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Study of Levelised Cost of Energy (LCOE) for Innovative Coating Materials for Geothermal Plant Components

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ABSTRACT

The aggressive environment of medium to high temperature geothermal resources makes the geothermal plant components vulnerable to corrosion, erosion and scaling, which is a challenge in maintaining the integrity of the various plant components. To combat against aggressive geofluid for future geothermal project development, the Geo-Coat project proposes cost-effective anticorrosion, anti-scaling coating materials for low-cost carbon steel (CS) substrates as an alternative to the state of art (SOA) materials with the aim of providing improved component performances during the lifetime of the plants. In Geo-Coat five high entropy alloys (HEAs) deposited through High-Velocity Oxy-Fuel spray (HVOF), Laser Cladding (LC) and Electro-Spark Deposition (ESD) is being studied as coating materials. Determining the economic impacts of these Geo-Coat substrate materials, coating materials and the deposition processes is an essential step in designing a sustainable technology for geothermal components. Therefore, in this study, the economic impacts of the Geo-Coat technology adopted for geothermal components have been evaluated along with SOA materials utilising LCOE (levelized cost of energy) methodology. This paper briefly presents the results of the LCOE study and suggest the best combination of coating material and its deposition technique, which can be used for identifying and promoting sustainable coatings for geothermal plant components.

1. INTRODUCTION

The coatings play a vital role against corrosion, erosion and scaling in extending the lifetime of geothermal components such as pipes and casings, heat exchanger tubes, and others. Geo-Coat is aimed to develop high performance synthesised coatings for geothermal components. The excellence of the Geo-Coat lies in the concept of developing innovative synthesised coatings, also referred to as Geo-Coat system or technology addressing corrosion, erosion-corrosion and scaling damages due to aggressive environment of medium to high temperature geothermal resources. In this study, we are investigating the economic impacts of the high entropy alloy coatings developed for geothermal components. Levelised cost of energy (LCOE) has been used to estimate and evaluate the economic performances of these synthesised coatings deposited onto the substrates through HVOF, LC and ESD processes.

The levelised cost of energy (LCOE) estimates the representative cost of generating electrical power from a power plant over its lifetime and is used to compare different methods of electricity generation on a consistent basis. LCOE is the ratio between all the discounted costs over the lifetime of a power plant divided by a discounted sum of the actual energy delivered. In other words, LCOE is the average revenue per unit of electricity (in €/kW-hr or €/MWh) that would be required to breakeven a power plant. LCOE estimation are dependent upon factors specific to the scenario being evaluated, with most of these factors defined by user inputs.

High temperature and pressure conditions of geothermal resources and corrosive nature of geofluid pose a significant threat to maintaining the integrity of the geothermal components such as pipes, turbine components, well casings, and pump impellers. Corrosion, erosion and scale formation or combination of these can occur in these components at different locations of the geothermal power plants. To obtain higher enthalpy geofluid for increased output of geothermal systems, drilling deeper wells are needed. Geothermal environments become more aggressive at deep wells and hence the increased corrosion, erosion and scaling effects put the efficiency and longevity of the plant components at risk. Several countries such as Iceland, New Zealand, Philippines, Indonesia, Kenya, Uganda, Mexico and US has carried out research activities to combat against aggressive geofluid for future geothermal project development [1]. These studies proposed use of expensive and corrosion resistant materials such as stainless steels 630SS, A470, 304L, titanium alloys, etc. as state of art (SOA) materials for different geothermal components. But the use of such materials will cause huge investment and thereby will make future deep geothermal projects less economically viable. It is proposed that the use of Geo-Coat technologies for different geothermal components instead of using SOA materials will enhance the growth of geothermal power.

First, we have studied the dimensions, length and diameters of different geothermal components such as pipes, well casings, and turbine components employed for representative geothermal plants and calculated the volume and inner surface area on the primary data provided by the consortium partners. Then, we have calculated the total volume of the SOA and Geo-Coat substrate materials for different geothermal components employed in Icelandic Case Study (ICS) and Romanian Case Study (RCS) power plants. The coating volume for different components have been obtained using the calculated total inner surface areas and the coating thickness and the respective coating volume. Coating thickness for each component has been chosen so that the component lifetime equals to plant lifetime removing any need for replacement.

