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FEATURING
POWER

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Dear **watt**now reader,

Power is at the forefront of all discussions, whether you are sitting in a meeting or grabbing a coffee at your nearest barista.

Because South Africa is experiencing power outages intermittently and many people are frustrated, I thought it apt to bring you this issue. We have to look at alternatives to reduce the load on our crippling utility.

Consumers do not understand that power stations need to be maintained, and without maintenance for an extended time, you will sit with what we are experiencing now!

Think about it this way - will you, for the next ten years, get in your car and drive it around without servicing it? Well, I hope your answer is no, so Eskom needs to catch up on the lack of maintenance in the last decade.

Our first feature article discusses what it will take for our ailing power utility to keep going. The country's Integrated Resource Plan of 2019, a cabinet-approved document, sets out the timelines for decommissioning coal-fired power stations and adding 44GW of new capacity, including 18GW of wind energy and 8GW of solar (photovoltaic). Read it on page 20.

I took the liberty of offering you an insider report on Fostering Effective Energy Transition on page 24. The World Economic Forum compiled this report given the current volatile macroeconomic and geopolitical environment. Trend analysis from historical energy data can currently provide only limited insights. Hence, instead of the annual country energy transition benchmarking report, this special 2022 edition builds on the ETI trends observed in recent years to provide a perspective on the current challenges affecting the transition and highlights priorities to supercharge it.

Page 66 offers you an article which takes a look into Carbon Offsets and asks the question if Africa is ready. As countries commit to reaching net-zero by 2050, how will carbon offsets significantly reduce emissions?

The July issue features IR4.0 - communications and new technologies. The deadline is 22 June. Please send your articles or papers to minx@saiee.org.za.

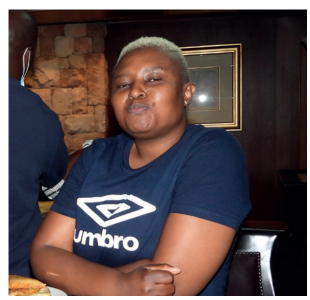
Herewith the June issue; enjoy the read!

Southern Cape Centre - President's Inaugural Address Tour

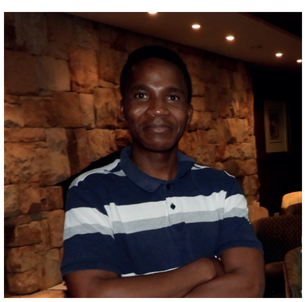
The SAIEE President, Prince Moyo, delivered a summary of his Inaugural Address entitled "Analytics and Decision-Making in Business" to members and guests of the Southern Cape Centre on Wednesday, 18th May. The meeting was held at the Pezula Golf Club in Knysna, and 19 people attended, including the Acting Municipal Manager for Knysna, Mr Johan Jacobs, and the Member of the Knysna Mayoral Committee responsible for the Finance and Economy Portfolio, Cllr Sharon Sabbagh.

From left: Mr George Debbo, SAIEE Past President; Prince Moyo, SAIEE President; and Steyn van der Merwe, Chairman SAIEE Southern Cape Centre.

During his presentation, Mr Moyo expressed his concern at the way engineers within utilities used the issuing of tenders and contracts as a first choice to address engineering problems rather than using their own skill and experience in solving such problems. In Mr Moyo's opinion, this action relegated engineers within the utilities to nothing more than project managers. This sentiment resonated well with both the Knysna Acting Municipal Manager and the Councillor responsible for Finance and economics. In the subsequent discussion, SAIEE agreed that we would approach the Knysna Municipality with the object of offering mentoring services. Past President George Debbo presented the vote of thanks after the discussion and gave the members present feedback on the recent visit that the Centre undertook to the Openserve Undersea Cable Landing Station at Melkbosstrand. A report on this visit will be published shortly.



After the meeting, the members and guests present were invited to join the President and Chairman of the Southern Cape Centre in refreshments. wn



SA's biggest gold mine to harness solar power – combatting load shedding and saving R123m a year

South Africa's biggest gold mine is switching to solar power later this year, saving R123 million in electricity costs, lowering its carbon footprint, and mitigating load shedding disruptions.

Gold Fields' South Deep mine will soon draw a quarter of energy from the sun. The mining company got the green light to construct a solar power plant from the National Energy Regulator of South Africa (Nersa) back in 2021.

The plant was initially planned to have a capacity of 40MW, but four months after Nersa's approval, the South African government increased the embedded generation threshold to 100MW. Following an additional optimisation study, Gold Fields increased the plant's planned capacity to 50MW, with the potential to expand to 60MW.

South Deep's Khanyisa solar power plant will consist of more than 100,000 photovoltaic (PV) panels and, occupying an area of 105ha or roughly 200 soccer fields. When fully operational, the plant will account for 24% of South Deep's annual electricity consumption and reduce the mine's carbon footprint by more than 110,000 tonnes of CO_2 a year.

The plant, which will cost Gold Fields around R715 million to build and operate, is expected to come online in the third quarter of 2022.

In addition to reducing electricity costs through renewable energy, aligned with Gold Fields' target of cutting a third of its carbon emissions by 2030, South Deep's plant will also take some pressure off South Africa's embattled power utility Eskom.

The country's mining industry consumes up to 30% of Eskom's annual power supply, according to Minerals Council South Africa. Decreasing its reliance on Eskom will effectively free up more energy for the rest of South Africa, and high-capacity renewable installations could keep mines operating during severe rotational cuts.

But while solar power will answer most of South Deep's electricity needs under the clear midday sun, there are still concerns that peak usage periods – in the mornings and evenings – will remain volatile.

"One of our challenges in interactions with Eskom has been the normal morning and evening peaks and concern raised by Eskom that as the solar comes off everybody is arriving home, cooking dinner, running baths, and similar things... and they get a double spike," explained Gold Fields' Executive Vice President Martin Preece, during a presentation on the Khanyisa plant, back in August 2021.

"So, one of the things we are looking to do, is how do we shift maintenance activities into these evening and morning peak windows to take pressure off Eskom to ensure that we don't add to their woes."

A presentation delivered at the recent Mining Indaba by Gold Fields CEO Chris Griffith noted that the company was "also examining wind power" – in addition to the solar power plant – at South Deep. wn

Corporate SA to take responsibility for Advancement of Women Engineers

Despite decades of efforts to drive diversity and increased the number of females within the local Science, technology, engineering, and mathematics (STEM) industry, there is still a wide gender gap that exists across related sectors. This gap could be attributed to the various challenges that women still face when looking to enter the sector and progress in their roles as STEM professionals.

This is according to the Regional Director of Sub-Sahara at Arçelik and CEO of Defy Appliances, Mustafa Soylu, who points to UNICEF South Africa research, which highlights that women continue to experience a gender gap in STEM-related careers after college, with less than 28.5% graduating to careers in STEM.

He says that while South Africa has made strides over the past few years when it comes to the number of women in STEM careers, the country and African continent still have a long way to go to bridge the gender gap that exists in the sector. "Corporates in South Africa need to play a pivotal role in addressing and transforming the gender gap across STEM, especially those who do business in the sector."

Soylu goes on to explain that this deep-seated conviction has underpinned the decision taken by Defy South Africa to take on a mission in line with the social commitments of Arçelik, Defy's parent company, to support the gender equality movement in technology and innovation in cooperation with UN Women's Generation Equality Forum. This movement has formed the backbone of the newly launched WE-inTech programme which aims to offer training, internships and job opportunities to women pursuing careers in the STEM field.

"Creating a workforce with STEM skills is critical to achieving global economic growth. And although the number of women in STEM fields has increased over the last 50 years, it appears that the trend has slowed, particularly since the 1990s. Our aim with the WE-inTech project is to raise awareness by emphasising the importance of Research and Development (R&D), encourage young women to pursue careers in related fields, and implement a long-term and effective programme to increase women's participation in new generation R&D.

We are proud to launch a project that reflects our commitment to giving back to South Africa while also demonstrating that we are true allies to women students on their educational and professional journeys. We look forward to welcoming applicants to this exciting initiative." wn

Hitachi Energy and Schneider Electric collaborate to speed up the energy transition

Hitachi Energy, a market and technology leader in transmission, distribution and grid automation solutions, and Schneider Electric, the leader in the digital transformation of energy management and automation, have announced that they have entered into a collaboration to provide greater customer value and accelerate the energy transition.

The non-exclusive collaboration will support customers' sustainability efforts, including decarbonising energy and industrial sectors. Hitachi Energy can leverage Schneider Electric's medium-voltage portfolio, while Schneider Electric will be able to use Hitachi Energy's high-voltage portfolio to provide more comprehensive offerings. This new collaboration builds on the trusted track record, global footprint, and extensive experience of these sustainable energy technology leaders in delivering projects for renewables, data centres, mining and other industry segments. Both companies expect this collaborative ecosystem to ensure benefits for customers across their operational life cycle, including a more holistic offering, strengthened supply chain and enhanced efficiencies.

"We continue to innovate with technology and business models to advance a more sustainable, flexible and secure energy system," said Claudio Facchin, CEO of Hitachi Energy. "We have chosen to collaborate with Schneider Electric by enhancing our complementary portfolios and address the need for faster deployment of grid solutions for our customers," he added.

"We are launching this collaboration to help our customers deploy the green electricity solutions instrumental in the fight against climate change," said Jean-Pascal Tricoire, Chairman and CEO of Schneider Electric. "With Hitachi Energy, we're committed to leveraging our respective strengths to solve our customers' most pressing energy challenges."

The MICT SETA and mLab partnership aims to equip South Africans for opportunities and challenges of Industry 4.0

An exciting new partnership between mLab and the Media, Information, and Communication Technologies Sector Education and Training Authority (MICT SETA) is poised to introduce several Information and Communication Technology (ICT) related interventions that will equip South Africans to respond to the demands and opportunities of a technology immersed future.

mLab is a technology-focused company that collaborates with partners to create a vibrant and robust innovation ecosystem. The non-profit organisation accomplishes this by identifying and nurturing young tech talent, assisting aspiring tech entrepreneurs and their fledgling businesses, and developing technology that affects change and improves the lives of ordinary South Africans.

mLab's headquarters are in Pretoria, Gauteng, with provincial offices in the Northern Cape and Limpopo. To make our skills academy as accessible as possible, we have academies in Tembisa, Tshwane, Soweto, Polokwane, and Kimberly. We also run programs in other Southern African markets and can provide program participants with access to international opportunities.

According to the Education Commission, more than half of the nearly 2 billion youth worldwide will not have the skills or qualifications necessary to participate in the future characterised by the convergence and complementarity of emerging technology domains, broadly referred to as the Fourth Industrial Revolution (4IR), or Industry 4.0. This dire shortage of skills translates to more than 50% of tomorrow's human capital being potentially unprepared to enter the workforce. This is bound to worsen existing chasms between those prepared for 4IR and those who are not.

The partnership between mLab and MICT SETA is set to address this pressing challenge in South Africa through many interventions, including accredited skills training, ecosystem building, workforce development programs, and public policy. ''The agreement between the two parties brings South Africa closer to the National Development Plan; Vision 2030," says mLab CEO Nicky Koorbanally, ''it is set to boost the economy, reduce unemployment, increase investment, and combat inequality by upskilling and reskilling South Africans to keep up with the rapidly changing labour market". wn

SAIEE CPD Competition at Enlit Africa

The SAIEE team, comprising Joanne Griffin, SAIEE Membership Coordinator, Zanele Sibiya, SAIEE Training Academy Manager and Minx Avrabos, attended the Enlit Africa Conference & Expo last week. During the conference, the SAIEE Training Academy ran a CPD Online Training Competition whereby the lucky recipient will win a 2-day online CPD training course of their choice, valued at R6 900.

We are pleased to announce that the lucky winner of the SAIEE CPD competition is **Shilongo Ndjaba** from Nampower, Namibia.

Thank you to all who entered. Please visit the CPD training calendar for our upcoming CPD courses and book yours now! We offer group bookings and in-house training and SAIEE Members receive great training discounts!

Emerging energy model to save large SA energy users 50% on power costs

A new private power supply model in South Africa is set to not only transform the country's power market from one dominated by a single entity to an open market with multiple suppliers, but also to provide large-scale industrial users energy savings of up to 50% on their electricity bill.

Representing a step-change in an energy market long dominated by power utility Eskom, the decision to implement third-party access, or wheeling, marks a seismic shift in support of the development of a competitive domestic electricity market.

Wheeling is a financial mechanism that allows an independent generator of electricity – predominantly wind and solar photovoltaics (PV) - to provide power to independent commercial and industrial users of energy through Eskom's existing transmission and distribution system. This, for example, enables a power producer to develop an energy plant in a high-performing solar area and sell that energy back into the grid for use by an end-user based in another location.

GREENING OF COMMERCIAL ENERGY ASSETS

With South Africa's wheeling market in its infancy, large-scale industrial power consumers are currently best positioned to benefit from wheeling agreements – from mining operators, data centres, property portfolios and industrial operations to automotive manufacturers.

Key advantages of this energy model include:

- Up to 50% cheaper tariffs than traditional grid prices for direct Eskom clients
- A reduction in carbon tax and carbon emissions through the use of clean energy such as wind and solar PV
- Higher penetration due to a Time of Use credits system
- No capital required

"In a nutshell, the two primary advantages of wheeling are considerable financial savings on the cost of energy and the use of green energy," explains solar energy firm SolarAfrica CEO David McDonald.

While Eskom levies a wheeling tariff for the use of its transmission infrastructure, the utility asserts that these are not additional charges.

"All customers buying from Eskom or through bilateral trade will pay the same standard Nersa-approved unbundled network-related tariff charges for the use of the network," it states.

ESKOM UNBUNDLING A KEY TRIGGER OF WHEELING IN SA

As power utility Eskom progresses the unbundling of its generation, transmission and distribution business units, legislative changes aimed at creating a more competitive domestic

energy market have acted as a critical accelerator of power wheeling.

The Department of Public Enterprises issued the Roadmap for Eskom in a Reformed Electricity Supply Industry in October 2019 which allows for a transition from a single buyer model to an open market model.

Eskom Power Systems Economist Keith Bowen explained during a South Africa Independent Power Producers Association webinar in July 2021 that the roadmap provides for a transmission entity which will effectively act as a single buyer that buys electricity from the Eskom generation entity and independent power producers (IPPs) and sells to the Eskom distribution entity, municipalities and large power users. "Competition [in the SA energy market] is a real thing, and the single buyer model doesn't really function anymore. In future, it's almost certain that domestic energy supply will be dominated by renewable power such as wind and solar PV, because it's the cheapest power on the grid," he remarked.

An August 2021 amendment to the Electricity Regulation Act now exempts embedded electricity generation projects of between 1 MW and 100 MW from the previous requirement of applying for a generation licence, requiring them only to register with the National Energy Regulator of South Africa.

"These legislative changes have been a key trigger for the injection of large-scale IPP-generated power into the grid and the scaling-up of power wheeling in South Africa. Eskom has also laid out a wheeling process that has been proven and ratified, leading to local sites that are already wheeling.

"The number of wheeling projects will further increase as Eskom's disbanding process progresses and we see multiple IPPs on the network," McDonald says.

Wheeling has, for years, been successfully practiced in several open electricity markets in Europe, with energy brokers allowing end users to procure power from 5 or 6 different independent power entities.

"This is what we believe is on the cards for South Africa."

SOLARAFRICA LEADING THE CHANGE

Pioneering South African solar energy provider SolarAfrica is in the process of developing several industrial-scale solar PV installations with Eskom grid connections that will inject renewable energy onto the grid and service large-scale power users through power purchase agreements (PPAs) and wheeling agreements

The first company in South Africa to offer solar financing through power-purchase agreements, SolarAfrica was named the continent's leading solar energy firm, scooping the Africa Solar Industry Association's African Solar Company of the Year award in 2021.

"These are exciting times for end consumers, and the possible energy cost savings for large energy consumers are in the billions. Other than the fact that it's green energy, the economic benefit is astronomical," says McDonald. wn

Small businesses are being left in the dark when it comes to renewable energy solutions

Although Eskom and government provide support for large renewable energy projects designed to bridge the power gap on a number of levels, there is still an important piece missing from these initiatives. Owen Murphy, Tax Specialist at BDO, shares some insights around the role government plays in supporting small businesses in the energy crisis.

A recent announcement by Eskom to lease land in Mpumalanga to renewable energy producers to feed production into the grid could see around 36,000 hectares of unutilised land owned by the parastatal made available to investors interested in renewable energy projects.

Although the plan, originally proposed in December 2021, has already reached the Request For Proposals (RFP) stage, Eskom Group Chief Executive André de Ruyter has explained that the leasing of the land would have to be made subject to production being achieved by a contracted date. Eskom COO, Jan Oberholzer, also cautioned that the initiative must be viewed in context of South Africa's power gap which was recently been estimated at between 4,000 MW and 6,000 MW. According to Oberholzer, the government's energy policy is insufficient to solve the country's worsening energy crisis which requires substantial new generation capacity.

However, this view was challenged in a report from the International Institute for Sustainable Development (IISD) which found that with the right business strategy and political support it is possible for Eskom to pivot away from fossil fuels and embrace more sustainable and cost-effective renewable energy solutions.

The Renewable Energy Independent Power Producers Procurement Program (REIPPPP), initiated and driven by the private sector, has demonstrated that competitive funding from both local and international markets is available and could prove to be a substantially more cost effective solution in terms of Rand per MW installed. For example, Eskom's land-leasing plan relies on existing infrastructure in Mpumalanga as opposed to the continued use of expensive state subsidised funds required by Eskom to fund the operation and maintenance of coal-fired power stations.

There are numerous other initiatives in progress for the funding of renewable energy projects in South Africa, but it is a crowded landscape of different government departments and semi government institutions, along with high profile industry players, attempting to streamline projects that are often stalled by policy-makers before any substantial traction can be gained.

So where does this leave small business, who more often than not bear the economic brunt of the energy crisis?

In order for small business to play a significant role in the renewable energy game, government must devise plans

to incentivise consumers to "go off the grid" and install solar panels for their electricity requirements. The call for government to provide such incentives is not a new one. For example, The Democratic Alliance lobbied strongly for a tax rebate of R75,000 for this in March 2020 as part of their budget proposals for the 2020/2021 fiscal year. The advantage of a rebate such as this would be that no government department would hold or administer the funds or manage the associated risk. With service providers estimating that a comprehensive off-grid solution would cost approximately R 100,000 to R 120,000, this proposed scheme would cover around 75% of the cost of the installation.

Although proposals such as this do need to address potential tax implications, the impact of taking pressure off the grid would have exponential economic benefits, specifically within the small business sector.

In addition, there would be substantial investment opportunities in local manufacturing for the required equipment and the potential to create an export market for similar small scale "off grid" projects to be rolled out in Africa. Job creation would be given a much-needed boost as the demand for artisans to install the equipment would rise and once trained in this field, a future workforce could be upskilled and employed within the sector.

A further advantage of incentivising consumers to adopt "off-grid" power solutions is that it will reduce the pressure on Eskom's ability to maintain a constant base load during the hours of 6pm to 10pm when there is no sunlight available to the grid that can be supplied by renewable energy providers.

South Africa also has immense potential to expand into renewable energy production when compared with other regions, as the country boasts some of the most sustained sunlight in the world and an abundance of water along its 2 800-kilometre coastline. Now is the time for government to harness the natural resources we have available to attract large scale investors and reduce the power gap so that small entrepreneurs are no longer left in the dark. wn

Owen Murphy
Tax Specialist | BDO

Africa's scientific agility in the face of a pandemic

The COVID-19 pandemic triggered a rapid curve for the governments tasked with containing it and the scientists tasked with understanding it and its cascading effects.

Two years on, as countries still battle to douse the remnants of the pandemic fires as successive waves continue to rise, the pandemic offers learning opportunities for scientists and policymakers worldwide.

From the outset, it was clear that innovation and creativity would be essential in the region's quick and agile response to the pandemic. And African scientists very quickly stepped up to the plate.

"For every 1 000 innovations globally that came out in response to Covid-19, 13% were from Africa. This shows the strength of the African innovation ecosystem, though it's still in its infancy stages. Creativity and innovation that Africa was able to tap into fast. Importantly, several of these innovations were low-cost and easily adaptable to low-and-middle-income country contexts," said Dr Uzma Alam, a global health researcher and partner with the Africa Institute for Health Policy.

She was speaking during a recent Sustainability Research and Innovation Congress (SRI) Inkundla, one of four curated conversations in the lead-up to the SRI2022 Congress in June.

Future Africa will host the Congress and be held onsite in Pretoria and online from June 20-24. It brings together a dynamic and diverse group of professionals committed to driving global sustainability forward through transdisciplinary research and innovation.

