



GEO THERM-FORA Deliverable D5.2

Annual Strategic Planning document for Policy Activities

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1 2024/2025 Review of the EU policy and regulatory developments

1.1 2025: Clean industrial deal

Since the new mandate of the European Commission in 2024, competitiveness and prosperity of the EU have been the highest priorities on its agenda. In this context, the Clean Industrial Deal¹ has been published on February 26th, 2025, as a guiding document for the upcoming political cycle and in support of European industries. The Clean Industrial Deal will mobilise over €100 billion to support EU-made clean manufacturing projects, a value of the European manufacturing market of €100 billion by 2030, and will create 500,000 new jobs.²

The Deal builds on internal and external political developments, the Draghi report and the engagement of industry leaders, but also social partners and civil society. The Competitiveness Compass,³ published in January 2025 is a key foundation to the Clean Industrial Deal, setting clear growth targets of a 17% share of the global GDP generated by the EU's single market, €10 trillion total savings held by European households and trade agreements with 76 countries. It clearly states the need to close the innovation gap in Europe by creating a friendly environment for young companies, helping big companies adopt new technologies, including AI, and supporting the development of new technologies by simplifying rules and laws. Reducing dependencies as well as decarbonising the European Economy remain central elements of the Competitiveness Compass.

The Deal addresses resilience, both in manufacturing but also to climate change. Consequently, the two major goals are the acceleration of decarbonisation and securing a European future with key manufacturing. Particularly important is the power that decarbonisation will have on the growth of European industries. The Deal will support European industries, facing high energy costs and high, sometimes unfair, global competition. It will allow for clear plan investments, ensure competitiveness while reaching the 2050 goal of a fully decarbonised economy.

Additionally, the Deal announces action by the Commission to reduce bureaucratic burden on the private sector and make the regulatory environment more efficient. Concrete actions include lower energy prices, creating jobs and adequate conditions for industries to thrive.

While boosting European companies, the Deal highlights European production capacity, adding to the well-known innovation capacity. It is centred around energy-intensive industries and clean tech – two highly interlinked sectors. In parallel, circularity and reducing raw material overdependencies on non-EU countries while maximising the EU's limited resources are key elements of the Deal. Tailored action to address these elements was announced, such as Action Plans for e.g. steel and metals.

Across the Deal, innovation to accelerate the transition, ensure European prosperity and competitiveness, is mentioned repetitively. The deal will stimulate engagement with industries, in particular SMEs and key sectors for the European economy, such as automotive, steel and metals, chemicals, transport and bioeconomy.

The Deal is divided into 6 chapters, each addressing a business driver to establish a thriving new European industrial ecosystem. These focus on the following:

1. Access to Affordable Energy

Competitiveness is built on the affordability of energy. The Commission adopted the Affordable Energy Action Plan, which entails the acceleration of electrification and roll-out of clean energy, completing the internal energy market physically and energy efficiency and cutting dependence on imported fossil fuels. Furthermore, lowering energy bills is essential, as well as promoting energy efficiency. This

¹ ('Clean Industrial Deal', n.d.)

² ('Clean Industrial Deal - European Commission', n.d.)

³ ('Competitiveness Compass - European Commission', n.d.)

includes the launch of a pilot programme for corporate Power Purchase Agreements together with the European Investment Bank and simplified State Aid rules. A European Grid Package has also been announced. Additional sub-chapters focus on the acceleration of the roll-out of clean energy manufacturing and ensuring well-functioning gas markets that deliver.

2. Lead markets: boosting clean supply and demand

This chapter focuses on building a business case for decarbonised products. Non-price criteria in public procurement and incentive for private purchases are addressed. With a connected publication – the Industrial Decarbonisation Accelerator Act – the demand for EU-made clean products will grow, motivated by public and private procurement criteria around sustainability, resilience and ‘made in Europe’. The public procurement framework will be reviewed in 2026 to adapt it accordingly. Moreover, renewable and low-carbon hydrogen will be promoted.

3. Public and private investments

To finance the clean transition, the Deal will mobilise over €100 billion in support of clean, EU-made production. To strengthen the EU level funding, the Commission will establish a new Clean Industrial Deal state aid framework, propose an industrial decarbonisation bank and reinforce the Innovation Fund. Horizon Europe funds will also be dedicated to stimulating research and innovation. Further, the InvestEU Regulation will be amended, increasing the amount of financial guarantees, mobilising up to €50 billion for clean tech, mobility and waste reduction. Thus, private investment shall be leveraged.

4. Powering the circular economy: a secure access to materials and resources

This chapter focuses on critical raw materials, crucial for Europe’s industry and decarbonisation. To reduce dependencies and enhance circularity, the Commission will build a mechanism for European companies to aggregate their demand for critical raw materials, create an EU critical raw material centre for joint purchases and in 2026, adopt a Circular Economy Act with the goal of 24% of materials being circular by 2030. This includes the fast implementation of the Critical Raw Materials Act (CRMA). Innovation is clearly mentioned as a driver for circularity.

