Deliverable Proof – Reports resulting from the finalisation of a project task, work package, project stage, project as a whole - EIT-BP2018

KIC project the report results from that contributed to/ resulted in the deliverable	E-Use - Europe-wide Use of Sustainable Energy from aquifers
Name of document	3.2.5 E-USE Validation of business cases
Summary/brief description of document	This report provides an overview of business case validation and lessons learnt for all pilots. The analysis is based on the evaluation of the trends of CAPEX and OPEX registered for the pilots of the Climate-KIC E-USE(aq) project.
Date of report	31/12/2018

Supporting documents: Report attached

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1. Introduction

This report provides an overview of the costs evolution and reviews the business cases for the pilots of the Climate-KIC E-USE(aq) project.

Within the E-USE(aq) project, focus is on the construction of pilot locations for ATES systems throughout Europe. In each pilot, aim is to overcome barriers for the implementation of ATES systems. Some of those barriers were defined in the predecessor of the current E-USE(aq) project; i.e. the pathfinder E-USE(aq) project. Most of those barriers are known to exist for a specific environment or country. While setting up the pilot locations within the current E-USE(aq) project however, sometimes, new barriers arose. Realizing and constructing a fully-functioning pilot is our proof that in each specific case, barriers for implementation of the ATES system have been overcome.

The E-USE(aq) project aims to pave the way for Europe-wide implementation of ATES systems; the way to widespread implementation in Europe is not just about overcoming barriers related to governance or technology, but is just as much about finances, i.e. **creating economically feasible ATES solutions.**

With the business case analysis, E-USE(aq) project aims to give more insight in this. In the E-USE(aq) pathfinder project, a first business case analysis has been made. A literature study was performed on business cases of different ATES systems in Europe.

In 2016, for the current E-USE(aq) demonstrator project, business cases for the individual pilots were created. Success factors for implementation of ATES systems in the Netherlands were analysed, since the implementation of ATES systems is more widespread in the Netherlands than in many other European countries.

In 2017, the approach has been more quantitative, developing a specific methodology for the business models by Nomisma Energia (NE).

The objective of the business model is to calculate payback times for each pilot (i.e. for each ATES system). This is done by calculating construction, operation/maintenance and financing costs and by comparing past and present energy consumptions. The pilots differ to great extend from each other. In some pilots, focus is entirely on developing fully operational ATES systems, while in other pilots, the focus is slightly more experimental in order to generate knowledge and experience that can be used directly for the implementation of ATES systems. Because of this, not all pilots generate the same kind of data as input for the business model. However, these different kinds of data are still able to give us valuable insights related to the business cases of ATES systems.

In 2018, the business cases were validated on the basis of the real cost values recorded for the projects, taking into account all the improvements and lessons learnt thanks to the pilot operations within the E-USE(aq) project. The main objectives of the activity carried out were:

Objectives	% Achieved
Validation of ATES business case	100%
Lessons learned from each ATES business case	100%

In the upcoming chapters, first the methodology for business case development is described. Next, a brief description of pilots is given, followed by the results of the economic assessment and a discussion about those results.

2. Methodology

The business case provides a management tool for a transparent decision making and a framework for the delivery, management and performance of the project. The first step in assessing the case for a new business venture or a project relies on the analysis of its economics.

Given the objective of the E-USE(Aq) project, which aims to assess the technical and commercial viability of ATES system in Europe, the first priority of the business case analysis was to have a clear understanding of all the pilot projects developed by the different partners.

After that, in order to have a common benchmark to evaluate the economics of each pilot project, NE elaborated a standardized business case spreadsheet that could form a basis of comparison between the different ATES systems.

Given that all ATES systems developed are brownfield solutions, in the sense that they were built and developed to substitute a former energy setting, the benefit/cost analysis considered all the new financial costs each partner faced and all the financial benefits as cost savings achieved/achievable after the installation of the ATES system.

The business case is about:

I. Attesting the value of the project (economic case);
II. Proving the affordability (financial case);
III. Proving commercial viability (commercial case).

The business case evaluation considered financial and non-financial aspects in order to balance out the feasibility of a project or venture. In analyzing the financial aspects, NE created a business model tool that could be the basis for a comparison among several projects. The tool has been organized in 4 modules as follows:

1. INPUT;
2. CALCULUS;
3. OUTPUT;
4. SUMMARY.

1.1. INPUT

The first window of the spreadsheet contains all the inputs connected to the main characteristics of the pilot project, costs and savings. All this data is used to calculate the energy savings connected to the installation of an ATES system. Input are divided into:

- Energy costs;
- Capital Expenditures (CAPEX);
- Operating Expenditures (OPEX);
- Loan simulator;
- Taxation;
- Incentives/subsidies.

Energy Costs

This section compares the energy consumption and related cost of the situation without ATES system with the new installation (with ATES system). The spreadsheet contains three types of energy consumption: diesel, natural gas (methane) and electricity. For each source, it is considered the installed capacity (Power), the average annual energy demand (Energy Demand) and the average annual consumption[1] (Consumption). "Power" and "Energy demand" are data that help to describe better the project, while "Consumption" is used for calculating the economics of the project. It is reasonable to expect that after installation of the ATES, the consumption for diesel and/or natural gas decreases, while the electricity consumption rises.

Figure 1 – Energy Costs, without and with ATES system

ENERGY COSTS - WITHOUT ATES

	Unit	**Diesel**	**Methane**	**Electricity**	Reference situation
System					
Power	*kW*				
Energy demand		*kWhth/y*	*kWhth/y*	*kWhel/y*	
			335.000	115.000	
Consumption		*t/y*	*Smc/y*	*MWh/y*	
			40.000	128	
Energy Costs		*€/t*	*€/Smc*	*€/MWh*	
			0,35	115,00	**Total NO-A**
Current Costs	€	*0*	*14.000*	*14.720*	**28.720**

ENERGY COSTS - WITH ATES

	Unit	**Diesel**	**Methane**	**Electricity**	New situation
System					
Power	*kW*				
Energy demand		*kWhth/y*	*kWhth/y*	*kWhel/y*	
				450	
Consumption		*t/y*	*Smc/y*	*MWh/y*	
			-	165	
Energy Costs		*€/t*	*€/Smc*	*€/MWh*	
		0	*0,35*	115,00	**Total W-A**
New Proposal Costs	€	-	-	**18.975**	**18.975**
Delta Costs (With ATES - Without ATES)	€	-	- *14.000*	*4.255*	- **9.745**

The template automatically calculates the yearly cost for each type of energy source. By including the energy consumption, the template automatically takes into account the SCOP (Seasonal Coefficient of Performance) of the new installation, thus the efficiency of the new technology.

[1] Where the energy consumption was not known, since there are not registered data available, the energy demand was used in order to calculate the consumption integrating the efficiency of the new installation.

The tool automatically computes the yearly energy costs with the ATES system and the difference between the new annual costs and the previous costs. A negative number results a saving, while a positive figure implies an extra-cost.

Capital Expenditures (CAPEX)

Capital expenditures (CapEx) represent all costs borne by a company in acquiring, maintaining, or improving fixed assets such as property, buildings, factories, equipment, and technology. Capital investments will be depreciated and the depreciation expense will run through the income statement over multiple periods.

Regarding the ATES system, CapEx includes all voices connected with:

- Cost of dismission of the previous system;
- All costs connected with the construction process;
- All costs connected with equipment and machineries.

In the figure below, a sample of all costs that can be considered as fixed costs of an ATES system is reported.

Figure 2 – Capital Expenditure

CAPEX

		Incl Tax
Costs of Dismissal current system	€	15.000
Design	€	5.000
Management	€	
Testing	€	
Other	€	
SubTotal	€	**20.000**
Specific cost for drilling	*€/m*	
Length	*m*	
Costs for Drilling	€	**0**
Specific cost for collectors	*€/m*	
Length	*m*	
Costs for Collecting	€	**0**
Type specific costs here	€	
Specific cost for heating pump	*€/kWel*	
Cost of HPP	€	**250.000**
Cost for Monitoring	€	
Cost for new distribution	€	
Costs for Electricity Systems	€	
Subtotal for Systems & Distribution	€	**0**
Cost of management system	€	
Type specific costs here	€	
Type specific costs here	€	
Type specific costs here	€	
Type specific costs here	€	
Type specific costs here	€	
Type specific costs here	€	
Type specific costs here	€	
Type specific costs here	€	
Sub total Specific Costs	€	**0**
Underground Inst: Cost 1	€	
Underground Inst: Cost 2	€	
Underground Inst: Cost 3	€	
Underground Inst: Cost 4	€	
Underground Inst: Cost 5	€	
Underground Inst: Cost 6	€	
Underground Installation	€	***150.000***
Overground Inst: Cost 1	€	
Overground Inst: Cost 2	€	
Overground Inst: Cost 3	€	
Overground Inst: Cost 4	€	
Overground Inst: Cost 5	€	
Overground installation	€	***20.000***
TOTAL CAPEX	€	***440.000***
TOTAL CAPEX - COFINANCING	€	***352.000***

Costs connected with the dismissal of the previous system and the design and construction of the ATES system (design, project management, testing, safety, others.

Fixed costs related to the construction process.

Fixed costs related to the Heat Pump.

For the sake of flexibility, the model allows to add new specific costs by typing down the description (here simply indicated as "cost of management system").

Underground costs: all costs related to underground works. It can be flexibly filled according to each installation.

Overground costs: all costs related to overground works. It can be flexibly filled according to each installation.

Computed as Total CAPEX – COFINANCING (eg. Climate KIC) when it is checked on the Incentives* window below. When uncheck, it equals TOTAL CAPEX

Operating Expenditures (OPEX)

OpEx must be filled to ensure the correct calculation. All the costs are VAT excluded.

OpEx are to be considered as the difference between the previous Operating Costs yearly sustained, without ATES system, and the new Operating Costs, with ATES system. Negative values reflect a saving while positive values are additional costs.