The SRI Inkundlas address this year's Congress themes: African science and innovation, New Horizons, Different Ways of Knowing, and Nexus Issues.

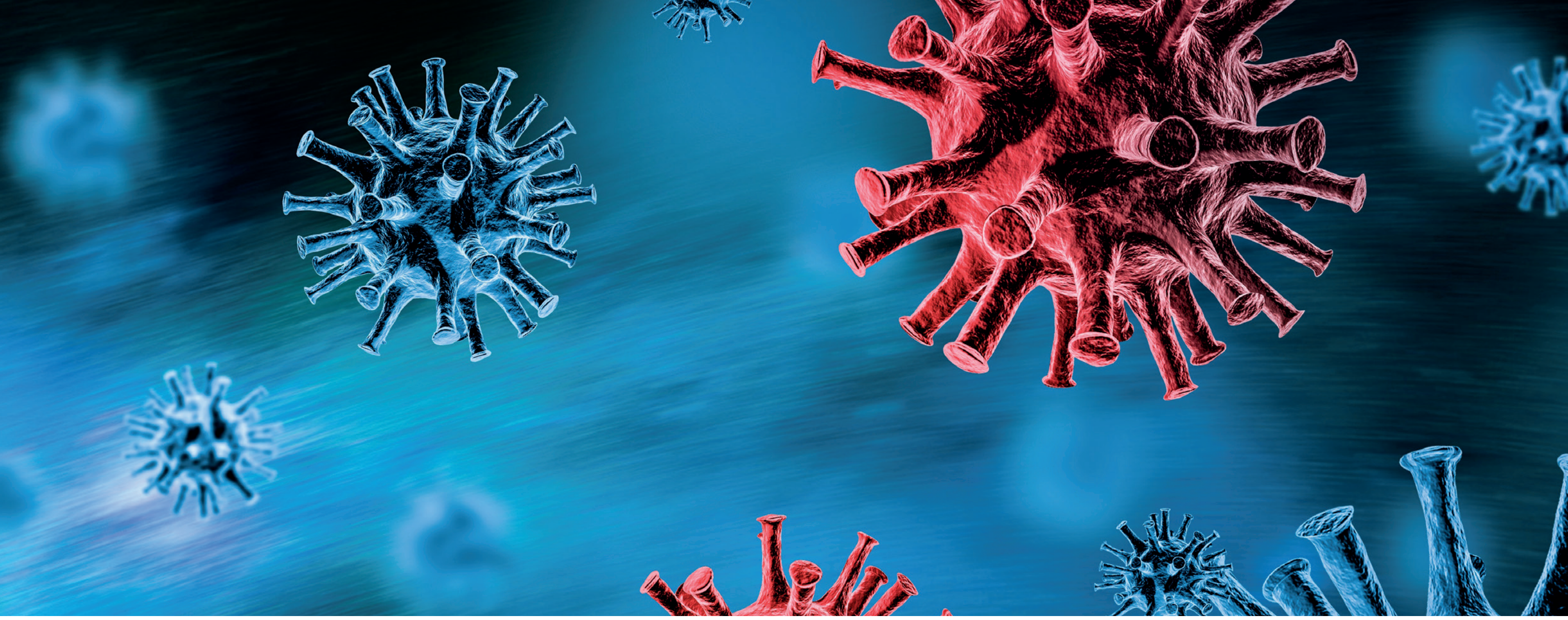
In the first session, Alam posited that innovation was essential when thinking through the sustainability, research and innovation lens, looking at Covid-19 as a case study, because it was able to bring in features that underpin resilient systems – such as our flexibility and adaptability as a continent.

Flexibility and adaptability were vital in the social sciences, too, particularly in anticipating and addressing the gaps in human rights and the many vulnerable populations left out in response to Covid-19.

Dr Leonore Manderson, a Medical Anthropologist and Distinguished Professor of Public Health and Medical Anthropology at the University of the Witwatersrand, led a team of five researchers from the Consortium for Advanced Research Training in Africa (CARTA) to effectively mine out the social science impact the pandemic would have in the context of Covid-19. "Our focus was on people who consistently slipped through the cracks or were on the margins of society. There were no societal mechanisms to support the people whose lives have yet to be documented concerning Covid-19. For example, people living in refugee camps such as in East Africa, no one counts those numbers of who has been affected by Covid, let alone died from it," she added.

"The challenge for us was to think through how one might engage populations whose lives were so precarious and who had no access (to societal mechanisms of support such as grants)," Manderson continued.

And while many countries across Africa recognised the social cost of the pandemic and tried to mitigate it by finding mechanisms to halt its impacts



– such as by increasing pensions and various social grants – there were populations of vulnerable people left out of that.

"Social science has an enormously important role in anticipating these pitfalls and creating conversations around addressing them," she said.

Data would be a fundamental pillar underpinning the healthcare system and the resultant responses to Covid-19 and future disease epidemics.

"Without data, you're not really able to know where you're going, how you've been performing or benchmarking and tracking progress," added Dr Tom Achoki, a faculty member at the school of health systems and public health at the University of Pretoria.

Achoki emphasised how critical data was in surveillance and response, especially in epidemics and determining what is working in identified hotspots.

Moreover, data was a key determining factor in managing and distributing human and financial resources in dealing with health crises such as epidemics and pandemics.

"Resources are not limitless, so we must make sure that we can allocate our resources in both a practical and judicial way to get the maximum bang for the cash we put out there.

"So, unless we can understand those differences at a sub-national level and also look at the healthcare systems' outcomes (like the effectiveness of interventions), seeing whether those are being delivered cost-effectively is fundamental to sustainability," Achoki said.

He added that there needed to be a regional culture of data use as an accountability mechanism.

Alam re-emphasised the innovation coming out from African scientists. The evidence that 13% of innovation during the pandemic came out of Africa, albeit relatively small, was a significant marker that innovation wasn't just one-directional and flowing from developed countries.

"Africa has its own place in the innovation ecosystem. However, we need to develop our innovation ecosystems, including how we fund innovation beyond the normal grant mechanisms. Africa needs to set its own agenda in terms of research and innovation, and the policies to support innovation are African driven," she said.

Alam continued: "For far too long and for whatever reasons, it (the agenda) has been a process-driven from the outside. The stakeholders are not the owners of that agenda, so there is no sustainability. Also, innovation doesn't occur in a vacuum, nor does science occur in a vacuum, so partnerships are key, but they need to be equitable."

The first session was moderated by Dr Richard Wamai, Associate Professor at Northeastern University, where he co-leads the Integrated Initiative for Global Health. He said that frameworks such as the African Union's Science, Technology and Innovation Strategy for Africa 2024 – among others – recognised research and innovation as enablers for achieving Africa's sustained growth and competitiveness and economic transformation.

"Africa is a continent on the rise. Some have said that this is the century for Africa. The push for science, innovation and technology is motivated by the need to find new solutions for complex problems including disease, population, climate change and natural resource management."

For more on the informative Inkundla discussions around sustainability, research and innovation, click here or register for the Congress here. wn

NERSA approves the first 100MW power generation projects in the private market

Following the landmark regulatory change announced by President Cyril Ramaphosa in August 2021, where Schedule 2 of the Electricity Regulation Act was amended to extend the limit over which a private power project must apply for a Generation Licence from 1MW to 100MW, the first 100MW projects have now been formally registered with NERSA.

The two projects to receive the NERSA approval are 100MW solar PV projects in the North West Province developed, financed, constructed and operated by the SOLA Group and its partners for Tronox Mineral Sands.

The regulation was significant because the Registration process is faster and less demanding than applying for a Generation License, which was previously the requirement.

"The significance of this first move is that it will pave the way for many more large scale private projects to receive approvals to contribute to generation capacity to the grid." Says Dom Wills, CEO Sola Group. "Further, this is a clear signal to the market that private power is achievable, and there are private funders excited to finance this market."

Sola's largest shareholder and equity partner in the projects, African Rainbow Energy, CEO Brian Dames says, "At the recent South Africa Investment Conference, African Rainbow Energy committed to investing R3Bn in the economy. These projects are starting to realise this commitment and the African Rainbow Energy's commitment to using new technology to provide large scale clean power solutions for the economy."

The projects have also received significant assistance from the presidency, who is keen to see the impact of the new legislation.

"The raising of the licensing threshold has unlocked a massive investment pipeline. To fast track these projects, we have established a joint task team between government and industry which meets weekly to remove many of the constraints. All of this is important to help alleviate the shortage in electricity supply." Rudi Dicks, Presidency.

Following this registration, the expected financial close of these projects is in July. The projects will require a construction period of 14 months to reach the Commercial Operation Date. The projects have an expected lifetime of 30 years.

The projects are also using the electricity wheeling framework enabled by Eskom. Under this mechanism, an IPP can produce the energy in one Eskom connected area and sell it to their client in other Eskom connected areas. Eskom charges a wheeling fee to facilitate this bilateral energy trade. "The advantage of the wheeling framework is that it allows perfect solar regions to be developed and used to provide power to perfect industrial and mining regions," says Wills. "A perfect solar region is a flat area, with high solar resource, minimal environmental or social impact, uncomplicated underground conditions and has access to a strong grid node with good power evacuation potential."

Large scale bilateral energy trading is the first step in South Africa's plan to open up the grid to allow more flexible electricity trading. Draft legislation has been released, which signals the intent to have a consolidated central purchasing agency allowing electricity traders to sell energy using the grid as a conduit.

Responding to the current and proposed changes in the legislation, Wills expressed his company's support for changed regulations that raised the licensing threshold for new generation projects to 100MW. "I hope we can develop and build fast enough. Scale and speed are key". wn

Two Young Professionals have the opportunity to attend the IEC Young Professionals Workshop to be held in conjunction with the IEC General Meeting in San Francisco, United States of America: **31 October to 4 November 2022.**

INVITATION

South African young professionals, Engineers, Technologists from the Electrotechnical discipline are invited to participate in the 2022 IEC Young Professionals Workshop by writing an essay on the following topic.

TOPIC

How can Standardization be used to enhance the integration of Renewable power system while reducing the energy cost of the end user.

GUIDELINES

1. Essays must be typed using (Arial,11 point) and should consist of +/- 3500 words (5 - 6 pages excluding the cover sheet provided).
2. Essays must be original and unpublished; plagiarised entries will be rejected.
3. Essays must be written by the entrant; co-authored essays will not be accepted.
4. Copyright of the essay entered will be assigned to the South African Bureau of Standards.

ARE YOU

- A young and dynamic manager, engineer or technician aged between 20 – 35?
- Are you interested in working with or developing standards or conformity assessment schemes?
- Working for a company, business, industry or studying at an institution that uses or benefits from IEC International Standards or conformity assessment systems?
- Wanting to become more involved in IEC-related activities?

CLOSING DATE:
All essay entries must be submitted to iec@sabs.co.za no later than 17 June 2022.

Efficiency In Electric Motors Drives Savings, Sustainability

In the absence of legislation to drive energy efficiency in South Africa, it is vital that local industries recognise the commercial benefit of converting to high efficiency motors, says Zest WEG sales manager for electric motors Francois Labuschagne.

In pursuit of global targets to reduce the pace of climate change, many countries have legally enforced the use of certain efficiency classes of motor, but not South Africa. Labuschagne points out that as much as 40% of the power consumed on the national grid is to drive electric motors. This means that any improvement in motor efficiency would significantly reduce the total electricity load, and help reduce carbon emissions from coal-fired power generation.

"However, even without being forced by law, motor users have a strong commercial incentive to install high efficiency motors," he argues. "This is because a motor's purchase price typically makes up only about 2% of its lifecycle cost over 10 years. With another 3% of this cost consumed by maintenance, a full 95% of the cost of running a motor is the energy it consumes."

It is clear, then, that reducing the energy consumption is the best way of saving costs when it comes to operating motors. One of the challenges, though, is that many companies incentivised their procurement departments to save money on upfront capital purchases – rather than on the broader cost to company.

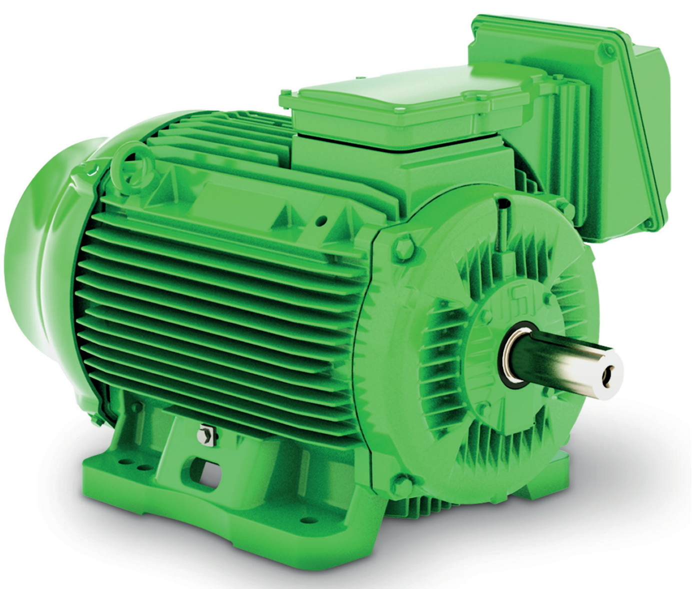
"Where a purchaser does not understand where their motors' real costs are incurred – that is, in their energy consumption – they will continue to pursue a false economy by choosing products with the lowest capital cost," he says. "The small amount saved upfront is very quickly lost through higher running costs."

He points out that, as a global electric motor manufacturer, WEG has been making efficiency innovations to its motors for decades – positioning it well to meet current and future market trends. In South Africa, Zest WEG has gone as far as to offer its IE4 super premium efficiency motors from 37 kW upwards at the same price as the IE3 premium efficiency units.

"We have recently taken another important step in our efficiency and sustainability journey, offering the market our new IE5 motor – and taking our offerings into the ultra-premium energy efficiency class," he says. "These motors are well suited for fan applications, and have great potential in the agricultural sector in environments such as chicken farms."

Using smaller fans in these situations can give users the opportunity to install multiple units where they used to have only one large fan. As temperature conditions change throughout the day, one or more of the fans can be switched off completely, further reducing energy consumption.

"We are very excited about this electronically commutated motor, which also comes with an integrated variable speed drive (VSD) and can be locally or remotely controlled," says Labuschagne. wn



A WEG IE4 super premium efficiency motor.

What it will take for South Africa's ailing power utility to keep going

The chief operating officer of South Africa's electricity utility, Eskom, warned in May that the government should urgently start building new generating capacity. He was referring to a new build programme which has existed for at least a decade.

By Prof David Richard Walwyn

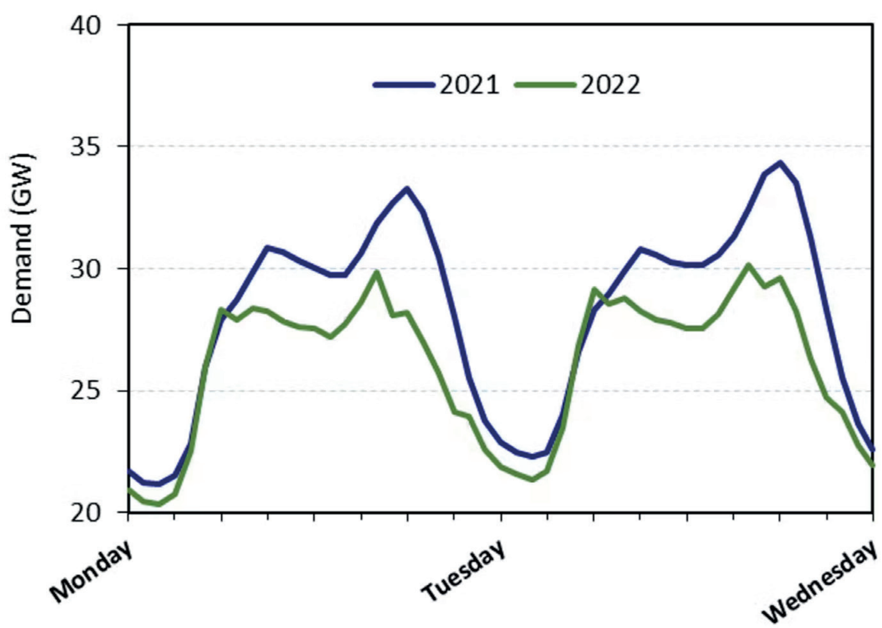


Figure 1: Energy demand from June 2021 and from May 2022. Provided by author.

The country's Integrated Resource Plan of 2019, a cabinet approved document, sets out the timelines for decommissioning coal-fired power stations and adding 44GW of new capacity, including 18GW of wind energy and 8GW of solar (photovoltaic).

The country is already way behind on this programme, limping along with antique power stations and regular power cuts. Outages are a regular ocurrence which are estimated to cost the country's economy about US$1 million an hour.

South Africans are all too aware that there is an energy crisis. But in my work on energy systems and transitions, I began to ask questions about the real nature and extent of it, and how Eskom should be responding. My views are informed by Eskom's data portal, a rich source for insights on South Africa's complex electricity system. The portal is designed to share detailed information on electricity demand and supply. It has data on sources of energy, levels of storage and the extent of loadshedding (power cuts) on an hourly basis.

I analysed the data for demand and supply for the first half of May 2022. It revealed three main trends: demand has fallen; power cuts aren't as big as they could be; and there's scope to get more out of the system using renewable energy sources.

SOUTH AFRICAN POWER SUPPLY AND DEMAND TRENDS

The data reveals three key trends for the utility. Firstly, Eskom has dropped 6GW (about 21%) of demand within a year. This is because many non-paying

customers have been disconnected and several large clients, among them industrial users like mines, are now generating their own power.

Figure 1 compares two days of demand, one from June 2021 and the other from May 2022. It reflects actual demand, not Eskom's supply. The difference in demand is staggering. At this rate, South Africa simply won't need Eskom in five years.

The second interesting finding is that the quantity of the power cuts is small relative to the total delivered energy. Over the week 12-19 May 2022, Eskom delivered 4,271 MWh of electricity and cut 70 MWh, which is only about 1.6% of the energy generated, as shown in the image below.

I'm making this point to show that power cuts could get much worse, unless the rebuild programme begins soon. One reason that the power cuts attract high media attention is that consumers bear a disproportionate share of the energy cuts relative to Eskom's anchor customers.

For instance, under level 4 where power cuts can last for over five hours in a day, lower end users have power for only 67% of the day – meaning 33% of their power supply is cut. But the total energy saving across the whole system is 10%. This suggests that Eskom deliberately preserves supply for its anchor customers – large industrial users and essential services – even during the power cuts.

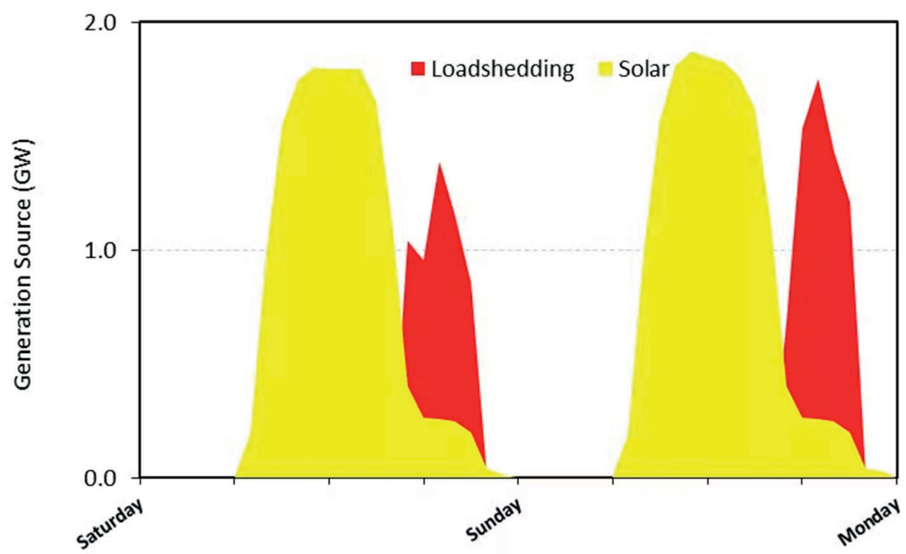


Figure 2: Energy supplied by solar power facilities.

The final issue is that Eskom could get more capacity from its pumped hydro schemes. These schemes use excess power at night to pump water to high storage dams, from which the water is released during the day to meet the higher demand during daylight hours. During the week 12-19 May, capacity utilisation of pumped hydro was only about 38%.

