PROTECTING THE FUTURE

GEOTHERMAL ENERGY RECOVERY

US$121T ESG INVESTORS DRIVING SECTOR AGENDA

42%
of Global GHG Emissions generated by the Oil & Gas industry

US$2.2T
Market Cap Loss of Oil & Gas Majors, before COVID-19

US$50-70T
investments to achieve the UN Sustainable Development Goals by 2030

US$30-60T
investments to achieve Net-Zero by 2050

100% Efficiency
along the value chain is required to achieve Net-Zero

THE PROBLEM

Climate Change, Environment & Impact on Society.

Oil & Gas industry generates 42% of global **Green House Gas (GHG) Emissions**, with 20% Scope 1 under their direct control.

Upstream >40% of industry Scope 1 Emissions using 20-year Global Warming Potential:

- 5% Flaring
- 10% Drilling & Operations
- 85% Fugitive & Venting[I]

Environmental, Social, and Governance (ESG) focused investors are becoming dominant and Climate Goals are core. The sector risk profile for investors had increased dramatically. The result is US$2.2T loss of Oil & Gas Majors[II] Market Cap, before COVID-19.

No investments in fossil fuel industries that do not have a clear **ESG** and sustainability agenda.

ESG SECTOR AGENDA

US$121T collective **Assets under Management (AuM)** of the 3,826 signatories of the UN supported **Principles for Responsible Investment (PRI)** in support of UN 2030 Sustainable Development Goals initiative[III].

US$50-70T investment needed to achieve the UN Sustainable Development Goals by 2030[IV].

Achieving **Net-Zero Emissions** by 2050 would cost an estimated US$30-60T of additional investments, or 1-1.5% of global gross domestic product per year[V].

Complete replacement of hydrocarbons as a source of energy in the short and medium term is not feasible. Therefore, it is imperative that industry stops the *"Business as Usual"* and achieves Net-Zero.

THE SOLUTIONS

The **Net-Zero Emissions** goal has to be achieved to solve the Climate Change, Environment & Impact on Society.

Net-Zero Emissions can be achieved with 100% efficiency, which requires digitalisation, integration & technology.

The PM Lucas technology solution allows full

- Monitoring,
- Reporting,
- Verification and,
- Mitigation

of **GHG's** by tracing product flows at the molecular level from reservoir pore space to the sales point.

To achieve client timelines and cost effectiveness targets, PM Lucas applies our proprietary technology to integrate your proven & existing industry processes to optimise operations and meet your **ESG** goals.

ACHIEVE NET-ZERO THROUGH 100% EFFICIENCY.
ACHIEVE 100% EFFICIENCY THROUGH
DIGITALISATION, INTEGRATION & TECHNOLOGY.

GEOTHERMAL ENERGY CONTEXT & OUTLOOK





94 TWh
Global Geothermal Power Generation

27%
Increase in Geothermal Energy Recovery between 2015 & 2020

〈 38 US$/MWh
Levelized Cost of Electricity

29+ Million
Abandoned Oil & Gas Wells, Many With Potential for Geothermal Energy Recovery

50% CAPEX Cut
Can be Achieved by Retrofitting Abandoned Oil & Gas Wells & Avoiding Drilling Activities[VI]

ESG DRIVEN INVESTMENT

No investments in fossil fuel industries that do not have a clear **ESG** and sustainability agenda.

The global effort in **ESG** responsible investment drives research in, and exploitation of renewables sources.

Development of geothermal energy resources can be an integral part of Oil & Gas companies' **ESG** driven portfolio management. With **emission trading** schemes emerging all around the world, significant opportunities arise by being in front of the development towards reaching **Net-Zero Emissions**.

Today, fossil fuels have share of total energy supply of four-fifths, but need to drop to just over one-fifth on a Net-Zero path[VII]. This creates a huge market for other technologies to fill this void.

An increase in geothermal electricity generation by more than 890% between 2020 until 2050 is required to achieve the path to **Net-Zero**[VII].

CURRENT STATE

The Levelized Cost of Electricity (LCOE) of many renewable energy sources is still too high for a rapid energy transition. Geothermal already offers an attractive LCOE of **38 US$/MWh**[VIII].

Worldwide primary energy demand increased by 65% between 1990 and 2020[VI], and the largest part was and is provided by fossil fuels.

Geothermal energy production was growing 27 % since 2015[IX]. A total of **94 TWh** of global geothermal power generation was realized as of 2020[X].

Many of the world's Oil & Gas fields passed peak production and are on decline. With this comes the need for Enhanced Oil Recovery (EOR) methods, but also the **abandonment of wells**. Today, the worldwide number of abandoned wells is estimated at more than 29 million[XI]. The abandonment of wells causes a financial burden on Oil & Gas companies and poses a serious risk for **Methane leaks** due to well or seal integrity issues.

OUTLOOK

The **Net-Zero Emissions** goal has to be achieved to solve Climate Change, Environmental Problems & Impact on Society.

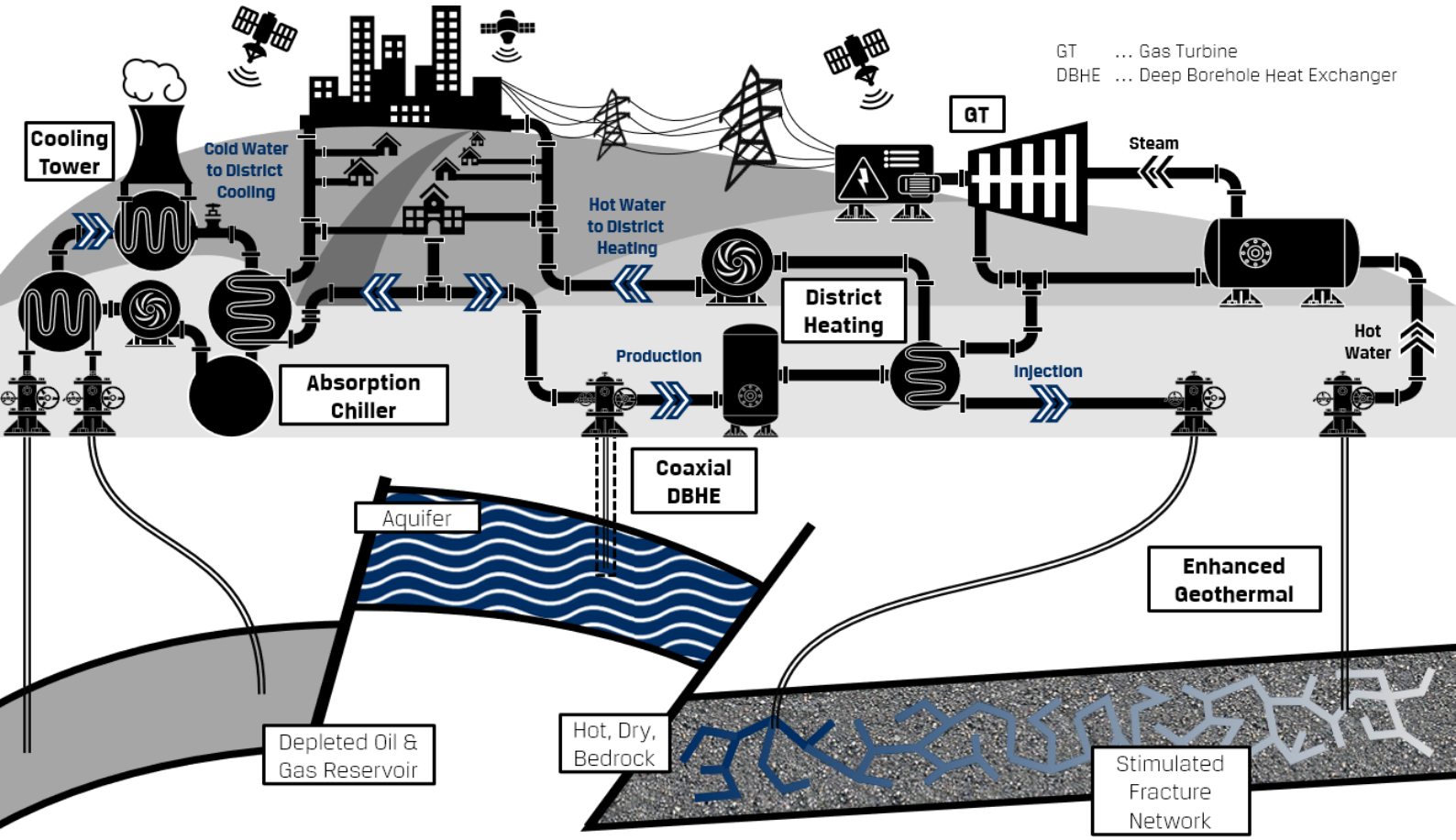
To achieve a **Net-Zero** emissions future, a reduction of global energy consumption by 8% until 2050 is targeted[VII]. Having this scenario in mind, geothermal power generation is required to **increase 13% annually** over 2021-2030 to achieve 330 TWh[X].

