Science, technology and innovation are key drivers for unlocking productivity potential at a time of uncertainty

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Introduction

Today's world can appear blurred and confusing. Unexpected global events, such as the COVID-19 pandemic and military conflict, are posing unique challenges for society not encountered previously. Added to this is the ongoing, unresolved struggle to tackle global warming.

The last two years, since the start of the pandemic, have been particularly turbulent. The consequences, along with strikes in Colombia at the end of April 2021, have intensified pressure on the oil industry, so critical for the functioning of the world economy. A combination of factors, including the pandemic response, market volatility, digitalization and energy transition, has introduced challenges for the "typical" oil and gas company.[1] In this dynamic and changing context, science, technology and innovation (STI) have become indispensable for rethinking people's lifestyle. STI has a critical role to play in enabling energy and utility's agility, sustainability and resilience as the energy transition unfolds.[2]

STI opportunities for growth

This year's *Global Innovation Index 2022* poses the question of technology stagnation versus revival. We believe that, despite a slowdown in productivity on a global level, we are at a stage that is neither stagnation nor revival. What we are experiencing is an inflection point: an opportunity for growth and diversification enabled by a high take-up of digital technologies that needs an agile implementation of those technology solutions associated with renewable energy and energy transition.

Colombia can be considered a good illustration of this hypothesis. The country ranks 63rd worldwide and 4th in Latin America and the Caribbean in the 2022 Global Innovation Index (GII).[3] According to the GII, Colombia is improving at a steady pace, but needs to strengthen its innovation policies and governance in order to become more sustainable.

In Colombia, certain elements of the productive sector, such as digital startups, have seen a growth in investment over these trying times. This appears to have kept the local technology sector at the forefront of productivity and away from stagnation. The main reason for this growth – over 200 percent – was Colombian innovators solving basic problems faster during the pandemic, in domains as wide apart as the supply chain, food logistics and real estate, and in the energy sector in particular.[4]

The momentum gained in digital innovation has helped set the ground for new domains. One example is the field of energy/emissions transition, which seeks to find an energy-mix balance that complies with global emission commitments and regulations. In this domain, nature-based solutions emerge as a differentiator, due to the CO_2 emissions compensation capabilities offered by the second most biodiverse country in the world – Colombia.[5]

To remain profitable, companies like Ecopetrol (the largest energy company in Colombia) are now developing STI strategies along two major lines: digital and clean. With regards to digital, technologies such as artificial intelligence (AI), blockchain, internet of things (IoT) and augmented and virtual reality (AR/VR) are being implemented at each point along the value chain, namely, upstream, middle and downstream. This helps the company enhance its operational safety, agility and productivity, and also unlock new revenue streams. Digital technologies have allowed Ecopetrol to keep pace with global players in the energy sector, rethink business models and adapt them to a digital era in which environmental, safety and economic concerns are leading the way.[6]

In terms of Cleantech, Colombia has one of the cleanest energy generation matrices in the world, due to hydraulic generation and the entry of new, non-conventional renewable sources such as solar, wind and geothermal energy generators.[7] At the same time, there is a great potential for growth in the generation capacity of these technologies, which makes the country more competitive.

Colombia possesses renewable resources able to produce green hydrogen at competitive prices. Additionally, the country has coal and gas, which, when coupled with CO_2 capture, storage or use, can diversify the source of low-emission hydrogen, contributing to self-sufficiency.

This situation presents an opportunity, not only for national energy supply and transition, but also for international markets. Colombia is an attractive destination for electricity-intensive production, especially along the country's north coast, which, in addition to its high generation potential using renewables, presents an opportunity to connect to seaports for exporting products.

Achieving innovation efficiency through specialized clusters – the Ecopetrol experience

In this section, we introduce Ecopetrol's STI strategy experience report, highlighting how energy transition and digital transformation can be used as productivity performance boosters in the current global context.

In 2021, Ecopetrol started reorienting its STI strategy toward a more agile and dynamic strategy focused on business aspirations. At its core, this strategy envisions supporting competitiveness and resilience as a source of value in the energy/emissions transition process.

Energy/emissions transition supports a paradigm shift from a focus on internal knowledge development to an ecosystem orchestration approach that facilitates and accelerates the adoption and application of new technologies. In other words, Ecopetrol aims to become an energy innovation orchestrator able to develop, appropriate, adapt or access STI as part of a global ecosystem.[8]

Ecopetrol's orchestration efforts are focused on six main clusters.

