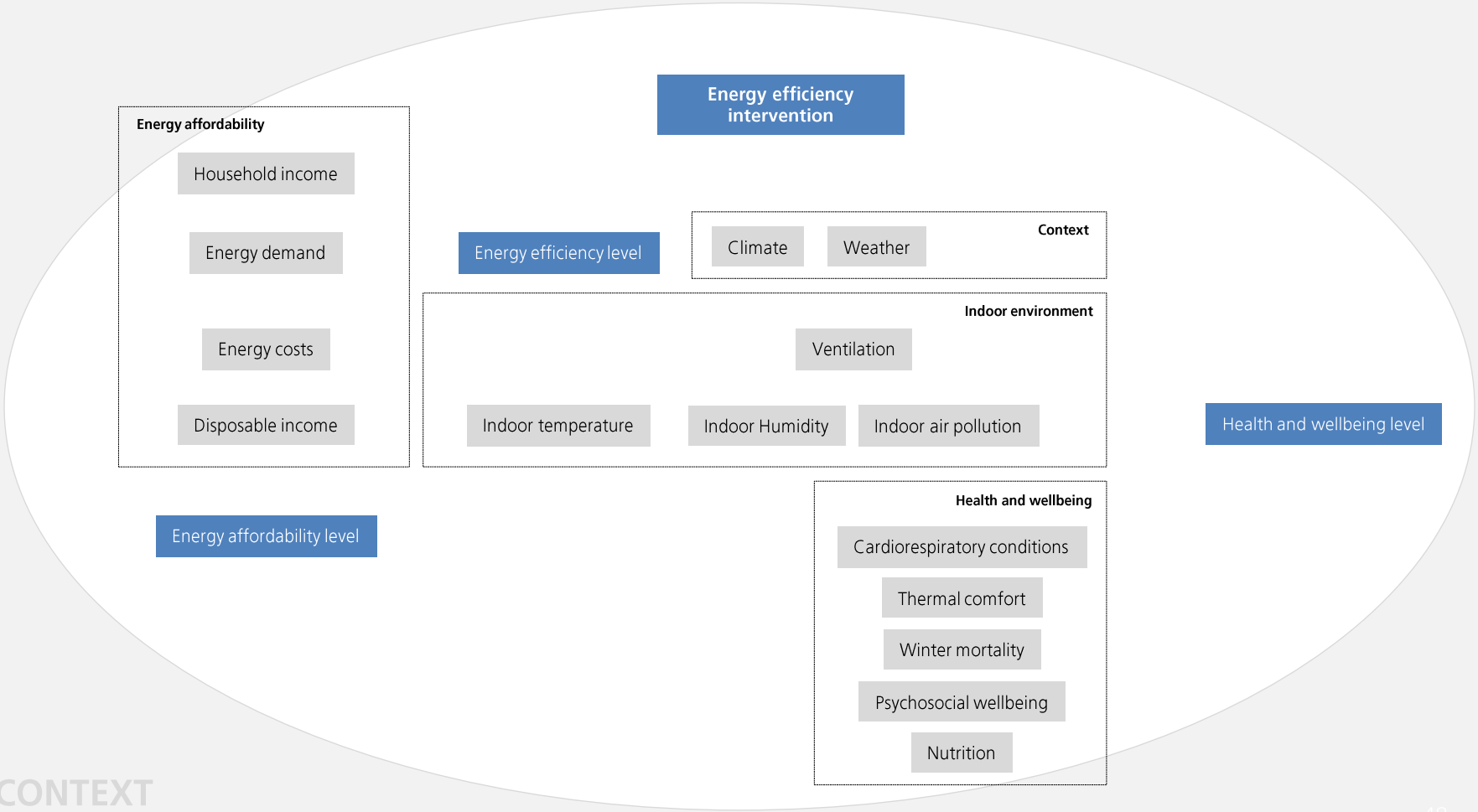
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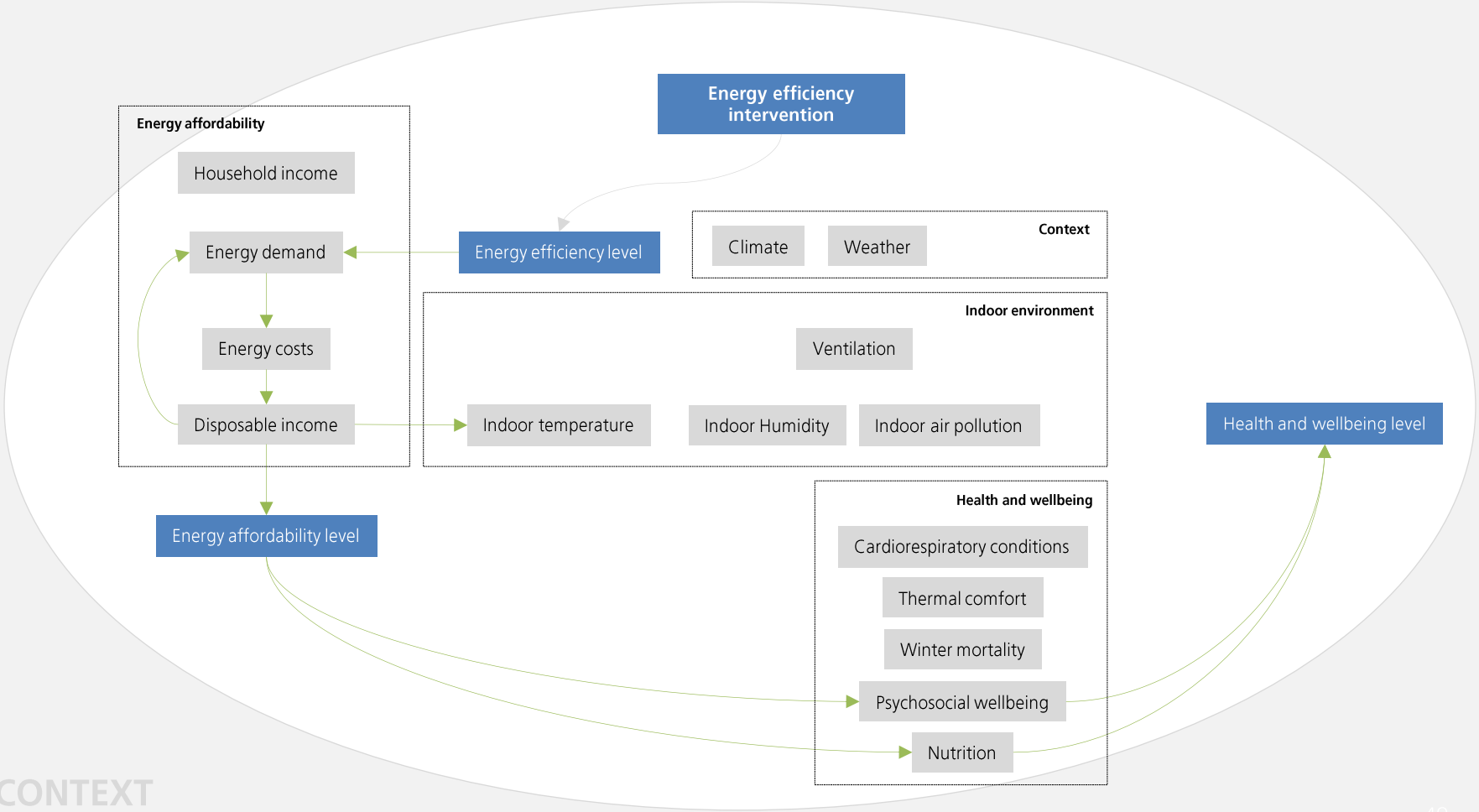
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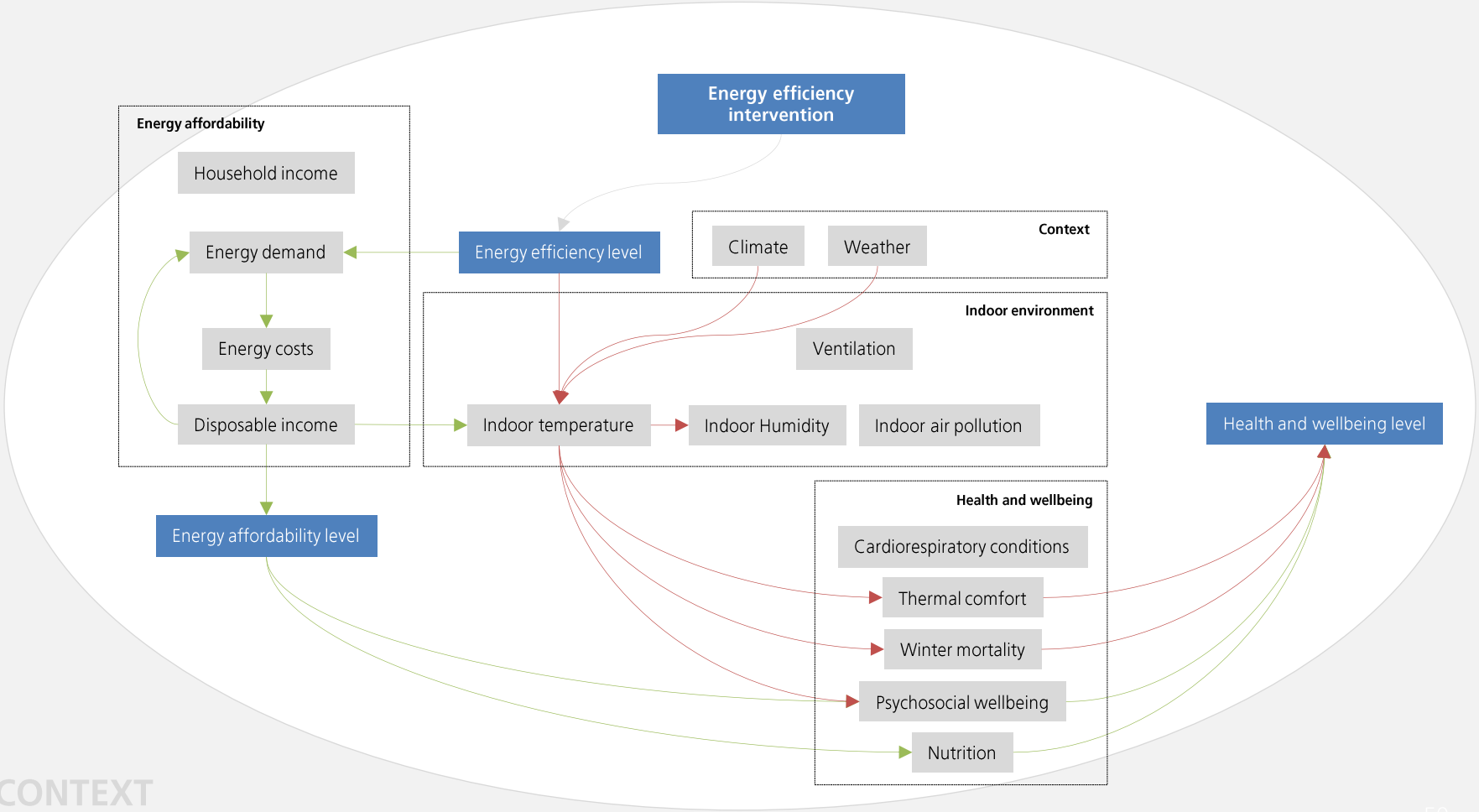