Figure 3 – Operating Expenditures

OPEX

Maintenance Costs	€	-10.000
Monitoring Costs	€	-2.000
Labour costs	€	- 5.000,00
Safety costs	€	- 500,00
Type ordinary costs here	€	
Type ordinary costs here	€	
Type ordinary costs here	€	
Type ordinary costs here	€	
Type ordinary costs here	€	
O&M Ordinary	*€/year*	***- 17.500***
Replacement Spare Parts	€	*- 1.000*
Replacement Component Parts	€	-
Type extraordinary costs here	€	
Type extraordinary costs here	€	
Type extraordinary costs here	€	
Type extraordinary costs here	€	
O&M Extraordinary	*€/year*	**- 1.000,00**
Purchases - Electricity	€	4.255
Purchases - GAS	€	- 14.000
Purchases - Diesel	€	-
Purchases - Biomass	€	
Subtotal Purchases	€/Y	***- 9.745***
Adiministration Costs	€/Y	
Insurance Costs	€/Y	2.500
Contingency Costs	€/Y	
Subtotal Other Costs	€/Y	***2.500***
TOTAL OPEX	€/Y	**- 25.745,00**

Ordinary O&M refers to the costs of keeping the installation up and running. Monitoring and periodic activities can be carried out resulting in a yearly cost. Average figures are to be inserted.

Extraordinary O&M refers to the costs which occur in case of failure, breakdown, end of components' lifecycle, replacement of component parts.

Energy costs are considered on the basis of the data inserted in the Energy costs above. No typing is required here except for biomass.

Other costs such as administration costs, insurance and contingency are considered.

OpEx includes the energy costs considered at the beginning.

Loan

The loan amortization schedule is a mortgage French amortization schedule simulator. The amortization is a methodology for paying off debt with a fixed repayment schema, in periodic instalments over a certain period. It is a useful tool for the investor who wants to simulate an investment scenario for acquiring the ATES plant by borrowing money with different terms, time and conditions.

It considers the major financial data inputs. Interest rates are customizable according to the country-specific scenario (it is possible to choose among various national interest rates such as Belgium, Italy, Spain and Netherlands).

Figure 4 – Loan Simulator

LOAN SIMULATOR

Total Amount to be Amortized	€	135,000
Initial Equity	€	5,000
Loan Amount	€	140,000
Annual interest rate	*percent*	4%
Amortization period	*year*	10
Instalments per year	*number*	1
Starting Date	*date*	01/01/2015
Optional extra instalments	€	-
Deduction from cost of borrowing	*% EBITDA*	30%

based on average interest rates:

1) Italy: 5%
2) Netherlands: 7.5%
3) Belgium: 6%
4) Spain: 4.3%

In simulating the loan schedule, the input needed are:

- the loan amount to be borrowed;
- the initial equity (money of own propriety);
- the interest rates at which the bank lends money;
- the starting date of the loan;
- the loan period in years and number of instalments per year;
- potential extra-payments (otherwise, leave blank);
- Deduction from cost of borrowing as % of EBITDA (Earnings Before Interest, Taxes, Depreciation and Amortization). This is the amount of money that can be deducted.

Taxation

Since all the costs are VAT excluded for the sake of flexibility, the taxation window has been built in a flexible way in order to allow possible different tax scenarios, according to the compliance that is country-related.

Figure 5 - Taxation

TAX

Average tax rate	%	26,00%
Depreciation rate used for tax	%	5%
Fiscal Leverage	%	0,00%
Rate of deductible interest	%	30%

It is composed by:

- **Average tax rate**: it depends upon the national compliance;
- **Deprecation rate**: it is equal to the interest rate of the loan;
- **Fiscal leverage**: it depends upon the national compliance;
- **Rate of deductible interest**: it depends upon the national compliance.

INCENTIVES/SUBSIDIES

In addition to consider tax regimes, incentives or subsidies, where available, can be added to the business plan.Figure 6 – Incentives and subsidies

INCENTIVES / SUBSIDIES

		as 20% CAPEX	€/toe - €	Years	Values	
☐	**White Certificates**				FALSO	-
☑	**Cofinancing**	0,2	88.000		VERO	88.000

Computed as Total CAPEX – COFINANCING (eg. Climate KIC) when it is checked on the Incentives* window below. When uncheck, it equals TOTAL CAPEX

The template considers two types of incentives:

- White certificates;
- Co-financing.

White Certificates are certificates traded on the market that constitute a premium on the savings achieved following the investment in an energy efficient technology. White Certificates are common only in few countries (Italy, France, Denmark, etc.) and are valorized as € per ton of oil equivalent (toe) of primary energy savings.

Co-financing, or any other form of subsidy that can be considered as a lump-sum subsidy, is calculated as percentage of the CAPEX. Different percentages (0%, 20%, 30%, 40%) can be considered.

1.2. CALCULUS

The calculus module does all calculations required to generate the output in the output module.

LOAN CALCULUS

Mortgage French amortization schedule simulator, with no depreciation feature. It considers major financial data inputs as Date, Investment Schedules, etc. Interest rates are customized according to the country-specific scenario.

OPEX CALCULUS

Calculator with the operation costs as input, necessary to compute the operational expenditures for the acquisition/changes of plants.

PAYBACK CALCULUS

Payback simulator that takes account of national subsidy or European incentives (i.e., White Certificates for Italy).

Payback gives back the number of the year necessary to earn profit after investing.

From the payback formula, it is possible to see the two most important form of project evaluation: the Net Present Value and the Internal Rate of Return.

IRR Definition:

"A project's internal rate of return (IRR) is the discount rate that makes the NPV of a project equal to zero. For example, to compute the IRR of investment A, we set NPV (A) equal to zero and find the discount rate that satisfies this condition. That rate is the investment's IRR."

A project's IRR is a measure of its operating profitability; in order to find out if a project creates value, the IRR value is compared with the WACC (Weight Average Cost of Capital): if IRR results to be bigger than WACC, the project can be financed profitably, otherwise the project should be rejected.

PBT Definition:

"A project's payback period is the number of periods (usually measured in years) required for the sum of the project's expected cash flows to equal its initial cash outlay. In other words, the payback period is the time it takes for a firm to recover its initial investment."

According to the payback period rule, a project results to be acceptable if its payback period is shorter than or equal to a specified number of periods called the cutoff period. If the choice is between several mutually exclusive projects with payback periods shorter than the cutoff period, the one with the shortest payback period should be selected.

1.3. OUTPUT

As OUTPUT of the tool, it was included a simplified financial modelling of the ATES installation, summing up OPEX, CAPEX, loan rates, taxes and potential revenues deriving from subsidies or non-specified sources (i.e. sales of electricity in case a PV system is integrated).

The CFS allows to understand how a simulated investment is running, where their money comes from and how the money is allocated. Comparing with income statement and balance sheet, the cash flow statement only considers the cash that enters and leaves the investment: core operation, investing and financing.

The **core operation** is the generated savings arising from the consumption of heating/electricity plus or earnings from the new proposal investment.

- **Savings** are computed as difference between the post-project energy costs to produce electricity/heating and the reference ones;
- **Earnings** are computed as amount of money received through subsidy or national regulatory, such as White Certificates.

The **investing part** relates to the amount of money connected to CAPEX and OPEX, and considers money spent to buy equipment, buildings, plants.

The **financing part** considers loans that the investor may contemplate (in case the LOAN table is filled) and the fiscal regulatory that interests its project.

- In case white certificates tab is on, as well as subsidy, the active cells are automatically computed;

- Fiscal leverage is the product of every investment (in case of amortization) and the percentage of deductible interests (by default, 30%).

The non-operating section comprehends miscellaneous extra revenue/expense that cannot be included in the sections above.

1.4. SUMMARY OF ECONOMIC INDICATORS

The summary presents all main economic indicators that are calculated by the spreadsheet in order to assess the economic viability of each single project.

This summary will form the basis of comparison across projects.

Figure 7 – Summary of all main economic indicators

SUMMARY

Category	Description	Unit	Amount
Investment cost		€	**440.000**
Loan amount		€	**352.000**
Cofinancing		€	**88.000**
Net Present Value			**2.294.596,42**
Payback	*Before Taxes*	*Year*	**6**
Internal Rate of Return	*Before Taxes*	*%*	**14,65%**

3. Description of Pilot Projects

3.1 ATES & DISTRICT HEATING:

Italian Pilot

The realization of the Italian pilot accumulated some delays and the pilot will not be concluded within the project deadline. Therefore, there are no novel information about pilot plant investment, operation and maintenance costs, or technical and non-technical issues coming from the plant operation experience.

Additionally, it has to be noted that the pilot case application in Italy is very specific and it is not directly scalable in terms of costs to other similar applications. In particular, the pilot plant is characterized by high redundancy, justified by the type of application (i.e. space heating and cooling of an electric station, wherein high safety standard has to be satisfied), the framework conditions (revamping of the warm and cold water distributing system, realization of a new substation for one building served by the pilot plant, realization of a centralized and automatized control panel for the whole heating/cooling plant), and the monitoring requests made by the regional authority that gave permits to the pilot plant.

On the other hand, through an investment analysis it is possible to realize a preliminary feasibility study for a more general application, that is the combination of ATES systems and district heating (DH) networks.

3.2 ATES & DYNAMIC CLOSED LOOP:

Spanish pilot

The pilot system is located in the municipal covered sports pools of the Town of Nules, on Avenida Jaume I, the northern edge of the town. It is a sports facility that houses a semi-Olympic heated pool, as well as showers and changing rooms and various offices.

The building has a dehumidification system by direct expansion in an Air Treatment Unit, plus a fan coil system for heating and direct expansion Split units with outdoor units for air conditioning. Furthermore, the heating system of the pool originally installed has two boilers of 320 kW each that use natural gas as a primary energy source.

A geothermal heat pump system has been installed using Dynamic Closed Loop geothermal probes, a technology developed by Itecon in the early 2012 that uses the Dynamic Closed Loop system. Itecon SL started developing the DCL® system in order to skip or reduce the usual technical barriers the company experienced in its projects. The DCL® first commercial model was a 10 meter-long, 100cm diameter probe with a 26 kW heat exchange power, able to power from domestic heat pumps up to any peak power system by modular design. The Spanish pilot system used three of these probes and a fourth one was tested with a metallic prototype able to exchange up to 45 kW. The site in Nules proved to be ideal for the testing of the newly developed probe.

3.3 ATES & SOLAR COLLECTORS:

The Netherlands – Delft

The Virtu PVT panels (developed by Naked Energy) integrate standard high efficiency photovoltaic cells within an evacuated tube solar thermal collector. For any given area more of the sun's energy is converted into heat and electricity than existing products with a commensurate impact on CO_2 displacement.

