1/3 OF THE CO2 EMISSIONS

BUILDING SECTOR RESPONSIBLE FOR 40% OF TOTAL ENERGY CONSUMPTION

SUSTAINABILITY TARGETS AND INITIATIVES

PARIS PROOF COMMITMENT: REDUCE ENERGY CONSUMPTION BY 2/3

INNOVATIONS: SMART BUILDINGS EQUIPED WITH EDVANCED SYSTEMS

"THE PROBLEM IS THAT OFTEN THERE IS A LACK OF AWARENESS OF THE GAP. MOST BUILDINGS HAVE THESE LATENT HEADACHES BUT DON'T NOTICE THEM"

MEASURED ENERGY USE IN BUILDING RISING UP TO 2.5X THAN INITIALLY PREDICTED

TU Delft 2024

Building the future, measuring the present

Addressing the energy performance gap in redeveloped office buildings to achieve the Paris Proof targets

TU Delft

P5 Master thesis
Feline Dupuits

Management in the Built Environment

0

Table of contents

1

Introduction & method

ENERGY PERFORMANCE GAP

The disparity between the predicted or expected energy efficiency of a building and its actual energy performance in real-world operation.

PROBLEM STATEMENT

- Deep renovations (offices > label C) → on average bigger energy gap
- Buildings with higher energy rates consume more energy than predicted compared to lower energy ratings
  - High expectations client
  - Problems certification promises
- Smart and automated building systems → increased building operations systems

- Problems related to office buildings:
  - Unpredictable and dynamic → difficult management
  - Average deviation of +22% and a standard deviation of 50%
  - Technical infrastructure → potentials
  - 80% of building stock expected to exist in 2050 is already constructed

Apel, et al. (2022)
Cozza et al. (2020)
De Wilde (2014)
Menezes et al. (2011)
Van den Brom et al. (2019)
Van Dronkelaar (2016)

RESEARCH QUESTIONS

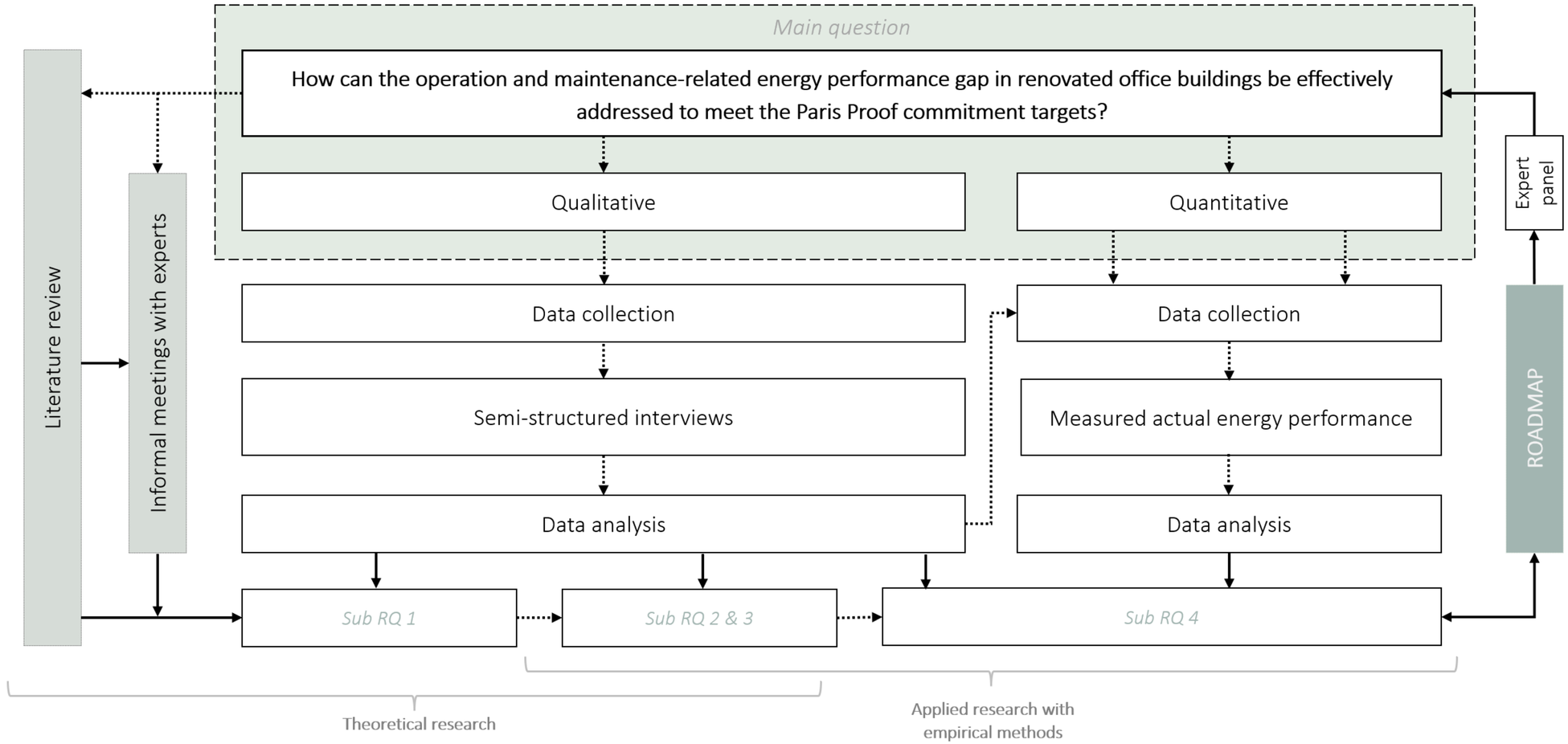
Main research question:

- *How can the operation and maintenance-related energy performance gap in renovated office buildings be effectively addressed to meet the Paris Proof commitment targets?*

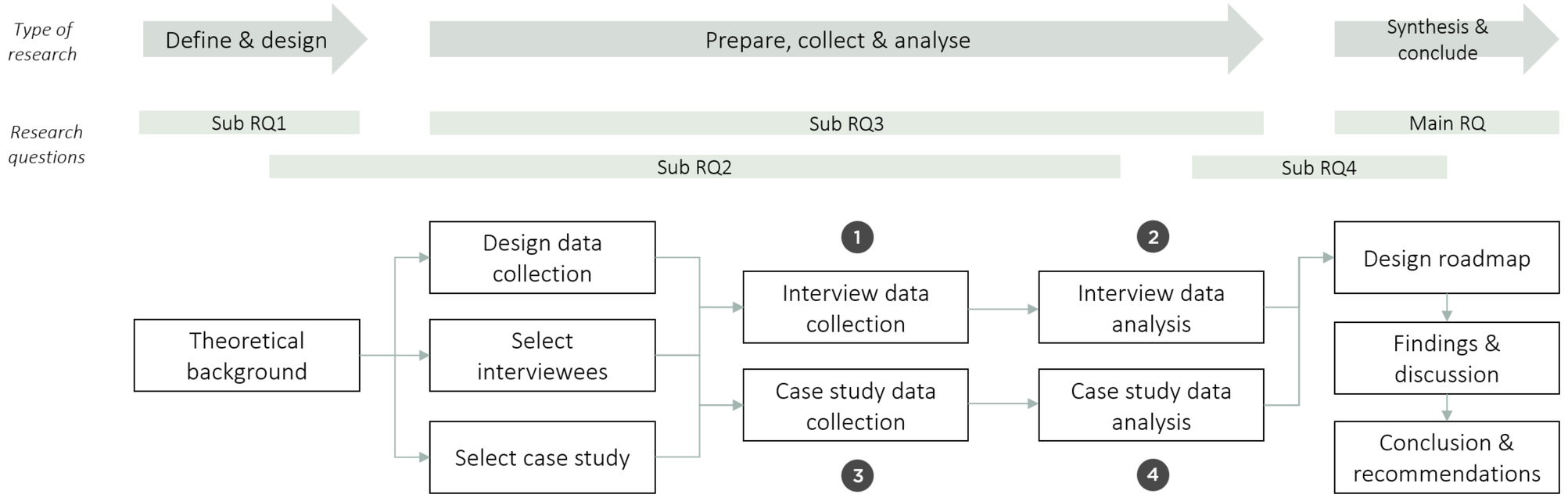
Sub research questions:

1. *What are the main factors influencing the energy performance gap in buildings?*
2. *What are the key operational and maintenance challenges that contribute to disparities in energy performance from predictions?*
3. *What responsibilities do various stakeholders have in relation to the energy performance of a building and what agreements and information exchanges are in place for this purpose?*
4. *What operational and maintenance practices should be implemented to realize Paris Proof redeveloped office buildings?*

EXPANATORY MIXED-METHOD RESEARCH



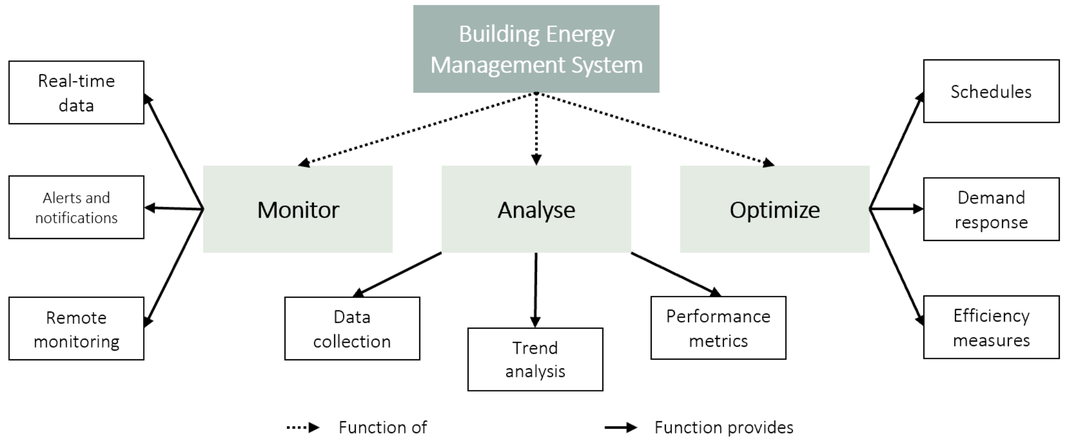
RESEARCH METHODOLOGY FRAMEWORK



DATA COLLECTION

- Literature review
- Semi-structured interviews:
  - Digital building operator
  - Data science specialist
  - Expert in building physics
  - Certification manager
  - Energy management advisor
  - Engineer
  - Developer
  - Smart solutions manager
  - Digital program manager
  - Project leader