Oil & Gas producers will be looking to **retrofit** some of their **wells** already abandoned or due to decommissioning for application of geothermal energy recovery.

Geothermal Energy projects open the possibility of selling **Carbon credits** on the international carbon market. This drives clean energy investment and innovation, particularly in developing countries and countries in transition.

ACHIEVE NET-ZERO THROUGH 100% EFFICIENCY.
ACHIEVE 100% EFFICIENCY THROUGH DIGITALISATION, INTEGRATION & TECHNOLOGY.

GEOTHERMAL BIG PICTURE



GHG EMISSION REDUCTION OPPORTUNITY

The use of geothermal energy recovery potential allows both industry & municipalities to lower their carbon footprint & to achieve their **ESG** goals.

Geothermal recovery systems emit **zero or a very small amount of GHG** emissions. The average GHG emissions of geothermal power plants are around 120 gCO_2 per kWh electric energy with an expectation that this can be reduced by a factor of 10^{XII}. This is significantly less than that of fossil fuel power plants.

By retrofitting **abandoned oil & gas wells**, leakages and **fugitive methane emissions** as well as pollution of groundwater can be mitigated. Closed-loop geothermal systems emit minimal to zero amounts of gases, whereas open-loop systems require meticulous monitoring. Retrofitting abandoned oil & gas wells into geothermal wells completely avoids emissions created during the drilling phase. Thus, already a major **reduction in carbon footprint** is realized.

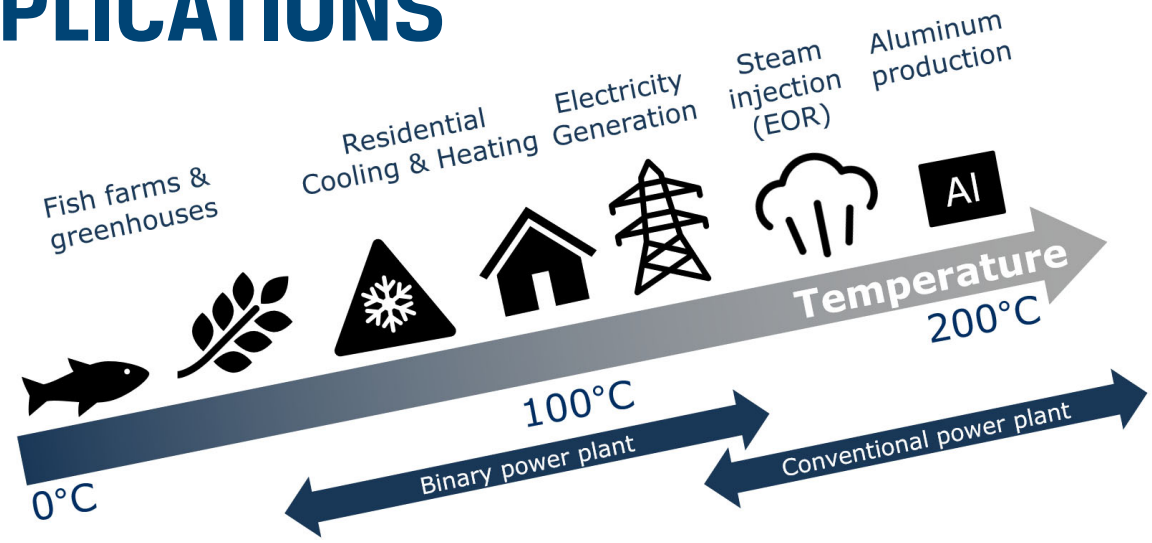
SUCCESS CRITERIA

- Complying with national & international regulations
- Minimizing carbon footprint & GHG emissions
- Reducing waste heat and environmental impacts
- Increasing the share of renewable energy production and promoting geothermal energy sources
- Successful screening and conversion of abandoned wells
- Reducing cost of drilling new wells by using current well stock and decommissioning of uneconomic producing wells
- Creating higher value jobs and increasing operational security based on digitalization & integration
- Achieving project established KPIs

PM LUCAS DOMAIN EXPERTISE

PM Lucas long-term experience in geology & geophysics, reservoir, production & process engineering is the foundation for development & implementation of geothermal energy recovery technologies & systems.

OIL & GAS RELATED GEOTHERMAL APPLICATIONS



ELECTRICITY

Conventional electricity generation is made possible when using high-temperature geothermal systems. Using conversion systems, temperatures as low as 80°C can be utilized for electricity generation. The generated electricity can be used for various applications, including **powering oilfield equipment such as ESP pumps**, industrial manufacturing plants, or feeding into the local grid. In this form, geothermal energy has best potential to be transmitted over long distances.

HEATING & COOLING

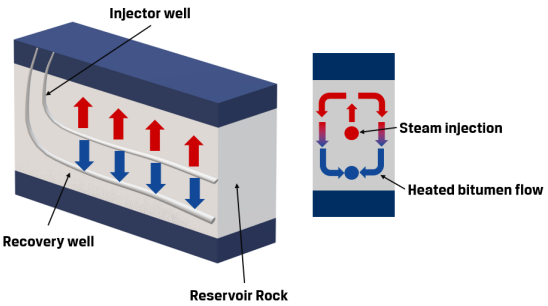
Hot water produced via geothermal energy recovery can be utilized for residential heating, industrial de-icing, soil warming and drying operations. Furthermore, by using conversion systems, geothermal energy can be used for cooling and refrigeration purposes. Air conditioning and cold storage applications significantly expand the potential utilization of geothermal energy sources.

Geothermal energy has the potential to considerably lower the carbon footprint of **heating / cooling operations of oil & gas treatment facilities**. Even in cases where the recoverable geothermal heat is insufficient it can substitute fossil fuels required for pre-heating or pre-cooling activities.

GEOTHERMAL ASSISTED EOR

Utilizing geothermal recovered heat is a possibility to reduce the carbon foot print of enhance oil recovery (EOR) operations considerably, especially when it comes to thermal enhanced oil recovery (TEOR).

TEOR is used to produce e.g. heavy oil by injecting hot water or steam into the reservoir. Despite all developments, TEOR is not always energetically, economically and/or environmentally feasible. The main reasons are surface footprint, water demand, burning gas for steam and consequently causing considerable GHG emissions. Geothermal energy extraction from refitted nearby abandoned wells is considered as one of the most promising techniques to **maximize the value of heavy oil assets** while **minimizing GHG emission**.



IMPROVING OIL & GAS PRODUCTION

Many well known and often experienced deferments in well production can be mitigated by **conserving the geothermal energy** originally contained in the produced reservoir fluid. By simply replacing conventional tubing strings with special relined tubulars the heat loss while producing oil and gas can be considerably reduced. This mitigates flow assurance issues such as wax deposition and liquid loading. Conserving geothermal energy can reduce workover requirements (e.g. hot fluid washes, wax scrapping, etc.) and production technology needs (e.g. gas lift). This results in in **lower costs & lower emissions**.

COMPANY PROFILE – WHO WE ARE

PM Lucas is an **Environmental Committed** Engineering and Technology Company, focused on delivering Leading-Edge Energy Technology Solutions to meet the needs of the world's Energy Companies in their quest for **Net-Zero emissions** and achieving their overall **ESG** goals.