If there had been sufficient power during the day to refill the reservoirs, Eskom could have added 1.7 GW of generation capacity during the early evenings, making full use of the pumped hydro capacity and avoiding the need for loadshedding. That daytime power could have come from the renewable energy programme, if the Department of Mineral Resources and Energy had followed the build schedule.

ESKOM'S OPTIONS

What are the options for Eskom, apart from starting the build programme?

To answer this question, we need some basics on energy systems. South Africa has a diverse energy system. Electricity is obtained from coal (the largest source), wind, solar, hydro-electric, nuclear, diesel and imports.

Wind, solar and nuclear can't be controlled by the operator. Gas, hydro-electric, pumped hydro and diesel can. Coal is somewhere in between the two. Eskom's role as the system operator is to blend all the sources to match the demand.

The difficulty is that both demand and supply are variable, as shown for solar in the image above. It is akin to managing a catering event when you have no idea how many guests will be there or how many meals will be delivered.

So, Eskom follows some simple rules (like other energy system operators). The rules are first to use sources it cannot control (wind, solar and nuclear), then add the coal power stations, and then top up with hydro-electricity and pumped hydro. And if there is still a shortfall, bring in the gas and diesel turbines.

The most obvious solution to Eskom's immediate problem is two-fold:

- bring in more renewable energy, especially wind and solar, of the independent power producers procurement programme
- make more use of pumped hydro by using any sources of additional low-cost power, available from independent power producers and elsewhere.

This approach has already been outlined in my previous publication covering the independent power producers procurement programme. I criticised the programme's requirement of stand-alone power producers and argued that interconnectedness of the producers would reduce cost and increase resilience in the system. It is precisely this arrangement which will provide a solution to the short-term issues within the national grid.

In the longer term, the country needs to properly implement the 2019 Integrated Resource Plan, even if it clashes with the Department of Mineral Resources and Energy's coal, gas and oil interests. If the country doesn't start the 2019 plan now, it will lead to the demise of Eskom as an energy producer as users are compelled to turn to other sources. wn

Courtesy of theconversation.com

Fostering Effective Energy Transition

INSIGHT REPORT - MAY 2022

Navigating the energy transition through a turbulent phase requires a balanced approach.

The Energy Transition Index (ETI) has benchmarked the progress of countries' energy transition for a decade on the three dimensions of the energy triangle – economic development and growth, energy security and access, and environmental sustainability – and on the enabling environment for transition.

In view of the current volatile macroeconomic and geopolitical environment, however, a trend analysis from historical energy data can currently provide only limited insights. Hence, instead of the annual country energy transition benchmarking report, this special 2022 edition builds on the ETI trends observed in recent years to provide a perspective on the current challenges affecting the transition, and highlights priorities to supercharge it.

The urgency for transformative measures to mitigate climate change has intensified. The latest assessments by the Intergovernmental Panel on Climate Change (IPCC) emphasize the need for global greenhouse gas (GHG) emissions to peak by 2025 and for emissions to decline rapidly thereafter. However, a series of systemic shocks over the past three years and their implications on the energy system highlight the challenges in pursuing long-term targets while responding to short-term emergencies. The ETI framework underscores the need to help advance energy affordability, security and access, and sustainability. The current environment poses simultaneous constraints on these three fronts.

Many countries have demonstrated resilience to the pandemic and exceptional economic recovery. However, the faster-than-expected rebound coupled with low investments in parts of the energy system have put stress on the energy supply, leading to very high energy prices and severely impacting households and businesses.

Supply-demand imbalances can recur through the transition as energy systems reconfigure, yet the transition cannot progress at pace if it leads to expensive energy or exacerbates inequalities.

The war in Ukraine has led many countries to rethink their energy security paradigm and what it means for their energy transition. A review of the best performing countries in terms of energy security in the past ETI editions reveals the benefits of dual diversification: energy mix diversification and fuel import diversification. The war has forced several countries to consider the trade-offs between energy security and sustainability to secure energy supply in the short term.

However, in the long term, we expect the energy transition will offer win-win opportunities, aligning security and sustainability imperatives through investments in renewables and other clean energy sources, as well as demand-side measures like energy efficiency.

We believe this is the time for governments, companies and consumers to intensify efforts to reduce their dependence on fossil fuels. Governments can invest in domestic decarbonized energy systems that will secure affordable and reliable energy, and companies have opportunities to adopt low-carbon technologies and energy-efficient processes. The decrease in GHG emissions observed during the pandemic due to the reduction in energy demand demonstrates the opportunities offered by demand management. Considering the critical role of energy-intensive industries in achieving demand-side emission reductions, this report includes a focus on the energy transition within the industrial sector. As the largest contributor of anthropogenic emissions, industries are regarded as the last frontier of decarbonization. We examine the multiple choke points that industrial firms encounter on their journey to net zero, and show how a new generation of collaboration models, coupled with new levels of ambition at the industry, country and global levels can help these companies break through their bottlenecks and accelerate the transition.

There are glimmers of hope, but also caveats. A few countries, for example, are linking COVID-19 recovery packages with enhanced sustainability solutions to "build back better". But many are not. And several large investment agendas are not yet fully approved.

Also, we welcome the additional commitments made at COP26 at the end of 2021. However, action has fallen short in several key areas that will need to be addressed in the future. Overall, we remain cautiously optimistic. But success will depend on countries carefully striking the balance between energy affordability, availability and sustainability, and further strengthening their commitment to climate action.

1

The energy transition under pressure

The challenge is compounded by risks to energy security, sustainability and affordable access.

Key highlights

1. Linked to the energy triangle's three dimensions, high energy prices, the risk of energy supply shortages and climate emergencies jeopardize the energy transition
2. The extreme volatility in energy markets raises concerns about energy security, energy affordability and the energy transition
3. Energy systems' resilience to supply and environmental shocks is essential to maintain energy affordability for economic growth and ensure a just transition
4. Energy mix and import diversification can bring countries greater energy security, affordability and sustainability
5. Now is the time to strengthen commitments to clean energy investments and anchor more efficient energy consumption habits in society
6. The energy transition must be made robust with adequate enablers and support mechanisms to maintain the momentum despite the challenges

The current context highlights trade-offs inherent in the energy transition, which are complicated by the energy sector's structure, socio-economic role and geopolitical significance.

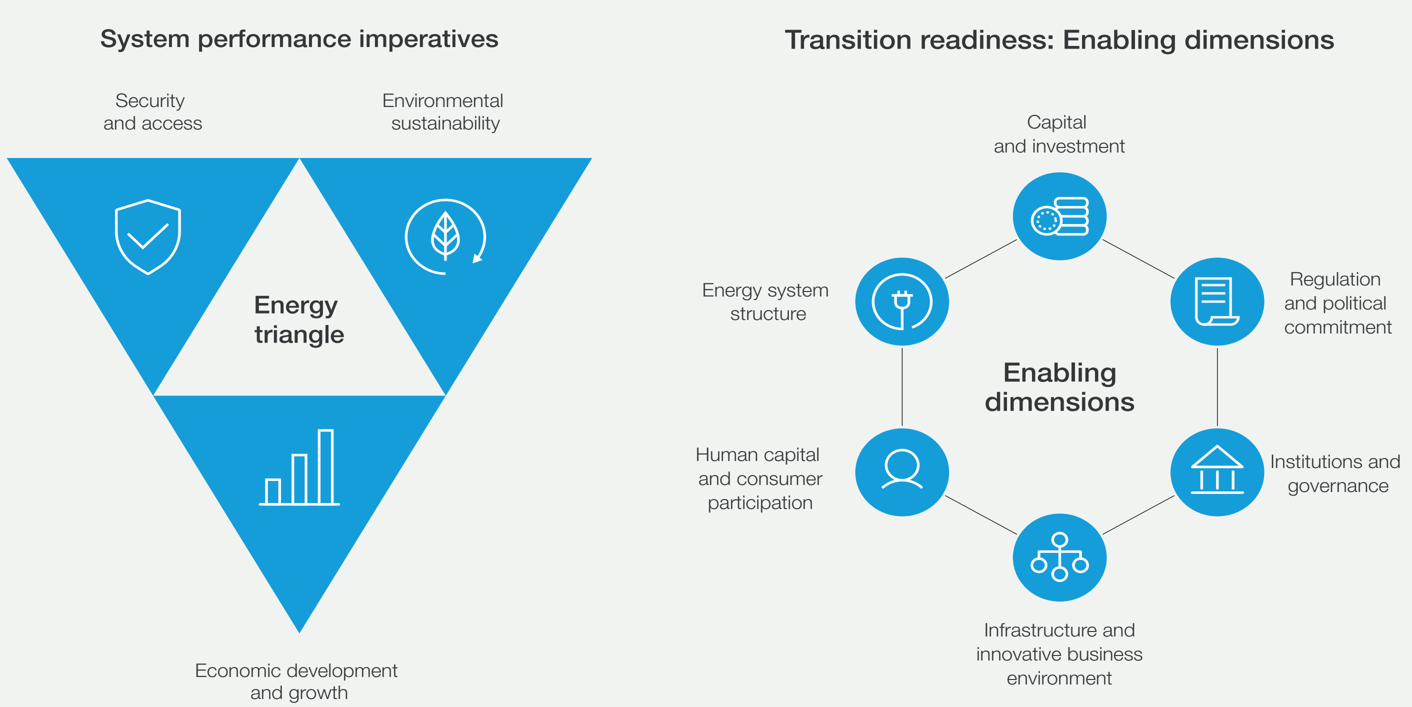
The COVID-19 pandemic, the war in Ukraine and collateral turmoil in the energy markets make clear the need for the global energy transition to simultaneously address the imperatives of economic development and growth, energy security and access, and environmental sustainability. Imbalances will continue to impede efforts to reach the pace required to limit warming to 1.5°C.

The global energy transition, pivotal to climate change mitigation efforts, is well under way. Over the past decade, the world has made progress during nine of the 10 years, as measured by the Energy Transition Index (ETI). However, the narrative's urgency continues to increase. The 2021 United Nations Climate Change Conference (COP26) warned the world that "we have kept 1.5 degrees alive, but its pulse is weak",[8] amid endeavours to turn this decade into one of accelerated climate action and support. The early 2020s have seen a series of systemic shocks that affect the energy system and merit careful examination to support the development of robust energy transition roadmaps. Following the unprecedented pandemic-induced energy demand reduction in 2020, the consumption of energy rebounded strongly in 2021. This rebound resulted in substantial imbalances in energy markets, triggering soaring energy prices as well as significant growth in greenhouse gas (GHG) emissions. The situation was further compounded by Russia's invasion of Ukraine. These events constitute a perfect storm, creating headwinds on all three imperatives of the energy triangle. High energy prices pose risks to economic growth[9] and have raised the cost of living. Progress on energy access has stalled and countries face imminent energy security risks.[10] The consumption of fossil fuels has also increased substantially, driving emissions up to their highest levels in history.[11] The current context highlights some of the trade-offs inherent in the energy transition, which are further complicated by the energy sector's structure, socio-economic role and geopolitical significance.

The same ETI framework published annually for the last 10 years is used to structure the analysis in this special edition. The framework (Figure 1) strives to assess the performance of energy systems across three fundamental imperatives: the ability to support economic development and growth, energy security and access, and environmental sustainability. Balanced progress for a country's energy transition means advancing along all three dimensions of the energy triangle.

Given the interconnectedness of the energy system across the modern economic and social fabric, the drivers and impacts of the energy transition are not restricted to the traditional boundaries of the energy system. Rather, a broad set of social, political, regulatory, macroeconomic and infrastructure-driven parameters enhance a country's transition readiness (Figure 1), enabling an effective energy transition.

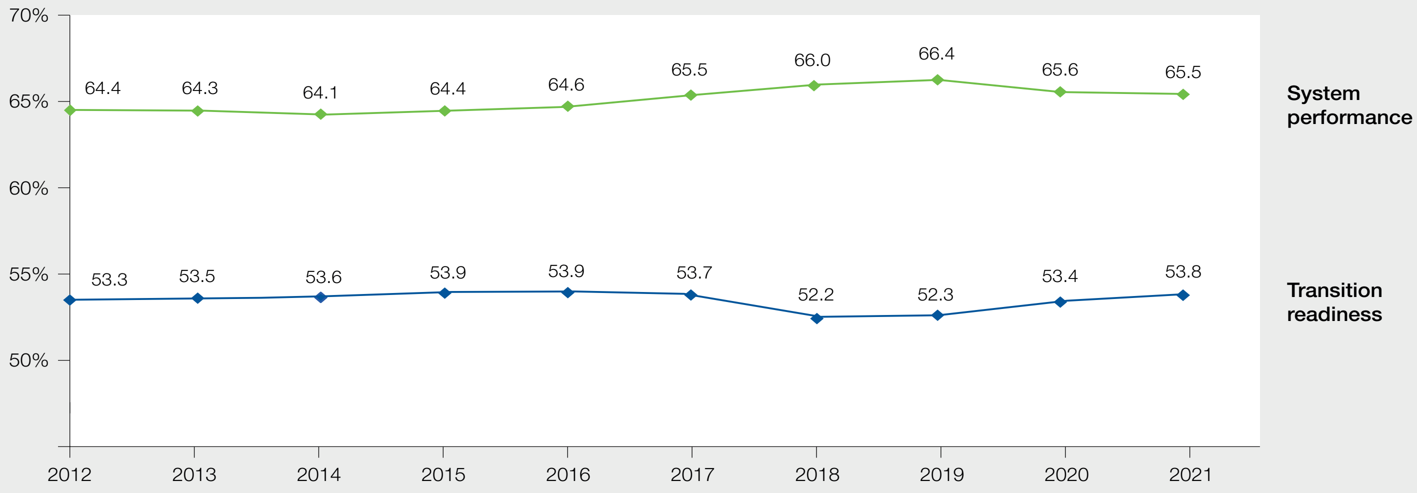
FIGURE 1 **The Energy Transition Index framework**



The ETI framework has been used for the past 10 years to reflect on countries' energy system performance and the readiness of their enabling environment for an effective energy transition. Slow but steady progress (Figure 2) was made from 2012 to 2021 on both the system performance and transition readiness dimensions.

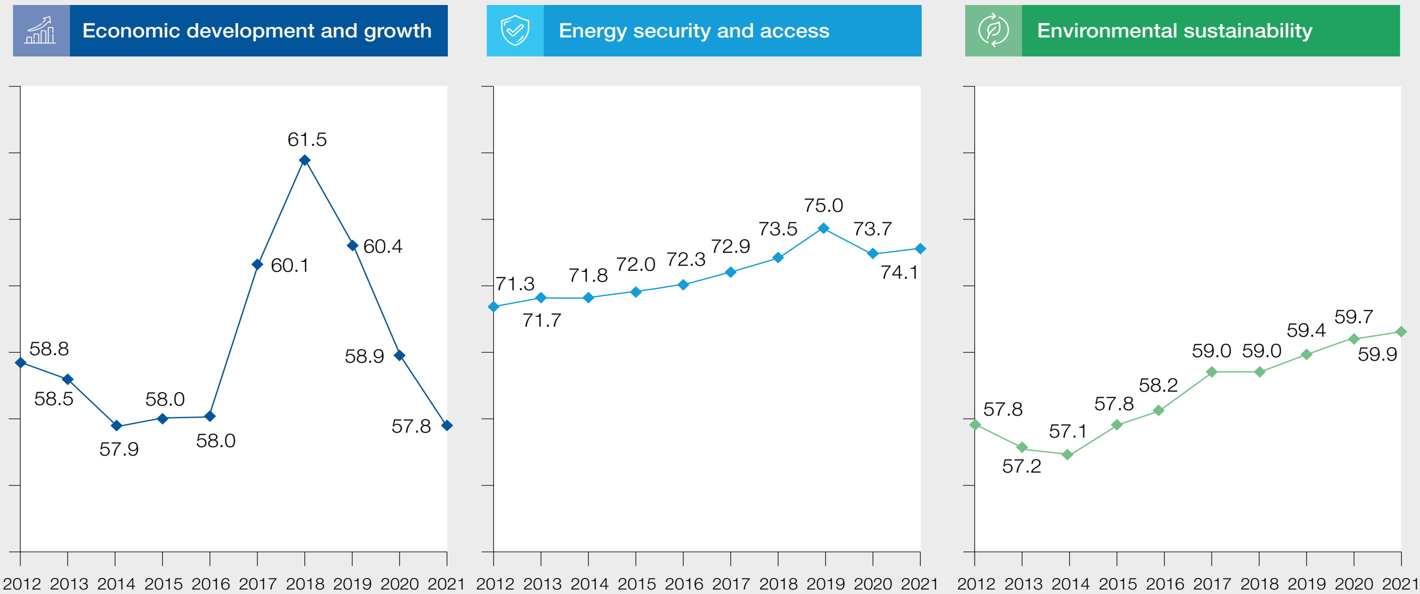
A closer look at the energy triangle (system performance) reveals that countries' progress over the last decade has not been uniform across the three imperatives (Figure 3). Environmental sustainability improved steadily at a deliberate pace, and energy security and access also improved largely consistently over time, although recent developments warrant a fundamental rethink on energy security. The downward trend in economic development and growth since 2018 shows that countries are facing challenges to maintain energy affordability while progressing on their energy transition pathways.

FIGURE 2 **Global average Energy Transition Index system performance and transition readiness scores, 2012-2021**



Sources: World Economic Forum, *Fostering Effective Energy Transition: A Fact-Based Framework to Support Decision-Making*, 2018 ; Accenture analysis

FIGURE 3 **Global average energy triangle sub-index scores, 2012-2021**



1.1 Economic development and growth

> The risks of high energy prices and economic headwinds are expected to flank the energy transition process, and increased volatility could be a recurring phenomenon.

Energy supply shocks are expected to accompany the energy transition journey, with significant pass-through effects on economic growth and the cost of living. Effective support mechanisms to protect vulnerable populations and businesses are necessary. Steady energy affordability is essential for economic growth and social justice, and both are key to keep the energy transition momentum going.

The past two years have significantly challenged national economies and energy systems. In 2020, pandemic-related restrictions resulted in a steep drop in the demand for energy[12] worldwide and reduced CO_2 emissions, providing a glimpse of the impact demand-side measures could have on climate mitigation.

