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WP6

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Publishable summary

The Environmental Impact Assessment assesses the positive and negative impacts of the project technologies on both the natural and human environments. The principal objectives of the task and the completion of the outline EIA are to:

- identify and/or predict the significant impacts of a development;
- identify what mitigation measures should be incorporated into the development to eliminate or reduce the perceived impacts;
- communicate and implement any mitigation strategies identified both in technical and non-technical terms;
- assist the project partners in developing improved long term strategies for commercialising the project technologies

The Outline EIA Deliverable 6.2 is structured in 2 main parts:

Part A describes the general methodology and structure of the outline EIA implemented which is based on a reduced implementation of a normal EIA for this assessment and outlines both the level of the study undertaken for each topic and those chapters that have been deemed communal. This methodology includes the application of a detailed risk register for each of the real cases.

Part B outlines results of the assessment for each of the real case study sites and describes in more detail any mitigation strategies specific to each site following the completion of the installations.

Abbreviations

BHE	B orehole H eat E xchanger
Cheap-GSHPs	Cheap and Efficient Application of reliable Ground Source Heat Exchangers and Pumps
DHW	Domestic Hot Water
EIA	E nvironmental I mpact A ssessment
GEO4CIVHIC	Most Easy, Efficient and Low Cost Geothermal Systems for Retrofitting Civil and Historical Buildings
GHE	Ground Heat Exchanger
GSHP	Ground Source Heat Pump
GW	Groundwater
LGV	Light Goods Vehicle
LVIA	Landscape and Visual Impact
HE	Heat Exchanger
HGV	Heavy Goods Vehicle
PPV	Peak Particle Velocity
PM10	Particulate Matter 10 micron

Part A – Scope of the EIA, Methodology & Common Chapters

A.1. Introduction

A reduced outline EIA methodology based on that previously adopted in the Cheap-GSHPs project has been implemented to assess the impacts of the GEO4CIVHIC technologies implemented at the four real case study sites to both the construction and expected operational phases of the innovative drilling systems and GHEs developed as well as the installation of the innovative heat pumps.

The outline EIA follows part of the methodology implemented in the completion of EIAs for major projects. A reduced scope has been implemented as part of this assessment to cover the chapters outlined in table 1. The scope of each chapter and the methodology for assessing the impacts as part of the common methodology is described in Part A of this document. The construction phase comprising the drilling and installation of the GHEs at the real cases share strong similarities. These include:

- The implementation of 2 No. drilling methodologies using a Hydra Joy-3 with the Hydra-RED and/or Hydra-TKI;
- the same equipment mobilisation and logistics for the real cases
- similar site operational logistics and plant machinery requirements.

As part of the reduced scope methodology, common chapters were implemented as shown below. These principal data sources for the assessment comprise completed deliverables, working documentation from specific WPs and background information comprising equipment specifications as well as publicly available and published data for the individual locations (air emissions, landscape views, traffic, geology and hydrogeology).

Table 1 – Case Study site outline EIA Methodology

Chapter Title	Chapter Type	Outline EIA Assessment Method	Section	Principal Data Sources
Case Study Site Summary	Site Specific	Desktop	Part B	WP5 information
Project Description	Site Specific	Desktop	Part B	D3.2, D3.3, D3.4
Soils and Geology	Site Specific	Desktop	Part B	T5.1
Hydrology & Hydrogeology	Site Specific	Desktop	Part B	T5.1 & Case Study Input sheets
Air Quality & Climate	Common	Desktop	Part A	D2.1, D2.2, D2.3 & Specific Data
Traffic and Transportation	Common	Desktop	Part A	WP5 & Specific Data
Noise & Vibration	Common	Measurement	Part A	D2.2, D2.3 & Specific Data
Landscape and Visual	Common	Desktop	Part A	Case Study Input Sheets

The common chapters referred to in the table above are presented in Part A of this document (§A.3). The individual assessment and resulting impacts for the site specific chapters is discussed in Part B of this deliverable.

A.2. Assessment Methodology

The methodology implemented as part of the outline EIA assessment covers the standard implementation of the methodology followed under the EU Directive 2014/52/EU on the assessment of the effects and impacts of public and private projects. The workflow defines three key parts for the assessment (figure 2.1).



Figure 2.1 Outline EIA Methodology

The definition of the baseline conditions at each real case study has been defined based on implementing a desktop assessment of the case study input sheets (ref T5.1) and through researching additional background information.

The proposed development is described in each case based on the following scope of work being implemented:

- The use of the drilling method for the installation of the GHEs
- The type of GHE installation and the detailed completion method
- The Heat Pump solution implemented and expected operational profile
- The scope of any refurbishment works undertaken at the specific sites

Real Case Risk Assessment Register

In order to define the impacts associated from the proposed developments at each site, a detailed risk assessment is implemented and reported as a Live Register. The objective of the Live Risk register is to use this throughout the project implementation process in order to facilitate the project construction phase, allow mitigation measures to be defined and modified throughout the implementation process and facilitate communication between the all of the parties involved with the design and construction of the real cases.

The live risk register for each of the cases is based on a standard project risk assessment methodology used by GeoServ in the implementation of turnkey geothermal project solutions. The register considers different project implementation aspects within the frame of the EIA chapters and baseline condition definitions and is reported individually for each real case. The current status of the live risk registers and their implementation is provided in more detail in Appendix A.

The following risk definition categories are defined in the risk registers in line with the topics covered as part of the EIA:

- General health & Safety
- Drilling and GHE installation
- Surface Groundworks
- Mechanical and Electrical Installations
- Operational Phase

Qualitative Impact Assessment

The methodology applied in the identification and assessment of the potential impacts in all the relevant topics comprises a qualitative risk assessment in which the probability of an impact occurring and the magnitude of the impact, if it were to occur, were considered. An outline of the matrix applied to determine this is outlined in table 2 below. This approach provides an indication of the *sensitivity* of the receptor and the *magnitude* of the impact or change.

Table 2: Matrix used to Assess Risk to the Receiving Environment

Probability of Occurrence	Significance of Potential Impacts			
	Significant / Pro-found	Moderate	Slight	Imperceptible
High	High	High	Medium	Low
Medium	High	Medium	Low	Near zero
Low	Medium	Low	Low	Near zero
Negligible	Low	Near zero	Near zero	Near zero

The individual magnitude of the expected impacts under the various EIA headings is outlined in the subsequent sections of Part A of this document.

The assessment under the common chapters is also undertaken in the sections below.

A.3. EIA Chapter Definitions

This section presents an introduction to the general content in each section of the EIA and presents the impact assessment for the common chapters.

Chapter 1- Summary of the Development

The first chapter of the EIA provides a short summary of the individual case study sites, the description of the surrounding area, and a summary of the proposed development.

Chapter 2 - Project Description

The project description chapter gives a detailed description of the work to be undertaken at each site, focusing on the construction operations including the drilling and GHE installation as well as the surface connections, the installation of the heat pump. The description presents the expected renovation work and discusses the final operational phase of the installed system.

Chapter 3 - Soils and Geology

The baseline geology at each site is assessed in this chapter and the potential geological impacts associated with the installation and operations of the GEO4CIVHIC technologies (chapter 2) are assessed and identifies how the impacts can be mitigated based on the matrix presented in table 2. The information presented in this section is derived from T5.1 and the case study input sheets provided by the partners that define the baseline geological environment at all the sites. The magnitude and the significance of the potential impacts on soil and geology are outlined in Table 3 below.

Table 3: Magnitude of Potential Geological Impacts

Significance	Description of Potential Impact	Nature of Potential Geological Impact
Imperceptible Impact	An impact capable of measurement but without noticeable consequences	No impact or alteration to existing geological environments.
Slight Impact	An impact which causes noticeable changes in the character of the environment without affecting its sensitivities	Some loss of rock or soils with no long term impact.
Moderate Impact	An impact that alters the character of the environment in a manner that is consistent with existing and emerging trends.	Slope failure or instability which may cause foundation problems; Loss of extensive areas of peat or agricultural soil; Damage to geological structures / features.
Significant Impact	An impact which, by its character, magnitude, duration or intensity alters a sensitive aspect of the environment	Slope failure or instability which causes significant damage to property. Permanent degradation of locally or regionally important geological feature.
Profound Impact	An impact which obliterates sensitive characteristics	Slope failure or instability which causes loss of life; Permanent degradation and loss of nationally important geological feature.

Chapter 4 - Hydrology and Hydrogeology - Methodology

The hydrological and hydrogeological baseline conditions are described based on the inputs defined in T5.1 by each real case study partner. The potential impacts generated by the installation and the operational phase of the projects are assessed based on the matrix in table 4. The definition of degrees of magnitude of potential impacts in terms of hydrogeology and hydrology are detailed in Table 4. The individual case study site risk registers provide recommendations for mitigation measures to reduce or eliminate any potential impacts.

Table 4: Magnitude of Potential Hydrogeological and Hydrological Impacts

Magnitude	Examples of Potential Impacts
Negligible	<p>No impact or alteration to existing important geological environs;</p> <p>No alteration or very minor changes with no impact to watercourses, hydrology, hydrodynamics, erosion and sedimentation patterns;</p> <p>No alteration to groundwater recharge, flow mechanisms or water levels; and</p> <p>No pollution or change in water chemistry to either groundwater or surface water.</p>
Mild	<p>Some loss of soils with no long term impact;</p> <p>Minor or slight changes to the watercourse, hydrology or hydrodynamics;</p> <p>Changes to site resulting in slight increase in runoff well within the drainage system capacity;</p> <p>Minor changes to groundwater recharge, flow mechanisms or water levels;</p> <p>Minor changes to erosion and sedimentation patterns; and</p> <p>Minor changes to the water chemistry.</p>
Moderate	<p>Slope failure or instability which may cause foundation problems, loss of extensive areas of peat or agricultural soil, damage to important geological structures/features;</p> <p>Some fundamental changes to watercourses, hydrology or hydrodynamics; Changes to site resulting in an increase in runoff within system capacity;</p> <p>Moderate changes to groundwater recharge, flow mechanisms or water levels;</p> <p>Moderate changes to erosion and sedimentation patterns; and</p> <p>Moderate changes to the water chemistry.</p>
Severe	<p>Slope failure or instability which causes loss of life, permanent degradation and loss of important geological feature.</p> <p>Wholesale changes to watercourse channel, route, hydrology or hydrodynamics; groundwater flow regime or water levels;</p> <p>Changes to site resulting in an increase in runoff with flood potential and also significant changes to erosion and sedimentation patterns; and</p> <p>Major changes to the water chemistry or hydro-ecology.</p>

Chapter 5 - Air Quality – Common Chapter

The potential impact of the GEO4CIVHIC drilling and GHE installation as well as the operation of the heat pumps at the different cases based on local monitoring data available in the vicinity of the case study sites. The chapter describes the scope, assessment methodology, the likely environmental effects; the mitigation measures required to prevent, reduce or offset any significant adverse effect.

A.3.1.1 *Impact Assessment and Evaluation methodology*

Air quality in the context of impact assessment as part of an EIA is considered against national and international standards, objectives, target values and limit values. These are typically outlined in the national, regional and local air quality strategies as well as standards and objectives. The EU Ambient Air Quality Directive and fourth Daughter Directive contain Limit Values and Target Values. The impact of a proposed development considered in an EIA is assessed based on local monitoring data in proximity to the site where the development is proposed, in the context of the expected construction operation emission (§3.5.1.1 & §3.5.1.2) and those generated as part of the long term operation of the plant (§3.5.1.3).

A.3.1.1.1 *Construction Phase - Fugitive Emissions - Dust*

The principal air quality impacts associated with the proposed development are fugitive dust emissions during the temporary construction phase (drilling operations and heat exchanger installation). Dust in the air has always been a natural occurrence. The action of wind over dry ground will carry small particles into the air. Although large emissions of dust occur naturally, man-made dust events such as construction works can increase these emissions. Dust is defined as particulate matter in the range 1 - 75µm. The particles of dust between 1 and 10µm are known as particulate matter <10µm (PM10), or ‘suspended particles’ for which there are standards for the protection of health, these occur predominantly as a result of combustion. Particles larger than 10µm, tend to deposit close to source and are associated with public perception and nuisance, where settled particles show up as deposits on clean surfaces such as cars and window ledges.

Dust may be generated by the drilling and grouting operations, the surface pipework trenching and back-filling, the most common concern regarding dust emissions is the potential nuisance effect from the larger fraction (greater than 10µm in diameter).

A.3.1.1.2 *Construction Phase Vehicle Traffic/ Diesel Generators Emissions*

Vehicle exhaust emissions resulting from traffic generated by the construction phase from the engine used to power the drilling unit, the operation of compressors and excavators as well as site deliveries, may have the potential to temporarily affect local pollution levels. No direct combustion emissions are expected during operation of the proposed development.

The pollutants of greatest concern in respect of the impact on public health, which are found in the exhaust emissions of road traffic and plant, are NO₂, PM₁₀, CO and benzene. Of these pollutants, NO₂ and PM₁₀ are present in the highest concentrations relative to air quality standards

The assessment of traffic related impacts is undertaken using the screening methodology. The qualitative assessment has been undertaken and the fugitive emissions from the plant equipment used at the construction phase are used.

The assessment criteria included reviewing the standard measured emissions from the following equipment:

- Hydra drilling machine engines
- Air compressors (where applicable – Greystones case study site only)
- Small 6t excavator for surface connections and rod handling system

The JOY 3 drilling rig is equipped with an IVECO N67 MNT series 6, cylinder 129kW air cooled diesel engine that meets EU Stage V and emissions standards.

Table 5: Drilling unit engine exhaust gas emission related to type of operation

Exhaust gas flow(max) m ³ /min	Prime (50Hz)	Stand- by (50Hz)	Prime (60Hz)	Stand-by (60Hz)
	10,5	11,4	13,5	14,3

Table 6: Drilling unit engine fuel consumption (litres/hour)

Speed (rpm)	110%	100%	75%	50%	25%
1500	16.5	14.8	11.2	8.0	4.6
1800	19.7	17.8	13.5	9.7	5.8

Table 7: Air Compressor (Atlas Copco 350cfm) fuel consumption (litres/hour)

Load	0%	100% (2,400rpm)
	9.6	23.5

Table 8: Surface Works Excavator (JCB) fuel consumption (litres/hour)

Load	Low	Medium	High
	2.8	4.3	5.7

The expected impacts for the construction operations can be simply expressed based on the reduction of vehicle and plant equipment fugitive emissions at the real cases. This would be expected to be considerably higher with conventional technologies where average fuel consumption per metre of installed GHE (Kivade, S. B., 2015 & Timonin, V. 2018) is expected.

A.3.1.1.3 Operational Phase Emissions

The operational phase emissions are assessed as part of this task in the context of the heating & cooling technologies being displaced by the GEO4CIVHIC heat pumps being installed. The assessment currently makes estimates only and will need to be further updated once the work at the real cases and the heat pump prototypes are completed. Table 9 presents the estimated CO₂ emissions from the existing technologies displaced and compares these to the annual projected emissions from the GEO4CIVHIC heat pumps based on local electricity emissions published and the expected heating, domestic hot water and cooling demand after renovation.

Table 9: Estimated CO₂ emissions from the operational phase

Case Study Location	BEFORE RENOVATION		AFTER RENOVATION		Difference in CO ₂ emissions (%)
	Existing Heating/DHW/Cooling Technology	Estimated Annual kgCO ₂	GEO4CIVHIC Technology	Estimated Annual kgCO ₂	
Ferrara	Gas	15028	Dual Source	3622	-75.8
Malta	N/A	N/A	Dual Source	1999	Increase
Greystones	Gas	8858	Dual Cycle HTHP	7140	-19.4
Battel	Gas	6314	W/W (Low/High Temp)	386	-93.9

A.3.1.2 Expected Impacts

Whilst the construction operations at each case study site were given careful consideration in the design of the EIA task, it is not possible to measure directly the likely impacts of the construction phase. Work previously carried out as part of the Cheap-GSHPs project (TECNALIA, 2018) has demonstrated that the

environmental impact assessment of the Global Warming Potential (GWP₁₀₀) and Acidification potential (AP) indices considered in the context of air quality, the transport, installation and maintenance of various drilling methods and the technologies at all the case study sites represents less than c. 15% of the total project impact.