PM Lucas delivers Integrated Technology & Project Solutions to meet the industry challenges of being environmentally sustainable, economically viable, technically robust and reliable.

For over 25 years PM Lucas has proven to be a reliable and innovative technology integrator.

Integrating the **Subsurface Technology & Surface Technology** our expertise and success are documented by our track record close to **1,000** contracts or **70,000,000** man hours of work covering the complete Domain Cycle of the Upstream Energy Industry. Single consulting specialist to complete turnkey EPCC solutions in excess of US$200 million.

Our expertise in understanding the reservoir underpins our capabilities to span both subsurface and surface development as well as their implementation and operation:

- G&G & Reservoir Studies › 200
- Subsurface Engineering Projects › 500
- Turnkey Drilling › 500,000 m
- Drilling Management › 2,500,000 m
- Well Interventions › 50,000
- Surface Technology Projects › 300

PM Lucas understands that the focal point is the reservoir and ensures that the reservoir engineering results feed directly into the surface engineering and technology implementation, thus providing an **Integrated Technology & Project Solution** conforming to **ESG** goals.

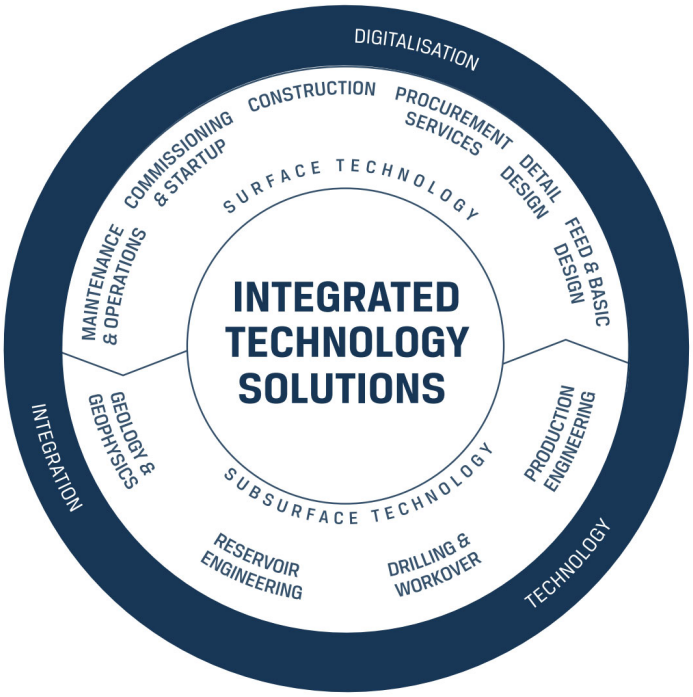
International Certification

PM Lucas is accredited by **TÜV NORD**:

- ISO 9001 Quality Management System
- ISO 14001 Environmental Management System
- ISO 45001 Occupational Health and Safety
- ISO 50001 Energy Management

PM Lucas Partners & Technologies

We are partnering up with world technology leaders, such as **SIEMENS, SAP, Amazon Web Services (AWS)**, to provide technically scalable and financially viable integrated solutions to achieve for the clients overall **ESG** goals and reach **Net-Zero emissions**.



We are experts in all standard industrial technologies from world leaders such as Schlumberger, Halliburton, Siemens, Honeywell, Rockwell, Rock Flow Dynamics (RFD), SAP, AspenTech, Computer Modelling Group (CMG), Amazon Web Services (AWS) and Microsoft.

Our Presence & Future

PM Lucas, through strategic investments based on our Client's **ESG** needs, will continue to be a Leading-Edge Energy Technology Solutions Provider.

In the context of the energy industry aligning itself to Paris Agreement emission cut targets, we can provide state of the art solutions for achieving

Net-Zero in Scope 1 & 2 Emissions

building on our track record of subsurface and surface projects and combining our expertise with the implementation of renewable energy sources such as photovoltaic or geothermal energy to make an energy assets life-cycle **Net-Zero**.

Building on successful and comprehensive digitalisation of the energy value chain monitoring, reporting and verification systems will be implemented to identify mitigation targets, develop mitigation strategies, and continuously monitor and report the success in achieving the client's **ESG** responsibilities.

GHG EMISSIONS MANAGEMENT

GHG EMISSIONS MANAGEMENT

The PM Lucas technology solution allows full

- Monitoring,
- Reporting,
- Verification and
- Mitigation

in order to

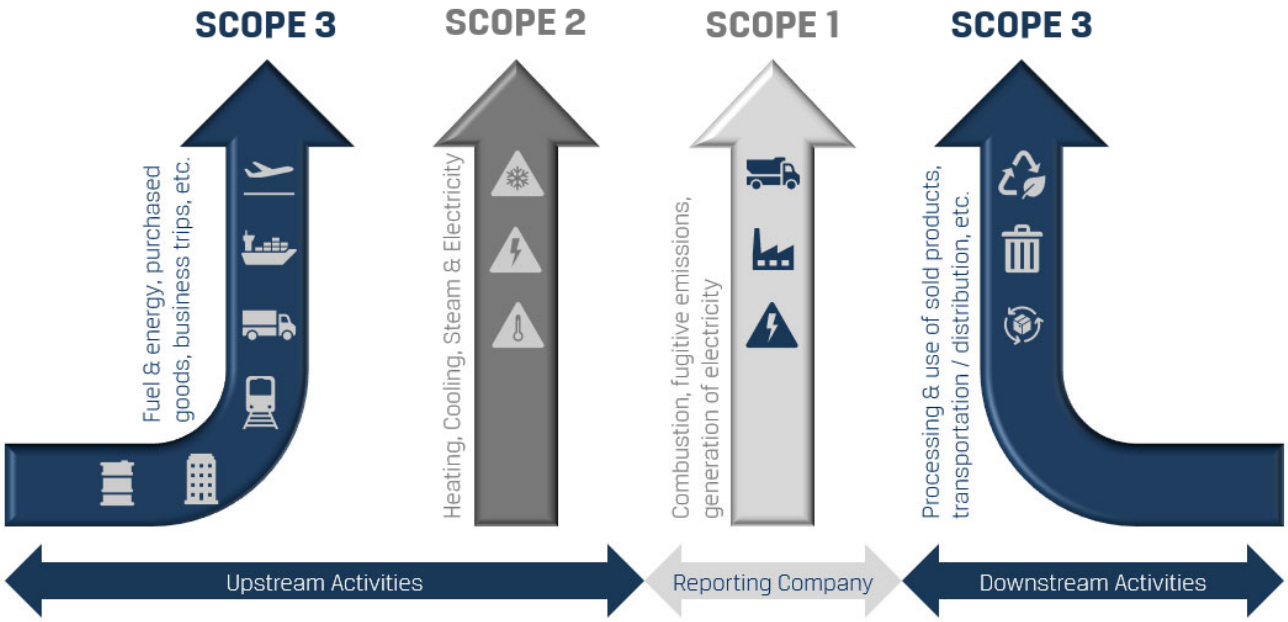
- Reduce **Scope 1** GHG Emissions (direct emissions) by utilizing renewable geothermal energy instead of energy generated by combustion
- Reduce **Scope 2** GHG Emissions (indirect emissions) by utilizing electricity from renewable geothermal energy sources
- Reduce **Scope 3** GHG Emissions (indirect emissions) by using renewable geothermal energy instead of upstream-processes fuel gas
- Provide a credible and transparent approach for quantifying and reporting GHG reductions from geo-thermal GHG projects
- Enhance the credibility of GHG project accounting through the application of common accounting concepts, procedures, and principles
- Provide a platform for harmonization among different project-based GHG initiatives and programs

CARBON ACCOUNTING & REPORTING SOLUTION

Reduction of **GHG** emissions by application of geothermal energy recovery, as a part of a dedicated GHG Project, are reflected in the reports and allow transparent communication of all environmental and financial benefits to stakeholders .