In contrast, 2021 experienced a fast rebound of demand for products and services and was marked by the global economy's strong and exceptionally rapid recovery with global GDP growth estimated at 5.9%.[13] As economic growth is strongly correlated with energy consumption, the global demand for electricity[14] and oil[15] promptly surpassed pre-pandemic levels, leading to the highest prices experienced in years. Natural gas prices also climbed to their highest in a decade in Europe, the United States and major Asian markets, owing to a combination of both demand-side and supply-side factors,[16] as well as a succession of extreme weather events.[17]

The energy market supply-demand imbalances of 2021 were carried over to 2022 with energy prices sustaining record-high levels even prior to Russia's invasion of Ukraine. The surge in energy prices emerged as an additional factor, fuelling inflation on top of several other factors, such as strong consumer demand,[18] restricted supply chains,[19] rising wages,[20] the increasing cost of housing[21] and food,[22] and low interest rates.[23] In 15 of the 34 economies that the International Monetary Fund (IMF) classifies as advanced, 12-month inflation through December 2021 measured above 5%.[24] A similar trend was observed in emerging markets and developing economies as 78 of 109 countries tackled inflation of above 5%.[25]

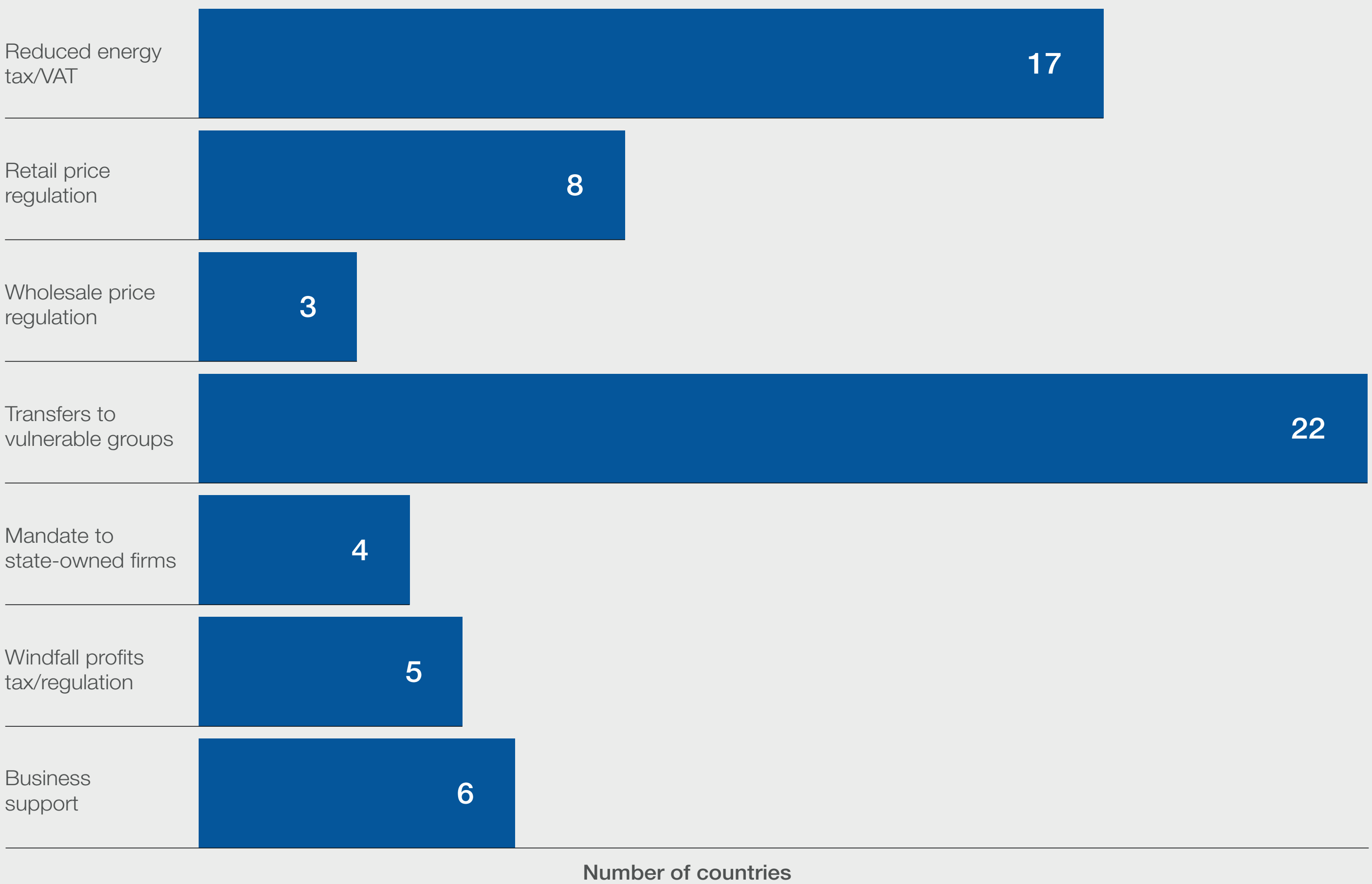
The ability of high oil and gas prices to percolate to other sectors hinges on the relative price inelasticity of its demand. The supply of oil has become more elastic in recent years with the advent of shale oil production in the United States.[26] But oil demand

remains rather inelastic, especially in the short run. Geopolitical events and severe weather events can disrupt supply.[27] **Because energy demand is quite unresponsive due to its lack of elasticity, the risks of high energy prices, inflationary pressure and economic headwinds are expected to flank the energy transition process, and increased volatility is likely to be a recurring phenomenon**.

Emerging and developing economies are disproportionately affected by spiralling inflation. Although the peak pass-through of high retail energy prices in advanced economies is twice that of developing economies,[28] the cumulative impact on consumer price index (CPI) levels in developing economies is higher as prices stay elevated for a longer period of time. Higher energy intensity and lower substitution effects may account for the larger impact on inflation in developing countries.[29] In essence, **the impact of volatility in energy markets is likely to be more pronounced on developing economies, which adds to the concerns of equity and justice of the energy transition.**

With the outlook of potentially recurring periods of supply-demand imbalance of transition fuels such as gas, and rising trends in carbon prices, the contribution of energy prices to CPI could be well above historical norms in the medium term, with potentially far-reaching consequences for households and businesses alike.[30] An increasing number of households, including in advanced economies such as the European Union (EU),[31] United Kingdom[32] and United States,[33] are unable to meet their basic need for heating and lighting at an affordable cost. The energy crisis has also affected companies producing energy-intensive materials like ammonia, steel or aluminium, with significant knock-on effects, such as rising costs of fertilizers, which has compounded food security concerns worldwide.[34] With the price of consumer goods and services already rising due to constrained global supply chains, a sustained increase in energy costs will likely impact the cost of living and consumer spending while adding an additional cost burden to businesses and governments. Countries have taken various emergency response measures (Figure 4) in response to these concerns.

FIGURE 4 **EU+ countermeasures enacted to combat high energy prices**



Note: EU+ includes the United Kingdom and Norway.

In the face of economic headwinds along with the geopolitical uncertainty, governments have also been taking measures to address energy affordability challenges from the supply side. As a last resort to counter recent sky-high gas prices, some countries have increased coal-based power generation. In the United States, where coal-based generation has been in decline since its 2007 peak,[35] it increased by approximately 22%[36] in 2021, with coal production expected to further increase by 4%[37] in 2022. Germany is also investigating extending the life of certain of its coal-powered plants[38] to maintain competitive energy access. In addition, some countries are reconsidering their nuclear power generation policy.

Moreover, strategic petroleum reserves (SPRs) have been leveraged and have proven once again to be a critical tool for emergency response measures[39] to mitigate energy supply shocks. These could be crude reserves, petroleum product reserves or gas caverns. In the face of severe supply disruptions, this countermeasure can help economies mitigate some of the immediate economic impacts of a sudden supply shock. In early March 2022, a coordinated effort was orchestrated by International Energy Agency (IEA) member countries[40] to address significant supply disruptions. At the time of writing, the United States announced the largest release of oil reserves in history, comprising 1 million additional barrels per day for six months.[41] SPRs can lower oil prices in a high-price environment, thereby having a stabilizing effect on the economy during an oil supply disruption scenario.[42] Their major impact is by way of price relief or even alleviating the physical shortage of supply to at-risk and strategic consumers.[43] The system, however, focuses on handling short-term disturbances and has limited impact on medium- to long-term markets.

“ Developing the necessary support mechanisms to cushion energy supply shocks until the low-carbon energy systems reach the scale and flexibility required will be essential.

No universal definition of energy poverty or basic energy needs exists, because of sensitivities related to regional and income-driven differences.[44] Addressing these concerns will rest on a robust framework of data transparency to determine the magnitude and prevalence of the challenge at the national and local levels, mechanisms to effectively target vulnerable consumers for financial transfers, and the design of support measures in a manner that does not reduce incentives for efficient consumption.[45] **However, the systemic nature of the challenge calls for long-term measures to safeguard vulnerable consumers and businesses from volatilities resulting from the transition.**

Building resilience in transitioning energy systems to mitigate the adverse effects of volatility on small and medium-sized enterprises (SMEs),[46] consumers and the most vulnerable households is key to help advance energy affordability and a just and socially accepted transition. In this sense, the pivotal events of the past two years advocate for an energy transition that helps ensure energy affordability while pursuing sustainability goals. Developing the necessary support mechanisms to cushion energy supply shocks until the low-carbon energy systems reach the scale and flexibility required to consign the risks of a major fossil energy crisis to history will be essential.

Building resilience will likely come at a price to countries, companies and consumers, owing to potential inefficiencies, redundancy, extra capacity or green taxation. However, by minimizing the risks of dropouts and delays for economic reasons, it will be the only viable pathway to achieve close to a net-zero[47] society by mid-century.

1.2 Energy security and access

> The prospect of robust progress hinges on the ability to manage short-term shocks.

High energy prices and new risks of energy shortages, resulting from the fast COVID-19 economic recovery and the war in Ukraine, have forced a reprioritization of energy security. Countries can strengthen energy security by diversifying their fuel import partners in the short term and diversifying their energy mix with low-carbon alternatives and improving energy efficiency in the long term.

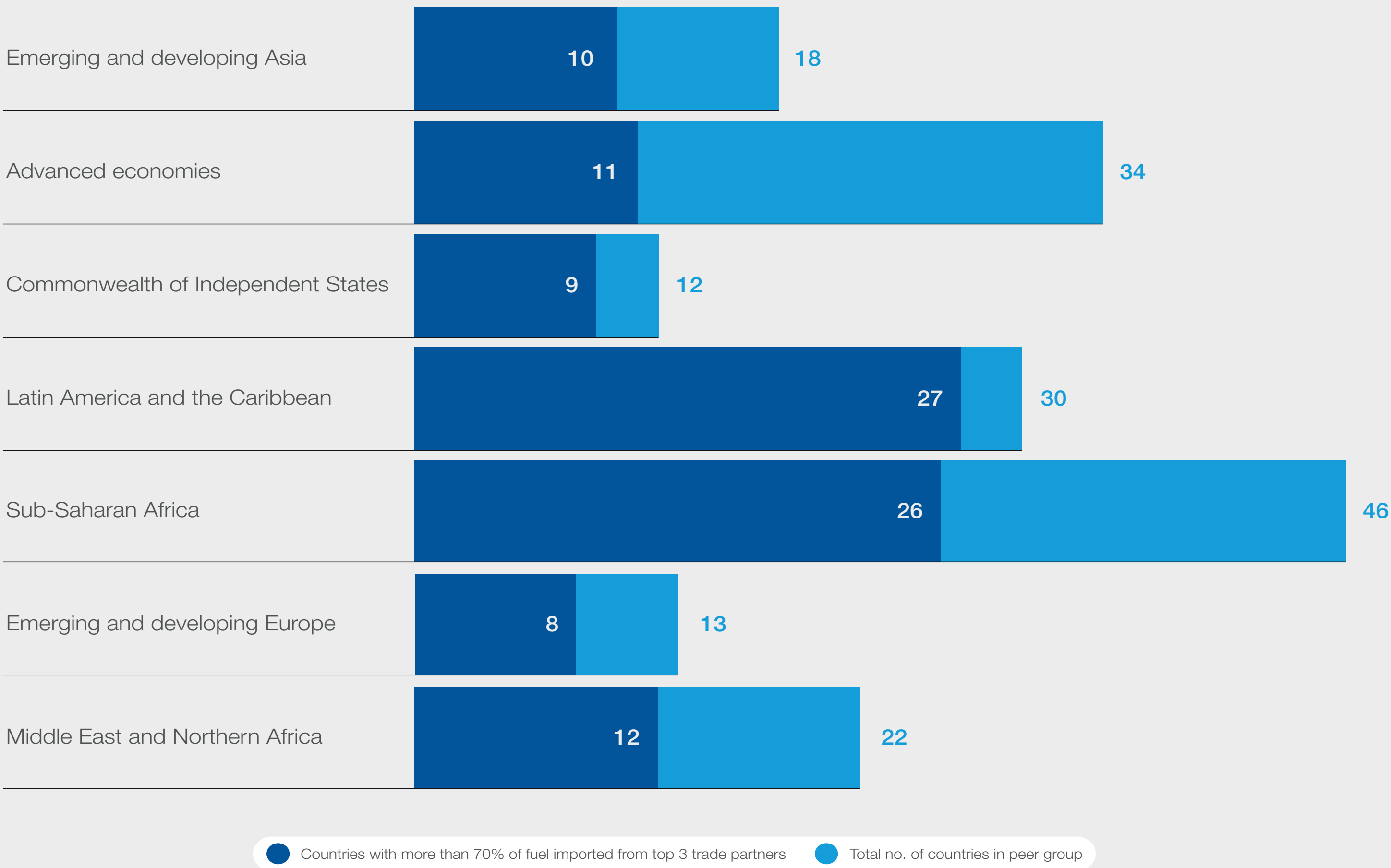
According to the latest evidence from the Intergovernmental Panel on Climate Change (IPCC), global emissions need to peak by 2025 to keep the target of 1.5°C alive. The reconfiguration of the entire energy system, including the underpinning fuels, technologies, markets and geopolitics, may not proceed smoothly.[48] The prospect of robust progress hinges on the ability to manage short-term shocks, especially those that pose risks to the reliability and affordability of energy. The IEA defines energy security as the "uninterrupted availability of energy sources at an affordable price".[49] As measures to combat climate change accelerate, adequate and affordable access to energy will be critical to the continued prioritization of environmental policies. In the long run, energy security means securing the energy supply needed for a country's economic development and growth. In a world aiming to reach net-zero emissions by mid-century, long-term energy security is closely tied, if not constrained, by national sustainability ambitions.

Energy market volatilities and geopolitical events over the past two years have elevated energy security risks. Following a period of low investment in legacy assets,[50] a faster-than-expected economic rebound from the COVID-19 pandemic[51] strained the energy supply chain,[52] leading to concerns about the availability of gas for winter heating,[53] industrial activity slowdown[54] and pressure on the fiscal budgets for energy subsidies.[55] Indeed, the record-high energy prices took countries by surprise and spotlighted their severe reliance on imported fossil fuels as well as the strong interdependence of their domestic electricity prices with global gas markets.[56]

High prices created heavy financial pressure not only on households but also on businesses of all sizes, leading to social protests and industrial production cuts in several countries.[57] Additionally, in 2021, intensifying extreme weather events pushed power grids to the breaking point,[58] which led to severe blackouts affecting 4% of the world's population.[59] And, currently, energy security concerns arising from the war in Ukraine are forcing a fundamental rethink of energy and foreign policy, even in countries not reliant on imported fossil fuels from Russia.

Bilateral energy trade among countries, globally integrated energy markets, and technology standards for mid-stream and downstream infrastructure are among the core building blocks of the current geopolitical landscape. Resource endowments aside, the spatial distribution of reserves vis-à-vis demand centres and infrastructure considerations including pipelines, refinery configurations, etc., necessitate even resource-rich countries to rely on imports, a case in point being Canada.[60] Hence, complete energy independence may not be feasible for countries in the near term. While a decarbonized future energy system can provide energy security dividends due to the localized resource abundance of low-carbon energy sources, ensuring energy security and affordability through the transition will require fossil fuels. Many countries either do not benefit from natural energy resource endowments required to meet their energy needs or are unable to exploit them for their own use due to political, technological or financial reasons. The essence of the energy security challenge in these countries is typically dual: countries' insufficient diversification of their energy mix or insufficient diversification of energy import partners, or both. As an example, Europe relies on natural gas for 19%[61] of its power generation and 38-41%[62] of its residential heating, and 45% of the EU's consumed natural gas is imported from Russia.[63] A majority of countries continue to rely on a handful of trade partners to meet their energy requirements (Figure 5).

FIGURE 5 | **Country fuel import diversification**



Note: See the appendix for the peer group classification.

Source: UNCTAD, World Economic Forum and Accenture analysis

> **An energy mix, dominated by low-carbon energy systems, is more likely to have a national or regional footprint, implying a convergence of energy security and sustainability.**

Eleven of 34 advanced economies are reliant on only three trade partners for over 70% of their economy's fuel imports. Similarly, 10 in emerging Asia, 8 in emerging Europe, 27 in Latin America and the Caribbean and 26 in Sub-Saharan Africa are heavily reliant on just three countries for a majority of their fuel imports. These are all at-risk countries whose energy supply chains could potentially experience disruption in the face of adverse climatic events, supply shortages or geopolitical crises. **The lack of diversity in imports results in the countries' energy system having less cushion to deal with disruptions in supply from a given partner, which eventually could precipitate into a national security concern.**

As nations continue to evolve their energy security priorities in light of the rising uncertainty, governments' role in ensuring energy security is not straightforward, as countries with different energy system structures may follow different pathways. What differentiates today's energy crisis from past crises, though, is the fact that scalable alternative technologies and renewable energy sources are available today, which enables policy-makers to facilitate a more integrated, efficient and flexible energy system. Whenever possible, countries can consider strengthening energy security by diversifying their fuel import partners in the short term as well as diversifying their energy mix with the development of domestic renewable and other low-carbon energy in the long term, driving down both the need for energy imports and strategic geopolitical dependencies.[64] There are reasons to believe that diversification will remain critical in increasingly decarbonized energy systems, where high-carbon energy systems powered by fossil fuels, at least in the coming decades, will continue to cohabit with low-carbon energy sources.

A future energy mix, dominated by low-carbon energy systems, such as solar, wind, hydrogen and biomass, is more likely to have a national or regional footprint, implying that a convergence of energy security and sustainability could be possible. Countries shifting towards more decarbonized domestic energy sources are likely to be more self-reliant and less dependent on the global trade of energy, especially if coupled with efficiency measures that reduce the overall energy needs.

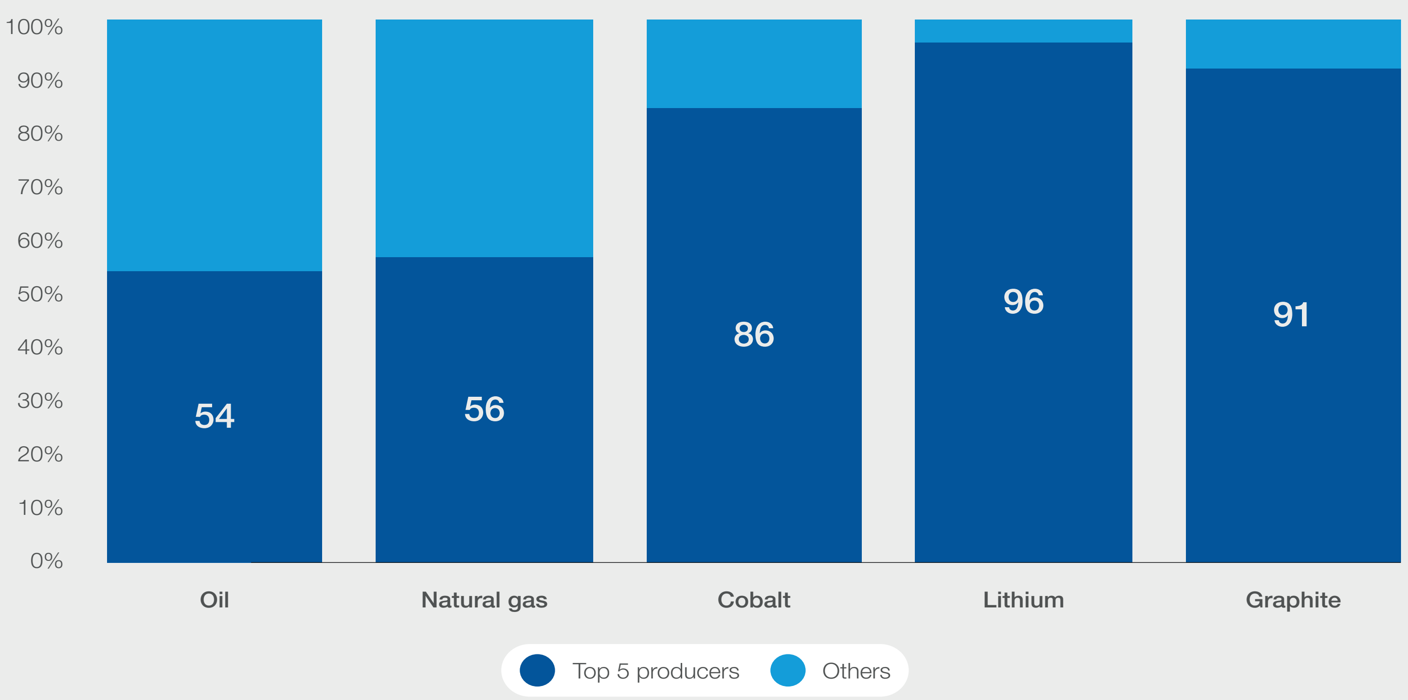
The impending surge of economies' electrification from the rise of renewables is expected to bring in a different set of security-related challenges. Crucial among them would be ensuring the reliability and efficiency of national and cross-border electricity grids. In particular, as the share of wind and solar increases in countries' energy mix, electricity grids will require systemic upgrades to accommodate these variable renewable energy sources. But going forward, countries will also need to think strategically about the technology mix and geographical spread,[65] aside from upgrading and redesigning their grid infrastructure. As a result, grid modernization is also emerging as a key priority for policy-makers and is one of the focus areas of new policy packages, such as in the United States[66] and EU,[67] for both energy security and energy transition imperatives.

