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# Enhancing the Efficiency of Geothermal Project Utilization With Modular Micro ORC Technology

Gad Shoshan, MSM, Energy Expert and Management Consultant to Enogia
gsd.shoshan@enogia.com ; nunrg4u@gmail.com

**Keywords:** MMO- Modular Micro ORC, Low temperature, higher total efficiency, energy efficiency, multi-application solution, low enthalpy, SMG (Smart Micro Grid), baseload support, REC (Renewable Energy Community), ORC (Organic Rankine Cycle), abandoned wells, topping solutions, bottoming solutions, single well head system, Enogia

**ABSTRACT**

The most capital-intensive element in geothermal development is drilling. From pre-feasibility through production testing, the process is both costly and uncertain. Only once test results are obtained can the potential applications of a geothermal resource be fully understood and promptly implemented. Since no two wells are alike in flow, temperature, or enthalpy, integrating all wells into a unified gathering system and one power plant is often challenging. This may lead to underutilization or abandonment of some wells after significant investment.

**Enogia** addresses this challenge by offering a modular Organic Rankine Cycle (ORC) solution designed to increase the overall efficiency of geothermal concessions. Its patented ORC system, featuring an innovative micro-turbine, can be deployed as a **Standalone Unit** directly at the wellhead. This enables the productive use of low-enthalpy or remotely located wells that would otherwise remain idle due to their incompatibility with centralized infrastructure.

In addition, Enogia's solution supports a **Topping** configuration for wells already used in applications such as district heating, agriculture, or balneology. When wellhead temperatures exceed the requirements of these applications, Enogia's compact ORC unit can harness the surplus thermal energy to generate clean electricity with minimal additional investment.

Capable of producing electricity from heat sources starting as low as 70°C, the system is delivered in a sealed containerized format, ready for plug-and-play installation. This approach significantly reduces installation time and cost while improving the total return on investment for geothermal field development.

The time has come for the market to recognize this solution as a reliable and proven way to improve the efficiency of existing geothermal sites with only a modest additional investment.

## 1 INTRODUCTION

There are two major paths in the exploration of geothermal concessions. One is the traditional path, seeking geothermal potential that includes a hot underground area and (hot) water to drill in, extract the water, utilize, and reinject colder. The alternative path, explored for over two decades and now beginning to show promising results, is known as HDR (Hot Dry Rocks) or EGS (Enhanced Geothermal Systems) - where the exploration is for as shallow as possible hot area under the surface, with some basic matching geological characteristics, and the attempt to inject water (or any other fluid) into engineered channels, where it is heated and, ideally, recovered at a temperature sufficient for power generation (or other applications).

In both cases, there is always a risk of investing heavily in the exploration and drilling phase, only to end up with a well or system that cannot fulfill expectations and will eventually be abandoned. From the first days of geothermal exploration, recognizing this risk, several major institutions, including the World Bank, EBRD, and ADB, have established insurance or grant mechanisms to mitigate the financial exposure of unsuccessful geothermal wells.

For years, the strategy and target of project developers was to seek as much power capacity as possible to justify the investment and total development cost and imitate traditional fossil fuel power plants technology. The huge

potential market for small units was largely neglected, as it targeted medium-low enthalpy, temperature, and flow resources. Part of the reason was a lack of economically, technically, and operationally viable solutions.

With the gathered experience in geothermal power plants all over the world, the selection of steam-based turbine technology was almost completely abandoned. Due to issues like the cost of maintenance, availability factor, auxiliary consumption rate, additive chemical treatments, time between initial project date and commissioning date, and impact of changes in resource characteristics, the preferred selection today is to use ORC technology, except for very rare cases.

The modern electric grid and operation, which includes a growing portion of renewable energy production, needs, and is indeed going to, restructure the whole concept of the electricity market, technically and economically. All major stakeholders are discussing Resilience, Diversity, Independence, and total Scale-Down when strategically planning the future of the electric market and grid, as well as production and consumption components. A new terminology and concept of REC – Renewable Energy Community- is defining the concept of the future micro grid solution and involves geothermal as a source wherever applicable. The correct solution for the REC concept is a small, modular, flexible ORC solution that can accept low-temperature input.
Today we acknowledge – Bigger is not necessarily better, Deeper is not necessarily better. We are scaling down.