5. Global markets and international partnerships

To ensure cooperation with reliable global partners, the Commission will set up Clean Trade and Investment Partnerships, trade defence and other instruments and simplify and strengthen the Carbon Border Adjustment mechanism. The goal is to have fair competition, mutual benefits and a secure and resilient European economy. This should be reached by promoting and protecting, and establishing a level playing field for the EU industry. In early 2026, the Commission will adopt guidelines on key concepts for the Foreign Subsidies Regulation and accelerate the use of Trade Defence Instruments.

6. Skills and quality jobs for social fairness and a just transition

This chapter addresses the just transition, with the goal of having every person and community benefit from the clean transition. To support the transition to a low-carbon economy, the EU workforce needs the right skills in clean tech, digitalisation and entrepreneurship. Via a Union of Skills, the Commission will invest in workers, skills development and the creation of quality jobs. Additionally, Erasmus+ will provide up to €90 million to reinforce education and training programmes.

1.2 2025: new policy initiatives

The publication of the Clean Industrial Deal was accompanied by an **Action Plan for Affordable energy**.⁴ The plan addresses the need for affordable energy to deliver on competitiveness targets, next to the fact that 46 million Europeans are affected by energy poverty. The plan is based on 4 pillars:

1. Lowering energy costs for all,
2. Completing the Energy Union,
3. Attracting investments and ensuring delivery,
4. Being ready for potential energy crises .

To reach those goals, 8 concrete actions have been identified with the aim of delivering several during the year of 2025.

- **Making electricity bills more affordable:** Particular efforts are needed in the field of network charges and taxation, for which incentives will be provided by the Commission. These include efficient use of the grid, lowering energy system costs, new grid investments and recommendations to EU Member States on lower national taxes on electricity.
- **Bring down the cost of electricity supply:** Existing EU electricity rules need to be applied, permitting procedures have to be accelerated, grids reinforced, and flexibility boosted. This could result in -40% wholesale electricity prices.
- **Ensure well-functioning gas markets:** cooperation between energy and financial regulators and regulatory oversight is required to get EU gas wholesale prices to pre-crisis levels. The EU will protect buyers and explore better deals for natural gas imports.
- **Energy efficiency – delivering energy savings:** Support by the Commission will be provided to energy efficiency solution providers through the Energy Efficiency Financing Coalition, and updating the energy labelling and ecodesign for products. This could raise savings to €162 billion in 2030 (€120 billion in 2023).
- **Complete the Energy Union:** This includes a fully integrated energy market via enhanced coordination to avoid a significant rise in costs by 2040 if no action is taken.
- **A tripartite contract to ensure affordable energy for Europe's industry:** These can counteract high energy prices and market uncertainty by bringing the public sector, energy producers and energy-consuming industry together to create a favourable investment climate.
- **Guarantee security of supply for price stability:** This is critical for economic resilience and ensures access to affordable energy and avoids extreme price volatility subject to external influences such as geopolitical tensions, extreme weather events or attacks.
- **Price crisis preparedness:** The Commission will guide Member States to incentivise consumers to reduce demand at specific times and allow transmission system operators and national regulatory authorities to temporarily increase electricity flows in cross-border interconnectors, in certain situations.

The **Vision for Agriculture and Food**⁵, published on February 19th, 2025, addressed the entire value chain within the EU and beyond, aiming to build up trust and create further dialogue.

The **Union of Skills**⁶, announced on March 5th, 2025, will allow for the delivery of higher level of basic skills, provide lifelong upskill and reskill opportunities, will facilitate recruitment by businesses across the EU and attract and retain the skills and talents. Via a strong governance foundation, it will be able to build on the new European Skills High-Level Board.

⁴ ('Affordable Energy - European Commission', n.d.)

⁵ ('Vision for Agriculture and Food - European Commission', n.d.)

⁶ ('A Union of Skills to Equip People for a Competitive Europe', n.d.)

The communication mentions the need to increase the energy workforce by 50% by 2030 to ensure the adequacy of renewable energy deployments, as well as grid and energy efficiency technologies. The latter shall be supported by a STEM Education Strategic Plan, published in parallel.⁷

With the kick-off of the new Commission's mandate, a set of simplification strategies is gradually published under the term: **Omnibus**. In February 2025, a proposal for a directive to simplify sustainability measures was published.⁸ The latter shall boost competitiveness and unlock additional investment capacity. It addresses legislations for sustainable finance reporting, sustainability due diligence, EU Taxonomy, carbon border adjustment mechanism, and European investment programmes. The goal is to reduce complexity for businesses, especially SMEs, while keeping up the possibility for sustainable finance for the clean transition for companies.

A financial relief of over €6 billion is expected on the administrative level, and the focus should go back to achieving the European Green Deal objectives.

On May 6th, 2025, the **Roadmap towards ending Russian Energy imports** was presented. This communication responds to the rebound in energy imports from Russia to the EU in 2024, despite the reduction from 45% to 19% of Russian gas imports, thanks to the REPowerEU Plan from 2022. The idea is to have a gradual removal of Russian oil, gas and nuclear energy from the EU energy market. By the end of 2025, EU Member States will prepare national plans indicating their contribution to phasing out energy imports from Russia. In parallel, the EU's energy transition and diversification continue to reduce risks on security of supply and market stability.

Measures include stopping all imports of Russian gas by the end of 2027, taking action on Russia's 'shadow fleet' transporting oil and restricting new supply contracts for uranium or other nuclear materials deriving from Russia. A legislative proposal will follow in the next month.