1. Resilient assets: Appropriate and adapt advanced technologies for the purpose of:
    a. extending technical and economic limits of assets;
    b. discovering and adding new reserves;
    c. maintaining basic production;
    d. strengthening the reliability and efficiency of operations;
    e. maximizing operational margins;
    f. reducing diluent use;
    g. diversifying infrastructure use;
    h. minimizing fuel and product losses.

2. Decarbonization: Develop, appropriate, adapt and access advanced technologies for the purpose of:
   a. optimizing and reducing the carbon footprint of operations;
   b. developing renewable fuels;
   c. leveraging the potential of carbon, capture, use and storage (CCUS) projects;
   d. implementing nature-based climate solutions and other methods for carbon capture assessment and sequestration in Colombian strategic ecosystems;
   e. transforming and automating operations for reducing (scope 3) emissions from products;
   f. offering renewable fuels as advanced biofuels.

3. Energy transition: Develop, appropriate and adapt technological opportunities for the purpose of:
   a. supporting low-emission businesses;
   b. identifying uses for hydrogen and strengthening demand, industrial use and export;
   c. converting low-cost raw materials into marketable products (Petrochemical 2.0);
   d. adapting onshore and offshore wind technologies in an efficient way;
   e. maximizing the cost-effective use of photovoltaic technology;
   f. valuing and promoting use of oceanic energy and of natural geothermal heat from Colombian deposits and basins;
   g. accelerating the development of a value chain for gas and its derivatives.

4. The Fourth Industrial Revolution: Adapt, appropriate and access cutting-edge technologies for the purposes of:
   a. Systemically scaling smart, safe and sustainable products and processes;
   b. Defining the skills needed for coping with technological challenges;
   c. Developing advanced materials;
   d. Hyper-automating and extending human capabilities with intelligent machines that execute repetitive processes in an autonomous and controlled manner;
   e. Maintaining effectiveness in risk reduction through cyber security;
   f. Incorporating quantum-cognitive computing for modeling advanced materials;
   g. Modernizing communications and technological services to increase availability and coverage.

5. SusTechnability: Adapt and appropriate technologies for the purposes of:
   a. connecting and co-creating STI in communities;
   b. facilitating access to technologies that promote economic and social development in areas of influence;
   c. creating community-based training spaces and platforms.

6. Circular economy: Adapt, appropriate and access technologies for the purposes of:
   a. reducing waste and generating value by giving it new uses;
   b. decreasing the collection and disposal of fresh water;
   c. reusing disposed water in agriculture;
   d. recycling chemical substances;
   e. converting plastic waste;
   f. generating new products from waste.

Each cluster is derived from the technological challenges and roadmaps to be implemented via projects or programs, either internally or through the support of partners from within the STI ecosystem.

Some examples of developed programs in this direction are as follows. By 2023, Ecopetrol plans to incorporate 400 MW of non-conventional renewable energy (NCRE) into its supply matrix. This process is aimed at self-consumption, including through the development of self-generation projects and the purchase of renewable energy through Colombia's National Interconnected System.[9] Since the launch of the San Fernando Solar Ecopark on October 9, 2021, and until reaching a capacity of 61 MW, the Ecopetrol Group incorporated a total of 112.5 MW of renewable energy in its supply matrix (8 percent of the installed capacity), making it the largest renewable energy self-generator in Colombia.[10] As of March 2022, San Fernando has made it possible for Ecopetrol Group to reduce emissions by about the equivalent of 8,700 tons of CO_2 for the same period.

Colombia is well positioned to identify any profitable opportunities offered by the growing hydrogen industry and thereby become a regional leader in energy transition. This process is further supported by its convenient geographical location and a stable regulatory framework that incentivizes investment.[11]

The development of hydrogen production and the adaptation of economic sectors to its use will require substantial investment in the development of technology and the creation of infrastructure. Colombia has created investment plans and incentives to develop complete value chains based around low-emission hydrogen. These plans have been combined with a series of regulatory developments, including the creation of relevant research and development (R&D) policies in line with industrial policy and the creation of markets encouraging hydrogen use. Colombia aims to accelerate the acquisition of national capacities and penetrate the global export market for hydrogen and derivatives, including through international cooperation in the areas of new technologies and project financing.[12] Currently, a Caribbean hydrogen export hub serving demand for hydrogen in markets both in the Atlantic and the Pacific is being strengthened. This hub is strategically located near North America, with direct access to European markets through the Caribbean, as well as access to Asian markets, either through the Panama Canal or from Colombian seaports along the Pacific coast. Colombia is also ideally positioned to serve any hydrogen demand originating from Central American countries.