It is therefore only a matter of time before an effective solution emerges that addresses all these long-standing challenges in geothermal development. Enogia has developed and manufactured such a system.

## 2 THE MARKET STATUS AND ITS FUTURE DIRECTION

### 2.1.1 Short history from the start till today

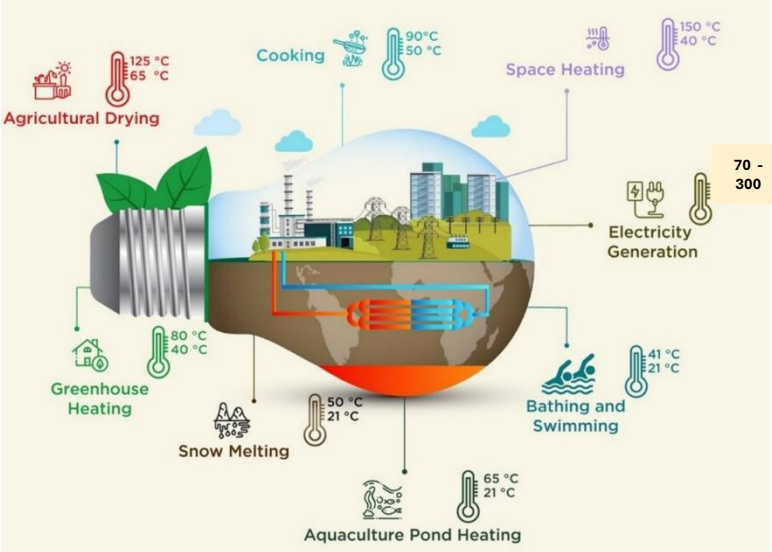
In 1904, the first experimental geothermal unit was established in Larderallo, Italy. It was based on extracting the steam of the geothermal resource and utilizing it in a steam-based turbine technology, which was the only technology known at the time. It started production in 1916. Since that time, the implementation of geothermal power plants and the utilization of geothermal resources have spread in all relevant areas in the world, where hot geothermal water was found at an economically viable depth and drilling cost. Until 1984, only steam-based turbines were installed, thus having most of them in Iceland, New Zealand, USA, Indonesia and Philippines, with the most significant development being at The Geysers in California, where 26 power plants were built by that year. Mentioning it because this was also the best case (out of several others) to teach the world the drawbacks of this technology. During 1984, Ormat commissioned the first ORC-based power plant in Wabuska, USA, and opened the era of ORC technology. It was not until the late 2000s, a time of which several tens of ORC-based power plants were operating, that the market started to understand the benefits of the ORC and the drawbacks of steam-based technology for geothermal resources. Today, over 95% of new geothermal projects will implement ORC ORC-based solution.

### 2.1.2 Why ORC for geothermal

Selecting steam-based solutions at the beginning was only natural, as it was known and accepted at the time that steam is the common way to generate electricity. The technology was there, the fossil-fueled power plants were all generating electricity with steam, and the “innovative” idea to use the geothermal steam was naturally selecting this path. Until the ORC was introduced and proved to be right, no other solution offered a real replacement. Nevertheless, wherever it was viable, supported by governments and local investors, steam-based power plants were established. This site remains one of the most illustrative examples of both the capabilities and the limitations of early steam-based geothermal technologies (mainly due to need of vacuum pumps) NCG contents, other mineral content, full overhaul of high cost and long standstill periods every 4-6 years, high sensitivity to geothermal resource characteristic changes, high cost of O&M, long period between first well to commissioning, long delivery period, high cost and long construction period, and maybe more. One can safely state that today, except for rare cases on pure high-enthalpy resource sites (mainly in Iceland), ORC is the preferred solution for geothermal resources. It offers just the opposite of all the drawbacks mentioned above, in addition to enabling the utilization of resources at a lower temperature and flow of what is needed for steam-based solutions. Nevertheless, until recently, ORC-based solutions did not offer an economically viable solution for resources lower than 110 °C and 100 T/Hr. This limitation left aside many cases of geothermal wells with such characteristics, which maybe could have been used for other applications, but could not participate in the generation of one of the best clean electricity sources.