It is estimated that based on the small scale of the drilling rig and plant equipment used for installing the GHEs and the short duration of the construction operations the impact associated with the construction operations can be deemed negligible with respect to the short and temporary nature of the works.

The majority of the impacts on air quality are attributed to the operation of the systems. It is expected to have a positive impact on air quality based on the reduction of CO₂ emissions expected from the technologies being displaced. A slight increase in CO₂ level at the Malta, against the local conditions, is expected due to the lack of previous heating or cooling technology present.

Chapter 6 – Noise & Vibration Methodology

The noise and vibration effects relating to the use of the Hydra-RED and the Hydra-TKI methods proposed as part of the installation at the case study sites is the focus of this chapter. A proposed common noise and vibration level measurement strategy is planned for implementation as part of the installation at the real cases. This aims to assess the likely impacts to any sensitive receptors identified at each site. A baseline assessment of the receiving environment that identifies the individual receptors in the area surrounding the sites where the real case installation are taking place was undertaken (refer to Part B for each case). The use of the Hydra-TKI roto-vibro method of drilling developed as part of the project will be used for the installation of geothermal heat exchanger in rock (consolidated) ground conditions.

The method is based on using 2 No. high frequency heads developed (VD-80 and VD-105) to allow the drill bit to cut and penetrate the bedrock, that will be mounted on the Hydra Joy 3 drill rig..

A.3.1.3 Noise

A.3.1.3.1 Background on Project Activities

As part of the outline EIA carried out in WP6, it is proposed to measure the noise generated by the drilling plant equipment at the site. The objective is to maximise the possibility of measurement the noise levels before the drilling operations and whilst the rig is being used irrespective of the method (Hydra-RED or Hydra-TKI).

The section below reviews the applicable standards and best practices with respect to noise for construction plant equipment and proposes measurement methods to be implemented during the individual real case installation sites. Whilst any impact is expected to be low and the noise will be only a temporary occurrence, the objective here is to demonstrate reduced noise levels compared to other drilling technologies.

A.3.1.3.2 Noise – Standards and Best Practice Guidance

A review of some of the applicable standards was carried out in development of this document. Table 10 below summarises the European and International standards applicable for construction noise assessment.

Table 10: International & European Standards on Construction Noise (non exhaustive)

	Country	Standard	Title
Europe		EN ISO 11200 2014	Noise emitted by machinery and equipment - Guidelines for the use of basic standards for the determination of emission sound pressure levels at a work station and at other specified positions
		EN ISO 11204 2019	Noise emitted by machinery and equipment - Determination of emission sound pressure levels at a work station and at other specified positions applying accurate environmental corrections
	UK	BS 5228-2:2009 +A1:2014	Code of practice for noise and vibration control on construction and open sites. Vibration
	Ireland	S.I. No. 632/2001	European Communities (Noise Emission by Equipment For Use Outdoors) Regulations, 2001
	Italy	UNI/TR 11727:2018	Acoustics - Operational Guidelines For Editing Information About Noise Emission Of Machines
International		ISO 8297:1994	Acoustics: Determination of sound power levels of multisource industrial plants for evaluation of sound pressure levels in the environment: Engineering method
		ISO 9613-1 : 1993	Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere

	ISO 9613-2 : 1996	Attenuation of sound during propagation outdoors – Part 2: General method of calculation
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Plant Machinery noise levels are discussed in several guidance documents, where outline machine noise is approximated for the construction sector based on machinery type and size.

BS 5228 sets out an approach for setting appropriate construction noise limits for residential dwellings, but it does not provide guidance for commercial or office buildings. The BS 5228 ‘ABC Method’ calls for the designation of a noise sensitive location into a specific category (A, B or C) based on existing ambient noise levels in the absence of construction noise (BSI British Standards Code of Practice for Noise and Vibration Control On, 2009). This then sets a threshold noise value that, if exceeded, indicates a significant noise impact is associated with the construction activities as summarised in Table 11.

Table 11: Example Threshold of Significant Effect of Noise at Dwellings (BS 5228)

Assessment Category and Threshold Value Period (LAeq)	Threshold Value (dB)		
	Category A	Category B	Category C
Night-time (23:00 to 07:00hrs)	45	50	55
Evenings & Weekends *	55	60	65
Daytime (07:00 – 19:00hrs) and Saturdays (07:00 – 13:00hrs)	65	70	75

(Note Category A: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are less than these values. Category B: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are the same as category A values. Category C: threshold values to use when ambient noise levels (when rounded to the nearest 5dB) are higher than category A values. *19:00 – 23:00 weekdays, 13:00 – 23:00 Saturdays and 07:00 – 23:00 Sundays).

A.3.1.3.3 Noise – Proposed Field Measurement Strategy

As part of the implementation of the case study site works, it is proposed to carry out short noise measurements during the drilling operations. This is to assess the total noise of the drilling equipment at the site (including the ancillary machinery) and compare this to other market drilling technologies for GHEs.

To achieve this, it is proposed to carry out noise measurements at each of the real cases based on the location of the proposed boreholes and the presence of the local receptors using a portable device. Each of the drill sites is considered and contours from the boreholes closest to structure are plotted at 5m, 10m, 20m and 30m spacing (refer to part B for the locations proposed for the individual cases) a monitoring point at each of these distances is proposed for the measurements.

An outline procedure for noise monitoring at the sites proposed (N – Noise Monitoring Points in refer to the individual case studies in part B) is outlined below. Table 12 demonstrates the proposed baseline measurement and how these will be taken.

A monitoring procedure was carried out using the same methodology and instrument at all 4 sites:

- Baseline Data – carry out up to **2 No. baseline readings** in advance of any drilling operations at the proposed baseline point. Reference to comparable baseline noise surveys in close proximity of the site (<30m can also be considered)

This step will record the natural background noise at the site without drilling – it is critical that no machine operations (drilling, tracking, moving, loading and unloading of materials/rods) is carried out during this time. The objective is to record the baseline noise of nearby traffic, and daily operations as if the drilling was not taking place.

- Monitoring Point measurements (N1 to N3) – carry out a recording at each location whilst the machine is drilling.

This step will record any increased noise levels generated by the rig and the other equipment on site. Recording should maximise the time of drilling, changing of rods and minimise any downtime or other operations when the drill rig is not operating.

Use the handheld sound meter in accordance with the instruction and set to **record the data in 3 Octave bands** for the duration of the measurement. Repeat a measurements (min 3 times) at each location and vary these where possible based on the rig operation.

- c) 10m Measurement – carry out a recording at 10m distance whilst the machine is drilling (use the 10m circle for reference from the figures). Measure as you are facing the borehole.

Table 12: Example Noise Data Record to be obtained

Measurement Point	Octave Band Frequency (Hz)								
	Band 1			Band 2			Band 3		
	31	63	125	250	500	1k	2k	4k	8k
Baseline – Measurement 1									
Baseline – Measurement 2									
N1- Measurement 1									
N1- Measurement 2									
N1- Measurement 3									
N2- Measurement 1									
N2- Measurement 2									
N2- Measurement 3									
N3- Measurement 1									
N3- Measurement 2									
N3- Measurement 3									
Rig 10m Measurement									

- d) Repeat Monitoring Point measurements (N1 to N3) – carry out a second round of measurements on a separate day of drilling using the same locations.

A.3.1.4 *Vibration*

A.3.1.4.1 *Background on Project Activities*

As part of the outline EIA carried out in WP6, it is proposed to measure the vibrations generated by this method to demonstrate any impact in urban settings, close proximity to buildings and historical centres that the technology may have.

The section below reviews the applicable standards and best practices with respect to vibration for construction plant equipment and proposes measurement methods to be implemented during the individual real case installation sites, to document the low impact expected from the proposed frequencies used by this method of drilling.

A.3.1.4.2 *Vibration – Standards and Best Practice Guidance*

A review of some of the applicable standards was carried out in development of this document. Table 13 below summarises the European and International standards by the International Society of Soil Mechanics and Geotechnical Engineering (Munro, 2018). Additional standards are considered from Norway, Sweden, Canada, Brazil, Russia, Finland & France.

Table 13: International & European Standards on Construction Vibration

	Country	Standard	Title
☐ ☐	Germany	DIN 4150-3 1986	Vibration In Buildings - Part 3: Effects On Structures

	UK	BS 7385-1993	Evaluation and measurement for vibration in buildings. Guide to damage levels from ground borne vibration
	Ireland	BS 5228-2:2009 +A1:2014	Code of practice for noise and vibration control on construction and open sites. Vibration
	Switzerland	SN 640 312a-1992	Vibrations - Vibration Effects In Buildings
	Italy	UNI 9916-2014	Criteria For The Measurement Of Vibrations And The Assessment Of Their Effects On Buildings
International	US	USBM RI 8507	US Bureau of Mines Safe Blasting Levels
		ISO 4866 -1990	Mechanical vibration and shock — Vibration of buildings — Guidelines for the measurement of vibrations and evaluation of their effects on buildings
		ANSI S2.47-1990	Vibration Of Buildings - Guidelines For The Measurement Of Vibrations And Evaluation Of Their Effects On Buildings

The standards considered above, outline building types and structures and determine vibration limits in terms of the peak particle velocity (PPV) for structural vibrations to prevent cosmetic cracking of structures and structural damage.

For the purpose of the GEO4CIVHIC project, the British and German Standards are considered below. Table 14 present the building classifications and PPV limits which are also summarised in figure 3.1. The frequency ranges that concern the use of the TKI method are highlighted in green in table 14.

Table 14: International & European Standards on Construction Vibration

Country	Standard	Building Type	Frequency Range (Hz)	PPV Limit (mm/s)
Germany	DIN 4150-3 1986	Commercial and industrial buildings	<10	20
			10 -50	40
			>50 – 100	50
		Residential Buildings (& similar design)	<10	5
			10 -50	15
			>50 – 100	20
Structures sensitive to Vibration	<10	3		
	10 -50	8		
	>50 – 100	10		
UK	BS 7385-1993 & BS 5228-2:2009	Industrial and heavy commercial buildings	4-100	51
			<4	0.6
		Residential or light commercial type buildings	4 - 15	15
			>15 - 40	20
		40 & above	50	

The Swiss Standard was also considered and the threshold and PPV limits set in the case of residential and historical buildings, have lower thresholds than the UK and German standards. The Italian Standard includes as reference the limits stated by the German DIN 4150 which proposes different limits for short duration and for long-duration vibrations. These limits are considered to be conservative for the typical historical buildings existing in Italy.

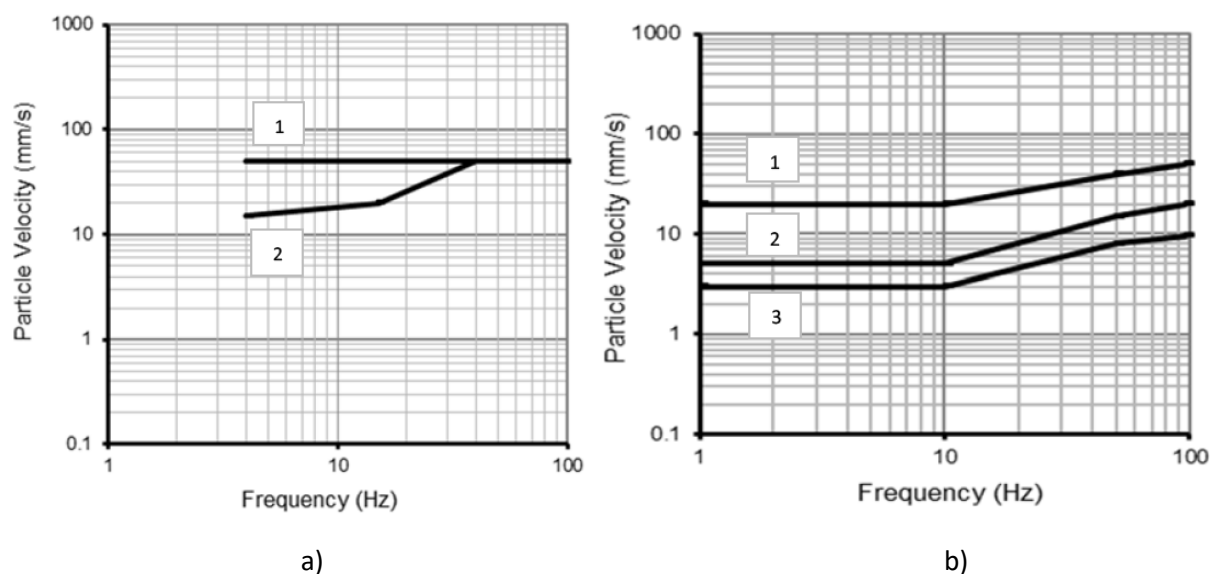


Figure 3.1 a) Vibration guidelines from BS 7385. Line 1: reinforced or framed structures, industrial and heavy commercial buildings; Line 2: unreinforced or light framed structures, residential or light commercial type buildings. b) Vibration guidelines from DIN 4150. Line 1: Buildings used for commercial purposes, industrial buildings of similar design; Line 2: dwellings and buildings of similar design and/or use; Line 3: structures that, because of their particular sensitivity to vibration, do not correspond to those listed in lines 1 and 2 and are of great intrinsic value (e.g. buildings that are under a preservation order). Data modified from DIN 1986 (Sottili et al., 2010)(Munro, 2018)

A.3.1.4.3 Vibration – Proposed Field Measurement Strategy

The assessment of proposed frequencies used by the TKI head during the deployment of the HYDRA-TKI drilling method demonstrate that these are at high frequencies (>80 Hz). The frequency ranges outlined in the standards suggest that the high PPV limits are likely not to result in adverse impact to buildings/structures in close proximity to drilling operations.

However, it is important to note that the thresholds are considerably reduced in the case of structurally sensitive and historical buildings and that PPV measurements will vary based on the local underground conditions at each site. It is therefore important to capture the low impact in a variety of site specific conditions, where nearby buildings are of different types, are located at different distances to the drilling location and in different rock properties.

To achieve this, it is proposed to carry out short vibration measurements at each of the real cases based on the location of the proposed Hydra-TKI borehole and the presence of the local receptors using a portable device. Each of the drill sites is considered and contours from the boreholes closest to structure are plotted at 5m, 10m, 20m and 30m spacing (refer to Part B for the individual real cases) a monitoring point at each of these distances is proposed for the measurements.

An outline procedure for vibration monitoring at the monitoring sites proposed (*V – Vibration Monitoring Points* in the figures) is outlined below. Use table 3 to determine where the baseline measurement should be taken.

It is important to note that the monitoring should be carried out similarly at all case studies using the following procedure:

- a) Baseline Data – carry out between **30 min and 1 hour of continuous recording** in advance of any drilling operations at the closest structure.

This step will record the natural background vibration at the site without drilling – it is critical that no machine operations (drilling, tracking, moving, loading and unloading of materials/rods) is carried out during this time. The site should be ‘quiet’ when the baseline measurement is taken. The data should be recorded to the data logger of the equipment

- b) Monitoring Point measurements (V1 to V4) – carry out minimum **1 hour of continuous recording** at each location whilst the machine is drilling.

This step will record any increase in vibration at the 4 monitoring points from the background level and provide the PPV levels. Recording should maximise the time of drilling, changing of rods and minimise any downtime or other operations when the head is not operating. The accelerometer/geophone shall be placed as close as possible to the structure ensuring that is well coupled with the ground close the structure. To improve the coupling you should push the sensor a little into the soil and consider using a sand bag to apply some weight and improve the coupling (figure 3.2). This is a critical step to ensure good data quality.



Figure 3.2 Example of improved coupling using sandbag b) Vibrock V901 instrument and single geophone (red)

- c) Repeat Monitoring Point measurements (V1 to V4) – carry out a second round of measurements as above minimum **1 hour of continuous recording** at each location whilst the machine is drilling.