The ATES system of Deltares in Delft was chosen to install the PVT-panels. Deltares has several buildings of which two are connected to an ATES system. One of the experimental lab buildings is not connected to the ATES system but has a very high heat demand, while the buildings with ATES have a heat surplus. Hence, the solar heat from the PVT-panels and the surplus of heat from one of the buildings already connected to the ATES can be stored in the ATES system and transferred to the building with a heating demand, which would decrease the overall energy use and would enlarge the available cooling capacity during summer for cooling for the building with a heat surplus. In Delft, 120 PVT panels are installed and connected with the ATES system.

For the business model calculations, it was chosen to upscale the system to a large building or campus area that would give good commercial return. The installation results to be 8 time larger than the original Delft Pilot. The larger scale reduces some of the balance of system and installation costs. In order to avoid a heat depletion within the aquifer and a drop in the heat pump efficiency after a few years of operation, the number of Virtu PVT tubes was increased up to 956 (209 kWh thermal and 64 kWh electric per tube per year with an average output temperature of 35 °C).

Belgium

This pilot consists of the expansion of Nike's European Logistics Center at Ham, Belgium, with a new, versatile and flexible storage facility. Nike wants this new storage facility to be the new standard in the logistics landscape and an example on the European market.

The ATES system in this pilot consists of 2 groundwater wells that have been drilled into the subsurface at a depth of 162,5 m in a specific geological formation (Zanden van Diest). The filter for the extraction and infiltration of the groundwater is installed between 80 m and 160 m (ground level). Besides the 2 production wells, 2 measuring wells with level ducts have been drilled in the field, in order to comply with the legislative requirements. The level ducts in the production and measurement wells were then equipped with glass fibers to monitor the evolution of underground temperatures.

A future imbalance between heating and cooling demand would lead to the depletion of the hot or cold well and a reduced heating/cooling capacity. Extra measures are necessary to create robustness against possible imbalance. To do so, Photovoltaic solar thermal (PVT) collectors are added to the ATES system. During summer, these panels produce hot water which is stored into the hot bulb of the ATES system, replenishing this bulb. When needed, this heat can be used to produce sanitary hot water or in winter aid in heating the buildings. PV-electricity is produced simultaneously.

Control of the ground balance is possible by loading the hot bulb with solar generated heat when necessary, or by using the PVT-technology in reverse mode to release heat to the air by cooling down the panels at night.

The PVT-system was chosen for its ability to load heat in the ATES system as in the Belgian pilot a dominant heating demand is expected.

3.4 ATES & BIOREMEDIATION (ATES+)

ATES-systems are highly effective energy-storage systems, and provide energy with low CO_2-emissions. There is an increasing interest in ATES systems, but their spreading could be limited by the presence of groundwater contamination. This is already the case in the Netherlands, where ATES-systems are widely employed, and the number of existing ATES plants is estimated to be between 1,500 and 2,700, plumes of chlorinated solvents is found to obstruct the development of ATES in urban areas. The potential in Denmark for ATES systems is evaluated to be at least 400 ATES plants.

Within the E-USE(aq) project, in two of the pilots, ATES systems are combined with the remediation of groundwater, as these processes proved to be synergic in lab studies because of the increased mixing and temperature effects. Anaerobic bacteria are cultivated and injected in the soil in combination with an ATES system while this is in operation. In laboratory studies of ETE-WUR (Environmental Technology Department - Wageningen University), E-USE(aq) partner, it was proven on lab-scale that the combination of ATES & Bioremediation of chlorinated solvents leads to a more than 13 times increase of the biodegradation rate compared to Natural Attenuation. Natural Attenuation uses naturally occurring processes to clean up polluted soils and groundwater. To effectively achieve attenuation of pollution, the correct (chemical) conditions must occur in the soil. This makes Natural Attenuation a relatively unreliable process. Bioremediation is, technically, a "perfect" version of natural attenuation, in which natural conditions are enhanced/stimulated for soil contamination.

The two pilots in E-USE(aq) where ATES and bioremediation are combined, differ as the first one is mainly focused on the bioremediation, while the second one is more focused on the energy aspect.

Danish pilot

In the Danish pilot, the commissioner, Copenhagen municipality, had the main aim of restoring the groundwater quality of an industrial area. In order to enhance this process, a similar system to ATES was installed to increase the temperature of the target aquifer area. The water is pumped and heated on the surface and reinjected to be intake again, thereby creating a heat-water cycle. The pilot was constructed to serve directly to the bioremediation. This system owns a well and a hot reservoir to complete the cycle. Furthermore, in order to improve the de-chlorination yield, an electron-donor soup was injected. In this case the ATES-kind cycle is only used to enhance the bioremediation, however it is possible to rethink it as a potential economic income by reutilizing the heated water.

The Netherlands - Utrecht pilot

The Utrecht installation is supplying heating and cooling to a sports building. The full ATES system owns 3 wells of extraction and its intake of heat to be transferred to the aquifer comes directly from the temperature of the environment. This system could have an approximate lifetime of 30 years.

In this project, the collection of energy was the main approach followed by the bioremediation of the underground water. Therefore, the initial investment was done to build only the ATES system, and later the injection and monitoring wells for the bioremediation were added to the existed construction.

For the business model comparison, a different approach is taken, because of the specific nature of the pilots, some of the parameters are not known in detail. Nevertheless, some parameters – like durability of the bacterial activity after injection – have very substantial impact on the economics of the system. Therefore, the cost comparison is defined as a first draft based on data available at the moment and parameter values that are under development. This is a different approach than the approach used for the other pilots (i.e. with the business model described in chapter 2). For the Danish and Utrecht case, a relative comparison is made between different scenarios:

1. ATES system vs. regular energy systems;
2. Pump & Treat remediation vs. bioremediation;
3. ATES + bioremediation (separately) vs. combined ATES and bioremediation.

4. Results

In 2017 NE conducted a business case study about Europe-wide implementation of ATES systems. By doing this, for any single pilot appropriate forecasts have been created, customized to the application context in each of the countries, in terms of economic and financial feasibility.

The scope of the following chapter is to analyze, one year after pilot operations, how the pilots evolved and which is the new pattern, the new variables and the new rates emerged throughout the year.

For the Spanish and the Belgian pilot as well as for the pilot in Delft it has been possible to update economic values. On the other hand, for the Italian and for the ATES+bioremediation pilots a different approach has been taken in order to account for the lack of performance data about the plant in one case (Italy) and for the too far to market situation of the ATES+bioremediation case.

When analysing the feasibility of the business case for each project, NE focused on 5 main components:

- **Investment costs**: the overall amount of costs needed to have the ATES system installed and ready to run.
- **Operative costs**: which are the yearly operational expenditures regarding the cost about installation running, operation & maintenance, electricity, maintenance and other unexpected components.
- **Net Present Value**: it's an indicator used to value the profitability of a project or an investment. It is calculated as the difference between the present value of cash inflows (savings in this case) and the present value of cash outflows (all the costs). A positive NPV indicates that the project is able to generate a profit over its lifetime. A negative NPV shows that the project results in a net loss.
- **Payback time**: the amount of time required to recover from the investment cost and have
- **Internal Rate of Return**: it's an indicator that measures the profitability of a project or an investment. It represents the discount rate that makes the NPV equal to zero. The higher the IRR the higher is the profit the project is able to produce, thus the more attractive the project is.

4.1 The Dutch case – Delft: ATES & Solar Collectors

The project has been realized in Delft by Naked Energy and includes the combination of ATES technology with PVT as auxiliary system to the heat stored in the ground. From the 2018's evaluation of ATES pilot project emerges a quite different economic-financial picture of Dutch case, as the 2018 scenario is scaled up

In the following table the update of economic and financial prospects of the applied ATES system are summarized.

Table 1. Economics of Dutch case (Delft).

Category	Assumption 2017	Update 2018	Δ % 2018 vs 2017
CAPEX	62,000 €	296,200 €	478%
Savings	7,685 €	36,968 €	381%
OPEX (first year)	3,000 €	6,000 €	100%
			Increase/Decrease value
Net Present Value	30,024 €	281,517 €	NPV increase: 251 k€
Payback-Time	8	5	PBT reduction: 3 years
Internal Rate of Return	12.69%	20.63%	IRR increase: 8%

The cost of investment (CAPEX) increased up to almost four times. The Capital Expenditure includes initial investments on the construction of the installation, and all the costs related to the design, the project management, the safety and efficient test and generally all the activities done during the construction period. The difference in the values between the two years is mainly due to the amount of over ground installation costs, passed from 62.000 € in 2017, to 296.200 € in 2018; this gap in CAPEX is essentially due to the higher foreseen number of Virtu PVT tubes, that passed from nr. 120 to 956.

Despite a number of tubes equal to 8 time the original pilot project, the Operative Expenditures (OPEX) only doubled. The related savings increase up to almost 37,000 €. As a consequence of the project data modification, NPV raised up too as IRR grew by almost 21%. A 5-years PBT shows how, compared to the as-is PBT in 2017, the project is more profitable as the project size increases.

Figure 8. KPI Dashboard of the Dutch (Delft) Pilot (revised for 2018).

4.2 The Belgian case: ATES & Solar Collectors

In the following table the update of economic and financial prospects of the applied ATES system are summarized.

Table 2. Economics of Belgian case.

Category	Assumption 2017	Update 2018	Δ % 2018 vs 2017
CAPEX	529,609 €	116,050 €	-78%
Savings	26,935 €	50,314 €	87%
OPEX (first year)	13,331 €	16,076 €	21%
			Increase/Decrease value
Net Present Value	115,499 €	341,367 €	NPV increase: 226 k€
Payback-Time	11	2	PBT reduction: 9 years
Internal Rate of Return	8.95%	47.87%	IRR increase: 39%

As for the Dutch case, the Belgian pilot is based on the combination of ATES and PVT panels. The PVT panels form a co-generation system able to produce both thermal and electric energy that through a connection with the system produces hot water to be stored, helping at the same time the ATES energy balance.

In table 2 some features of the Belgian pilot are shown, particularly the initial high investment costs of the project in 2017 (529,609 €), which hasn't been co-financed. Anyway in 2018, a fall in the cost of dismissal of the precedent technology system, of the specific costs of the heating pump and other costs of installation led the precedent value to the current 116,050 €. Please be noted that the 2017 CAPEX results to be preliminary (energy data not yet available), so it was over estimated.