These **GHG** reductions provide major benefits to all stakeholders. As mandatory reporting, external GHG programs, and **Emission Trading Systems** evolve, it is becoming more and more essential for companies to understand the implications of accounting for GHG emissions changes over time on the one hand, and, on the other hand, accounting for offsets or credits that result from GHG reduction projects.

To quantify the results of GHG reduction projects, a transparent and consistent Carbon Accounting Solution is required to identify mitigation targets, develop mitigation strategies, and continuously monitor and report the success in achieving the client's **ESG** responsibilities.
Our Carbon Accounting Solution reports **GHG** emissions with a fine granularity and based on latest international standards.



DRIVING CUSTOMER VALUE

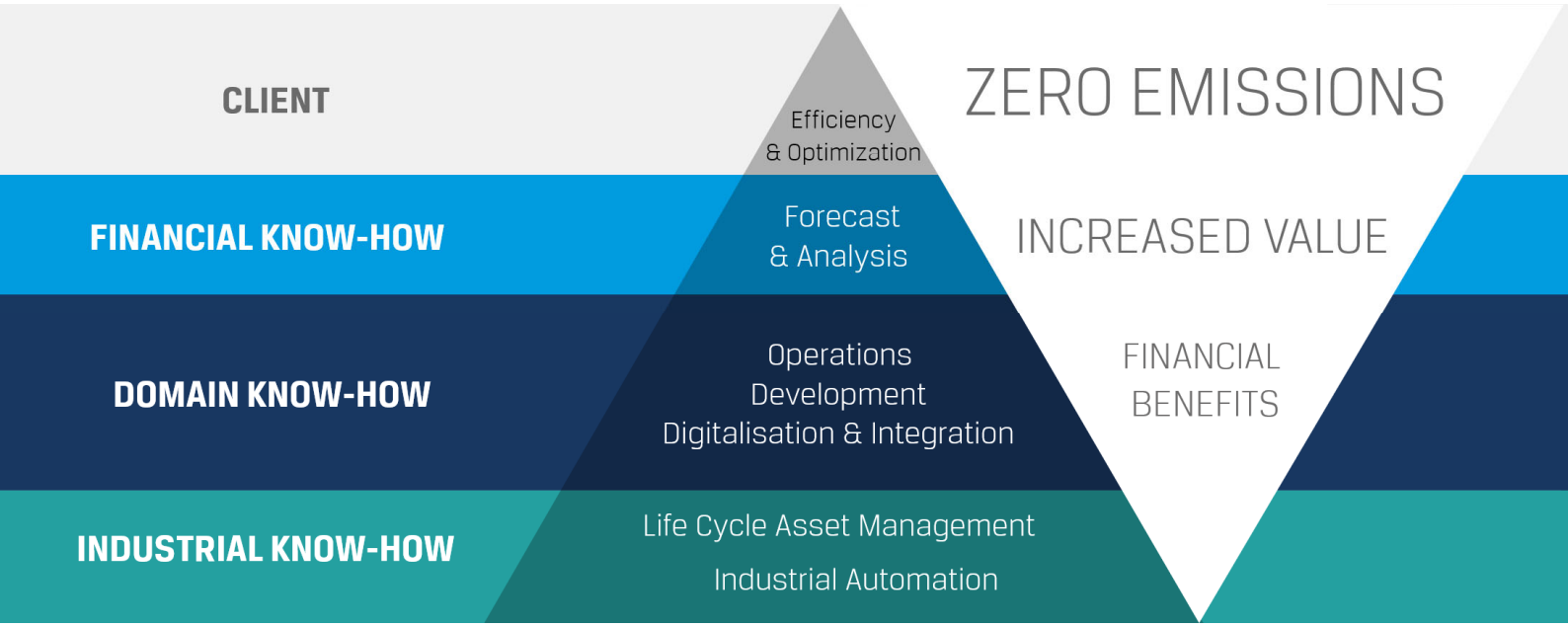
DIGITALIZATION & INTEGRATION

The PM Lucas digital solutions build on vertical integration of business processes. They span from the industrial automation foundation, over asset and plant life cycle assessment & management, considering **CAPEX** and **OPEX** related domain specific know-how and expertise to incorporate **Enterprise Resource Planning (ERP)**. This provides the solution to achieve the client's **ESG** goals, operational excellence, increased efficiency & value. Operational, process, expert, financial and other data from all over the business processes are utilized to boost efficiency in environmental, financial, process, operational & execution aspects. Building on digitalisation of the energy value chain **monitoring, reporting and verification** systems are enabled to identify mitigation targets, develop mitigation strategies, and continuously monitor and report the success in achieving the client's **ESG** responsibilities.

EVERGREEN PLANT MANAGEMENT & ASSET LIFE CYCLE MODELS

Integration of business processes supported by **continuous operations & asset monitoring** enables maintaining an evergreen digital twin. It offers dynamic life cycle analysis, matching of past and actual asset performance, forecasting of the future and evaluation of what if scenarios. This ensures performance in alignment with **ESG** goals. Depending on available instrumentation, near-real-time modelling, fore-casting, and reporting is also offered.

3D models offer the possibility of intuitively accessing plant data that is always up to date. The operating personnel receives all the necessary information in real-time to collaborate in teams & make effective decisions. They can quickly see where equipment is located and how they can best access it and retrieve related maintenance information.



DATA MANAGEMENT & AUTOMATED REPORTING

AUTOMATED REPORTING

PM Lucas Automated Reporting System represents state-of-the-art technology innovations tied together with existing systems and 3rd party software. It provides data **consistency**, **accuracy**, and **transparency** in real-time, for faster and more efficient decision making.

With PML Automated Reporting System in place, human error and the time necessary for completion of repetitive tasks are reduced to a minimum. All reports (interactive and/or static) are automatically generated by the system and quickly distributed throughout the company via emails, push notifications, alerts, etc. The dissemination of relevant and appropriate information is customized for each role in the company. With intuitive, near-real time, interactive dashboards all the data is just a few clicks away.

For a company to achieve its **ESG** goals, the entire management structure needs to make **informed decisions**. All executive and operational management needs correct & integrated information available in real-time, based on holistic views that go across all fields of domain knowledge and are integrated with the company's financial and Enterprise Resource Planning systems.

More and more legislations require automated submission of KPI's to the regulator & authorities. Reporting frequencies are ranging from daily updates down to near-real time uploading to governmental servers. PM Lucas has a proven track record of implementing **automated governmental reporting systems**.

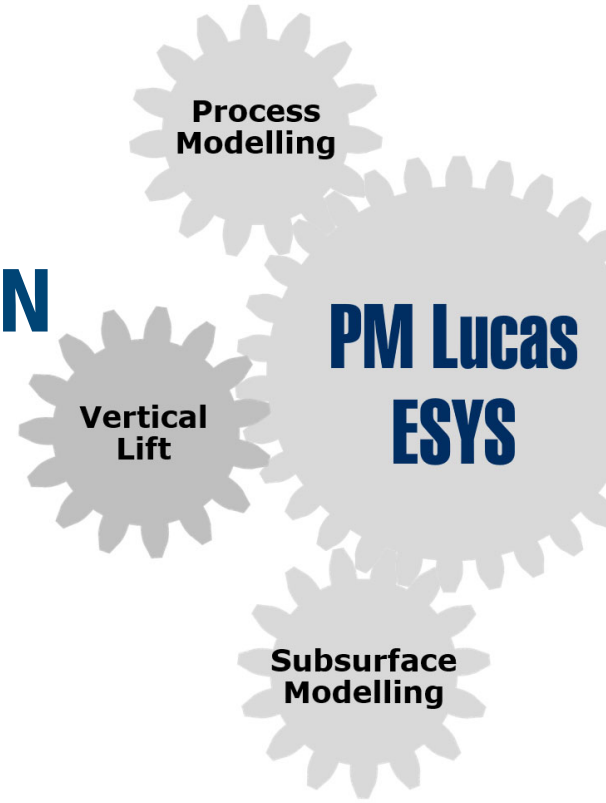
DATA MANAGEMENT

The most important aspect of any data-based system is data management, including the data collection, quality assurance, security, architecture, governance, storage, accessibility, etc.