The main goal of the LCOE studies is to provide the economic performances with and without the adoption of Geo-Coat technology applied for geothermal components considering ICS and RCS power plants. The following goals should be achieved:

- Quantify and evaluate the economic impacts of the SOA materials and Geo-Coat systems (Geo-Coat substrate plus ranked coating) used for geothermal components such as pipes, turbine components and well casings.
- Compare the total economic impacts with and without the adoption of Geo-Coat systems for Icelandic and Romanian case studies.
- Use this study as a marketing tool for policymakers, stakeholders, and environmental agencies.

In this study, we have analysed two representative geothermal power plants from Iceland and Romania. The scope of the study is to establish the baseline information to SOA and Geo-Coat systems employed for pipes, well casings and turbine rotors and blades and then to compare the economic impacts of the power plants in terms of LCOE with and without adoption of the Geo-Coat technology.

The Geo-Coat project has been developing novel coating and MMC component systems (Geo-Coat technologies) for six geothermal application areas: i) pipes and casings (S1), ii) valve stem & turbine blades (S2), iii) turbine rotors (S3), iv) turbine blades (S4), v) pump impellers (S5), and heat exchanger tubes (S6). The overall ranking of Geo-Coat technologies per application area have been evaluated based on lab-based results of the corrosion, tribological and cost performances considering the weightages of different performances as suggested by the advisory board, experts in geothermal energy within Geo-Coat consortium. 1st ranked Geo-Coat technologies have been selected for each of the six geothermal application areas and listed in ***Table 0-a***.

***Table 0-a**: Ranked Geo-Coat technologies for each application area*

Substrates	Application areas	1st ranked Geo-Coat system
S1	Pipes & casings	LC_HEA2
S2	Valve stem & turbine blades	LC_HEA2
S3	Turbine rotors	LC_HEA2
S4	Turbine blades	LC_HEA5
S5	Pump impellers	HIP_Ti64+10% TiB2
S6	Heat exchanger tubes	Undercoat: High P%; Topcoat: Low P%, 10 g/l PTFE, no HT (ENP41_DC)

The Geo-Coat substrate materials were selected as a cheaper and environmentally lighter alternative to the SOA substrate materials with the aim of providing improved component performances when coated. The Geo-Coat project has selected five Geo-Coat substrate materials where best selected Geo-Coat coatings to be applied. The pipe and well casing component materials (S1) such as stainless steel 630SS, 316L, carbon steel S235JR or P265GH, K-55, etc., are currently being used at different locations of the pipe network of geothermal power plants worldwide. The SOA substrate materials of either CrMoV steel or 2% Cr Steel or A470 steel for turbine rotors (S3) are being used. Ti alloys are highly resistant to localised corrosion and stress corrosion cracking in the presence of chlorides, halides, halogens and to hot highly acidic solutions [2], whereas most carbon steels, stainless steels and Ni-based alloys show poor performance. Ti alloys are also recognised for their high resistance to erosion and erosion-corrosion, which is an important characteristic in areas of the geothermal plant where high-flow geothermal fluid is found. For the above reasons, Ti alloys have been recommended to use in turbine blades and well casings as SOA materials [3]. Geo-Coat project focuses on material and component development for highly corrosive geothermal environment. As case study locations are not representative scenarios for Geo-Coat application, for economic impact studies the materials 630SS, Ti-6Al-4V, A470, and Ti-6Al-4V have been considered for the pipes, well casings, turbine rotors, and blades respectively – referred to as SOA materials for highly corrosive geothermal environment (SOA_{hcge}).

***Table 0-b**: substrate materials considerations for geothermal components of well casings, pipes and turbines*

ID	Application areas	SOA substrate materials employed for Icelandic (ICS) and Romanian case (RCS) studies	SOA materials for highly corrosive geothermal environment (SOA_{hcge})	Geo-Coat proposed SOA substrate materials
S1	Well casings	ICS: K-55 RCS: P265GH	Ti-6Al-4V	P265GH
S1	Pipes	ICS: S235JR & 316L RCS: P265GH	630SS	P265GH
S3	Turbine rotors	ICS: low alloy steel CrMoV	A470	A470
S4	Turbine blades	ICS: stainless steel (17-4PH for last stage)	Ti-6Al-4V	304L

For maintaining the integrity of the pipe, turbine and well casings components during the lifetime of the plant, it is recommended to use Geo-Coat substrates coated with the best Geo-Coat coatings (LC_HEA2, LC_HEA5) – referred to as Geo-Coat technologies/systems alternative to SOA_{hcge} systems in future geothermal power plants.