### 2.1.3 Market potential and opportunity

The electric market is marching into a new era, which in a few words can be described as "**Resilience, Diversity, Scale-down, Independence**"**.** The massive introduction of renewable energy, the fast implementation of energy storage solutions, the speed of electric car penetration into our lives, and the several disastrous cases of national grid failure in recent years, all are forcing the world to rethink the electric market and the grid. A new term in this market is emerging. It is called REC- "**Renewable Energy Community**," which represents a group of mutual needs and potential production of energy in a defined area, which will develop a smart microgrid for its usage and needs, while maintaining communication with other such communities in its vicinity. Examples of such existing communities- hospitals, ports and airports, industrial areas, data centers, agro-tech communities, and many more. All of these communities have the potential to generate renewable energy locally, tailored to their specific needs and site conditions. Some may have geothermal resources available, but in most cases, not enough to justify a large-scale ORC power plant. Together with some existing cases and geothermal markets, they represent a huge opportunity for the small ORC solution, which can be installed easily on top of a well and deliver a mixture of electricity and heat to its immediate surroundings.




Geothermal applications
*Source: University of North Dakota*

## 3 METHOD AND TECHNOLOGY-

The Carnot efficiency of a typical geothermal resource is about 2.5 times lower compared to a conventional heat source power plant, motivated by water and heated by natural gas or coal burning, due to typically lower resource temperatures. This vast difference in Carnot and, consequently, in actual conversion efficiencies drives the industry of inherently low efficiency to focus on the minimization of all exergy deteriorating processes, where 0.5% in overall conversion efficiency can lead to 4% in power generation and affect a project's feasibility. Utilization of a low-grade heat source, such as geothermal, for power generation immediately raises a dilemma regarding the method of practical heat-to-power conversion implementation, obtaining maximal power at minimal cost. Assuming direct geothermal steam expansion is dismissed due to relatively low resource enthalpy or high NCG content, high O&M costs, or environmental considerations, at least four alternatives have been proposed by researchers and were actually implemented commercially or experimentally in an operating application. One of the main focal points for optimization is the heat input exchanging process where, under a finite temperature difference, the same amount of available heat can be converted to significantly differing exergy states of motive fluid, the loss of exergy or irreversibility, is proportional to the magnitude of the temperature difference over the heat transfer process. The most common geothermal heat resource to power conversion method is the Organic Rankine Cycle (ORC), Simplicity in operation and high equipment integrity based on vast engineering experience have driven this technology to be the favorite in terms of power generation availability and efficiency. The practical way of reducing the heat input irreversibility in an ORC is the utilization of two two-level single unit (high-pressure and low-pressure). For high enthalpy resource, superheating combined with internal heat recuperation was also found practical.

Until recent development of Enogia, practical experience showed that high working pressure combined with high fluid density of an optimized supercritical ORC provides for significantly higher cycle pump power consumption compared to a subcritical ORC, thus usually negating the attractiveness in terms of net power. Relatively high pressure and high turbine inlet density usually mean high turbine speed and the necessity of a speed reduction gear between the generator and the turbine, which reduces efficiency, along with lubrication and maintenance requirements. A complicated shaft sealing system is usually in place due to high rotational speed and high pressure.

Enogia has developed, manufactured, and installed over 230 units worldwide of its unique solution, which incorporates a very high RPM turbine, encapsulated in a patented way with the generator on the turbine shaft, and integrated into a relatively small compartment that includes also the heat exchangers, cycle pump, electric boards, and controls. The patented high-speed turbine enables reduction of the physical size to a small scale, which allows reduction in manufacturing cost, reduction of weight, and a significant reduction in working fluid quantity. Including the generator in the same encapsulated compartment enables sharing cooling system, avoiding gear, and several other benefits, including a better seal and bearing system. It also introduced a better service practice, as, with its small size, customer with full maintenance contract, at time of bearing service and replacement phase (4-7 years), receive the full encapsulated compartment, and replace it as a whole, with no need for field operations to open turbine, replace bearing, close again, with all hustle of full working fluid evacuations, etc. in a 2-3 day work the whole capsule is simply replaced, and the "old" capsule is shipped back for rehabilitation on the manufacturing ground.