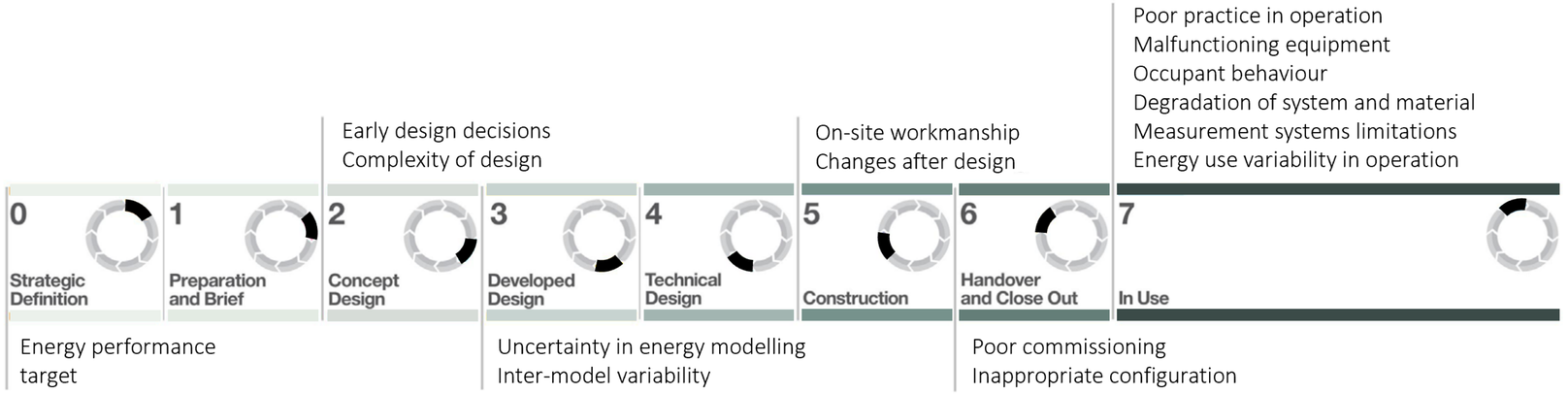
- WEii indicator
  - Electricity usage
  - Heat usage

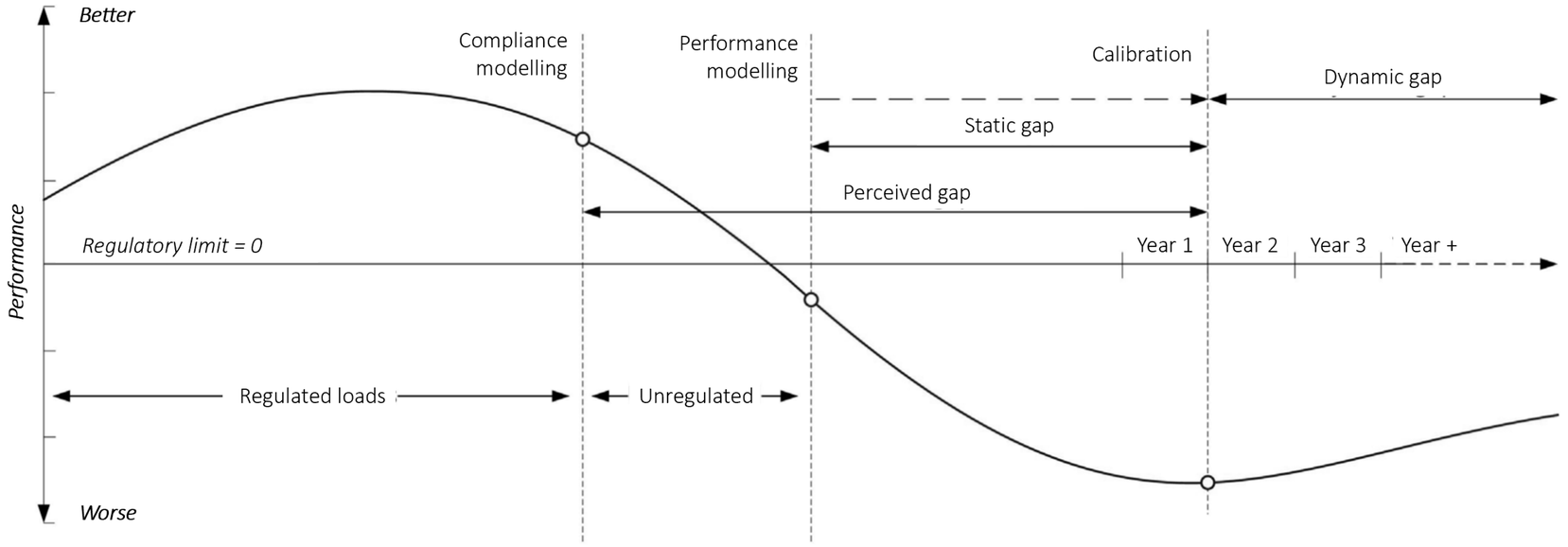


2

Theoretical background

UNDERLYING CAUSES IN DIFFERENT STAGES

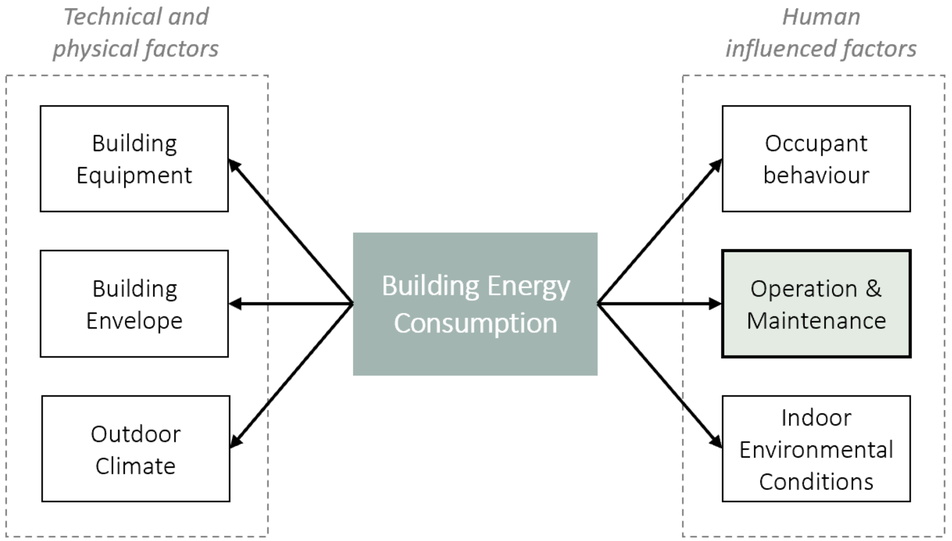




Van Dronkelaar (2016)

OPERATION AND MAINTENANCE

- Automated systems → direct occupant behaviour limited → influence building operator
- Operational activities account for 76% of emissions throughout the typical building's life cycle
- Operational practices account for 15-80% of uncertainties in energy consumption
- Inefficient operations → 49–79% increase in energy use
- Efficient operations → 15–29% decrease in energy use
- Facility managers with higher education levels are 13% more likely to implement temperature setbacks



Apel, et al. (2022)
Liang, et al. (2019)
Van Dronkelaar, et al. (2016)
Yoshino et al. (2019)
Zou, et al. (2020)