In most cases, data is scattered throughout the company in a many different formats from many different data sources. Each of these data worlds comes with its own unique management challenges. Each has its own intricate subsystems and plays an important role in an organizational infrastructure.

PML Automated Reporting System combines all these data worlds together in **one centralized system**, from where data is sent, received, and transformed in a controlled environment. Depending on prevailing legislative framework and/or operator needs either a cloud base or server based solution can be implemented.

HOLISTIC GEOTHERMAL NUMERICAL SIMULATION



THE VALUE OF NUMERICAL SIMULATION

The physical and chemical processes driving and occurring to geothermal operations are inaccessible to simple analytical solutions.

Numerical simulation is in fact the only tool to

- assess the feasibility & risk,
- select the concept,
- support the design & optimization,
- predict the asset's life cycle performance,
- ensure economic viability & cost effectiveness and,
- to investigate the long-term operational security & environmental impact

of geothermal projects.

GEOTHERMAL NUMERICAL SIMULATION

Software tools widely used and accepted in the Oil & Gas Industry for modelling and simulating the subsurface (e.g. geology, reservoir, wellbore) and surface (e.g. facilities, piping network, etc.) domains are a profound basis for geothermal investigations.

Especially when it comes to geothermal energy extraction using retrofitted, **abandoned oil & gas wells**, the legacy of reservoir, well bore and facility models and the related production and operations data turn into an **invaluable treasure**. However, to adequately utilize and leverage on the decades of collected data, it must be properly digitized, stored and managed. Furthermore, most of the (especially reservoir) models in use by oil & gas companies assume isothermal conditions.

This simplification does not hold when it comes to geothermal energy recovery. Correctly capturing the transient heat transfer in the reservoir and assessing the temperature profile from the pore space to the geothermal plant are **key to geothermal project success**.

But not only thermo-hydraulic phenomena have to be understood for a proper investment decision.

OPERATIONAL & MODELLING CHALLENGES

Long term operability and security are heavily impacted by thermo-hydraulic-mechanical and thermo-hydraulic-chemical processes. To give just two examples:

1) Thermal stress induced by injecting cold water into the reservoir rock may lead to rock mechanical failures & hazardous situations. Thorough investigations are required to mitigate the risk of well bore integrity problems and cap rock fracturing. Holistic modelling is required to define a safe & economic viable operating envelope. Automated, fully digital 24/7 monitoring and reporting (alert triggering) complements the geothermal operations.
2) For open loop systems, where the injected working fluid is in direct contact with the in-situ reservoir fluids and porous material, geo- and biochemical reactions may lead to precipitation resulting in reduced permeability or even complete pore plugging. To avoid this, proper treatment of the working fluid (e.g. removal of ions & bacteria) is mandatory, as it is done for pressure maintenance applications in the Oil & Gas industry.

Operational excellence by improving domain activities and meeting the main KPIs including achieving **ESG Goals** can only be achieved through

- digitalisation,
- integration and,
- technology.

ESG FOCUSED R&D

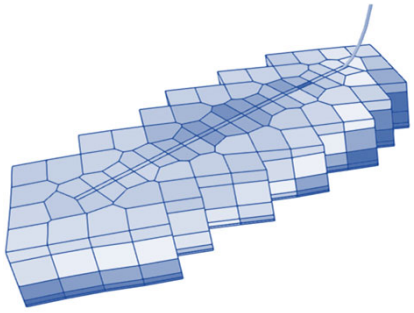
PM LUCAS ESYS

PM Lucas develops and maintains its proprietary simulation engine ESYS. As an integral part of PM Lucas Digital Oil Field solution, it is tightly connected to data collection and reporting systems. Projects are benefiting from the integration of available real-time operational and process data feeds.

Having its roots in reservoir simulation almost halve a century ago, ESYS evolved to a **Closed Loop Integrated Numerical Asset Modelling & GHG Emissions Simulator**.

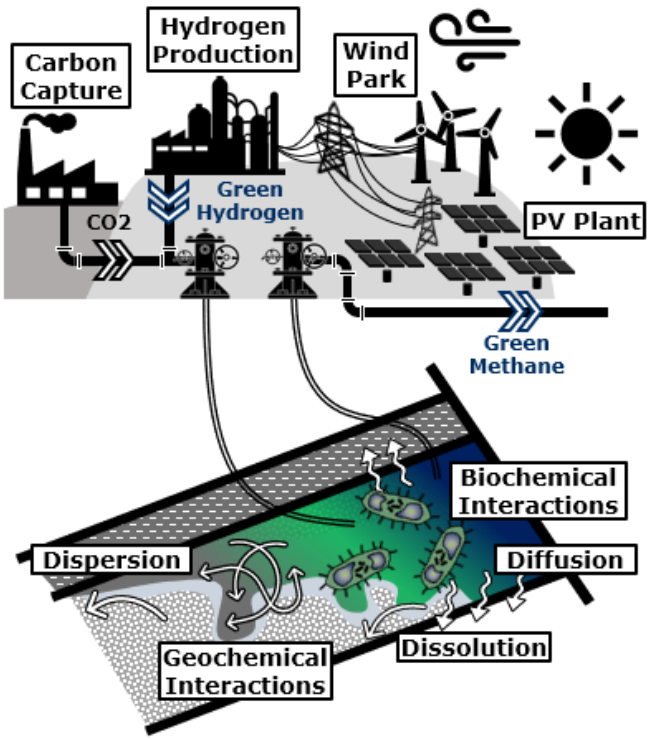
ESYS integrates numerical simulation, spanning from the subsurface (pore space) to surface facilities (sales point, CO_2 capturing site, power grid feed from conventional and renewable, intermittent energy sources such as wind parks and photovoltaic plants, etc.) and vice versa, depending on production or injection/sequestration operations. ESYS is an Equation of State (EOS) based numerical engine that ensures consistency along all modelling domains in terms of fluid description, heat transfer, pressure profiles, mass and molar balance.

One of the key specialties of PM Lucas modelling technology is a highly specialized representation of the subsurface near wellbore area.



For almost all applications this is the dedicated area of interest, where the governing processes (pressure drop, fluid filtration, heat transfer, geo- and biochemical interactions, etc.) happen most rapidly and need special considerations.

To ensure predictive capabilities of our models they are calibrated with various measurements and field observations, such as pressure, temperature, rate and fluid composition. Alongside emerging technologies such as satellite imagery, this comprehensive integration of data from various sources helps us to verify our results.



PM Lucas has over 25 years of project experience in all facets of Oil & Gas industry subsurface and surface activities. The PM Lucas R&D department leverages this hands-on-experience by integrating domain know-how and technology with the prime objective of putting the emissions under control.

Our **ESG** centred R&D efforts are focused on all aspects of mitigation of GHG emissions in the upstream Oil & Gas industry, carbon capture (utilization) and sequestration (CCS/CCUS), hydrogen production and underground hydrogen storage (UHS), green methane production and geothermal energy recovery from low temperature (< 25°C) aquifer thermal energy storage (LT-ATES), high temperature (~ 25°C to ~ 90°C) aquifer thermal energy storage (HT-ATES), and abandoned, retrofitted O&G wells.

RESEARCH & TECHNOLOGY PARTNERSHIPS

PM Lucas R&D department is located on the premises of the **Montanuniversität, Leoben** (MUL), Austria. PM Lucas is cooperating with two of the leading petroleum engineering departments in the world, those at MUL and **Texas A&M University** (TAMU). Amongst other departments and chairs at MUL, PM Lucas is closely cooperating with the **Chair of Petroleum and Geothermal Energy Recovery**. It is recognized as a leading centre for education, training and research in petroleum production and geothermal engineering with strong ties to a wide range of industries.

PM Lucas is also in collaboration with many **ESG** centred leading-edge international technology institutions and leading technology industry partners such as Siemens and SAP and are currently evaluating together with AWS integration into existing AWS Cloud & Machine Learning Infrastructure in order to acquire unprecedented speed, storage & scalability.