The OPEX slightly increase of about 20%, while it is observed a greater saving in energy purchase (natural gas particularly). The NPV increase of 226 k€ and PBT reduced by more than 80% (2 years in 2018), coherently with an IRR grown up to 47.9%. Rates on the Table confirm the financial solidity of the specific Belgian project.

Figure 9. KPI Dashboard of the Belgian Pilot (revised for 2018).

4.3 The Italian case: ATES & District Heating

DH system of Modena has been identified as interesting feasibility case study for the business case analysis since it is representative for size and design principles of the DH networks that are currently working in the central-north Italy. It is also the first example of DH system realized in Italy. Table 3 summarizes few data about the DH network.

Figure 10. Geographical location of Modena district heating (DH) network.

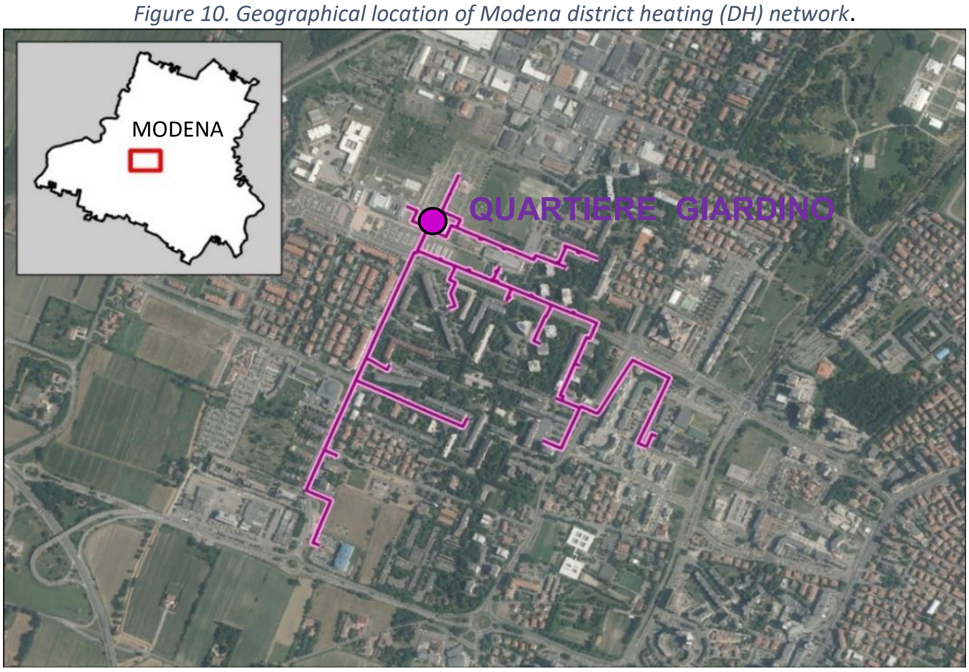


Table 3. Main characteristics of Modena district heating network.

Thermal energy produced	25 GWh_{th}/year
Temperature (delivery)	90°C
Temperature (return)	70°C
Installed total power of n°4 natural gas boilers	24.6 MW_{th}
Installed total power of n°3 cogeneration units	3.6 MW_{th}
	3.6 MW_{th}
Total volume heated	687,410 m^3
Network length	9,338 km

The business model of this kind of DH network, realized in the '70-'80, is based on economic assumptions that are not sustainable anymore. In fact, the main revenues were supposed to be generated by the selling of electricity production via co-generation plants.

The realization of a network for heating supply was considered as a sort of secondary benefit, useful to increase the system efficiency and the electricity fed-in tariffs. In the last ten years the electricity purchasing price decreased of about 25-30% (see Table 4); at the same time, fed-in tariffs have been strongly reduced. The consequence is that electricity production through cogeneration is not anymore remunerative for a not negligible period of the year.

The final result is that DH system is fed by natural gas boilers (that were supposed to be used only as integration or back-up units), especially in summertime when the electricity purchasing price is lower due to the overproduction of electricity generated by PV and wind turbine power plants.

Table 4. Purchasing price of electricity in Italy from 2007 to 2017 (source: GME, 2018).

Year	Purchasing price €/MWh in Italy		
	Average	Min	Max
2007	70.99	21.44	242.42
2008	86.99	21.54	211.99
2009	63.72	9.07	172.25
2010	64.12	10.00	174.62
2011	72.23	10.00	164.80
2012	75.48	12.14	324.20
2013	62.99	0.00	151.88
2014	52.08	2.23	149.43
2015	52.31	5.62	144.57
2016	42.78	10.94	150.00
2017	53.95	10.00	170.00

In Modena DH network, a mean thermal power production of 5 MW_{th} is present for about 2,000 hours per year, while a mean thermal power production of about 0.5 MW_{th} is present for about 7,000 hours per year. So, in summer the natural gas boilers or the cogeneration units are in operation to keep the temperature of the network warm enough to respect the contractual obligations of the DH network manager (i.e. warm water delivery at 90°C ±5°C) at the substation inlet. Since only domestic hot water (DHW) is produced during summer, it means that 0.5 MW_{th} of thermal power mainly corresponds to the network heat losses.

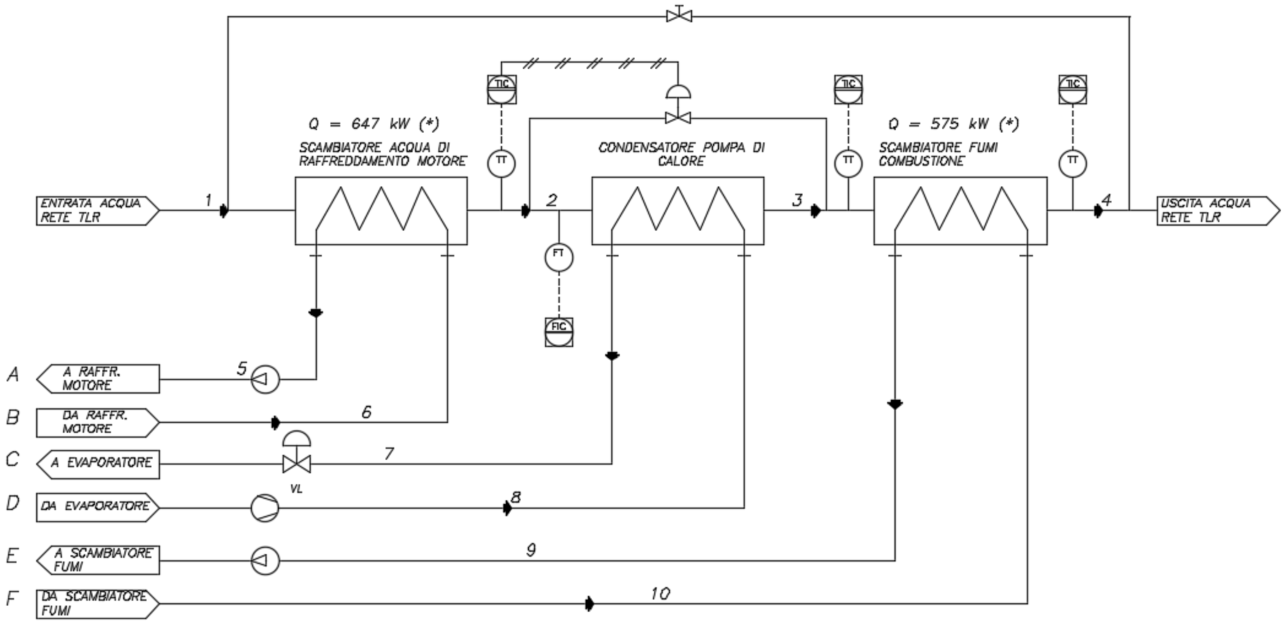
DH network managing companies are looking for alternative sources of thermal energy to be integrated in the existing systems, moving towards the reduction of fossil fuel consumption and of CO2 emission, as well as operation cost reduction and efficiency increasing, in particular in summertime. Furthermore, European policy requests for a higher efficiency in energy production (Directive 2012/27). The use of shallow geothermal energy, and in particular of ATES system with heat pump is of potential interest.

Nevertheless, one of the main problems related to the application of ATES system with heat pump to DH network is the relatively high temperature required (about 90°C) in the water delivery circuit. Working at so high temperatures is not energetically feasible with common heat pumps (i.e. working with R134), or it may result as more expensive than traditional heat pumps (i.e. working with ammoniac). So, smart solutions have to be developed in order to guarantee high COP and low investment and operation costs.

The solution identified for Modena DH network, and that can be replicated in other similar DH systems, is to integrate an ATES system with heat pump between the water-cooling heat exchanger and the flue gas cooling system of the cogeneration units (see Figure 2). The temperature in point 1 is set at 73.5°C, while the temperature in point 4 is set at 91.2°C (maximum temperature allowed by the flue gas heat exchanger).

The idea is to use the heat pumps as temperature boosters between the two heat exchangers, thus increasing thermal production of the system. The integration of heat pumps in the existing system requires an increasing in the water flowrate of the heat exchangers.

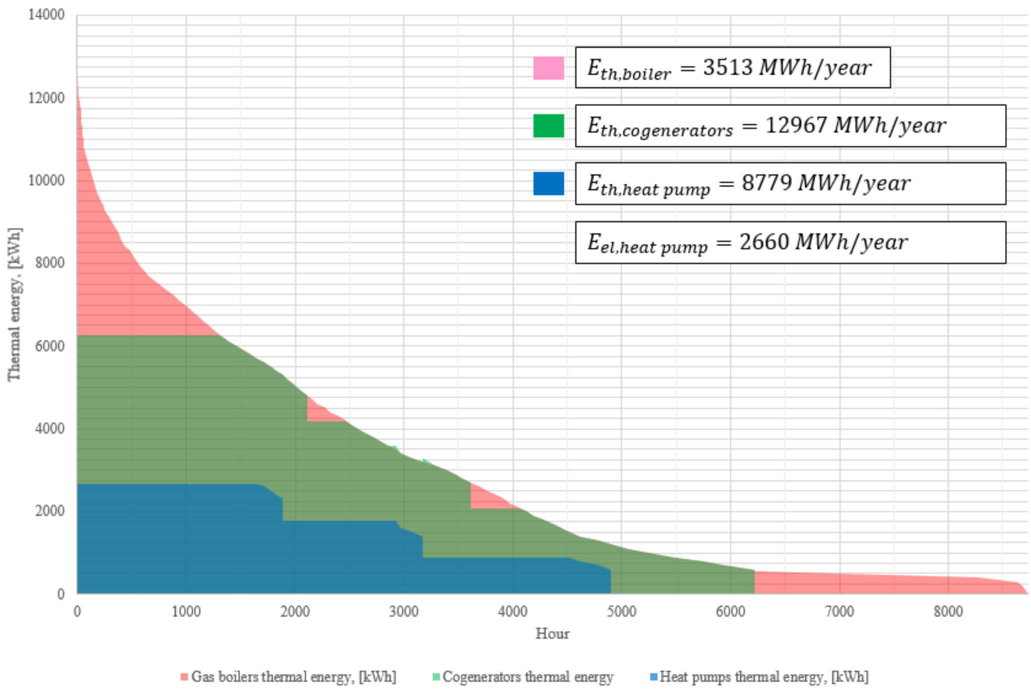
Figure 11. P&ID of the proposed solution.