PARIS PROOF

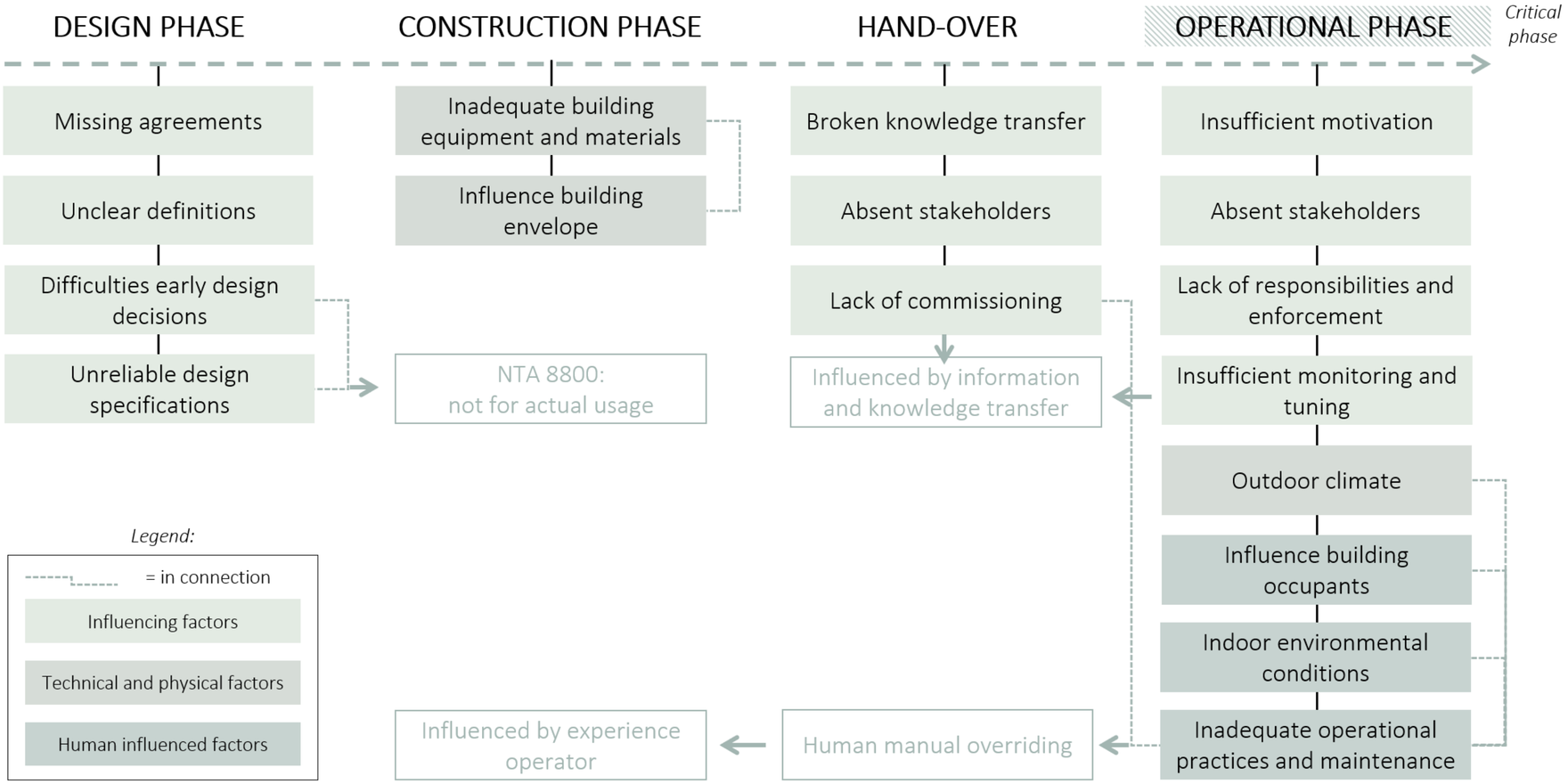
NTA 8800

- Energy performance calculation
- Does not provide the actual energy performance
- Energy labels, BREEAM and BENG certificate

WEii (Werkelijke Energie Intensiteit Indicator)

- Actual energy intensity over time, reflecting real energy performance
- 7 classes: WENG, Paris Proof, very efficient to very inefficient
- Paris Proof
  - Reducing energy consumption by two-third by 2040
  - Existing office buildings → max 70 kWh/m^2

NEN (2024)
BREEAM-NL (2023)
TVVL & DGBC (2023)


DESIGN PHASE
CONSTRUCTION PHASE
HAND-OVER
OPERATIONAL PHASE
Critical phase
Missing agreements
Unclear definitions
Difficulties early design decisions
Unreliable design specifications
Inadequate building equipment and materials
Influence building envelope
NTA 8800: not for actual usage
Broken knowledge transfer
Absent stakeholders
Lack of commissioning
Influenced by information and knowledge transfer
Insufficient motivation
Absent stakeholders
Lack of responsibilities and enforcement
Insufficient monitoring and tuning
Outdoor climate
Influence building occupants
Indoor environmental conditions
Inadequate operational practices and maintenance
Human manual overriding
Influenced by experience operator
Legend:
= in connection
Influencing factors
Technical and physical factors
Human influenced factors

SUB RESEARCH QUESTION 1

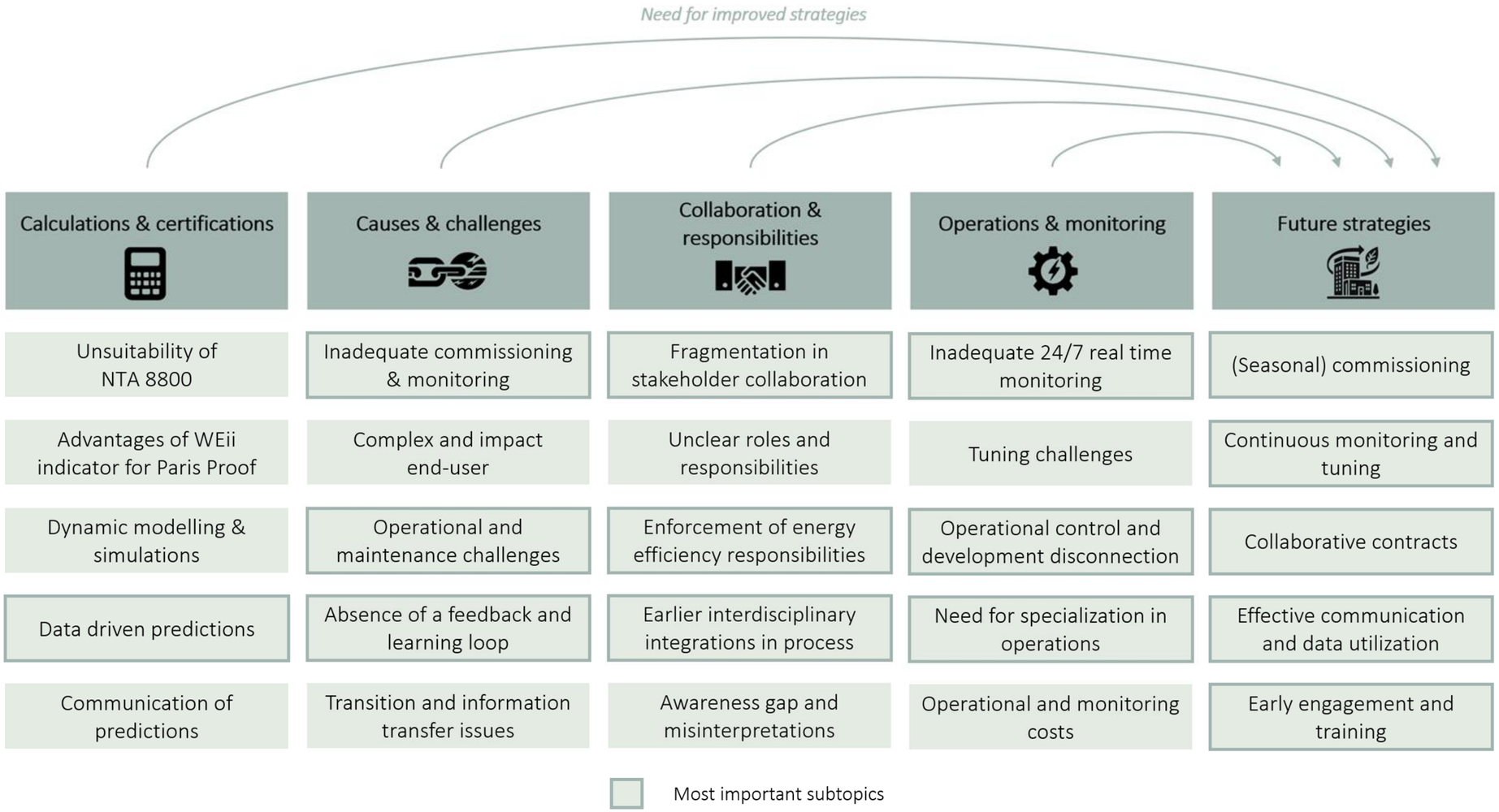
- *What are the main factors influencing the energy performance gap in buildings?*

- Influencing factors
  - Human: operations and maintenance, occupant behaviour, indoor conditions
  - Technical: outdoor climate, building envelope, building equipment
- Operational inefficiencies
- Smart office buildings
  - Dynamic occupancy
  - Mismanagement of advanced systems