The deployment of sustainable energy vectors, such as hydrogen, will encourage the creation of innovative industrial capacities and technological knowledge, mobilizing potential investments and creating jobs with high added value. For instance, on March 18, 2022, Ecopetrol began a pilot project into producing low-carbon hydrogen at its Cartagena Refinery. It began with a 50 kW capacity electrolyzer. The project aims to generate sufficient data to evaluate the feasibility of hydrogen production, transportation and usage.

One example of the many opportunities afforded by digital technologies is an integrated emissions management digital platform. In alliance with Microsoft and IHS Markit, Ecopetrol is working to develop an innovative green-house gas emissions digital management tool for strategic emissions optimization. The intention is for the digital platform to improve emissions measurement and benchmarking, foster more accurate emission projections and develop more dynamic abatement cost curves for better decision-making on abatement opportunities. The platform will define a standard data model for emission measurement and connect and blend all the data from the different systems that contain emissions-related data in the model. The platform will expose anonymized data in web services. Through Ecopetrol's data platform it will exchange information with third parties for benchmarking purposes. This platform is projected to meet Net-Zero Roadmap and emissions reduction goals and will contribute to making into a reality a program on methane emissions reduction in operations, in accordance with the United Nations Environmental Programme's (UNEP) Oil and Gas Methane Partnership (OGMP) 2.0 Framework.

Another example is an innovative hydrocarbon volumetric management approach based on disruptive technologies. This transformation was realized through the implementation of a platform named TRUE. TRUE is a solution focused on tackling the needs and challenges of the digitalization process by integrating the digital technologies of the Fourth Industrial Revolution, for example, cloud computing, blockchain, machine learning, big data and robotics. By integrating the different aspects of the supply chain and systematizing business processes, TRUE is able to predict scenarios for high-level decision-making. The solution adopted allows the following:

- perform daily inventories of property with estimated balances;
- automate the handcrafts in the field and in the closings of the volumetric balances going from 5 days up to 1;
- send to the ERP system the information on monthly costs and inventories with the required frequency;
- assign volumetric responsibilities to a business allowing it to measure, record, analyze and act on relevant processes;
- consolidate measurement, quality and balance sheets in order to assure standards, balances (operational, estimated and official), losses and process performance.

The platform was implemented using 100 percent agile methodologies that accelerated adoption and reduced complexity.

The platform is based on blockchain technology, which, thanks to its transparency, traceability, immutability and consensus mechanisms, allows a timely and reliable flow of information. The modeling of the supply chain on blockchain was innovative, because it enabled a full vision of all volumes of data and enabled Ecopetrol to visualize crude and refined products in a timely manner at every node. Currently, the platform supports Ecopetrol's value chain and its transporters. However, the chain can be extended to incorporate external transporters and actors, who could use it for modelling the main actors within the country and their interactions. In the TRUE platform's case, there are two differentiating technology factors that have enabled value capture: first, the use of logic and smart contracts to perform real-time validation of the origins and destinations of each node and of the products that can enter or leave each node; and second, the use of consensus mechanisms every time an event triggers changes to chain nodes. This helps guarantee the integrity and consistency of information and ensures a timely capturing of simple information.

One final example of how digital technologies can contribute to solving circular economy challenges has to do with water management. Water is a vital resource for the development of Ecopetrol's operations, as well as for communities in those areas where it carries out its operations. On average, 13 barrels of water are extracted for a single barrel of oil. The primary challenges for effective integrated water management are:

- lack of real-time water volume and quality monitoring across the value chain;
- a complex decision-making process regarding water usage;
- operational risks associated with water supply due to non-homogeneous availability (quantity and quality) across time.

Essentially, the objective of this initiative is to develop a solution that will provide real-time visibility and optimize water usage across the extended value chain (including communities) by addressing the innovation challenge faced by Ecopetrol. This solution should facilitate the decision-making process based on operational, environmental and financial drivers (e.g., water as potential revenue stream), suggesting the next-best-action to optimize general interest objective functions. Moreover, the platform should provide meaningful insights and predict operational impacts based on a lack of a homogeneous availability (quantity and quality) of water and other risks, by integrating existing internal tools and leveraging analytical and AI models. In partnership with Amazon Web Services (AWS) and Accenture, we are conducting an innovation exercise into water neutrality throughout Ecopetrol's segments and watersheds by implementing disruptive digital technologies.

The solution should be able to follow and manage key performance indicators (KPIs) related to water usage, efficiency and pressure on water resources (water footprint). The ecosystem is facing the following challenge: how can we transform Ecopetrol's water value chain, starting from the water required to operate to the effluent management thereof, covering each segment's requirements, namely those of location, communities and watersheds.