An ammoniac heat pump has been selected among others (i.e. R134 and innovative heat pumps working with zeotropic fluids) as reference technology through a preliminary assessment based on COP at the operation temperatures and size available in the market, while a plant configuration of three 888 kWh_{th} heat pumps (one per cogeneration unit) results as the most interesting since it maximizes the benefits of the smart combination between heat pumps and cogeneration units.

Figure 10 shows the simulated thermal energy production over the year: with the suggested configuration 86% of the heat demand is covered by cogeneration units and heat pumps, while the peak demand in winter and the summer demand for covering DHW production is guarantee by the natural gas boilers (14% of the whole yearly heat demand). Figure 10 also shows the three steps heat production realized through the cascade activation of the three heat pumps. The heat pumps consumed 2,660 MWh_{el} per year, but the electric energy can be totally self-produced by the DH system through cogeneration units.

Figure 12. Yearly heat production divided by source as a function of working hours.



Assuming a COP for the ammoniac heat pump equal to 3.3, the evaporator needs about 619 kW_{th}. The heat source of the system is supposed to be a shallow aquifer. Since a maximum groundwater temperature variation equal to 5 °C is usually allowed by regional authorities, the minimum groundwater flowrate able to sustain the heat exchange process results equal to 30 l/s.

Specific information at the site is not available, but several wells for drinking water extraction are present near the DH centralized plant: in particular, it is known that 84 l/s of groundwater are continuously extracted at a distance of 500 m from the DH centralized plant. The aquifer is identified at 28-38 m b.s.l., while some relevant chemical-physical characteristics are reported in Table 5.

Table 5. Available data about aquifer characteristics near Modena DH centralized plant (source: ARPAE).

Date	Temperature [°C]	pH	Conductivity [µS/cm]	Hardness [mg/l $CaCO_3$]
16/04/2015	13.8	7.2	1,200	512
19/10/2015	13.5	7.5	1,190	501

On the basis of E-USE pilot plant experience, it may be assumed that the ATES system in Modena should be realized with a "recirculation system" configuration, which is usually applied in high ambient groundwater flow conditions (over 25 m/year). This kind of configuration does not allow the seasonal storage of cold and heat, since the high ambient groundwater flow velocity naturally conveys the thermal plume away from the injection wells.

The investment considered in the techno-economic assessment is substantially reduced if compared with the Italian pilot plant in terms of Euros per kW_{th} installed. The reduction is justified by the peculiarity of the pilot plant application, which requires higher costs due to:

i) redundancy requested by the pilot owner,
ii) realization of civil works,
iii) modification/substitution of heat/cold water distribution systems in the pilot plant buildings,
iv) realization of an automatized control system. These costs can be reduced/avoided in the case of integration of the ATES system in a DH network (i.e., the ATES plant control system can be integrated into the DH existing one, and so relevant savings can be expected).

It may be found that the aquifer in Modena is suitable for the application of doublet or mono-well ATES system configurations. In this case ATES system can be applied to DH networks also with innovative solutions, like:

1. storing heat during wintertime in the aquifer, and use it in summertime (to avoid natural gas consumption for boilers or cogeneration units feeding). A first option is to store heat at a relatively high temperatures (>70°C) to be used to directly heat up the water circulating in the DH network. This solution seems to be feasible and effective only in new and low temperature DH networks. A second option is to boost the temperature of the stored heat in the aquifer via heat pump. This solution can be used also in existing DH networks, but it may require a deep analysis of legislative/normative barriers.

2. using ATES system as balancing storage elements in cold low temperature district heating (LTDH) networks. Cold LTDH network can be defined as a system for distributing cold water in a temperature range between 10°C and 25°C to end-user's substations where it is used to produce, also simultaneously, hot and cold water at different temperatures and for different purposes (space heating, cooling, domestic hot water production) via heat pumps and chillers. ATES systems may be used to balance the temperature in the cold LTDH network to keep it in the desired range, thus balancing heating and cooling demands over the years.

The following table sums up the economic and financial prospects of the new ATES system identified for the analysis of Italian context. The values of the previous business case are also reported, despite it referred to a totally different kind of project. At regard, a comparison with assumptions of 2017 results to be not suitable (for further economic and financial information about the previous project please refer to Deliverable "D 3.1 E-USE(aq) business case evaluation" edited on 2017).

Table 6. Economics of Italian case

Category	Assumptions 2017	Update 2018 (New Project)	Δ % 2018 vs 2017
CAPEX	460,736 €	1,810,000 €	293%
Savings	23,040 €	381,470 €	1,556%
OPEX (first year)	1,500 €	176,364 €	13,574%
			Increase/Decrease value
Net Present Value	54,947 €	2,644,219 €	NPV increase: 2,589 k€
Payback-Time	11	3	PBT reduction: 8 years
Internal Rate of Return	7.83%	29.66%	IRR increase: 22%

So, given the dimension and the efforts of the project's investment during the year, it increased by almost 3 times.

Differently from the previous cases, in the Italian pilot the budget structure recorded a gap between OPEX and EBITDA and that's because of the presence of extra earnings. These latter consist in a kind of incentive (White Certificates) given by the Regulator to any energy distributors obliged by law and other entities, due to energy efficiency measures applied. Anyway, even in this case, cost reduction increased in a very impressive way and EBITDA too.

NPV totally changed and consequently PBT decreased to 3. IRR followed the same pattern having reached almost a rate equal to 30%.

Figure 13. KPI Dashboard of the Italian Pilot (revised for 2018).

4.4 The Spanish case: ATES & Dynamic Closed Loop

Thanks to the tests and learnings experienced with the E-Use project pilot site, both on the design and the performance efficiency of the system, the Spanish project shows nowadays significant cost reduction opportunities (-12%), as well as interesting reductions in the construction time. The OPEX didn't change, as well as the savings.

The following table sums up the update economic and financial prospects of the ATES system applied.

Table 2. Economics of Spanish case.

Category	Assumption 2017	Update 2018	Δ % 2018 vs 2017
CAPEX	62,694 €	55,196 €	-12%
Savings	15,663 €	15,663 €	0%
OPEX (first year)	2,766 €	2,766 €	0%
			Increase/Decrease value
Net Present Value	140,862 €	144,539 €	NPV increase: 4 k€
Payback-Time	3	3	PBT reduction: 0 years
Internal Rate of Return	34.90%	47.44%	IRR increase: 13%

In the table below the main costs' reduction areas identified during the project are summarized.

Table 7. Cost reduction of Spanish pilot

Subsystem	2016 system	Current system	Difference	Cost reduction	Improvement
Control and electric power	3,920.00 €	2,499.00 €	1,421.00 €	36.25%	Inverter system for DCL probes not necessary; less electrical components for less probes.

Drillings and casing	11,361.00 €	10,111.00 €	1,250.00 €	11.00%	Only two drillings, bigger diameter (270 mm vs. 220 mm) and bigger PVC jacket, overall costs reduced.
Probe and capturing system	16,630.00 €	13,831.00 €	2,799.00 €	16.83%	Two 50 kW probes instead of four 26 kW probes. Metallic probes, more expensive each but reduced cost €/kW.
Heat pump	19,800.00 €	19,800.00 €	0.00 €	0.00%	The heat pump is the same model so that the comparison can be done about the geothermal system.
Heat transmission and fluid mechanical & pumping system	10,983.00 €	8,954.81 €	2,028.19 €	18.47%	Integrated circulating pumps in the heat pump as an optional, costs reduction reflected here.
Others	62,694.00 €	55,195.81 €	7,498.19 €	11.96%	-

GEOTHERMAL SYSTEM COSTS REDUCTION (Whole system except heat pump and engineering and legal fee)	
TOTAL:	-17.48%

The overall cost reduction comprises too the reduced need of trenches, piping, auxiliary machinery such as generators and safety measures, although it is not feasible to estimate those indirect costs reduction with accuracy.

Figure 14. KPI Dashboard of the Spanish Pilot (revised for 2018).

4.5 The Netherlands case - Utrecht: ATES & bioremediation (ATES+)

In Utrecht, the Netherlands, a pilot project was carried out partly financed by Climate-KIC project, combining ATES with bioremediation. The pilot test was executed between July 2017 and October 2018. In this concept, off-site high density cultivated anaerobic bacteria are injected in the proximity of an existing ATES system (mono wells). For the pilot in Utrecht in total 4 m^3 containing approximately 1,010 cells of specific organisms (Dehalococcoides spp.) per litter was injected around three meters besides the warm well.

Monitoring showed a clear positive effect of the injection on the chlorinated solvents (VOC) concentrations. Within the influenced soil and groundwater zone, degradation of VOC takes place, at least for one year, resulting from this one-time injection.

In order to obtain some estimation of the cost for this concept, calculations were made for the cultivation and injection of the necessary biomass. The anaerobic bioreactor system, developed and operated by the consortium "WKO+" (Bioclear Earth, Brabant Water and T&K Service), has a total volume of 10 m^3. The order of magnitude for the cultivation process is calculated taking into account:

1. The cost for the bioreactor itself and maintaining the same:

- electricity for running and heating the system;
- material and chemicals (VOC, nutrients, Nitrogen gas, etc.);
- operating the system;
- extraction of the cultivated bacteria and pre-treatment (flushing and storage);
- analyzing composition of culture medium, amount of Dehalococcoides spp. and certificates (containing information on cell density);
- depreciation of the hardware;
- insurance of the system;
- rental of the building where reactor is placed and operated;
- maintenance of the reactor, pumps etc.