The Commission has officially proposed a **new 2040 target**⁹ emission reduction target, to be embedded in the EU's Climate Law. Published on July 2nd, 2025, the 2040 EU climate target should be 90% in net greenhouse gas emissions compared to the 1990 levels. This target will set certainty for investors, innovation and industrial leadership while increasing energy security. The target is in line with current initiatives such as the Clean European Deal, builds on the legally binding reduction target of 55% by 2030 and responds to a recently released study by Eurobarometer revealing strong citizen support for EU climate action. The proposal refers to geothermal twice, highlighting its key role amongst other RES for the energy transition. The publication presents certain flexibilities for Member States, such as international credits starting in 2036, the use of domestic permanent removals and cross-sector cooperation to help achieve the target. The proposal highlights the need for enabling conditions such as a competitive European industry, a fair transition and a level playing field with international partners. The proposal is now subject to discussions in the European Parliament and Council ¹⁰.

Additionally, the Commission published the **Recommendation on Tax Incentives** to incentive investments in clean technologies and industrial decarbonisation.

Further policy initiatives expected for the year 2025 and impacting the geothermal innovation and research branch are the multiannual financial framework (MFF) and the Affordable Housing Action Plan.

⁷ (European Commission. Directorate General for Education, Youth, Sport and Culture. 2024)

⁸ ('Commission Simplifies Rules on Sustainability and EU Investments, Delivering over €6 Billion in Administrative Relief - European Commission', n.d.)

⁹ ('EU's Climate Law Presents a New Way to Get to 2040', n.d.)

¹⁰ ('Communication on Innovative Technologies and Forms of Renewable Energy Deployment - European Commission', n.d.)

1.3 Paving the way for priorities in future EU R&I programmes

Geothermal energy R&I has historically received less funding compared to other renewable sectors. As the International Energy Agency (IEA) comments in its recent report on geothermal energy, “funding has been given to five times more wind energy and hydrogen R&I projects each since the 1990s, highlighting the disparity in funding priorities”. Last year, several EU institutions have been looking at the geothermal energy deployment in the EU, calling for more funding to allow the untapping geothermal potential within the European continent.

The **Council conclusions on geothermal energy** encourage "the Commission and the Member States to further increase the presence of geothermal projects in research, development, and innovation programmes, such as Horizon Europe, the Innovation Fund, and the SET-Plan, including its Deep Geothermal Implementation Plan." To bridge this gap, Horizon Europe WP 2026 should:

- Increase dedicated funding for geothermal R&I;
- Support technological advancements in drilling techniques to reduce costs and enhance efficiency, as emphasised in the **European Parliament resolution**, which calls for “investments in R&D in geothermal technologies and new drilling techniques”;
- Allocate a portion of existing EU research initiatives specifically for geothermal innovation, as proposed by the **European Economic and Social Committee (EESC)** opinion stating that “part of the existing R&D funding at EU level, including STEP initiative, should be earmarked for the development of geothermal energy”;
- Develop financial credit lines for geothermal heating and cooling infrastructures, as stressed by the **Committee of Regions (CoR)**: “Local geothermal energy production could be further developed and scaled up where it already exists, through the provision of suitable public guarantees and financial credit lines for geothermal heating and cooling, and electricity infrastructure development”.

Despite being a market-ready renewable energy solution, the geothermal energy sector is subject to impactful innovation and research. The following five stages can generally be assessed for R&I opportunities when looking at geothermal projects

1. Site investigation;
2. Exploration for resource assessment;
3. Drilling and subsurface engineering for resource development;
4. Utilisation and management of the resource to generate electricity and heating & cooling;
5. Operation and maintenance for the sustainable management of the resource and
6. Decommissioning after the end of life.

2 ETIP Geothermal activities in policy advocacy and engagement

2.1 Contributions to legislative discussions

ETIP geothermal actively participated in several open consultations launched by the European Commission on several topics relevant to the sector. These consultations offer a crucial opportunity to communicate the unique contributions and needs of geothermal energy as a key enabler of Europe's decarbonisation and energy resilience goals. By engaging in this process, ETIP Geothermal not only reinforces the visibility of geothermal within the EU's clean energy landscape but also advocates for policy frameworks that recognise its full potential. This proactive engagement helps align sectoral priorities with the evolving European regulatory and funding landscape, ultimately supporting a more inclusive and effective transition to a climate-neutral economy.

In April 2024, ETIP Geothermal provided its feedback on the open consultation launched by the European Commission on R&I challenges and priorities in the areas of clean energy and mobility. The survey served as input for the elaboration of future priorities in these areas for the EU.

In May 2025, ETIP Geothermal contributed to the call for feedback from the European Commission on the Horizon Europe Work Programme 2025. The contribution was given on Cluster 4 (Digital, Industry and Space) and on Cluster 5 (Climate, Energy and Mobility).

In May 2025, ETIP Geothermal participated in the public consultation opened by the European Commission on the 2028-2034 Multi Annual Financial Framework. In particular, ETIP Geothermal provided feedback on the consultations covering the "EU funding for competitiveness" and "EU funding for cross-border education, training and solidarity, youth, media, culture, and creative sectors, values, and civil society".