Chapter 7 – Traffic & Transportation – Common Chapter

potential impacts of the installation of the GHEs, the installation of the HP and the operation of the system at each site are assessed in this chapter. The scope and common methodology adopted for this chapter is presented below and only summary impacts with respect to traffic and transportation are provided in part B of this deliverable.

A.3.1.5 *Impact Assessment and Evaluation methodology*

The assessment methodology determines the construction and operational impacts on local traffic in the worst case scenarios and determines how these would impact traffic flows and receptor safety. The very short nature of the refurbishment, GHE drilling and installation as well as the heat pump installation and

commissioning and the limited equipment requirements to complete the work are likely considered a common assessment methodology to all four real case study sites. A qualitative assessment is undertaken based on the knowledge that similar limited traffic movements are required at each of the sites as the Joy 3 rig was used and based on similar transport and logistical plans developed as part of WP5. Very limited traffic data is available for each of the case study sites.

Traffic impacts were determined at each of the sites by describing the access roads to each site and estimating potential traffic movements that would be generated based on ‘light’ (LGV) and ‘heavy’ (HGV) vehicle trips associated with the mobilisation and demobilisation of the drilling rig, the disposal of waste and supply of materials for the renovation, BHE installation and the HP installation operations. The LGV were considered in the context of personnel movements, equipment and materials delivery and later maintenance at the operational phase. The potential impacts are presented in table 15 ((IEMA, 1992)below.

Table 15: Environmental impacts arising from changes in traffic volume and composition

Potential Impact	Description
Severance	Perceived division that can occur within a community when it becomes separated by a major traffic artery.
Driver delay	The potential magnitude of changes in driver delay arising from the Proposed Works can be assessed (critical junctions & peak hour capacity)
Pedestrian delay	Pedestrians delay as a direct consequence of their ability to cross roads. Thus the provision of crossing facilities, the geometric characteristics of the road, and the traffic volume, composition and speed are all factors that can affect pedestrian delay and have been considered when assessing this effect.
Pedestrian Amenity	Defined as the relative pleasantness of a journey. It is considered to be affected by traffic flow, speed and composition as well as footway width and the separation/protection from traffic.
Fear and intimidation	An impact traffic may have on pedestrians is fear and intimidation. The impact of this is dependent on the volume of traffic, its HGV composition, its proximity to people or the lack of protection caused by such factors as narrow pavement widths.
Accidents and road safety	Establish the effect on the road safety record of the adjoining road network.
Hazardous Loads	No hazardous loads are expected.

The above impacts need to be considered in the context of the sensitivity of potential receptors to the proposed sites and the work. The sensitivity of these receptors is outlined in table 16 below.

Table 16: Definitions of Traffic receptor sensitivity

Sensitivity of receptor	Definition
High	Sensitivity to traffic such as: <ul style="list-style-type: none"> • Schools, colleges and other educational institutions; • Retirement / care homes for the elderly or infirm; • Roads used by pedestrians with no footways; and • Accident clusters at a regional scale.
Medium	Sensitivity to traffic such as: <ul style="list-style-type: none"> • Hospitals, surgeries and clinics; • Parks and recreation areas; • Shopping areas; • Roads used by pedestrians with narrow footways; and • Accident clusters at a local scale.
Low	Some sensitivity to traffic such as: <ul style="list-style-type: none"> • Open space; • Tourist / visitor attractions; • Historical buildings;

- Churches;
- Public Right of Ways (PROWs);
- Roads used by pedestrians with standard footways; and
- Residential areas.

Guidance documents (IEMA, 1992) advise that the day to day flow variation of + or – 10% is to be expected in the base situation and that projected changes in traffic of less than 10% would create no discernible environmental impact. Therefore, increases in traffic levels of below 10% will be considered as no impact.

The expected traffic movements for the construction and operational phases of the work undertaken at each of the cases is summarised in table 17 below. The estimate is based on the knowledge of:

- Planned refurbishment works at each site
- The drilling and heat exchanger mobilisation/demobilisation is based on a single load HGV delivery with the materials to all the sites
- The delivery and installation of the HP will require the same logistical requirements at all sites

Table 17: Expected Traffic Levels during the construction and operational phases.

CONSTRUCTION PHASE				
Cas	No. LOADS	Frequency	Typical Size	Site specificities
Retrofit Works - Major	6	Twice weekly	HGV/LGV	Belgium
Retrofit Works – Minor	5	Twice	LGV	Malta, Italy
Drilling Rig Mobilisation	2	Twice	HGV	All sites
Other Equipment Mobilisation: compressor /excavator	2	Twice	LGV	All sites
Fuel Supply / Materials	4	Every 2 days	LGV	All sites
HP Delivery	1	Once	LGV	All sites
Personnel Movements (Plumbing, Electrics, Commissioning)	20	Daily	Car	All sites
OPERATIONAL PHASE				
Regular scheduled maintenance personnel	2	Yearly	Car	All sites
Visitors - system presentation	2	Yearly	Car	All sites

A.3.1.6 *Traffic & Transportation - Expected Impacts*

Based on the above expected vehicle movements and loads for all the case study sites, table 18 below summarises the impact assessment for all the real cases.

Table 18: Traffic & Transportation Impact Assessment.

CONSTRUCTION PHASE				
ACTIVITY	Malta	Ferrara	Battel	Greystones
Local Baseline Traffic Description	The site is located on Triq Vincenzo Dimech in the old city of La Valletta	The site is flanked by a busy main ring road (Via Riccardo Bacchelli) on the northern side of the city of Ferrara. The road comprises a large open verge section and a cycle lane. Traffic on this section can be described as heavy and most extreme during peak time hours with access to the city and the main national road (SS16).	The site is located on a residential street off the Battelse Berge. The road is connected to a principal road (N106) to the south and the N16. The baseline traffic is expected to be characterised by residential peak time traffic with extended use of the road network at peak weekly hours in the morning afternoon and evenings.	The site is located in a residential area in the centre of the town of Greystones off Church road. The main road is the principal access point to the town and the baseline traffic is characterised as heavy during the hours of 8am to 10am, as well as between 3pm and 6pm during week days, due to commuter traffic and the proximity of three schools within 150m of the site.
Receptor Type & Sensitivity	Medium to Low – the road has limited pedestrian access	Low – areas for the proposed construction is flanked by an open space along side a busy road with a public cycle route	Low – denominated by a residential area with standard pedestrian footways	Medium to Low – denominated by a residential area with standard pedestrian footways but with access to shopping area and town centre
Potential Impact	Driver delay – Pedestrian delay	Driver delay – Pedestrian/Cyclist delay – Road Safety	Driver delay – Pedestrian delay	Driver delay – Pedestrian delay
Proposed Mitigation Measure	Limit major HGV movements to off peak hours so as to minimise driver delay	Use signage to warn drivers and cyclists of vehicle movements – use of spotter and traffic management to facilitate HGV movements in and out of the site	Limit major HGV movements to off peak hours - communicate with local receptors	Limit major HGV movements to off peak hours - use of spotter and traffic management to facilitate HGV movements in and out of the site
Residual Impact	Limited/Negligible	Limited/Negligible	Limited/Negligible	Limited/Negligible

Chapter 8 – Landscape & Visual Impact – Common Chapter

potential impacts of the construction works and location of the main heat pump units considered.

A.3.1.7 *Impact Assessment and Evaluation methodology*

The assessment methodology considers the receiving environment by assessing viewpoints of the respective sites through the use of satellite imagery and published on street photography. The impacts are assessed based on:

- undertaking a description of the landscape and visual baseline and viewpoint sensitivity based on potential existing receptors in a 250m radius of the site;
- describing the aspects that have a potential to cause a landscape or visual effect based on the magnitude of such effects and the long term significance with respect to the proposed development

Table 19 below outlines the viewpoint sensitivity methodology typically implemented as part of EIAs that has been reference to complete this assessment.

Table 19: Visual sensitivity in relation to Land Use

Sensitivity	Definition
High	Users of outdoor recreational facilities including strategic recreational footpaths, cycle routes or rights of way, whose attention may be focused on the landscape; important landscape features with physical, cultural or historic attributes; principal views from residential buildings, beauty spots or picnic areas.
Medium	Other footpaths; secondary views from residential properties, people travelling through the landscape on roads, trains or other transport routes.
Low	People engaged in outdoor sports or recreation (other than appreciation of the landscape), commercial buildings, and other locations where people’s attention may be focused on their work or activity.
Negligible	Views from industrial areas.

The results of the impact assessment are summarised in the relevant sections of Part B of this document for each real case.

Part B – EIA & Impacts for the Real Case study Sites

B.1. Msida Bastion Historic Garden Building, Malta

B.1.1. Case Study Site Summary

The proposed case study site is the Cafeteria building of the Msida Bastion Historic Garden in Floriana, Malta. The site is adjacent to a historic protestant cemetery from 1806 to 1856. This is a single storey public building with a floor area of 97m² where a deep retrofit is envisaged and will include the installation of a dual ground and air source heat pump. The GHEs installation is planned using the new drilling and coaxial heat exchanger technologies developed as part of the project. The majority of the site and cemetery were restored in 2002. A large room at the top of the bastion currently serves as a display area and visitor centre. It is envisaged to convert this to a tea room and museum.



The building currently does not have any energy consumption as no existing heating or cooling plant is present. A limited energy demand for DHW is served mainly by electric heaters.

B.1.2. Project Description

The real case study site works at the Msida Bastion building comprise a number of intervention measures to retrofit the building as well as install a new heating and cooling solution. A resulting energy demand of 10kW of cooling and 6.9kW of heating is expected post completion of the building refurbishment works (Fodor, L. Rossi, L. Tanase, 2019). The retrofit project is summarised below based on the construction phase and expected operational phase of the system. A schematic of the proposed works is shown in figure B.1.1.

CONSTRUCTION PHASE:

Building Retrofit:

- Insulation southeast façade & roof
- Double glazing 6mm-13mm Argon filled including insulation

Dual Source Heat Pump Installation:

- Installation of 4 to 8 stainless steel coaxial Heat exchangers
- Drilling using the Hydra-TKI method with water flush and Hydra RED methods
- Surface pipework trenching and connections works
- Preparation of the outdoor heat pump area
- Installation of fan coil units and connection the HP

OPERATIONAL PHASE:

- Dual air source and ground source operation to meet the heating and cooling demand

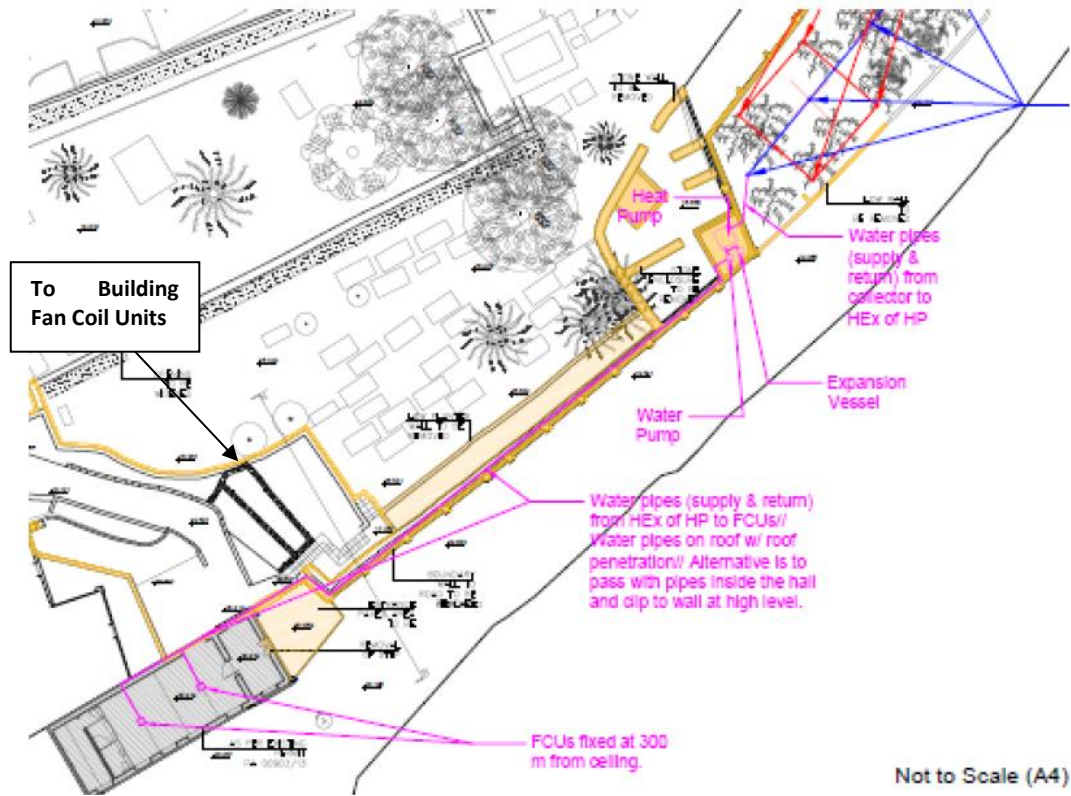


Figure B.0.1 – Msida Bastion Case Study Site Schematic of proposed works

B.1.3. Soils & Geology

B.1.3.1. Baseline Assessment

The baseline geology at the site is defined by local geological conditions described by DLH in the data input sheets for the case study site and summarised in D 1.2 (Dalla Santa, G. Galgaro, A. Di Sipio, 2019). Table 20 summarises the geological conditions expected.

Table 20: Geological Profile of the Msida Bastion Site

Geological Layer	Depth (m)	Stratigraphic Description
Overburden	Final depths to be confirmed at the drilling stage	<i>Detailed profile not yet known</i>
Globogerina Limestone	to > 120m	<i>Fine grained planktonic, foraminiferal, fossiliferous limestone of Miocene Age. The unit comprises three members with the upper member characterised by fine grained limestone to c. 28m depth. The middle Member is characterised by soft, carbonate mudstones to 38m depth with the lower member comprising wackstones and packstones to a depth of 80m.</i>

B.1.3.2. Soils and Geology Impact Assessment

The impact assessment on the soils and geology was considered in the context of the Hydra-TKI drilling method that will be used at the site and the design on borehole heat exchangers. The drilling will be performed with a water flush system to complete the boreholes. The ground heat exchangers will be installed in the boreholes drilled with the Hydra-TKI method and the annular space between the casing and the heat exchanger will be grouted.

The operational phase will focus on exchanging energy from the GHEs for heating and cooling. The operational impacts cannot fully assessed at present in advance of the final HP performance information and the assessment of these against the modelled energy demand curves (RED, 2020a). However, the impact on the soils and geology is expected to be low as the ground heat exchange will only address part of the energy demand from the building, with air source providing addressing the remaining demand. A preliminary impact assessment of the construction phase of the work is outlined in table 21 below.

Table 21: Soil & Geology Impact assessment – Msida Bastion

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc. to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Erosion of soils and subsoils during construction and drilling	Local and long term	Low	Slight	Low	Soil erosion is likely to be minimised as the excavation area is contained
Contamination of soils and subsoils from drilling operations	Local and long term	High	Moderate	Low	The probability of occurrence is low as no evidence of contamination is present at the site
Removal of rock (drill cuttings) via drilling process	Local and permanent	High	Slight	Low	Not applicable
Operational Phase					
Change in ground temperature during heating and cooling	Local and permanent	Low	Slight	Low	The probability of occurrence is low as the load to the ground during heating and cooling when the GSHP part of the system is in operation is mostly balanced, thus generating a net imperceptible impact to the ground

B.1.4. Hydrology & Hydrogeology

B.1.4.1. Baseline Assessment

The baseline hydrogeological conditions are poorly defined at the site, with little or no information on the likely groundwater table elevation. Regional groundwater data for the island of Malta suggest that the subsoil section (refer to section above) is likely to be dry with any groundwater expected at sea level below the site location (Dalla Santa, G. Galgaro, A. Di Sipio, 2019; Fodor, L. Rossi, L. Tanase, 2019).