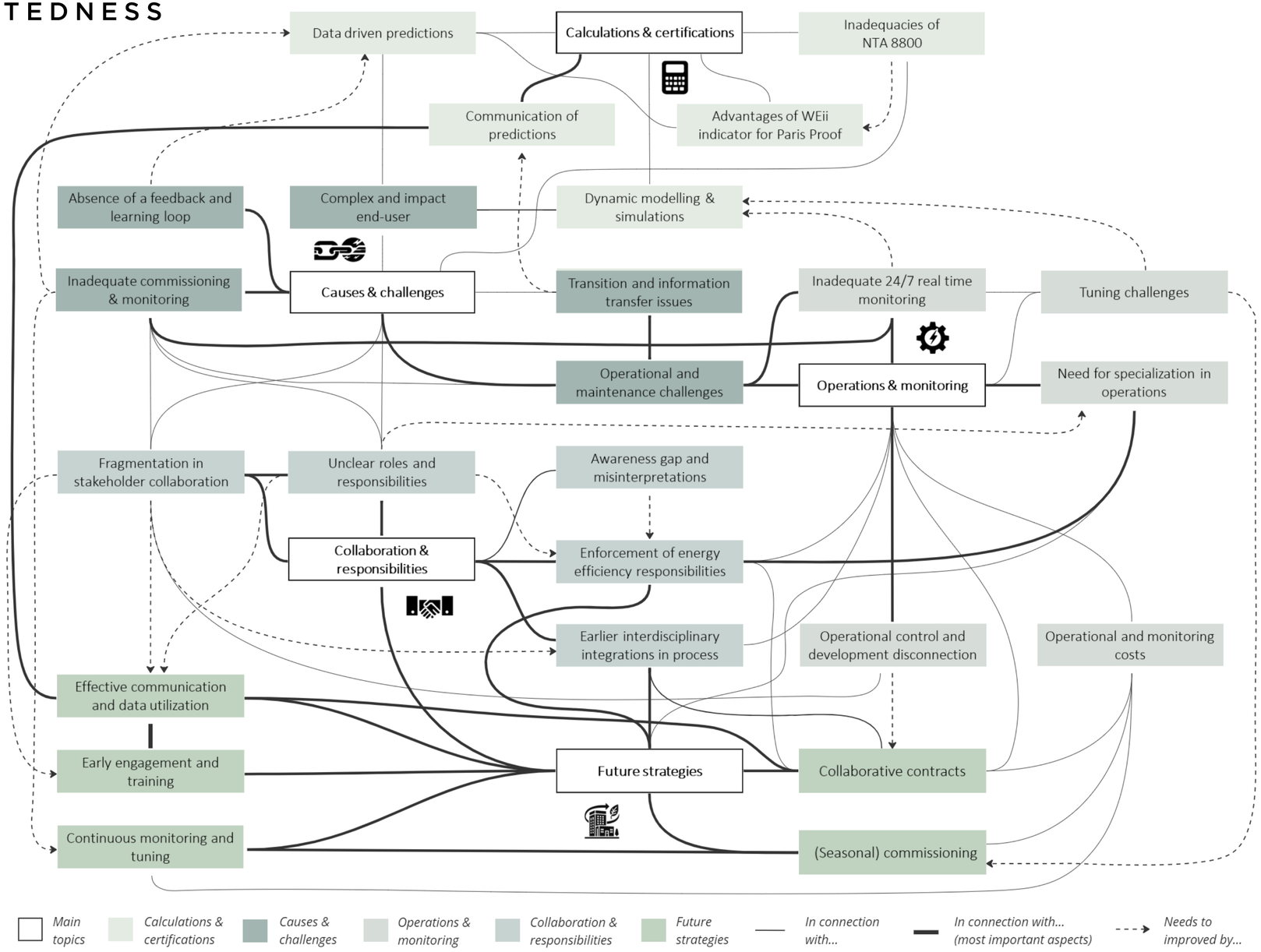
3

Qualitative research

INTERVIEW MAIN & SUBTOPICS



INTERCONNECTEDNESS TOPICS



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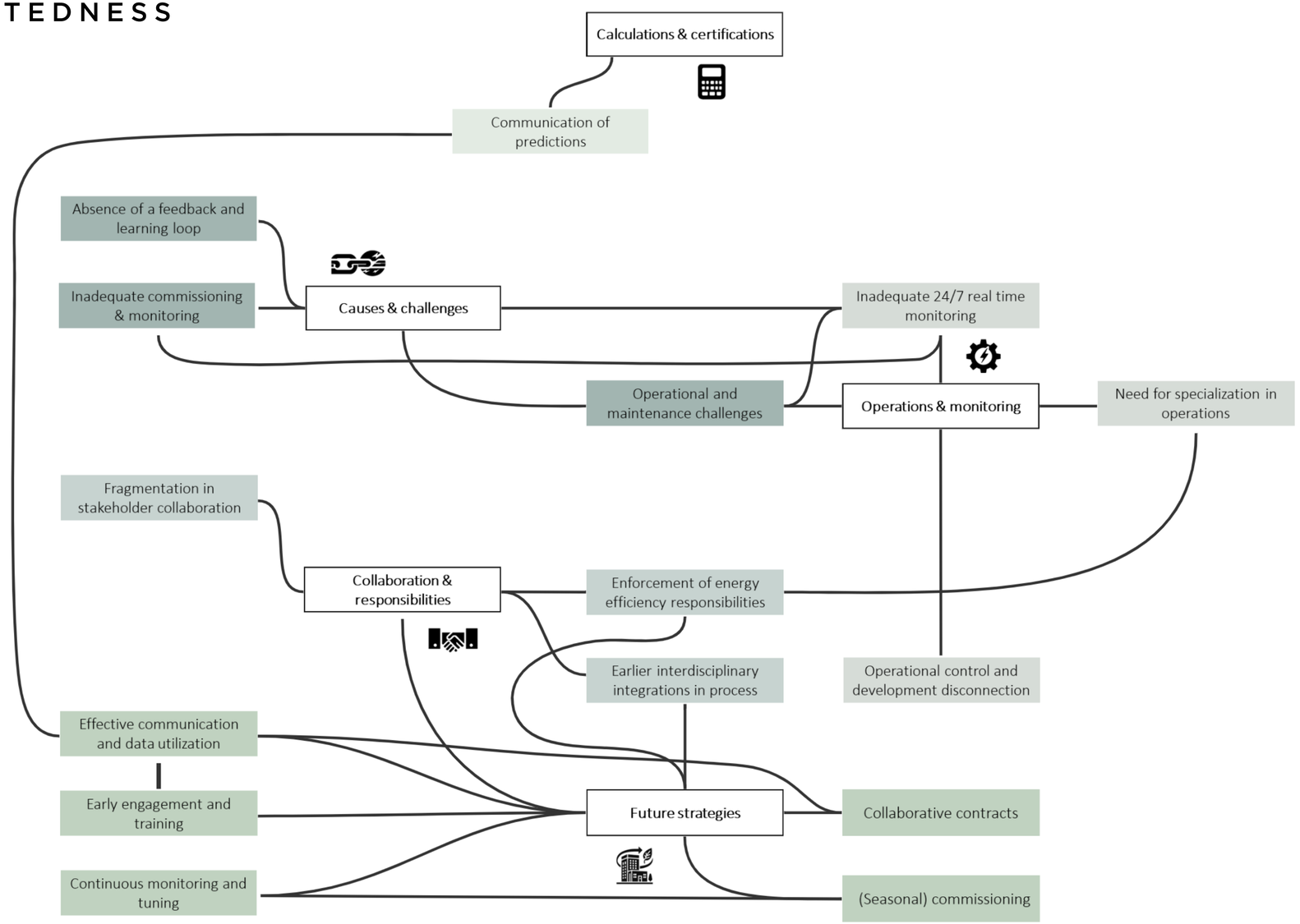
INTERCONNECTEDNESS TOPICS



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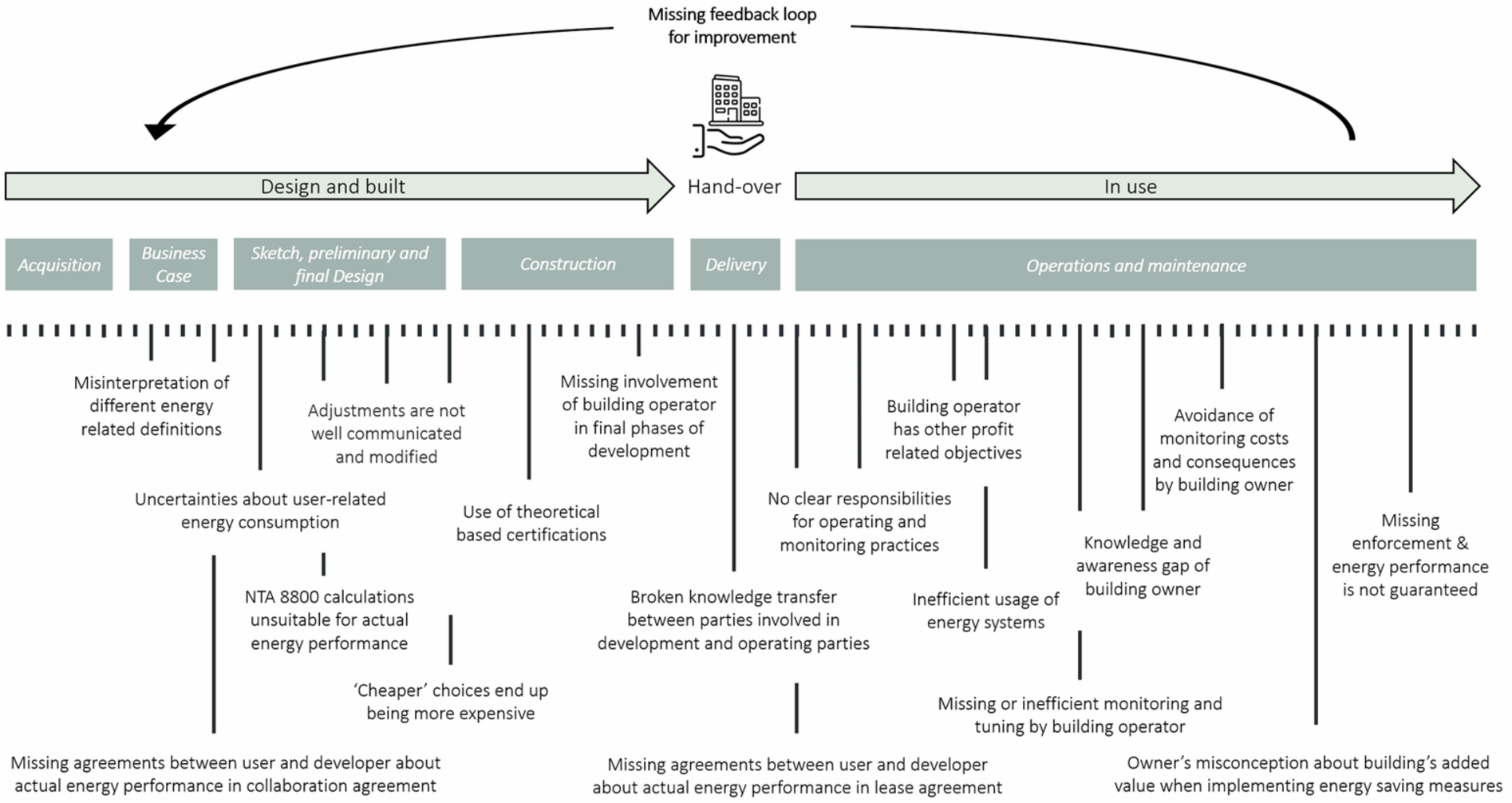
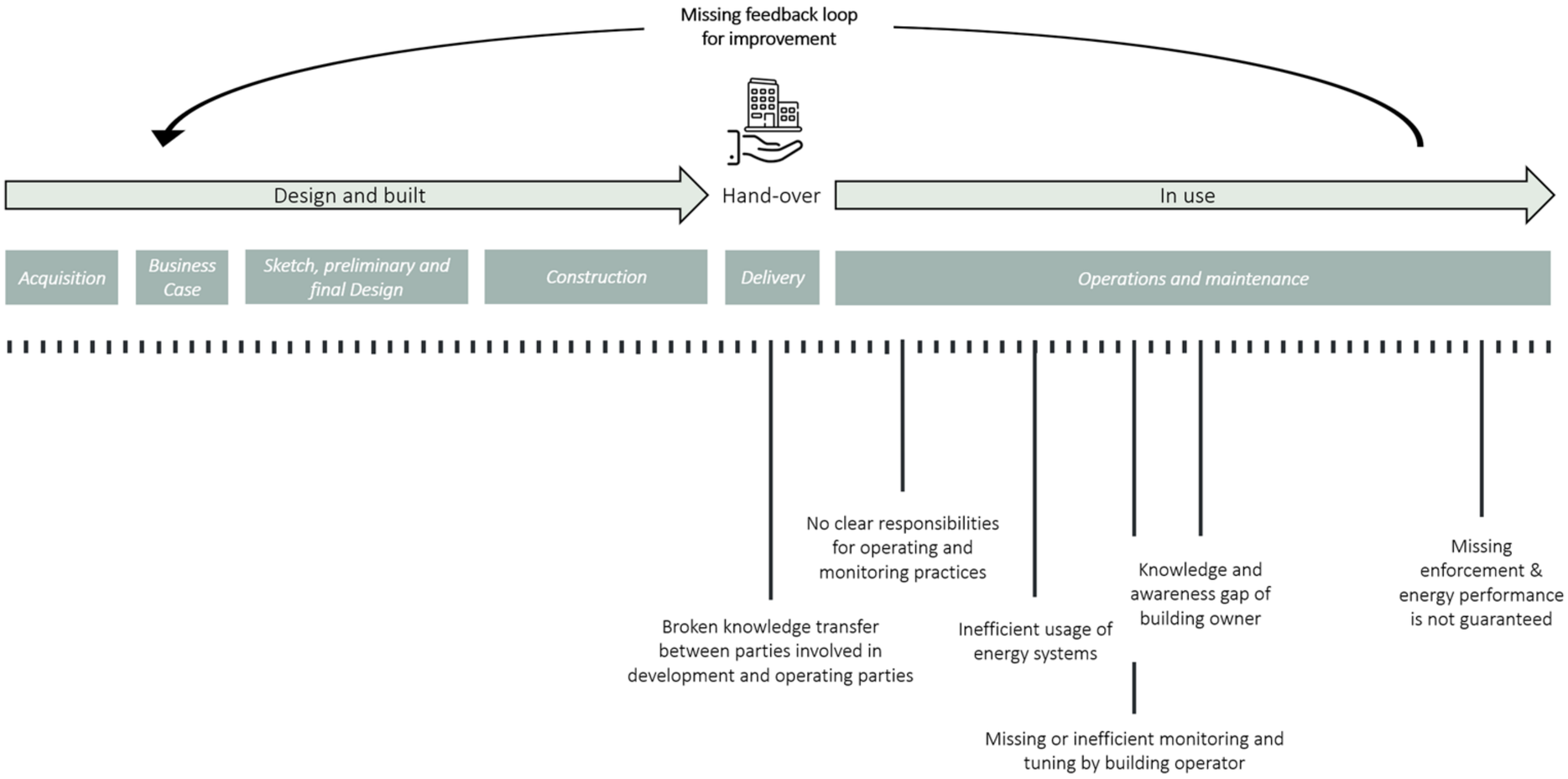
Main topics · *Calculations & certifications* · *Causes & challenges* · *Operations & monitoring* · *Collaboration & responsibilities* · *Future strategies* · *In connection with...* · *In connection with... (most important aspects)* · *Needs to improved by...*