In May 2025, ETIP Geothermal also responded to the call for evidence on the European Strategy on Research and Technology Infrastructures. The position signals the following challenges:

- Fragmentation and limited coordination: Despite a number of excellent geothermal research infrastructures, they remain largely fragmented and under-coordinated across Member States. This limits Europe's ability to capitalise on synergies and scale up technological advancements.
- Funding limitations and sustainability: The financial sustainability of geothermal research infrastructures is a major bottleneck.
- Access and visibility: The geothermal research community and industry often face challenges accessing suitable infrastructure across borders. In many cases, awareness of existing facilities is limited, and access procedures are not harmonised.

2.2 Engagement with EU institutions and relevant stakeholders

During the course of the GEO THERM-FORA project, the ETIP Geothermal and/or the Geothermal IWG have successfully implemented a range of activities jointly with above listed initiatives and partnerships in order to increase the audience and maximise the impact of their activities.

- Participation in Clustering event of CINEA : 17 October 2022, side event to the EGC2022, Berlin Germany : A workshop together with other EU-funded project that are managed by CINEA
- Participation to the EU-pavilion at the EGC2022, Berlin, Germany, jointly with other geothermal EU-funded projects and the GEO THERMICA initiative (see **Error! Reference source not found.**)
- Geothermal Heat pump days, Berlin, Germany, 16-17 Nov 2023, jointly organised with RHC ETIP

- Roundtable on the « Heat Transition & Geothermal Energy Opportunities »¹ in Ptuj, Slovenia on 12 December 2023, jointly organised by GEOTHERMICA Initiative, CETPartnership TRI4 Heating & Cooling, Geothermal IWG, EEA Grants, Geological Survey of Slovenia, and the Ministry of Environment, Climate & Energy of Slovenia (see Figure 2)
- Geothermal Heat Pump Days 2024, 16-18 October 2024, Dublin, Ireland, jointly organised with the RHC ETIP
- Geothermal Innovation Days 2024, 21 November 2024, focus on latest advancements in geothermal technology, funding and market ready solutions, jointly organised with EGEN
- Supported RHC-ETIP National Roundtable for Croatian Solutions to Renewable Heating and Cooling, 11 February 2025
- CST4All Industry workshop² on the hybridization of Concentrated Solar Thermal Technologies with Geothermal, 10 March 2025, online (see Figure 3)
- Supported RHC-ETIP National Roundtable for Finnish Solutions to Renewable Heating and Cooling, 14 April 2025
- 100% RHC Event 2025, 7 May 2025, Brussels, Belgium

Next to the co-organised activities listed above, ETIP Geothermal and or Geothermal IWG have also participated in further activities, giving presentations at events, attending others and sharing inputs via written contributions.

- Active participation in 3rd ETIPs Forum meeting, 11 October 2022 – Discussion on merger of ETIPs and IWG Secretariats, future challenges and cross-cutting topics, participation of ETIPs FORUM at SET Plan Conference in Prague and Enlit Europe in Frankfurt and position paper with 10 recommendations to the EC
- Active participation in ETIP DG's Annual General Meeting, 13.12.2022 - Hybrid event focusing on Strategic Research and Innovation Agenda on geothermal technologies, Funding opportunities for R&I in geothermal and Review of R&I project results
- Active participation in 23rd ETIP SNET Governing Board Meeting, 8 February 2023 – Focus on restructuring and action plan, roadmap, clean transition energy partnership, WG dashboard work plans, communication activities, BRIDGE initiative
- SET Plan Progress Report 2023 ETIPs Input, 3 October 2023
- Active participation in ETIPs FORUM meeting, 15 February 2024 – Focus on NECPs, Upskilling and Reskilling, joint letter on continued funding, SET Plan conference and next common initiatives
- ETIP SNET Governing Board Meeting, 12 March 2024, Focus on policy updates, new focus area, admin aspects
- Active participation in Cooperation across SET Plan Implementation Working Groups (IWGs), 24 April 2024, Co-organised by SET Plan IWG6 and IWG4 ; Inter-IWG meeting: Geothermal Heat for industry ('Kable Zero'). The SET Plan IWG6 – Industry covering Action 6 on 'Sustainable and Efficient Energy Use in Industry' and the IWG4 – Energy Systems covering Action 4 on "Resilience & security of energy system" hosted the Cooperation across SET Plan Implementation Working Groups (IWGs).
- Contribution to SET Plan 2024 Reporting Exercise, 15 May 2024
- IWG5 policy session with DG Ener, 3 June 2024, focus on the implementation of the SET Plan 2023 and role of support office and task forces
- Active participation at Geothermal Transition Summit 2024, 8-9 October 2024, Luca Xodo speaking
- Active participation in the 18th SET Plan Conference on 14-15 November 2024 by GEOTHERM-FOR A partners. Gerdi Breembroek and Miklos Antics gave a presentation.
- Contribution to EuroGeoSurveys Strategic Research and Innovation Agenda: Building a Geological Service for Europe, 25.11.2024
- Attendance of Antwerp meeting with EC President von der Leyen launching the Clean Industrial Deal, February 2025, Marco Baresi (ETIP SC member) attended

- Active Participation at EU Investors Dialogue on Energy, 27.02.2025, EGEC (Sanjeev Kumar) speaking
- Active participation at ETIPs Forum Conference, 19 March 2025 on Advancing the SET Plan, ETIP Geothermal speaking on “Closing the Innovation Gap – reviving the virtuous innovation cycle”
- Contribution to EU Industrial electrification's Survey, 5 May 2025, EGEC contribution

Finally, ETIP Geothermal has also actively engaged with the European Commission, meeting representatives from DG ENER (B4) and DG RTD C.2 to present ETIP Geothermal priorities for the Horizon Europe Work Programme 2026-2027.