2. The cost for:

- transportation of the culture (per batch containing 10 m^3 of culture solution);
- injection of the high-density culture at the ATES site.

Various parts of the costs mentioned for maintaining the system are independent of the number of batches that are produced, such as depreciation, rental of building, insurance, and a part of the maintenance. Other costs are directly related to the actual cultivation process and only apply when cultivation is running. This also means that the total cost per batch (of 10 m^3) strongly depends on the number of batches that may be produced per time period. At this moment the consortium is capable to produce six batches of 10 m^3 annually.

Based on the assumption that the consortium is preparing at least three batches annually with a maximum (at this moment) of six batches annually, the cost per batch of 10 m^3 will vary from approximately 37,000 € (at three batches per year) to approx. 22,000 € (at six batches per year)

These costs per batch also includes additional profit/fee that is needed for financing the investments done by the developing consortium.

For transportation of a 10 m^3 batch a cost estimate of 3,000 € to sites in western Europe seems reasonable.

Cost for injection of the bacterial culture will be depending on the company that may perform the injection. The culture is provided in 1 m^3 vessels that already contain an easy-to-use connection for pumping the liquid culture into wells or the connection on the ATES system. Expenses of 2,000 € seem a good estimation for these costs.

Therefore, the total cost per batch of 10 m^3, including the preparation of the culture, the transportation and injection at the site will vary from approximately 42,000 € (at three batches per year) to 27,000 € (at six batches per year).

Future perspective:

With the existing bioreactor multiple ATES systems can be fed, since we expect that at large scale ATES systems one to two dosings per year should be sufficient (in very large systems multiple shots of 10 m^3 may be needed to get sufficient radius of influence and sufficient bacterial mass).

If continuous cultivation is needed – e.g. in large scale ATES systems with relatively high VOC load - we expect to be able to produce ten batches per year (in continuous reactor mode). Cultivation costs per batch may be lowered towards approx. 15,000 €. Including transportation and injection would result in approx. 20,000 € per batch.

Only rough drafts can be made at this moment for the total cost of an ATES+ project, since the number of batches to be produced per year is not known yet. This is mainly because the long-term durability of the bacterial mass that is injected is not known. Obviously, the number of batches will strongly influence the total cost for the "+" within a new or existing ATES system.

For a first estimation and comparison we defined a VOC contaminated groundwater volume of 100,000 m^3.

For traditional remediation with pump and treat normally ten times the contaminated volume has to be pumped and treated to remove contaminants. Therefore, pump and treat will result in treating 1,000,000 m^3 of groundwater, with an average price of 1.50 €/m^3 (taking into account the removal of iron). This will result in total remediation cost of 1,390,000 € (Net Present Value) and 13.90 €/m^3, based on a 10 m^3/h flow during 11.5 years.

If using the bioaugmentation technology TCE/BEAT® (injection of low-density bacterial culture cultivated on-site) the total cost – based on two years of treatment with a flow of 8 m^3/h and treating 1.5 times contaminated groundwater volume – would be 525,000 € and 5.25 €/m^3.

Chemical oxidation, e.g. with (per)ozone, would take at least one year against approx., 3,500,000 € remediation cost, being 35 €/m^3.

For the ATES+ we calculated with a treatment period of 25 years in a new or existing ATES system, resulting in 50 cycles of groundwater flow through the activated zones. We estimated one batch of 10 m^3 per year to obtain sufficient degradation capacity; so, in total 25 batches of biomass injection. In case the cost would be approx. 40,000 € per batch, the total cost will be 840,000 € or 8.40 €/m^3 based on net present value over 25 years. If calculation with the lower cost per batch of 20,000 € the total cost will be 420,000 € or 4.20 €/m^3 based on net present value over 25 years.

In this comparison the ATES+ technology will be obviously competitive with the existing biological in situ treatment options, and will be more cost efficient compared to pump and treat and chemical oxidation.

Main advantage of the ATES+ is that ATES can be conducted without necessity of first remediating the groundwater. In that case only chemical oxidation technology would be relevant, because only with this technique a remediated groundwater can be reached within one year (sufficient to be able to install afterwards the ATES in clean groundwater). But this chemical oxidation technology will be 3-5 times as costly than ATES+ and may also influence the groundwater composition resulting in being less suitable for ATES.

4.6 Comparison of results

The following is a comparative analysis of the results for different cases.

4.6.1 CAPEX - OPEX

Except for the Spanish pilot, all projects have significantly changed their economic schemes. A comparative analysis loses its meaning without historical data. In the following table the values of 2018 arose from the analysis carried-out are reported.

Figure 15. CAPEX reviewed for 2018

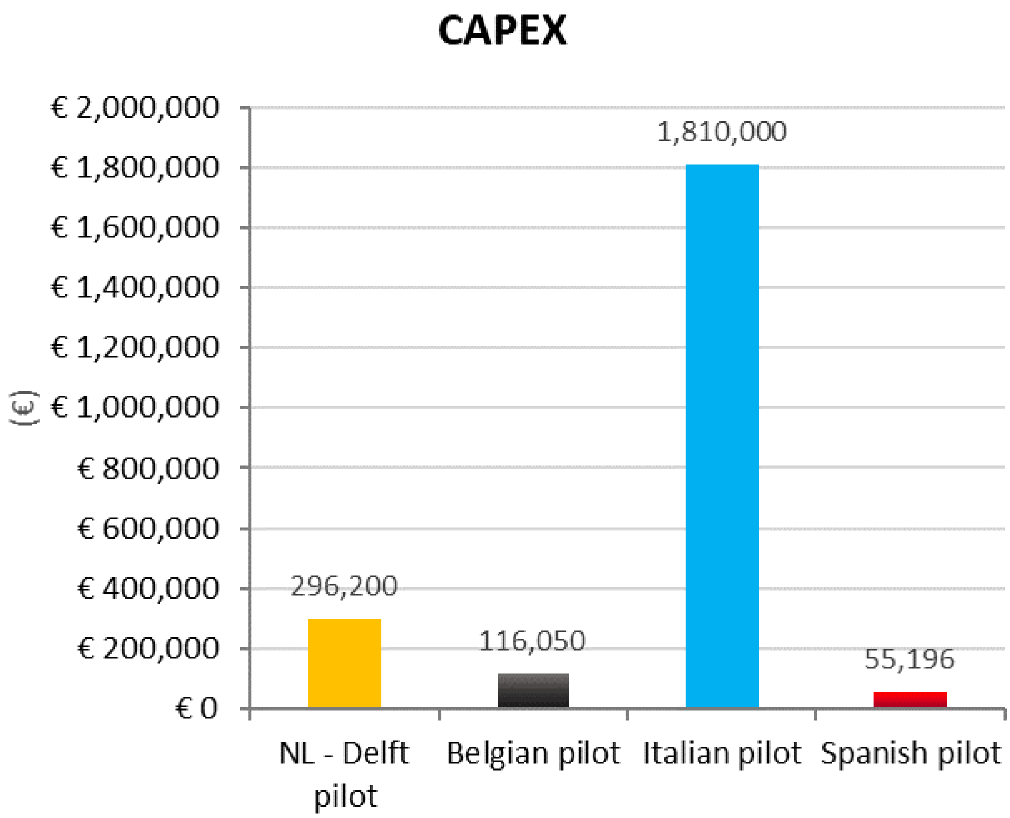


Figure 16. OPEX reviewed for 2018

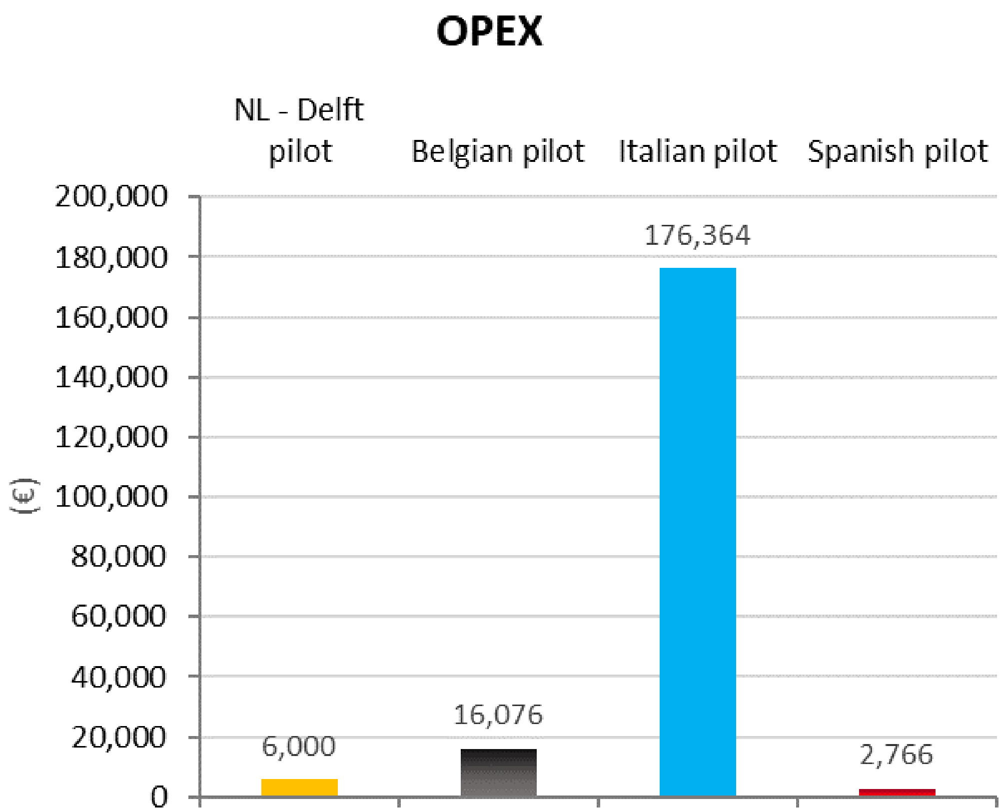
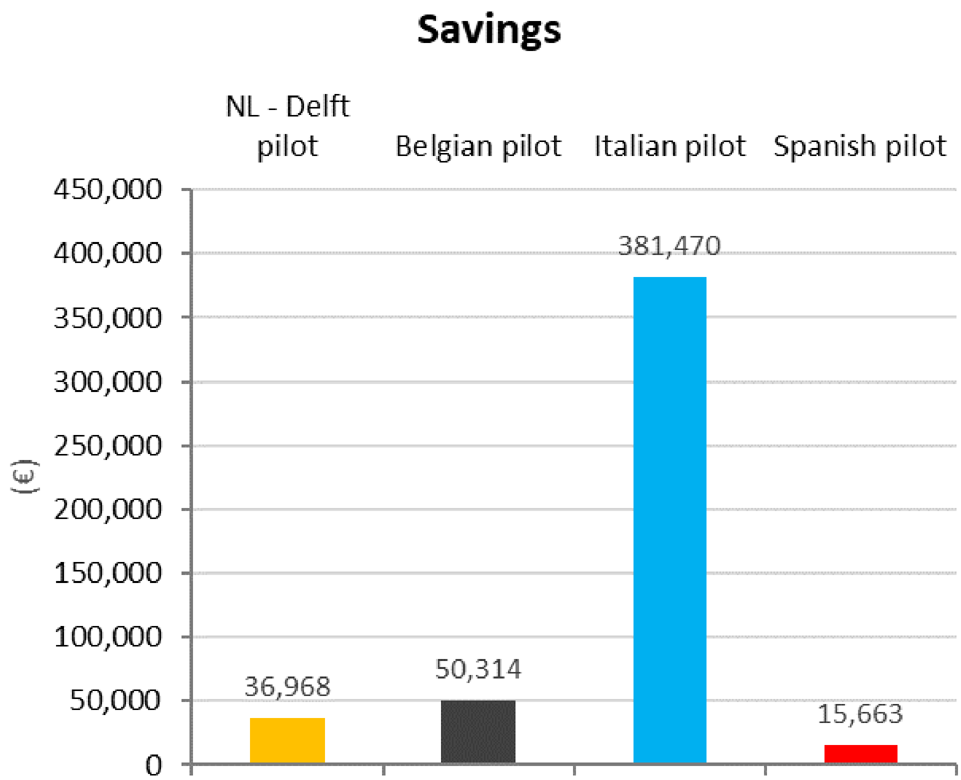