The Globigerina limestone is characterised by primary matrix porosity (estimated >15%) with interbedded layer of clay and mud rich units.

Detailed hydrogeological data from the drilling operations was not obtained. During drilling to a depth of 74m below ground level, the groundwater table was not intersected and the no static water level in the aquifer could be recorded.

B.1.4.2. Hydrology & Hydrogeology Impact Assessment

Table 22 presents the initial outcomes of the assessment based on the desktop review and expected works. Operational impacts cannot be fully determined until such time that the installation is complete and the system is operational.

Table 22: Hydrology & Hydrogeology Impact assessment – Malta Site

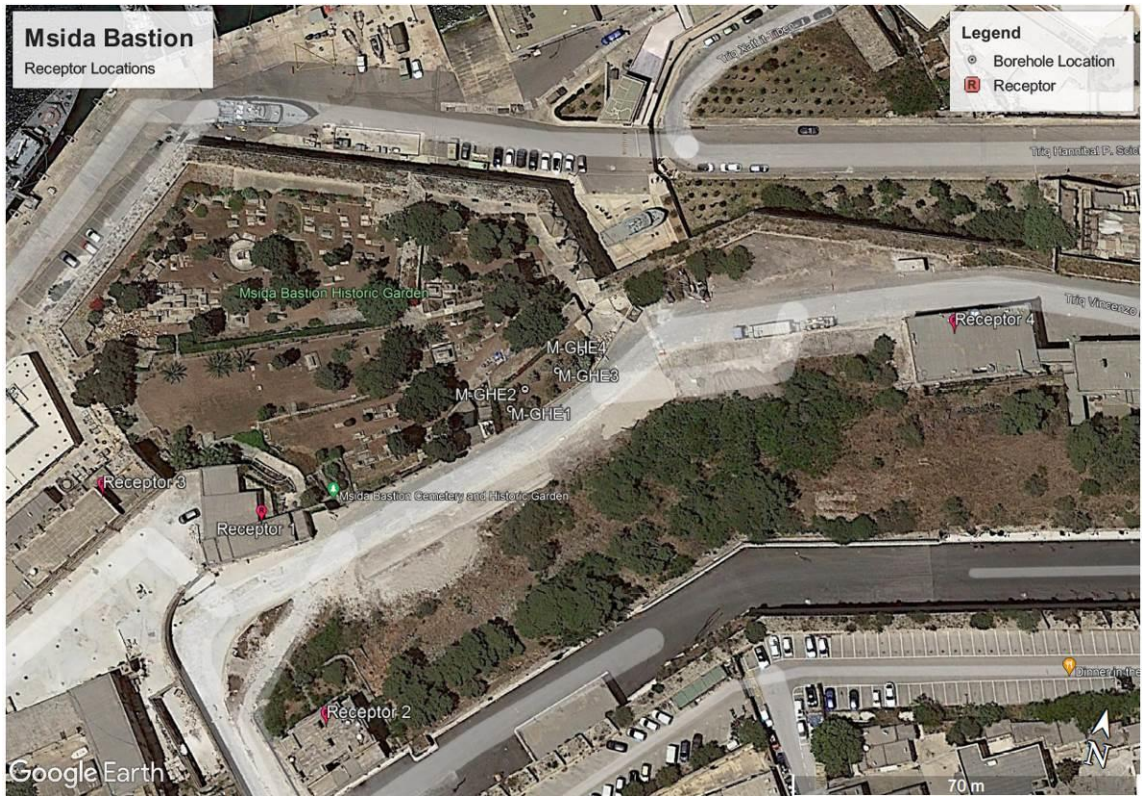
Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Contamination of Aquifers during drilling	Local and long term	Medium	Moderate	Low	Yes – ensure adequate grouting methods are used when installing the with the Hydra TKI method through the use of mud and grout containment pits. Ensure no leaks in GHE connections resulting from the heat exchangers are present following installation through pressure testing
Waste water generated from drilling	Local and permanent	High	Slight	Low	Yes – use of water recirculation and treatment system – dispose of water in accordance with local regulations
Operational Phase					
Change in groundwater temperature during heating and cooling	Local and permanent	Low	Slight	Low	The collector length is adequately designed and minimises adverse temperature change with balanced heating and cooling loads from the installed system

B.1.5. Noise & Vibration

The impact assessment methodology including field measurement for construction noise and vibration is outlined in Part A section 3.6.

B.1.5.1. Baseline assessment and receptors

A baseline assessment was carried as part of the initial screening process and a series of noise and potential vibration receptors identified (figure B.0.2 a)



(a)



(b)

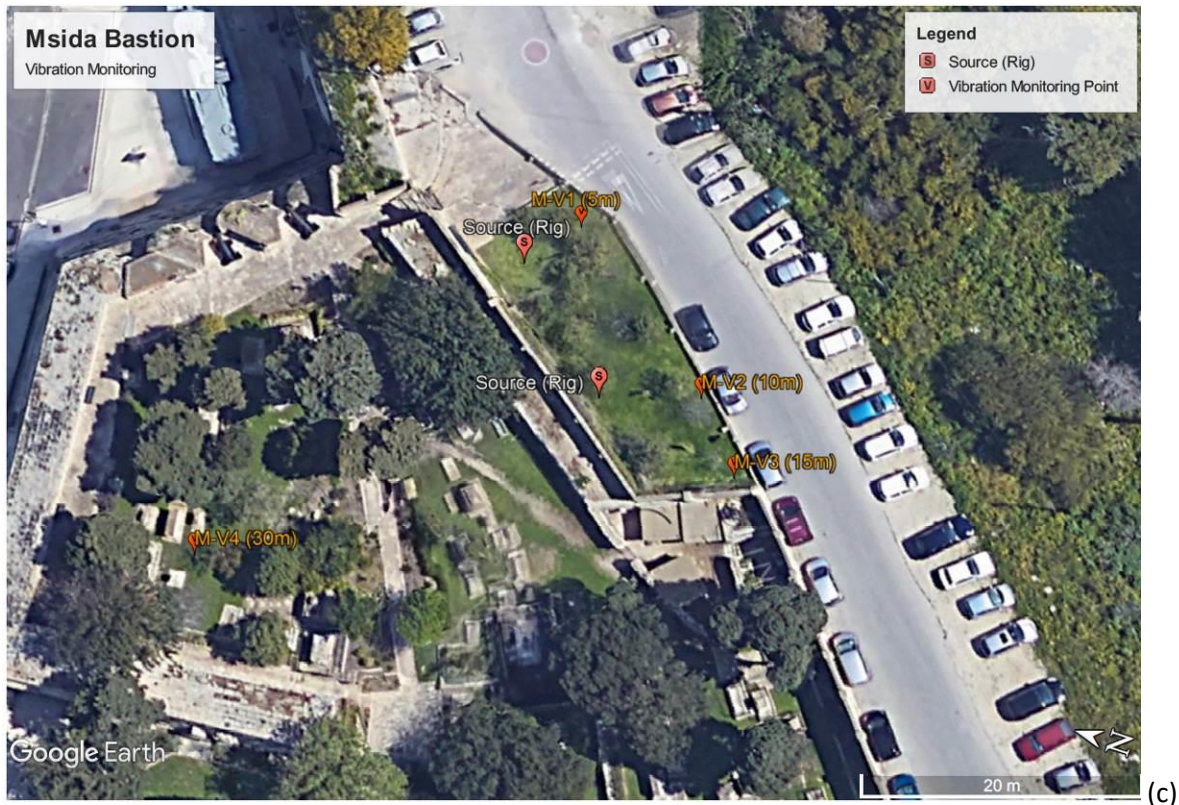


Figure B.0.2 – Msida Bastion Case Study Site Monitoring showing Receptors (a), Noise (b) & Vibration (c)

B.1.5.2. Noise & Vibration Impact Assessment

The noise and vibration impact assessment at the Malta case study site was undertaken by making direct noise & vibration measurements during the main construction operations, where the Hydra-TKI drilling methodology using a water flush method was implemented.

A series of noise measurements at M-N1, M-N2, M-N3 and M-N4 were taken (figure B.0.2 b) along with one baseline measurement completed prior to the commencement of the drilling operations (table 23). The baseline value of 75.8 dBA demonstrates a relatively high baseline that is attributed to the traffic along Trinq Vincenzo Dimech that borders the case study area. Records from the drilling operations demonstrate that values between 92.5 dBA and 90 bBA were recorded at 5m and 10m from the noise source that included the drilling rig, mud circulation pump and the TKI VD80 head. These values are 15.7 dBa above the baseline maximum value.

However, at a distance of up to 30m, a maximum value of 77.6 dBA was recorded demonstrating a significant decrease of noise levels with increased distance from the source. These values are only 1.8 dBA above the local baseline.

Based on the assessment of the noise data obtained and the distance of the three principal receptors identified in close proximity of the site, the impact from noise generated from the drilling operations is considered to be low given the distance of the receptors identified being greater than 70m from the noise source. The temporary nature of the works also confirms this.

Table 23: Noise Measurements dBA (Max) recorded at the Malta case study site

Monitoring Point	Activity	Distance (m)	Average dBA (Max)
Baseline			75.8
N1	Drilling	15	89.96
N2	Drilling	10	92.46
N3	Drilling	30	77.6

Vibration monitoring was completed by using a portable seismometer placed at 4 No. locations during the drilling operations at 10m and 12m distance from the drilling rig and TKI VD80 head (figure B.0.2 c). The unit was placed in continuous recording mode for the duration of each measurement.

Table 24 shows the maximum PPV values on three axes recorded during each measurement, with a maximum values of 54.04 mms^{-1} recorded at M-V2. The PPV records for the continuous 5 hour period of recording are plotted in figure B.0.3. The maximum frequencies of at the monitoring points are shown in table 25. The PPV and frequency values recorded at M-V4 at 30m distance from the source cannot be considered representative. Analysis of the data from the seismogram shows excessive spurious measurements during the course of the drilling and casing operations. This is attributed to poor coupling of the seismometer with the ground and/or pedestrian traffic in the cemetery in close proximity to the seismometer during the recording process. The data from M-V4 therefore needs to be discarded.

The higher PPV values recorded at M-V1 and M-V2 are attributed to the drilling and casing operations being implemented at shallower depths at the start of the drilling operations in each respective borehole. Lower PPV and frequency values recorded at M-V3 are attributed to the increased distance of the measurement and the recording taking place during drilling at deeper depths in the boreholes.

Table 24: PPV Measurements (mms^{-1}) recorded at the Malta case study site

Point	Activity	Distance (m)	Long PPV mms^{-1}	Vertical PPV mms^{-1}	Transv PPV mms^{-1}
M-V1	Casing & Drilling	5	43.95	22.075	13.25
M-V2	Drilling	10	28.35	23.05	54.05
M-V3	Drilling	15	8.375	5.825	7.35
M-V4	Drilling	30	40.5	0.225	40.5

Table 25: Frequency Measurements (Hz) along the longitudinal, vertical and transverse axes recorded at the Malta case study site

Point	Activity	Long Freq (Hz)	Vertical Freq (Hz)	Transv Freq (Hz)
M-V1	Casing & Drilling	1.58	10.6	2.45
M-V2	Drilling	22.7	20.8	33.3
M-V3	Drilling	33.3	14.3	23.8
M-V4	Drilling	18.5	55.6	18.5

The PPV and frequency values recorded are considered in the context of the DIN standard and BS guideline values (table 14 and figure 3.1). These demonstrate that the impact to nearby receptors, in this case study site at a distance >30m from the source (Hydra-TKI drilling method) is low as all values are below the thresholds set for sensitive structures and historical buildings.

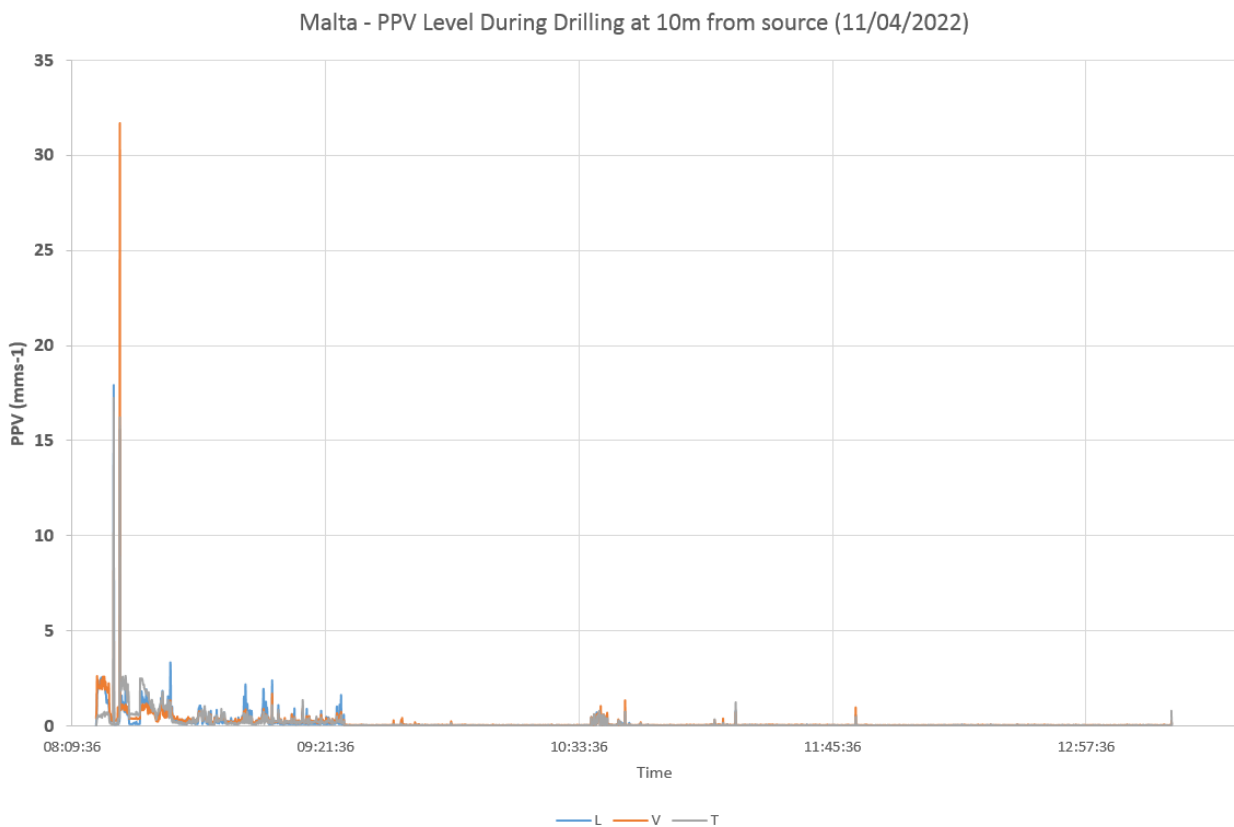


Figure B.0.3 – Msida Bastion Case Study seismometer PPV recorded values at monitoring point M-V2 over a 5 hour period.

B.1.5.3. Noise & Vibration Mitigating Measures & Residual Impact

Based on the initial assessment completed noise and vibration mitigating measures proposed for the Malta case study site include:

- Repositioning of GHE if elevated vibration levels are measured at nearby structures or reduction of frequency if measurements are above guideline standards;
- Use of portable noise barriers to reduce emissions during the construction phase where noise measurements are found to exceed more than 20% of daytime baseline values;
- Use of soundproofing material in the Heat Pump casing to reduce operational noise.

B.1.6. Landscape & Visual

A proposed impact assessment methodology is proposed in Part A section 3.7.

B.1.6.1. Baseline assessment and receptors

A baseline assessment was carried as part of the initial screening process and a series of visual receptors were identified in the southern part of the proposed area considered adjacent to the construction works and the final location of the HP (figure B.0.4). Additional receptors in the visitors to the gardens on the north/north east side of the plant room were also considered. Screening from local views from existing walls surrounding the proposed outdoor plant location are noted.