2.3 Policy events

With its aim of supporting and strengthening the geothermal innovation and industry sector, GEOTHERM-FORA, represented by Geothermal IWG and ETIP Geothermal, organised a variety of impactful policy events. These have been organised in different formats such as in-person high-level events, workshops, webinars or conferences, always providing a space to promote geothermal and related research and innovation with a wider audience. Throughout the events, staff of the European Commission, national governments and associations as well as sector representatives and partners have been present, leading to further impact of the events.

Deliverable 5.4 presents a full list of policy events organised between October 2022, the start of the project and Summer 2025, the end. Highlights include the following:

- The **ETIP Geothermal Annual Conference 2023**¹¹ which took place on November 21st and 22nd, 2023, in Pisa, Italy. The event focused on the Strategic Research and Innovation Agenda on Geothermal Technologies, the Review of R&I project results, funding opportunities, Research and Innovation to accelerate the geothermal market deployment and Innovation (high temp heat pumps). Members gathered for two days of enriching discussions and valuable insights. Attendees seized the opportunity to connect with industry peers, share ideas, and participate in engaging social activities.
- The High-Level Dialogue on a forward-looking Research and Innovation Agenda for Climate Neutrality by 2050, organised on June 12th, 2024, brought together experts to discuss how research and innovation can help accelerate the transition to net-zero emissions. The online event featured a presentation of the report ‘Research and Innovation for Climate Neutrality by 2050: Challenges, Opportunities and the Path Forward’¹² and a panel discussion. There was very successful engagement with the participants.
- The **Geothermal Policy Summit**¹³, which took place on June 17th, 2025 in Brussels was a high-level policy conference hosted by EGEC in partnership with ETIP Geothermal and GEOTHERM FORA, with the support of the Ministry of Climate and Environment of the Republic of Poland. This landmark event explored how the much-anticipated **European Geothermal Action Plan** can mobilise investment, foster innovation, and support cities in decarbonising their heating, cooling and power systems through the deployment and implementation of geothermal solutions. The event was attended by Commission representatives, Polish

¹¹ ('ETIP Geothermal Annual Conference 2023 – ETIP-Geothermal', n.d.)

¹² (Cambridge Econometrics et al. 2024)

¹³ ('European Geothermal Summit 2025', n.d.)

government representatives as well as local policy makes next to the usual attendance of the industry and research community working on geothermal energy.

Additionally, the forum attended a wide range of external policy events, many at which a representative – based on invitation - presented relevant content on geothermal. Key events are outlined below and just as for events organised by the FORA more details and events can be found in D5.4.

- At the 3rd ETIPS Forum meeting on October 11th, 2022, ETIP Geothermal representatives actively participated in a discussion on merger of ETIPs and IWG Secretariats, future challenges and cross-cutting topics, participation of ETIPs FORUM at SET Plan Conference in Prague and Enlit Europe in Frankfurt and position paper with 10 recommendations to the European Commission.
- The Cluster Workshops IWG and ETIP in Budapest, Hungary on November 13th, 2024 gathered ETIPs. Representatives provided input on needs and success of ETIP geothermal, addressing topics such as digitalisations, skills and market access with the goal to continue and strengthen input and outreach of ETIP geothermal.
- At the **18th SET Plan Conference: scaling up research, innovation and competitiveness in clean energy technologies on November 14th and 15th, 2024**, the Chair of the Geothermal IWG Gerdi Breembroek and the president of EGECE Geothermal Miklos Antics spoke about the role of Geothermal energy within the framework of the RepowerEU Plan and the Net Zero Industry and Critical Raw Materials Acts. This high-level policy event was attended by various Commission representatives.

3 Strategic priorities and future policy actions

3.1 Key R&I priorities to support climate and energy policies

The key R&I priorities are divided into 5 topics.

First, the focus is on increasing the sustainable production of geothermal in Europe. Efficient resource development requires increasing or sustaining the production of geothermal resources in the long run. To achieve this, some specific challenges need to be addressed, such as advancing drilling technologies, which involves, for example, developing high-penetration-rate drilling using AI-driven resource development, enhancing drilling fluids.

Another challenge is the optimisation of production and well design. This includes, among others, innovating production and stimulation technologies to enhance extraction efficiency, developing novel and optimised well architectures to improve geothermal system performance and encouraging advanced well designs to extend the lifespan of geothermal projects.

The aim is to optimise the performance of the geothermal system for long-term sustainability, enhance production from low-permeability reservoirs through innovative stimulation and well-completion techniques, improve the efficiency of geothermal fluid uplifting from the well bore and to increase cost-efficiency and competitiveness by integrating AI-driven optimisation and innovative drilling solutions.

