Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Vera Inez Koster
Student number	4368789

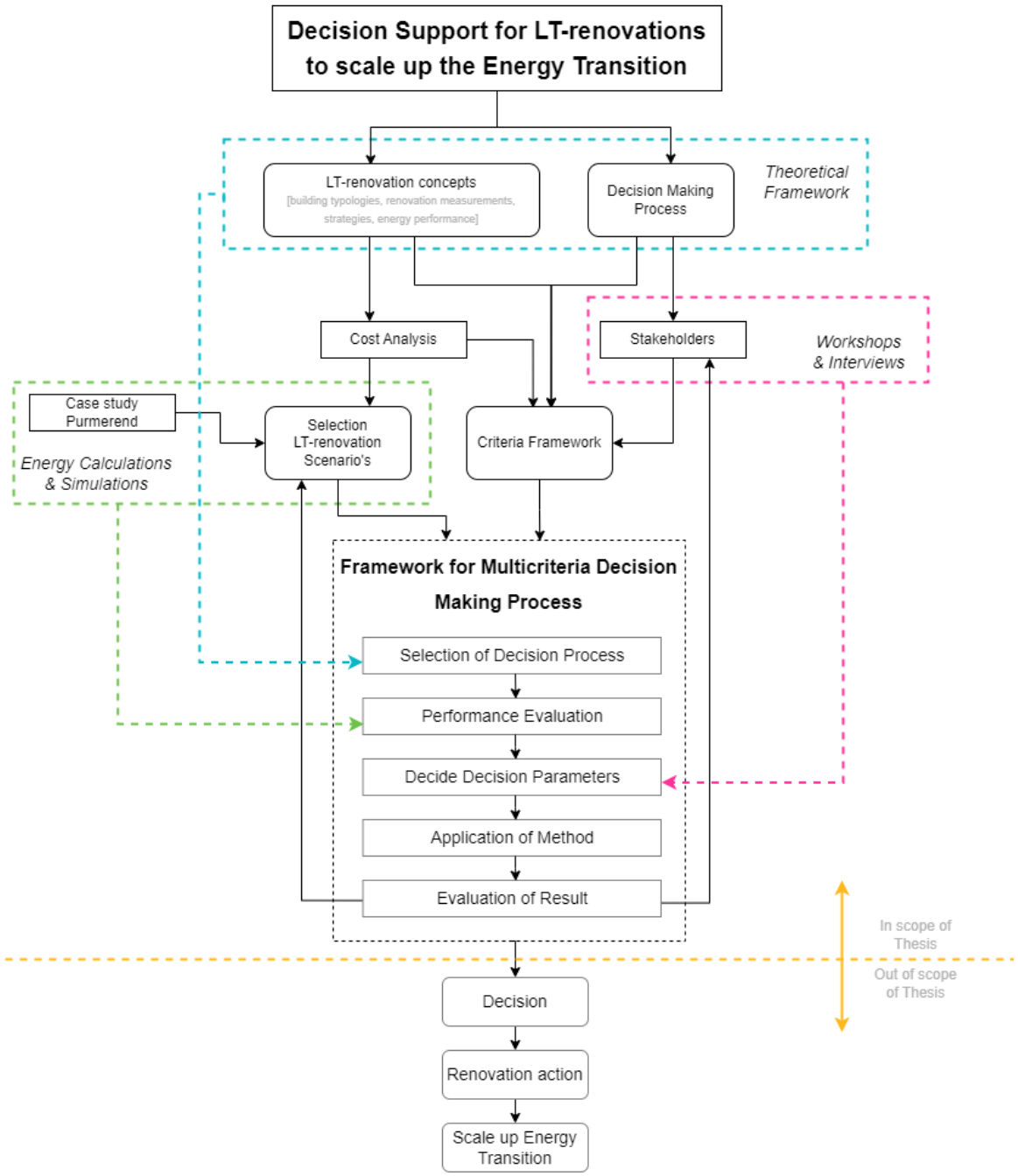
Studio		
Name / Theme	Façade & Products | Energy & Climate	
Main mentor	Thaleia Konstantinou	Building Product Innovation
Second mentor	Eric van den Ham	Building Physics and Services
Argumentation of choice of the studio	The combination of these studios provide the opportunity to explore the link between the decision making process and energy performance assessments of dwellings to contribute to the scalability of the energy transition. This combination encompasses a high level of complexity through its multi-scale character, with the goal to make the link between urban renovation strategies, decision making and building interventions explicit in a comprehensive and simple way. A challenge that fits a MSc thesis of the TU Delft.	

