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Contents

Cover page

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European foreword

This CEN Workshop Agreement has been developed in accordance with the CEN-CENELEC Guide 29 "CEN/CENELEC Workshop Agreements – A rapid prototyping to standardization" and with the relevant provisions of CEN/CENELEC Internal Regulations - Part 2. It was approved by a Workshop of representatives of interested parties on 2022-MM-DD, the constitution of which was supported by CEN following the public call for participation made on 2022-02-25. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

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Introduction

In Europe, the building sector is responsible for 40% of the total energy consumption and represents about a third of Europe's CO_2 emissions. Heating and cooling accounts for 50% of annual energy consumption in EU, making it the biggest energy end-use sector ahead of both transport and electricity[1]). This is a huge socioeconomic and environmental problem, considering that roughly 75% of EU buildings are not energy efficient[2]), and that approximately 75% of heating and cooling is still generated from fossil fuels[3]). On this basis, buildings represent a large energy-savings potential, once renovated and upgraded, if the heating and cooling sector sharply reduces its energy consumption and cuts its use of fossil fuels to fulfil the EU's climate and energy goals. However, today the annual renovation rate of the building stock varies from just 0.4 to 1.2% in the Member States. According to the European Green Deal, this rate will need to at least double to reach the EU's energy efficiency and climate objectives.

Given the labour-intensive nature of the construction sector, which is largely dominated by local businesses, building renovation plays a crucial role in European economic recovery especially following the COVID-19 pandemic. To kick-start the recovery, the Commission has launched several initiatives to further support the renovation of EU buildings[2]).

To pursue this dual ambition of energy savings and economic growth, in 2020 the Commission published a new strategy to boost energy-efficient building retrofitting called "A Renovation Wave for Europe – Greening our buildings, creating jobs, improving lives". Also, the EU has established a legislative framework (which includes the Energy Performance of Buildings Directive 2010/31/EU (EPBD) and the Energy Efficiency Directive 2012/27/EU), providing direction to the future sustainable built environment by supporting low carbon energy usage in buildings.

In this context, shallow geothermal energy (SGE) is a renewable energy source (RES) with large potential to facilitate energy savings and GHG emissions reduction in the building sector and therefore help to achieve all major objectives of the EU's energy policy. Moreover, the main reference organisations - such as ECTP[4]) and RHC-ETIP[5]) - have promoted and roadmapped the cost-effective integration of RES into building technical systems. The development of effective and affordable enhanced geothermal systems (EGSs) is crucial to exploit the EU geothermal potential as a major source of energy supply for heating and cooling purposes, by targeting bottlenecks that hinder the full deployment of geothermal systems as one of the key concepts in energy efficient building retrofitting.

This CWA is motivated by the main goals of the EU Horizon 2020 GEOFIT innovation project (funded under grant agreement number 792210). It is meant to provide general management guidelines for stakeholders involved in a building retrofit project based on SGE technologies.

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1) https://ec.europa.eu/energy/topics/energy-efficiency/heating-and-cooling

2) https://ec.europa.eu/energy/topics/energy-efficiency/energy-efficient-buildings

3) Eurostat 2019

4) ECTP European Construction, built environment and energy efficient building Technology Platform

5) RHC-ETIP European Technology and Innovation Platform on Renewable Heating and Cooling

The type of SGE building retrofit project which is addressed in this CWA focuses on the technologies described below. However, it is necessary to consider that SGE building retrofitting does not explicitly require the use of all these specific technologies.

- **Information and communication technologies (ICT) tools for ground research and worksite monitoring:** non-invasive and integrated techniques for ground research, worksite and building monitoring.

  The following innovative technologies can be considered:

  — Monitoring tools capable of assessing the stability of buildings involved in retrofitting operations, for example Ground Based Interferometric Synthetic Aperture Radar (GBInSAR).

  — Radar interferometry enabling 3-D spatial measurements.

  — Ground Penetrating Radar (GPR), with automatic detection process.

  — Interface between the GPR and Web Map Services (WMS) to download/upload the underground asset maps before/after the survey.

  — Building information modeling (BIM) integration of structural building monitoring tools during drilling works.

  — Drone monitoring.

- **Drilling technologies:** adapted to the context of SGE building retrofitting:

  — Vertical drilling.

  — Trenchless - horizontal directional drilling (HDD) techniques that enable the deployment of horizontal loops like geothermal heat exchangers in this context.

- **Geothermal/ground source heat exchangers (GHEX):** with corresponding suitable configurations for SGE building retrofitting and effective installation.

  — Vertical borehole type heat exchangers.

  — Earth basket and helical type heat exchangers.

  — Shallow horizontal or slinky type heat exchangers.

- **Ground Source Heat Pumps (GSHPs):** optimized for the use of geothermal heat and building retrofit applications. As existing buildings are less flexible compared to new buildings, this issue must be addressed explicitly.

  — Hybrid (thermally and electrically driven) heat pump (HP) system for high temperature lifts which integrates better with a smaller GHEX compared to conventional systems.

  — Electrically driven HP system for high temperature lifts which integrates better with a normal sized GHEX.

  — Integration of other RES (e.g., photovoltaic and solar thermal) to increase the total RES share.

- **Heating and cooling solutions** for energy-efficient building retrofitting.
    - — Easy-to-install installed and efficient heating solutions, for example low-temperature heating (LTH) technology suitable for GSHPs.
    - — Easy-to-install and efficient cooling solutions, for example high-temperature cooling (HTC) technology enables a high coefficient of performance (COP) of GSHPs used in building retrofitting.
- **ICT based control systems and building energy management systems (BEMS)** that enables the full utilization of the EGS in retrofitted buildings by unlocking energy flexibility services using demand side response techniques.
- **BIM** enabled tools for management of SGE building retrofitting.

Considering the interoperability of the aforementioned technologies, this document provides a general methodological management framework using an Integrated Design and Delivery Solutions (IDDS) approach for the SGE building retrofitting process, adaptable to project and site specificities.