Consequently, the following actions are necessary:

1. **Reservoir performance and sustainable management**
 - Develop and test AI-driven thermodynamic models
 - Improve subsurface characterisation to enhance the predictability and seismicity impacts
2. **Advanced well design and production technologies**
 - Develop effective and safe technologies for increasing energy production through: advanced well designs, innovative permeability enhancement procedures and new well completion technologies
3. **Next-generation geothermal pumps and lifting technologies**
 - Design second-generation geothermal pumps with prolonged lifetimes
 - Develop alternative lifting technologies to prevent mechanical erosion
 - Target technological readiness from TRL 6-7 today to TRL 8-9 by 2027
4. **Optimised thermal flow and energy management**
 - Enhance the ability to design and operate thermal flow systems in geothermal reservoirs
 - Improve the efficiency of geothermal power and heat plants by integrating advanced modelling and operational strategies.

The budget required in of €40 million for 4 projects with €10 million budget each.

The second topic is on innovative approaches for the geothermal acceleration areas, often blocked by accessible subsurface data. Hence, data acquisition has to be upscaled as well as exploration efforts. This requires harmonised protocols amongst EU Member States and assessment of geothermal energy stocks across Europe.

This translates to the main objective of **advancing exploration technologies** by improving resource imaging techniques to enhance subsurface characterisation and developing AI-enhanced reservoir modelling. It also includes **standardising data and resource assessment**, which can be done through

establishing harmonised geothermal databases for publicly accessible and shared data across the EU and implementing standardised resource and reserves estimation methods. Additionally, **ensuring sustainable geothermal management** is key via enhancing predictive capabilities to assess reservoir sustainability before and after drilling and encouraging continuous R&D innovation. Lastly, the objective is to enhance **economic viability and sectoral integration**. Thus, strengthening EU competitiveness in geothermal exploration through standardised data-sharing protocols and technological advancements and expanding geothermal integration in agri-food sectors to create sustainable energy applications should be done.

With these advancements, the aim is to improve geothermal resource identification and prediction before drilling, harmonise and share geothermal data across the EU to enable wider adoption, increase cost-efficiency and reduce exploration risks through advanced monitoring and modelling and to optimise well placement and reservoir management for long-term sustainable use.

To reach these objectives, the following actions are necessary:

1. **Innovative subsurface characterisation and forecasting**
 - Develop advanced methods to estimate and forecast subsurface properties and define the techno-economic feasibility of resources by 2028 (TRL 3 to 5)
 - Demonstrate developed concepts through resource access and business model refinements by 2030 (TRL 5 to 6)
 - Mitigate feasibility and operational risks
2. **Enhanced exploration and monitoring technologies**
 - Develop cost-efficient exploration and underground imaging technologies (TRL 3 to 6 by 2028)
 - Improve multidisciplinary exploration approaches (TRL 3 to 6 with an extended demo)
 - Enhance well logging and logging-while-drilling methods (TRL 3 to 6)
3. **Integrated resource and energy system management**
 - Develop innovative processes, materials, and technologies to enhance the management of geothermal resources
 - Promote geothermal applications in agri-food

This will require a budget of another €40 million, with 4 calls with €10 million budget each.

Topic 3 looks at enhancing geothermal energy integration in the energy system. The challenges addressed here are twofold. First, heating and cooling relate to **underground thermal energy storage (UTES)**, including the optimisation of high-temperature Aquifer Thermal Energy Storage (HT-ATES) for efficient energy storage and water quality management and integration of UTES in district heating and cooling (DHC) to enhance energy system flexibility. For **geothermal district heating and cooling**, the focus is on transforming 2nd to 5th-generation DH networks through retrofitting, grid coupling, and improved building efficiency. This is related to the smart integration of geothermal energy in dense urban environments for optimised seasonal storage and distribution. Additionally, **industrial and agri-food applications** require expanding the use of geothermal heat and cooling in industrial sectors requiring high-temperature applications, developing solutions for combined heat, cold and power supply to serve baseload industrial and agricultural demands efficiently and utilising geothermal heat for greenhouses and food processing to increase productivity and reduce operational costs.

As for electricity and Combined Heat & Power (CHP), **advanced Binary Plants & Binary cycle exploitation** are needed. This requires the development of advanced low-to-medium temperature (usually 100-180°C) binary plants to improve efficiency and scalability (TRL 5-6 to 8 by 2030). It includes the improvement of binary cycle performance through advanced heat exchangers, enhanced working fluids, material selection, and hybrid cooling technologies (TRL 4-5 to 6-7 and then 8) and the demonstration of the feasibility of flexible power generation, allowing geothermal plants to dynamically adjust output in response to grid demands.

The main objectives are to enhance geothermal energy integration into heating, cooling, electricity, and industrial processes, to improve system flexibility and efficiency through technological advancements and to reduce the costs of geothermal infrastructure and operations, making it more competitive. As well as strengthening sectoral integration, ensuring geothermal energy plays a key role in housing, industry and agri-food applications.