Enogia unique ORC +generator
- Enogia library







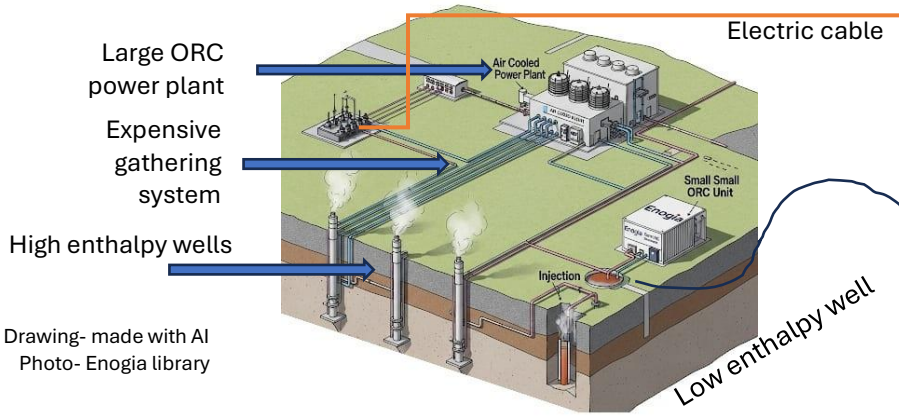
The introduction of the Enogia small PRC unit, referred to widely as MMO (Micro Modular ORC) enables Enogia to offer a wide range of small capacity selection of solutions. Since its establishment in 2009 until recently, Enogia has put its focus on the waste hit market, industrial, marine, and gensets. After constant improvement and R&D efforts, it is now time to introduce the solution, and its specific advantage for the geothermal market.

## 4 IMPLEMENTING THE ENOGIA SOLUTION TO THE GEOTHERMAL MARKET NEEDS

The immediate opportunity for the small ORC solution may be found today within 4 configurations (others may follow)–

### 4.1.1 Standalone wellhead unit –

Existing wells that were abandoned due to lower-than-expected temperatures can now be repurposed for efficient power generation using compact ORC units. It can also be an abandoned oil & gas well, which ended its original purpose but may still deliver hot water. In every such case, we can install a unit that will be designed and deliver electricity efficiently from this well, and add whatever power to the grid. Cost is minimal to the equipment and installation, no need for gathering system, switch yard, or whatever. It can also serve to deliver the auxiliary consumption of the entire field.




Drawing- made with AI
Photo- Enogia library



**Standalone Enogia unit at a geothermal wellhead**

4.1.2 Topping for existing operational wells-

In many places, geothermal energy is used for other applications, not electric production. The reason may be many, but in most cases, it is because temperature, flow, or other local reasons make it not economical. Most common applications in this segment are district heating, greenhouses, food processing, and balneology. Each of them needs a different range of flow and temperature. Nevertheless, many of these wells deliver a higher temperature than is required for their original application. A small ORC unit can be installed at the wellhead with minimal additional investment, allowing for efficient electricity generation before the geothermal fluid enters the existing system.

4.1.3 Mobilized MMO (Mobilized Micro ORC) for waste heat recovery from exhaust gases of the generator and other engines of drilling RIGs and their peripheral equipment.