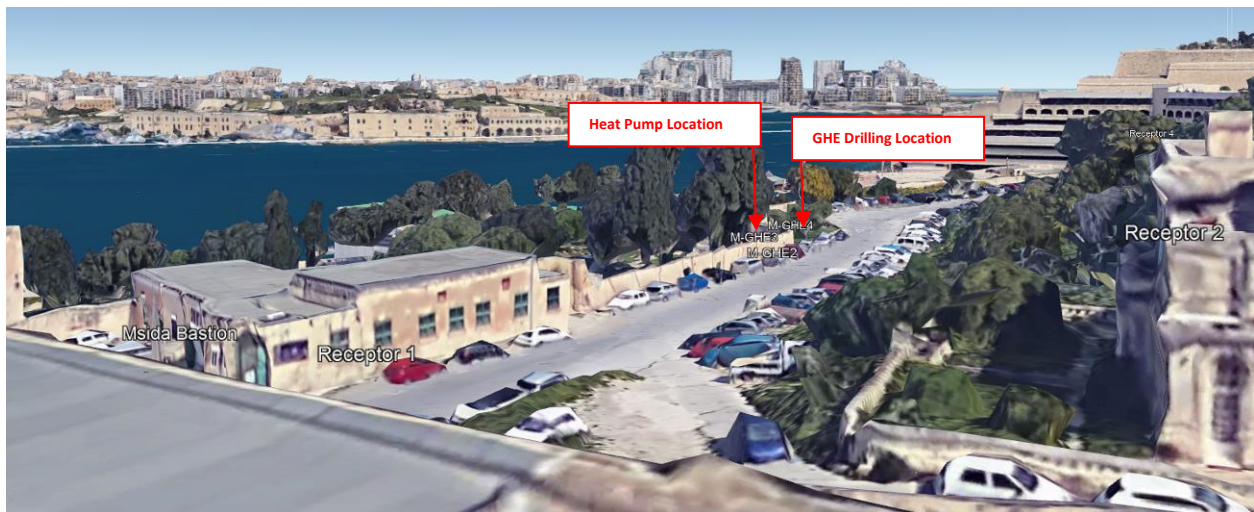


Figure B.0.4 – Msida Bastion Visual Receptors with respect to the location of the collector and the location of the heat pump

B.1.6.2. Landscape & Visual Impact Assessment

Table 26 provides a summary of the landscape and visual impact assessment for the Msida Bastion Historic Garden Building.

Table 26: Landscape and Visual Assessment Summary – Msida Bastion Garden Building

Landscape Characteristics	Assessment	Definition
Landscape Designation	High	UNESCO world heritage designation
Landscape Quality	Exceptional /High	Scenic and historical/cultural areas
Nature of Views	High	Short and long distance views characterise the landscape

Sensitivity	Medium – High	The land use comprises views with significant cultural and historic attributes. These are also characterised by frequent recreational and tourist users as well as comprising principal views from residential buildings and scenic spots
Magnitude	Negligible	Very minor loss or alteration to one or more key elements/ features/characteristics of the baseline conditions. Change will be barely distinguishable, approximating to ‘no change’
Significance of Effect	None	The new installation is appropriate in its context. It may be difficult to differentiate from its surroundings and would affect very few or no receptors. The long term impact from the HP plant location behind the screening wall will not be perceptible to nearby receptors

B.1.7. Msida Bastion Historic Garden Building Summary EIA

A summary impact assessment for the Msida Bastion case study site based on the Part A common chapter and the information available upon completion of the installation works is provided in table 27.

Table 27: Msida Bastion Historic Garden Building –EIA Summary

EIA key aspects	Significance of Impact	Nature of Impact
Soils and Geology	Imperceptible	No impact or alteration to existing geological environment due to the installation of grouted borehole heat exchangers in the subsurface.
Hydrology and Hydrogeology	Negligible	No alteration to groundwater recharge, flow mechanisms or water levels; and no pollution or change in water chemistry to either groundwater or surface water.
Air quality	Limited	Minor dust emissions, traffic generated by the construction, and combustion emission during the construction phase only. Mitigation measures including the use of water flushing as part of the drilling will reduce any potential impacts. The operational phase impacts are deemed to be slight based on the current baseline values for fugitive emissions in the area as a result of an increase of CO2 emissions compared to the baseline conditions where no heating or cooling solutions was present at the case study site.
Noise and vibration	Limited	Noise from the construction operations, in particular relating to the use of the Hydra-TKI drilling method, is low due to the temporary nature of the construction phase and deemed to be imperceptible at a distance >10m from the source compared to the local baseline. Noise from the operational phase of the heat pumps is likely to be imperceptible due to the screened location of the installation and the low level of noise from the air source units. Vibration related impacts from the drilling operations to nearby receptors are deemed to be low to imperceptible due to all PPV and frequency values measured falling within DIN & BS standards for buildings & sensitive structures.
Traffic and Transportation	Limited/Negligible	Conventional construction traffic transporting construction materials to the site, higher traffic level compared to the baseline gener-

		ated during the construction phase only. Near zero traffic in the operational phase (mainly for maintenance duties). No sensitive receptors. Road network not affected. Low baseline of pedestrian traffic.
Landscape and Visual	Limited/Negligible	Small scale landscape, high landscape quality, long distance views. Views from higher ground to the south of the site. Very minor loss or alteration to one or more key elements/ features/characteristics of the baseline conditions. Change will be barely distinguishable at the construction phase due to the short nature of the work. Longer term impacts are limited as position of the plant equipment will not reduce the receptor views. The impact is considered as approximating to ‘no change’.

B.2. Porta Degli Angeli, Ferrara, Italy

B.2.1. Case Study Site Summary

The Porta Degli Angeli (Angel’s Gate) in Ferrara is located in the very core area of the UNESCO World Heritage Site of Ferrara. The building was originally a watchtower and provides special views of the fortified walls of the town and surrounding landscape. It has been always used as an exhibition hall and underwent renovations in 1984 with the addition of a steel staircase and installation of a gas fired boiler (Fodor, L. Rossi, L. Tanase, 2019) and an annual gas consumption of 71,256 kWh. The building currently has no cooling plant or infrastructure.



The tower is equipped with an old and inadequate heating system and without cooling. The upgrade to the building heating and cooling system includes the replacement of the old system using one of the innovative heat pumps developed by the project.

B.2.2. Project Description

The Historical building nature of the structure limits the possible retrofit interventions to increase the energy efficiency of the building. A moderate level of refurbishment has been undertaken and is focused on the replacement of the gas boiler with a dual, high temperature, air source and ground source heat pump of 35kW_{th} and the installation of terminals for heat delivery to the building.

The new installation includes the completion of up 4 No. stainless steel coaxial heat exchangers originally envisaged by using the Hydra-RED and Hydra-TKI Method in an area to the NE of the plant room. However due to requirements imposed by the local authority on the GHE permits, the boreholes were required to be drilled using conventional drilling methods. The heat pump is installed in a pillar section below the boardwalk to the north of the main building (figure B.0.5)

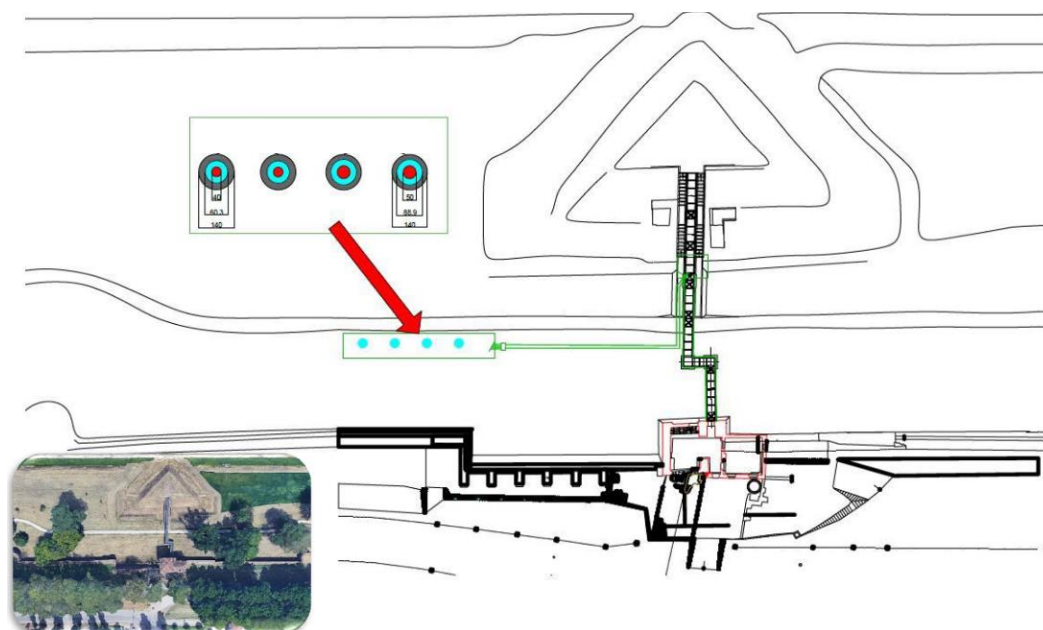


Figure B.0.5 – Porta Degli Angeli project layout showing the location of the ground heat exchangers and location of the plant room below the board walk.

B.2.3. Soils & Geology

B.2.3.1. Baseline Assessment

The baseline geology at the site is defined by UNIPD in the data input sheets for the case study site and summarised in D 5.2 (Fodor, L. Rossi, L. Tanase, 2019). Table 28 summarises the geological conditions.

Table 28: Geological Profile of the Porta Degli Angeli Site

Geological Layer	Depth (m)	Stratigraphic Description
Layer 1	0-15 m	<i>lense-shaped sandy bodies (deposits of abandoned channels, meanders, lateral banks) in silt and clay layers locally alternating with peat</i>
Layer 2	15-40 m	<i>Pleistocene sand (synglacial sand) associated with an eustatic lowstand and subsequent widespread braided-river sedimentation</i>
Layer 3	40-55 m	<i>silt or silty clay layer representing alluvial and/or swap environments</i>
Layer 4	55-82 m	<i>sand deposits of continental origin</i>
Layer 5	82-94 m	<i>silt-clay layer representing alluvial and/or swap environments</i>
Layer 6	94-120 m	<i>Medium-grained sands interpreted as frontal delta or beach deposits</i>

B.2.3.2. Soils and Geology Impact Assessment

The impact assessment on the soils and geology was considered in the context of the drilling methodology implemented at the site and the proposed design on borehole heat exchangers. The use of conventional drilling using a ‘casing while drilling’ method with a water flush system was used to complete the boreholes. The ground heat exchangers were installed in the borehole and the annular space between the casing and the heat exchanger grouted before the casing being withdrawn.

The operational phase of the new system focusses on exchanging energy from the GHEs for heating and cooling. The operational impacts are determined in this assessment based on the initial HP performance information and the modelled energy demand curves (RED, 2020a).

Table 29: Soil & Geology Impact assessment – Porta Degli Angeli

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc. to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Erosion of soils and subsoils during construction and drilling	Local and long term	Medium	Slight	Low	Yes – ensure soil erosion is minimised at the trenching stage – stockpile and reuse excavated material
Contamination of soils and subsoils from drilling operations	Local and long term	High	Moderate	Low	Yes – use adequate casing methods in the upper sections of the boreholes – segregate any contaminated material for disposal at a licensed facility
Removal of rock (drill cuttings) via drilling process	Local and permanent	High	Slight	Low	Not applicable
Operational Phase					

Change in ground temperature during heating and cooling	Local and permanent	Low	Slight	Low	Yes – ensure adequate collector length is designed to minimise long term temperature variations
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B.2.4. Hydrology & Hydrogeology

B.2.4.1. Baseline Assessment

The baseline hydrogeological conditions at the site are characterised by the presence of four principal aquifers to a depth of 100m. These are characterized by the aggradation of fluvio-deltaic and alluvial plain deposits with sediments originating from both the Po River and the Apennines streams. In particular, the coarser deposits (fine-to-coarse grained sands) are commonly associated with fluvial channels while the finer ones (mainly silt and clay) represent alluvial and/or swap environments (Fodor, L. Rossi, L. Tanase, 2019). The three main aquifers are interbedded with low permeability layers of mostly silt and clay. Table 30 summarises the main characteristics.

Table 30: Geological Profile of the Porta Degli Angeli Site

Aquifer characteristics	Depth (m)	Description
Aquifer A0	0-15 m	<i>unconfined or locally semi-unconfined aquifer system hosted in lense-shaped sand bodies</i>
Aquifer A1	15-40 m	<i>confined aquifer system hosted in Pleistocene sands</i>
Aquifer A2	55-82 m	<i>permeable deposits of continental origin</i>
Aquifer A3	94 - 120 m	<i>medium-grained sand – Older deposits</i>

B.2.4.2. Hydrology & Hydrogeology Impact Assessment

Table 31 presents the outcomes of the assessment based on the desktop review and the results of the works implemented. Operational impacts are determined based on the initial performance data from the installation.

Table 31: Hydrology & Hydrogeology Impact assessment – Porta Degli Angeli

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Contamination of Aquifers during drilling	Local and long term	Medium	Moderate	Low	Yes – ensure adequate grouting is used to prevent aquifer interconnection
Flood Risk	Local and short term	Low	Moderate	Low	Yes – ensure plant room elevation above local recorded flood levels
Waste water generated from drilling	Local and permanent	High	Slight	Low	Water recirculation to the used with water flush system
Operational Phase					
Change in groundwater temperature during heating and cooling	Local and permanent	Low	Slight	Low	The collector length is adequately designed and minimises adverse temperature

change with balanced heating and cooling loads from the installed system

B.2.5. Noise & Vibration

The impact assessment methodology including field measurement for construction noise is outlined in Part A section 3.6.

B.2.5.1. Baseline assessment and receptors

An initial screening was carried out to identify potential noise receptors prior to the works being implemented (figure B.0.6 a). The potential noise receptors are located to the south of the proposed GHE installation area and location of the Heat pump and technical room. The city wall which is adjacent to the proposed installation provides heavy screening with respect to noise generated from the drilling operations. Vibration impacts on nearby receptors was not deemed applicable at this case study site give the use of a conventional water flush drilling methodology and the inability to test the Hydra-TKI drilling method. No receptors are identified to the north of the installation area.

A number of monitoring points were used to measure the expected impacts at the time of installation.