The transition to a decarbonized future energy system lowers the security risks from geopolitics of fossil fuels but can also create new potential concerns. Declining fossil fuel demand may further concentrate the remaining supply as higher cost producers exit the market. Additionally, the transition to clean energy depends heavily on access to minerals, such as lithium, cobalt, nickel, copper, etc., to manufacture solar panels, wind turbines and batteries. While the demand of these minerals is expected to grow six-fold for a transition to net zero by 2050 according to the IEA,[68] the production of transition minerals, such as cobalt, lithium and graphite, is more concentrated than that of fossil fuels oil and gas (Figure 6). While a complete phase-out of fossil fuels would reduce countries' energy mix diversification, an increased reliance on renewable power, battery storage and other low-carbon sources could also pose new energy security risks.[69]

Furthermore, as an increasing number of countries, including the United Kingdom,[70] the United States,[71] Japan,[72] India[73] and China,[74] reconsider the role of nuclear energy due to its low emissions and baseload operational profile, security risks from design specifications[75] and nuclear fuel supply chains can arise.[76]

As the transition remakes the energy system, energy security concerns also require upfront risk mitigation measures. Investment in contingency measures, such as strategic reserves for petroleum and storage infrastructure for natural gas, can reduce the impact of disruptions in the supply of these fuels through the transition period. Similarly, considering the criticality of transition minerals' supply to support the manufacturing of the renewable energy components necessary for the energy transition, investing sufficiently in responsible mining, diversifying sources of supply and strategically stockpiling minerals in some cases can ensure a resilient minerals supply chain.[77] **Furthermore, considering the energy security premium, maintaining some legacy assets through market mechanisms that support reserve capacity might be required to address supply demand imbalances during the transition.**

FIGURE 6 **Market share of top five energy commodity producing countries**



Source: bp, *Statistical Review of World Energy 2021*, 70th edition, 2021, https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

> Maintaining some legacy assets through market mechanisms that support reserve capacity might be required to address supply demand imbalances during the transition.

While governments across the globe continue to focus on the critical aspects of their countries' energy security, it is vital that they sustain ongoing efforts to provide energy access to those in need. Even before the pandemic arrived, the world was lagging in providing universal access to electricity and clean cooking fuel.[78] As of 2019, 759 million people do not have access to electricity and over 2.6 billion people do not have access to clean cooking fuels.[79] The rate of progress reveals that the world is not on track to achieve the targets for universal access, and the impact is more acute for the most vulnerable countries that were already lagging.

Emerging and developing economies are likely to suffer longer and more severely from the economic impacts of the Covid-19 pandemic, exacerbating hunger, poverty and inequality worldwide.[80] Early evidence indicates that the pandemic might also have dismantled some of the steady progress towards universal energy access. In 2021, the number of people without access to electricity increased by 2% to 768 million.[81] The lack of access to energy is a constraint in delivering timely and adequate healthcare and vaccination programmes. Only 28% of healthcare facilities in Sub-Saharan Africa have access to reliable electricity,[82] making basic health services in some rural communities inaccessible.

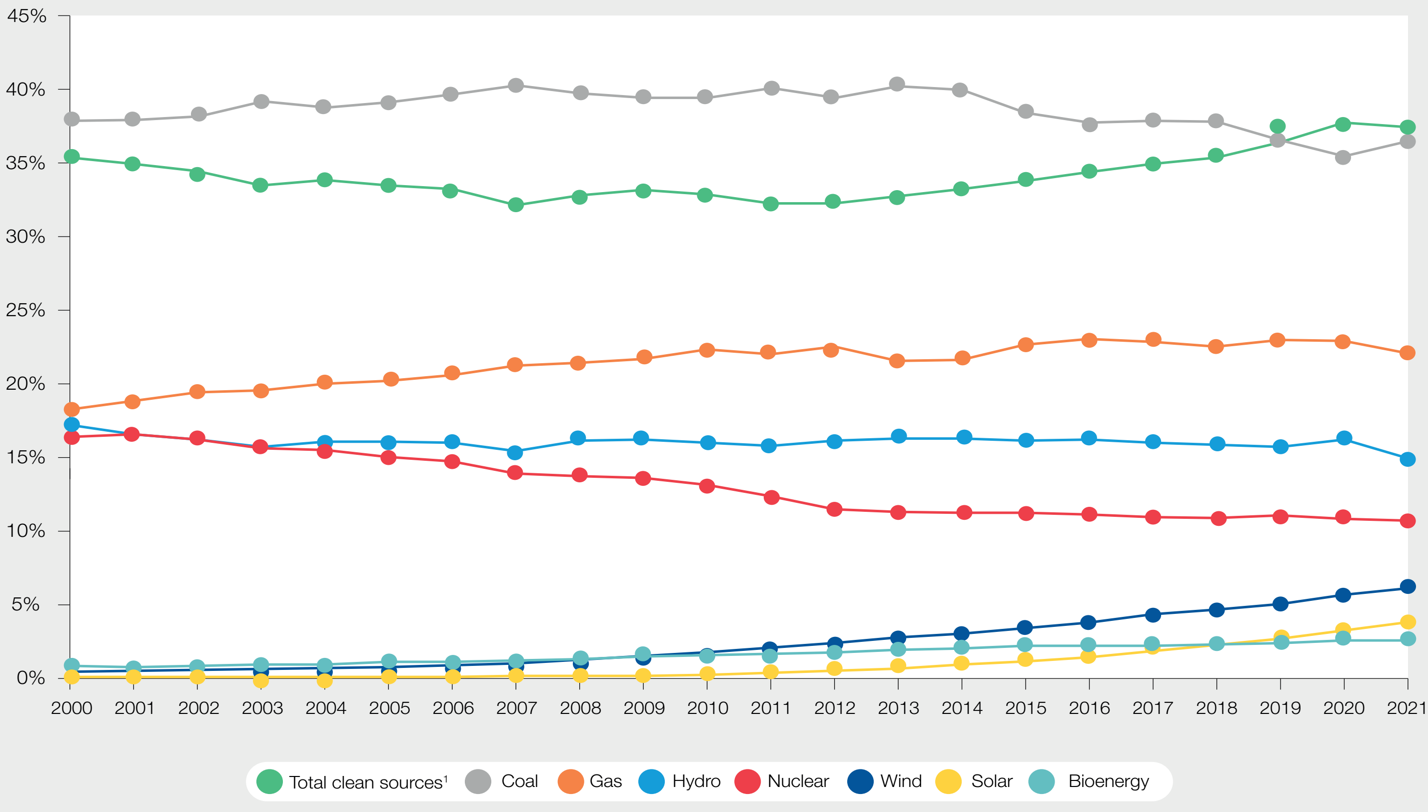
Delivering universal energy access by 2030 remains a key UN Sustainable Development Goal (SDG) with the potential to better the lives of millions. However, the COVID-19 pandemic has significantly damaged ongoing efforts as companies working on providing off-grid solutions continue to suffer from supply chain disruptions.[83] Achieving the UN's seventh SDG also requires large investments, to the tune of $20 billion[84] annually to 2030 in Africa alone, yet fiscal implications of economic recovery programmes tend to indicate that valuable resources are instead being diverted from energy access programmes in the current context.

1.3 Environmental sustainability

Energy affordability and security challenges reinforce the need to supercharge the transition by accelerating investments in the "new" (decarbonized) energy system and embedding more efficient energy consumption habits in post-pandemic societies. The strengthening of governments' and companies' efforts to reduce their reliance on fossil fuels is key, but individuals' "civic duty" towards energy use must also intensify.

The momentum on environmental sustainability has been strong throughout the past decade. Enabled by policies, investments and innovations, renewable energy technologies, such as solar photovoltaics and wind power, are cost competitive with fossil-fuel-based power generation alternatives in countries around the world.[85] Although low at absolute levels, the market share of electric vehicles has steadily increased, doubling in 2021.[86] Costs of energy storage solutions, such as lithium-ion batteries, critical for providing flexibility services to a decarbonized grid, are rapidly approaching cost competitiveness.[87] Despite COVID-19 pandemic restrictions, periods of lockdowns, supply chain bottlenecks and the increasing turmoil on energy markets, the past two years accelerated the global momentum in the transition towards more sustainable energy systems, with record capacity expansion of solar photovoltaics and wind power. Wind and solar energy combined now generate 10% of global electricity for the first time ever (Figure 7).[88] In addition, low-carbon power sources including solar, wind, hydro, nuclear and bioenergy combined generated 38% of the world's electricity in 2021, overtaking coal, with Europe leading the way and China and Japan making over a tenth of their electricity from wind and solar for the first time.[89] An analysis of historical trends from the ETI supports this trend, with the global average score on the environmental sustainability dimension of the index increasing in seven of the past 10 years (Figure 3), with more than 70% of countries showing growth on this dimension. Energy security challenges arising from fossil fuel dependency have intensified due to the ongoing war in Ukraine, strengthening political and popular resolve to accelerate the pace of the clean energy transition.

FIGURE 7 **Share of global electricity generation by source, 2000-2021**



Notes: [1]Total clean sources include solar, wind, hydro, nuclear and bioenergy; The combined solar (3.72%) and wind (6.59%) shares of global electricity generation amount to 10.31%.

Nevertheless, the ground to cover remains considerable. The latest IPCC assessment indicates that average annual GHG emissions between 2010 and 2019 were higher than in any previous decade.[90] Emission reductions in carbon dioxide from fossil fuels and industrial processes were insufficient to offset the increase from rising global activity in industry, energy supply, transport, agriculture and buildings.[91] While the drop in energy demand in 2020 from COVID-19 pandemic restrictions led to reduced global CO_2 emissions by almost 6%,[92] emissions sharply rebounded in 2021 above pre-pandemic levels to their highest level in history on account of the rapid restoration and rebound of economic and industrial activity levels, and energy market volatilities. To contain the average temperature increase to below 1.5°C, the global GHG emissions must peak before 2025 and be reduced by 43% by 2030.[93] At the same time, methane, the second fastest growing GHG emissions behind CO_2,[94] would also need to be reduced by about a third by 2030. According to IEA's *Net Zero by 2050* report, annual capacity additions of solar and wind need to be higher than 1,000 GW, four times the record installation levels achieved in recent years.[95] Additionally, annual sales of electric vehicles would need to scale up eighteen-fold by 2030. **Achieving a transformation of this magnitude and complexity necessitates long-term and ambitious policies, enabling infrastructure and investments, as well as supporting consumption behaviour changes.**

At COP26, governments and businesses demonstrated strong commitment to address the climate emergency, with 197 countries signing the Glasgow Climate Pact, formalizing their commitments and pledges to net-zero targets.[96] As of the end of 2021, countries responsible for 90% of global emissions have announced or are considering net-zero targets.[97] In addition, over 100 countries have joined the Global Methane Pledge, which aims to cut global methane emissions by 30% by 2030.[98] However, current ambitions still fall short of fulfilling the targets set in the Paris Agreement on climate change in 2015. Despite the momentum at COP26, analyses by the IEA and Climate Action Tracker show that even if all climate pledges are met, the world would still not be on track to limit global warming to 1.5°C by the end of this century.[99,100] Additionally, **pledges must be turned into concrete policies and actions that make a difference on the ground in the few remaining years to 2030; the widening gap between pledges and implementation effort is a growing concern.**

The demand for electricity grew at a record pace[101] in 2021, equivalent to adding the demand of India to the world's grid.[102] Lack of requisite natural gas supply led to a record increase in the use of coal in power generation, including in regions where coal had been in structural decline, such as the United States and the EU. Considering potential energy security implications in the medium term, China, India, Indonesia, Japan and Viet Nam plan to build more than 600 coal power plants, which accounts for 80% of new coal power investment.[103] According to the IPCC, unabated emissions from existing or planned fossil fuel infrastructure until the end of their lifetime is equivalent to the emissions allowance from all sectors in pathways to limit global warming to 1.5°C.[104] **Phasing out coal requires the accelerated capacity expansion of not just proven alternatives like solar and wind, but also of other low-carbon sources of energy, such as hydro, bioenergy, hydrogen-based geothermal technologies and infrastructure to capture and store carbon dioxide.**

Carbon capture and sequestration, while a mature yet costly abatement technology for gas processing and enhanced oil recovery, remains unproven in the power sector, highlighting the need for investment in research and development, and policy measures to support demonstrations and deployment. Additionally, clean energy investments would have to triple by 2030 to meet demand in a sustainable way, according to the IEA.[105] While investments in energy transition have approximately doubled over the last decade, China, the United States and the EU account for more than 80%[106] of the investments.

“ Pledges must be turned into concrete policies and actions that make a difference on the ground in the few remaining

Current paradigms with heightened energy security risks indicate the need to further harness the synergistic potential of energy efficiency.

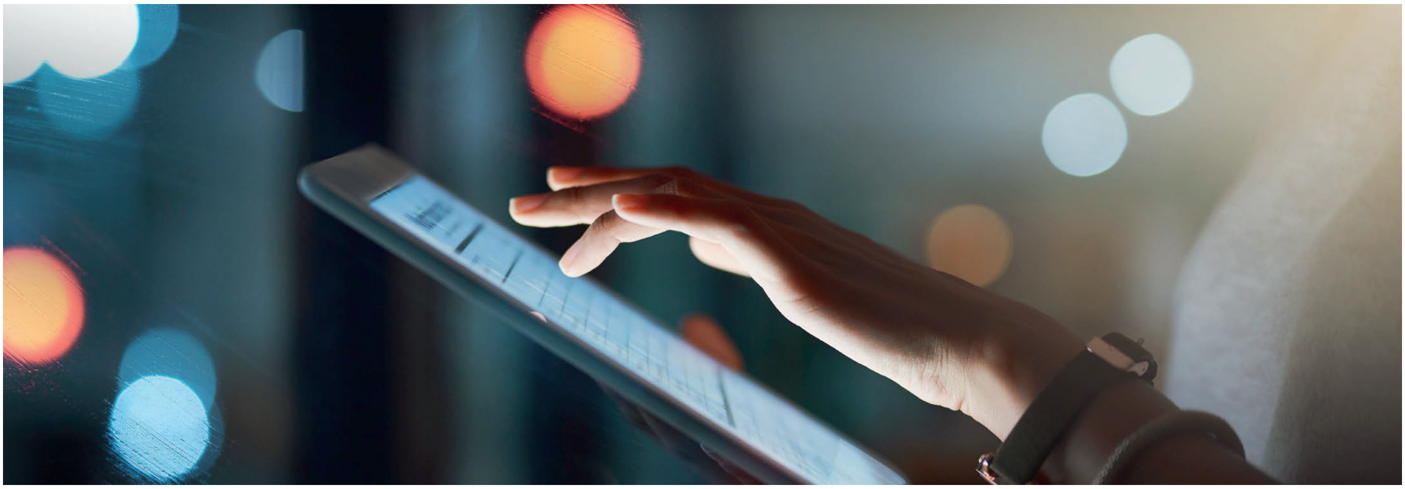
Africa, which has 39%[107] of global renewable energy potential, attracted only 2% of global investment in renewable energy over the last decade.[108] Geographical disparities in global climate finance aside, investments in fossil fuel assets remain higher than low-carbon assets, also reflecting a mismatch between pledges and actions.[109]

Overall, the macroeconomic challenges that came with the 2021 economic recovery as well as the energy affordability and energy security concerns for many countries exacerbated by the Russian invasion of Ukraine reinforce the rationale to supercharge the energy transition.

Apart from supply-side measures, energy efficiency is regarded as the world's "first fuel" and is the strongest lever in the transition to net zero, according to the IEA.[110] While the energy intensity of GDP has been declining, the rate of decline needs to double to meet the levels for net-zero emissions by 2050. Given the energy footprints across economic sectors, this highlights the importance of improving energy productivity of such end-consuming sectors as industry and transport, as well as economic diversification to decouple growth from energy consumption. An analysis of G20 countries indicates an inverse relationship between their level of national economic output from the industrial sector (including energy-intensive sectors such as manufacturing, mining, construction and energy producing activities) and their scores on the ETI. **Fostering an innovative business environment and human capital development can support the growth of higher value added sectors, enabling necessary economic diversification.**

In addition to supporting sustainability ambitions, integrated demand-side measures to improve energy efficiency can also offer security dividends. For example, Japan, a major energy importer, was able to reduce its import burden of oil and gas by 20% in 2016, as a result of energy efficiency improvements since 2000.[111] Current paradigms with heightened energy security risks indicate the need to further harness the synergistic potential of energy efficiency. Effective demand-side management can offset supply-side additions as well as the need for carbon capture and storage solutions for emissions management. A combination of the right policies, infrastructure and efficient end-use technologies for demand-side mitigation can lead to a 40-70%[112] reduction in GHG emissions by 2050 across the three primary end-use segments: transport, buildings and industry. The expansion of transport electrification infrastructure with incentives to purchase electric vehicles, utilizing remote work arrangements to restrict business air travel, and providing affordable and reliable public transportation where possible can significantly reduce emissions from transportation. Optimizing residential energy consumption through the electrification of heating and cooking, and adopting simple lifestyle changes such as shorter showers or adjusting the setpoint for heating and cooling on thermostats, coupled with sustainable urban design can reduce residential emissions by more than 50%.[113] **Active consumer engagement and participation are pivotal for effective demand-side management.**

While behavioural and cognitive barriers have been persistent in energy efficiency initiatives, the experience from the COVID-19 pandemic demonstrated that social behaviour adaptation is possible in the short term. Lessons from the management of the pandemic highlight the importance of transparent information dissemination campaigns and of the trust in institutions. Additionally, as the pandemic restrictions disproportionately affected low-income households, it also highlights the distributional considerations of lifestyle and behaviour change programmes, emphasizing the need for equity measures to enhance social acceptance.



1.4 Transition readiness enablers

The window of opportunity to prevent the worst consequences of climate change is closing fast. It is essential to make the energy transition robust by building the necessary enablers that will keep the transition going if the economic and energy security context deteriorates. This includes making legally binding commitments, designing long-term visions for domestic energy systems, building an attractive investment landscape for private capital and promoting consumer participation as well as building the local workforce required for the transition.

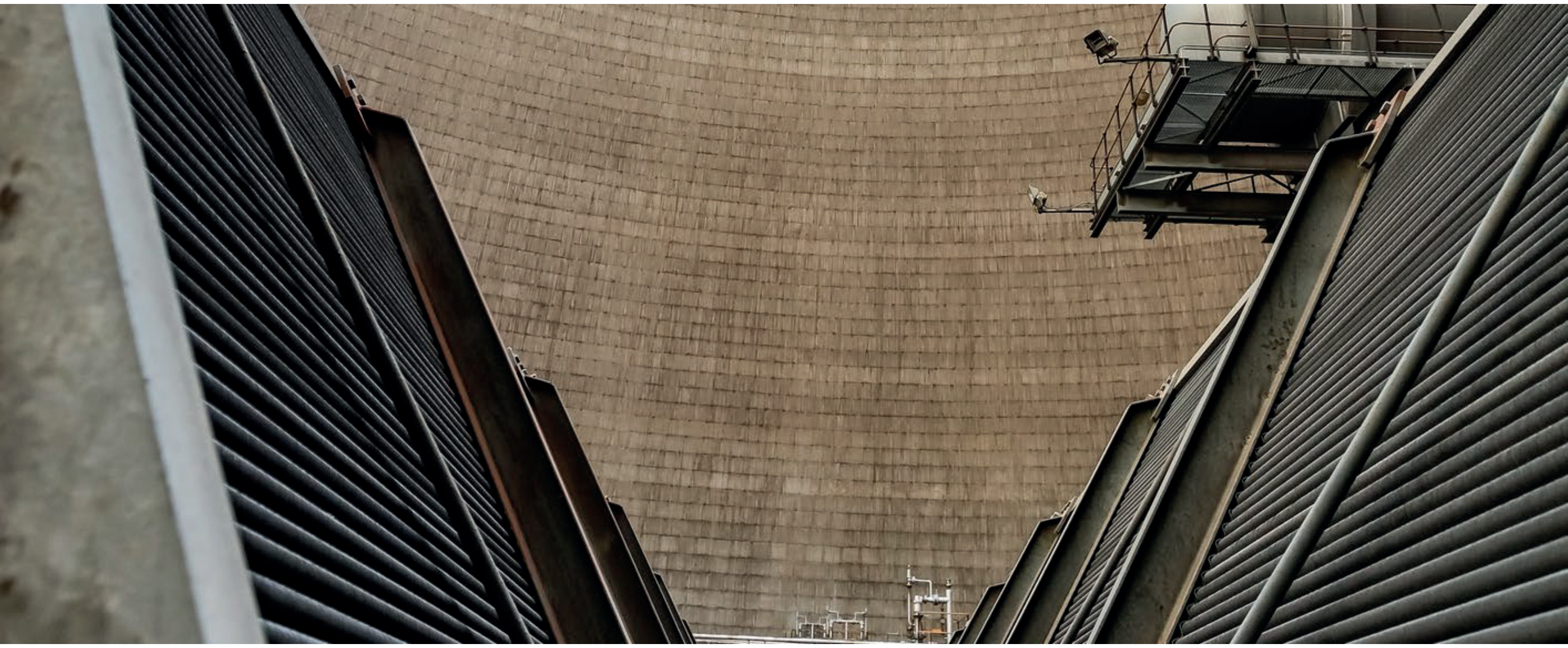
As outlined in the ETI framework, the readiness of a country to transition its current energy system towards one that enables the development of a sustainable low-emission economy depends on a multitude of factors that can be measured and analysed along a country's energy system structure, regulation and political commitment, investment climate, human capital and consumer participation, infrastructure and business environment, and the robustness of institutions (Figure 1). Progress on these dimensions is critical for countries to increase their support of the energy transition and accelerate their efforts.