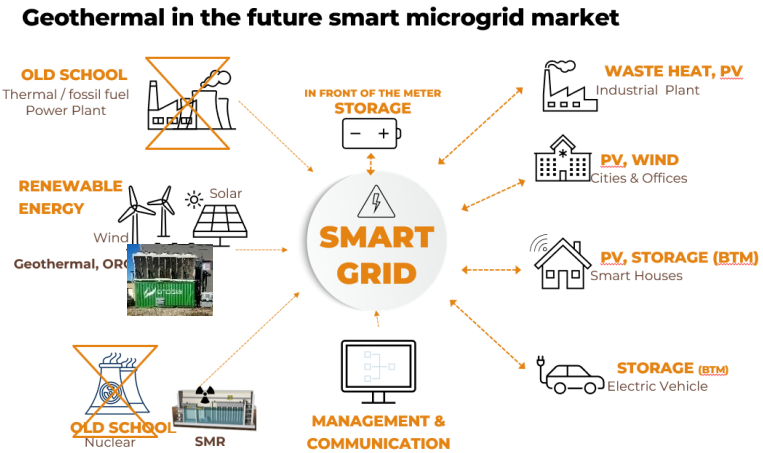
Electricity and power for the drilling rig operation and its peripheral equipment are a crucial factor, and are provided by a generator, usually fed by diesel. Other engines also operate in the RIG drilling sites. Drilling sites are usually remote and not near an electricity grid or other power facilities. Diesel fuel and/or other fuels need to be mobilized to the drilling camp regularly, a costly operation. By utilizing the waste heat from the exhaust gases of engines on site, the energy efficiency significantly improves, and costs are cut. With this Enogia unique mobilized ORC solution, the unit is fully transferable with the rest of the drilling RIG equipment.



Mobilized ORC
Photo- Enogia library

4.1.4 Integration with the REC – the new direction and future of the electricity market

Each such solution, as small as it may be, contributes to the local Smart Microgrid, delivers 24/7 baseload solution, increases the energy efficiency balance, improves the ROI and cost performance to the community, and stabilizes the grid. It is designed to work in a multi-production environment, changing resource situations, unstable grid, and in an island mode, as needed. The proposed solution of Enogia can include a well-managed and integrated energy storage unit,




Drawing made with AI,
photo- Enogia library

## 5 THE ENOGIA TECHNICAL AND COMMERCIAL PROPOSITION

Based on all the above, Enogia has developed what it believes is the most suitable solution. The solution, designed, manufactured, and offered by Enogia includes several key new innovative elements that match the needs and challenges described above:



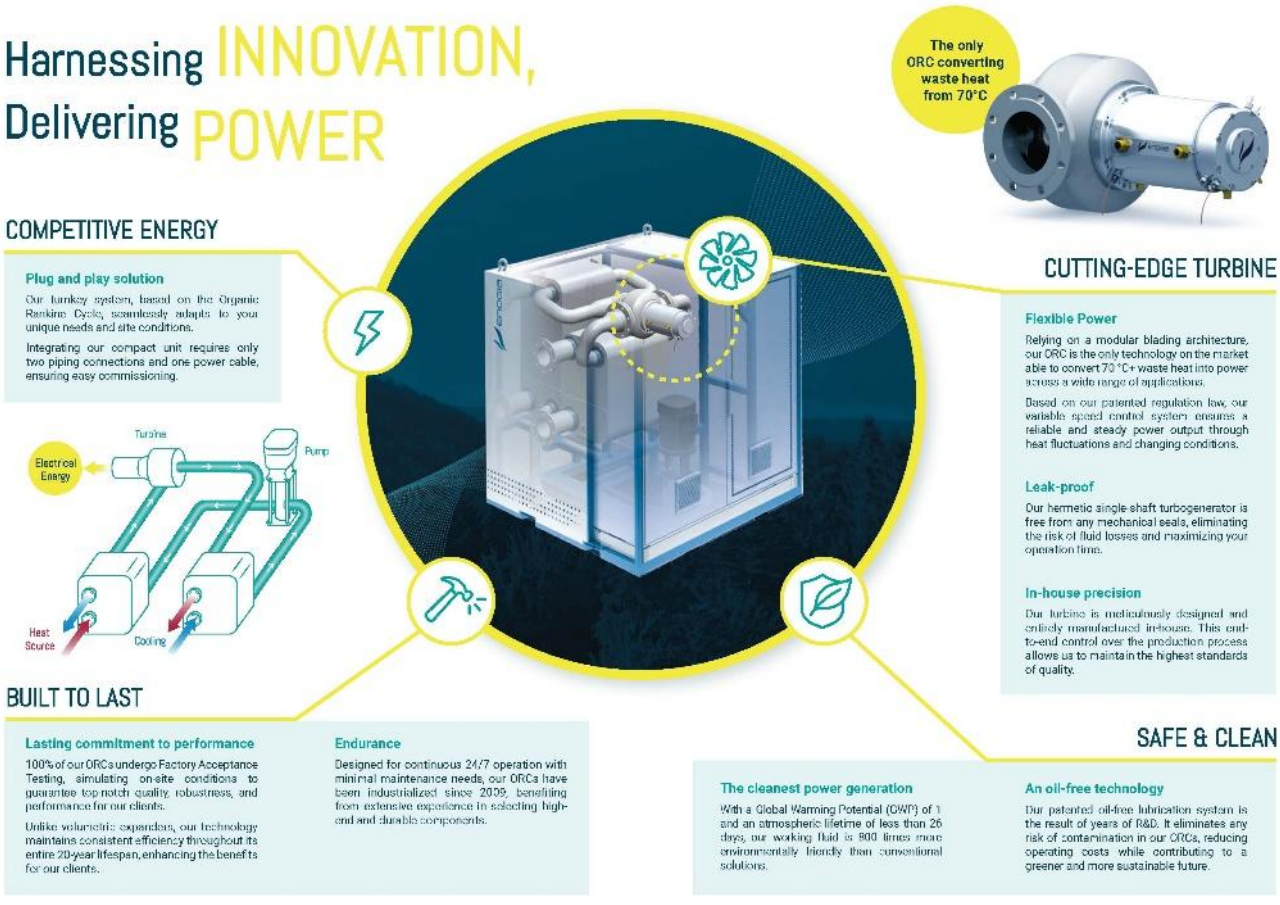
ORC +air cooling + containerized
Photo- Enogia library

### 5.1.1 The generating unit

- Micro-ORC high-speed turbine
- One shaft turbine-generator
- Patented generator seal and bearing
- Closed encapsulation of all rotating equipment
- Closed internal cycle of working fluid
- Inlet temperature of the resource starting at 70 °C
- Water or air cooled

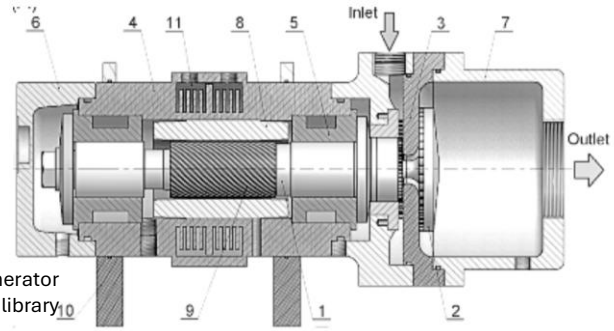
### 5.1.2 The power plant

- All components tested and fully assembled, ready for use at manufacturing
- Option to use external HX as needed
- Option to integrate with other applications, flexible thermodynamic design
- Fast delivery and construction
- low O&M
- Full compliance with all standards, regulations, and local needs



### 5.2 Turbine

ENOGIA turbine architecture is very different from traditional existing technologies. It includes hermetic integrated generator with a single shaft architecture, shown in the schematic below.




Conceptual drawing of the ORC+ Generator - Enogia library

The choice of a high-speed single-shaft hermetic coupling system tied to the grid through a grid feed inverter (active front-end) becomes particularly advantageous in Organic Rankine Cycle (ORC) applications. Here's an explanation of why this modern innovative configuration, taking advantage of the latest development in permanent brushless magnet generator and active power electronics technologies, is superior, especially in scenarios where minimizing leakage and optimizing power output are critical:

#### 5.2.1 Leakage Mitigation:

In ORC applications, where the working fluid is often expensive or environmentally sensitive, minimizing leakage is paramount. The high-speed single-shaft hermetic coupling system, devoid of gland seals and split shafts, significantly reduces the risk of leakage, ensuring the integrity of the working fluid and preventing costly losses.