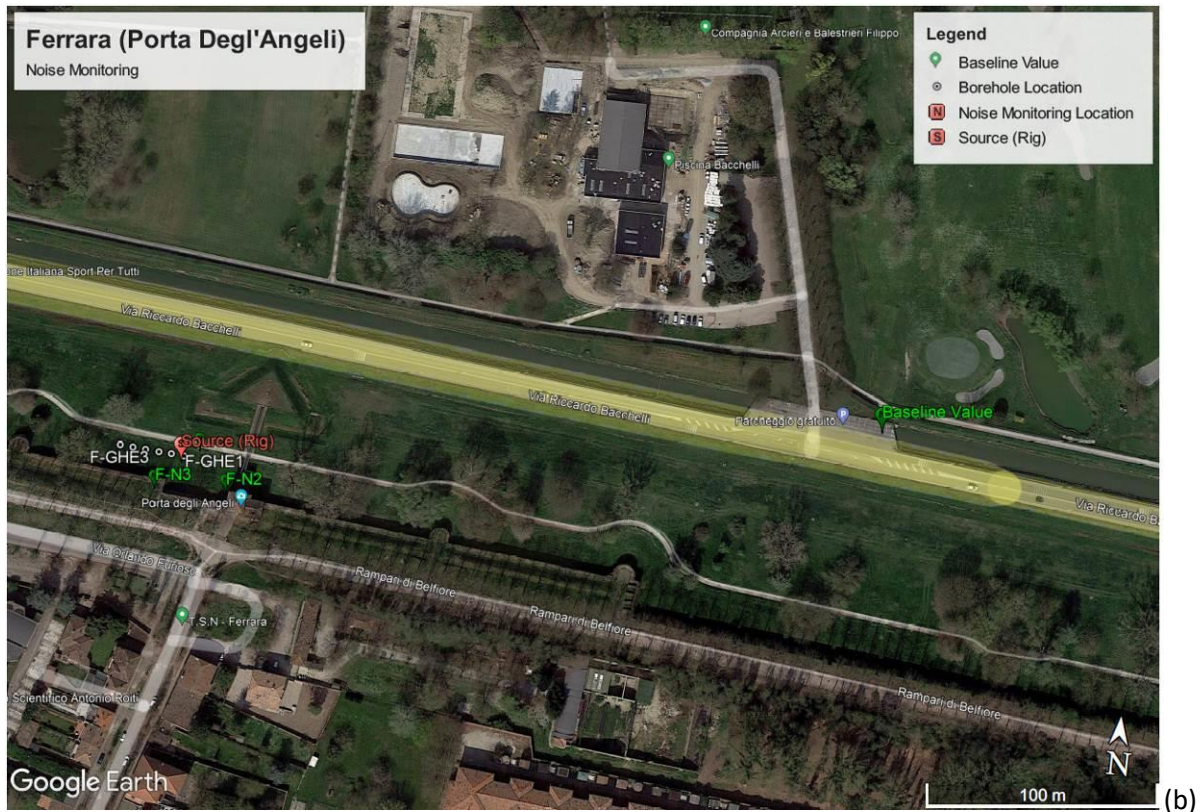


Figure B.0.6 – Porta Degli Angeli Case Study Site Monitoring showing Receptors (a), Noise Monitoring Points (b) & Baseline data (Airis, 2016)

B.2.5.2. Noise & Vibration Impact Assessment

The noise and vibration impact assessment at the Ferrara case study site was confined to noise measurements only. The use of the Hydra-RED or Hydra-TKI drilling methods was not possible due to the imposition of conditions from the regulatory authority on the drilling methodology. A conventional water flush drilling methodology was used to complete the boreholes and in this case, the risk of vibration to nearby structures and receptors is not applicable as the technique does not use high frequency vibration.

The noise measurement data values were assessed against a local baseline value survey undertaken for the local municipality of Ferrara (Airis, 2016) where noise measurement surveys were undertaken to assess the impacts of the traffic on via Riccardo Bacchelli that borders the northern side of the site.

The traffic on the main road adjacent to the drilling location is considered the main source of local background noise. The impact of the noise of the drilling operations to the local receptors compared to the local baseline (Table 32) is deemed imperceptible as the values are close to or within the range of the daytime baseline values recorded.

Table 32: Noise Measurements dBA (Max) at the Ferrara case study site

Monitoring Point	Activity	Distance from source(m)	Average dBA (Max)
Baseline (location P15 – Airis, 2016)	Daytime Road Traffic	52	63
N1	Drilling	5	67.2
N2	Drilling	15	63.5
N3	Drilling	25	63.2

This is demonstrated by the values observed at 15m and 25m from the source that are estimated to be influenced by the local baseline traffic noise rather than showing increased levels caused by the drilling operations. The noise values are also comparable to the values recorded at the Battel case study site (table 38) where the Hydra-RED drilling method was implemented but in a quiet residential area with lower baseline Dba max values recorded.

B.2.5.3. Noise & Vibration Mitigating Measures & Residual Impact

The initial desktop assessment completed has identified a possible number of mitigating measures for the construction phase. These include:

- Repositioning of GHE if elevated noise measurements are recorded at nearby receptors;
- Use of soundproofing material in the Heat Pump casing to reduce operational noise if the operational level are found to be above the local baseline.

B.2.6. Landscape & Visual

The LVIA impact assessment methodology is outlined in Part A section 3.7.

B.2.6.1. Baseline assessment and receptors

The location of potential visual receptors in close proximity to the drill site and the location of the technical room is shown in figure B.0.7.



Figure B.0.7 – Porta Degli Angeli proposed development and Location of Visual Receptors

B.2.6.2. Landscape & Visual Impact Assessment

The LVIA carried out for the Ferrara site is summarised in table 34 below.

Table 33: LVIA Summary – Porta Degli Angeli, Ferrara

Landscape Characteristics	Assessment	Definition
Landscape Designation	High	UNESCO world heritage designation
Landscape Quality	Exceptional /High	Scenic and historical/cultural areas
Nature of Views	High	Short and long distance views characterise the landscape
Sensitivity	Medium – High	The land use comprises views with significant cultural and historic attributes. These are also characterised by frequent recreational users as well as comprising principal views from residential buildings located to the south of the site
Magnitude	Negligible	Very minor loss or alteration to one or more key elements/ features/characteristics of the baseline conditions. Change will be barely distinguishable, approximating to ‘no change’
Significance of Effect	None	The new installation is appropriate in its context. It may be difficult to differentiate from its surroundings and would affect very few or no receptors. The long term impact from the HP plant located below the board walk will not be perceptible to nearby receptors. Short term effects on the residential receptors during the installation process will be screened by the wall and tall vegetation.

B.2.7. Porta Degli Angeli Summary EIA

A summary impact assessment for the Ferrara case study site based on the Part A common chapter and the information available upon completion of the installation works is provided in table 35.

Table 34: Porta Degli Angeli, Ferrara –EIA Summary

EIA key aspects	Significance of Impact	Nature of Impact
Soils and Geology	Imperceptible	No impact or alteration to existing geological environment expected due to the installation of grouted borehole heat exchangers and the application of a balanced heating and cooling load to the ground.
Hydrology and Hydrogeology	Negligible	No alteration to groundwater recharge, flow mechanisms or water levels; and no pollution or change in water chemistry to either groundwater or surface water given the planned use of grout in the BHEs.
Air quality	Limited	Minor dust emissions, traffic generated by the construction, and combustion emission during the construction phase only. Mitigation measures including the use of water flushing as part of the drilling to reduce any potential impacts and the use of screening to the nearby road and cycle path. The operational phase impacts are deemed to be an improvement on the current baseline values for fugitive emissions in the area with a reduction of 75% of CO ₂ emissions compared to the gas fired heating technologies being displaced by the new installation.
Noise and vibration	Limited	Noise related impacts from the construction operations , in particular relating to the drilling operations are deemed to be imperceptible as a result of high noise baseline values due to the adjacent road. Noise from the operational phase of the heat pumps is deemed to be imperceptible due to the high baseline values. Vibration related impacts from the drilling operations are not applicable due to the use of water flush rotary drilling technique.

Traffic and Transportation	Limited/Negligible	Conventional construction traffic transporting construction materials to the site. Imperceptible impact to local traffic conditions given high volumes of traffic on the local access roads
Landscape and Visual	Limited/Negligible	Small scale landscape, high landscape quality, long distance views. Views from higher ground to the south of the proposed drilling areas are restricted by the city’s old wall. No loss or alteration to one or more key elements/ features/characteristics of the baseline conditions. Change will be barely distinguishable at the construction phase due to the short nature of the work and the implementation away from local receptor views. Longer term impacts are limited as the plant equipment positioning is screened by a walkway and existing structure. The impact is considered equivalent to ‘no change’.

B.3. Residential Building in Battel, Mechelen, Belgium

B.3.1. Case Study Site Summary

The real case study site is a two-storey detached residential family house originally built in 1963 with a total surface area of 185m². The current heating and DHW energy demand is met using a central gas boiler with a total of 30,452 kWh per annum. The proposed real case installation will include a deep retrofit of the building fabric to increase energy efficiency and reduce consumption as well as the installation of a single source, dual temperature heat pump and a radiant floor system.

B.3.2. Project Description

The installation work undertaken included extensive retrofit of the building as well as the installation of a new heating a cooling solution. These retrofit intervention result in an energy demand of a 10kW of heating and cooling post completion of the building refurbishment works (RED, 2020b). The retrofit project is summarised below based on the construction and initial operational phase of the system. A schematic of the works is shown in figure B.0.8, with the GHEs installed at the rear of the house. The phased programme of works is described in below.

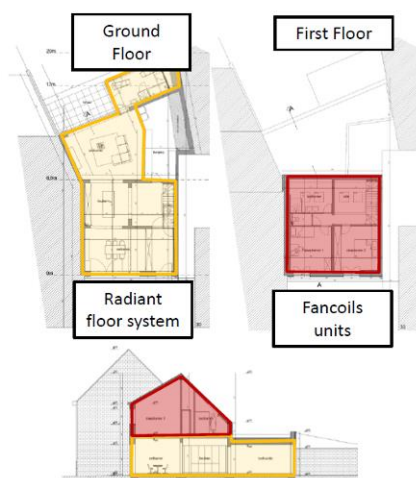


Figure B.0.8 – Battel project layout

CONSTRUCTION PHASE:

Building Retrofit works implemented:

- Demolition of internal building structure
- Roof replacement
- Insulation of roof & external walls
- Window replacement including insulation
- Electrical and Plumbing upgrade
- Internal wall finish and plastering

- Radiant underfloor installation including screed

Dual Source Heat Pump Installation:

- Installation of 496 m deep stainless steel coaxial Heat exchangers
- Drilling using the Hydra-RED method with water flush
- Surface pipework trenching and connections works
- Preparation of the HP technical room
- Installation of fan coil units and connection the HP

OPERATIONAL PHASE:

- Single source, dual temperature heat pump operation to meet the heating and cooling demand

B.3.3. Soils & Geology

A.3.1.8 Baseline Assessment

The baseline geology at the site is summarised in D 5.2 (Fodor, L. Rossi, L. Tanase, 2019) and comprises unconsolidated sediments with no hard rock formations. Table 35 summarises the geological conditions.

Table 35: Geological Profile at the Battel Site

Geological Layer	Depth (m)	Stratigraphic Description
Alluvium	0 –8.7	
Pleistoceen van de Vlaamse Vallei	8.7-12.8	
Boom Aquitard	12.8-14.1	<i>Stiff Clay</i>
Ruisbroek-Berg Aquifer	14.1-19.3	<i>Clayey Sand</i>
Tongeren Aquitard	19.3-20.9	<i>Clay</i>
Oligocene Aquifer System	20.9-26	<i>Sand, gravels and cobbles</i>
Bartoon Aquitardsysteem	26-47.3	<i>Stiff Clay</i>
Wemmel-Lede Aquifer	47.3-66.6	<i>Clayey Sand</i>
Paniseliaan Aquitard	66.6-77.1	<i>Clay</i>
Ieperiaan Aquifer	77.1-85.5	<i>Clayey Sand</i>
Kortemark Silt	85.5-90.2	<i>Silt</i>
Alluvium	90.2-181.7	<i>Clay</i>

B.3.3.1. Soils and Geology Impact Assessment

The impact assessment on the soils and geology was considered in the context of the drilling methodology implemented (Hydra-RED with water flush) at the site and the installation of the borehole heat exchangers. However, the use of the Hydra-TKI method was not implemented due to the geological conditions at the site. The probes installed with the Hydra-RED method were be piled directly into the ground

The operational phase impact focuses on the exchange of energy from the GHEs for heating and cooling. The operational impacts are determined based on the initial data of the HP performance information and the assessment of these against the modelled energy demand curves (RED, 2020a).

Table 36: Soil & Geology Impact assessment – Battel Site

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc. to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Erosion of soils and subsoils during construction and drilling	Local and long term	Medium	Slight	Low	Yes – ensure soil erosion is minimised at the trenching stage – stockpile and reuse excavated material
Contamination of soils and subsoils from drilling operations	Local and long term	High	Moderate	Low	Yes – possible from previous use of the site. The Hydra-RED method piling the HE directly in the ground preventing contamination. Boreholes grouted to further reduce impact
Removal of rock (drill cuttings) via drilling process	Local and permanent	High	Slight	Low	Not applicable
Operational Phase					
Change in ground temperature during heating and cooling	Local and permanent	Low	Slight	Low	The probability of occurrence is low as the load to the ground from during heating and cooling when the GSHP part of the system is in operation is mostly balanced, thus generating a net imperceptible impact to the ground

B.3.4. Hydrology & Hydrogeology

B.3.4.1. Baseline Assessment

The baseline hydrogeological conditions at the site are characterised by the presence of four principal aquifers to a depth of 100m. These are highlighted in table 32 above which characterises the site conditions. These comprise by unconsolidated Oligocene aged sands and gravels interbedded with clay dominated aquitard layers (VLAREM, 2018). The local groundwater level at the site is expected to be 2m below ground level.

B.3.4.2. Hydrology & Hydrogeology Impact Assessment

Table 37 presents the initial outcomes of the assessment based on the desktop review and the works undertaken at the site. The operational impacts are assessed based on the initial operational data from the system.

Table 37: Hydrology & Hydrogeology Impact assessment – Battel Site

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Contamination of Aquifers during drilling	Local and long term	Medium	Moderate	Low	Yes – ensure adequate grouting methods are using when installing the heat exchangers. Ensure no leaks in GHE connections resulting from the Hydra-RED method are present following installation (pressure testing to be implemented)
Waste water generated from drilling	Local and permanent	High	Slight	Low	Yes – use of water recirculation and treatment system – dispose of water in accordance with local regulations
Operational Phase					
Change in groundwater temperature during heating and cooling	Local and permanent	Low	Slight	Low	The collector length is adequately designed and minimises adverse temperature change with balanced heating and cooling loads from the installed system

B.3.5. Noise & Vibration

The impact assessment methodology including field measurement for construction noise and vibration is outlined in Part A section 3.6.

B.3.5.1. Baseline assessment and receptors

A baseline assessment was carried as part of the initial screening process and a series of noise receptors identified (figure B.0.9)



Figure B.0.9 – Battel Case Study Site Monitoring showing the location of Receptors & Noise Monitoring Points. Baseline estimated.

B.3.5.2. Noise & Vibration Impact Assessment

The noise and vibration impact assessment at the Battel case study site was confined to noise measurements only. The use of the Hydra-TKI drilling methodology was not implemented at this case study site. The Hydra-RED piling method using a water flush system was implemented. In this case the risk of vibration to nearby structures and receptors is not perceptible as the technique does not use high frequency vibration.

The noise measurement data values were assessed against an estimated baseline value for daytime noise in a quiet residential areas located more than 30m away from a main road.

The impact of the noise of the drilling operations to the local receptors with respect to the position of the source (in this case the Hydra Joy 3 drilling rig) compared to the local baseline (Table 38) are deemed low to moderate, however the overall impact is considered low due to the temporary nature of the drilling works.

Impacts related to noise at the operational stage of the heat pumps is deemed to be imperceptible to local receptors due to the internal location of the plant and heat pump inside the building.

Table 38: Noise Measurements dBA (Max) recorded at the Battel case study site

Monitoring Point	Activity	Distance from source(m)	Average dBA (Max)
Baseline	Daytime Road Traffic	10	54 (estimated based on EIA benchmark values for noise in quiet residential areas away from main roads)

N1	Drilling	2	72
N2	Drilling	5	65
N3	Drilling	15	54

B.3.5.3. Noise & Vibration Mitigating Measures & Residual Impact

The initial desktop assessment completed identified a possible number of mitigating measures for the construction phase. These include:

- Repositioning of GHE if elevated noise values are measured in proximity of receptors;
- Use of soundproofing material in the Heat Pump casing to reduce operational noise inside the building.

B.3.6. Landscape & Visual

The LVIA impact assessment methodology is outlined in Part A section 3.7.

B.3.6.1. Baseline assessment and receptors

A baseline assessment was carried as part of the initial screening process and a series of visual receptors identified (figure B.0.10)



Figure B.0.10 – Battel, Mechelen Case Study Site Visual Receptors

B.3.6.2. Landscape & Visual Impact Assessment

The LVIA carried out for the Battel site is summarised in table 49 below.

Table 39: Landscape and Visual Assessment – Battel, Mechelen, Belgium

Landscape Characteristics	Assessment	Definition
Landscape Designation	Low to Negligible	No specific designation
Landscape Quality	Medium to Low	Residential Area
Nature of Views	High	Short distance views characterise the landscape where the installation will take place
Sensitivity	High to Medium	The land use comprises views principal and secondary views from residential buildings located all around the proposed development
Magnitude	Negligible	Very minor loss or alteration to one or more key elements/ features/characteristics of the baseline conditions. Change will be barely distinguishable, approximating to ‘no change’
Significance of Effect	None	The new installation is appropriate in its context. It may be difficult to differentiate from its surroundings and would affect very few or no receptors. The long term impact from the HP plant located inside the house will not be perceptible to nearby receptors. Short term effects on the residential receptors during the installation process will be minor due to the short nature of the works.