Graduation project	
Title of the graduation project	Framework for the Decision Making Process of Low-Temperature Renovations
Goal	
Location:	Case study location: Purmerend, Mercuriusweg (Apartment block)
The posed problem,	The main problem that will be tackled in the research is two-fold: 1. Current research lacks information on how to **scale the LT-heating transition** a. It lacks scalability due to the widely varying difference in dwelling types, heating capacity, energy demands and consumption per household b. It lacks scalability due to the complexity of the transition, which leads to prolonged processes. Certain influences, like social and institutional, are often excluded from research but are key factors in the decision making process.

	2. It is unclear how to **select a suitable renovation concept** to switch from a HT-heating system to a LT-heating system that is **feasible to initiate renovation** a. It is unclear who is responsible for the initiative of LT-renovations b. It is unclear how to select a suitable renovation concept due to the amount of renovation measurement options and (often conflicting) criteria with varying outcomes, resulting in a complex project c. It is unclear how to select a suitable renovation concept due to the conflicting interests of the stakeholders involved
research question and	*Main question:* How can the **selection process** of **renovation concepts** that aim to make existing dwellings compatible with **low-temperature heat supply** be **decomplexed**? *Sub-questions:* 1. How are complex decisions made? a. What type of decision support methods are known and validated in scientific research? b. How are scenarios related to the decision making compared in research? c. What are the criteria involved? d. What are the decision parameters? e. Which steps are identifiable in complex decision making? f. Who makes the decision? 2. What makes a low-temperature heat supply renovation concept compatible for existing dwellings? a. What is low-temperature heating? b. What common dwelling types are identified in the Netherlands? c. Which energy renovation strategies for LT-heating are developed in the Netherlands? d. What options for renovation measurements are there to make a dwelling compatible with low-temperature heat supply? e. How can the heating demand and heating capacity of a dwelling be quickly but reliably estimated/calculated? For elaboration on problem statement and sub-questions contemplate Research Framework.
design assignment in which these result.	Hypothesis: the selection process of renovation concepts can be decomplexed through a decision support

framework, provided that all main criteria topics are taken into consideration and the renovation scenarios are diverse enough. The design for this thesis will encompass the development of the decision support framework and testing of the model. For the renovation scenarios that will be compared in the decision making framework a case study in Purmerend is used, which has a design part namely the combination of different renovation measurements applied to said case study.

For the structure of the thesis, see flowchart 1.



Flowchart 1: Thesis Structure

Process

Method description

The thesis will go through seven stages, and will deliver 5 products in total. A quick methodological overview of the thesis is provided in flowchart 2.

Stage 1

The first stage is the literature review. Within the literature review, two main topics are researched: the decision making process (methods, weighting methods, criteria, stakeholders) and LT-renovations (renovation measurements, LT-strategies, energy performance, building typologies). The collected literature comes from databases like ResearchGate, Google Scholar, ScienceDirect, TUD Repository and the TUD Library. The type of literature includes scientific papers, reports, books, PhD-theses and MSc-theses.

Stage 2

The second stage will be the evaluation of reviewed Multi-Criteria Decision Making (MCDM) methods found in literature, which is necessary to select the correct method for the decision making framework. Simultaneously in stage 2, a semi-structured interview with relevant stakeholders is set up to explore what information is necessary for said framework. The stakeholders comes from the group that worked on the renovation of the case study in Purmerend, contacts are provided by Prateek and Thaleia. The framework will be based on the information of the interviews and the literature review combined.

Stage 3

A concise cost analysis is necessary to get an overview of the economic factors of the renovation and to derive the needed input for the criteria of the framework. For the cost analysis, the case study in Purmerend will be used. [I'm working on getting the Total Cost of Ownership analysis from OverMorgen, but it is not yet certain that I'll be allowed access to that information].

