



A GEOTHERMAL APPROACH TO POWER-TO-X

in El Salvador, Chile, and Kenya

APPENDICES

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Questionnaires

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ESPINOS S.A.

Geotérmica del Norte, subsidiaria de Enel Green Power

Other responses

OR

Enel

CRI

BID

Letter of Introduction

Iceland, June 14th 2022

To whom it may concern / NAME,

Our company is performing an assessment of the opportunities to use geothermal resources for Power-to-X (PtX) products, such as Hydrogen, Ammonia or Methanol. The study is funded by GIZ who is a public-benefit federal enterprise which is Germany's leading provider of international cooperation services for sustainable development.

The aim of the study is to identify and to assess advantages and co-benefits of PtX with geothermal sources and to evaluate PtX production costs with geothermal sources compared to other pathways using renewable electricity from wind, solar and hydro. The potential for PtX will be assessed for Chile, El Salvador and Kenya. The outcome of this analysis will feed into the international discussions on PtX and green hydrogen. It should provide an overview for decision makers to easily understand the potential for PtX with geothermal energy.

For this reason, we would appreciate to receive from you some information as presented in the questionnaire attached.

In exchange for your data and in case you consider the study could be of interest to you and your company, GIZ is willing to share the results of the study with your company.

We have a strict time limit and thus hope for your kind cooperation to provide answers to the questionnaire by **June 30th**. In case of any questions or comment, please feel free to contact me.

Many thanks for your kind attention.

On behalf of the team,

Ms. Katrín Ragnarsdóttir, katrinr@mannvit.is

Mannvit hf.

Questionnaire for geothermal developers, power plant operators and power producers

General information		
Name of the company:		
Name and location of the geothermal power plant(s):		
Installed power:		
Heat supplied:		
The annual availability/"uptime" of each geothermal power plant:		
Are there any geothermal power plants planned that have not yet been installed?	Yes	No
Electricity price at the power plant location:		
What is the composition and amount of non-condensable gases from each geothermal power plant (existing and planned, if applicable)?		
Does the plant use any abatement technology to achieve specific environmental constraints (i.e., technologies for H ₂ S or CO ₂)? If so, what technology is used?		

PtX information	
What is the available electrical power from each power plant (existing and planned, if applicable), that could be available for PtX production?	
If possibly planned or existing hydrogen / methanol / ammonia production is or could not be located close to the power plant, what is the electricity transmission cost in the area?	
Do you know of any CO ₂ sources from geothermal power plants in the country that could be utilised for PtX?	
Do you know of any other resources of CO ₂ in the country that could be utilised for PtX?	
What are the distances from the power plant's location to next harbour and industrial sites, where	

potential off-takers might be located, or the products stored for transport / export?	
Is there any infrastructure for large scale storage of chemicals existing close to the plant, i.e., tank storage sites? If so, do you know if they used for storage of methanol or ammonia?	
Do you know of methanol and / or ammonia plants / producers in the country?	
Do you know of any potential off takers in the area for hydrogen, methanol, ammonia or other potential PtX products?	
Which energy (heat) and mass flows are available from the geothermal power plant that could be used in a PtX plant or the subsequent processing (for chemical / steel / pharma industry) besides the electrical energy? Would they need additional processing steps?	
What would be benefits or issues of using geothermal energy instead of wind or solar power for PtX with regards to sustainability?	

Questionnaire for chemical process engineering companies, PtX developers and producers

General information	
Name of the company:	
Name and location of the plant(s):	
What does your plant produce?	
How much does your plant produce?	
Are you willing to tell us at what price you sell your product?	
Can you tell us how much you pay for electricity for the operation of your plant and who is the electricity seller?	
Do you know of any (other) CO ₂ sources in the country that could be utilised for PtX?	
Do you know of any (other) methanol and/or ammonia plants/producers in the country?	
Do you know of any potential off takers in the area for hydrogen, methanol, ammonia or other potential PtX products?	
Which energy and mass flows are required for operating the PtX plant or processing of PtX products for the industry (entire process chain) that could be sourced from geothermal power plants? (e.g., heat for preheating or DAC desorption, water, ...)	

Questionnaire for energy and environmental ministries

General information	
Name of ministry:	
Can you inform us about the cost of capital for investments (interest rate) in the country?	

PtX information	
Does the country have any policy regarding PtX, i.e., with regards to the power source?	
Do you know of any CO ₂ sources in the country that could be utilised for PtX?	
Do you know of methanol and/or ammonia plants / producers in the country?	
Do you know of any potential off takers in the country for hydrogen, methanol, ammonia or other potential PtX products?	

Legislations and regulations		
Are there any emission limits in the country?	Yes	No
If yes, what are the emission limits; concentration, total emitted quantities, long or short-term basis, wastewater discharge limits, other environmental issues or requirements?		
Are there any specific legislations in the country in regard to geothermal electricity production or geothermal direct use?		

Questionnaire EPRA, Kenya

General information	
Name of ministry:	Energy and Petroleum Regulatory Authority (Ministry of Energy)
Can you inform us about the cost of capital for investments (interest rate) in the country?	Between 8 -12%

PtX information	
Does the country have any policy regarding PtX, i.e., with regards to the power source?	No. However, opportunities for use of geothermal and Variable Renewable Energy Technologies (wind and solar) under consideration
Do you know of any CO ₂ sources in the country that could be utilised for PtX?	
Do you know of methanol and/or ammonia plants / producers in the country?	Most of the ammonia is imported. However, we have blending plants detailed in Refer to BASELINE STUDY ON THE POTENTIAL FOR POWER-TO-X / GREEN HYDROGEN IN KENYA REPORT
Do you know of any potential off takers in the country for hydrogen, methanol, ammonia or other potential PtX products?	Potential exists for steel processing, ammonia production, port transport etc. Refer to BASELINE STUDY ON THE POTENTIAL FOR POWER-TO-X / GREEN HYDROGEN IN KENYA Report

Legislations and regulations		
Are there any emission limits in the country?	Yes	No
If yes, what are the emission limits; concentration, total emitted quantities, long or short-term basis, wastewater discharge limits, other environmental issues or requirements?	Refer to National Environmental Management Authority website. This is available	
Are there any specific legislations in the country in regard to geothermal electricity production or geothermal direct use?	Energy Act, 2019, Geothermal Resources Act	

Questionnaire Ministry of Energy, Kenya

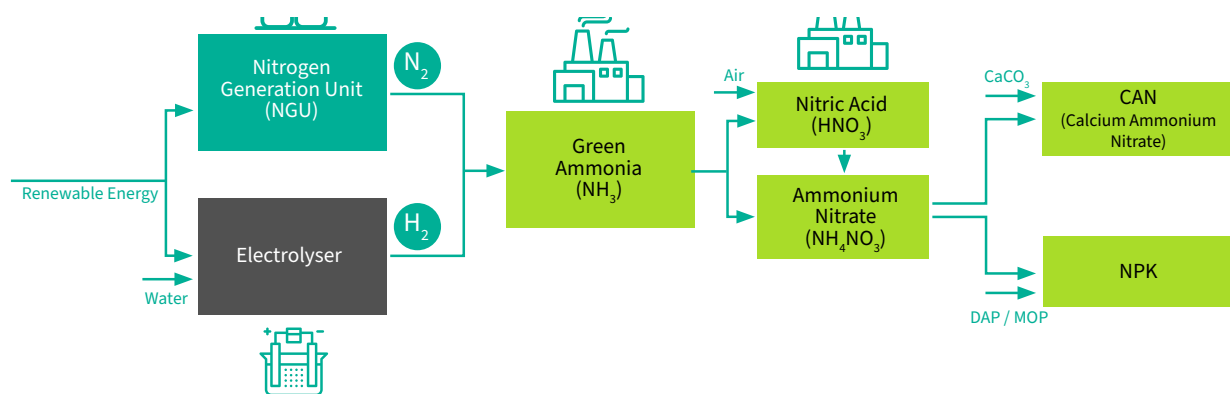
General information	
Name of ministry:	Ministry of Energy
Can you inform us about the cost of capital for investments (interest rate) in the country?	

PtX information	
Does the country have any policy regarding PtX, i.e., with regards to the power source?	We currently don't have any policy but the Ministry is working towards that. With support of GIZ, we did th baseline stufy to evaluate the value chains for Green Hydrogen and Ptx. Currently working on developing a strategy and roadmap.
Do you know of any CO ₂ sources in the country that could be utilised for PtX?	Cement making and in small scale steel industry
Do you know of methanol and/or ammonia plants / producers in the country?	Not sure.
Do you know of any potential off-takers in the country for hydrogen, methanol, ammonia or other potential PtX products?	Fertiliser manufacturing, Transport, Steel industry

Legislations and regulations		
Are there any emission limits in the country?	Yes	No
If yes, what are the emission limits; concentration, total emitted quantities, long or short-term basis, wastewater discharge limits, other environmental issues or requirements?		
Are there any specific legislations in the country in regard to geothermal electricity production or geothermal direct use?	The Energy Act 2019	

Questionnaire MET Development, Kenya

General information	
Name of the company:	MET Development
Name and location of the plant(s):	We do not have an operating plant, but we are studying a power-to-fertiliser plant in Kenya.
What does your plant produce?	No plant operational yet. The plant will make use of geothermal energy to produce hydrogen, which will be subsequently processed into ammonia and further downstream to CAN and NPK as fertiliser (see figure of the schematic scheme of the plant).
How much does your plant produce?	Not in operation yet.
Are you willing to tell us at what price you sell your product?	Not in operation yet.
Can you tell us how much you pay for electricity for the operation of your plant and who is the electricity seller?	This is under negotiations, and we cannot share any figures at this stage.
Do you know of any (other) CO ₂ sources in the country that could be utilised for PtX?	
Do you know of any (other) methanol and/or ammonia plants/producers in the country?	
Do you know of any potential off takers in the area for hydrogen, methanol, ammonia or other potential PtX products?	
Which energy and mass flows are required for operating the PtX plant or processing of PtX products for the industry (entire process chain) that could be sourced from geothermal power plants? (e.g., heat for preheating or DAC desorption, water, ...)	In general, we believe the big advantage of geothermal electricity is that electricity is available 24/7 which allows for an optimal use of the electrolyzers. Other sources such as solar or wind or a combination might require either a lower usage of the electrolyzers, electricity storage or access to the grid. In the end it is a CAPEX/OPEX evaluation that will determine the most optimal cost structure. Of course, one should consider the potential CO ₂ emission involved in geothermal power production, which could negatively impact the case.