IDDS was launched in 2009 and developed as a new priority theme of the board of the worldwide CIB organization (International Council for Research and Innovation in Building and Construction or "Conseil International du Bâtiment" in French). The CIB White Paper on IDDS[6)] defines it as "*the use of collaborative work processes and enhanced skills, with integrated data, information, and knowledge management to minimize structural and process inefficiencies and to enhance the value delivered during design, build, and operation, and across projects*".

This IDDS vision extends beyond new buildings to encompass modifications and upgrades, particularly those aimed at improving local and area sustainability goals. IDDS will therefore facilitate greater flexibility of design options, work packaging strategies and collaboration with suppliers and tradespeople, which will be essential to meet evolving sustainability targets.

The four key IDDS elements are: collaborative processes across all project phases, enhanced skills of the team, integrated information and automation systems, and knowledge management.

1 Scope

This CEN Workshop Agreement (CWA) provides orientation for the management of building retrofitting projects based on enhanced shallow geothermal technologies.

This document provides guidelines for the classification of an integrated design team and the identification of the primary roles of actors among the whole project life-cycle. This document also provides a general workflow for building retrofitting projects based on enhanced shallow geothermal technologies, to be adapted or modified considering the specificities of each project requirements, and site characteristics, and stakeholder profiles involved in the process.

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6) Owen, R., Palmer, M., Dickinson, J.K., Tatum, B., Kazi, A.S., Amor, R., & Prins, M.M. (2009). CIB White Paper on IDDS Integrated Design & Delivery Solutions [328].

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2 Symbols and abreviations

BEMS Building energy management systems

BIM Building Information Modelling

BMS Building Management Systems

BPE Building performance evaluation

DHW Domestic Hot Water

EGS Enhanced Geothermal Systems

FEM Finite Element Method

GBInSAR Ground Based Interferometric Synthetic Aperture Radar

GHEX Ground Source Heat Exchanger

GPR Ground Penetrating Radar

GSHP Ground-Source Heat Pump

HP Heat Pump

HTC High-Temperature Cooling

HVAC Heating, Ventilation, and Air Conditioning

IDDS Integrated Design and Delivery Solutions

LTH Low-temperature Heating

RES Renewable Energy Source

SGE Shallow Geothermal Energy

3 Steps for an integrated approach

Building retrofitting is a complex and holistic process in which decisions should be taken by considering a large diversity of constraints, stakeholders, and specific objectives.

The integrated IDDS-based approach of a SGE building retrofitting project comprises three major aspects: people, processes, and technologies. For implementing the integrated approach of the project, three main steps should be followed (see Figure 1 for an explanatory scheme):

- **Building the project's integrated team:** The first step is to clearly identify the project team and to classify these actors according to their expertise and skills.

- **Defining project phases and identifying primary roles of the team members:** This step aims to define the main phases of the project and to identify the team responsibilities for each phase.

- **Developing a collaborative workflow schedule:** This phase aims to integrate all involved actors to develop the workflow and dataflow and to implement the BIM platform for the project site.

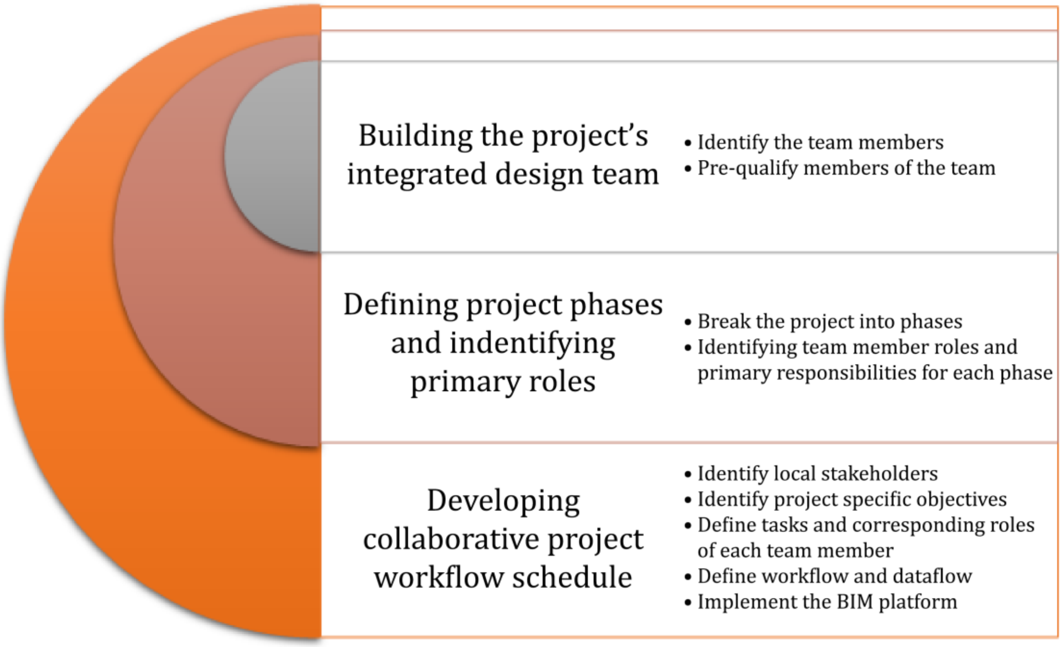

Figure 1 — Main steps for implementing the integrated approach of a SGE building retrofitting project

3.1 Building the integrated project design team

To support an integrated project approach, a building retrofit project should comply with systems associated with different kinds of users. The four main actor categories in an integrated project are (1) clients, (2) designers, (3) contractors, and (4) managers. Each of these categories encompass different types of actors. They should establish a high-level of collaboration with one another to pursue common objectives.