#### 5.2.2 Compact and Streamlined Design:

The hermetic coupling system's single-shaft design offers a more compact and streamlined approach. With fewer components prone to wear and leakage, it minimizes the chances of system inefficiencies and maintenance requirements, making it particularly well-suited for ORC applications where space constraints may be a concern.

#### 5.2.3 Enhanced Reliability:

The simplified design of the hermetic coupling system results in fewer points of failure, thus increasing the overall system's reliability. This is crucial in ORC applications, where system downtime can disrupt processes and lead to production losses.

#### 5.2.4 Efficiency and Power Optimization:

ORC systems typically operate at lower power outputs compared to traditional steam cycles. The high-speed hermetic coupling system, paired with a grid feed inverter, allows for precise control and optimal performance even at lower power levels, ensuring that the ORC system operates efficiently regardless of varying loads.

#### 5.2.5 Adaptability to Variable Conditions:

ORC applications often encounter variable heat sources or load fluctuations. The hermetic coupling system's ability to operate at variable speeds allows it to adapt to changing conditions, optimizing energy capture and efficiency while maintaining a steady power output.

#### 5.2.6 Lifecycle Cost Savings:

The reduced maintenance, improved efficiency, and minimized fluid losses lead to significant long-term cost savings, making it a cost-effective choice for ORC applications.

Opting for a high-speed single-shaft hermetic coupling system connected to the grid through a grid feed inverter in ORC applications offers substantial advantages. It addresses the specific challenges of ORC, such as minimizing leakage, optimizing power output at lower scales, and ensuring reliability. Its streamlined design, enhanced efficiency, grid integration capabilities, and adaptability to variable conditions make it an ideal choice for efficient and sustainable energy generation in such scenarios.

### 5.3 Working fluid

The calorific fluid used in ENOGIA's LT ORC modules (for the Jacket Water) is the R1233zde. This fluid is chosen for its outstanding performance for the low temperature ORC applications while having the lowest Global Warming Potential (GWP) among refrigerants (<2). Thus, coupled with the ENOGIA turbo expander technology, it allows the waste heat recovery and conversion even with "low" temperatures such as water at 70°C.

Besides the performance aspect, these working fluids possess safety properties that guarantee the security of the people and the environment around the ORC:

- Non-flammable
- No color
- Very weak smell
- Non-toxic
- Neutral pH
- Very low Global Warming Potential

## 6 FINAL CONCLUSION

The highest portion of investment and risk in the geothermal market is in exploration, field studies, and drilling, up to the point where a resource is tested and proven to suit the needs. Thus, once a tested well/field is in place, it is only expected that the resource will be utilized to its best, enabling both high efficiency in whatever application is used, and well-managing the resource, to ensure as long life expectancy as possible. This statement applies to both natural geothermal resources and EGS / HDR projects.

Until now, it is relatively rare to find proper multi-application installations, where the resource is utilized not only for one application, be it generating electricity, district heating, balneology, agricultural uses, or other. The reason varies from actual needs on-site to a lack of understanding of the possibilities. But most of the time, technology was also a limitation, as electric generation was limited to a starting inlet temperature of 110°C and above, which is well above other applications' needs. In addition, the expected capacity was in most cases for 3MW and above, which left aside many resources that can also be utilized to generate electricity, but were "too small".

Today we can consider a proven, tested, and implemented solution for the "small" cases, both in low temperature and flow, that will increase the total efficiency of the resource, allow multi-application utilization and include abandoned wells that were previously left out of a project as it was "not aligned" with the rest of the wells.

Geothermal is a strong, stable source of energy for many applications, which should be utilized wherever possible in the most efficient way, while maintaining its life expectancy by well managing the resource. With the future trend of the REC (Renewable Energy Communities) that is fast developing in the world, small ORC units as discussed in the article above, should play a major role, wherever applicable, as the baseload of the smart grid.

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