Questionnaire Oserian Development Co., Kenya

General information	
Name of the company:	Oserian Development Co. LTD
Name and location of the plant(s):	Oserian Geothermal Power plants, Naivasha, Kenya
What does your plant produce?	Power in the form of electricity
How much does your plant produce?	Installed capacity- 3.2Mw
Are you willing to tell us at what price you sell your product?	Power generated is for our own use
Can you tell us how much you pay for electricity for the operation of your plant and who is the electricity seller?	We do not buy power from the national grid, we generate our own.
Do you know of any (other) CO ₂ sources in the country that could be utilised for PtX?	No
Do you know of any (other) methanol and/or ammonia plants/producers in the country?	No
Do you know of any potential off takers in the area for hydrogen, methanol, ammonia or other potential PtX products?	Not sure but may be fertiliser producing plants.
Which energy and mass flows are required for operating the PtX plant or processing of PtX products for the industry (entire process chain) that could be sourced from geothermal power plants? (e.g., heat for preheating or DAC desorption, water, ...)	We do not have a Ptx plant in Oserian.

Cuestionario Consejo Nacional de Energía, El Salvador

Información general	
Nombre del ministerio / institución:	Consejo Nacional de Energía
¿Puede informarnos sobre el coste del capital para inversiones (tipo de interés) en el país?	Según los datos del Banco Central de Reserva (BCR) las tasas de préstamo para empresas promediaron para el 2021: <ul style="list-style-type: none"> Hasta un año plazo: 6.33% A más de un año plazo: 7.69%

Información PtX	
¿Tiene el país alguna política acerca de PtX, es decir, con respecto a la fuente de energía?	<p>Si.</p> <p>El Salvador cuenta con la Política Energética Nacional 2020-2050 (PEN), la PEN tiene como principal objetivo estratégico garantizar el abastecimiento y consumo de recursos energéticos que requiere el país para su desarrollo bajo un enfoque de sostenibilidad, modernización, eficiencia, seguridad y neutralidad de carbono durante los próximos 30 años, con base a ello se está trabajando en la promoción de tecnología energética limpias. En este marco, se apuesta a la neutralidad del carbono en el sector energía, despliegue de las energías renovables, reducir la dependencia del petróleo, así como una fuerte apuesta a Investigación, Desarrollo e Innovación, entre muchas otras acciones.</p> <p>Respecto a la producción y aprovechamiento de hidrógeno verde: En 2021 se elaboró y se aprobó la Agenda Nacional de Hidrógeno verde que tiene cuatro ejes estratégicos:</p> <ol style="list-style-type: none"> 1. Desarrollar la Estrategia Nacional del hidrógeno verde de El Salvador (responsabilidades, horizontes, demanda local/creación de demanda, Exportación, incentivos) 2. Establecer normativas y estandarización (brechas regulatorias/nacional, regional, denominación de origen, certificación de la producción) 3. Desarrollo de capacidades gestoras y técnicas (tomadores de decisión, técnicos en todos los niveles) 4. Fomento de proyectos piloto de diferentes alcances con hidrógeno verde (inversión, financiamiento, infraestructura, capacidades locales, usos, certificación). <p>El Salvador por medio de una cooperación técnica del El BID (Banco Interamericano de Desarrollo) desarrollará:</p> <ol style="list-style-type: none"> a. La Estrategia Nacional de hidrógeno verde de El Salvador (responsabilidades, horizontes, incentivos, interacción entre con políticas nacionales energéticas y de cambio climático, aspectos de seguridad). b. El potencial de GH2 en El Salvador, incluyendo la identificación, caracterización, dimensionamiento del aprovechamiento en la industria, mercados nacionales e internacionales para el GH2 de El Salvador, habilitadores de adopción, priorización de acciones y aplicaciones, así como la sostenibilidad (disponibilidad de recursos). c. Caracterización de la industria nacional para el aprovechamiento del GH2 y de productos obtenidos

	<p>por medio de este, amoníaco verde, combustibles sintéticos (metanol, metano), entre otros, simulación de hub de producción-aprovechamiento de hidrógeno verde, captura de CO₂.</p> <p>d. Programa educativo entorno al GH2, a niveles estratégico como técnicos.</p> <p>Es este sentido, El Salvador cuenta con respaldo político y compromisos, por medio de la Política Energética Nacional 2020-2050 y las Contribuciones Determinadas a nivel Nacional (NDC), que son una base sólida para impulsar todo tipo de proyectos energéticos sustentables, y planes que faciliten alcanzar los objetivos energéticos estratégicos en los próximos 30 años.</p>
¿Sabe de algún tipo de recurso de CO ₂ en el país que podría ser usado para PtX?	Producción de cemento, industria metal-mecánica (metalurgia), generación de energía eléctrica (térmica, biomasa).
¿Tiene conocimiento de algunas plantas o productores de metanol y/o amoníaco en el país?	en El Salvador no se produce: amoníaco, metanol.
Tiene conocimiento de algún tipo de comprador / consumidor en la zona en el sector de hidrógeno, metanol, amoníaco u otros productos de PtX potenciales?	<p>Industria química (fertilizantes, entre otros).</p> <p>Industria farmacéutica.</p> <p>El Salvador importa un promedio de 1.30 millones de kilogramos de amoníaco al año y un promedio de 1.01 millones de kilogramos de metanol al año. (BCR)</p>

Legislación y normativa		
¿Existen límites de emisión en el país?	Si	No
<p>Si es así, ¿cuáles son los límites de emisión; concentración, cantidades totales emitidas, base a largo o corto plazo, límites de vertido de aguas residuales, ¿otras cuestiones o requisitos medioambientales?</p>	<p>El Salvador en función de los límites de emisión cuenta con Norma Salvadoreña de emisiones atmosféricas fuentes móviles NSO 13.11.03:01, en el cual se establecen los límites permisibles de emisiones de contaminación a la atmosfera generada por fuentes móviles. Se anexa el NSO. Así mismo, cuenta con los Reglamentos Técnicos Centroamericanos (RTS) para gasolinas y aceite combustible diésel, en estos se especifican aspectos de calidad de los combustibles, entre los que destacan limitantes en el contenido de azufre para ambos combustibles.</p> <p>Para El Salvador es importante y mandatorio que se frene la magnitud y aceleración que el cambio climático manifiesta y proyecta de aquí a 2030 y mitad de siglo, por tanto, en cumplimiento a los compromisos adquiridos en el marco del Acuerdo de París y las NDC, el país se compromete a tener una reducción de emisiones anuales (para 2030 y respecto a un escenario tendencial (BAU) desde 2019) de 640 Kton CO₂e por actividades de quema de combustibles fósiles en el Sector Energía y hasta una reducción de emisiones anuales de 819 Kton CO₂e en las mismas actividades y sector.</p> <p>Además, El Salvador se compromete a tener una reducción acumulada de emisiones, para el período entre 2035 y 2040, contada desde 2015, de 50,857.5 Kton CO₂e por reducción de emisiones y actividades de aumento de sumideros y reservorios de carbono en el paisaje agropecuario de su Sector AFOLU (Agricultura, Silvicultura y Uso de Suelo).</p>	

¿Existe alguna legislación específica en el país en relación con la producción de electricidad geotérmica o el uso directo de la geotermia?

Si.

El recurso geotérmico pertenece al Estado y se otorga concesiones para su explotación debido a que la Constitución de la República establece el otorgamiento de concesiones para la explotación de bienes demaniales, subsuelo, lecho marino y territorio insular. En este marco, la Asamblea Legislativa aprueba las concesiones y la Superintendencia de Electricidad y Telecomunicaciones (SIGET) en la entidad encargada de regular, ordenar, organizar y fiscalizar las concesiones para la explotación del recurso geotérmico.

La GEO es la única empresa salvadoreña estatal que actualmente explota el recurso geotérmico.

El marco jurídico que respalda, la explotación del recurso geotérmico es, la Ley de Electricidad, Ley de Concesiones de SIGET, siendo esta última, la que establece mecanismos para el otorgamiento de concesiones para la operación de plantas generadoras de energía eléctrica de pequeña escala, con capacidad nominal igual o menor a 5 megavatios.

Por otra parte, en el marco del apoyo con GIZ y Banco Mundial (BM) se está realizando la revisión del marco regulatorio y recomendaciones para facilitar el desarrollo de la geotermia de baja entalpía en El Salvador.

Así como los siguientes documentos anexos al mismo:

- Norma emisiones atmosféricas fuentes móviles, en adjunto a este correo.
- <https://www.edrhym.gob.sv/drhym/Documentos/EX-COMIECO-D-3%20%20ANEXO%20II%20RES%20425%20RTCA%20GASOLINA%20REGULAR%20%20ESPECIFICACIONES%20-%20COMIECO.pdf> (gasolina regular)
- <https://www.edrhym.gob.sv/drhym/Documentos/EX-COMIECO-D-2%20ANEXO%20I%20RES%20425%20RTCA%20GASOLINA%20SUPERIOR%20%20ESPECIFICACIONES%20-%20COMIECO.pdf> (gasolina superior)
- <https://www.edrhym.gob.sv/drhym/Documentos/Anexo%201%20Res%20187-2006%20RTCA%20DIESEL.pdf> (diésel).