GEOTHERMAL ENERGY RECOVERY BASICS

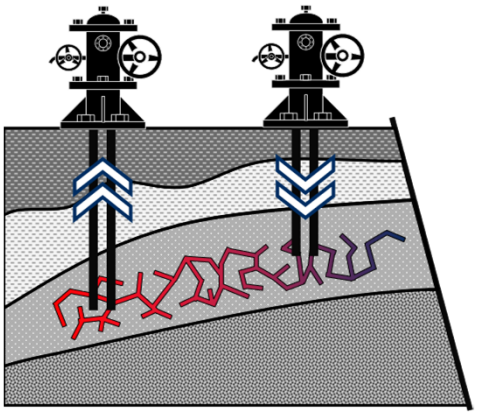
GEOTHERMAL ENERGY SOURCE

Geothermal energy originates from the heat of the earth's core and radioactive decay. The heat dissipates through many geological layers up to the surface. This energy source is **available around the entire globe**, with an average heat flux of 87 mW/m2.

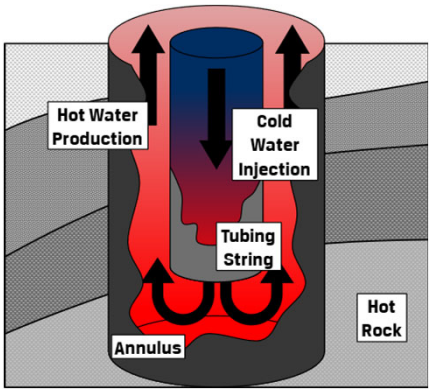
The possibility to utilize this renewable source of energy depends on the geological conditions, which dictate one of the key parameters for all geothermal energy recovery systems – the **geothermal gradient**.

The geothermal gradients ranges from 20°C/km up to 150°C/km. In some areas of the world geothermal energy is visible already on the surface in form of volcanoes, geysers, hot springs , etc.

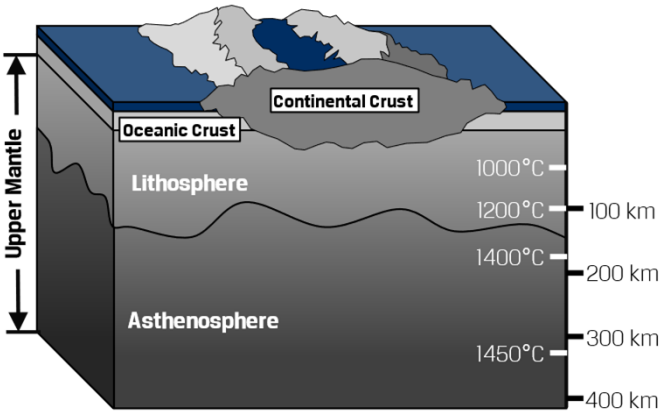
Favourable geological settings for high geothermal gradients include plate boundaries, volcanic hotspots, and deep penetrating fault irregularities.



Open-Loop



Closed-Loop



OPEN-LOOP VS CLOSED-LOOP SYSTEMS

For harnessing geothermal energy, two basic configurations exist: closed-loop and open-loop

Open-Loop

Consisting of injection and production wells, this configuration provides the **highest energy extraction efficiency**. Cold fluid, typically water or CO_2, is injected into a permeable formation, and is flowing to a production well. Direct contact between the working fluid and the hot rock results in high fluid temperatures at the production well. Complex interactions of the working fluid with the already in place brine or hydrocarbons significantly impact the performance of this configuration. Detailed analysis can only be performed by combined thermal reservoir and surface facility simulation.

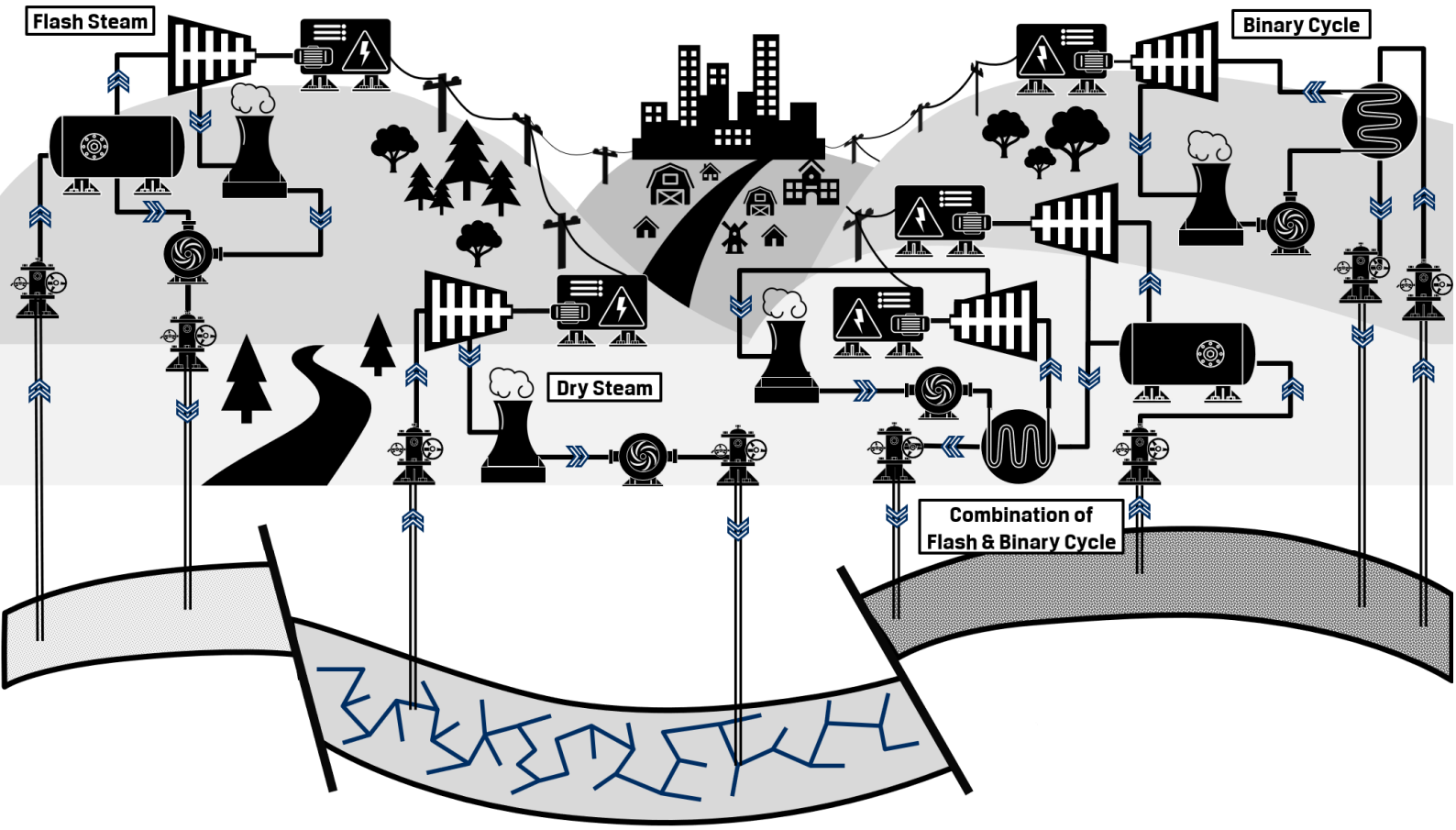
Closed-Loop

This configuration requires only a single well, where a working fluid will be circulated either using annulus and tubing or a U-tube. The **borehole** itself acts as a **heat exchanger** with the surrounding formations. Generally, this configuration has a lower efficiency, but the possibility of arising GHG emissions is reduced.

SOURCE TO CONSUMPTION DISTANCE

Optimal efficiency of geothermal applications requires the source (e.g. geothermal production well) and the consumption of the recovered geothermal energy to be proximate to each other. Any distance between those will decrease the efficiency or make a project neither economically nor technically viable. Instead of transporting the working fluid in pipes over greater distances, it is better to locally convert it to electricity to directly feed the grid.