For comparisons of economic impacts with and without adoption of Geo-Coat system i.e. Geo-Coat technology, the pipes (S1), turbine (S3-S4) components and well casings (S1) have been considered for Icelandic and Romanian perspectives. For these comparative economic impact studies, we have used the 1st ranked Geo-Coat systems for well casings, pipes, turbine rotors, blades and pump impellers and listed in ***Table 0-c***.

***Table 0-c**: 1st ranked Geo-coat systems for different application areas of the geothermal power plants*

Rank	Well casings (S1)	Pipes (S1)	Turbine rotors (S3)	Turbine blades (S4)	Pump Impellers (S5)
1st	LC_HEA2_S235JR	LC_HEA2_S235JR	LC_HEA2_1.2746	LC_HEA5_304L	HIP_Ti64+10% TiB2

Geo-Coat LCOE estimation considerers all phases of geothermal project development, with unique duration and discount rate applied to each. Costs are estimated for the activities in each project phase, along with the estimated power generation over the plant lifetime, are the basis for the LCOE estimate.

2. METHODOLOGY

For the Geo-Coat project, we have developed a LCOE framework based on the GETEM and GEOPHIRES LCOE calculators. During the development, we have modified several design and cost parameters of the GETEM LCOE calculators. We have also considered some methods from the GEOPHIRES LCOE calculator such as levelised cost of heat (LCOH) models, different levelised cost models etc, that are appropriate for the Geo-Coat project. GETEM, originally developed for the Department of Energy's Geothermal Technologies Program (GTP), is a method for estimation of the cost of power generation from geothermal energy, and a means of assessing how technology advances might impact generation cost, determined as LCOE. The entire framework of the Geo-Coat LCOE calculator, in general, considers the different components and functionality of a full-scale geothermal plant. Because the Geo-Coat project only considers some components of a geothermal plant, the economic impact of Geo-Coat innovations has been estimated keeping the cost of other components unchanged.

LCOE input data for the two case studies have been collected from Geo-coat partners and literature study. However, due to lack of complete dataset, in this study we have chosen to perform LCOE estimates on geothermal plants based on, but not exactly the plants data has been collected from. We have used as much data as available for the case studies and for the rest input parameters we have used GETEM defaults. This approach still provides us with the economic benefits we can expect from Geo-Coat technologies.

In this study, LCOE estimation is based on the number of production wells. Once the project size is determined, the capital and operating costs are estimated. The well field characterization assumes that the production or injection wells are identical. Production wells have same depth, casing configuration, flow rate, temperature, and productivity index. The injection wells are similarly identical. The estimates of power generation over plant lifetime are based on the premise that the resource temperature declines with time, while the geothermal flow rate remains same. To account for the impact of resource temperature decline, the power sales are predicted at monthly interval and determined for each period based on the temperature decline. Makeup drilling will occur if the temperature decline is excessive and the production temperature is assumed to return to the initial value.

To simplify estimation in this study we have considered greenfield projects only. This is also justified by the fact that in both case study sites corrosion, erosion is not a major concern and hence Geo-Coat technologies are not in demand. It is assumed that multiple prospects will be needed to evaluate and drill to develop a successful project. It is also assumed to full-sized wells at one or more sites will need to be drilled to verify commercial potential. In this study we have not considered exploration costs as a function of size of the project. Also, default costs are based only of those incurred at the successful site which include initial exploration activities, permitting and leasing, drilling of small diameter wells, and the drilling and testing of a limited number of full-sized wells to establish that the resource is commercially viable.

In this study number of production wells for the case studies comes as an input. Production well flow rate, total flow injected and the ratio of the production to injection well flow rates (default value 0.75) are used to determine required injection wells. From the well depth drilling cost is estimated. In this study we have assumed that all production & injection wells have same depth & costs regardless of whether they are successful or not. A drilling success rate (75%) is used to determine how many wells mut be drilled to get the required number of production and injection wells. Though we have considered that unsuccessful production wells will be used to supplement injection resulting in reduction of no of successful injection well requirement. Permitting, testing and indirect costs such as engineering, management etc are considered in total drilling costs. This study assumes that 60% of the total field capacity must be developed to obtain a PPA. In this study well stimulation was not considered.

Geofluid gathering system cost is based on the number of wells. Each well has an associated cost for surface equipment and is determined using average distance between plant and well and pipe size. If production pump is used then pump setting depth and size in horsepower (hp) is based on the casing configuration, flow rate, well depth, geofluid temperature and the productivity index. Similarly cost associated with injection well is determined except for the injection pump which is assumed to be in a single location. The total cost of geofluid gather system is the sump of surface equipment and pumps. In addition, total geofluid gather system included an indirect cost that is 12% of the total cost.