Cuestionario ESPINOS S.A., Chile

Información general	
Nombre del ministerio / institución:	ESPINOS S.A.
¿Puede informarnos sobre el coste del capital para inversiones (tipo de interés) en el país?	Costo de capital mínimo (2022): 6%

Información PtX	
¿Tiene el país alguna política acerca de PtX, es decir, con respecto a la fuente de energía?	Sí, Estrategia Nacional de H2 (https://energia.gob.cl/sites/default/files/estrategia_h2_-_ingles2022.pdf)
¿Sabe de algún tipo de recurso de CO2 en el país que podría ser usado para PtX?	Generación termoeléctrica de ciclos abiertos (gas natural), ciclos combinados (gas natural) y plantas a carbón
¿Tiene conocimiento de algunas plantas o productores de metanol y/o amoniaco en el país?	Methanex, LINDE
Tiene conocimiento de algún tipo de comprador / consumidor en la zona en el sector de hidrógeno, metanol, amoniaco u otros productos de PtX potenciales?	No, hoy el foco es en la exportación y se está realizando un levantamiento de la demanda de H2 Piloto en Santiago: Cristalerías Chile (horno fundición de vidrio)

Legislación y normativa		
¿Existen límites de emisión en el país?	Si	No
Si es así, ¿cuáles son los límites de emisión; concentración, cantidades totales emitidas, base a largo o corto plazo, límites de vertido de aguas residuales, ¿otras cuestiones o requisitos medioambientales?	Ver ley: https://portal.sma.gob.cl/index.php/portal-regulados/instructivos-y-guias/normas-de-emision/	
¿Existe alguna legislación específica en el país en relación con la producción de electricidad geotérmica o el uso directo de la geotermia?	No, el regulador sólo se preocupa que exista competencia en el mercado y no establece metas de producción para ninguna tecnología. Hay una meta general: 20% de Energías Renovables al año 2025 (ya cumplida al 2021), y una meta de largo plazo correspondiente a la carbono neutralidad al 2050	

Cuestionario Geotérmica del Norte, Chile

Información general	
Nombre de la empresa:	Geotérmica del Norte, subsidiaria de Enel Green Power
Nombre y ubicación de la(s) planta(s):	Cerro Pabellón, Comuna de Ollagüe, II Región
¿Que está produciendo su(s) planta(s)?	Energía Eléctrica, potencia bruta instalada 81 MW
¿Cuánto está produciendo su planta?	El Budget de producción de 2022 es 390 GWh
¿Estaría dispuesto de comentar a qué precio vende su producto?	No podemos comentar
¿Podría comentar cuanto está pagando por la electricidad de la operación de la planta y quién es el vendedor de la electricidad?	No podemos comentar
¿Tiene conocimiento de algunas fuentes de CO ₂ proveniente de plantas geotérmicas dentro del país que podrían ser utilizadas para PtX?	La planta procesa por diseño 2300 t/h de fluido geotérmico, y éste contiene un 0,14% de CO ₂
¿Tiene conocimiento de algunas (otras) plantas o productores de metanol y/o amoníaco dentro del país?	Si, pero son a base de energía solar o eólica, y se encuentran en las regiones de Antofagasta y Magallanes
¿Tiene conocimiento de algún tipo de comprador / consumidor en la zona en el sector de hidrógeno, metanol, amoníaco u otros productos de PtX potenciales?	No podemos comentar
¿Qué flujos de energía y de masa son necesarios para el funcionamiento de la planta de PtX o para el procesamiento de los productos de PtX para la industria (toda la cadena de procesos) que podrían obtenerse de las centrales geotérmicas? (por ejemplo, calor para el precalentamiento o la desorción DAC, agua, ...)	En masa 2300 t/h de fluido geotérmico por diseño y en energía térmica el rendimiento es alrededor de 10-11% para los 81 MW, es decir, el valor de flujo térmico del fluido geotérmico es 10 veces más energía que la producción eléctrica

Questionnaire OR Reykjavik Energy, Iceland

General information																																																																																																																															
Name of the company:	OR – Reykjavík Energy																																																																																																																														
Name and location of the geothermal power plant(s):	Hellisheiði (HEL) Nesjavellir (NES)																																																																																																																														
Installed power:	HEL: 303 MWe, NES: 120 MWe																																																																																																																														
Heat supplied:	HEL: 210 MWth, NES: 350 MWth																																																																																																																														
The annual availability / "uptime" of each geothermal power plant:	Around 80-90%.																																																																																																																														
Are there any geothermal power plants planned that have not yet been installed?	Yes <input type="checkbox"/> No <input type="checkbox"/>																																																																																																																														
Electricity price at the power plant location:	Depends on a lot of factors, i.e., the magnitude of the power sale, the usage of the customer, is it a flat usage, fluctuating.																																																																																																																														
What is the composition and amount of non-condensable gases from each geothermal power plant (existing and planned, if applicable)?	<table border="1"> <thead> <tr> <th>Extraction</th> <th>H2</th> <th>N2</th> <th>CH4</th> <th>CO2</th> <th>H2S</th> <th></th> </tr> <tr> <th>2021 [tonn]</th> <th>[tonn]</th> <th>[tonn]</th> <th>[tonn]</th> <th>[tonn]</th> <th>[tonn]</th> <th></th> </tr> </thead> <tbody> <tr> <td>Hellisheiði</td> <td>380</td> <td>600</td> <td>75</td> <td>44.000</td> <td>10.000</td> <td></td> </tr> <tr> <td>Nesjavellir</td> <td>360</td> <td>530</td> <td>40</td> <td>13.000</td> <td>6.500</td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <th>Injection</th> <th>CO2</th> <th>H2S</th> <th></th> <th></th> <th></th> <th></th> </tr> <tr> <th>2021 [tonn]</th> <th>[tonn]</th> <th>[tonn]</th> <th></th> <th></th> <th></th> <th></th> </tr> <tr> <td>Hellisheiði</td> <td>13.500</td> <td>7.500</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <th></th> <th>H2</th> <th>N2</th> <th>CH4</th> <th>CO2</th> <th>H2S</th> <th>L gas / kg steam</th> </tr> <tr> <th></th> <th>%</th> <th>%</th> <th>%</th> <th>mg/kg</th> <th>mg/kg</th> <th></th> </tr> <tr> <td>Nesjavellir</td> <td>90</td> <td>5-8</td> <td>0.7-1.2</td> <td>1500-3000</td> <td>1000</td> <td>0.4-0.8</td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <th></th> <th>H2</th> <th>N2</th> <th>CH4</th> <th>CO2</th> <th>H2S</th> <th>L gas / kg steam</th> </tr> <tr> <th></th> <th>%</th> <th>%</th> <th>%</th> <th>mg/kg</th> <th>%</th> <th></th> </tr> <tr> <td>Hellisheiði</td> <td>70-90</td> <td>7-15</td> <td>1-3.5</td> <td>2000-4000</td> <td>400-800</td> <td>0.25-0.4</td> </tr> </tbody> </table>	Extraction	H2	N2	CH4	CO2	H2S		2021 [tonn]	[tonn]	[tonn]	[tonn]	[tonn]	[tonn]		Hellisheiði	380	600	75	44.000	10.000		Nesjavellir	360	530	40	13.000	6.500									Injection	CO2	H2S					2021 [tonn]	[tonn]	[tonn]					Hellisheiði	13.500	7.500																				H2	N2	CH4	CO2	H2S	L gas / kg steam		%	%	%	mg/kg	mg/kg		Nesjavellir	90	5-8	0.7-1.2	1500-3000	1000	0.4-0.8																H2	N2	CH4	CO2	H2S	L gas / kg steam		%	%	%	mg/kg	%		Hellisheiði	70-90	7-15	1-3.5	2000-4000	400-800	0.25-0.4
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Does the plant use any abatement technology to achieve specific environmental constraints (i.e., technologies for H ₂ S or CO ₂)? If so, what technology is used?	<p>HEL – Carbfix method for removing CO₂ and H₂S from exhaust gas. At present, 30% CO₂, 70% H₂S removal, with project ongoing to increase to 100% by 2025.</p> <p>NES – currently no removal, but pilot project ongoing, and project ongoing to increase to 100% by 2030.</p>																																																																																																																														

PtX information	
What is the available electrical power from each power plant (existing and planned, if applicable), that could be available for PtX production?	Up to 90% of the installed capacity of the plant but depends entirely on agreements with other power purchase agreements at each given time.
If possibly planned or existing hydrogen / methanol / ammonia production is or could not be located close to the power plant, what is the electricity transmission cost in the area?	https://landsnet.is/english/business/transmission-tariff/tariff/ Depends on if the production is classified as Power Intensive Unit (PIU).

Do you know of any CO ₂ sources from geothermal power plants in the country that could be utilised for PtX?	Yes, there are CO ₂ emissions from all geothermal power plants in the country. At our plant a project to clean CO ₂ from the exhaust was stopped, as it was considered too costly compared to removing it with Carbfix technology.
Do you know of any other resources of CO ₂ in the country that could be utilised for PtX?	Possibly exhaust from aluminium smelters and from waste disposal.
What are the distances from the power plant's location to next harbour and industrial sites, where potential off-takers might be located, or the products stored for transport / export?	Distance to next harbour; HEL – Þorlákshöfn, 28 km NES – Sundahöfn, 39 km
Is there any infrastructure for large scale storage of chemicals existing close to the plant, i.e. tank storage sites? If so, do you know if they used for storage of methanol or ammonia?	No, closest large scale storage for chemicals would be at the harbours.
Do you know of methanol and/or ammonia plants / producers in the country?	Yes, for example Carbon Recycling.
Do you know of any potential off takers in the area for hydrogen, methanol, ammonia or other potential PtX products?	No.
Which energy (heat) and mass flows are available from the geothermal power plant that could be used in a PtX plant or the subsequent processing (for chemical / steel / pharma industry) besides the electrical energy? Would they need additional processing steps?	Both HEL and NES are combined heat and power plants. Therefore, there is some extra heat available, but not much.
What would be benefits or issues of using geothermal energy instead of wind or solar power for PtX with regards to sustainability?	Geothermal energy acts as a base load, therefore it is more stable for production, compared to the fluctuating wind and solar power, where larger installed capacity would be needed. Geothermal also has less visual impact. Geothermal could be less sustainable, if nothing is done to reduce CO ₂ emissions, f.ex. with the Carbfix method.

Questionnaire Enel Green Power, Italy

General information		
Name of the company:	Enel Green Power Italia srl	
Name and location of the geothermal power plant(s):	file "Elenco Centrali"	
Installed power:	915,79 MW (EMAS – pag. 29 File "dichiarazione ambientale 2021"	
Heat supplied:	9,3 TWh (abstract: stati generali della geotermia)	
The annual availability / "uptime" of each geothermal power plant:	File http://www.arpat.toscana.it/documentazione/report/r_eport-geotermia/monitoraggio-delle-aree-geotermiche-toscane-anno-2020 Table 8 (central column)	
Are there any geothermal power plants planned that have not yet been installed?	Yes	No
Electricity price at the power plant location:	See file: " GME- statistiche- dati di sintesi MPE- MGP.pdf"	
What is the composition and amount of non-condensable gases from each geothermal power plant (existing and planned, if applicable)?	File: Dichiarazione ambientale aggiornamento 2021. Pdf EMAS – Pag.40 "Emissioni in atmosfera"	
Does the plant use any abatement technology to achieve specific environmental constraints (i.e., technologies for H ₂ S or CO ₂)? If so, what technology is used?	The abatement system installed is the "AMIS": see chapter 3.1 file http://www.arpat.toscana.it/documentazione/report/r_eport-geotermia/monitoraggio-delle-aree-geotermiche-toscane-anno-2020 http://www.arpat.toscana.it/temi-ambientali/sistemi-produttivi/impianti-di-produzione-di-energia/geotermia/controllo-delle-emissioni/abbattimento-delle-emissioni-delle-centrali-geotermiche	