With such an integrated water management tool, Ecopetrol will not only be able to optimize its internal process, but also positively impact communities and watersheds by improving water supply and securing access to this vital natural resource. In addition, this solution has the potential to unlock new revenue sources through finding other uses for water.[13]

Leveraging innovation through orchestration – the Ecopetrol experience

"Energy that Transforms" is Ecopetrol's comprehensive, long-term strategic response to current challenges in the environmental, social and governance domains which maintains a focus on generating sustainable value for stakeholders.[14] Its objective is to foster an agile and dynamic organization able to adapt quickly to changes in the energy industry, paving a way for the Company to become an energy-transition leader on the continent of America.

To meet the goal of becoming a multi-energy company, a transition from a value chain to a value ecosystem is needed. Therefore, it is important to join forces in order to structure, launch and implement Innovation and Technology Centers across different regions of the country. This will only be possible through multilateral agreements and commitments from governmental institutions, academia, chambers of commerce and other large companies active within the energy sector.

In Colombia, government agencies, such as INNPulsa or the chambers of commerce, help reach relevant actors at the regional level. At the national level there exist initiatives such as Cemprende, a Colombian Government effort launched in December 2019 to facilitate a connection between entrepreneurs, academia, the private sector, government and society for the sake of strengthening and energizing the development of entrepreneurship and innovation within the country.[15]

The question is how to start guiding an ecosystem toward acquiring knowledge and high-tech capabilities? A starting point is understanding the business strategy and how it can be supported by STI. Earlier, we reviewed six clusters that serve to focus technology efforts on improving business strategy. A first attempt to look for answers was made in 2019, when the Digital Innovation Studio was founded in Cemprende Bogotá. The Digital Innovation Studio promotes the solving of problems through digital technologies, such as machine learning, big data, elastic computing, IoT, edge-computing, AR/VR, blockchain and so on. The objective of a program named 100×100 was to solve 100 challenges facing 100 Colombian entrepreneurs. This was the first actual innovation node associated with cluster 4, the Fourth Industrial Revolution. Later, two additional innovation centers were founded in two other Colombian cities and associated with clusters 1 and 2, resilient assets and decarbonization. One of the centers was named S-Innova. Launched in Bucaramanga, its goal was to start developing solutions associated with nanotechnology and biotechnology.

In 2021, 253 new digital products were launched by Ecopetrol. They included robots, analytic models, dashboards, workflows, integrations and portals; one of the best achievements among 4,600 similar initiatives globally.

Conclusions

Oil and other energy companies must protect their core business, when expanding into new markets, balancing climate change pressures and their own financial viability. A great many oil and gas companies are starting to diversify into a range of low carbon opportunities, from electrification using renewables (solar, wind, geothermal) to CCUS, biofuels, and blue and green hydrogen. These endeavors must be closely aligned with existing portfolios, strengths and corporate capabilities.

Transition-oriented technologies, such as digital and energy/emissions technologies, offer an opportunity to halt productivity decline or stagnation. Ecopetrol has emerged with an ambitious energy transition agenda. In March 2021, it was the first Latin American national oil company to adopt a net-zero target, and one of the few with a target encompassing Scope 3 emissions.

As an immediate call to action, Ecopetrol has planned a new STI strategy, with a strong focus on six clusters encompassing technology adaptation, appropriation, development and access. Those clusters are: resilient assets, decarbonization, energy transition, the Fourth Industrial Revolution, susTechnability, and a circular economy. Each cluster includes technological challenges that cannot be solved solely by internal capabilities.

Leading an energy ecosystem has become essential for keeping pace with international competition. Being an excellent orchestrator is vital for finding new ways of executing processes across the whole energy value chain. It is not only about being exposed to cutting-edge technologies, but also connecting with disruptive thinking processes.

Orchestrating the ecosystem also requires the involvement of an array of parties, including government agencies, universities, research institutes, communities of knowledge, consortia and so on. Therefore, having a vision that incorporates all relevant clusters is a significant advantage. An effective approach to existing challenges can improve productivity figures, not only at the organizational level, but at the ecosystem level. Adapting, appropriating, accessing and developing technologies will make greater business sense, once investments obtain the desired return.

Notes

1 Ellerback, 2022.
2 Ecopetrol, 2022e.
3 WIPO, 2021.
4 Government of Colombia, 2022.
5 Ecopetrol, 2022c.
6 Ecopetrol, 2022b.
7 IDB, 2019.
8 Ecopetrol, 2022a.
9 Ecopetrol, 2021a.
10 Ecopetrol, 2021b.
11 IDB, 2021.
12 MinEnergia, 2021.
13 Accenture, 2022.
14 Ecopetrol, 2022d.
15 Impacto TIC, 2019.

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