Depending upon plant type i.e. binary for flash two different methods are used for power plant capital costs. The capital cost of a binary plant is based on resource temperature, plant size and specific plant output. Binary power plant equipment costs are estimated from the second law efficiency, which is determined from specific plant output and resource temperature. The equipment costs for the binary plant therefore vary directly with this second law efficiency i.e. a more efficient plant may have higher plant equipment costs, but will need less flow, fewer wells, less geothermal pumping power etc. To get the minimum LCOE a trade-off between plant efficiency and cost is therefore required. But, to get an apple-to-apple comparison between state-of-art and Geo-Coat technologies, in this study, this optimisation was not performed. Flash power plant costs and performance estimates are based on flash pressures that are determined using a built-in model. These pressures, along with estimates of heat rejection and parasitic power requirements, are used to estimate the equipment costs. In this study no transmission line cost was considered. An installation multiplier is applied to the equipment costs to obtain the installed plant cost. This installation multiplier includes both the direct construction costs and the indirect costs, including engineering, start-up etc. The approach for estimating installed plant costs by estimating equipment costs and applying an installation multiplier was adopted from Electric Power Research Institute's Next Generation Geothermal Power Plants study (EPRI 1996).

The different phases and activities in project development have costs such as planning and management, limited testing of exploratory wells, engineering, and other similar costs that are difficult to categorize and assign a specific value. These indirect costs are estimated as a percentage of the total cost for the activity or phase and in this study GETEM default percentages were used.

The operation and maintenance costs used in estimating the LCOE include:

- labour costs
- Maintenance costs: a specified fraction of the capital costs for
  - power plant (1.8% of capital costs)
  - well field (1.5% of capital costs)
  - field gathering system (1.5% of capital costs)
- With Geo-Coat equipment maintenance need is reduced hence maintenance costs fraction was estimated assuming that if we replace e.g. a pipe with Geo-coat it will not need replacement in plant lifetime and hence adjustment to the maintenance cost factors is required.
- Property taxes and insurance: based upon the total capital cost for the power plant, surface equipment, geothermal pumps, and wells that support the operation of the facility
- Royalties

3. RESULTS AND DISCUSSIONS

To evaluate economic performance of Geo-Coat technologies, LCO analysis for two case studies (ICS, RCS) based upon but not exactly Icelandic and Romanian geothermal power plants was performed. ICS has been modelled after but not exactly Hellisheiði power plant and considered to be a double flash plant. RCS has been modelled after but not exactly TRANSGEX-Oradea power plant and considered to be a binary plant. Though component dimensions from respective power plant has been used in this study but substrate for the components are the 'SOA material for highly corrosive geothermal environment (SOA_{hcge})' from ***Table 0-b*** (column 4). The reason behind is that Geo-Coat project focuses on material and component development for highly corrosive geothermal environment. Comparative LCOE studies has been performed with adoption of Geo-Coat systems (LC_HEA2_S235JR, LC_HEA2_1.2746, LC_HEA5_304L) and without adoption of Geo-Coat systems i.e. with SOA_{hcge} systems (630SS, A470, Ti-6Al-4V and Ti-6Al-4V) for surface pipes, turbine rotors, blades and well casings, respectively. Pump impeller has not been considered for ICS since they are not used in the power plant and heat exchanger is not included in this study due to the unavailability of data. Pump impeller and heat exchanger is not included for RCS study due to the unavailability of data.

From data inventories of substrate and Geo-Coat systems, the total material volume, the total area of coating, and the coating thickness (area of coating times the required thickness of the coating for 30- and 20-years lifetime for ICS and RCS respectively) for those components have been calculated based on the primary data provided by the plant operators. For ICS, the total thickness of the coatings, using the 1st ranked coatings LC_HEA2 and LC_HEA5 whose corrosion rates of 87.38 µm/year, have been calculated for 30 years lifetime of the plant and obtained about 2610 µm. And for RCS, the total thickness of the coatings, using the 1st ranked coatings LC_HEA2 and LC_HEA5 whose corrosion rates of 87.38 µm/year, have been calculated for 20 years lifetime of the plant and obtained about 1740 µm.

With these data overall cost factors for the components has been calculated and presented in ***Table 2-a***. The overall cost factors are then used to compute LCOE for Geo-Coat coatings and is presented in ***Table 2-b*** and ***Table 2-c*** or ICS and RCS respectively.