Within these four actor categories, those who should be considered at the earliest stage of a SGE building retrofitting project are shown in Figure 2. A variety of views, scientific or technical approaches, objectives, working methods, etc. are inherently present within a project. It is therefore necessary to define a management framework in order to deal with this diversity, to keep focus on the essentials and to ensure good communication between actors, to drive effective and collaborative work.

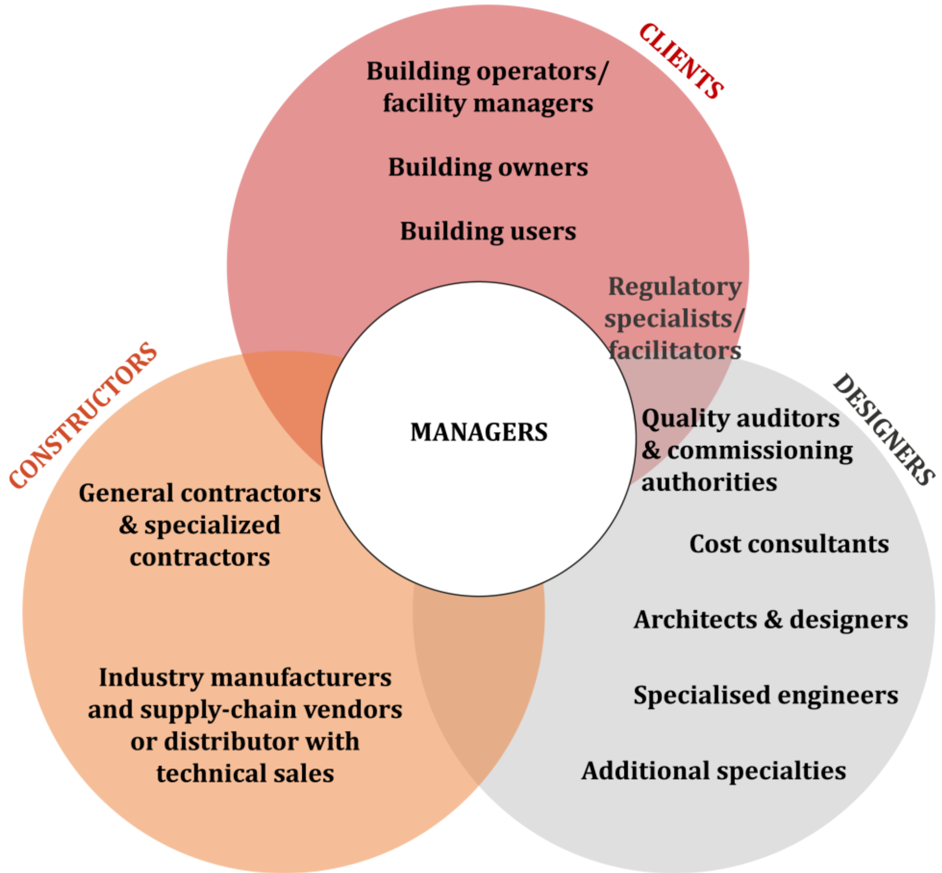

Figure 2 — Main categories and sub-categories of actors for a SGE building retrofitting project

3.1.1 Clients

In a SGE building retrofitting project, clients are broadly defined as the **local stakeholders** who are likely to be directly or indirectly affected by the intervention (building occupants) and any individual or group who may influence the management of the project. They can be for instance the building owners, the end users, the building operators, or the facility managers. All these actor profiles could interact with the building, its management and its systems after the project, and are therefore considered as clients using the systems or services provided by the project.

Building owners: According to the Integrated Project Delivery (IPD) Guide (Richard Cook 2007), building owners in particular take "*an active role in evaluating and influencing design options*". In addition, building owners may "*participate to establish project metrics at an earlier stage than in a traditional project*" and will also "*assist designers and constructors to solve issues*".

Building occupants: It is necessary to involve an occupant representative (or proxy thereof) who would be directly impacted by the retrofitting works in terms of disturbance, comfort improvement, accessibility, aesthetics, etc. The local project partners can facilitate the involvement of occupants and communicate relevant information to the project team.

Building operators or facility managers: Essential in SGE building retrofitting projects is the involvement of building operators or facility managers. Commissioning, monitoring and especially maintenance are critical during the retrofitting, but also during the building operation and the post-occupancy phases. During the construction, they can act as material suppliers. After commissioning, at least one person responsible for the building maintenance should be designated and trained accordingly or, instead, one operator and maintainer (O&M) should be outsourced.

3.1.2 Designers

Designers can be cost consultants, architects, specialised engineers (structural, mechanical, civil, environmental design and energy efficient design, geotechnical, soil, geothermal), commissioning agencies and other specialists (ecologist, daylighting, marketing expert, surveyor, R&D, consultant office) who take part in the design. As IDDS is a collaborative process, clients and contractors are also involved in the design, but they are not the appointed designers.

Regulatory specialists/facilitators: should be designated within the project team to facilitate communication between clients and regulatory authorities. A partner with appropriate knowledge of local regulation is recommended for this role, with support from geothermal and drilling specialists, local engineers and planning consultants (the latter are necessary in some countries).

Quality auditors and commissioning authorities: should be designated within the project team to oversee process quality and adequate documentation management. These actors should work in collaboration with the rest of the technical partners.

Cost consultants: should be designated within the project team to ensure that the budgeted costs are compliant with the market trends. This task is normally undertaken by the role of a quantity surveyor in many countries.

Architects and designers: are typically not very involved in a SGE building retrofitting project. More involvement would be required if major façade elements are to be considered, if internal layout of the systems is of high importance, or if it’s a major large scale renovation project. Otherwise, the technical equipment is normally concentrated in a technical room of the building, and the only visible part of the installation could be the distribution piping and the heat emitters, which are under the responsibility of the building owners. On the other hand, the drilling activities and the installation of undergrounded heat exchangers could affect the surrounding visual appearance. The aesthetic issues should be discussed with the building owners and occupants.