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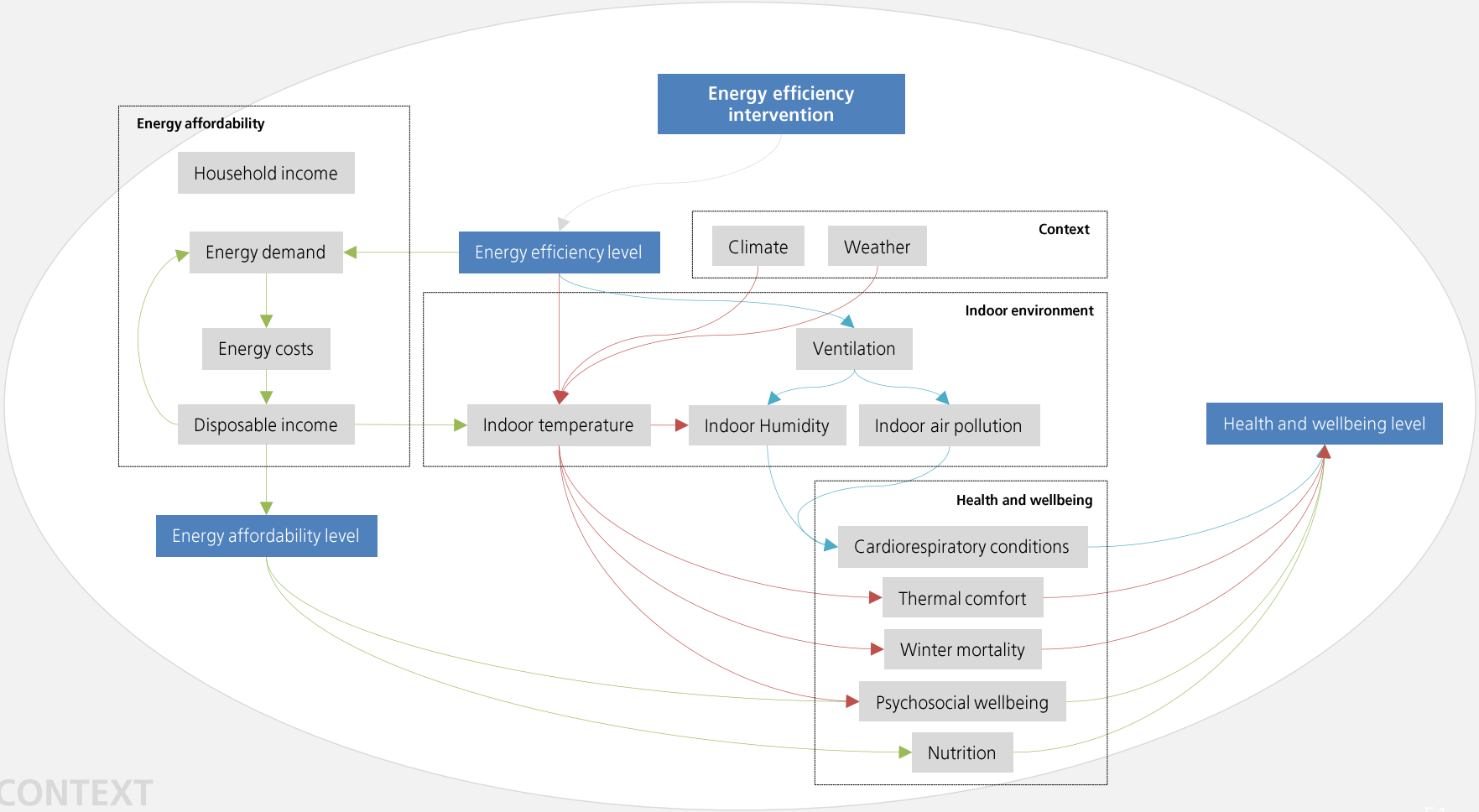
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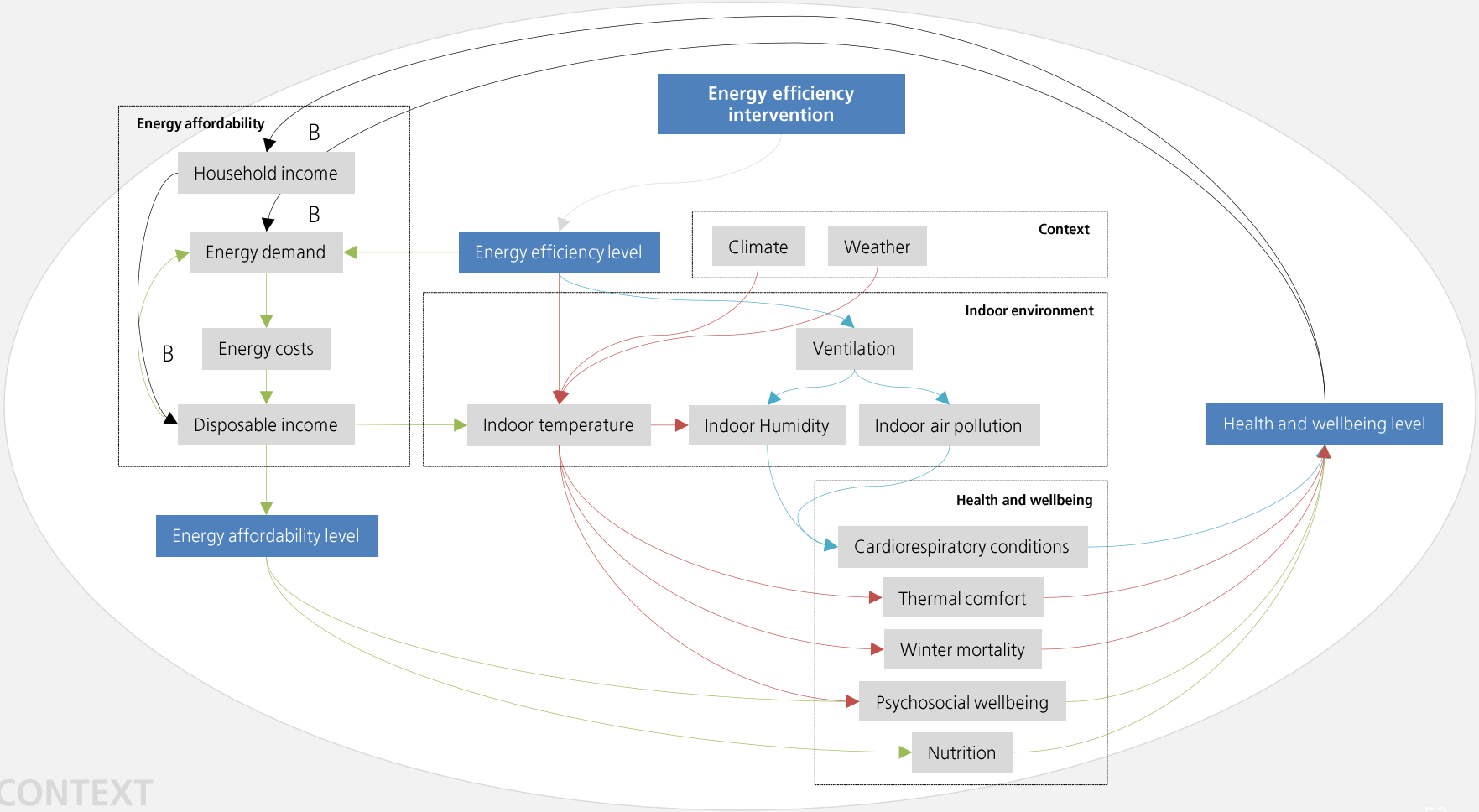
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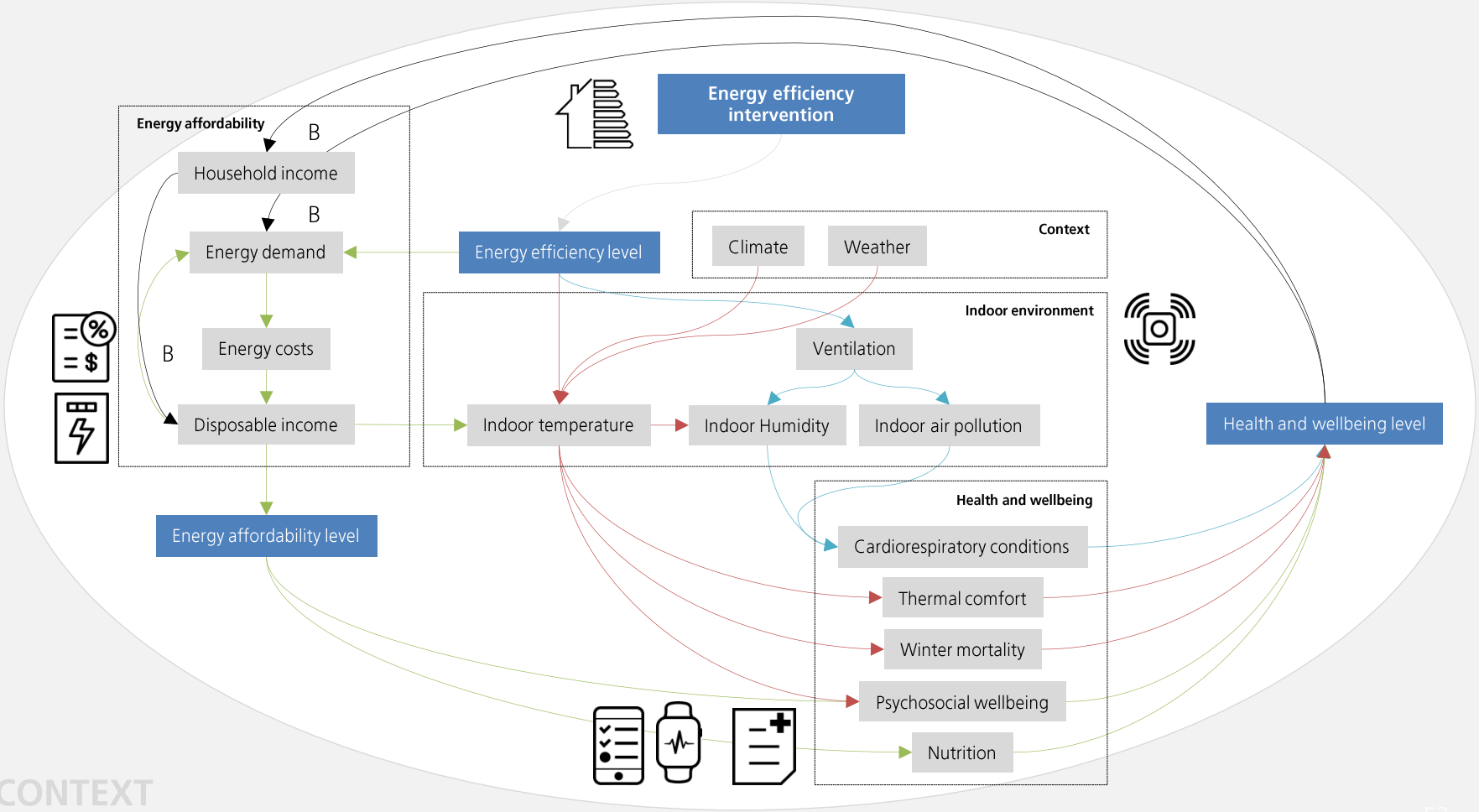