Stage 4

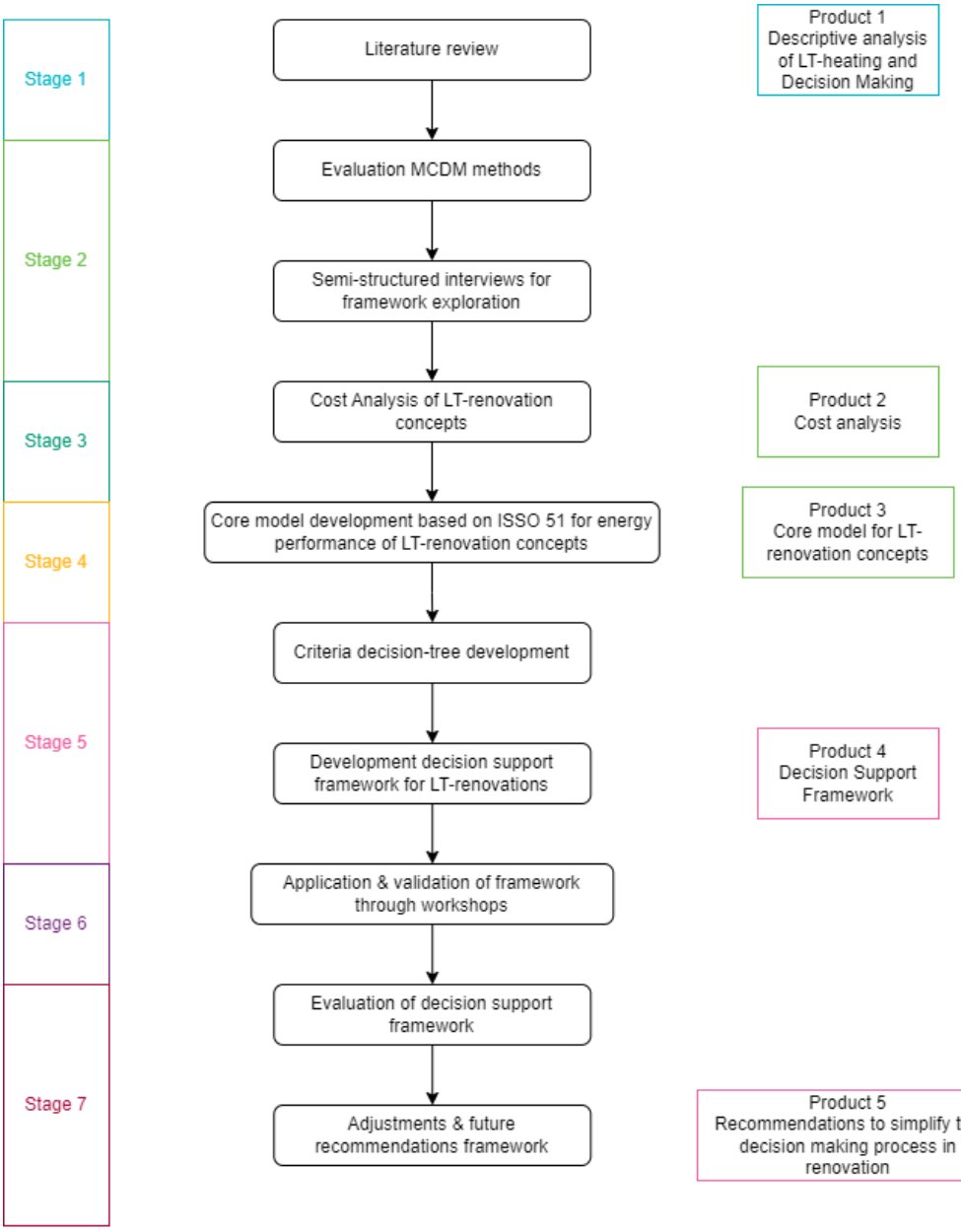
By developing a core calculation model based on the ISSO 51, the energy performance of the LT-concepts can be quickly compared and key parameters can be easily changed compared to time-consuming dynamic models. However, as a control system one dynamic simulation will be made to check the accuracy of the core model. This will probably be done through the use of DesignBuilder.

Stage 5

In the fifth stage the decision-tree for the criteria of the decision support framework will be developed. This is done with the criteria identified in the previous stages through literature study, interviews and cost analysis. The criteria will be categorized and sub-divided for easy identification of the stakeholders preferences, something that is needed for the framework development. This phase will also encompass the development of the framework, and will use the LT-concepts from stage 4 as scenario examples and the criteria decision tree as indicators for the decision making process.