Specialised engineers: the design team of a SGE building retrofitting project should include the following specialised engineers:

— **Ground specialists for ground detection, drilling and excavation works.**

  These specialists are required for surveying and producing utility maps for private engineering companies, DOT and municipalities. The identification of underground utilities should include: the collection of all information in the project area, the application for the intervention authorization from the local municipality, the execution of the data collection on site, the analysis of the collected data and localisation of features, the drafting of a report (including properly formatted computer-aided design drawings), the execution of a field cross check to compare the achieved output (cartography map) with real time radar data (if required), and the final delivery the project to the client.

  They are also required to measure possible displacement of the building/structures close to the area where excavation will occur.

  Within this actor category, drilling tool designers can be also considered for the tool material and tool geometry design, and for increasing drilling tool resistance, for increasing rate of penetration, and for reducing drilling costs.

— **Specialists of ground heat exchangers design for shallow geothermal systems.**

— **Specialists of heating, ventilation, and air-conditioning (HVAC) facility design and sizing: geothermal HPs, heat storage, hydronics, emitters…**

— **Specialists of control strategies and monitoring systems.**

Control engineers or building management systems (BMS) integrators are required for controlling a BMS. Electrical engineering specialists are required for studying the impact of the SGE systems on the grid, since an increase in the peak capacity can be foreseen. They shall perform a study of the available power and the maximum additional power for the HP system. It can be necessary or recommended to modify a BMS to a building energy management system (BEMS). The best working period for the HP can be indicated by estimating the required demand for the next period (typically 24 – 48h). This is intended for the system to use electricity when it is cheapest and to avoid additional peaks on the import of net energy. When there is also local energy production (as with solar panels) the surplus of electricity should be stored as heat in a buffer tank. This functionality can be added to the local BMS or come from services in the cloud that analyse and predict consumption, production and checks the available electricity prices on a contractual basis.

Additional specialists: BIM specialists, structural health survey specialists or demand response specialists can be included in this actor category.

Regarding BIM specialists, a team focused on data curation and management is required for a digitalised project. This team should also have expertise in internet of things (IoT), simulation and artificial intelligence (AI) to support the creation of digital mirrors.

Regarding structural health survey specialists, it is recommended that they have expertise in:

— Design an excavation plans to avoid/limit vibration propagations during excavation – in cooperation with a drilling company.

— Building monitoring during the excavation phase for rapid building health assessment before and during drilling.

Other additional specialists can be required depending on the project specificities.

3.1.3 Contractors

Contractors are actors taking part in construction. They can be construction companies, a construction manager, or equipment and material suppliers.

General contractors and specialised contractors: should have operational knowledge of the different system parts. This category includes groundwork contractors, general building contractors, and mechanical and electrical (M&E) contractors.

Industrial manufacturers and supply-chain vendors or distributors with technical sales who can provide added value**:** the designer team of a SGE building retrofitting project should include suppliers of the main components of the new SGE system (e.g., GSHPs, GHEXs, HVAC systems, monitoring and control devices).

3.1.4 Managers

Managers are responsible for controlling and/or administering the entire project. Two types of managers can be considered in an IDDS project: the IDDS facilitator, and the project manager or the building program representative.

IDDS facilitators: provide guidelines for project management, “allowing team members to focus on their tasks and goals, while at the same time fostering teamwork and collaboration” (Clark 2003).

The IDDS facilitator should work jointly with the project manager and with all team members to check that initial goals are in line with client needs, using workshops for periodic checkpoints.

Project manager: should act as supervisor to ensure good communication between the different actors and to provide oversight according to the schedule and budget established.

The project manager should ensure actor cooperation and trust in the IDDS process to ensure the project progresses correctly.

Geothermal specialists should provide feedback on technical choices and propose innovative options to be considered by the project team.

3.2 Defining main phases and identifying primary roles in the SGE building retrofitting project

3.2.1 Project life-cycle phases

This section provides a brief summary of each phase in a building retrofitting project life-cycle (see Figure 3 for a visual explanatory scheme):

— **Strategic definition.** This phase aims to identify the owner's business cases, strategic brief and other core project requirements, review feedback from previous projects and fix the initial consideration for assembling the project team.

— **Pre-design.** This phase consists of preparing the project objectives, quality objectives, project outcomes, sustainability aspirations, project budget and risk assessments. This is done through meetings and workshops that aim to foster creativity and interdisciplinary thinking. The objective is also to establish communication pathways. Then this phase will find agreements on schedules, design responsibilities, communication strategies, common standards and to continue assembling the project team. Feasibility studies and review of site information are also stated.

— **Concept design.** This phase consists of preparing the concept design, including cost information and project strategies in accordance with program design. It fixes the sustainability strategy, maintenance and operational strategy, handover strategy and construction strategy including health and safety strategy. Consultations are undertaken on research and development (R&D) aspects. In this phase actors should seek agreement on the final project brief.

— **Technical design.** This phase consists of developing design, cost information and project strategies in accordance with design program. It reviews and updates previous strategies.

— **Detailed engineering.** This phase prepares technical design in accordance with design programme. It also prepares and submits building regulations and other third party required consent. Finally, this phase reviews and updates project execution plan.

— **Construction** (offsite and onsite). In this phase the team must resolve design queries and prepare the "as-constructed" information.

— **Commissioning and handover.** Building operation consists of ensuring the handover of the retrofitted building to the building owner and/or operator and therefore execute the conclusion of the intervention contract.

— **Post-occupancy.** During this phase, feedbacks are collected through a monitoring and assessment period.

Normally, a **tendering stage** is needed once a procurement-ready design package is finally designed. This involves choosing the procurement methods, packetization, market research, method for awarding contracts, contractual frameworks (JCT, NEC3) and contractual negotiations.