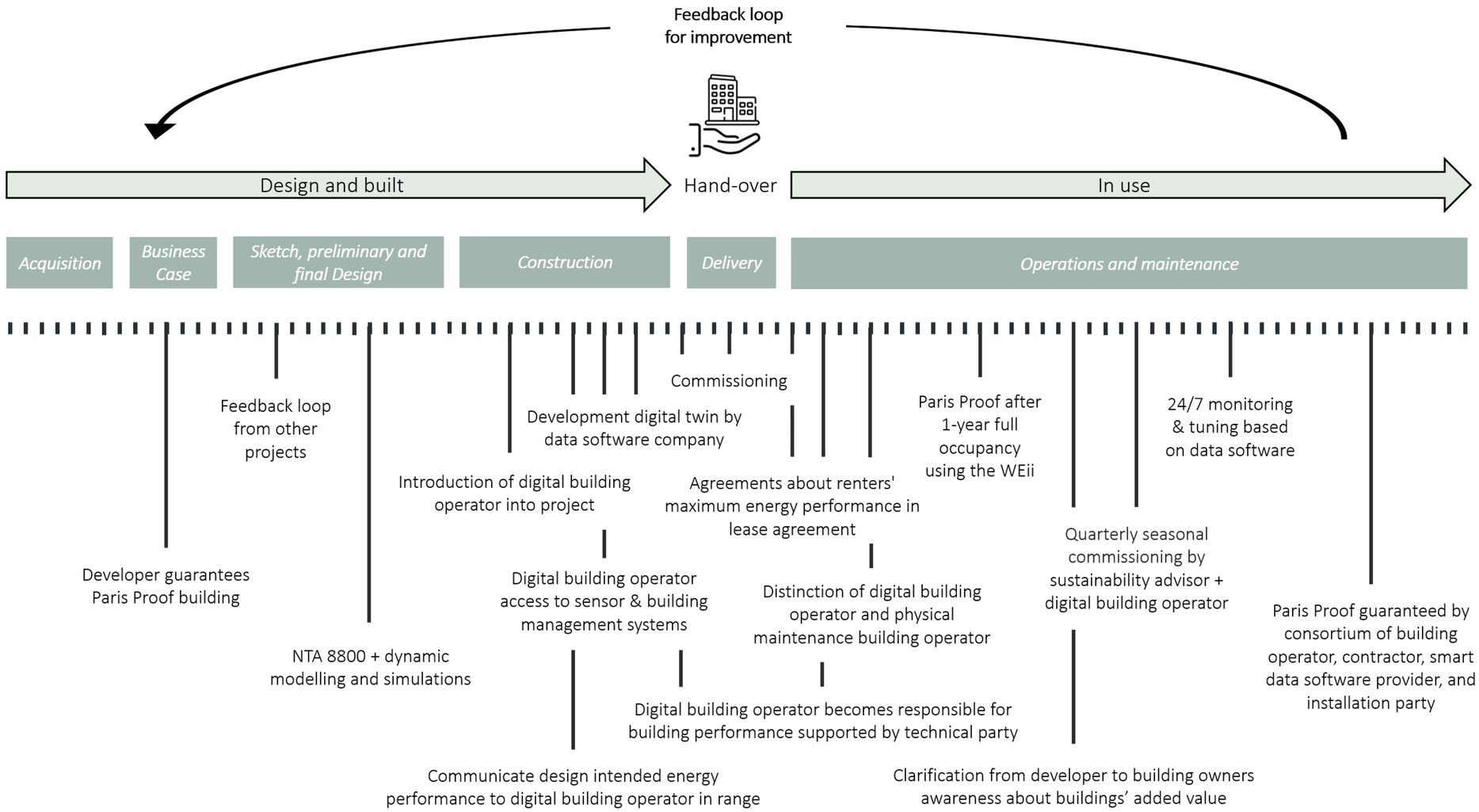
ENERGY PERFORMANCE GAP
CAUSES AND CHALLENGES



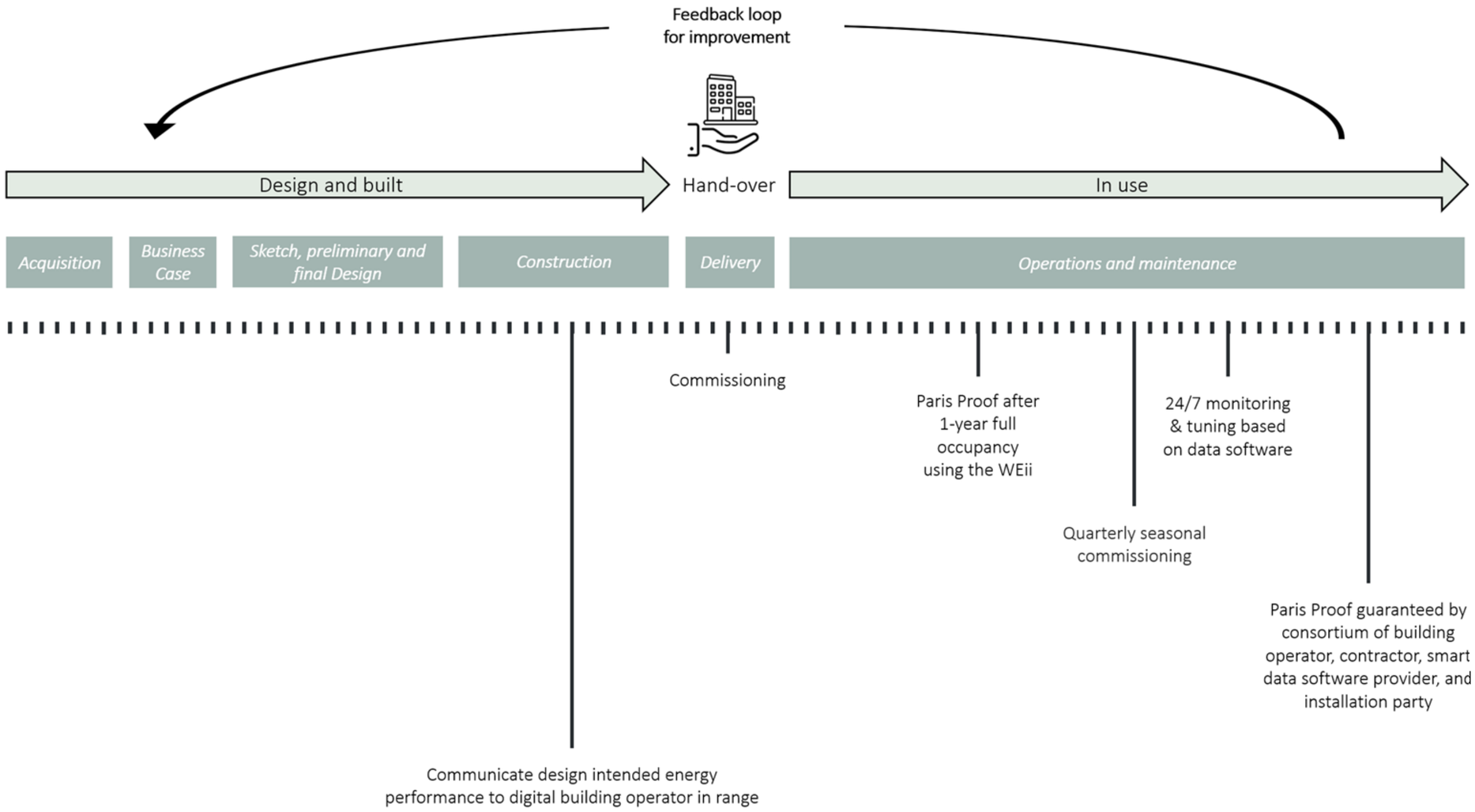
ENERGY PERFORMANCE GAP
CAUSES AND CHALLENGES