Stage 6
After the development of the framework, it needs to be tested. This is done through a workshop with (if possible) the same stakeholders from phase 2. The stakeholders will determine the importance of selected criteria, and after analysis of the input a preference for a certain renovation concept will prevail. The stakeholders can validate weather the framework functions accordingly to its aim, or if it does something else or nothing at all.

Stage 7
The next stage is the evaluation of the framework: does the framework yield the desired output? Does it contribute to the decision making process? If not, what adjustments to framework can be made to make it work? Depending on the available time left for the thesis, adjustments will be made or suggestions for adjustments and other recommendations will be given.



Flowchart 2: Thesis methodology

Literature and general practical preference

Literature related to the topic of renovation in combination with the decision making process (MCDM), criteria weighting methods, stakeholders, energy planning, LT-renovation concepts and LT-renovation measurements are consulted. Besides that, information from Dutch institutions and advisory/research groups like the ECW, RES, NAT, TKI, KIV, Rijksoverheid and municipalities are consulted for their developed heat strategies, policies, budgets and general energy transition related information. Open data from the CBS and TNO is used for input of basic energy and building stock analysis. Data on the case study will be provided by Intermaris and OverMorgen. The 'methodology stage 1' elaborates on the type of databases used for the literature review and type of sources found. The following sources are deemed important to this thesis (selection of references):

Ebrahimigharehbaghi, S., Qian, Q. K., Meijer, F. M., & Visscher, H. J. (2020). Transaction costs as a barrier in the renovation decision-making process: A study of homeowners in the Netherlands. *Energy and Buildings, 215,* 109849. https://doi.org/10.1016/j.enbuild.2020.109849

Jensen, P.A., & Maslesa, E. (2015). Value based building renovation – A tool for decision-making and evaluation. *Building and Environment, 92,* 1-9. https://doi.org/10.1016/j.buildenv.2015.04.008

Kamari, A., Corrao, R., & Kirkegaard, P. H. (2017). Sustainability focused decision-making in building renovation. *International Journal of Sustainable Built Environment, 6*(2), 330-350. https://doi.org/10.1016/j.ijsbe.2017.05.001

Kennisinstituut voor Installatietechniek. (2017). *ISSO 51: Warmteverliesberekening voor woningen en woongebouwen.*

Ozorhon, B., Batmaz, A., & Caglayan, S. (2018). Generating a framework to facilitate decision making in renewable energy investments. *Renewable and Sustainable Energy Reviews, 95*, 2017-226. https://doi.org/10.1016/j.rser.2018.07.035

Pinzon Amarocho, J.A., Hartmann, T. (2022). A multi-criteria decision-making framework for residential building renovation using pairwise comparison and TOPSIS methods. *Journal of Building Engineering, 53*, 104596. https://doi.org/10.1016/j.jobe.2022.104596

Pohekar, S., & Ramachandran, M. (2004). Application of multi-criteria decision making to sustainable energy planning – A review. *Renewable and Sustainable Energy Reviews, 8*(4), 365-381. https://doi.org/10.1016/j.rser.2003.12.007

Rutten, S. (2021). *LT-READY, affordable renovation concepts that enable low-temperature heating and provide thermal comfort* [Msc thesis]. TU Delft.

TKI Urban Energy. (2022, December 8). *Kennisdossier Warmtenetten*. https://www.topsectorenergie.nl/tki-urban-energy/kennisdossiers/warmtenetten

Besides these references, my general practical knowledge I intent to consult is my network: my brother works at OverMorgen (company that did the TCO and energy performance analysis of the case study), my dad is a specialist in social housing corporations at Arcadis (to get in contact with stakeholders), I have friends who studied Science Communications (experience with MCDM) and my fellow students from BT can also support me through my thesis. Obviously I'll use relevant knowledge from the bachelor and master courses I followed, and I'll put my native language (Dutch) skills to use when communicating with the stakeholders.

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?