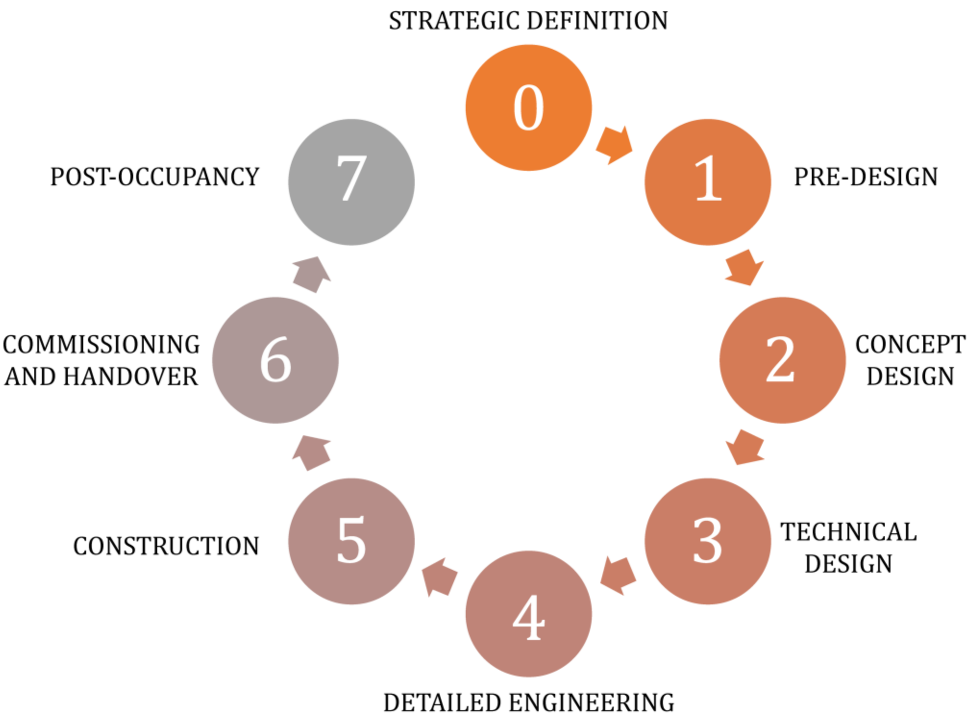

Figure 3 — Building retrofitting project life-cycle

3.2.2 Primary roles of actors

This section provides, within the Table 1, the description of the specific tasks that should be carried out by each subcategory of actors during each specific project life-cycle phase. This is not intended to be an exhaustive list but an orientation to be adapted according to the specific project needs.

Table 1 — Primary of roles of actors during each specific project life-cycle phase

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
MANAGERS							
PROJECT MANAGER, BUILDING PROGRAM REPRESENTATIVE	— Work with the client to kick-start the project and coordinate the team	— Ensure effective communication between team.	— Help the team stay on schedule and on budget. Ensure new team members have necessary information.	— Help the team stay on schedule and on budget. Ensure new team members have necessary information.	— Help the team stay on schedule and on budget. Ensure new team members have necessary information.	— Ensure a seamless handover to the client	
IDDS FACILITATOR	— Work with Project Manager and architect to set up initial goal setting workshops	— Facilitate workshops - Ensure that adequate Documentation is provided so the team can remember their deliverables & goals.	— Continue to facilitate workshops – evolve the format to reflect the progress of the design process	— Continue to facilitate workshops – evolve the format to reflect the progress of the design process			— Work with the building performance evaluation (BPE) team to help them understand how goals were set, what they were, etc.
CLIENTS							
BUILDING OWNERS	— Hire motivated & experienced team — Communicate project vision & goals — Explore the regulatory feasibility of possible retrofit strategies	— Work with team in decision-making process — Ensure Project funding sources	— Help team make decisions that confirm goals & reflect life-cycle thinking	— Help the team to ensure that decisions made in previous stages are not lost with the value engineering process	— Get involved in the construction progress — Check that all construction phases progress as expected	— Facilitate operation staff coordination and user training — Verify the expected behaviour of the system	— Work with the professionals involved to execute monitoring and building performance evaluation

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
BUILDING USERS, OCCUPANTS	— Collaborate in requirements elicitation with the design team by expressing their needs and expectations at an early stage	— Participate fully in design workshops. Use the opportunities to express opinion on design alternatives — Listen to the team's expertise	— Continue to participate in design workshops when feedback is needed		— Get involved in the construction progress, if it provides added value.	— Receive training to ensure proper and safe facilities use.	— Work with the BPE team to help them understand how the building is working – both the good & bad
BUILDING OPERATOR AND FACILITY MANAGERS	— Collaborate in requirements elicitation with the design team by expressing their needs and expectations at an early stage — Help building owner to explore the regulatory feasibility of possible retrofit strategies	— Participate fully in design workshops. Use these opportunities to express opinions on the building and lessons learned from operating other buildings. — Listen to the team's expertise	— Continue to participate in design workshops. Review design documents as needed	— Continue to provide reviews as needed.	— Site visit to ensure project specifications are met — Check that all construction phases progress as expected		— Work with BPE team to help them understand how the building is working – both the good & bad
DESIGNERS							
REGULATORY SPECIALISTS/FACILITATORS	— Facilitate communication between clients and regulatory authorities. — Provide guidance on the applicable local regulation.						