Among the major targets and KPIs related to generation technologies, this action refers to:

1. **Underground Thermal Energy Storage (UTES):**
 - Subsurface characterisation and optimisation of recovery efficiency for HT-ATES
 - Development of new borehole thermal energy storage (BTES)
 - Integration of phase change materials (PCM)
 - Optimisation of UTES integration with district heat networks
2. **Geothermal grid integration and transformation**
 - Smart DH integration: develop and implement optimised solutions for urban environments
 - Seasonal heat storage solutions for increased grid flexibility
 - Resource management strategies for high-density installation areas (TRL 6-9)
3. **Industrial and agri-food sector applications**
 - Integration of geothermal heat supply at low and medium temperatures for industries
 - Expansion of geothermal-based cooling solutions
 - Application of geothermal heating for greenhouse and food processing
4. **Advanced Binary Plants & Binary cycle exploitation**
 - Increase geothermal power plant efficiency by 15% by 2030 (from 12% average in 2019)
 - Reduce production costs by 15% across key applications by 2030
 - Develop geothermal binary plants with capacities greater than 30Mwe
 - Support the cost reduction of surface power plant components

This requires a total budget of €60 million for 4 calls with €15 million budget each.

Topic 4 addresses novel materials and equipment for the smart operation of geothermal plants. To ensure the long-term sustainability and cost-effectiveness of geothermal energy systems, the development of advanced materials, equipment, and eco-friendly solutions is essential. Key challenges include improving resistance to scaling and corrosion, enhancing high-temperature sensor technology, and integrating eco-friendly chemicals and materials into geothermal applications.

To address the need for alternative anti-scaling and corrosion-resistant materials, it is essential to develop environmentally benign scaling and corrosion prevention technologies (TRL 6-8 by 2028, TRL 9 by 2033), to design corrosion-resistant and anti-scaling materials for high-temperature applications to extend equipment lifespan and reduce downtime (TRL 5-7 by 2030, TRL 8-9 by 2035) and to develop safe and effective scaling removal solutions to maintain system performance (TRL 6-7 by 2028, TRL 8-9 by 2033).

For equipment and high-temperature solutions, **next generation geothermal pumps and lifting technologies** are of interest. This includes developing second-generation geothermal pumps with extended operational lifetimes under aggressive fluid conditions (TRL 6-7 by 2030, TRL 8-9 by 2035). It also refers to designing alternative lifting technologies to optimise geothermal fluid extraction and the development of high-temperature industrial heat pumps capable of operating at >200°C with COP <2 to improve efficiency. Additionally, **high-temperature sensors and monitoring tools** can benefit from the development of durable electronics and sensors for use in geothermal drilling operations to enhance wellbore stability and reduce operational risks, the creation of high-temperature data communications and telemetry technologies for real-time subsurface monitoring (TRL 6-9 by 2030) or

the development of electronics and sensors capable of withstanding up to 350°C by 2030 to enable more reliable geothermal system monitoring.

Eco-friendly solutions for geothermal systems require **eco-friendly drilling fluids and chemicals**. **this can be developed** with high-temperature, high-pressure stable eco-friendly drilling fluids to prevent equipment corrosion and extend system longevity (TRL 4-5 by 2026, TRL 6-7 by 2030, TRL 8-9 by 2035). **Advanced eco-friendly materials for geothermal applications** are of interest as well, including to develop sustainable casing couplings and cements to improve heat transfer efficiency, well integrity, and resistance fatigue and to conduct laboratory testing (TRL 5-6 by 2025-2030) and transition to realistic condition field testing (TRL 7-8 by 2026-2028).

The main objectives of these innovations are to: extend geothermal well and equipment lifespan through advanced materials and corrosion prevention, to improve geothermal efficiency and sustainability through eco-friendly solutions and to enhance geothermal competitiveness by reducing maintenance costs and improving operational reliability, as well as supporting different applications by ensuring geothermal energy remains a cost-effective and durable solution.

Concrete actions are the following:

1. **Advanced materials for long-term geothermal sustainability**
 - Improve heat transfer efficiency, durability, and scaling resistance
 - Develop cost-effective solutions for reducing operational risks in geothermal wells
2. **High-temperature equipment and sensor technologies**
 - Increase geothermal pump lifetimes and efficiency in harsh fluid conditions
 - Enhance sensor durability and communication reliability for high-temperature environments
3. **Eco-friendly materials and chemicals for sustainable geothermal operations**
 - Develop non-toxic, high-performance drilling fluids to enhance well stability
 - Optimise geothermal cementing and casing materials to ensure long-term system integrity

This requires a total budget of €40 million divided on 4 projects with €10 million budget each.

Topic 5 focuses on the demonstration of critical raw materials production made in Europe from geothermal sources. The development of critical raw materials (CRM) and other valuable minerals from geothermal brines presents an opportunity to support Europe's clean energy transition, economic competitiveness, and resource self-sufficiency. This requires overcoming challenges related to efficient extraction technologies, reinjection compatibility, and integration into market supply chains.

To address those, selective extraction technologies are important and can be addressed by developing advanced contaminant removal and selective extraction technologies to improve purity and recovery rates, optimising scalable and energy-efficient separation techniques for lithium, silica, magnesium and potassium and ensuring reinjection compatibility to maintain sustainable reservoir management and prevent environmental degradation. **Production and concentration enrichment technologies** benefit from developing innovative concentration and enrichment processes to increase the value of extracted minerals or creating cost-effective transformation technologies to convert geothermal brine components into market-ready products. **Geothermal brine product integration** needs new market opportunities for strategic materials derived from geothermal brines.