GEOTHERMAL POWER PLANT CONFIGURATIONS



DIRECT USE OF GEOTHERMAL ENERGY

When the temperature of the produced fluid is sufficient (>150°C), geothermal heat can be directly used for electricity production at a **very high efficiency**. At lower temperatures, direct use is still possible for heating applications with various use-cases.

Dry Steam: In a dry steam configuration, the fluid temperature is sufficient that the produced fluid can be transferred directly to a turbine for electricity generation. Afterwards, the fluid is condensed and pumped back to the sub-surface.

Flash Steam: In a wet steam system, the produced fluid contains liquids, which must be separated from the steam before transferring it to a turbine. The separated condensate is pumped back to the subsurface together with the condensed steam from the turbine.

BINARY & COMBINED CYCLES

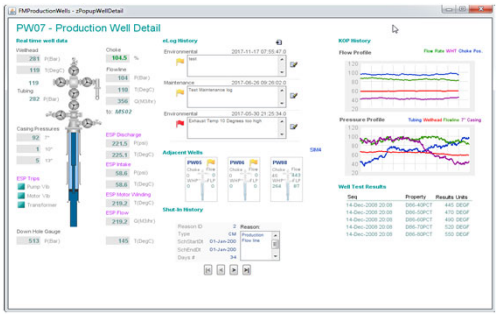
Binary cycles are applicable for power generation in geothermal temperature ranges starting at about 70°C up to 150°C. One possibly binary cycle is the so-called **Organic Rankine Cycle**. It consists of refrigerant, evaporator, turbine, condenser and a working fluid pump as the major components in the basic configuration. It can be used in various configurations with a range of efficiencies.

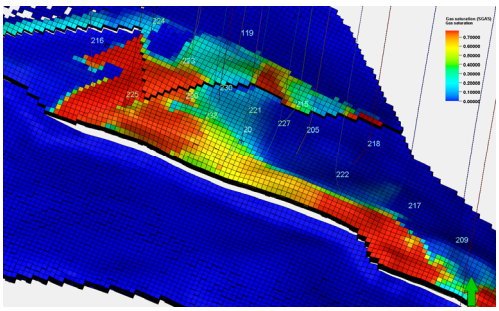
The working fluids are refrigerants, which can be potent **GHGs**, making it imperative to continuously monitor the system and avoid leakages. The Global Warming Potential (GWP) of such refrigerants varies greatly and can reach values of up to 15,000.

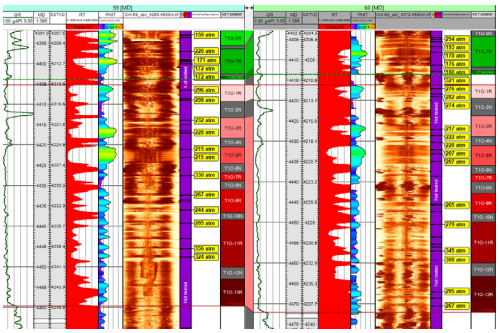
OUR TRACK RECORD
RELEVANT REFERENCE PROJECTS

CHINAREVSKOE OIL & GAS FIELD

CLIENT: ZhaikMunai LLP, Kazakhstan







ASSET DIGITALIZATION – DIGITAL OIL FIELD IMPLEMENTATION

- March 2018 – ongoing
- Full compositional, equation-of-state numerical modelling from the reservoir to the backend of the processing facility, integrating subsurface & surface simulation models
- Automated Reporting System implementation
- Governmental Reporting System implementation
- Real-time monitoring of operations
- GHG emissions monitoring, reporting & forecasting
- Bottom-up accounting of Scope 1 and Scope 2 GHG emissions

PRODUCTION OPERATIONS AND PETROLEUM ENGINEERING SUPPORT

- May 2010 – ongoing
- Water production & injection wells performance monitoring and analysis
- Workover and well services monitoring and well test planning
- Geological & Geophysical & Reservoir Engineering services, including 3D dynamic, numerical simulation
- Operations and management system development and implementation
- Well integrity assessments & solution

GEOLOGICAL MODELLING & DYNAMIC NUMERICAL SIMULATION

- 2010, 2011 – 2012 , 2014, 2015, 2018, 2019
- 3D geological model construction (geology, geophysics & petrophysics)
- 3D dynamic, numerical simulation
- Water flood efficiency assessment & optimization
- Tracer tracking study
- Economic and risk evaluation

WATER PRODUCTION, TREATMENT & INJECTION SYSTEM DESIGN FOR RESERVOIR PRESSURE MAINTENANCE

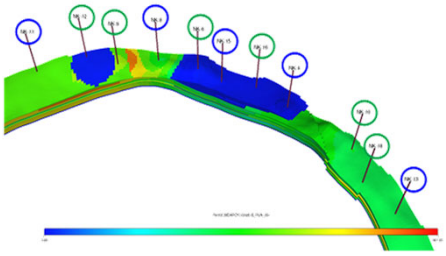
- Jun 2013 – Sep 2014 (update & extension)
- Jan 2010 – Jul 2011 (EPCC) & Sep 2008 – Jan 2009 (EPCM)
- Water injection facilities: system design & plant layout
  - Water injection pump sets & tanks
  - Water filtering & distribution package
  - Chemical injection package
  - Control room & PLC control system
  - Routing of water transfer and distribution lines
  - Pipeline hydraulics & 3D modelling
- Heat & material balance
- Ecological Study & Environmental Impact Assessment
- Water well system performance assessment

WATER FLOODING STUDY

- February 2007 – March 2007
- Source water considerations
- Water analysis
- Ground water production system performance optimization
- Injection system optimization
- Well integrity study

OUR TRACK RECORD
RELEVANT REFERENCE PROJECTS

KONYS OIL FIELD
WATER PRODUCTION & FLOODING
CLIENT: Galaz and Company LLP



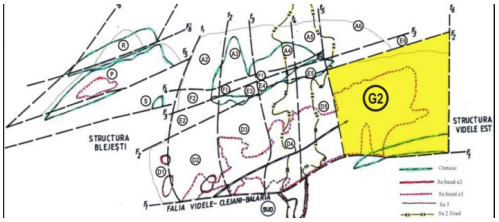
RESERVOIR STUDY RESERVOIRS M-II
- November 2012 – December 2012
- Geological model construction
- 3D dynamic simulation
- Water flooding efficiency optimization

RESERVOIR STUDY RESERVOIRS J-0-1
- June 2012 – November 2012
- Geological model construction
- 3D dynamic simulation
- Water flooding & gas-reinjection optimization

KOMSOMOLSKOE OIL FIELD
DEVELOPMENT & WATER HANDLING
CLIENT:OMV Petrom Group on behalf of KomMunai LLP

FAST TRACK TURNKEY EPCC PROJECT
- August 2009 – December 2009
- Gathering piping network (trunks, flowlines, pigging facilities, distribution manifolds, various process equipment)
- Central Processing Facility for oil water and gas separation
- Two stages of water separation
- Produced water storage
- Produced water pumping station
- Water injection piping distribution network
- Gas injection piping distribution network
- Amine plant for H_2S removal
- Crude oil desalting facility
- Export metering system for pipeline leak detection

ENHANCED OIL RECOVERY
HOT WATER & POLYMER INJECTION
CLIENT:OMV Petrom, Romania



EOR FOR THE OIL FIELD WIDELE VADU-LAT, Block G2
- 2007-2008
- Feasibility study
- Geological model construction
- 3D dynamic simulation
- Source water analysis
- Water treatment design
- Hot water system design
- Polymer system design
- Well integrity study
- Major equipment packages and utility systems (foundations, process buildings, control systems, communications, measurements, fuel system, camp, etc.)