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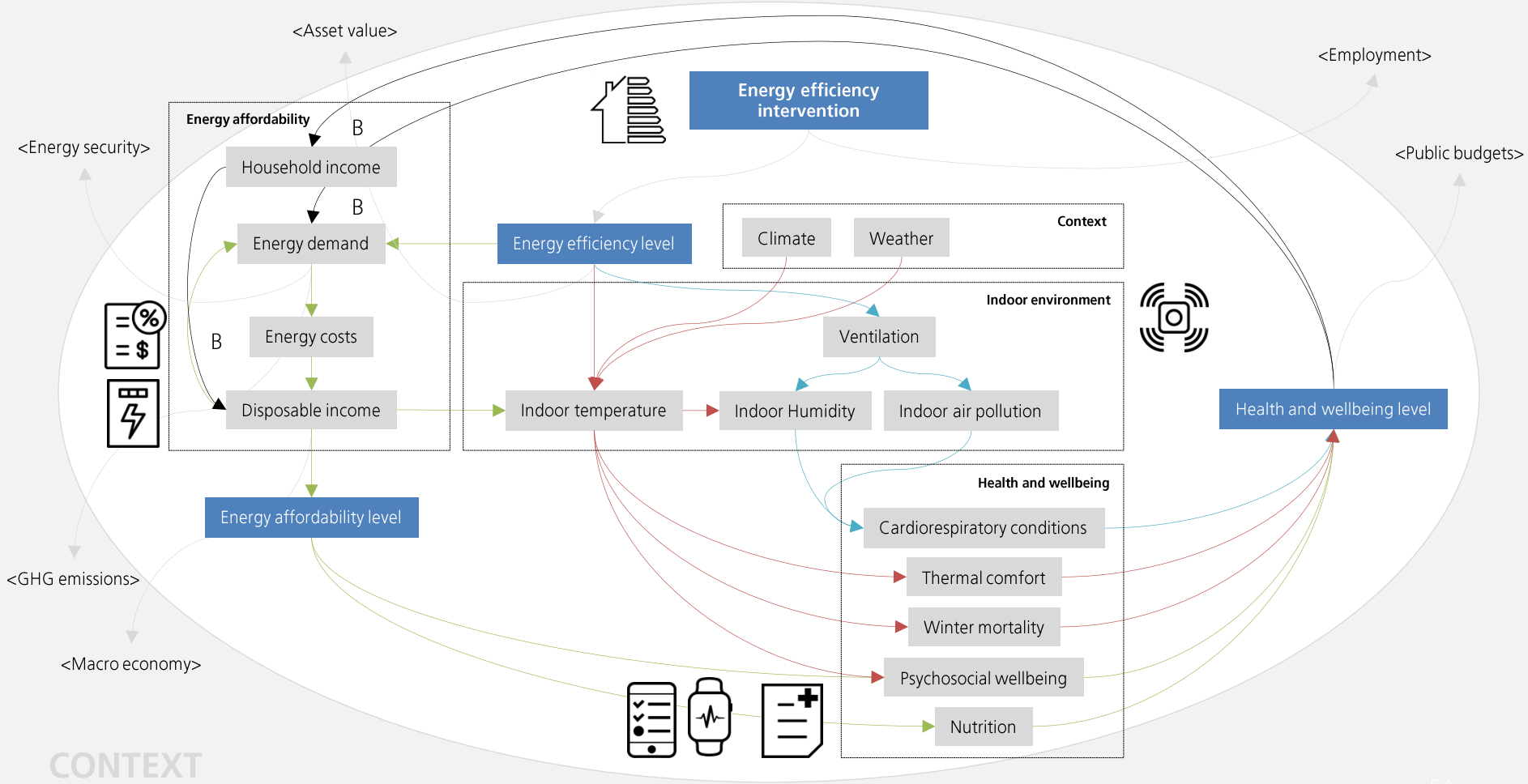
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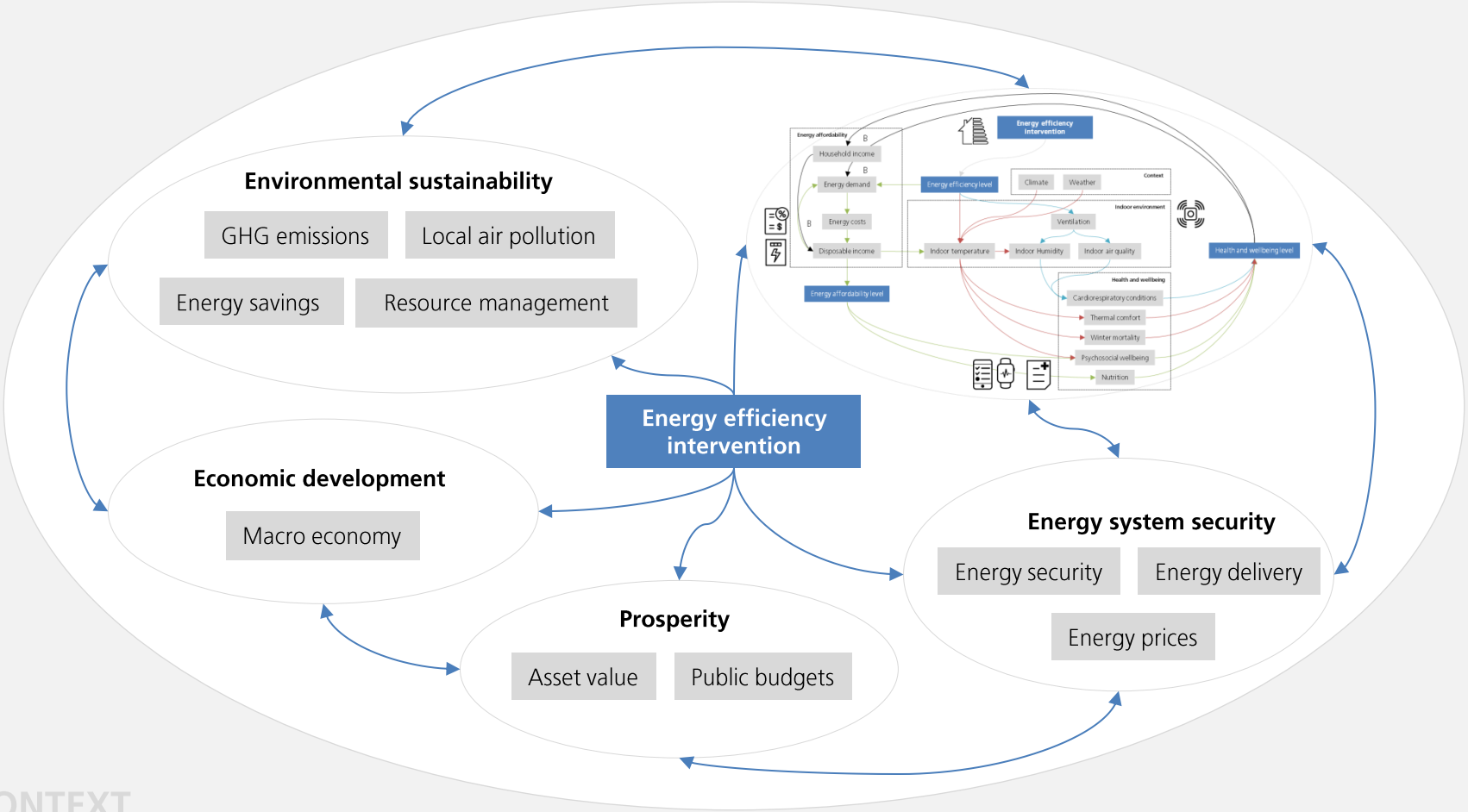
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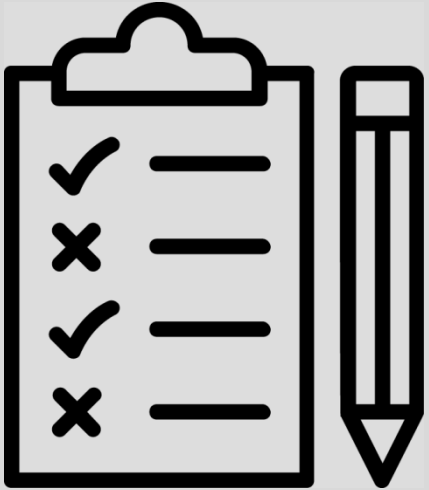