The main objectives are to develop advanced mineral extraction technologies to enhance geothermal plant competitiveness, improve the efficiency and sustainability of geothermal brine processing for CRMs and strategic minerals and to support EU self-sufficiency by reducing reliance on imported raw materials.

Consequently, the following actions are needed:

1. **Demonstration and validation of extraction technologies**
 - Develop TRL 5–7 pilot extraction technologies for lithium, silica, and magnesium (2024–2026)
 - Scale up TRL 8–9 production-ready technologies for commercial implementation (2027–2030)

- Deploy demonstration sites to test large-scale metal extraction for market integration
- 2. **Optimising geothermal plant economics**
 - Improve geothermal plant flexibility by enabling combined energy and mineral production
 - Enhance economic competitiveness
- 3. **Sustainability and reinjection strategies**
 - Develop solutions to minimise brine waste and optimise reinjection process
 - Conduct environmental impact assessments to ensure long-term reservoir stability
 - Implement life-cycle assessments to measure sustainability improvements in CRM recovery

This requires a budget of €50 million for 4 projects, €20 million to develop technical solutions to extract minerals and €30 million to test solutions in demonstration sites.

3.2 How Geothermal R&I contributes to policy priorities?

Geothermal energy plays a critical role in Europe's energy transition, providing a reliable, renewable, and local energy source for heating, cooling, and electricity generation. As the EU works toward its long-term goal of climate neutrality by 2050, geothermal energy stands out as a uniquely valuable renewable resource. Unlike other renewables, geothermal offers constant, baseload energy for both electricity and thermal applications, making it a reliable and flexible contributor to a decarbonised and secure energy system. R&I in geothermal technologies helps to unlock this potential by enabling the development of more efficient, cost-effective, and scalable solutions for harnessing heat from the Earth.

From a **competitiveness** perspective, geothermal R&I strengthens Europe's technological leadership and industrial capabilities in the global clean energy race due to its "Made in Europe" nature. Continued innovation in drilling techniques, subsurface imaging, reservoir engineering, and hybrid systems allows European companies to maintain a first-mover advantage in a rapidly expanding global geothermal market. It also supports the emergence of high-value supply chains, skilled jobs, and export opportunities, particularly in equipment manufacturing, engineering services, and digital solutions. By fostering home-grown technological expertise and reducing dependency on imported energy and technologies, geothermal R&I contributes to EU strategic autonomy and industrial resilience—objectives that have become even more urgent in light of global supply chain disruptions and geopolitical tensions.

At the same time, geothermal innovation is directly linked to **improving energy system resilience**. As a weather-independent source, geothermal can provide an uninterrupted energy supply, supporting grid stability and complementing variable renewables like solar and wind. This is particularly important in the context of increasing electrification, decentralised energy production, and growing demand for clean, dispatchable energy. Research into innovative system integration models, such as geothermal district heating, heat storage, and sector coupling, helps create a more flexible and robust energy system capable of adapting to changing consumption patterns and extreme climate events. Additionally, R&I is driving the development of new applications such as repurposing abandoned oil and gas wells for geothermal use, thereby accelerating the energy transition while minimising environmental impact and capitalising on existing infrastructure.

Energy affordability is another domain where geothermal R&I delivers tangible benefits. By lowering the costs of exploration, drilling, and operation through technological advances and digitalisation, geothermal energy becomes increasingly competitive with conventional energy sources. In areas with suitable resources, geothermal can provide long-term, predictable pricing for heat and electricity, shielding consumers and industries from volatile fossil fuel markets and contributing to more stable energy bills. Moreover, by tapping into local energy sources, geothermal reduces transmission losses and the need for expensive energy imports, which in turn alleviates pressure on national budgets and improves trade balances.

4 Conclusions

Geothermal energy plays a critical role in Europe's energy transition, providing a reliable, renewable, and local energy source for heating, cooling, and electricity generation. ETIP geothermal welcomes the European Commission's new initiatives and other strategic frameworks aimed at accelerating the green transition. Initiatives such as the Clean Industrial Deal and the Energy Affordability package recognise the importance of secure, affordable and sustainable energy, and geothermal energy plays a critical role in meeting these objectives. However, geothermal deployment faces significant barriers, including high upfront costs, subsurface uncertainties, and limited research and innovation (R&I) funding.

Geothermal energy R&I has historically received less funding compared to other renewable sectors. As the International Energy Agency (IEA) comments in its recent report on geothermal energy "**funding has been given to five times more wind energy and hydrogen R&I projects** each since the 1990s, highlighting the disparity in funding priorities".

The **Council conclusions on geothermal energy** encourage "the Commission and the Member States to further increase the presence of geothermal projects in research, development, and innovation programmes, such as Horizon Europe, the Innovation Fund, and the SET-Plan, including its Deep Geothermal Implementation Plan." To bridge this gap, funding dedicated to geothermal R&I should be increased, as well as support technological advancements in drilling techniques to reduce costs and enhance efficiency. A portion of existing EU research initiatives should be allocated for geothermal innovation. Finally, financial credit lines should be developed for geothermal heating and cooling infrastructures.

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