ADDRESSING THE ENERGY PERFORMANCE GAP



ADDRESSING THE ENERGY PERFORMANCE GAP



SUB RESEARCH QUESTION 2

- *What are the key operational and maintenance challenges that contribute to disparities in energy performance from predictions?*

- Fragmented sector approach
  - Critical phases: handover and operations & maintenance
- Insufficient commissioning
- Lack of 24/7 monitoring
- Absence of feedback and learning loops
  - Limited documentation
  - Missing benchmark
- Misalignment in decision-making
  - Knowledge gap
  - Timely fixes
  - Systems not set as design intent
  - Need for specialized roles

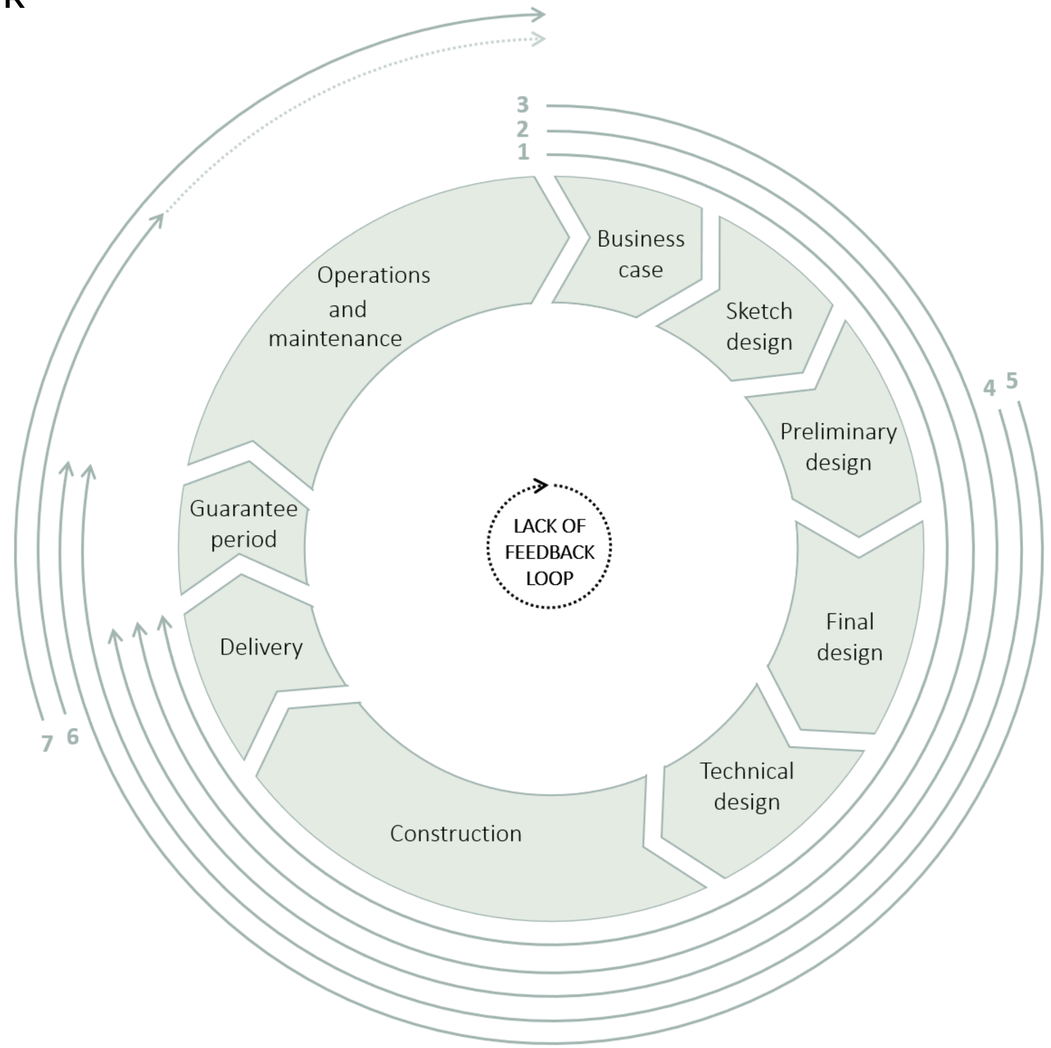
SUB RESEARCH QUESTION 3

- *What responsibilities do various stakeholders have in relation to the energy performance of a building and what agreements and information exchanges are in place for this purpose?*

- Stakeholders
  - **Real Estate Developer**, Cost Expert, Structural Engineer, Client, Building Physicist Engineer, Architect, **Installation & Energy Advisor**, General Contractor, Installer, **Digital Building Operator, Expert Building Systems & Platforms, Commissioning Manager**, Technical Engineer, End User

- Fragmented stakeholder collaboration
- Unclear roles and responsibilities
- Varying objectives and expectations
- Lack of enforcement and incentives
- Awareness gap
- Misinterpretations

IMPROVED STAKEKEHOLDER INVOLVEMENT

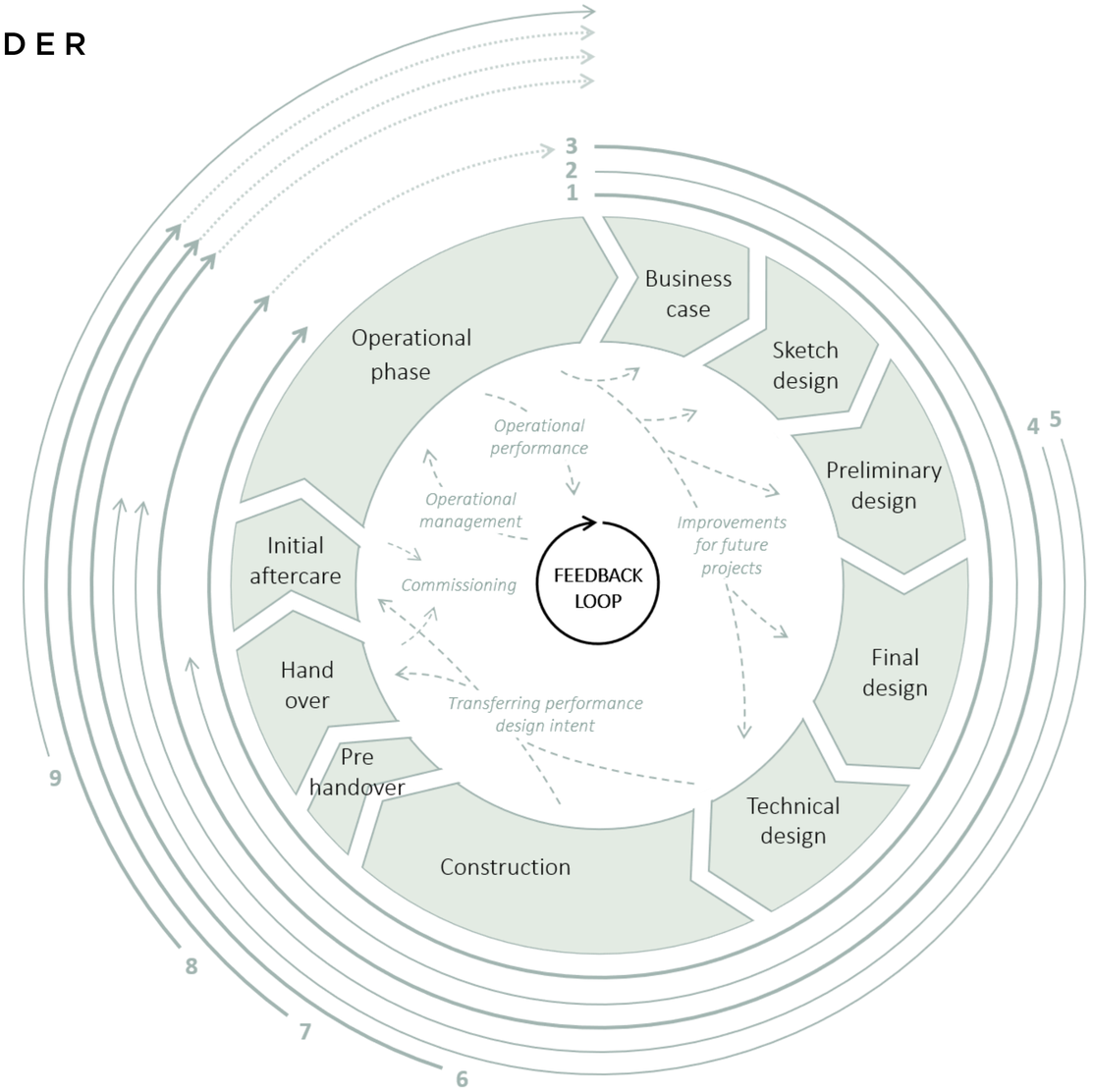


1. Real estate developer
2. Building physics engineer
3. Installation & energy advisor
4. General contractor
5. Installer
6. Building operator
7. End user