PtX information	
What is the available electrical power from each power plant (existing and planned, if applicable), that could be available for PtX production?	Total installed capacity 769,34 MW – See column "Potenza disponibile di riferimento (PdR)" -- pag. 29 File "dichiarazione ambientale 2021" EMAS
If possibly planned or existing hydrogen / methanol / ammonia production is or could not be located	Data not available yet

close to the power plant, what is the electricity transmission cost in the area?	
Do you know of any CO ₂ sources from geothermal power plants in the country that could be utilised for PtX?	See file “Dichiarazione ambientale aggiornamento 2021. Pdf” EMAS – Pag. 40 “Emissioni in atmosfera” Concerning natural gas emissions from soil, see file “energies- 14-04101.pdf”
Do you know of any other resources of CO ₂ in the country that could be utilised for PtX?	n.a.
What are the distances from the power plant's location to next harbour and industrial sites, where potential off-takers might be located, or the products stored for transport / export?	See file: “PORTI vc Centrali”
Is there any infrastructure for large scale storage of chemicals existing close to the plant, i.e., tank storage sites? If so, do you know if they used for storage of methanol or ammonia?	n.a.
Do you know of methanol and/or ammonia plants / producers in the country?	n.a.
Do you know of any potential off takers in the area for hydrogen, methanol, ammonia or other potential PtX products?	n.a.
Which energy (heat) and mass flows are available from the geothermal power plant that could be used in a PtX plant or the subsequent processing (for chemical / steel / pharma industry) besides the electrical energy? Would they need additional processing steps?	Theoretically, two-phase stream collected by draining systems installed along the steam pipelines could be evaluated.
What would be benefits or issues of using geothermal energy instead of wind or solar power for PtX with regards to sustainability?	With respect to other renewable sources, geothermal energy is fully predictable and contributes to stabilise the grid.

<http://www.arpat.toscana.it/documentazione/report/report-geotermia/monitoraggio-delle-aree-geotermiche-toscane-anno-2020>

<http://www.arpat.toscana.it/temi-ambientali/sistemi-produttivi/impianti-di-produzione-di-energia/geotermia/controllo-delle-emissioni/abbattimento-delle-emissioni-delle-centrali-geotermiche>

Questionnaire Carbon Recycling Inc., Iceland

General information																
Name of the company:	Carbon Recycling International hf (CRI hf)															
Name and location of the plant(s):	GO plant – 4 kta (Iceland) XX (under commissioning – startup 2022) – 110 kta (China) XY (under design – startup 2023) – 100 kta (China)															
What does your plant produce?	Methanol															
How much does your plant produce?	GO plant – 4 kta (Iceland) XX (under commissioning – startup 2022) – 110 kta (China) XY (under design – startup 2023) – 100 kta (China) XZ (under design – startup 2025) – 100 kta (Norway)															
Are you willing to tell us at what price you sell your product?	Confidential information															
Can you tell us how much you pay for electricity for the operation of your plant and who is the electricity seller?	Price is confidential information. Seller is HS Orka															
Do you know of any (other) CO ₂ sources in the country that could be utilised for PtX?	Industrial emissions: - Metallurgy - Cement - Waste management															
Do you know of any (other) methanol and/or ammonia plants/producers in the country?	No															
Do you know of any potential off takers in the area for hydrogen, methanol, ammonia or other potential PtX products?	Yes, bio-diesel producers and fossil fuel end users															
Which energy and mass flows are required for operating the PtX plant or processing of PtX products for the industry (entire process chain) that could be sourced from geothermal power plants? (e.g. heat for preheating or DAC desorption, water, ...)	Feedstock and utility requirement for a typical methanol plant (per 1 ton methanol) <table border="1"> <thead> <tr> <th>Feedstock/utility</th> <th>Unit</th> <th>Per 1 ton methanol</th> </tr> </thead> <tbody> <tr> <td>CO₂</td> <td>MT</td> <td>1,46</td> </tr> <tr> <td>H₂</td> <td>MT</td> <td>0,19</td> </tr> <tr> <td>Electricity</td> <td>MWh</td> <td>10,56</td> </tr> <tr> <td>Steam</td> <td>MT</td> <td>2,87</td> </tr> </tbody> </table>	Feedstock/utility	Unit	Per 1 ton methanol	CO ₂	MT	1,46	H ₂	MT	0,19	Electricity	MWh	10,56	Steam	MT	2,87
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Steam	MT	2,87														

Cuestionario Banco Interamericano de Desarrollo, Representación Honduras

Información general	
Nombre del ministerio / institución:	Banco Interamericano de Desarrollo Representación Honduras
¿Puede informarnos sobre el coste del capital para inversiones (tipo de interés) en el país?	En el documento puede encontrar detalle del coste de capital para las operaciones en Honduras se encuentra en el Link ver pag 5 https://www.iadb.org/Document.cfm?id=EZSHARE-1644412538-63

Información PtX	
¿Tiene el país alguna política acerca de PtX, es decir, con respecto a la fuente de energía?	Aun no
¿Sabe de algún tipo de recurso de CO2 en el país que podría ser usado para PtX?	No me queda clara la pregunta. Se refiere a CO2 producido que luego se usa a Power-to-X
¿Tiene conocimiento de algunas plantas o productores de metanol y/o amoníaco en el país?	No conozco
Tiene conocimiento de algún tipo de comprador / consumidor en la zona en el sector de hidrógeno, metanol, amoníaco u otros productos de PtX potenciales?	Si considero que en Islas de la bahía hay ese potencial, sobre todo porque buscar eradicar combustibles fósiles

Legislación y normativa		
¿Existen límites de emisión en el país?	Si	No
Si es así, ¿cuáles son los límites de emisión; concentración, cantidades totales emitidas, base a largo o corto plazo, límites de vertido de aguas residuales, ¿otras cuestiones o requisitos medioambientales?	Se encuentra en las guías ambientales de operaciones de energía aprobadas por Miambiente. También el BID está coordinando con la secretaria de energia y Miambiente en la aprobación del reglamento ambiental y social para actividades del sector eléctrico de Honduras y desarrollo de guías que incorporarán límites de emisiones.	
¿Existe alguna legislación específica en el país en relación con la producción de electricidad geotérmica o el uso directo de la geotermia?	Se está trabajando en una propuesta de descarbonización pero no existe legislación	

Appendix B Minutes of meetings PtX dialog

Minutes of meetings with Kenyan attendees

Nickson Bukachi, EPRA

Bengisu Yavuz and Ralph Koekkoek, MET Development

Fredrick Apollo, Oserian Development Company

Minutes of meetings with El Salvadorian attendees

Alejandro Alle, The Network Co.

Aida Flores, Edwin Alvarado and Luis Adrian Mayén Flamenco, CNE

Minutes of meetings with Chilean attendees

Carlos Jorquera, Espinos S.A.

Enrique Espinoza, H2 Chile

Rubén Munoz, Ministry of Energy Chile

Minutes of meetings with other attendees

Alessandro Lenzi, Enel Green Power, Italy

Kristjana Kristjánsdóttir and Emeric Sarron, CRI, Iceland

Vala Hjörleifsdóttir, OR, Iceland

Juan del Valle, Ad Astra Company, Costa Rica

MINUTES OF MEETING EPRA

Interview with EPRA

Organiser: Mannvit	Meeting No.: 1 (Teams)
Minutes of Meeting: KR	Doc. no.: 5692143-001-MMN-0001
Participants Katrín Ragnarsdóttir (KR), Mannvit Kevin Kerigu Mwangi (KM), GIZ Nickson Bukachi (NB), EPRA	Date: 19.07.2022
	From: 8:30 (GMT)
	To: 9:05 (GMT)
	Next meeting: n/a
Distribution: Participants	

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting recorded</u> The meeting was recorded, as KR led the discussions and made notes for the MoM. Agreed by all participants.	n/a	n/a
1	<u>Brief introduction of the project</u> The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya.	n/a	n/a
2	<u>Status in Kenya</u> Like in most countries there is interest in PtX in Kenya. According to NB, PtX opportunities are considered to exist in Kenya, to produce hydrogen using the available renewable energy resources. Currently, there is an excess on the grid during the night and even sometimes during the day as well. The excess power could be used for PtX. There is also a special interest in ammonia production as fertiliser is imported.	n/a	n/a
3	<u>PtX projects in Kenya</u> According to NB, there are more than 5 private companies considering PtX in Kenya, one aiming to use geothermal energy. EPRA has been in contact with them to consult on power transmission for the production and various other aspects such as transport of PtX products, as their main interest is to	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	<p>produce hydrogen and ammonia for export to Germany.</p> <p>There is also public interest. KM explained that KenGen are looking into a pilot project, producing fertiliser using geothermal energy with assistance from stakeholders.</p> <p>NB also mentioned MET development company but most of their information are still confidential.</p>		
4	<p><u>Government involvement</u></p> <p>The government conducted the baseline study to try to identify PtX opportunities. The use of ammonia has been considered one of the easiest pathways. To NB knowledge there are no direct incentives at the moment.</p> <p>A working group was formed that is supposed to bring together which pathway the government should support to actualise a project. Much interest in what is happening globally.</p>	n/a	n/a
5	<p><u>Potential off-takers</u></p> <p>The baseline study contains a global mapping of potential off-takers. NB expressed that there is also interest from the private sector players.</p> <p>There are also some global issues and policies like the shipping industry – blue economy and clean energy for ships. This is something that is expected to affect port operations and is important to prepare for. NB mentioned that there has been talk of trying to become a refilling point for ships in the Indian ocean.</p> <p>Overall, active engagement with private sector for green hydrogen production. Moreover, active discussions with the ministry of agriculture in Kenya as fertiliser import is costly.</p>	n/a	n/a
6	<p><u>CO₂ sources for PtX</u></p> <p>NB and KM pointed out that the largest industrial sector, emitting CO₂, are steel and cement production plants. However, a large portion is also relating to the transport sector, which is not a point source suitable for CO₂ capture for PtX.</p>	n/a	n/a
7	<p><u>The results of the study</u></p> <p>NB was curious as to why Kenya, El Salvador and Chile were specifically selected for the project and whether the study would develop a pathway for PtX along the geothermal industry. KR explained that not many PtX projects have been developed in the geothermal sector and the report would consider the</p>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	benefits and opportunities of using geothermal energy for PtX opposed to other renewable sources. KM mentioned that the PtX hub (GIZ) is working in these different countries. Together with having available geothermal resource, the support of the PtX hub, could identify potential opportunities.		
8	<u>Use of gases (e.g., H₂S)</u> KM wondered whether the use of gases, such as H ₂ S, would also be considered in this study. From KR best knowledge the focus would rather be on the geothermal energy, CO ₂ and H ₂ specifically.	n/a	n/a
9	<u>Constraints of using energy for PtX</u> NB asked whether the constraints of using geothermal energy for PtX were considered as part of the project, i.e., stress on water availability, reducing available electricity for general usage, etc. Moreover, would the electricity demand from geothermal in short and medium term in Kenya be considered. KR answered that although not completely certain, the study is more focused providing a general overview for using geothermal energy and the comparison to other renewable energy sources rather than assessing the available electrical potential for a specific PtX project.	n/a	n/a