Figure 17. Savings reviewed for 2018



4.6.2 Internal Rate Return and Payback Time

- **Internal Rate of Return:** the IRR varies from a minimum 20% connected with the Dutch ATES&Solar collector pilot to a maximum of 47% connected to the Belgian pilot;
- **Payback Time:** the time needed to recover the whole cost of the investment goes from a minimum of 2 years for the Belgian project to a maximum of 5 years for the Dutch ATES&Solar collector pilot (including the use of subsidies for pilots where possible).

Figure 18. Internal Rate of Return of project pilots (revised for 2018)

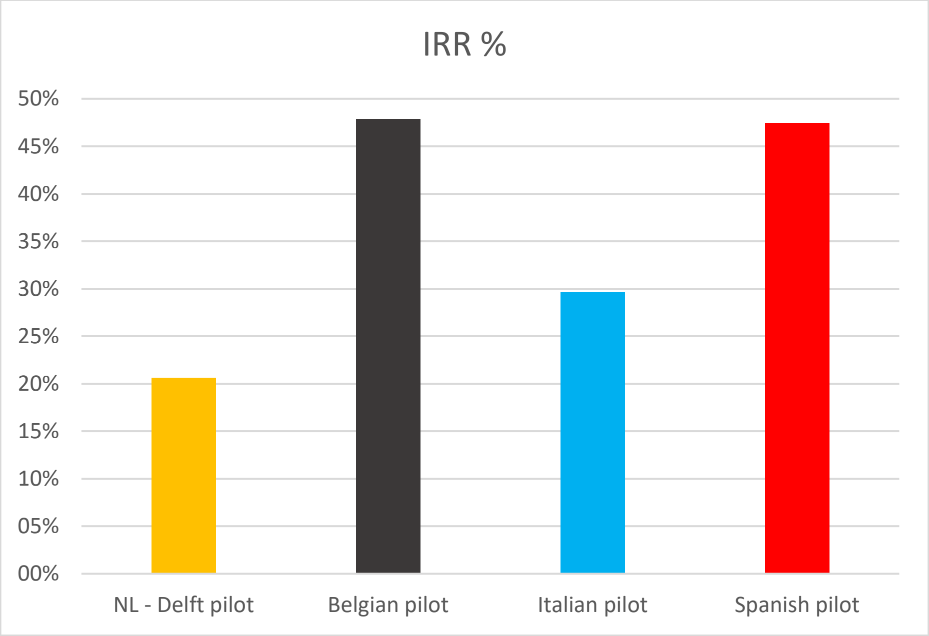
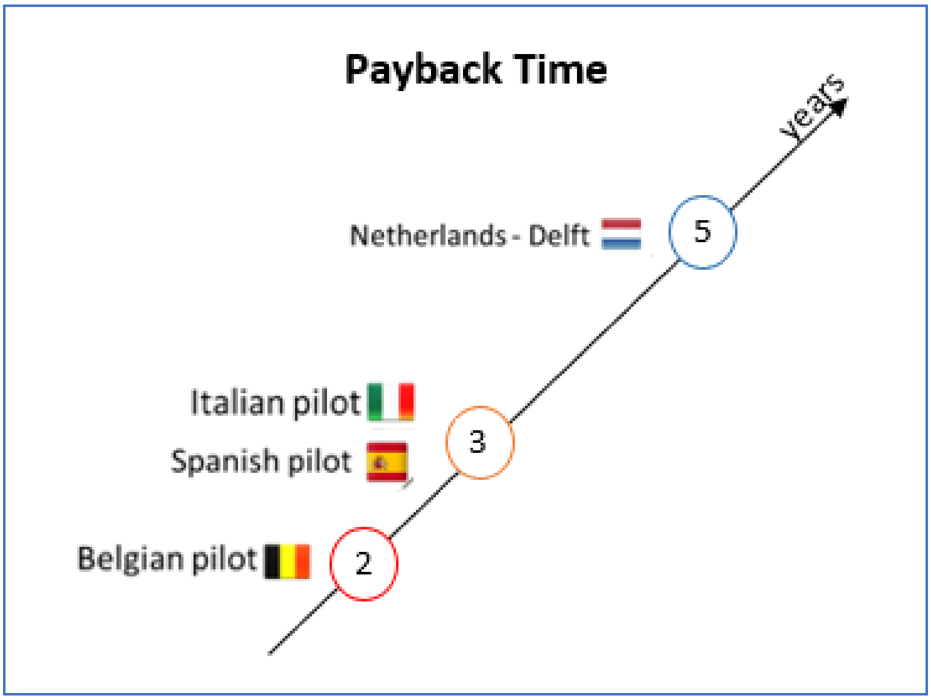


Figure 19. Payback Time (revised for 2018)



It results to be clear that each pilot project shows a very interesting economic performance in terms of IRR and PBT. Even in the worst case (Delft pilot), the PBT results fully consistent with standard financial approaches that foreseen a maximum PBT of about 4/5 years for energy efficiency projects carried out by industrial specialized sponsor. The application or the of national grants and subsides in European countries where this kind of technology is not adequately developed could help to improve the financial performance of the projects.

As previously reported, a direct comparison with 2017 business case assumptions results does not appear to be suitable for most of E-USE(aq) pilot projects (all except Spanish pilot) due to the modification occurred to the original design.

Therefore, in order to allow a comparison between these different cases, the indicator of "Energy Saving ES on invested Euro" was derived. Please be noted that the KPI results independent from local energy costs and makes a better comparison of the economic efficiency of the different technologies (or pilots).

The values of energy were obtained converting the energy savings of each pilot (electricity and/or standard cubic meters of natural gas) in primary energy (kWh).

In the following table the KPI of each pilot is summarized.

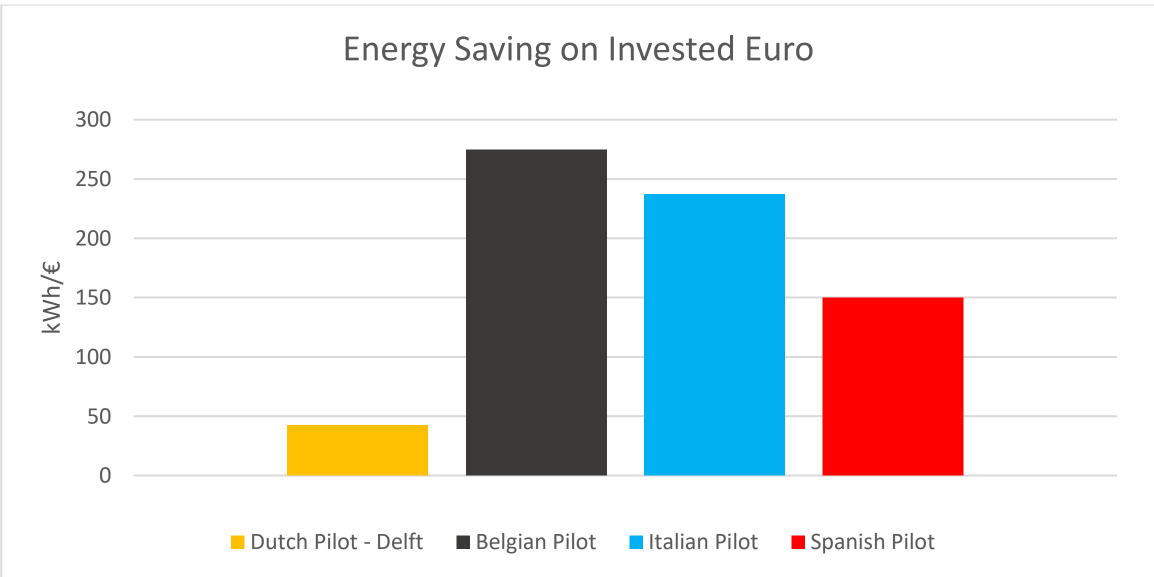
Table 8. Energy savings on Invested Euro KPI (2018)

Energy Savings (*) on Invested Euro	kWh/€
Dutch Pilot (Delft)	43
Belgian Pilot	275
Italian Pilot	237
Spanish Pilot	150

(*) Primary energy

From this analysis, the Belgian and the Italian pilots allow to get better level of energy savings relating to the invested Euro, while the Dutch pilot registered the lower value of this specific KPI.