However, improving these dimensions is gradual as the path to institutional, socio-economic and systemic transformations depends on established processes and systems. Given the disruptive environmental, macroeconomic and geopolitical events of the last two years and their implications for the energy transition, this section outlines four measures that countries can take to support their transition journey.

1) Anchoring climate commitments in legally binding frameworks that can endure political cycles and enforce the long-term implementation of national transition objectives

The long-term structural changes required for the energy transition will take longer than the usual 4- to 5-year political cycles of many countries so they must be made resilient to political changes in the executive, legislative and judicial branches of government. Turning climate commitments into laws (e.g. France attempted a change in constitutional law in 2021[114]) can support the transition effort in the long run. Climate-related laws then overarch the policies to promote energy efficiency, renewable energy and electricity access, the participation in international climate diplomacy, the evolution of GHG reduction targets (both 2030 nationally determined contributions and longer-term net-zero targets), as well as the policy stability required for long-term energy system transformation.

Countries, cities and businesses have vowed to achieve net-zero emissions in the coming decades. In 2021, a wave of pledges were made, raising the number of countries committed to net-zero targets, covering 88%[115] of global emissions. Particularly, prior to COP26, several



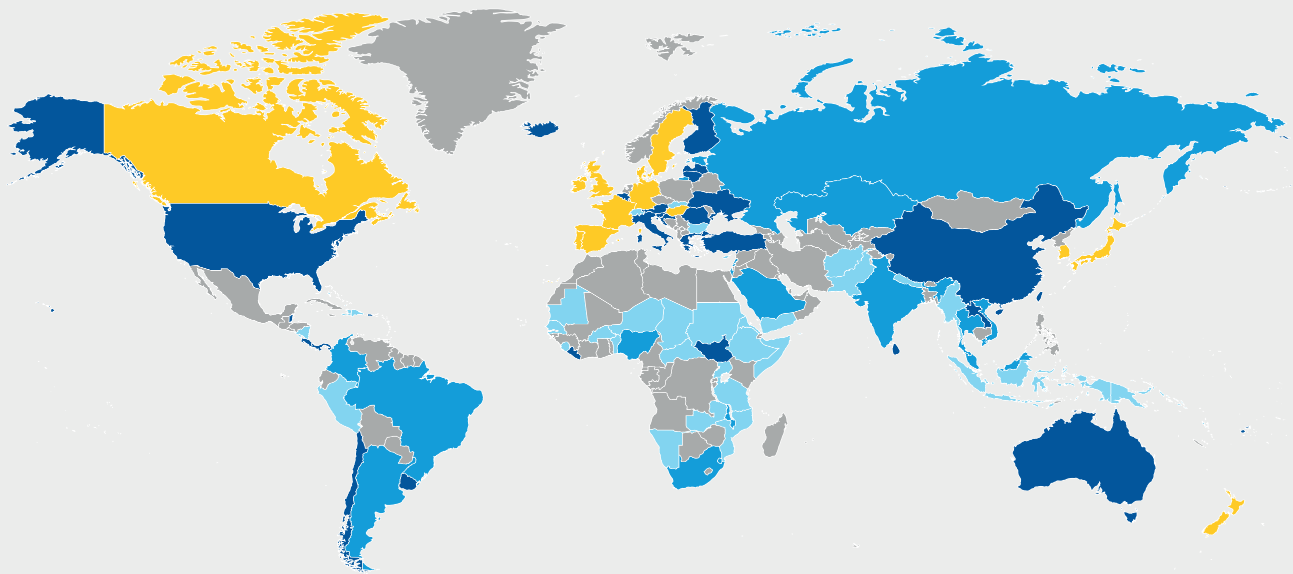
large economies submitted more ambitious 2030 emission reduction targets, notably China, the EU and the United States. But, although these new targets can reduce GHG emissions by 7.5% this decade, 55% is needed by 2030 to align with the Paris Agreement goal of keeping the global temperature rise below 1.5°C.[116]

To help political ambitions translate into on-the-ground action, introducing net-zero commitments into a legal institutional framework and complementing them with binding policies could help strengthen the urge for action of future governments regardless of other existing priorities. To date, 13 countries have made their net-zero targets legally binding and 33 countries have put their net-zero targets in policy documents.[117] Figure 8 shows the status of countries' net-zero targets in 2021. The 2050 climate goals require more countries to transition their commitment into legally binding frameworks to enforce long-term on-the-ground climate action.

2) Taking and holding long-term decisions with regard to the decarbonization of the national energy system structure

A country's existing energy system structure significantly influences transition readiness as the path depends on legacy infrastructure and resource endowments. Technological lock-in, economies of scale, the long lifetimes of current energy infrastructure and end-use behaviour patterns

FIGURE 8 **Status of countries' net-zero targets, 2021**



Net-zero target status	Share (%) of global total energy supply	Share (%) of global CO_2 emissions from fuel combustion	Share (%) of global total nominal GDP
Achieved	0	0	0
In law	14	12	25
In policy document	44	50	50
Declaration/pledge	21	21	12
Purposed/in discussion	5	4	4
Uncovered	16	13	9

Note: The boundaries shown in this map do not imply official acceptance or endorsement by the World Economic Forum.

Sources: Energy and Climate Intelligence Unit; International Energy Agency; World Bank create barriers to entry for disruptive technologies. Creating a new energy system that can gradually complement and eventually supplant the legacy infrastructure requires enhancing the flexibility of electricity system, improving end-use efficiency and increasing the share of renewable energy in power generation, among other measures.

As an example, coal is generally the most polluting source of power generation today. It emits nearly twice the amount of CO_2 when combusted compared to natural gas at most power plants where it is used,[118] yet it still represents a major share of many countries' energy mix.

Long-term commitments for the future of the national energy system structure can ensure countries make fundamental and irreversible changes in line with their energy transition goals. The emergency returns to coal witnessed in recent months should also make countries rethink how they can build resilience and contingency plans for their energy systems that do not rely on coal.[119] Multinational partnerships can play a crucial role in ensuring long-term visions and structural changes are implemented. For instance, the Just Energy Transition Partnership[120] between South Africa and France, Germany, the United Kingdom, the United States and the EU will provide support to transform South Africa's economy away from coal and towards a low-emission climate resilient economy.

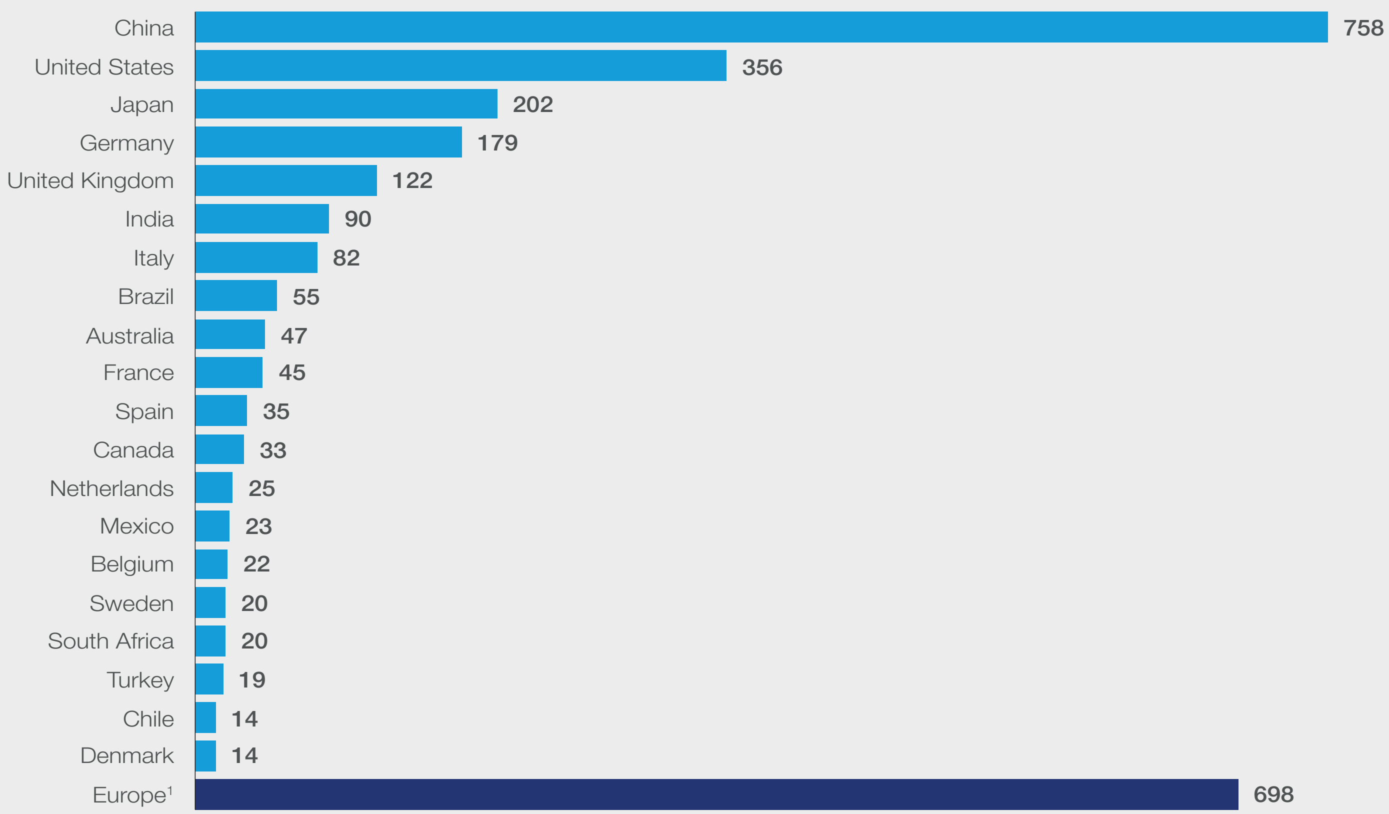
3) Building an attractive investment landscape for private capital, both foreign and domestic, to finance energy transition projects, especially in emerging and developing countries

A country's ability to attract capital depends on a multitude of factors, including supportive policy and legal frameworks, stability of the currency and exchange rates, a secure and safe environment, the quality of infrastructure and the availability of the latest technologies. Adopting and promoting these factors can create strong momentum for capital to flow into the transformation of the energy system.

While advanced economies continue to attract capital under favourable terms, including for higher-risk new low-emission technology industrial projects, developing and emerging countries are still struggling to attract both foreign and domestic private investments essential for the financing of large energy projects and infrastructure. Even though the last decade saw record investment in new renewable power capacity ($2.6 trillion globally[121]), most of these investments were made in countries with stable and favourable investment landscapes, such as China, the United States, Japan and Germany (Figure 9). Additionally, the effects of the COVID-19 pandemic were felt differently across regions, with emerging and developing countries facing acute challenges given the fiscal impacts of the pandemic on their national budgets. Owing to the continued reluctance of a number of financial institutions to fund the transition in emerging and developing countries,[122] it is worth stressing that climate goals cannot be reached without a global transition; solutions must be found to rally the financial sector. Technical and financial support to emerging and developing economies, leveraging a mix of public and private investment instruments, grants, concessional finance and market-based capital could help keep the transition on track. International collaboration, not only on finance flows but also on policies, regulatory practices, best technical practices and new business models is critical.

While governments continue to put in place the necessary enablers to build private investors' confidence, investing entities such as multilateral development banks, philanthropic funds, specialized branches of sovereign wealth funds and commercial banks can play a role in bridging the gap and invest in countries where higher financial risks are involved.

FIGURE 9 | **Renewable energy capacity investment, top 20 countries, from 2010 to first half of 2019 ($ billion)**



Note: [1]All European countries, including those listed beyond the top 20, plus the United Kingdom.

Source: UNEP, *Global Trends in Renewable Energy Investment 2019*, 11 September 2019, https://www.unep.org/resources/report/global-trends-renewable-energy-investment-2019

4) Promoting consumer participation and building the local workforce required for the transition, paying particular attention to the livelihoods of vulnerable populations

Consumer participation involves increasing customer awareness of the stakes of climate change, of carbon footprints and of individual actions that can be taken to support national climate change ambitions. The energy transition will likely create a significant number of new jobs and require a trained workforce with very different skill sets than a country has historically developed (e.g. petrotechnical professionals in oil producing countries). Developing the consumers and workers of the future can be a key enabler of a long-term sustainable energy transition.

When empowered, environmentally conscious consumers can achieve substantial emission reductions, as shown by a recent study[123] that researched household preferences for reducing GHG emissions in cities in France, Germany, Norway and Sweden. These consumers can drive distributed grid networks, apply energy efficiency measures and reduce their overall carbon footprint. Policies raising the awareness of consumers' energy consumption, such as mandating energy labels on products and providing peer-to-peer comparative energy consumption reports to households, or providing monetary incentives like variable power rates and feed-in tariffs can be used to drive long-lasting behavioural changes in consumers.

While moving to clean energy can create new jobs in the clean energy industry, it can also lead to job losses in other industries and can be detrimental to the livelihood of dependent communities. In addition, the transition can negatively affect low-income households, which might struggle to keep up with the rising costs and consumption changes brought about by the transition. Governments can partner with private institutions to reskill, cross-skill or upskill the existing workforce, particularly within jobs at risk, such as those in the fossil fuel industries. They can also adapt the education system to stay abreast of the technologies in the renewables and digital space. Similarly, policies that develop or expand social protection benefits to accompany energy transition reforms can be used to mitigate the negative effects on low-income households.

2

Unlocking the net-zero transformation of industries

A paradigm shift in collaboration is needed to increase progress.

Key highlights

1. Industry-heavy economies may face additional challenges, due to the greater complexity of the industrial net-zero transformation
2. Five industries – cement and concrete, iron and steel, oil and gas, chemicals, and coal mining – represent 80% of all industrial emissions
3. Industries need to overcome difficult choke points whose solutions are seldom found within a single company or even industry
4. A new generation of collaboration models could help overcome the industry decarbonization choke points
5. Industry leaders now favour collaboration and transparency over competition, and view decarbonization as a win-win solution
6. Thanks to industry pioneers, multiple collaboration models have emerged that could be replicated and expanded to help advance the journey to net zero

2.1 No net zero by 2050 without industries

Industries are the backbone of the global economy; their transformation is critical to a net-zero world.

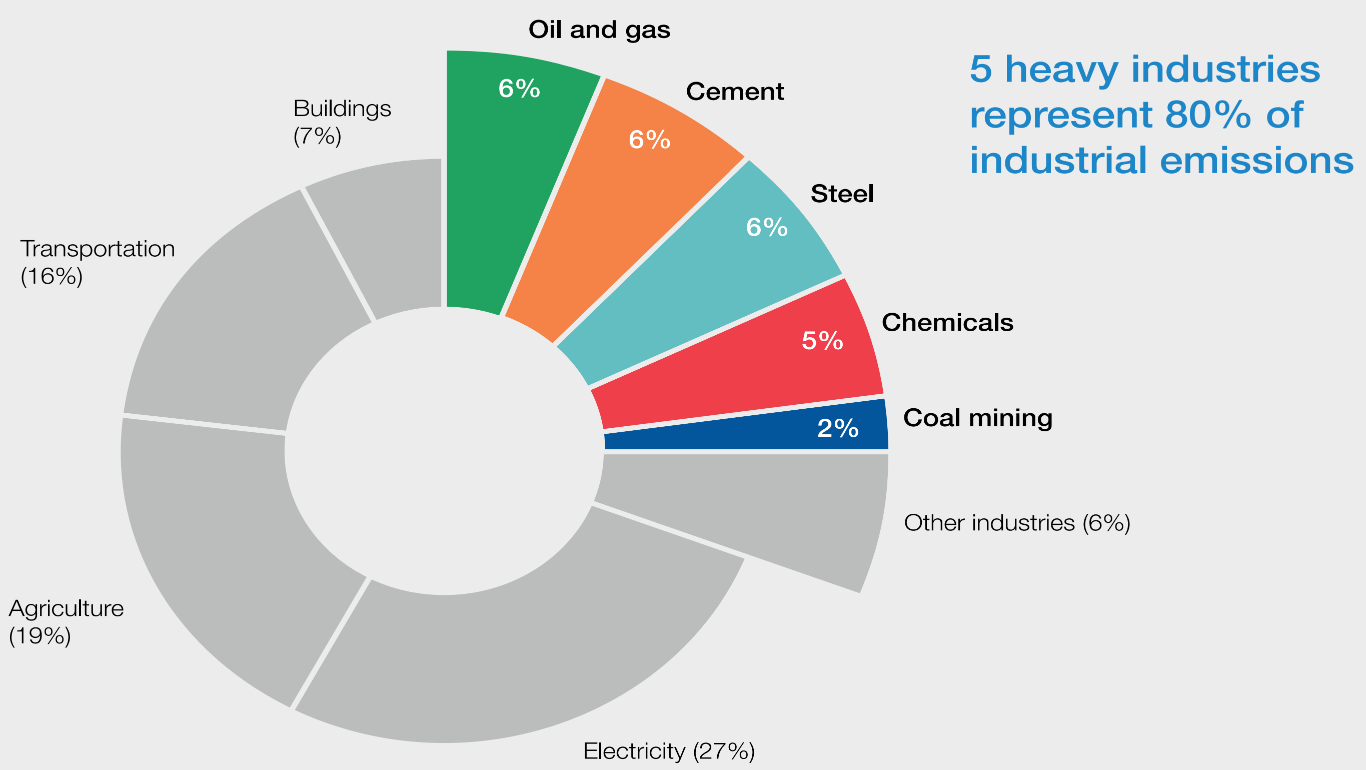
Industries generate more than 30% of anthropogenic emissions[124] – no net-zero economy is possible without them. Yet, industries face considerable challenges to decarbonize, such as the lack of competitive low-emission technology, the limited development of enabling infrastructure or the scarce availability of capital to transform. Going forward, "clean demand" signals could be a turning point to accelerate "clean supply".

Industries are the backbone of the global economy, providing the energy and materials needed to sustain and grow modern society. Emissions from fuel combustion and processes in industries contribute to more than 30% of global GHG emissions[125] (out of a global total of 51 GT of CO_2 equivalent[126]); hence, the transformation of industries is critical to a net-zero world.