 Consultant

 Client

MINUTES OF MEETING MET Development

Interview with MET Development

Organiser: Mannvit

Meeting No.: 1 (Teams)

Minutes of Meeting: KR

Doc. no.: 5692143-001-MMN-0003

Participants

Bengisu Yavuz (BY), MET
Katrín Ragnarsdóttir (KR), Mannvit
Manuel Andresh (MA), GIZ
Ralph Koekkoek (RK), MET

Date: 25.07.2022

From: 12:30 (GMT)

To: 13:00 (GMT)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting recorded</u> The meeting was recorded, as KR led the discussions and made notes for the MoM. Agreed by all participants.	n/a	n/a
1	<u>Brief introduction of the project</u> The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya.	n/a	n/a
2	<u>PtX in Kenya</u> MET Development is running a power-to-fertiliser project in Kenya with other partners. According to BY, they have seen that there is big interest of power-to-H ₂ in Kenya. Many conceptual studies mentioned in the baseline study led by GIZ. BY also mentioned that their power-to-fertiliser project goes a bit further than most projects in Kenya, as it includes an end product with substantial local demand.	n/a	n/a
3	<u>Government support</u> There is much interest from the government as is evident from the many conceptual studies. BY said currently there is nothing concrete regarding government incentives. But the number of studies indicate that they might be aiming at such	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	incentives in the future. RK pointed out that a strong incentive scheme cannot be expected from Kenya. This must come from the western world.		
4	<p><u>Green Fertilizer Plant</u></p> <p>KR asked if there was anything MET could share regarding the location, size, layout etc. of the Green Fertilizer Plant planned. BY stated that the idea is to go from renewable power to ammonia to fertiliser to be used in the country. The planned location is in Naivasha area, where the GPPs are located. The reason that geothermal power is considered is because it enables the plant to run 24/7. This highly impacts the economy of the plant.</p> <p>RK shared a presentation regarding the configuration and location of the plant. BY explained that solar plant is also being considered for the peak hours, too to be determined based on economies. Most other projects in the area stop after green hydrogen production. The final products of the process are Calcium Ammonium Nitrate and NPK fertilisers.</p> <p>BY stated that the planned location is in the Oserian Industrial Park (owned and operated by Oserian Development Company). This location has access to water, renewable energy and has the benefit of being close to the end users, as the transport of end products can be expensive.</p>	n/a	n/a
5	<p><u>Off-takers</u></p> <p>BY pointed out that this project is sized for local use of fertiliser. RK explained that one of the reasons is the importance of giving back to the local community when setting up a green hydrogen project, even though export is also intended. The project uses local available electricity, producing ammonia going downstream to a product in which there is really a demand for in the country. To help local farmers to get affordable fertiliser and in that way support the local community.</p> <p>This project aims for sustainable production but also creating local employment, support smallholder farmers and food security, in a country where this is a real issue.</p> <p>According to RK that is why this project focuses on fertiliser for local use. In other projects they would also consider a combination of export and fertiliser production.</p>	n/a	n/a
6	<u>Power-to-Methanol</u>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	<p>KR asked whether other X products were considered. BY responded that in Kenya fertiliser was the only product they could move forward with due to the local demand. However, in other countries they are working on different products.</p> <p>RK pointed out that the project was set up to use the excess capacity in Kenya. Hence, it would not be big enough for export, without requiring additional generation capacity. Different end products were considered: hydrogen, methanol, and fertiliser, but fertiliser was the only one with local demand.</p>		
7	<p><u>Co-benefits of using geothermal</u></p> <p>MA was curious to why geothermal energy was considered for their project. Previously mentioned that it allowed 24/7 runtime but whether other co-benefits such as sustainability, available heat or gas streams were also factors.</p> <p>RK responded that even though it is still a bit early in the development he believes that there is good potential for geothermal in combination with SOEC electrolyser technology, using heat to reduce electricity requirements. RK used the opportunity to ask MA thoughts.</p> <p>MA explained the reason for the study is to identify all the co-benefits that could come out of using geothermal. Right now, heat utilisation is a big aspect e.g., to regenerate the membrane used for direct air capture (not relevant for ammonia as it does not require the CO₂ source). There are also some studies that point out that there are some gas streams where you could extract.</p>	n/a	n/a
8	<p><u>CO₂ from geothermal wells</u></p> <p>RK asked about the CO₂ production of the different geothermal wells in El Salvador, Chile and Kenya. It would be of interest for MET to get the data for CO₂/MWh released from the geothermal wells. MA answered that this is addressed, however MA and KR were not sure how exactly the sharing of data from this study will be conducted. KR made a note of this, and MA will check on how this can be done.</p>		

 Consultant

 Client

MINUTES OF MEETING Oserian Development Co.

Interview with Oserian Development Co.

Organiser: Mannvit

Meeting No.: 1 (Teams)

Minutes of Meeting: KR

Doc. no.: 5692143-001-MMN-0006

Participants

Fredrick Apollo (FA), Oserian
Katrín Ragnarsdóttir (KR), Mannvit
Manuel Andresh (MA), GIZ

Date: 11.08.2022

From: 10:30 (GMT)

To: 11:00 (GMT)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting recorded</u> The meeting was recorded, as KR led the discussions and made notes for the MoM. Agreed by all participants.	n/a	n/a
1	<u>Brief introduction of the project</u> The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya.	n/a	n/a
2	<u>Power production at Oserian</u> KR mentioned that it came as a surprise to her that Oserian had its own geothermal power production and asked for a short introduction of Oserian's operation. FA explained that Oserian started the geothermal heating project in 2000, which started with 20 ha of land and later expanded to 50 ha. About 2 years later they built a binary power plant (Ormat) with installed capacity of 1,8 MW. This is the first binary plant built in Kenya. In 2007 another plant, a back pressure unit, was built with 1,4 MW installed capacity. A 1 MW solar plant was also commissioned in January 2019.	n/a	n/a
3	<u>About the operation of Oserian</u>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	<p>Other than producing the electricity FA explained that Oserian's operation take care all operations related to the farm.</p> <p>The geothermal energy is used for electricity, heating and humidity control of greenhouses.</p> <p>The geothermal heat is the main benefit at the moment. In Naivasha the heat can reach 0°C in the night. Important to control the heat in the greenhouses and the relative humidity (below 80%). Use heat exchangers to heat water to approx. 88°C with the geothermal fluid. The hot water is kept in a tank during the day and is fed to the greenhouses at night.</p>		
4	<p><u>NCG from the geothermal power production</u></p> <p>According to FA, NCG is released to the atmosphere, but it is minimal as with binary plants. Majority of the gas is CO₂ and H₂S (approx. 1%).</p> <p>Stopped using CO₂ from the exhaust gas to enhance plant growth in the greenhouses due to the impact of the H₂S on the metallic structure in the greenhouses. It was mainly rust which reduced the lifetime of the greenhouse structures.</p>	n/a	n/a
5	<p><u>Future plans</u></p> <p>FA mentioned that Oserian has moved out of the flower production. The flower business has been sold off to another entity and Oserian provides them with heat and electricity.</p> <p>Moreover, FA said that Oserian is currently developing an industrial park. Number of companies has shown interest. One organisation is already building up a factory and require 1,4 MW electricity. Therefore, Oserian is already looking at expanding the power production. The challenges are that geothermal power is capital intensive, and they are still looking for funding.</p>	n/a	n/a
6	<p><u>PtX at Oserian</u></p> <p>According to FA this is not something that Oserian would go into themselves. Rather something another company would bring to the Oserian industrial park.</p> <p>FA mentioned that one of the potential projects for the industrial park is interested in PtX. This is still under discussion and constructions have not started yet. The idea would be to use geothermal energy for producing fertiliser.</p>	n/a	n/a
7	<p><u>Purpose of the project</u></p>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	<p>FA further asked about the purpose of the meeting, whether it was for general information or looking for investment.</p> <p>KR explained that this is an information study, and the report will evaluate the opportunities of using geothermal energy for PtX in these countries.</p> <p>MA added that the PtX hub and GIZ try to support with building up capacities to use PtX and green H2 in their partner countries. To get a better idea of what is technically possible and economically feasible. Gathering knowledge that they can share with their partners around the world.</p>		

 Consultant

 Client

MINUTES OF MEETING Network Co

Interview with the Network Co.)

Organiser: Mannvit

Meeting No.: 1 (Zoom)

Minutes of Meeting: KR

Doc. no.: 5692143-000-MMN-0003

Participants

Alejandro Alle (AA), The Network Co.
Julian Hebold (JH), GTN
Katrín Ragnarsdóttir (KR), Mannvit
Kristín Steinunnardóttir (KS), Mannvit
Rafael Parada Perez (RP), GIZ

Date: 28.06.2022

From: 15:00 (GMT)

To: 15:40 (GMT)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting in English</u> The meeting was conducted in English, agreed by all participants so that KR and KS could contribute. Although e-mail and questionnaire were sent in Spanish.	n/a	n/a
1	<u>Brief introduction of the project</u> The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya.	n/a	n/a
2	<u>PtX projects in South America</u> In South America, Chile is the country doing most with regards to PtX. Ad Astra Rocket produces H ₂ for transportation (buses) in Costa Rica, but at a small scale with limited potential.	n/a	n/a
3	<u>PtX projects in El Salvador</u> Currently, there are no PtX plants and projects in El Salvador. There is definitely interest for PtX projects in El Salvador and there have been discussions on ammonia production for export.	n/a	n/a
4	<u>Potential off-takers</u>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	The Network Co. is not aware of any potential off takers in El Salvador. However, preliminary discussions are ongoing with potential off-takers in Germany and Houston, interested to import H ₂ . AA mentioned Uniper as a potential international off-taker. El Salvador has no coast to the Atlantic Sea, hence crossing Panama would be required for transportation to Europe.		
5	<u>Regulations and government support</u> AA is in frequent exchange with governmental institutions but hasn't heard of any specific initiatives for PtX from the government, but the government is working on the National Hydrogen strategy. The CNE will soon be transformed and there are upcoming changes in regulations. Therefore, it has not been easy to move forward with PtX projects.	n/a	n/a
6	<u>Project investment</u> AA pointed out that it would be very difficult for this sort of project to be fully funded by a private initiative and that it is important to involve public stakeholders and possible funds. Moreover, international off-takers are required if the project should be bankable. Also, it is important to get contracts prior to launching a project.	n/a	n/a
7	<u>Geothermal power generation</u> One company has approached the Network Co. interested in investing in geothermal energy production in El Salvador. Fichtner intends to tender for geothermal power.	n/a	n/a
8	<u>Emission regulation</u> No emission limits or reduction goals for energy generation. Talk of decarbonisation but no regulations apply.	n/a	n/a
9	<u>Future power generation</u> LNG has replaced heavy fuel oil in El Salvador (See project Energía del Pacífico). The related decarbonisation was initialised by the market and not the politics. Discussions on the future potential for power generation in El Salvador.	n/a	n/a