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
QUALITY AUDITORS AND COMMISSIONING AUTHORITIES		— Work with the design team & owner to ensure that the project goals are being incorporated into the design documentation	— Provide review functions as required to ensure proper integration of needs & requirements	— Continue to provide review functions as required to ensure proper integration of needs & requirements	— Review select contractor submittals, as applicable. — Keep communication lines open between owner, contractor and design team	— Ensure that sufficient time is allowed for hand-over training & commissioning activities	— Participate in BPE
COST CONSULTANTS	— Assist team to set realistic budget, bearing in mind current market conditions.	— Help the team to understand what choices may help keep costs under control	— Assist team with life-cycle-cost analysis — Ensure that both costs and credits for proposed technologies are accounted for	— Assist team with updated cost estimates	— Review final bid documents with the design team		

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
SPECIALISED ENGINEERS (GENERAL)	— Provide feedback on each design choice — Work with the design team to find environment-specific opportunities & features that answer building specifications — Help the team consider new options	— Provide input into the discussions on respective topics (energy, light, materials, environment, water, air quality, landscape, access, grid...) — Help the team to understand local specificities and how to take advantage of it — Assist thanks to engineering tools	— Provide input into discussion by performing calculations, simulations, analysis — Work with the design team to refine choices to stay within the established targets — Plan strategy geological test requirements and potential design changes — Coordinate with project manager impact on scope, schedule and cost of the required changes if decided (dealing with geological uncertainty)	— Work with the design team to refine system choices to stay within the established targets — Perform simulations calculations, simulation, analysis — Ensure that equipment selections, materials selections, and construction methods reflect sustainable goals — Update studies to reflect latest design — Aid in value engineering process	— Work with the contractor to ensure compliance with new strategies/ technologies — Design and coordinate the construction and monitoring of experimental mock-ups when needed — Prepare and submit compliance model as required — Quantify impact of changes during construction — Participate for certification	— Participate in commissioning & user and operations staff Training to ensure proper handover. — Work with operations staff to understand optimisation options	— Perform or participate in BPE — Engage in BPE studies, including evaluating differences between simulation model and built environment. — Work with the team to understand differences between modelled & actual data — Work to spread information on results within industry

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
— Ground specialists for ground detection, drilling and excavation works.	— Kick off with the Project Manager — Collection of all the information of the project area e.g. dimension, critical issues, cartography maps (digital or printed) with the utilities, rock/soil materials, etc.	— Application for the authorization, from the local municipality, to access the job site — Design of the survey considering installation and site constraints — Prepare the equipment — Selection of drilling tools (materials and geometries)	— Execution of the survey for identifying the underground utilities in the excavation area	— Perform data analysis and produce a cartographic map of the underground utilities — Eventually execute a further on-site inspection to validate the results — Provide input to the installation designers	— Install a monitoring equipment to verify in real time possible displacement of buildings/structures during the excavation — Run the system and check the results — Drilling works monitoring (rate of penetration)	— Quantify drilling tools performance	— Analyse drilling tools damaging mechanisms to improve future tool material and geometries designs

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
— Specialists of ground heat exchangers design for shallow geothermal systems	— Collect and evaluate relevant information from building and HVAC system design team — Collect and evaluate information from environment agency — Collect and evaluate information on geological conditions and ground thermal parameters — Collect and evaluate information on hydrology	— Assess different GHEX options and select appropriate GHEX technology for project	— Perform design calculations regarding the Ground Source Heat Exchanger design framework). — Establish materials, parameters and dimensions of design in report and drawings.	— Tender drilling / excavation works — Check site anomalies (water/electricity) are available — Perform risk assessment and health and safety checks — Coordinate site access and	— Coordinate GHEX installation — Verify installation according to specifications	— Monitor GHEX operation and verify operating conditions within design limits and within legal limits	

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
— Specialists of HVAC facilities design and sizing: geothermal HP, heat storage, hydronics, emitters…	— Collect information on requirements from the project team and provide feedback. — Consider the limitations arising from the current state of the building — Evaluation of what is required from the system based on standards and norms	— Participate in design workshop — Provide options for technical solutions for the respective field — Low-level estimation of the pros and cons of each option	— Review the most suitable options for the technical solutions based on calculations or modelling — Share information on costs and delivery time of respective components — Preselection of system components	— Sizing and design of the selected HVAC-system components following standards and established practices — Share information on the components chosen (size, connection details, control variables, standards to be met). — Determine the control strategy of the system	— Provide components according to project plan — Sharing installation instructions with installers — Ensure correct installation of the system	— Participate in commissioning to ensure correct operation — Provide instruction material and guidelines for operators — Check proper operation of the respective components — Train the end-users to operate the system optimally — Support with questions and problem-solving regarding operation and maintenance	— Monitor the performance of the system to validate the estimations made during the design phase — Provide technical service and maintenance — Assist Engineers to understand differences between model and operation — Analyse the design process to improve future projects

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
— Specialists of control strategies and monitoring systems	— Definition of pre monitoring data gathering, sensors installation — Assist Loads calculation using monitoring data — Propose sub metering — Energy price schemes available — Advise on infrastructure to support M&V strategy and KPIs	— Assist on general decision on BMS architecture or ICT solution technology options and constraints — Advise on infrastructure to support M&V strategy and KPIs	— Define control strategy and BMS components — Study the impact of the HP system on the BMS — Define a Data Management plan	— Detailed design of sensors and field components — Detailed design of BMS-ICT topology — Define and coordinate commissioning sequence, tasks and responsibilities with M&E installers — Define the flexibility that is needed to limit the power needed from the grid	— Installation and provision of ICT, sensors and BMS components in coordination with M&E installers — Foresee time for optimization and for training the control algorithms	— Commissioning of previously installed ICT, sensoring, and BMS components — Calibration of sensors — Control logic programming and testing with final geothermal system installed — Demonstration and training to clients and final users — Handover of BMS-ICT manuals	— Continuous monitoring of data — Providing data back-up — Providing standardized performance monitoring reports as agreed during — Tune in of control logic according to real usage patterns of the facility — Additional feature requests from customer or as added value offers as part of post-sales or O&M contract
ADDITIONAL SPECIALTIES (GENERAL)	— Bring broad knowledge to the table (green design strategies, daylight, marketing…)	— Start working with modelling or analysis to help team understand impacts of choices in different fields	— Direct team when needed - Complete analysis	— Ensure that design features and choices are well documented in specs & drawings so contractors can easily follow requirements	— Work with the contractor to ensure compliance with new Strategies/ materials.	— Participate in commissioning & user and operations staff training to ensure proper handover	— Participate in BPE. — Work to spread information on results within the industry