Table 2-a: *Overall cost factors*

Component	Overall cost factor		
	ICS		RCS
Casing	0.0060		0.0054
Pipe	0.6236		0.5215
Turbine	0.0104		n/a

***Table 2-b**: LCOE comparison of ICS*

		SOA_{hcge}	Geo-Coat
LCOE	€/MWh	1,332.714	182.079
Power Sales	MW	266.21	266.21
Exploration Drilling Costs (full-sized)		264,818,040.25 €	19,052,266.51 €
Small Diameter Exploration Drilling		1,989,934.18 €	1,989,934.18 €
Non-Drilling Exploration Costs		420,155.45 €	420,155.45 €
Permitting & Leasing Costs		480,317.53 €	480,317.53 €
Other Indirect Costs		13,937,791.59 €	1,002,750.87 €
TOTAL EXPLORATION COST		281,646,239.00 €	22,945,424.54 €
Well Count			
Number Production Wells Required		30.00	30.00
Number Injection Wells Required		11.32	11.32
Number of Wells Drilled to Complete Field		52.43	52.43
Well Cost			
Production Well Cost		55,170,425 €	3,969,222 €
Injection Well Cost		55,170,425 €	3,969,222 €
Drilling Cost			
Production Capacity Drilled before PPA		60%	60%
Permitting Costs		916,280 €	916,280 €
Production Well Costs		2,059,695,869 €	148,184,295 €
Injection Well Costs		832,990,848 €	59,929,315 €
Non-Drilling Costs		152,439,196 €	11,145,875 €
TOTAL DRILLING COST		3,046,042,193 €	220,175,765 €
Total Production Flow	kg/s	2400.00	2400.00
Flow per well	kg/s	80.00	80.00
Production Pumping	MW	0.00	0.00
Total Injection Flow	kg/s	1946.57	1946.57
Injection Pumping	MW	12.56	12.56
Wells Used for Injection		24.43	24.43
Surface Equipment Costs		1,083,536,471 €	675,675,933 €
Total Production Pump Costs		0 €	0 €
Total Injection Pump Costs		4,705,429 €	4,705,429 €
Indirect Costs		148,396,623 €	92,779,277 €
TOTAL FIELD GATHERING SYSTEM COST		1,236,638,523 €	773,160,639 €
Estimated Generator Nameplate	MW	290.61	290.61
Power Plant Net Output	MW	278.76	278.76
Geothermal Pumping Power	MW	12.56	12.56
Power Plant Cost (per net MW)	€/MW	50,960,823 €	1,081,026 €
Power Plant Cost		14,206,070,407 €	301,351,788 €
TOTAL POWER PLANT COST		14,206,070,407 €	301,351,788 €
TOTAL CAPITAL COST (w/o Contingency)		18,770,397,362 €	1,317,633,616 €
TOTAL CAPITAL COST (with Contingency)		21,112,331,253 €	1,481,203,777 €
Facility Staff		44.9	44.9
Labour Cost	per yr	3,499,477 €	3,499,477 €
Plant Maintenance	per yr	256,224,984 €	175,329,926 €
Field Maintenance	per yr	63,118,528 €	1,809,480 €
Geothermal Pump Maintenance	per yr	0 €	0 €
Taxes & Insurance	per yr	154,601,662 €	10,099,746 €
TOTAL ANNUAL O&M COST		477,444,651 €	190,738,630 €