Consultant

Client

MINUTES OF MEETING CNE

Interview with Consejo Nacional de Energía (CNE) El Salvador (MS-Teams)

Organiser: GTN

Meeting No.:

Minutes of Meeting: JH

Doc. no.: 692143-001-MMN-0007

Participants

Aida Flores (AF), CNE
 Edwin Alvarado (EA), CNE
 Luis Adrian Mayén Flamenco (LAMF), CNE
 Rafael Edgardo Parada Perez (RP), GIZ
 Ingmar Budach (IB), GTN
 Julian Hebold (JH), GTN

Date: 7.07.2022

From: 1:00 (GMT-4)

To: 2:00 (GMT-4)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting language and recording</u> The meeting was recorded and conducted in Spanish, agreed by all participants. Emails and questionnaire were sent in Spanish, too.	n/a	n/a
1	<u>Brief introduction of the project</u> The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya.	n/a	n/a
2	<u>Role of H2 in the National Energy Policy</u> The “Política Energética Nacional” (PEN) 2020-2050 is El Salvador’s newest national energy strategy, which is about to be fully developed and implemented in the upcoming months. https://www.cne.gob.sv/wp-content/uploads/2021/12/PEN2050.pdf EA mentions the different goals of the PEN. Generally, the national energy strategy consists of various main aspects and EA comments, that green H2 is directly related to many of those. The main purpose of the strategy is to point out clearly, which way to go for El Salvador in the future regarding its energy supply and markets. El Salvador plans to implement the strategy in the next 2-16 months. As EA mentions, green H2 will open up new markets for the country. AF adds, that green H2 also helps to decarbonise the sectors which presents a big step towards the goal of carbon neutrality of the country until 2050.	n/a	n/a

3	<p><u>PtX in El Salvador</u> Neither methanol nor ammonia is produced in El Salvador yet, but both are seen as important potential export products in the future.</p> <p>IB asked for percentages concerning the technologies used for hydron production. EA answered that this was part of the National Energy Strategy's output awaited in the next couple of months.</p> <p>AF mentions that there is a study realised in cooperation with the GIZ about hydrogen production and geothermal energy, which is being renewed / actualised at the moment. AF offered to share the document when it's finished.</p> <p>AF shows the electricity expansion plan 2023 – 2030 (https://estadisticas.cne.gob.sv/wp-content/uploads/2021/06/Plan-indicativo-de-la-generaci%C3%B3n-de-la-expansi%C3%B3n-2020-2030-vf.pdf) in which geothermal has the third highest share regarding the capacity to install (with around 100 MW). AF and EA offered to share both the electricity expansion plan presentation as well as the green hydrogen strategy documents.</p> <p>They are well aware of the need of a modernisation of the legal regulations in order to be competitive on an international level.</p>	n/a	n/a
4	<p><u>PtX projects in South America</u> There is a lot of production of grey hydrogen in Latin America. But e.g., Chile, Uruguay and Colombia have strategies regarding green hydrogen which are relatively new.</p>		
5	<p><u>Geothermal projects in El Salvador</u> LAMF mentions that there are two projects which are in the phase of financial support acquisition at the moment. One is the project of San Vicente, the other is the project of Chinameca. They consist of around 55 MW of electricity production together. Apart from that they are planning a fifth unit in the plant "Berlin" for this year still. All the projects are led by the GEO.</p>	n/a	n/a
6	<p><u>Potential off-takers</u> The market inside El Salvador is very small. Export to Europe might be interesting.</p>	n/a	n/a
7	<p><u>Actual Pilot Project of green H2 and green ammonia production in El Salvador</u> (See also project description pdf sent by AF)</p>	n/a	n/a

<p>It is the first project of ammonia production in El Salvador. It's about green ammonia and H2 production using geothermal electricity, solar energy or hydrothermal energy. AF and EA comment that the project is still in the financial support acquisition phase.</p> <p>EA comments further, that there is an average of 1.31 Mio. kg/a of ammonia and hydrogen used in the industries of hydrogen-based fertilisers and the pharmaceutical production industry. Therefore, the local production presents a big market, too. EA thinks, that the most efficient way of hydrogen transportation is via ammonia.</p>		
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Consultant

Client

MINUTES OF MEETING ESPINOS S.A.

Interview with ESPINOS S.A. (MS-Teams)

Organiser: GTN

Meeting No.:

Minutes of Meeting: JH

Doc. no.: 692143-000-MMN-0004

Participants

Carlos Jorquera (CJ), ESPINOS S.A.

Ingmar Budach (IB), GTN

Julian Hebold (JH), GTN

Date: 6.07.2022

From: 9:00 (GMT-4)

To: 0:00 (GMT-4)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting language and recording</u> The meeting was recorded and conducted in English, agreed by all participants. Emails and questionnaire were sent in Spanish.	n/a	n/a
1	<u>Brief introduction of the project</u> The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya.	n/a	n/a
2	<u>PtX projects in South America</u> CJ did several studies together with GIZ regarding H2 Co-generation. He is currently working on a study on the geothermal potential for PtX, similar to this GIZ-project. CJ's project is on behalf of the Chilean Energy Ministry and the Inter-American Development Bank. The project will be finished end of October and CJ suggest sharing results of both projects. CJ mentioned the GEOLAC conference that take place in November in Mexico. In South America, Chile is the most active country with regards to PtX. The two main X producers in Chile are Methanex and Linde.	n/a	n/a
3	<u>PtX plants operated in Chile</u> CJ mentions, that there is no geothermal power plant producing electricity for PtX reasons in Chile. CJ mentions two main projects, one in the south by Methanex using Wind and natural Gas to produce methanol and one in the north using wind and solar energy to produce hydrogen. The Methanex plant located close to Punta Arenas is the biggest methanol facility in the	n/a	n/a

	<p>world, using Chilean and Argentinian Gas. After CJ, 100 % is exported to Canada. Source of CO2 unknown.</p> <p>Very close (Argentinean Patagonia), there is a big H2 production site (10 GW Wind farm is running an 8 GW Electrolyser) exporting H2 to Volkswagen and Porsche. The region in the south consists of high wind potential and a better export connection to Europe.</p> <p>CJ mentioned another project for Green Ammonia production in the northern Atacama Desert using solar and wind energy and offered to share more information about it.</p>		
4	<p><u>PtX projects in Chile</u></p> <p>Currently, there are no further geothermal power plants or PtX plants and projects in Chile planned.</p> <p>The government does not involve in projects directly but builds the frame of regulations and support programs as well as funding for some pilot projects. https://hifglobal.com/hif-chile</p> <p>The government is supporting the use of H2 in the mining sector. Diesel trucks are fuelled partly with hydrogen.</p> <p>There are two geothermal projects in the stage before deep drilling, but they struggle to get a Power Purchase Agreement (PPA). Mariposa and ADOBERA.</p> <p>In Chile everybody can participate in the national energy auctions. This pushes the development of solar and wind production without storage.</p>	n/a	n/a
5	<p><u>Potential off-takers</u></p> <p>Generally, the market in Chile is very small, but e.g., ENAP Chile uses H2 in their refineries. There exist three refineries in Chile.</p> <p>Apart from that, Cristalerias Chile is following a blending combustion concept (Gas + H2) next to Santiago.</p>	n/a	n/a
6	<p><u>H2 production in Chile</u></p> <p>The amount of H2 Chile wants to produce lies around 30-50 GW of electrolyser capacity.</p> <p>Problem: If that industry grows as expected, there will not be sufficient transmission capacity, thus grid stability.</p> <p>Peak electricity demands at the moment in Chile are at 11 GW.</p> <p>Chile has promising resources for renewable energies from the north to south but is polarised either in the north or in the south so far.</p>	n/a	n/a
4	<p><u>Regulations and government support</u></p> <p>CJ mentions that the price structure for geothermal electricity production is the PPA + 10 US\$/MWh for capacity payment.</p>	n/a	n/a

	In the risk assessment for a hydrogen unit in Chile there must be taken into account, that a geothermal power supply is much more stable and resistant against Ambiental influences, which is an advantage in comparison with solar and wind energy.		
6	<u>Geothermal power generation</u> There is only one geothermal power plant operating in Chile: Cerro Pabellon, which operates with 81 MW at the moment but shall be extended up to 100 MW. Two projects are in an advanced state (but will still need min. 5 years): Mariposa project (400 km south of Santiago; https://www.edcltd.cl/proyecto-mariposa/) and Adobera (800 km south of Santiago; https://transmark-renewables.com/projects/peumayen-adobera).	n/a	n/a
7	<u>Price structure for H2 generation with solar / wind energy</u> Regarding a speaker from GIZ in a recent event, it is possible to produce green hydrogen at a cost of 6 US\$/kg in Chile and that this price is compatible with diesel fuel in the transport sector.	n/a	n/a
8	<u>Important aspects for the future</u> Firstly, it is important to achieve a compatible PPA (~6 US\$/MWh). Secondly, the market needs to recognise, that geothermal power plants offer flexibility / grid stability, greenness and a 24/7 operation. Those elements are not valued in the PPA yet. PPAs are awarded using the best price only. CJ see that as the main obstacle that hinders the advancement geothermal power in Chile. A newly structured PPA process that values geothermal's contribution for baseload capacity and grid stability could boost development. Current PPAs are in the range of 40 – 60\$/MWh. CJ speaks about another possible advantage for geothermal in the future: The installed capacity of volatile renewable energy sources reached a critical capacity regarding the grid structure. The grid is having a lack of flexibility. Geothermal can furthermore contribute to a healthy social development all over Chile by installation of power plants in the middle of the country, avoiding a polarised north or south distribution.	n/a	n/a
Consultant		Client	