Stakeholder involvement

Possible extended stakeholder involvement

IMPROVED STAKEKEHOLDER INVOLVEMENT



1. **Real estate developer**
2. Building physics engineer
3. **Installation & energy advisor**
4. General contractor
5. Installer
6. **Digital building operator**
7. **Expert smart building systems & platforms**
8. **Commissioning manager**
9. End user

Stakeholder involvement

Possible extended stakeholder involvement

4

Case study

AMSTERDAM

EDGE Olympic

Size
11.185 sq m

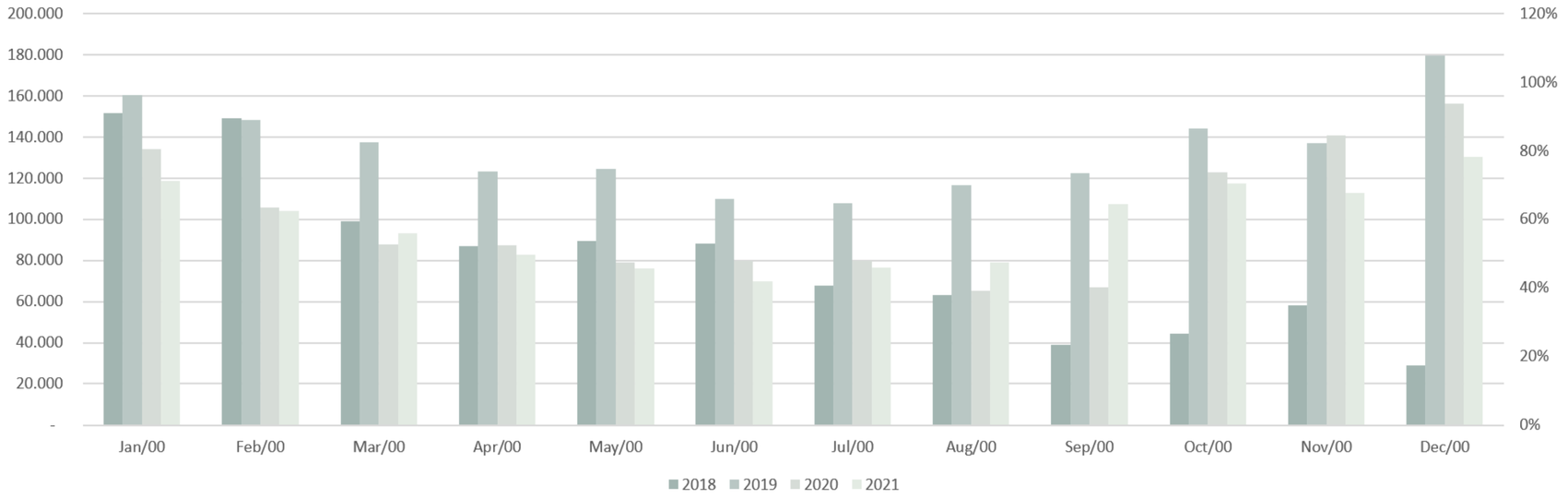
Completion date
Q2 2018

Certifications
BREEAM Excellent
Paris Proof
Energy label G to A+++

Inefficiencies
24/7 character and not segmented

Developer
Edge

ENERGY CONSUMPTION



Function	Specifics	Floor area	Paris Proof limit
Meeting function	Meeting function other	1405 m2	70 kWh/m2
Meeting function	Restaurant	590 m2	200 kWh/m2
Sports function	Sports accommodation	60 m2	70 kWh/m2
Office function	Office	9130 m2	70 kWh/m2
		Total: 11185 m2	*Total: 81 kWh/m2*

Year	Electricity	Heat	Total	Total EV chargers	Correction factor	Corrected usage	kWh/m2	
2019	1.103.553	506.124	1.609.677		0,7893348	1.270.574	110,32	Start
2020	839.179	366.168	1.205.347		0,7964631	960.014	83,36	Operations
2021	727.412	440.563	1.167.975	-80.044	0,6660029	777.875	67,54	Paris Proof
2022	810.432	323.859	1.134.291	-106.449	0,703229	797.667	69,76	Paris Proof
2023	847.963	376.613	1.224.577	-121.947	0,6839071	837.497	72,72	Paris Proof

OPERATIONAL IMPROVEMENTS

- Operational improvement: decrease in energy consumption of 34,08% from 2019 to 2023

Involvement of the digital building operator

- Changing the 24/7 character
  - ➢ Operating timeslots divided into normal office and extended hours
- Fragmentation of zones
- Seasonal commissioning
  - ➢ Total energy consumption 77,42% higher in February compared to May 2023
- Real time monitoring
- Feedback loops

COMPARISON WITH QUALITATIVE TOPCIS

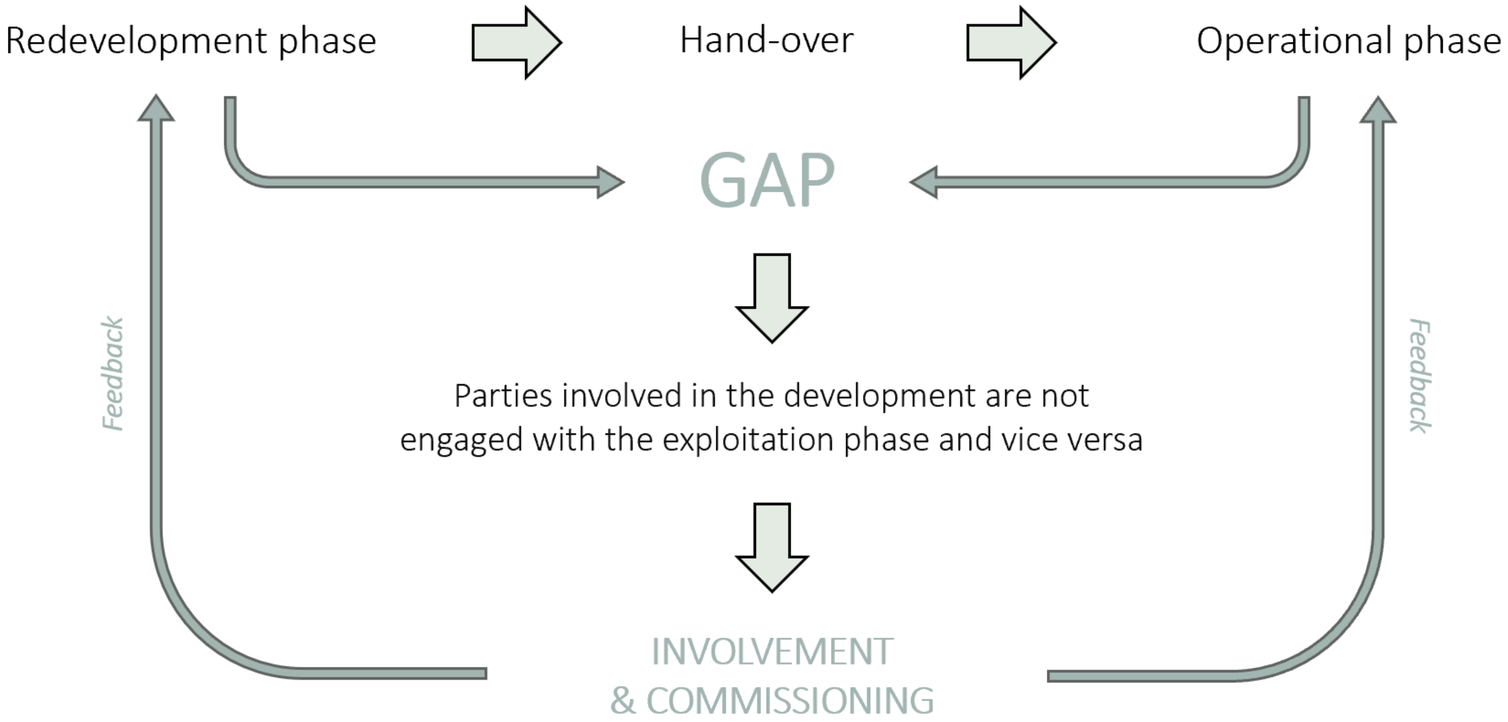
Calculations & certifications	Causes & challenges	Collaboration & responsibilities	Operations & monitoring	Future strategies
Unsuitability of NTA 8800	Inadequate commissioning & monitoring	Fragmentation in stakeholder collaboration	Inadequate 24/7 real time monitoring	(Seasonal) commissioning
Advantages of WEii indicator for Paris Proof	Complex and impact end-user	Unclear roles and responsibilities	Tuning challenges	Continuous monitoring and tuning
Dynamic modelling & simulations	Operational and maintenance challenges	Enforcement of energy efficiency responsibilities	Operational control and development disconnection	Collaborative contracts
Data driven predictions	Absence of a feedback and learning loop	Earlier interdisciplinary integrations in process	Need for specialization in operations	Effective communication and data utilization
Communication of predictions	Transition and information transfer issues	Awareness gap and misinterpretations	Operational and monitoring costs	Early engagement and training

Addressed in both the interviews and case study

Addressed in the interviews

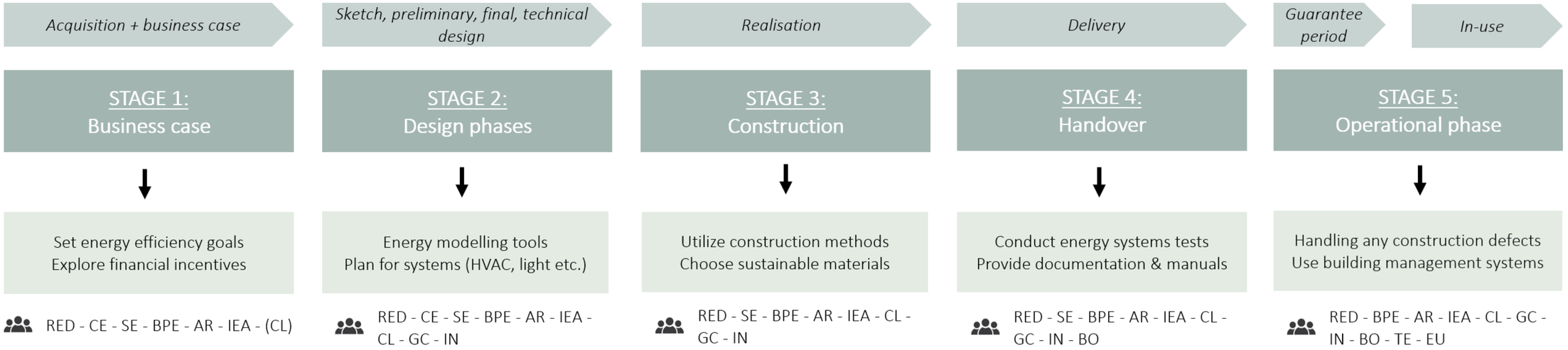
5

Strategic roadmap



Ensuring that all systems and components of the building are designed, installed, tested, operated, and maintained according to the requirements and specifications.