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
— Demand-response specialists				— Check the impact on the capacity of the grid		— Check the used capacity of the grid	— Periodic peak reporting and evolution
— Structural health survey specialists	— Work with the design to analyse all the main building structural features to better asses the whole design of the geothermal retrofitting in order to avoid any damage from the excavation activities on site — Coordinate the actions with the Project Manager — Help to identify required structural health test	— Drafting the drilling strategy to avoid/limit vibration propagation through the building — Participate in design workshops. and express opinions about the structural health of the building	— Continue defining the drilling strategy by doing building FEM analysis or others. — Work with the design team to refine choices and prevent structural damages during construction	— Perform simulations calculations, simulation, analysis — Work with the technical design team to refine choices and prevent structural damages during construction — Making the strategy ready to be implemented on site by proper technical report, technical drawings (e.g. plan of excavation), and so forth	— Making on site data acquisition to evaluate the building behaviour during the excavation activities	— Participate in commissioning & operations	— Perform or participate in BPE

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
ARCHITECTS AND DESIGNERS	— Ensure that other consultants are part of early consultations, especially on building form & programming — Provide input into site-specific opportunities and risks.	— Work with the design facilitator to schedule workshops early to gain maximum benefit	— Coordinate strategies and help to present information on pros and cons of design solutions	— Ensure all design features are well documented in specs & drawings so contractors can easily follow requirements	— Work with the contractor to ensure compliance with new strategies / technologies	— Participate in users and operations staff training to ensure proper handover	— Perform or participate in BPE
CONTRACTORS							
GENERAL CONTRACTORS AND SPECIALISED CONTRACTORS	— Depending on procurement process engage in the project as early as possible to provide a perspective and discussion on project feasibility — Help design team to understand key risks related to equipment choices and construction feasibility	— Help design team with design decision informing about constructability, equipment choices and early risk detection of all design choices considered	— Work with the design team to accurately cost differences in construction methods, materials, etc. based on current market conditions	— Review and feedback the detailed engineering documents	— Execute project work according with detailed engineering project specifications — Work proactively with the design team in case alternative solutions or change orders arising from geological conditions	— Work with the design team to ensure that a smooth handover to facilities staff is possible — Help with education of users and facilities staff	— Work with BPE team to support them regarding special construction methods used, etc.

PHASES / ACTORS	(1) PRE-DESIGN	(2) CONCEPT DESIGN	(3) TECHNICAL DESIGN	(4) DETAILED ENGINEERING	(5) CONSTRUCTION	(6) COMMISSIONING AND HANDOVER	(7) POST-OCCUPANCY
INDUSTRY MANUFACTURERS AND SUPPLY-CHAIN VENDORS OR DISTRIBUTOR WITH TECHNICAL SALES	— Give indication of general production time of equipment — Give indications on prices for different equipment options			— Support detailed engineering with equipment test data or sizing alternative loads or operating points.	— Verify GHEX materials according to design specifications		

3.3 Developing a collaborative workflow schedule

For each project, a specific detailed workflow should be developed for a collaborative and integrated approach to SGE building retrofitting. Due to the specificities of each site, the roles, actions and interactions of each actor can differ from one project to another and also all along the phases of the same project. The organization of the workflow can depend on national tender regulation issues, specific roles of actors and stakeholders, technical specificities of the site, and finally complexity of the technical solutions.

For developing a general workflow, a model SGE building retrofitting project can be divided into four main categories of technical activities. These categories are represented in the Figure 6 and are listed as follows:

— Building envelope retrofitting activities.

— Geothermal activities from study to installation of GHEX.

— HP and distributing system activities.

— Smart piloting and monitoring activities.

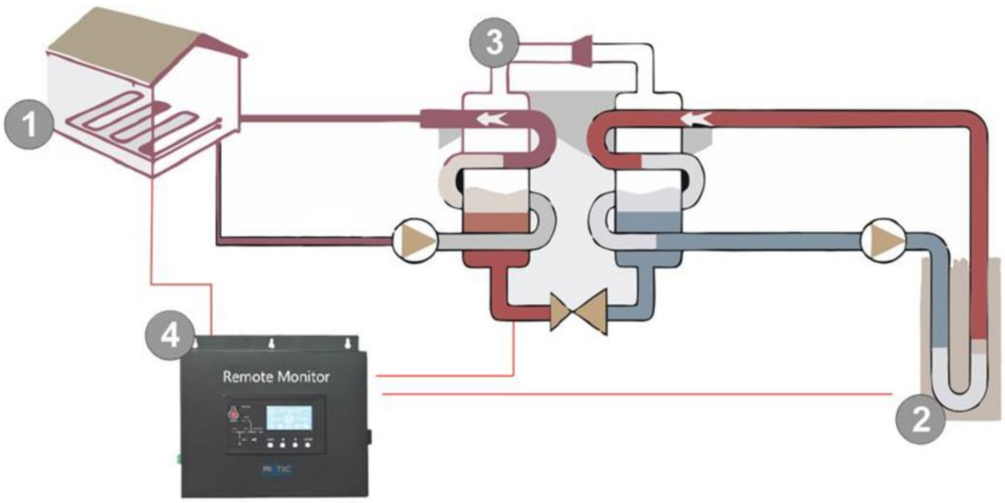

Figure 4 — Main categories of technical activities for a building retrofitting project based on enhanced shallow geothermal technologies. 1- Building envelope retrofitting activities, 2- Geothermal activities from study to installation of GHEX, 3- Heat pump and distributing system activities, 4- Smart piloting and monitoring activities

The development of a specific detailed workflow for a project can be based on the general workflow represented in Figure 5. This general workflow provides both information on the process and on the data types to be processed at every phase of the project.