MINUTES OF MEETING H2 Chile

Interview with the Chilean Hydrogen Association - H2 Chile (MS-Teams)

Organiser: GTN**Meeting No.:****Minutes of Meeting:** JH**Doc. no.:** 692143-001-MMN-0008**Participants****Date:** 6.08.2022

Enrique Espinoza (EE), H2Chile

From: 9:00 (GMT-4)

Ingmar Budach (IB), GTN

To: 9:45 (GMT-4)

Julian Hebold (JH), GTN

Next meeting: n/a**Distribution:**

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting language and recording</u> The meeting was recorded and conducted in Spanish, agreed by all participants. Emails and questionnaire were sent in Spanish, too.	n/a	n/a
1	<u>Presentation of the participants and brief introduction of the project</u> Enrique Espinoza is a Project Engineer at H2 Chile working in the regulations committee. The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya.	n/a	n/a
2	<u>PtX Projects in Chile at the moment</u> EE showed Power Point slides from the presentation "Proyectos Chile" which he afterwards forwarded to us via email. The two biggest potentials / production locations are in the region of Antofagasta in the north of Chile using solar energy and in region of Magallanes in the very South using the wind potential. The majority of the projects focuses on exporting the hydrogen via ammoniac (due to easier logistics handling ammoniac). According to EE, the energy ministry wants a stronger development of the local H2 consumption without leaving aside the export market.	n/a	n/a
3	<u>Role of H2 Chile in the market</u> H2 Chile (and the government) does not develop projects itself, but most importantly supports the industry by guiding through the existing and upcoming regulations and decrees that result from being a relatively new market.	n/a	n/a

	Therefore, H2 Chile works together closely with the Chilean government and the industry, trying to figure out which regulations are practically implementable. Furthermore, they inform the industry about new technologies and financing possibilities.		
4	<p><u>PtX pricing</u></p> <p>EE mentions prices of the national hydrogen strategy.</p> <p>estrategia nacional de hidrogeno verde - chile.pdf (energia.gob.cl)</p> <p>Until 2025, there are supposed to be 5 GW of electrolyzers installed. Until 2030, 25 GW of installed electrolyser capacity are planned. The expected price is 1.5 \$/kg hydrogen. To reach this, an electricity price of 20 \$/MWh is needed. As the system costs for using the electricity grid in Chile are very high, which causes the raw energy price to double before sale, the electricity production in these projects is most likely going to be off grid in order to reach those competitive prices. Also, because Chile has excellent renewable energy sources. At the moment just the pure system costs in Chile can reach values of up to 30-60 \$/MWh.</p> <p>The actual price for one kg of green hydrogen in Chile at the moment is around 3 – 5/6 \$.</p>		
5	<p><u>Potential off-takers</u></p> <p>EE mentions that the electromobility market as well as the transport vehicles in the mining sector would appreciate the H2 development.</p> <p>EE says that the trucks in the mining sector have a consumption of diesel of around 3600 l/day.</p> <p>The biggest amount of exported hydrogen and/or derivatives goes to Europe, especially to the harbour of Rotterdam.</p> <p>EE mentions that regardless of the distance, Chile would have an advantage of exporting the hydrogen and its derivatives to Japan, which is a big consumer of hydrogen.</p>	n/a	n/a
6	<p><u>Future development of the PtX in Chile</u></p> <p>At the moment there exists a very positive business cycle of green hydrogen in Chile. The new administration created a committee only for the development of green hydrogen production projects. EE mentions that there will be between 9 and 11 ministries involved, that gather every few weeks in order to accelerate the development of the industry, which shows the great interest of the government in the industry.</p> <p>EE mentions the construction of a new high voltage power line from Kimal-Lo Aguirre that</p>	n/a	n/a

<p>will boost renewable energy electricity and will be finished by 2030: https://econojournal.com.ar/2021/12/chile-adjudico-la-construccion-de-una-moderna-linea-de-alta-tension-de-corriente-continua-para-facilitar-el-transporte-de-energia-renovable/</p> <p>EE says that movement in the sector of green hydrogen can also be seen in Colombia, Mexico and Costa Rica.</p>		
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Consultant

Client

MINUTES OF MEETING Enel Green Power

Interview with Enel Green Power

Organiser: Mannvit

Meeting No.: 1 (Teams)

Minutes of Meeting: KR

Doc. no.: 5692143-001-MMN-0002

Participants

Alessandro Lenzi (AL), Enel
Julian Hebold (JH), GTN
Katrín Ragnarsdóttir (KR), Mannvit
Manuel Andresh (MA), GIZ

Date: 20.07.2022

From: 13:00 (GMT)

To: 13:40 (GMT)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<p><u>Brief introduction on Enel's operation</u></p> <p>AL introduced Enel's operation. They have 3 geothermal power plants (GPPs) in the USA, 1 in Chile but their main geothermal production is in Italy (34 GPPs). Most of the questions were answered in the questionnaire based on publicly available data. Particular care is now being taken about sharing important data, due to the renewal of a concession for geothermal power in Italy.</p>	n/a	n/a
1	<p><u>Brief introduction of the project</u></p> <p>The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya. Even though most of Enel's operations are outside these countries, they are one of the largest geothermal energy producers, with a high number of plants operating.</p>	n/a	n/a
2	<p><u>Heat and CO₂</u></p> <p>AL explained that the X of primary interest to Enel relating to power-to-X, is the heat. Enel also offers the exhaust gas, which is rich in CO₂, impurified for free to potential users.</p> <p>District heating is provided to all municipalities hosting Enel's GPPs.</p>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
3	<p><u>Potential off-takers</u></p> <p>According to AL, Enel has been in discussion with several companies interested in using the CO₂ from the exhaust gas and heat.</p> <p>2 companies are currently using heat to grow plants and herbs (such as basil) in greenhouses. There has also been interest in using the exhaust gas directly or purified, as CO₂ enhances crops production.</p> <p>AL mentioned agreement with 2 companies to use CO₂ and heat to produce algae / Spirulina, but they have not been commissioned yet.</p> <p>AL commented on the use of compressed CO₂ for technical uses at Enel but wasn't able give more information due to running agreements.</p>	n/a	n/a
4	<p><u>PtX at Enel</u></p> <p>AL said some evaluation has been performed on the potential for PtX production. The energy consumption is always high and even though they have some contact with a company interested in H₂ it is not Enel's intention to start production.</p> <p>However, they do have a CO₂ stream available for free if some other company wants to use it for PtX.</p> <p>Enel is starting a pre-feasibility study in collaboration with a university for the production of food grade CO₂.</p> <p>In general, AL pointed out that PtX is energy consuming and that it is better for Enel to sell the energy than transforming it to X such as ammonia, methane or hydrogen. There have been discussions with a company to sell green methane (which offers a higher price than non-green methane), but there are no agreements yet.</p>	n/a	n/a
5	<p><u>Ammonia</u></p> <p>AL pointed out that there is significant amount of NH₃ in the geothermal fluid at Mt. Amiata.</p> <p>At Bagnore 3 and 4 ammonium ions are present in the geothermal fluid. The ammonia is abated to reduce emissions to the atmosphere, using sulfuric acid to stabilise the ion and keeping it in the liquid phase. This abatement is additional to the AMIS abatement system installed in all Enel's GPPs. The fluid is then reinjected.</p> <p>AL stated the ammonia would be available if some company wants to extract it. One company has expressed interest in studying ammonia extraction.</p>	n/a	n/a
6	<p><u>Electricity price</u></p>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	KR was curious about the electricity price Enel provided with the questionnaire. AL explained that the energy in Italy is an auction market. There is support from the Italian state so that at the moment some power plants receive some incentives for renewable energy production.		
7	<u>Access to geothermal resources</u> AL mentioned that GPPs are often situated in remote locations, where geothermal energy can be exploited. The transport of electricity is quite simple to the grid. However, it is more difficult to transport products and process streams from these sites. Transport of H ₂ and CO ₂ is expensive. CO ₂ can be transported quite easily via pipeline to locations at fair distance, but competition with other companies producing CO ₂ has made this too complicated for Enel.	n/a	n/a

Consultant

Client

MINUTES OF MEETING CRI

Interview with Carbon Recycling International (CRI)

Organiser: Mannvit

Meeting No.: 1 (Teams)

Minutes of Meeting: KR

Doc. no.: 5692143-001-MMN-0004

Participants

Emeric Sarron (ES), CRI
Julian Hebold (JH), GTN
Katrín Ragnarsdóttir (KR), Mannvit
Kristjana M. Kristjánsdóttir (KK), CRI

Date: 08.08.2022

From: 14:00 (GMT)

To: 14:20 (GMT)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting recorded</u> The meeting was recorded, as JH led the discussions and KR could not make notes for the MoM during the meeting. Agreed by all participants.	n/a	n/a
1	<u>Methanol production</u> KK explained that CRI is a CO ₂ -to-methanol technology solution provider. KK pointed to the press release on their website regarding the 3 plants, including the one being started up now in Anyang, China.	n/a	n/a
2	<u>CRI's process</u> ES pointed out that the process is designed to work with variety of sources either recycled H ₂ sources or generated from electrolysis. JH asked about the capacity of the electrolyzers. ES said the capacity of the electrolyzers depends on the plant capacity and there are also some design choices that can vary e.g., whether the operation is at baseload or different conditions. In Iceland the capacity is around 6 MW. The other plants that are based on electrolysis of significantly larger scale are around 120-130 MW.	n/a	n/a
3	<u>Feasibility of smaller plants</u>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	<p>JH asked about the minimum size CRI would consider economically feasible for a methanol plant. KK answered that this completely depends on the end user price, the market and what industry supplies the H₂ and CO₂. ES mentioned that if the process streams are already quite pure the CAPEX decreases as investment in carbon capture and electrolysis is not required.</p> <p>KK added that PtX is such an emerging market. The taxation of carbon, electricity prices and the prices achieved in the market are all tied together and changing fast in the current market. CRI has seen indicated prices of even tripled what was seen 3 years ago, with methanol and other renewable chemical products.</p>		
4	<p><u>Hydrogen market</u></p> <p>JH was curious on their view on the development of the H₂ market.</p> <p>KK mentioned that there are key drivers in the European market today which have only been escalating in the current geopolitical circumstances.</p> <p>ES pointed out that in general the H₂ market is expanding as part of the switch towards the green economy. We can expect to have more and more H₂ used for PtX, for liquids for industrial applications. All the sectors will be transformed with it, also renewable methanol production.</p>	n/a	n/a
5	<p><u>Plans in Kenya, Chile and El Salvador</u></p> <p>JH asked whether CRI has plans in the countries of specific interest in this report: Kenya, Chile and El Salvador.</p> <p>KK answered that as CRI is mainly a technology solution provider, they are a global company, even though they have operated the GO plant in Iceland. The main focus is on providing and deploying the solution globally. CRI has countries within Africa in the pipelines, in Kenya, but this is evaluated on a case-by-case basis.</p> <p>At this point CRI could not elaborate on the specific projects in these countries.</p>	n/a	n/a
6	<p><u>Horizon 2020 projects</u></p> <p>ES mentioned the Horizon 2020 projects in Europe. CRI was part of 2 projects, both are public and information available on CRI's website. One project was deployed in Sweden connected to steel manufacturing offgas.</p>	n/a	n/a