***Table 2-c**: LCOE comparison of RCS*

		SOA$_{hcge}$	Geo-Coat
LCOE	€/MWh	6,206.714	2,846.148
Power Sales	MW	11.28	11.28
Exploration Drilling Costs (full-sized)		355,897,957.11 €	21,063,068.96 €
Small Diameter Exploration Drilling		1,989,934.18 €	1,989,934.18 €
Non-Drilling Exploration Costs		420,155.45 €	420,155.45 €
Permitting & Leasing Costs		193,198.48 €	193,198.48 €
Other Indirect Costs		18,731,471.43 €	1,108,582.58 €
TOTAL EXPLORATION COST		377,232,716.65 €	24,774,939.65 €
Well Count			
Number Production Wells Required		2.00	2.00
Number Injection Wells Required		1.35	1.35
Number of Wells Drilled to Complete Field		1.79	1.79
Well Cost			
Production Well Cost		74,145,408 €	4,388,139 €
Injection Well Cost		74,145,408 €	4,388,139 €
Drilling Cost			
Production Capacity Drilled before PPA		60%	60%
Permitting Costs		916,280 €	916,280 €
Production Well Costs		0 €	0 €
Injection Well Costs		132,984,030 €	7,870,379 €
Non-Drilling Costs		7,191,686 €	606,757 €
TOTAL DRILLING COST		141,091,997 €	9,393,416 €
Total Production Flow	kg/s	220.00	220.00
Flow per well	kg/s	110.00	110.00
Production Pumping	MW	0.89	0.89
Total Injection Flow	kg/s	220.00	220.00
Injection Pumping	MW	1.18	1.18
Wells Used for Injection		1.79	1.79
Surface Equipment Costs		8,644,579 €	4,507,753 €
Total Production Pump Costs		500,133 €	500,133 €
Total Injection Pump Costs		473,231 €	473,231 €
Indirect Costs		1,311,538 €	747,425 €
TOTAL FIELD GATHERING SYSTEM COST		10,929,481 €	6,228,543 €
Estimated Generator Nameplate	MW	23.17	23.17
Power Plant Net Output	MW	13.35	13.35
Geothermal Pumping Power	MW	2.07	2.07
Power Plant Cost (per net MW)	€/MW	205,256,779 €	100,199,462 €
Power Plant Cost		2,739,771,564 €	1,337,464,408 €
TOTAL POWER PLANT COST		2,739,771,564 €	1,337,464,408 €
TOTAL CAPITAL COST (w/o Contingency)		3,269,025,758 €	1,377,861,307 €
TOTAL CAPITAL COST (with Contingency)		3,686,047,324 €	1,580,200,485 €
Facility Staff		7.9	7.9
Labour Cost	per yr	605,667 €	605,667 €
Plant Maintenance	per yr	49,315,888 €	41,418,284 €
Field Maintenance	per yr	4,355,890 €	6,034 €
Geothermal Pump Maintenance	per yr	165,709 €	165,709 €
Taxes & Insurance	per yr	26,045,482 €	11,720,920 €
TOTAL ANNUAL O&M COST		80,488,636 €	53,916,614 €

The adoption of Geo-Coat technology instead of SOA$_{hcge}$ in ICS showed a significant savings in LCOE (from 1,332€/MWh to 182€/MWh). The adoption of Geo-Coat technology instead of SOA$_{hcge}$ in RCS showed a significant savings in LCOE (from 6,207€/MWh to 2,846€/MWh).

Cost factor is multiplied with SOA_{hcge} product cost to estimate Geo-Coated components cost i.e. a cost factor of less than one will reduce component cost and reduce LCOE. Geo-Coat technologies shows cost factor of less than one for all components. The study shows that Geo-Coat technologies is the best costing in terms of economic performance and reduces LCOE for case studies. The study also shows that benefits from Geo-Coat is higher for larger plant size.

4. CONCLUSIONS

Geo-Coat technologies are being developed and designed to protect different parts and components in the geothermal power plant, particularly from corrosion, erosion and scaling effects. Geo-Coat technology can be applied on steam turbines, surface pipes, pump impellers, and well casings to extend their lifetime and reliability. Geo-Coat technology will enhance the growth of geothermal energy as it will enable to exploit corrosive and aggressive geofluid to generate electricity - while significantly reducing the environmental impacts.

For comparative LCOE studies, Geo-Coat systems for different application areas such as surface pipes (S1), turbine components (S3-S4) and well casings (S1) have been adopted for Icelandic & Romanian case studies which are based on but not exactly on 303MW Hellisheiði power plant and 50kW TRANSGEX-Oradea power plant respectively. Based on GETEM and GEOPHIRES LCOE calculators we have developed Geo-Coat LCOE calculator which was used in this study to perform LCOE estimation with and without adoption of Geo-Coat systems for different geothermal components such as well casing, surface pipe network, turbine rotor & blades. The study shows LCOE reduction of 54.14-86.34% for Geo-Coat coatings. All Geo-Coat material, coating, surface preparation and coating application costs use in this study are lab-scale costs, which are not representative costs for large scale production. We expect further reduction in LCOE for large scale productions.

This study assumes that coating will be applied for plant lifetime for all casing, pipes and turbine rotor & blades. This can be optimised if corrosion rates of different sections of these components is known, allowing for optimised coating application which will further reduce costs and LCOE.

This study reveals that the adoption of Geo-Coat systems for geothermal components will reduce costs for those geothermal plants operating with highly corrosive geofluid. Application of Geo-Coat technologies will also make geothermal prospects with highly corrosive geofluid commercially viable.

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