B.3.7. Residential Building Battel, Mechelen - Summary EIA

A summary impact assessment based on the Part A common chapter and the information available following the completion of the installation is provided in table 40.

Table 40: Battel, Mechelen –EIA Summary

EIA key aspects	Significance of Impact	Nature of Impact
Soils and Geology	Imperceptible	No impact or alteration to existing geological environment expected with the implementation of a balanced heating and cooling load to the subsurface.
Hydrology and Hydrogeology	Negligible	No alteration to groundwater recharge, flow mechanisms or water levels; and no pollution or change in water chemistry to either groundwater or surface water given the planned use of grout in the BHEs.
Air quality	Limited	Minor dust emissions, traffic generated by the construction, and combustion emission during the construction phase only. Mitigation measures including the use of water flushing as part of the drilling to reduce any potential impacts and the use of screening to the nearby road and cycle path. The operational phase impacts are deemed to be an improvement on the current baseline values for fugitive emissions in the area with a reduction of 94% of CO ₂ emissions compared to the gas fired heating technologies being displaced by the new installation.
Noise and vibration	Limited	Noise related impacts from the construction operations , in particular relating to the drilling operations, are moderate to low against the estimated local baseline values. However, these can be considered to be low due to the temporary nature of the construction works . Noise from the operational phase of the heat pumps is deemed to be imperceptible due to location of the heat pumps inside the building. Vibration related impacts from the drilling operations are not applicable.

Traffic and Transportation	Limited/Negligible	Conventional construction traffic transporting construction materials to the site. Imperceptible impact to local traffic conditions given high volumes of traffic on the local access roads
Landscape and Visual	Limited/Negligible	Small scale landscape, high landscape quality, long distance views. Views from higher ground to the south of the proposed drilling areas are restricted by the city’s old wall. No loss or alteration to one or more key elements/features/characteristics of the baseline conditions. Change will be barely distinguishable at the construction phase due to the short nature of the work and the implementation away from local receptor views. Longer term impacts are limited as the plant equipment positioning is screened by a walkway and existing structure. The impact is considered equivalent to ‘no change’.

B.4. Historical Residential Building in Greystones, Ireland

B.4.1. Case Study Site Summary

The single storey historical residential building was built in the 1890's and extended c. 15 years ago and comprises a floor area of 165m². The building is a protected structure and therefore, refurbishment works to retrofit it would require permission and would affect the character of the building. The current heating and DHW demand was previously met using a 38kW gas fired boiler with an estimated consumption of 42,000 kWh of gas per annum. The building comprises single glazed sash windows that are part of the protected features.



B.4.2. Project Description

Due to the historic character of the building, no immediate retrofit measures were implemented. The case study site works included the installation of a 15kW, dual cycle, high temperature heat pump to partially displace the original gas fired central heating system. The gas fired boiler was retained as a backup to the new heat pump installation and to provide peaking load capacity in the coldest months of the heating season. The existing radiators and heating terminals were retained. A new plant room comprising high efficiency buffer vessels for the heating and domestic hot water elements has been installed in a purpose built plant room adjacent to the house.

240m of stainless steel coaxial heat exchanger were installed in the driveway opposite the plant room using the Hydra-TKI method assisted by an air flush system. The project tested the drillability of the Vibro-drill head in hard rock conditions. The boreholes were individually drilled, the drill string removed and the GHEs installed using factory pre-fabricated connections. A sacrificial grout tube was connected to the lower section of each GHE and Geotherm-X GR thermally enhanced grout was pumped to surface to seal the annular space. Figure B.0.11 shows an outline schematic of the site and the works completed.

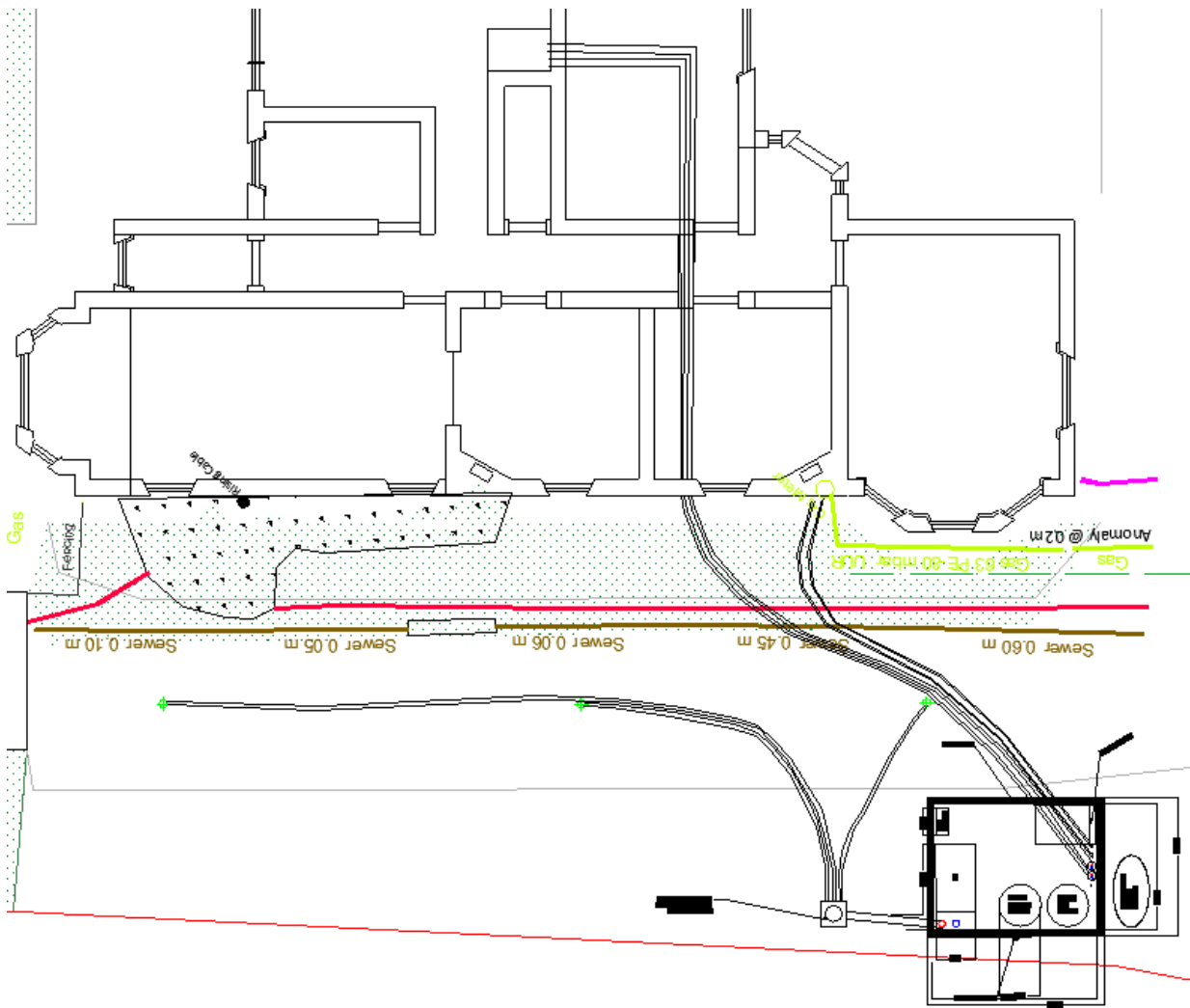


Figure B.0.11 – Greystones Case study site layout showing the location of the BHEs, the new technical room and the connection of both the boreholes and the pipework to the building.

B.4.3. Soils & Geology

B.4.3.1. Baseline Assessment

The baseline geology characterising the unconsolidated sediments and the hard rock geology at the site is summarised in D 5.2 (Fodor, L. Rossi, L. Tanase, 2019). Table 41 summarises the geological conditions encountered at the site.

Table 41: Geological Profile at the Battel Site

Geological Layer	Depth (m)	Stratigraphic Description
Till	0–8.7	Till Derived from Cambrian SSTs and Shales comprising mostly clayey sand with occasional gravels and cobbles
Bray Head Formation	8.7-100m	Cambrian aged metasediments comprising grey-green wackes and purple/grey siltstones

B.4.3.2. Soils and Geology Impact Assessment

The impact assessment on the soils and geology was considered in the context of the drilling methodologies used at the site and the design and completion of the borehole heat exchangers. The use of the Hydra-TKI methods with air flush system was implemented. The ground heat exchangers annular space was grouted using a sacrificial grout tube from the base of the borehole to the surface.

The operational phase of the scheme will focus on exchanging energy from the GHEs during the heating season. The operational impacts are estimated based on the operation of the new plant installed in advance of the final HP performance information being available at the time of writing and compared to both the modelled energy demand curves (RED, 2020a) and the partially displaced gas fired boiler.

Table 42: Soil & Geology Impact assessment – Greystones Site

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc. to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Erosion of soils and subsoils during construction and drilling	Local and long term	Low	Slight	Low	Yes – stockpile and reuse excavated material
Contamination of soils and subsoils from drilling operations	Local and long term	Moderate	Moderate	Low	Yes – possible as site runoff is towards the GHE area. Grouting and tops up at each GHE to be undertaken to ensure seal to surface
Removal of rock (drill cuttings) via drilling process	Local and permanent	High	Slight	Low	Not applicable
Operational Phase					
Change in ground temperature during heating	Local and permanent	Low	Slight	Low	Yes – adequate collector length is installed to minimise low collector temperatures (not below 0°C) during long term operation of the system in heating only mode. Gas fired boiler back up to facilitate the need for reduced load to the ground

B.4.4. Hydrology & Hydrogeology

B.4.4.1. Baseline Assessment

The baseline hydrogeological conditions at the site are based on the presence of a limited number of groundwater boreholes within a 1km radius of the site as well as the results of the drilling works implemented during the installation. There are two potential aquifer zones in the unconsolidated sediments and in the bedrock. These described in table 43 (Geological Survey Ireland - DCCA, 2020). The static groundwater level at the site was measured as 7.8 metres below ground level following completion of the drilling.

Table 43: Hydrogeological Characteristics of the Greystones site

Aquifer characteristics	Depth (m)	Description
Till	0-8.7	<i>Perched groundwater confined to lenses of gravel and cobbles at the bedrock surface. Groundwater quality expected to be poor</i>
Bray Head Formation	8.7->100m	<i>Classified as a Poor aquifer, generally unproductive except in Local Zones by the Geological Survey Ireland. Groundwater flow is dominated by fracture permeability and expected yields are between 20-40 m³/day based on records in groundwater wells in the same formation. Two main water strikes associated with fault structures in the bedrock were observed during the drilling operations at 27.8m and 142m below ground level with a combined estimated yield of about 1m³/hr.</i>

The drilling operations at the site demonstrated that a perched groundwater table from confined sand and gravel deposits in the overburden is present at a depth of between 2.75 and 3.8 metres below ground level.

The Bray Head Formation is characterised by fracture permeability with 2 main water strikes encountered during drilling at depths of 27.8 and 142 metres below ground level. A static water level of 7.8 metres below ground level was recorded 2 weeks following the completion of the drilling operations in December 2021.

B.4.4.2. Hydrology & Hydrogeology Impact Assessment

Table 44 presents the outcomes of the assessment based on the desktop review and the works implemented. Operational impacts cannot be fully determined until such time that the system is operational. For the purpose of this assessment, the operational impacts have therefore been estimated.

Table 44: Hydrology & Hydrogeology Impact assessment – Greystones Site

Potential Impact	Spatial and Temporal Impact	Probability of Occurrence	Significance of Impact	Risk from Impact	Mitigation Required?
Construction Phase					
Leakage of fuels etc to soils and subsoils during drilling	Local and long term	Medium	Moderate	Medium	Yes – storage of fuels in bunded tanks
Contamination of Aquifers during drilling	Local and long term	Medium	Moderate	Low	Yes – ensure adequate grouting methods are using when installing the with the TKI method. Ensure no leaks in GHE connections resulting from the Hydra-RED method are present following installation
Waste water generated from drilling	Local and permanent	High	Slight	Low	Yes – use of water recirculation and treatment system – dispose of water in accordance with local regulations
Operational Phase					
Change in groundwater temperature during heating and cooling	Local and permanent	Low	Slight	Low	Based on the ground conditions recorded at the site, and the static water level encountered, impacts on groundwater are expected to slight with a possible ned reduction of baseline temperatures from the operation of the heat exchangers in heating only mode.

B.4.5. Noise & Vibration

The impact assessment methodology including field measurement for construction noise and vibration is outlined in Part A section 3.6.

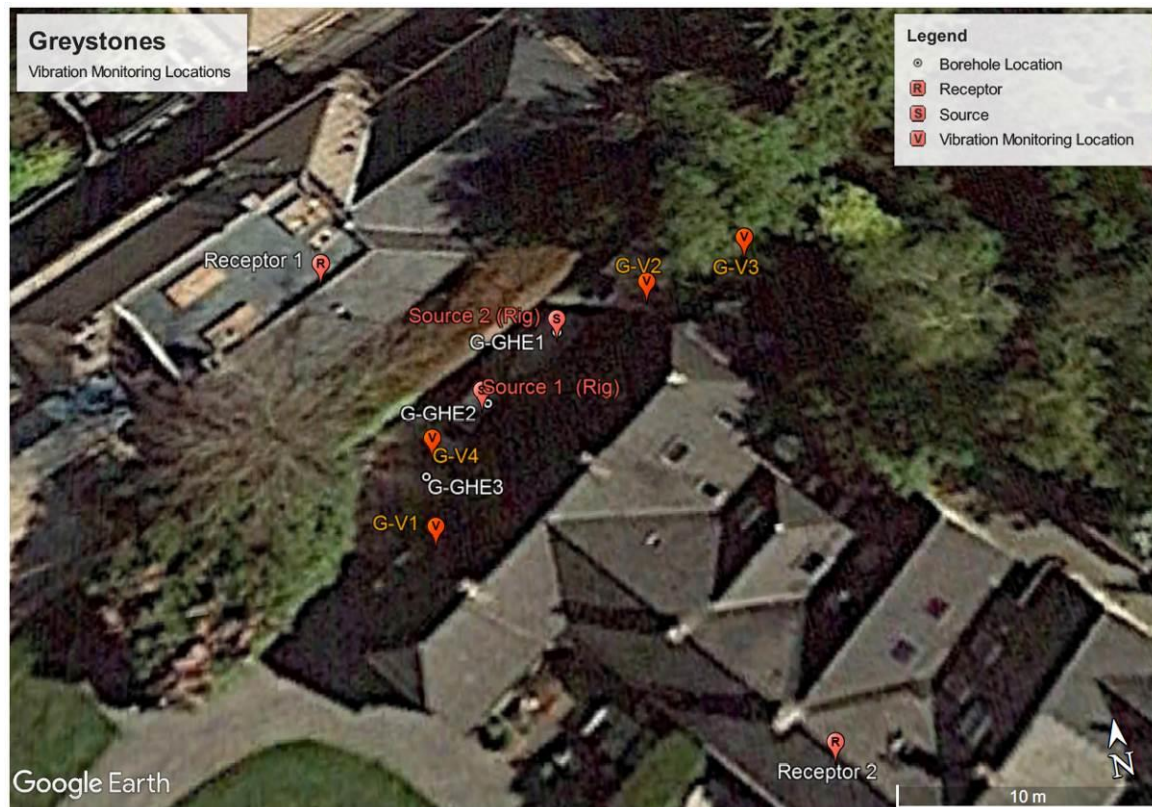
B.4.5.1. Baseline assessment and receptors

A baseline assessment was carried as part of the initial screening process and a series of noise and potential vibration receptors identified (figure B.0.12 a). These are located in immediate proximity to the proposed areas where the GHEs were installed and where the technical room is located. A number of measurement points based on the location of these receptors are implemented for the impact assessment.