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	The other one was in Germany, called MethCO ₂ , which had to do with intermittent electricity, hence to use the fluctuating load to produce methanol.		
7	<p><u>Electrolyser technology</u></p> <p>ES said they could discuss the electrolyser technology in general terms, without referring to specifics. There are currently 3 main technologies for electrolysis: PEM, SOEC (high temperature) and alkaline. CRI is not an electrolyser. According to ES, each technology comes with its own advantages and cons. CRI's policy is to evaluate and select which technology is the most suitable on a case-by-case basis, considering factors such as flexibility, price, performance etc. CRI does not promote one technology over the other.</p> <p>KK pointed out that one of the key factors today is the capability of the manufacturer to produce at such a large scale. This is one of the key factors when looking at technology and the key suppliers. The suppliers that have been supplying for a long period of time are more interesting for large scale installations. ES mentioned that more companies are emerging that can supply on the large scale (from MW to GW). Costs are coming down and competition is increasing, in general this is a positive development for PtX and renewable methanol.</p>		

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MINUTES OF MEETING OR

Interview with Reykjavík Energy (OR)

Organiser: Mannvit

Meeting No.: 1 (Teams)

Minutes of Meeting: KR

Doc. no.: 5692143-001-MMN-0005

Participants

Katrín Ragnarsdóttir (KR), Mannvit
Manuel Andresh (MA), GIZ
Vala Hjörleifsdóttir (VH), OR

Date: 10.08.2022

From: 14:00 (GMT)

To: 14:20 (GMT)

Next meeting: n/a

Distribution:

Participants

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<p><u>Meeting recorded</u></p> <p>The meeting was recorded, as KR led the discussions and made notes for the MoM during the meeting. Agreed by all participants.</p>	n/a	n/a
1	<p><u>Brief introduction of the project</u></p> <p>The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya. Even though OR's operations are outside these countries, their feedback as a large geothermal energy producer and producer of H2 in Iceland is of great value.</p>	n/a	n/a
2	<p><u>PtX from OR's perspective</u></p> <p>From VH point of view, obviously PtX is very interesting.</p> <p>Considering OR's perspective as an energy company, they are willing to work with producers. The primary focus is to sell energy. Hence, they see PtX as a potential customer of energy rather than something they will go into themselves.</p> <p>OR's view is more in the context of: What kind of customers would we be looking for? What are we willing to give them? What sort of price would we need? Etc.</p>	n/a	n/a

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
	OR already has big customers and are not necessarily in this business (PtX) yet - not quite there yet.		
3	<p><u>H2 production in Hellisheiði</u></p> <p>VH mentioned that OR has a test facility to produce H2. This is currently the only H2 producer in Iceland, even though it is a small production.</p> <p>It started as an EU funded research project. The station was built and is still running, supplying the 2 distribution stations in Iceland. This is enough for the few dozen H2 vehicles running in Iceland. OR's core business is still energy production. As a result, they have not been actively pursuing this but went ahead with the project to better understand what sort of customers they would be looking at in the future.</p> <p>H2 is produced using electrolyzers in Hellisheiði. MA asked about the process steps of the H2 production, but VH was not familiar with that.</p>	n/a	n/a
4	<p><u>CO₂ from exhaust gas</u></p> <p>KR asked regarding the comment in the questionnaire about the project to clean CO₂ from the exhaust gas – which was stopped.</p> <p>VH explained that this was a part of one of their EU funded projects. At this point it was decided that this was not good business. Both because the treatment of CO₂ is costly but also because the CO₂ is eventually released if it is used instead of being permanently sequestered in the ground (with CarbFix). Better for the environment to get rid of the CO₂.</p>	n/a	n/a
5	<p><u>Involvement of geothermal in PtX</u></p> <p>KR asked whether VH had something to add regarding the use of geothermal in PtX, as most studies have focused on other renewables e.g., wind and solar.</p> <p>VH commented that it might be something to consider that for using geothermal energy several conversions are required. It was revealing to her to see the primary energy usage in Iceland, which is mostly geothermal. However, the electricity produced from geothermal was very little compared to the house heating.</p> <p>Since the efficiency is reduced each time the energy is transformed, geothermal should be the primary source for house heating, in her opinion. Electricity production should come second.</p>	n/a	n/a

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	VH pointed out that of course this needs to be studied on a case-by-case basis and might be different in climates where heating is not required. In general, it is wasteful to generate electricity from geothermal and using the electricity for heating. Even generating electricity from geothermal could be wasteful according to VH, if there is a need for the heat.		
6	<u>CarbFix</u> MA asked about the CarbFix method to sequester CO ₂ . VH explained the process roughly and pointed to the CarbFix website.	n/a	n/a

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MINUTES OF MEETING Ad Astra Rocket

Interview with the Ad Astra Rocket Company – Costa Rica (MS-Teams)

Organiser: GTN

Meeting No.:

Minutes of Meeting: JH

Doc. no.: 692143-001-MMN-0009

Participants

Date: 2.09.2022

Juan del Valle (JDV – Ad Astra Company)

From: 9:00 (GMT-6)

Claus-Bernhard Johst (CBJ) (GIZ – El Salvador)

To: 0:10 (GMT-6)

Ana Lucia Alfaro Murillo (AL – GIZ Costa Rica)

Next meeting: n/a

Julian Hebold (JH – GTN)

Distribution:

Issue No.	Discussions, decisions, conclusion:	Finish by:	Responsible:
0	<u>Meeting language and recording</u> The meeting was recorded and conducted in Spanish, agreed by all participants. Emails and questionnaire were sent in Spanish, too.	n/a	n/a
1	<u>Brief introduction of the project, Presentation of the interviewee and the company</u> The interview is a part of the PtX study conducted by Mannvit and GTN funded by GIZ, to assess opportunities to use geothermal resources for PtX projects in Chile, El Salvador and Kenya. Juan del Valle is mechanical engineer, working at the Ad Astra Company for 16 years, basically since the beginning of the existence of the company. Ad Astra Rocket Company is a Spin-off of the NASA's Johnson Aerospace Centre, was founded in 2005 and is based in Huston, Texas. Its core business sector is the aerospace industry and especially the propulsion technology. Since 2010-11 the Ad Astra Company in Costa Rica is working in research and development of green energy technologies and especially in decarbonizing the transport sector, which has the biggest impact in CR, given that the energy matrix of CR is fully renewable yet. The company is part of the study due to its broad professional insight in the technology of green hydrogen production. Ad Astra Company operates a small production plant with an output of 2kg(H ₂)/day. The plant presents a fully equipped small-scale system of the whole production chain, starting with the renewable energy production (by wind and solar) feeding	n/a	n/a

	<p>a compressor and an H2 production unit (electrolyser) as well as H2 storage tanks with further connection to a transport vehicle using two different distributor types.</p> <p>In the beginning the objective of the plant was to produce green H2, not yet with applications of the transport sector involved. In 2016 the interest in the transport sector grew and an alliance of different companies that were interested in the topic was founded. At that moment a distribution system including a H2-driven bus was implemented in order to be able to simulate the complete system. As Ad Astra Company is not (yet) producing the components of the system themselves, their short-term goal is to further investigate on the technology characteristics in order to evolve to a well-rounded service provider / consultancy / planning company for any green hydrogen application in CR, Centro America and whole Latin America.</p> <p>In CR there are a few commercial transport applications as e.g., in the luxury sector, where clients can use cars or buses driven by H2 in order to have a zero-emission driving experience.</p> <p>In order to further push and support the development of the H2 industry, the government founded the continuously growing H2-Alliance Costa Rica which by now includes members of 27 different companies.</p>		
2	<p><u>PtX Projects in CR</u></p> <p>The Ad Astra Company is part of various pilot projects in CR financed by the Nama Facility Climate Fund together with the company "Hidrogeno Verde S.A.".</p> <p>Furthermore, at the moment the Ad Astra Company is part of a study about the potential of green hydrogen in CR.</p> <p>JDV mentions, that they plan to increase the size of their hydrogen demonstration plant up to 1 MW of electrolysis capacity, which then would result in an amount of 2500 kg(H2)/day.</p>	n/a	n/a
3	<p><u>PtX pricing</u></p> <p>According to JDV with regards to the transport sector, the most expensive parts are the vehicles themselves. The main aspects regarding a competitive price for the PtX products are both the productions components as well as the electricity costs used in the process.</p> <p>An advantage of CR is, that the grid electricity is to 100 % renewable. Therefore, it is not necessary to install a RE plant in order to</p>		

	<p>produce green hydrogen, however the electricity's grid price has several fees that increase the price in comparison to the raw off-grid production. In that case, a combination of during-the-day RE (e.g., solar) supply and grid supply during the night might be a cost-effective solution.</p> <p>By increasing the H2 production capacity, very high price reduction percentages are reachable.</p> <p>According to JDV, models show that at scales of 1 MW energy consumption, it is possible to produce 1 kg of hydrogen between 10-12 \$ final costs. He further mentions, that nevertheless the hydrogen cost needs to be at around 5 \$ or less in order to be economically competitive.</p>		
4	<p><u>Potential off-takers</u></p> <p>As written above and below.</p>	n/a	n/a
5	<p><u>PtX technology characteristics</u></p> <p>It is of high interest, that a H2 production plant operates 24/7, which is a big benefit of using geothermal energy as the energy source.</p>		
6	<p><u>Future development of the PtX in Latin America and CR</u></p> <p>According to JDV, Colombia, Panama, Chile and Uruguay are taking big steps towards the development of green hydrogen production. He further explains that generally the countries in South America are focusing more on the export of PtX products, even though Colombia and Uruguay are investing in the transport sector as well.</p> <p>According to AL there is a new law which now allows the private sector to generate electricity for private purposes as e.g., the production of green hydrogen from geothermal power plants, which was not allowed so far.</p>	n/a	n/a

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