While encouraging progress has been made in the past decade to decarbonize power generation (the renewables share in global electricity generation rose from 20% to 29% between 2010 and 2020[127]), many industries are still defining their pathways to a low-carbon future. Particularly, five heavy industries – cement and concrete, iron and steel, oil and gas, chemicals, and coal mining – which together represent 80% of all industrial emissions (Figure 10), need to make a major shift by 2030 to keep the net-zero 2050 objective within reach.[128]

Population and economic growth will likely continue to fuel demand for industrial products beyond 2050, and so will the energy transition itself. For instance, aluminium, steel and many minerals[129] are key elements in the making of solar panels, wind turbines, power grids and electric vehicles. Steel demand is projected to rise by 30%,[130] cement and ammonia by 40%[131,132] and aluminium by 80%[133] in the coming three decades (Figure 11). In addition, all but the most aggressive decarbonization scenarios forecast that oil and gas could continue to play a significant, though diminished, role in the energy mix through 2050 and beyond.[134]

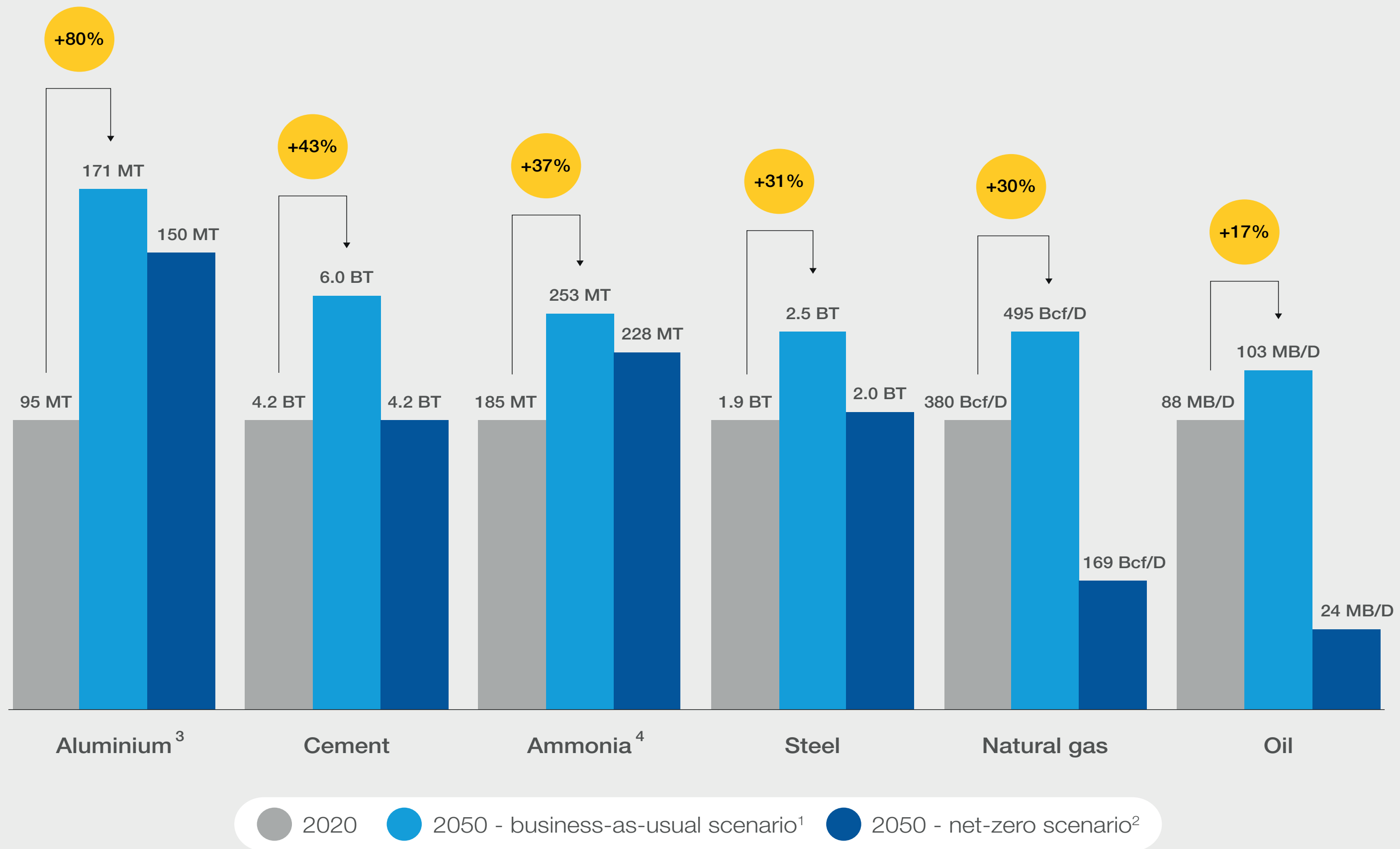
FIGURE 10 **Emissions by sector vs global emissions (51 $GTCO_2e$)**



Notes: Oil and gas also includes refining; Steel includes iron; Cement includes concrete.

Source: Breakthrough Energy, Sectoral Analysis, "Emissions breakdown for Manufacturing, by subsector"

FIGURE 11 | **Global demand projections by industry, 2050**



Notes: [1]Based on IEA Stated Policies Scenario (STEPS) for all except aluminium (International Aluminium Institute (IAI) Business-as-Usual scenario) and cement (Global Cement and Concrete Association (GCCA) Business-as-Usual scenario); [2]Based on IEA Net-Zero 2050 scenario for all except aluminium (IAI 2050 Net-Zero scenario); [3]Demand for aluminium based on 2019 data; [4]Ammonia demand does not include ammonia as an energy carrier; Bcf/D: billion cubic feet per day; BT: billion tonnes; MB/D: million barrels per day; MT: metric tonne.

Sources: IEA, *Net Zero by 2050: A Roadmap for the Global Energy Sector*, 2021; IEA, *Iron and Steel Technology Roadmap: Towards more sustainable steelmaking*, 2020; GCCA, *Concrete Future: The GCCA 2050 Cement and Concrete Industry Roadmap for Net Zero Concrete*, 2021; IEA, *Ammonia Technology Roadmap: Towards more sustainable nitrogen fertiliser production*, 2021; IAI, “Aluminium Sector Greenhouse Gas Pathways to 2050”, 2021; IEA, *World Energy Outlook 2021*, 2021

Moreover, viable alternatives to today’s heavy industry products remain limited. New cement chemistries could be less carbon-intensive but are likely to substitute only a small share of the global market due to scarcities of resource supply (e.g. fly ashes, calcinated clays) and the differences in the resulting cement properties. While other materials provide alternatives to steel, “its high strength, recyclability and durability, the ease with which it can be used to manufacture goods, and its relatively low cost make its wholesale substitution unlikely” even by 2050.[135] In the absence of scalable substitutes, the only potential way forward would be aggressive decarbonization.

Heavy industries, particularly steel, cement, chemicals and aluminium, are often referred to as “hard-to-abate” sectors, i.e. hard to decarbonize, due to a number of intrinsic characteristics:

– These sectors have energy-intensive complex value chains that sometimes also generate process emissions (e.g. 60% of cement emissions come from the calcination of limestone;[136] 42% of oil and gas emissions come from vented and fugitive methane[137]).

– They are capital-intensive sectors with long investment cycles and low margins, all of which present challenges for the industry to change course; opportunities to significantly cut emissions, such as for major overhaul, relining or plant rebuilding, only appear every 2-3 decades.[138]

– They operate production facilities that are historically located close to natural resources (e.g. a coal mine, quarry) and/or demand centres; these locations can be quite distant from abundant clean energy sources (e.g. solar, hydropower).

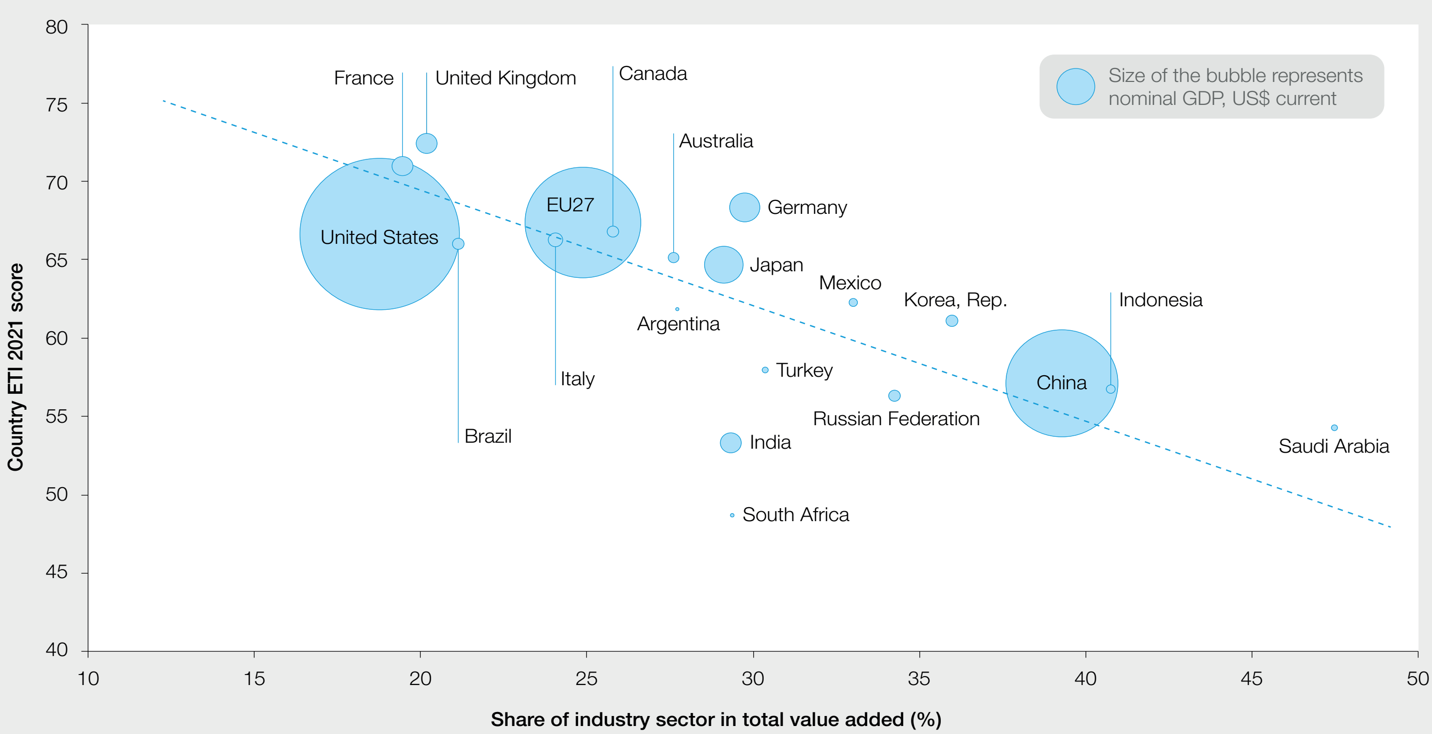
- They are critical to domestic economies while supplying into global markets, making emission reduction measures complex to introduce if requirements might lead to a weakened competitive position.
- They often employ a large workforce of specialists and sustain extensive networks of local suppliers and customers. Pacing a just transition for these sectors is a priority for public authorities.[139]

G20 countries, which produce 85% of global industrial output[140] and are responsible for 75% of global GHG emissions,[141] can provide a useful lens to examine the nexus between energy transition and industrial activities.

Despite similar historic development trajectories, the level of present-day industrial activity across G20 economies varies greatly. The industrial sector's contribution to the total economy ranges from 19% to 47% of the total value add of goods and services produced (gross value added, GVA), according to United Nations Conference on Trade and Development (UNCTAD).[142] A country's economic activity is commonly categorized into three sectors: the agriculture sector (consisting of agriculture, livestock, forestry and fishing), the industry sector (made up of manufacturing, mining, construction and utilities providing electricity, gas, water) and the services sector (including a diverse range of services, as distinct from goods). The relative shares of these sectors in total economic activity evolves over time as countries develop and industrialize. Typically, as countries industrialized, the share of the industry sector in output and employment rose, while that of the agricultural sector fell. After industrialization, at an advanced stage of economic development, the share of the industry sector in both output and employment diminished, while that of the services sector rose.[143]

An assessment of energy transition progress in G20 countries, as observed through the ETI (2021), indicates a slower pace of transition in industry-heavy economies, suggesting the greater complexity for countries to decarbonize energy systems tied to industrial performance. Specifically, G20 countries with a larger share of industrial activity (including manufacturing, mining, construction and energy-producing activities) score lower than their G20 counterparts with a lower share of industry (Figure 12).

FIGURE 12 **G20 overall 2021 Energy Transition Index scores vs share of industry**



Sources: World Economic Forum ETI 2021 analysis; UNCTAD statistics; World Bank data

The analysis of countries' historical ETI sub-indices, dimension and indicators show a few noteworthy trends. Countries with a larger share of industrial activity tend to suffer from poorer air quality and have higher CO_2 intensity of GDP as a result. These economies also tend to rely more on fuel subsidies to make their industries more competitive. In addition, G20 countries with a larger share of industrial activity are likely to face transition readiness challenges caused by a possible combination of indirect factors. These factors can include the lack of availability of skilled labour and of an innovative environment to foster economic activities with higher value addition and productivity levels. These results are in line with the view that decarbonizing an economy with a large industry sector is likely to be challenging since one must address emissions not only from heat, power and transport but also from complex, energy-intensive, high-emission industrial processes. In this regard, the decarbonization of industry-heavy economies will require large amounts of transformative capital and access to low-emission technologies along with associated infrastructure, such as low emission power, hydrogen and carbon storage.

Ultimately, the path is still long for all industries, and not only the hard-to-abate sectors, as they look to implement decarbonization strategies. In the IEA Net Zero by 2050 roadmap, while global emissions are expected to drop by 81% between 2020 and 2040, industrial emissions are only expected to decrease by 58%, which would account for half of 2040 emissions.[144] G20 countries, which are likely to have considerably more resources at hand than other nations, are often considered to have a greater opportunity to lead in the emergence and diffusion of zero and low-emission solutions for global industries.[145] This aligns with the priorities set during the 16th G20 summit, held in October 2021 in Rome. The summit resulted in a number of agreements on climate change, such as maintaining the "goal of limiting global warming to 1.5°C compared to pre-industrial levels within reach" and to "accelerate actions towards achieving global net-zero GHG emissions or carbon neutrality by or around mid-century".[146]

Nevertheless, a reflection on the challenges ahead for industrial decarbonization and the significant effects of high-impact events such as the COVID-19 pandemic indicates more than ever that international cooperation must be a key factor to accelerate industrial decarbonization. The reference to G20 countries by no means suggests that other countries outside the G20 are not needed to lead transition initiatives around industry. They are in fact essential to positively impact the progress of the transition, especially as emerging markets and developing economies are expected to see the biggest increase in energy growth through 2050.[147]

To enable global industrial decarbonization, international cooperation needs to be strengthened through technological transfers and financing support to economies in need. The G20 countries have focused on the theme, *Recover Together, Recover Stronger*, recognizing the importance of collective action and inclusive collaboration between major developed countries and emerging economies around the world, and encouraging all countries to work together to achieve an accelerated and more sustainable recovery.[148]

" To enable global industrial decarbonization, international cooperation needs to be strengthened through technological transfers and financing support to economies in need.

GUEST PERSPECTIVE

Accelerating the energy transition is the only option

by Arifin Tasrif, Minister of Energy and Mineral Resources of Indonesia

The latest Intergovernmental Panel on Climate Change report indicates that global CO_2 emissions continue to rise and have reached an unprecedented level, creating more severe impacts on humanity. As the key factor of enhancing ambitions to confront this situation, the acceleration of energy transitions is a must.

Moreover, in the acceleration towards sustainable energy transitions, we need to embed just transitions. As addressed in the 2030 Agenda for Sustainable Development, particularly Sustainable Development Goal (SDG7), we must ensure universal energy access while implementing energy transitions, in order to *leave no one behind*. In this light, the critical challenges of energy transitions should be revisited.

First, countries have their unique challenges and needs in transitioning their energy systems. The existing energy structures and systems, from infrastructure to the established organizational systems, should be continuously transformed and readjusted to respond to global challenges and support the process of energy transitions.

Second, just energy transitions will require significant financing. This challenge has been exacerbated by the effects of the COVID-19 pandemic, as around 150 million people have been pushed below the poverty line. Countries tend not to disadvantage the socio-economic burdens of their people, and measures are necessary to mitigate the disproportionate impacts on vulnerable communities.

Third, just energy transitions will require changing and shifting technologies, jobs and other economic opportunities. New skills, capacities and expertise should be developed domestically to support the availability, affordability and reliability of sustainable energy, pertaining to the broader public interests. A just energy transition will create new opportunities such as jobs and other prospects and will support global recovery.

In this context, the IEA recommends four clusters for "people-centred energy transitions": decent jobs and workers' protection; social and economic development; equity, social inclusion and fairness; and people as active participants. We must underline these clusters to set a benchmark to prepare towards the current and future challenges of global energy transitions.

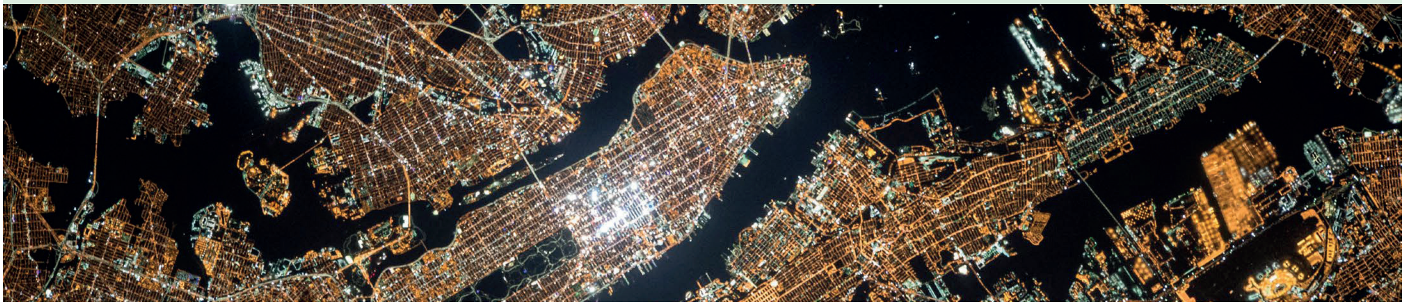
In the acceleration of energy transitions, innovations should be continuously explored and financed to support expansion. This scale-up relates to *industrial decarbonization*, which is well addressed in this Forum report. The focus truly reveals the great challenges we are facing in enhancing emission reductions.

Decarbonizing the hard-to-abate industries will require not only new and more reliable technologies but also companies to transform entire production processes. The challenges are more evident in the contexts of emerging economies and developing countries, which need to finance and support industries for socio-economic goals while improving sustainability. Industries and energy transitions involve multi-SDGs goals on industries and infrastructures, sustainable energy, decent jobs, climate actions and other related goals.

Reflecting these significant challenges, international cooperation must become the key factor to enable industrial decarbonization. Highlighting the G20 figures, the G20 countries hold 80% of global industrial output. The landscape of the G20 is divided between the countries of the Global North and Global South. The importance of common but differentiated responsibilities, the principle of international environmental law, will contribute to enhancing just energy transitions. International cooperation needs to be strengthened with technological transfers and financing support to emerging economies.

In this context, the G20 2022 Indonesian Presidency is keen to promote the three pillars that the Presidency considers most relevant to our current global challenges: global health architecture, digital economic transformation and energy transitions. These pillars are expected to actualize the Presidency's main theme, *Recover Together, Recover Stronger*, which international communities are currently working towards. The energy transitions pillar aims to strengthen just energy transitions and accelerate their pace, by collecting initiatives to prepare the pathways towards the acceleration. The forum on energy transitions sets three main priorities: access, technology and financing. In the priority area on technology, we seek to address issues pertinent to industrial decarbonization, such as the integration of renewables, expansion of the widest variety of technologies, energy efficiency, and the development of greener and cleaner industry.

While having no option but to accelerate energy transitions, no single stakeholder can cope with these transformational stages alone. This Presidency year will become the opportunity to attract additional green investments, engaging multistakeholders, international partners and global forums.



2.2 Net-zero choke points: A call for multistakeholder collaboration

Heavy industry companies increasingly face implementation choke points whose solutions are seldom found within a single firm or even industry.

Heavy industries are likely to be the last frontier of decarbonization. In response, an increasing number of heavy industry companies are establishing net-zero targets and strategies. For example, the Global Cement and Concrete Association (GCCA), which represents over 40 leading cement companies, has announced the production of net-zero concrete by 2050.[149]

The momentum is growing across industrial companies and sectoral players such as business alliances, but also across a larger ecosystem of stakeholders, from governments to international organizations and non-governmental organizations (NGOs). For example, the Mission Possible Partnership (MPP) has outlined roadmaps for four hard-to-abate industrial sectors (concrete, steel, aluminium, chemicals) to reach net zero.[150]

While pledges and roadmaps are essential to jump-start the net-zero transformation and to provide a long-term vision, tackling the implementation challenges faced by companies is critical to progress at the necessary pace. Ten challenges have been identified as "choke points", or barriers, that will limit the transition unless solutions are found outside of business-as-usual improvements:

1. **Breakthrough technologies**: Most technologies to decarbonize heavy industry sectors are either yet to be proven at scale or expensive compared to current alternatives (e.g. +15-40% for low-emission steel,[151] +50-85% for low-emission cement,[152] +10-100% for low-emission ammonia[153]). Solutions must be found to accelerate the technology readiness levels (scale and cost) of "clean" production processes.[154]

2. **Infrastructure access**: Many net-zero compatible technologies considered by heavy industries involve low-emission hydrogen (e.g. for direct reduced iron in steelmaking[155]), renewable power (e.g. for mechanical vapour recompression in aluminium-making[156]) or carbon capture, utilization and storage (e.g. cement plants[157]). Solutions must be found to provide the infrastructure required for supplying these energy sources and handling captured CO_2.

3. **Demand for low-emission products**: Today, low-emission products in heavy industries require a high selling price for producers to maintain economic margin structures. Solutions must be found to generate reliable demand-side signals and provide visibility on offtake to reduce risks for first movers.

4. **Policies and regulations enablement**: Public incentives, including direct or indirect carbon pricing, subsidies or tax breaks, product use specifications or technology mandates, strongly influence the business case for low-emission investments in heavy industries. Solutions must be found to align public-private objectives

while also ensuring efficiency and a just transformation; lessons exist from the growth of wind and solar energies.