(b)



(c)

Figure B.0.12 – Greystones Case Study Site Monitoring showing Receptors (a), Noise (b) & Vibration (c)

B.4.5.2. Noise & Vibration Impact Assessment

Table 45 shows the dBA maximum noise measurements recorded during the drilling and completion operations of the heat exchangers using the Hydra TKI method with compressed air. Two main noise sources (the drilling rig with the TKI VD80 head and the Keiser 8m³ compressor at two different locations) represent the main sources (figure B.0.12 b). Noise measurements were taken at three different locations (G-N1, G-N2 and G-N3) with a baseline measurement taken one week prior to the commencement of the drilling operations in September 2021.

The noise levels recorded during drilling are noted as being significantly higher than the local baseline value and the accepted standards for background noise in residential area based on BS5228 (table 11).

Table 45: Noise Measurements dBA (Max) recorded at the Greystones case study site

Monitoring Point	Activity	Distance (m)	dBA (Max)
Baseline			55.6
G-N1	Drilling	14	112.3
G-N2	Drilling	10	110.4
G-N3	Drilling	8	99.3

Vibration monitoring was completed by using a portable seismometer placed at 3 No. locations during the drilling operations at 10m and 12m distance from the drilling rig and TKI VD80 head (figure B.0.12 c). The unit was placed in continuous recording mode for the duration of each measurement.

Table 46 shows the maximum PPV values on three axes recorded during each measurements with a maximum values of 4.8 mms⁻¹ recorded at G-V2. The PPV records for the continuous 4 hour period of recording are plotted in (figure B.0.13). The maximum frequencies of at the monitoring points are shown in table 47. A distinct reduction in longitudinal frequency is observed at G-V2 compared to the frequencies recorded at G-V1 and G-V3 as a result of the increase drilling depth (below 20m from ground level) in the case of G-V2, with the higher frequency values of 71.4 Hz recorded during the casing and drilling operations at shallow depths.

Table 46: PPV Measurements (mms⁻¹) recorded at the Greystones case study site

Point	Activity	Distance (m)	Long mms ⁻¹	PPV	Vertical mms ⁻¹	PPV	Transv mms ⁻¹	PPV
G-V1 (Source 2)	Casing & Drilling	10	1.55		0.8		1.65	
G-V2 (Source 1)	Drilling	10	3.5		2.3		4.8	
G-V3 (Source 2)	Drilling	12	0.675		1.15		0.95	

Table 47: Frequency Measurements (Hz) along the longitudinal, vertical and transverse axes recorded at the Greystones case study site

Point	Activity	Depth (m)	Long Freq (Hz)	Vertical Freq (Hz)	Transv Freq (Hz)
G-V1 (Source 2)	Casing & Drilling	0 to 4.2	71.4	38.5	71.4
G-V2 (Source 1)	Drilling	13 to 40	35.7	45.5	20.8
G-V3 (Source 2)	Drilling	3 to 21	71.4	50	26.3

The PPV and frequency values recorded are considered in the assessment against the DIN standard and BS guideline values (table 14 and figure 3.1). These demonstrate that the impact to nearby receptors from the Hydra-TKI drilling method is low as all values are below the thresholds set for sensitive structures and historical buildings.

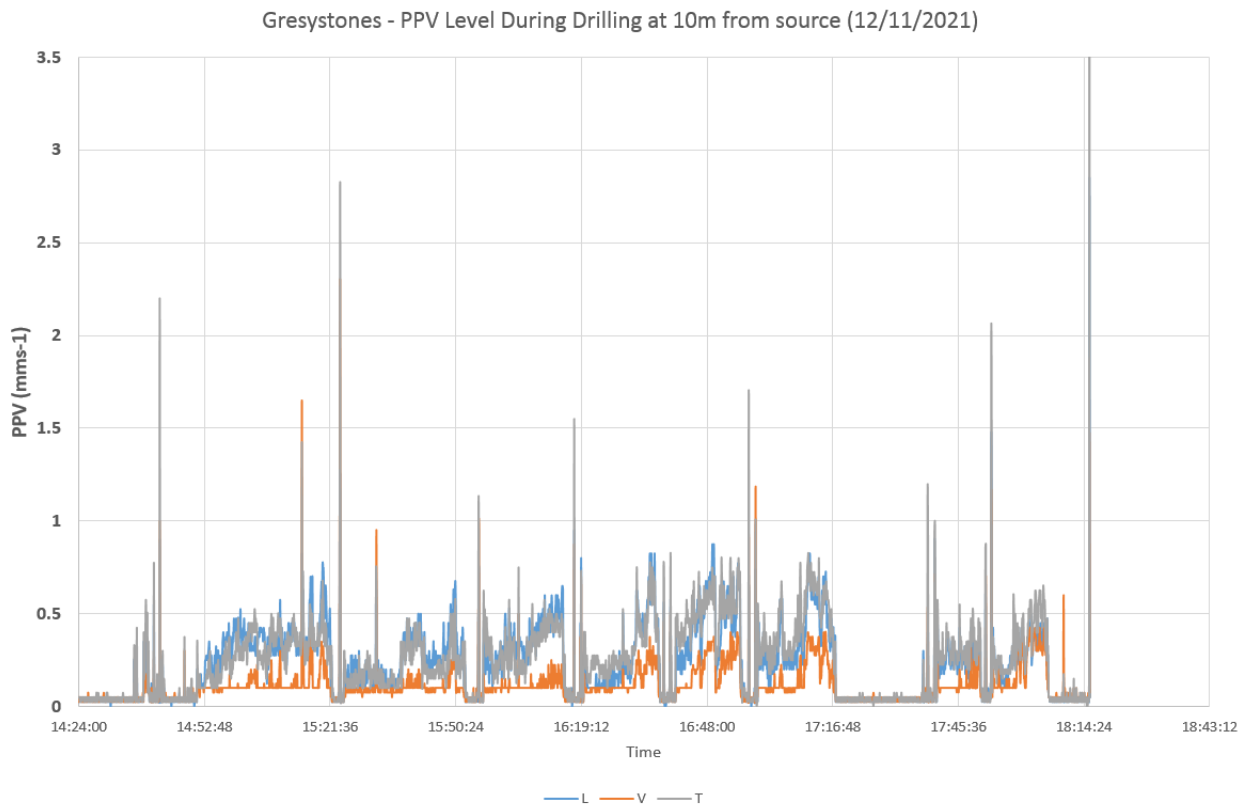


Figure B.0.113 – Greystones Case Study seismometer PPV recorded values at monitoring point G-V2 over a 5 hour period.

B.4.5.3. Noise & Vibration Mitigating Measures & Residual Impact

The initial desktop assessment completed identified a possible number of mitigating measures for the construction phase. These include:

- Repositioning of GHE further away from the house if elevated vibration are measured at nearby structures;
- Use of portable fencing barriers to reduce noise.

B.4.6. Landscape & Visual

The LVIA impact assessment methodology is outlined in Part A section 3.7.

B.4.6.1. Baseline assessment and receptors

A baseline assessment was carried as part of the initial screening process and a series of visual receptors identified (figure B.4.3). These mostly represent residential receptor located immediately adjacent to the drilling site and overlooking the property. The property boundary comprises mature trees and hedgerows that provide extensive screening resulting in short views.



Figure B.0.14 – Greystones Case Study Site Visual Receptors

B.4.6.2. Landscape & Visual Impact Assessment

The LVIA carried out for the Greystones site is summarised in table 48.

Table 48: Greystones Landscape and Visual Assessment Summary

Landscape Characteristics	Assessment	Definition
Landscape Designation	Low to Negligible	No specific designation
Landscape Quality	Medium	Residential Area with Historical Buildings
Nature of Views	High	Short distance views characterise the landscape where the installation will take place
Sensitivity	High to Medium	The land use comprises views principal and secondary views from residential buildings located all around the proposed development with historical buildings and place of worship in close proximity
Magnitude	Negligible	Very minor loss or alteration to one or more key elements/ features/characteristics of the baseline conditions. Change will be barely distinguishable, approximating to ‘no change’
Significance of Effect	None	The new installation is appropriate in its context. It may be difficult to differentiate from its surroundings and would affect very few or no receptors. The long term impact from the HP plant located inside the newly built plant room will be slight due to the presence of heavy screening from the existing hedgerow vegetation to receptor 1. The impact will not be perceptible due to the presence of heavy vegetation screening around the property and along the road.

B.4.7. Greystones Ireland - Summary EIA

The summary impact assessment based on the Part A common chapter is provided in table 49.

Table 49: Greystones, Ireland –EIA Summary

EIA key aspects	Significance of Impact	Nature of Impact
Soils and Geology	Imperceptible	No impact or alteration to existing geological environment expected to the use of grouted borehole heat exchangers at the site.
Hydrology and Hydrogeology	Negligible	No alteration to groundwater recharge, flow mechanisms or water levels; and no pollution or change in water chemistry to either groundwater or surface water given the use of grout in the BHEs.
Air quality	Limited	Minor dust emissions, traffic generated by the construction, and combustion emission during the construction phase only. Mitigation measures including the use of water to reduce dust from the air flush drilling as well as the use of screening to the around the drill site to reduce impact to neighbouring properties. Operational impacts on air quality are estimated to be a slight improvement of the local baseline as a result of the operation of the ground source heat pump. The combined HP and gas boiler back up system is estimated to result in a 20% reduction of CO ₂ emissions at the site from the displaced technology.
Noise and vibration	Limited	Noise related impacts from the construction operations , in particular relating to the drilling operations are severe against the local baseline values as a result of a significant increase from the local baseline. However, these can be considered to be moderate to low due to the temporary nature of the construction works . Noise from the operational phase of the heat pumps is deemed to be low to imperceptible due to location of the heat pumps in the insulated external plant room. . Vibration related impacts from the drilling operations to nearby receptors are deemed to be low to imperceptible due to all PPV and frequency values measured falling within DIN & BS standards for buildings & sensitive structures.
Traffic and Transportation	Limited/Negligible	Conventional construction traffic transporting construction materials to the site. Imperceptible impact to local traffic conditions given high volumes of traffic on the local access roads to the main village. Logistical plan has been focussed on delivery of machinery and site supply in off peak hours to minimise impact.
Landscape and Visual	Limited/Negligible	Small scale landscape, high landscape quality, short distance views. No loss or alteration to one or more key elements/ features/ characteristics of the baseline conditions. Change imperceptible at the construction phase due to the short nature of the work and the heavy vegetation providing screening to nearby receptors. Longer term impacts are deemed imperceptible as a result of the new plant room being heavily screened by existing mature vegetation.

Conclusion

The results of the outline environmental impact carried out at the real case study sites with respect to the implementation of the GEO4CIVHIC technologies has been summarised at the end of each respective case study section (refer to tables 25, 31, 36 & 42 respectively). Part B of the documented has been updated with the EIA assessment completed following the implementation of the installation works at each of the real case study sites and with the initial operational data.

A detailed risk register has been developed for each of the real cases and aimed at providing a working document of assess project implementation risks and develop/change necessary mitigation strategies as the installations progress.

General conclusions with respect to those common chapters that have been implemented as part of a desktop assessment are summarised below:

- Project Description: an overview of the installation works at each of the real cases has been summarised based on the level of implementation and the expected drilling, GHE installation methods as well as any works for building retrofit and installation of the HP prototypes developed as part of the project. A detailed description of the measures implemented is given in the relevant sections of Part B of the document.
- Soils & Geology: The expected impact based on the planned drilling operations and the potential operation of the ground heat exchangers was considered. The drilling and GHE completion methodology ensures that minor to negligible impact to the baseline environment will be achieved. This was broadly achieved through the installation at each of the case study sites of grouted BHEs and the implementation of a balanced load from the heating and cooling demand at the Malta, Ferrara and Battel case study sites. A slight impact is expected at the Greystones site where the HP and BHEs are operating in heating only mode resulting in a potential reduction of the long term ground temperatures. However these are expected to be mitigated by the presence of natural groundwater flow in the bedrock.
- Hydrology & Hydrogeology: Minor or negligible impacts to the baseline environment are expected at each of the sites. The drilling and grouting of the heat exchangers provides a mitigation strategy for the protecting the baseline environment. The long term impacts to the local hydrogeological conditions in the context of the operation of the HPs is estimated to be low given the balanced heating and cooling load applied to the different heat exchangers resulting in a ‘net 0’ (or near net ‘0’) temperature change. The slightly higher impact expected for the Greystones case study site is expected to be mitigated by the presence of groundwater in several fractures horizons in the bedrock.
- Air Quality & Climate: The air quality and climate impacts were considered for the construction stage based on the machinery and vehicle movements and how these would impact on local air quality. The impacts are estimated as low due to the low fuel consumption from the hydraulic based drilling plant at all case study sites with a higher impact in Ireland where air compressors were used. The operational impacts are considered based on the CO₂ emissions of the final heating and cooling system operation and compared to the pre-retrofit fossil fired technologies displaced. Overall reductions in CO₂ emissions from 19% up to 90% are expected from the real cases with the GEO4CIVHIC HPs in operation, with an increase in CO₂ emissions expected only at the Malta case study site as a result of the lack of space heating and cooling infrastructure prior to the installation of the new GEO4CIVHIC hybrid system.

- **Traffic and Transportation:** The impacts of the construction and operational phases at each site were considered based on local road network and surrounding land use characterisation. A logistical plan developed for each site was used to define the number of vehicle movements. Based on the individual assessments, the construction traffic is considered low to moderate due to the short temporary nature of the works. The operational traffic is considered imperceptible.
- **Noise & Vibration:** Applicable European and international standards on noise and vibration have been reviewed and a detailed monitoring and measurement methodology for the construction works at each of the real case study sites has been implemented during the completion of the installation works in WP5. Based on the noise monitoring data recorded, the impacts from noise generated from the drilling operations during the construction phase is considered to be the most important. This is overall considered low to imperceptible in the case study sites where the Hydra-RED and conventional water flush drilling method was implemented (Battel and Ferrara). A moderate to low impact is considered where the Hydra-TKI method was implemented (Malta and Greystones), with the highest impact recorded using the Hydra-TKI method with compressed air (Greystones). Overall the noise impact from the construction phase is considered low due to the temporary nature of the drilling works. The impacts from vibrations caused by the drilling and construction phase operations was considered negligible to imperceptible at the Battel and Ferrara case studies where the Hydra-RED and conventional water flush drilling methods were used. The impact from the use of the Hydra-TKI method in Malta and Greystones was considered as low with PPV and frequency values observed to be within the DIN standard and BS guideline values for sensitive structures and historical buildings.
- **Landscape & Visual Impact:** A detailed assessment based on local receptors, sensitivities and local views has been undertaken to understand the impacts at the construction stage of each site and the subsequently any longer term impacts resulting from the operations of the GSHP system. The retrofit works as well as the drilling and GHE installation are deemed to have the greatest impact at each site given. However the short and temporary nature of the proposed works has resulted in minor construction impacts only. The operational impacts are considered to be imperceptible, with the operating HPs being located either inside buildings or installed in areas heavily screened to receptors by existing walls and structures.

Table 50 presents a summary of the residual impacts at all 4 No. case study sites based on the results of the individual assessments at the construction and operational phases.

Table 50: Summary of EIA Residual Impacts at each of the case study sites

EIA key aspects	Malta – Msida Bastion	Ferrara Porta Degli Angeli	Battel - Belgium	Greystones - Ireland
Soils and Geology	Imperceptible	Imperceptible	Imperceptible	Imperceptible
Hydrology and Hydrogeology	Imperceptible	Imperceptible	Imperceptible	Low
Air quality	Low	Improved	Improved	Moderate Improvement
Vibration	Low	Imperceptible	Imperceptible	Low
Noise	Low	Imperceptible	Low	Moderate
Traffic and Transportation	Low	Low	Low	Low
Landscape and Visual	Imperceptible	Imperceptible	Imperceptible	Imperceptible

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APPENDIX A – Case Study Site Live Risk Register