Conceptual Validation

- Due to the conceptual stage and the lack of data to test and calibrate the model all assumptions are based on prior research and expert knowledge

✓ System components

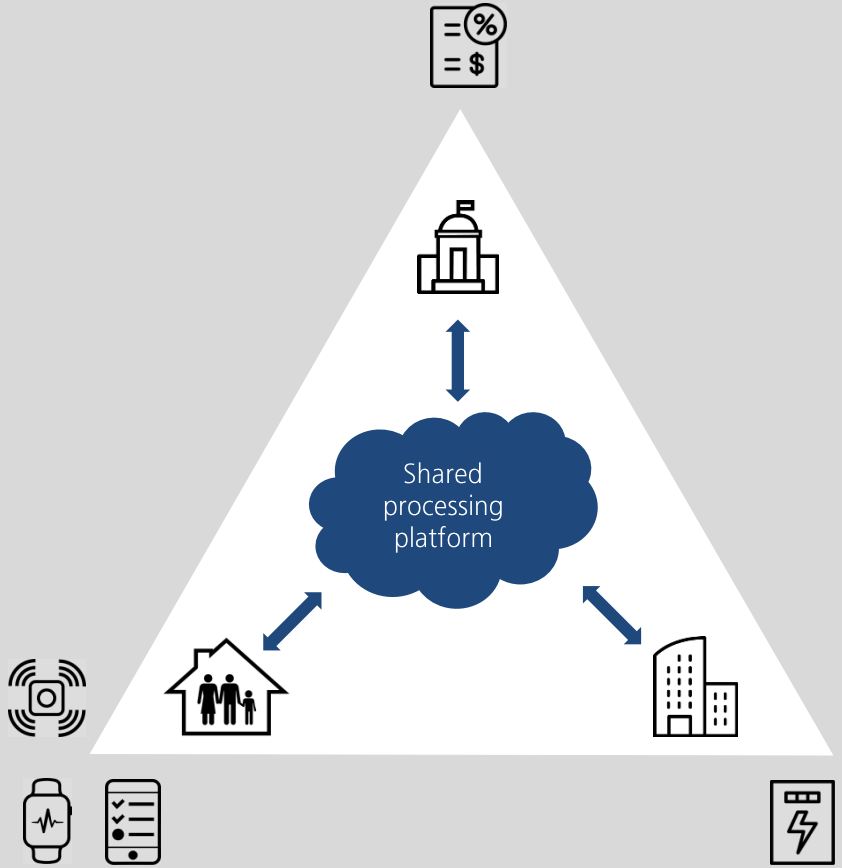
✓ Structure (dependencies + interactions)

✓ Input and data source



Taking a Look Ahead

- Enable a dynamic behaviour-driven policy-making process (fine-grained interventions, quick adaptations and overall more effective resource allocations)
- Public authority and private household would become partners in the process (exchange of data and services)



Further Research Recommendations

- The presented final product is the **first stage in a huge process** and requires further in-depth exploration of many aspects such as accessibility, security, privacy or causality and the role of theory
- **In-depth verification** of the conceptual model and assumptions followed by a **transposition into an operational model**
- Explore and **link model to other sub-systems** such as economic development or environmental sustainability
- **Direct exchange** (e.g. focus group) between involved disciplines could be very helpful to generate further insights

Thank you for your attention!

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