   The master track of Building Technology consists of four main pillars: façade design, climate design, computational design and structural engineering. The first two of those pillars have a very explicit link with this master thesis. Redesign of the building (façade, floor, roof) is necessary to make it compatible with LT-heating, and of course the redesign needs to be structurally sound. Redesign of the installations (heating, ventilation) is also necessary to make it compatible with a LT-heat supply, and interacts with the other renovation measurements of the building. Besides (re)design, changing the building physical aspects requires engineering through calculations and simulations. What combination of renovation measurements is suitable and effective depends on many factors and criteria, which differs per case and per decision maker. Decision making is the odd one out, but in a way relates to computational design: creating a (software) model/framework to help with acquiring overview and/or decision making in complex projects. Therefore it is safe to say that this thesis falls well within the scope of the MSc Building Technology master.

   This thesis also fits the description for the master programme AUBS. Although this research is done within the BT master, redesign for renovation is inherently linked to architecture, while LT-renovation closely connects to urban energy. The framework for the decision making process involves multiple stakeholders, something familiar for building management. This displays the diverse and innovative nature of the thesis, by stepping out of the usual BT framework through combining knowledge and skills with design and engineering from all tracks. This way, the thesis contributes to the building science related body of knowledge, which will eventually lead to a more sustainable built environment.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

   Social relevance

   Energy renovations often have the goal to reduce the energy consumption as much as possible. The focus lies on increasing the energy performance, while economic factors decide what renovation measurements are feasible to invest in. This tends to disregard aspects like social acceptance of the renovation, energy poverty, the level of thermal comfort residents are looking for, 'risky' but promising new technologies and the unique character of the dwelling. Disregarding those aspects can lead to resistance and polarisation within society, something that is counterproductive towards the energy transition. Most energy renovations are already complex projects and lengthy in nature, while the available time for the energy transition is limited. By creating a framework that incorporates the social and institutional aspects into the decision-making process of a renovation concept, a more balanced approach will be the result with room for conversation. Besides that, the framework will also provide structure and overview in the complex matter of renovation, making the decision-making process for stakeholders like housing corporations, energy companies, municipalities and homeowners quick and simple. The framework will bring together the different perspectives and backgrounds on

energy renovations, which will eventually contribute to the scalability of the energy transition.

Scientific relevance

Contributing to body of knowledge

In literature studies on energy planning and energy renovations, social and institutional aspects are often left out (Ahl. et al, 2020). This leaves a research gap between the interaction of qualitative and quantitative aspects of renovation concepts, and how this could potentially influence the decision making process when choosing a renovation concept. Furthermore, current literature on MCDM and energy planning often limits to one decision maker (stakeholder), while it is quite common for energy renovations to have a group of stakeholders (Pinzon Amorocho & Hartmann, 2022). This thesis will thus fill in the research gap on energy renovation and its complex decision making process in building engineering.

Building Stock

Studies on LT-renovations in the Netherlands are often focussed on terraced housing, since this is with 42% the most common building type (CBS, 2021). Building characteristics, or generalized the building type, influences the parameters for energy performance massively. By focussing this thesis on the second most common building type (multi-family covers 36% of the Dutch building stock) (CBS, 2021), it is an expansion of the research field on LT-renovations in the Netherlands.

Integrale Energietransitie in Bestaande Bouw (IEBB)

This thesis is related to the IEBB project 1.5 Collective Heat, which researches innovative solutions on how to connect neighbourhoods to collective heat networks that provides a low supply temperature.

Professional relevance

The Netherlands is in need of energy experts and people that can translate policies and strategies into renovation action. Through this thesis valuable knowledge on the energy transition, renovations strategies and complex decision making will be gained. This will contribute to filling in the current gap in the working field. Through methods like energy simulations, workshops and interviews useful skills and a relevant network will be developed that can be applied in the energy profession.

References

Ahl, A., Yarime, M., Goto, M., Chopra, S.S., Kumar, N.M., Tanaka, K., & Sagawa, D. (2020). Exploring blockchain for the energy transition: Opportunities and challenges based on a case study in Japan. *Renewable and Sustainable Energy Reviews, 117,* 109488. https://doi.org/10.1016/j.rser.2019.109488

CBS StatLine (2021). *Woningvoorraad; woningtype op 1 januari, regio*. [Dataset, 2021]. https://opendata.cbs.nl/statline/#/CBS/nl/dataset/85035NED/table?ts=1673610976228

Pinzon Amarocho, J.A., Hartmann, T. (2022). A multi-criteria decision-making framework for residential building renovation using pairwise comparison and TOPSIS methods. *Journal of Building Engineering, 53*, 104596. https://doi.org/10.1016/j.jobe.2022.104596