Figure 20. Energy savings on Invested Euro KPI (2018)



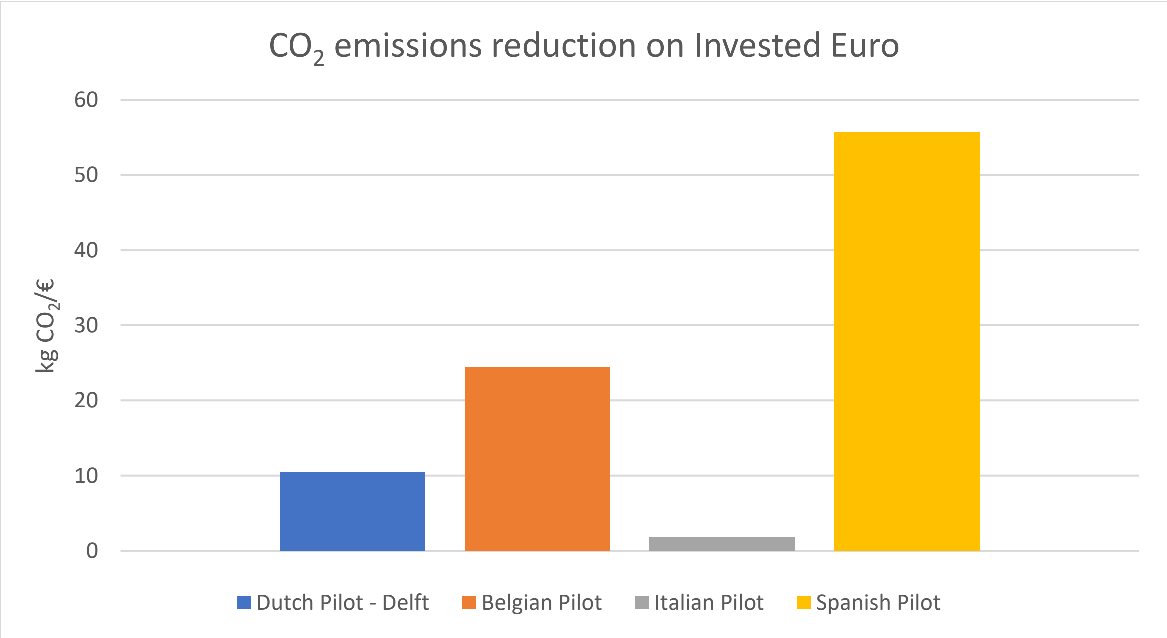
The calculus of CO_2 emission reduced by implementing ATES systems is reported in the following table (specific emission factors for each Country was taken into account – Source: Covenant of Mayors).

Table 9. CO_2 emissions reduction on Invested Euro KPI (2018)

	Reducing CO_2 emissions		CO_2 emissions reduction on Invested Euro
	tons/year	tons/useful life	kg CO_2/€
Dutch Pilot (Delft)	102	3,069	10
Belgian Pilot	94	2,834	24
Italian Pilot	105	3,144	2
Spanish Pilot	103	3,077	56

Please be noted that during the entire useful lifetime, equal to 30 years, all the projects result to be able to reduce the CO_2 production of about 3,000 tons. The Spanish pilot allows to get better level of CO_2 emissions reduction relating to the invested Euro, while the Italian pilot registered the lowest value of this specific KPI.

Figure 21. CO_2 emissions reduction on Invested Euro KPI (2018)



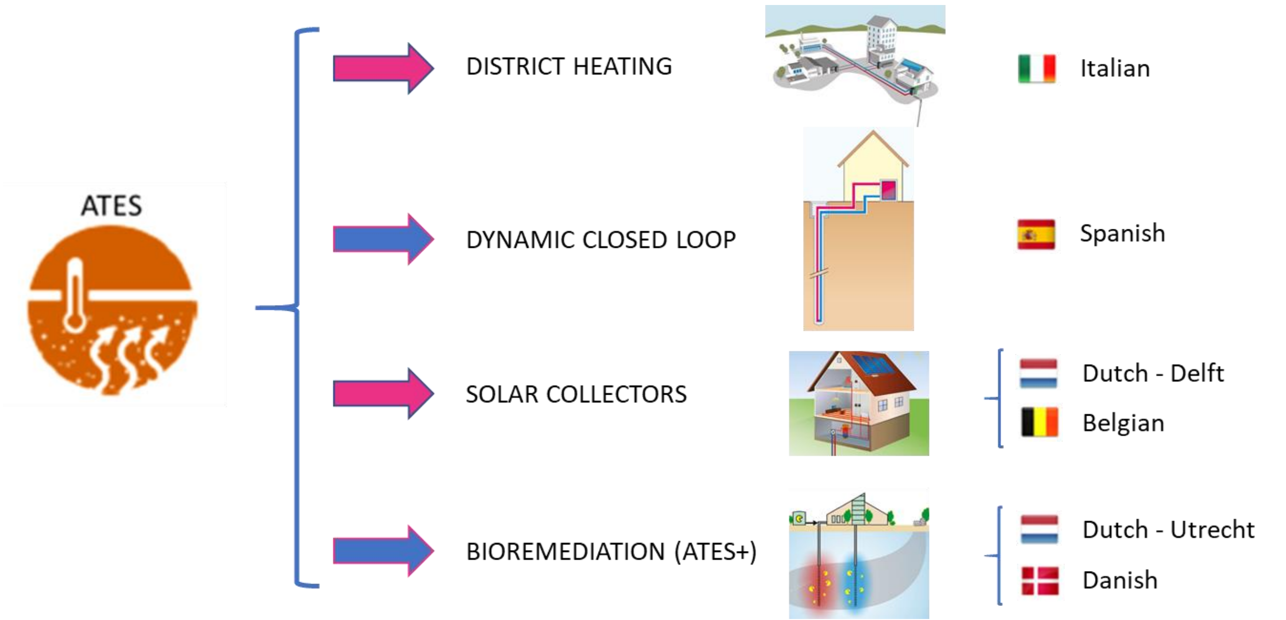
5. Conclusions

The business case is elaborated as a result of the technical analysis carried out by all project partners, integrating all the evidences which were gathered along the project. The aim is to try to test the profitability of each project, while understanding the critical points and the potential scalability.

Combining the technical and economic feasibility of the project, the final analysis aims at identifying the degree of its replicability and formulate recommendations.

The portfolio of pilot cases developed within the E-USE(Aq) project can be outlined as follows:

Figure 22. Pilot cases portfolio divided by the specific application of ATES system



From the 2018's evaluation of the ATES pilot projects developed through the different countries it is clear that an “economies of scale” approach would be the main driver for a constant profitability and replicability of this low carbon energy solution for space heating and cooling.

Once larger than a certain size, each project shows IRR and PBT levels fitting with the financial and economic industrial benchmarks. <u>ATES results get better and better if integrated with other energy efficiency technologies, since the global efficiency of the system results to be improved, also in terms of CO_2 reduction</u>.

The combination of ATES systems and DH networks can be considered an innovative solution, in order to increase the efficiency of existing DH systems, and it is also a fascinating solution for the design of novel low temperature DH systems with renewable energy sources. Furthermore, this application shows benefits in terms of higher energy efficiency and simplicity, given the use of one single technology in the generation of heat and cold. This leads to a reduction of CO_2 and other GHG emissions, which is benefitting the environment. As highlighted in the Italian pilot, ATES project characterized by a substantial size can’t be developed with a standard approach, but needs to be designed through a tailored method.

The addition of an ATES system to an existing heating system could allow to implement retrofitting actions on the facilities, applying best available technology able to reduce operative costs of the global system.

Thanks to the data analysis and the extensive testing performed on the developed probes by Itecon during the past years, the Company was able to reduce the experienced usual technical barriers of DCL and optimize the cost of investment of its installations.

The Belgian pilot project (ATES+PV) also shows a costs improvement due to the technology evolution and a better detail of the project.

It is desirable to be able in the next future to bring further improvement on technological performance, in order to reduce costs and make ATES projects more profitable. All the projects fit with the opportunity to be flexible and scalable.

As for the ATES and bioremediation case, interest in the concept has recently risen due to the demand for both renewable energy technology and sustainable groundwater management in urban areas, which often face strong competition for space. The combination of ATES and bioremediation in one construction could be an effective solution to tackle both soil contamination and mitigate climate change at the same time.

In 2017, the business case for the combination of ATES and bioremediation was qualitatively described. The difficulty in trying to compare the business cases for the pilots related to ATES and bioremediation is due to the cumulative cost-structure that such projects entails: being not just aimed at the production of energy, the combination of ATES & bioremediation needs a proper assessment of all costs related to the bioremediation activity and the potential savings that can be generated combining the two systems. It is hard to incorporate bioremediation in the business model, since bioremediation only adds extra costs, without reducing energy demand and/or improving the efficiency of the ATES system. The added value of the combination of ATES and bioremediation lies in the cost reduction that is created when ATES is combined with bioremediation in one design, when the alternative is to design an ATES system and bioremediation separately.

In the carried-out analysis, a comparison was made between two different scenarios:

- Pump and treat (i.e. a popular remediation technique);
- Bioremediation;
- ATES & bioremediation.

Now, in 2018, it is still early to develop a quantitative business case given that the technology requires further optimization. There is still a lot to learn about how ATES and bioremediation can be combined best and how the business case could be optimized by making the OPEX and CAPEX as low as possible and the system as efficient as possible. However, in 2018, some valuable monitoring results have been delivered, which enabled us to make some suggestions on how to improve the system and, eventually, improve the business case.

In the Utrecht pilot, the number of bacteria that is injected in the soil is very high. This is done on purpose, since it is yet unknown how the number of bacteria relates to the scale and the nature of the contamination in the soil. It is also unclear how long the bacteria can stay alive. Therefore, it is unclear if we have injected too many or less bacteria that needed have been injected. The number of bacteria that needs to be injected and the frequency of bacteria injections also depends on the characteristics of the soil system, and in turn these parameters will affect the cost structure.

To conclude, the update of the economic parameters of E-USE(aq) pilot sites shows positive performances and improved parameters which are promising to support market uptake.