CURRENTLY ORGANIZED REDEVELOPMENT PROCESS



RED = Real Estate Developer
CE = Cost Expert
SE = Structural Engineer

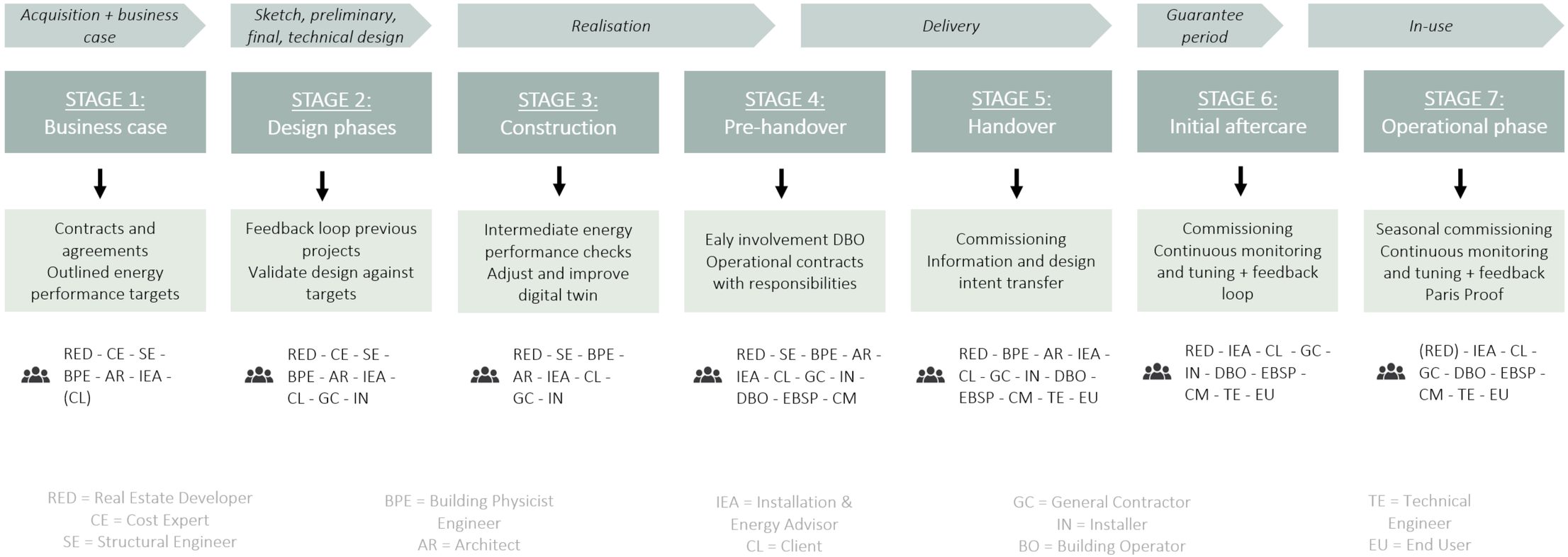
BPE = Building Physicist Engineer
AR = Architect

IEA = Installation & Energy Advisor
CL = Client

GC = General Contractor
IN = Installer
BO = Building Operator

TE = Technical Engineer
EU = End User

STRATEGIC ROADMAP
PROPOSED REDEVELOPMENT



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BO = Building Operator

TE = Technical Engineer
EU = End User

SUB RESEARCH QUESTION 4

- *How should the currently organized operations and maintenance be changed in order to realize Paris Proof redeveloped office buildings?*

- Strategic shift
  - ➢ Seasonal commissioning
  - ➢ Ongoing monitoring and tuning + feedback loops
- Defined roles and responsibilities
  - ➢ Specialised roles and early involvement
- Effective communication and training
- Stakeholder engagement and interdisciplinary collaboration
- Performance-aligned contractual incentives and targets
- Advanced technologies and dynamic and data-driven frameworks
- Case Study: Edge Olympic
  - ➢ Seasonal commissioning, real-time monitoring, feedback loop, modified operating hours, multi-tenant zoning

6

Discussion & conclusion

SUB- AND MAIN THEMES

Main theme	Continuous monitoring and tuning	Advanced technologies and specialisation	Responsibilities of roles and incentivisation	Knowledge transfer and trainings
Subtheme	Real-time monitoring and data utilization	Implementation of advanced technologies	Defining tasks and responsibilities	Seamless knowledge transfer among teams
	Feedback loops for operational adjustments	Specialized expertise and role division	Contracts and incentives for performance	Training and expertise development

ROLE DIVISION
BUILDING OPERATOR

Building operator	
Building systems monitoring	Contract management
Maintenance and repairs	Budgeting and financial management
Energy management	Record keeping and documentation
Tenant services	Tenant relations
Safety and security	Compliance and regulatory requirements

Digital building operator → process & operations	Building operator and maintenance → physical
24/7 remote monitoring and control	Routine inspections and maintenance
Data analysis and optimization	Equipment repairs and troubleshooting
Alarm management and troubleshooting	Emergency response and resolution
Performance reporting and analysis	Physical security and safety checks
Tenant communication and support	Site supervision and coordination
Vendor and contractor coordination	Documentation and reporting

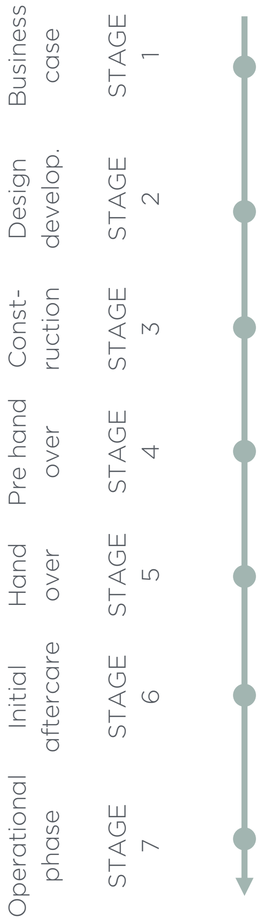
EXPERT PANEL

- Fragmented information transfer and collaboration during transitions to new owners.
  - “…approximately 50% of the available information will be lost.”
  - Importance of a handover manager
- Building is a production line → preserving building “memory"
- Issues with Commissioning:
  - Check marks rather than improving system operations: conflicting priorities
- Dynamic and Data-Driven Approach
  - Privacy concerns
- Strategic and tactical involvement in addition to operational

MAIN RESEARCH QUESTION

- *How can the operation and maintenance-related energy performance gap in renovated office buildings be effectively addressed to meet the Paris Proof agreement goals?*

MAIN RESEARCH QUESTION



Align stakeholders on vision and objectives.
Define and document project objectives, performance criteria, roles, and responsibilities.
Establish clear energy performance targets and legal terms.

Develop and refine energy-efficient designs and conduct performance simulations.
Ensure stakeholder input through regular reviews.

Align construction practices with designed energy standards and perform compliance checks.
Verify installation and energy efficiency standards adherence.

Conduct system tests and tuning to ensure operational efficiency.
Develop digital tools for ongoing performance monitoring and finalize documentation.

Inspect systems and conduct final verifications.
Train operational teams and transfer essential energy management knowledge.

Optimize systems based on actual occupancy patterns and perform continuous monitoring.
Adjust operations based on performance data and document outcomes.

Implement seasonal commissioning.
Continuous data driven system improvements, integrating new technologies and responding to feedback.
Documentation and records necessary for maintaining the Paris Proof standards.

7

Limitations & recommendations

LIMITATIONS

1. One single case study
   - Limited focus may not reflect broader range of challenges

2. Limited interviewees
   - Potentially effecting the representativeness

3. Time constraints
   - Potential to go more in depth or expand topics

4. Focus on smart buildings
   - Strategies may be less applicable to buildings lacking these systems

5. Certification guidelines
   - Standards and tools are not globally known
   - May undergo changes over time

RECCOMMENDATIONS

1. Conduct research in diversify of building types
   - Different buildings functions
   - Buildings without advanced energy management systems

2. Expand the research in different (re)development structures and cooperations
   - Different companies
   - Different regions

3. Implement and test the roadmap in a real-world projects
   - Evaluate practical applicability

“ The problem is that often there is a lack of awareness of the gap due to inadequate monitoring. Building owners are not aware of potential problems. It is referred to as the difference between the headache and the paracetamol. Most buildings have these 'latent headaches' but do not notice them.”

Questions

TU Delft

P5 Master thesis
Feline Dupuits

Management in the Built Environment