OUR TRACK RECORD
RELEVANT REFERENCE PROJECTS

KYZYLKIA
WATER TREATMENT & INJECTION FACILITY
CLIENT: PetroKazakhstan Kumkol Resources JSC

EPCM
- 2005-2006
- Heat & material balance
- Process study & modelling
- Detail design of water injection facility & piping network
- Piping and instrument diagram development
- Equipment tender assessment and recommendation to client
- Process and safety system development c/w cause and effects matrix
- Development of explanatory notes for regulatory approval
- Construction supervision

KUMKOL
WATER TREATMENT & INJECTION FACILITY
CLIENT: PetroKazakhstan Kumkol Resources JSC

SOUTH KUMPL WATER INJECTION (BKNS) FACILITY - EPCM
- 2005-2006
- Heat & material balance
- Process study & modelling
- Detail design of water injection facility & piping network
- Process and safety system development c/w cause and effects matrix
- Construction supervision

KUMKOL WATER INJECTION (BKNS) FACILITY- EPCM
- February 2001 – November 2001
- Heat & material balance
- Process study & modelling
- Detail design of water injection facility & piping network
- Process and safety system development c/w cause and effects matrix
- Construction supervision

AKSHABULAK
WATER TREATMENT & INJECTION FACILITY
CLIENT: KazGerMunai LLP, Kazakhstan

BOOM – Build, Own , Operate & Maintain
- May 2003 – December 2004
- Project management
- Process modelling
- Detail design
- Procurement
- Construction management
- Operation and maintenance of facility
- Spare parts management

For our complete reference lists for surface technology, subsurface technology and drilling & workover, please visit
www.pmlucas.com/downloads

GLOSSARY

AuM	Assets Under Management.
Binary Cycle	A power generation method with a high temperature and a low temperature circuit, e.g. the Organic Rankine Cycle.
Caprock	Is a harder or more resistant rock type overlying a weaker or less resistant rock type. Caprock is generalized to any nonpermeable formation that may prevent oil, gas, or water from migrating to the surface.
CAPEX	Capital expenditure or capital expense is the investment an organization or corporate entity makes to buy, maintain, or improve its fixed assets, such as buildings, vehicles, equipment, or land.
Carbon Capture & Sequestration (CCS)	The process of capturing CO_2 emissions from the atmosphere, flue gases or other industrial sources, and storing them in deep subsurface geological formations.
Carbon Capture, Utilization & Sequestration (CCUS)	The process of capturing CO_2 emissions from the atmosphere, flue gases or other industrial sources, and storing them in deep subsurface geological formations with partial utilization of captured CO_2 for industrial processes.
Closed-Loop	Geothermal configuration using a working fluid that is circulated in a closed system, with the heat exchange occurring directly at the contact between the fluid circulation tubes and the hot rock.
Dry Steam	Geothermal power plant configuration with a very high temperature fluid stream coming from the geothermal reservoir, allowing a direct transmission of the vapour to a turbine for power generation.
Equation of State (EOS)	A thermodynamic equation, which relates pressure, volume & temperature of a fluid
ESG	Environmental, Social and corporate Governance, factors indicating the sustainability and ethical impact of an investment.
Flash Steam	Geothermal power plant configuration which uses a flash tank (separator) for removing liquids from the high temperature fluid steam coming from a geothermal reservoir before transmitting the vapour stream to a turbine for power generation.
Geochemistry	The science that uses the tools and principles of chemistry to explain the mechanisms behind major geological systems such as the Earth's crust and its oceans.
Geothermal	Geothermal energy is heat derived from the sub-surface of the earth. It can be used for heating, cooling and electricity generation.
Green House Gases (GHG)	Green House Gases are gases that absorb and emit radiant energy within the thermal infrared range. Green House Gases cause the greenhouse effect on planets. The primary Green House Gases in Earth's atmosphere are water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).
Global Warming Potential (GWP)	is a measure how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of CO2.
EOR	Enhanced Oil Recovery: An oil recovery enhancement method using sophisticated techniques that alter the original properties of oil by utilizing chemical or thermal processes.
Enterprise Resource Planning (ERP)	A tool for managing core business processes in an integrated and consistent manner.
Fugitive (Emissions)	Emissions of gases or vapours from pressurized equipment due to leaks and other unintended or irregular releases of gases, mostly from industrial activities. As well as the economic cost of lost commodities, fugitive emissions contribute to air pollution.
HT-ATES	High temperature aquifer thermal energy storage.
Levelized Cost of Electricity (LCOE)	The measure of the average net present cost of electricity generation for a generating plant over its lifetime.
Life cycle analysis	Methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service.
LT-ATES	Low temperature aquifer thermal energy storage.
Net-Zero	The balancing of carbon dioxide emissions with removal (often through carbon offsetting).
Numerical simulation	is the process of mathematical modelling, performed on a computer, which is designed to predict the behaviour of or the outcome of a real-world or physical system.
Open-Loop	Geothermal configuration which needs at least one injection well, injection cold fluid, and one production well, producing hot fluid. The heat transfer occurs within the geothermal reservoir, providing a large heat exchange area.
OPEX	An operating expense, operating expenditure, operational expense, operational expenditure is an ongoing cost for running a product, business, or system.
Organic Rankine Cycle	A binary cycle using a refrigerant or hydrocarbons as the working fluid, allowing the generation of steam at lower temperatures than would be possible with water.
Pore space	Very small void spaces in the subsurface rock, which can be either filled with hydrocarbons and/or water (brine).
PRI	Principles for Responsible Investment: UN-supported network of investors, works to promote sustainable investment through the incorporation of environmental, social and governance.
Renewables	Energy sources that can be used for electricity, heat or cooling generation, including bioenergy, geothermal, hydropower, solar photovoltaics, concentrating solar power, wind and marine energy.

GLOSSARY

Reservoir rock	Is a subsurface pool of hydrocarbons contained in porous or fractured rock formations.
Scope 1 (Emissions)	Emissions from operations that are owned or controlled by the reporting company.
Scope 2 (Emissions)	Emissions from the generation of purchased or acquired electricity, steam, heating, or cooling consumed by the reporting company.
Scope 3 (Emissions)	All indirect emissions (not included in Scope 2) that occur in the value chain of the reporting company, including both upstream and downstream emissions.
Subsurface simulator	or reservoir simulator, is a software tool in the area of reservoir engineering in which computer models are used to predict the flow of fluids (typically, oil, water, and gas) through porous media.
Surface facilities simulator	Software used to simulate the material and energy balances of chemical process plants.
Thermal Enhanced Oil Recovery (TEOR)	The application of thermal energy to increase oil production, including steam assisted gravity drainage, cyclic steam injection and other methods.
Thermo-hydraulic-chemical	Consideration of heat transfer, fluid & heat advection & fluid-rock interactions
Thermo-hydraulic-mechanical	Consideration of heat transfer, fluid & heat advection & deformation due to stress
Underground Hydrogen Storage (UHS)	Storage of large volumes of hydrogen in the subsurface either in porous media (e.g. saline aquifers or depleted natural gas reservoirs) or salt caverns.

[I] McKinsey & Company "The Future is now: How oil and gas companies can decarbonize", 01.2020
[II] Oil Majors sample includes Exxon Mobil, Chevron, Royal Dutch Shell, PetroChina, Total, BP, Petrobras, Sinopec, CNOOC, ConocoPhillips, Equinor, Eni, Occidental Petroleum
[III] PRI 2020 Annual Report
[IV] UNCTAD World investment report 2014
[V] Energy Transitions Commission, Making Mission Possible - Delivering a Net-Zero Economy, September 2020
[VI] Alimonti et al. "Coupling of energy conversion systems and wellbore heat exchanger in a depleted oil well", Geothermal Energy, 2016
[VII] IEA Report "Net Zero by 2050 – A Roadmap for the Global Energy Sector", October 2021
[VIII] EIA Report "Levelized cost and levelized avoided cost of new generation resources", 2020
[IX] Huttrer "Geothermal power generation in the world 2015-2020 update report", World Geothermal Congress 2020
[X] EIA Geothermal Power Tracking Report, November 2021
[XI] Reuters "Special Report: Millions of abandoned oil wells are leaking methane, a climate menace", June 2020
[XII] Rybach "CO2 Emission Mitigation by Geothermal Development – Especially with Geothermal Heat Pumps", World Geothermal Congress 2010