The **general concept design** and the definition of the objectives are considered as a prerequisite.

The next step is the **collection of data** required for the establishment of a baseline (reference situation of the building). This includes information from on-site audits, collection of monitoring data, simulations, and energy consumption data. The operating parameters of the current energy systems are also analysed, as well as the site conditions and geology related parameters.

Once the data are collected, one of the first steps of the **concept design analysis** should be the geothermal studies, which include GHEX technology selection, thermal and hydraulic design, followed by an optimization and sensitivity analysis. This feasibility of the selected optimal solution should then be analysed. In the case of a positive evaluation, these first stages of geothermal design should be validated and included in a design document.

A similar approach is done in parallel with other concept design activities: HP and heat distribution systems, building energy retrofitting measures, monitoring and smart piloting design.

All these concept design analyses shall be carried out while considering the current national regulation context, which will determine in some cases what is possible and what is not.

When the concept design analyses are finalized, the potential need for a permit application should be considered. When the permit is obtained, it is possible to start the technical design stages.

The **technical design** should involve a detailed design carried out simultaneously on every technical component of the SGE building retrofitting solution: building envelope retrofitting, shallow geothermal systems, HP and heat distribution systems, piloting and monitoring systems. If the detailed designs of the components are consistent enough, a common **execution plan** can be produced and submitted for approval. If approved, the technical design documents should be produced and should serve as the main outputs of the design stages.

During the subsequent **construction stage**, the manufacturing, supply and installation of each technical component should be done (see Figure 5, right side). Once the construction of all the components is finalized, it is then possible to proceed with the handover and commissioning stages.

This integrated general approach, implemented in detail or modified for each specific project, should ensure that the four main component developments (building, geothermal, HP + distribution, piloting/monitoring) are executed in parallel but not independently. The actor collaboration (building owner, main contractor, design teams, industrial partners, subcontractors) should ensure the consistency of each component within the whole SGE building retrofitting solution.

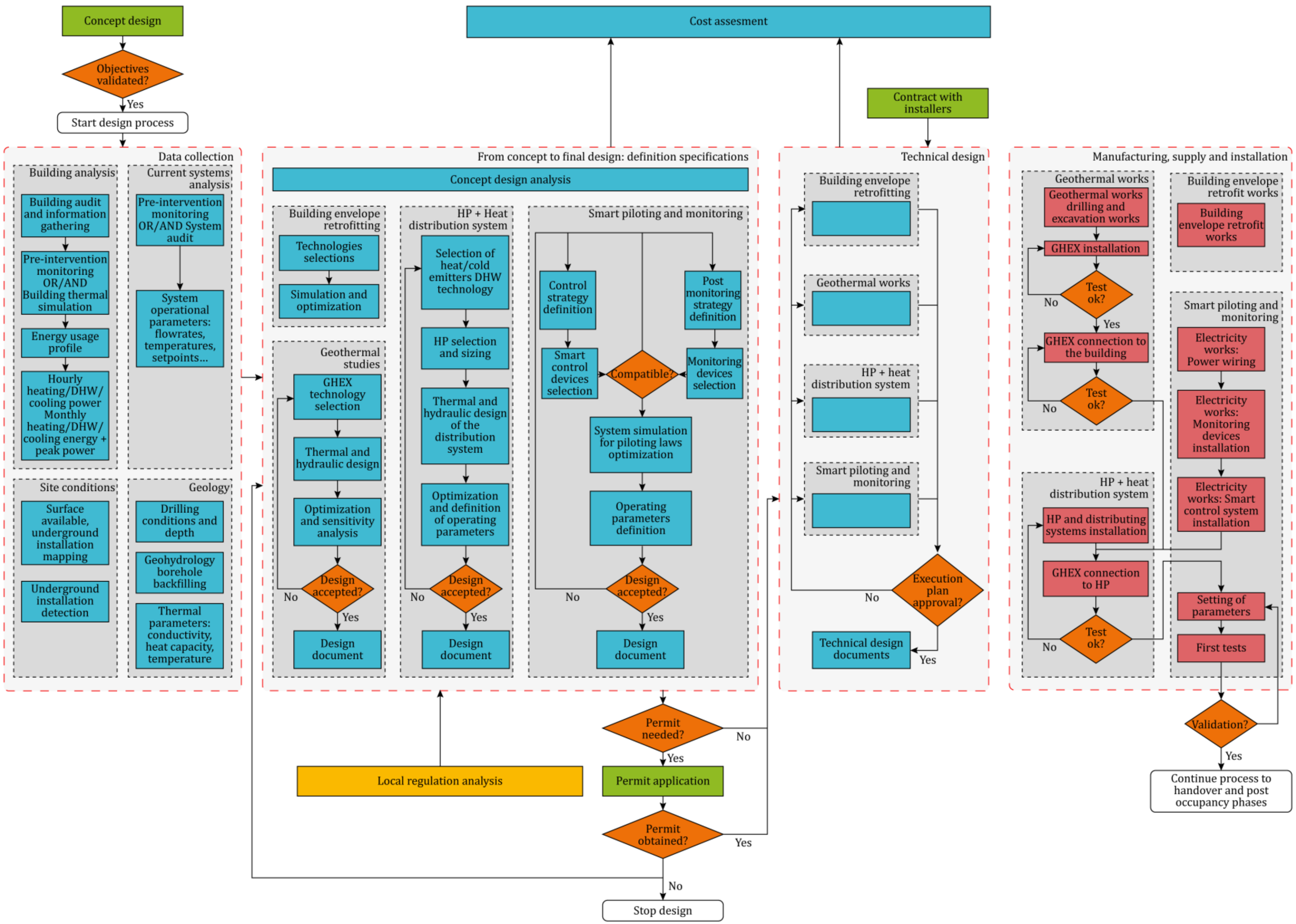

Figure 5 — General workflow/dataflow for a SGE building retrofitting project