5. **Scaling capital**: Heavy industries' low-emission pilot projects require significant capital expenditure while offering less certain or immediate returns than other assets. Solutions must be found to attract capital for investments in necessary higher risk, subeconomic projects that could demonstrate commercial scale feasibility – not only in advanced economies but also in emerging and developing economies where capital markets are less developed and the cost of capital is higher.

6. **Transition capability building**: The transformation requires heavy industry firms to integrate new, often very different, capabilities. Just and sustainable solutions must be found to rapidly upskill or reskill companies' management and workforces to align expertise with new strategies and activities.

7. **Carbon measurement and management**: Measuring, monitoring or forecasting emissions different in nature and scope is complex for heavy industry firms with myriad industrial processes. Solutions must be found to help companies establish standardized transparency for effective action.

8. **Supply chain circularity**: Primary production generates many times the emissions of secondary/recycled production (e.g. 4 times for steel,[158] 30 times for aluminium[159]). Solutions must be found to adapt companies' business models and production processes to circularity.

9. **Scope 3 abatement**: Scope 3 emissions[160] (e.g. estimated at around 80% of all oil and gas emissions[161] and 30% of ammonia emissions[162]) are particularly hard to measure and address. Solutions must be found to create end-to-end transparency and effective abatement solutions with suppliers and customers.

10. **Residual emissions offsetting**: For heavy industries, reaching the net-zero end goal will require substantial investments in GHG avoidance or removal projects to address residual emissions. Solutions must be found to accelerate the provision of quality offset solutions at scale in a transparent and impact-driven manner.

Among these choke points, technology, financing and policies are typically already at the forefront of companies' and governments' net-zero strategies. However, in addition, it is critical to boost demand-side initiatives such as the First Movers Coalition[163] and the Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (IDDI)[164] to create a strong "clean demand" pull (e.g. visibility on offtake volumes, acceptance of green premiums, etc.) for low-emission products. Demand-side initiatives can be a game changer for sectors where low-emission technologies already exist but investments lag, such as steel and ammonia. Today, such initiatives are scarce, and global, synchronized efforts are needed to replicate and scale them and channel much larger investments into low-emission techologies and production assets.

GUEST PERSPECTIVE

First Movers Coalition

by John Kerry, US Special Presidential Envoy for Climate

The urgency of the climate crisis and its existential threat to the planet require an all-hands-on-deck approach. In concert with ambitious government policies, private sector leadership that recognizes and seizes the enormous opportunities in this transition is critical for the world to swiftly reach net-zero emissions. The highest-leverage climate action that companies can take is to dramatically accelerate the energy transition in the sectors of the global economy that urgently need clean solutions to reach commercial scale.

That's why last year at the COP26 meeting in Glasgow, President Biden and the World Economic Forum launched the First Movers Coalition. Leading global companies are sending the biggest demand signal in history for technology innovation across the so-called "hard-to-abate" sectors. These sectors, which include heavy industry and long-distance transportation, already represent a third of global carbon emissions today and could produce a majority by mid-century.

These companies recognize that joining the First Movers Coalition represented a dual opportunity to take action on climate and seize competitive advantage at the same time. Thirty-five companies, representing $6 trillion in market value, made ambitious pledges across steel, aviation, trucking and shipping. These are precise purchasing commitments that will help bring emerging clean technologies to market by 2030. By creating early market demand for these technologies, companies can secure access ahead of their competitors to clean supply chains and next generation technology.

The technology successes that shape the modern world inspired the approach of the First Movers Coalition. NASA's commitment to purchase next generation spacecraft fuelled the innovations that made private commercial space flight possible. Similarly, purchasing commitments by governments and non-governmental actors alike accelerated the introduction of life-saving COVID-19 vaccines. The First Movers Coalition is bringing that strategy to the hard-to-abate sectors of the energy transition.

The Founding Members of the First Movers Coalition are already catalysing technology innovation, from announcing purchase orders for new zero-carbon ships to buying electric heavy-duty trucks.

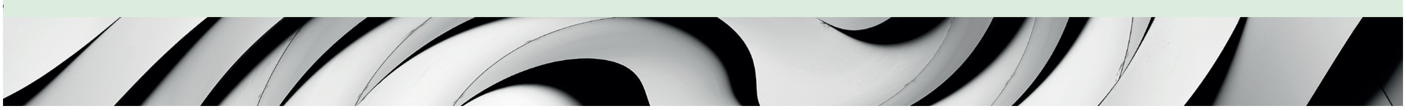
For example, First Movers Coalition steel commitment companies pledged that by 2030, 10% of new purchases will be green steel produced with virtually no carbon emissions. Only one Swedish plant currently produces zero-emissions steel today, using green hydrogen instead of fossil fuels. Now, major automakers and energy developers are ensuring investors and innovators can rely on this demand signal to build additional clean steel plants, knowing they will have ready buyers for their output.

That innovation is badly needed. In aviation, for example, by 2030 the companies that make the First Movers Coalition aviation commitment will displace 5% of their conventional fuel with technologies and fuels that reduce carbon emissions by 85%. This is unprecedented in the aviation sector, encouraging innovators to scale promising approaches spanning clean synthetic fuels, next-generation biofuels and zero-emission propulsion. Bringing these new technologies to market in this decade is absolutely critical to driving down the sector's emissions towards zero.

The companies that have joined the First Movers Coalition recognize that there may initially be a premium cost for these emerging technologies. But they also recognize that creating early markets to scale up breakthrough technologies is by far the most cost-effective way for companies to speed the global energy transition. Companies need only devote a small fraction of their total purchasing power to make a critical First Movers Coalition demand commitment. As these technologies gain a market foothold, their costs will plummet, erasing the green premium and paving the way for massive global technology deployment.

Though they may be first, the companies that join the First Movers Coalition aren't alone. President Biden's administration is committed to helping reach these ambitious technology goals through a whole-of-government strategy. Earlier this year, the President announced that the Departments of State, Energy and Commerce, as well as the U.S. International Development Finance Corporation, are all pursuing initiatives to partner with the First Movers Coalition. President Biden's Bipartisan Infrastructure Law will invest tens of billions of dollars in supplying the clean technologies that companies have committed to buy, and departments such as the Energy Department's Loan Programs Office are looking to invest further billions of dollars in clean technology projects in hard-to-abate sectors. Outside of the government, First Movers Coalition companies benefit from close collaboration with Bill Gates' Breakthrough Energy Catalyst, the primary implementation partner of the First Movers Coalition, as well as the World Economic Forum, the Mission Possible Partnership, and many other organizations.

This is a remarkable period of clean technology innovation. In 2021, climate technologies raised a record $147 billion in funding from venture capitalists, corporations and institutional investors. Public policy and private investment are aligning to speed the development of critical technology solutions. Companies that join the First Movers Coalition can seize the opportunity to ride this wave, demonstrate climate leadership and secure early access to the clean supply chains of the future.



Furthermore, it is worth noting that the transition capability building choke point underpins all other choke points as well as the progress rate of the energy transition across all economic sectors. The transformation of the global economy towards net zero is strongly challenging the boundaries of companies' capability and expertise. This is particularly evident when decarbonization pathways require companies to shift towards completely new production processes (e.g. from steam methane reforming to electrolysis to make ammonia). A scenario from the International Labour Organization estimates that 25 million new jobs will be created from the energy transition by 2030.[165] Preparing the current workforce and the new generation for these jobs essential to the transition will require "education and training strategies; active labour market measures to provide adequate employment services; retraining and recertification together with social protection to assist workers and communities dependent on fossil fuels", among other solutions.[166] This reconfiguration of the workforce also provides a unique opportunity for companies to improve inclusion and diversity, creating a more equal and resilient economy.

GUEST PERSPECTIVE

Enabling the energy transition and reaching net-zero: The talent imperative

by Julie Sweet, Chair and Chief Executive Officer, Accenture

Across industries, every business must be a sustainable business, both because it is the right thing to do and because it is a source of competitive advantage. To become truly sustainable, every part of every business must find solutions to decarbonize. Innovation and digital transformation are essential, but even the best technology will not lead to our ambition without the right people.

As things stand, we risk failing to meet key climate targets due to skills shortages. Globally, the talent shortage exceeded 40 million skilled workers at the end of 2020, according to US Labor Statistics. By 2030, organizations worldwide could lose $8.4 trillion in revenue directly because of the lack of skilled talent. The talent shortage has deep implications for the energy transition and delivering on our net-zero commitments. The skills in short supply are those required to meet the complex challenges of building a circular economy, decarbonizing hard-to-abate industries and scaling sustainable fuels. It is time to close the gap.

As companies, we need to redefine our relationship with talent and move from being talent consumers to talent creators. This requires taking action now to deliver two mindset shifts.

First, we need to focus on skills, not roles. This is something we are doing at Accenture and for our global clients. For example, in early 2020, we knew we needed more people with cloud skills because the pandemic accelerated our clients' need to move to cloud. We used AI algorithms against our skills database to identify the right people and then upskilled 100,000 people in six months, empowering our people with opportunity for growth while also addressing complex client needs.

The second mindset shift is to think about people's potential to lead. The energy transition requires strong leaders who actively embrace net-zero ambitions and act to embed sustainability across every area of the business. When I think about who we will need to meet our sustainability objectives, I think of Accenture's eight leadership essentials; the first is to always do the right thing, and the eighth is to commit to active innovation both inside and outside of Accenture. We are continuously redesigning Accenture to build the leadership behaviours required for the energy transition.

This is incredibly important as we move to deliver on net-zero goals because none of us can make a big enough impact – on carbon reduction, equality and equity, or anything else – working alone. We need to partner across industries, and with governments, non-profits and communities, to create lasting change. We need to move beyond partnering on projects and think about partnering for purpose, sharing everything from data to talent.

It is our responsibility – and our privilege – as leaders to help advance sustainability by partnering with and creating a talented global workforce with the skills and leadership mindset to move at speed and scale.

The answers and emerging solutions to industry net-zero transformation choke points are rarely found within a single firm or even industry. To solve these challenges, heavy industry companies will need to explore new forms of collaboration. The MPP net-zero roadmaps clearly show where industries need to be by 2030 (e.g. over 70 commercial-scale low-emission steel plants producing 240 MT by 2030) and also highlight that closing the gap will require an unprecedented level of collaboration.[167] Thankfully, heavy industry companies, suppliers, customers, peers from other industries, other businesses, governments, civil society and many other stakeholders recognize the need to reduce global emissions, including their own carbon footprint. This shared challenge creates common interests across organizations and establishes a robust platform for multistakeholder collaboration towards net zero.

The following section lays out how a new generation of collaboration models combined with a step change in ambition level can address the net-zero transformation choke points for heavy industries.

2.3 Clearing the path to net zero with "next generation" partnerships

The "next generation" of ambitious multistakeholder collaborations between suppliers and customers, between industry and cross-industry peers, and between the wider industrial ecosystem of stakeholders can overcome decarbonization choke points and accelerate the industrial transformation towards net zero. However, action is needed now to keep the net-zero by 2050 goal within reach.

A new generation of multistakeholder collaborations focused on decarbonization and net-zero objectives has gained momentum since 2015. These "next generation" collaborations differ from past partnerships due to a step change in ambition level, greater focus on emission reductions, new types of partners and new areas of emphasis. The sense of urgency combined with the steepness of the net-zero pathways have led leaders from both the public and private sectors to view collaborations as a key transition catalyst. Leaders now favour collaboration and transparency over competition, and increasingly consider decarbonization as a win-win solution that does not necessarily entail extra costs.

Three archetypes of collaboration have emerged: collaboration between customers and suppliers, collaboration between industry and cross-industry peers, and collaboration between the wider ecosystem of stakeholders (Figure 13). The following section outlines the rationale, benefits and collaboration models under each archetype, and offers more than 35 examples. Such initiatives are critical to pave the way for similar partnerships in other geographies and industries, and to inspire leaders worldwide to move quickly from pilots to a pipeline of commercial-scale projects by 2030.

FIGURE 13 **Three archetypes of collaboration to accelerate the net-zero transformation of industries**

Archetype 1

- Climate-aware end customer centricity
- "Value chain" as the decarbonization unit
- New products, new supply chains, circularity, collective risks

Archetype 2

- Shared industry responsibility towards reinvention and decarbonization
- "Industry" as the decarbonization unit
- Collective over competitive transformation, requiring new levels of transparency and resource sharing

Archetype 3

- System-wide solutions for net-zero industries
- Any industry "win" = a society "win"
- Solutions going beyond the traditional partners and partnerships

Cross-sectoral collaboration is essential for industrial decarbonization

by Jan Jenisch, Chief Executive Officer, Holcim

Given the scale of today's net-zero challenges, no single organization or industrial sector can tackle decarbonization alone. We need close collaboration: between government and industry as well as along our entire value chain.

Government and industry must work as partners to make sure the business case of short- and long-term investments in industrial decarbonization is sound.

At Holcim, we are seeing this collaboration take shape in the deployment of next generation technologies, such as carbon capture, use and storage (CCUS). We are exploring the potential use of CCUS technologies in over 30 pilot projects worldwide, from repurposing CO_2 from our plants for use in vertical farming, all the way to alternative fuel for aviation, thereby also creating new growth opportunities for the company.

To help deploy these technologies at scale, a number of our CCUS projects are receiving public support today, from entities such as the US Department of Energy to Germany's Federal Ministry of Economic Affairs and Energy. Further public-private collaboration is essential to ensure abundant and clean energy to power CCUS, the recognition of technologies such as co-processing that significantly eliminate the use of fossil fuels, enabling the circular economy through effective waste management, and efficient carbon pricing mechanisms.

Moreover, actors from all sectors must collaborate to strengthen market demand for low-carbon and circular solutions across the industrial value chain. As a global leader in innovative and sustainable building solutions, Holcim is playing a central role to decarbonize this sector. This includes reducing Scope 3 emissions from the transport of our materials through optimizing routes, loads, moving load from road to waterways and rail, and replacing diesel with eco-friendly fuels in fleets.

As a founding member of the First Movers Coalition (FMC), we are ambitious to drive more green demand and low-carbon technologies to advance our world's climate goals. On the green procurement side, we commit to FMC's trucking ambition of reaching 30% of zero-emission heavy-duty truck purchases or contracts by 2030. On the supply side, we will continue to scale up our green building solutions and next generation technologies for net-zero construction, building on Holcim's industry-first 2050 net-zero goals, validated by the Science Based Targets initiative.

Leading by example, we hope to inspire the virtuous cycle of collaboration and partnership that is necessary to reach net-zero in our industry. There is no other way forward.

2.4 Net-zero collaboration between customers and suppliers

Value chain emissions are increasingly being scrutinized by progressive climate-conscious end consumers, particularly the younger generations. A recent survey[168] found that 73% of Gen Z consumers (21-25-year-olds) are willing to pay more than every other generation for sustainable products. Reducing direct emissions within an industry will impact the indirect emissions of suppliers and customers (Scope 2 or Scope 3 emissions), and vice versa. This common ground strongly encourages new collaborations between heavy industries and value chain stakeholders.

FIGURE 14 **Collaboration model types between customers and suppliers**

	Collaboration model	Potential collaboration partners	Targeted choke point
Collaboration between customers and suppliers	Supply and offtake agreement	Industry peers, Suppliers, Customers	Demand for low CO_2 products
	Pre-commercial public procurement	Industry peers, Public authorities	
	Circular supply network	Single firm, Other businesses, Suppliers, Customers	Supply chain circularity
	Circular product development	Single firm, Other businesses, Suppliers, Customers	
	Joint value chain decarbonization	Single firm, Other businesses, Suppliers, Customers	Scope 3 abatement
	Supplier performance programme	Industry peers, Suppliers	

Single firm · Cross-industry peers · Suppliers · Researchers · Non-profit and think tanks · Public authorities · Industry peers · Other businesses · Customers · Start-ups · Financiers (public and private) · Regulators

Source: World Economic Forum and Accenture

Collaboration with customers through offtake agreements or pre-commercial public procurement (Figure 14) can provide heavy industry companies with the visibility they need for investments in low-emission solutions (public procurement accounts for 46% of US cement consumption[169]). Customers in return can secure the supply of low-emission products, which will initially be scarce.

In addition, heavy industries can reduce their emissions by increasing the proportion of recycled versus primary feedstock and material – what is now referred to as the "circular economy". Collaboration with suppliers and customers through the development of circular supply networks or circular product development can support that objective. Suppliers can engage in new value-added activities (e.g. high-resolution waste sorting) and customers can benefit from lower emission products.

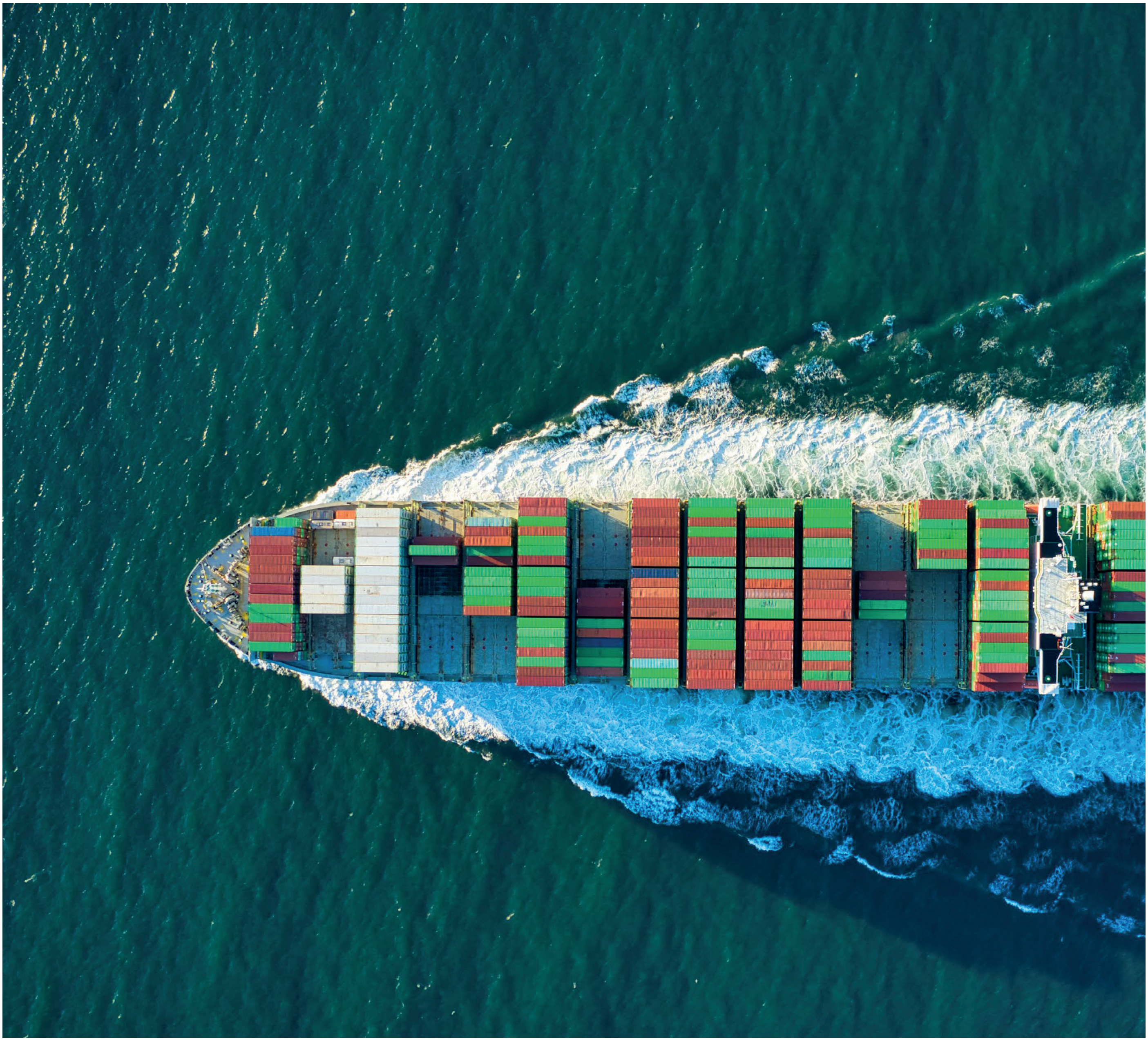
Heavy industries are increasingly engaging to limit their Scope 3 emissions (estimated at 80% of total oil and gas CO_2 equivalent emissions,[170] 20% of steel emissions[171] and 20% of cement emissions[172]), which are driven by companies' upstream and downstream value chain activities. Collaboration with suppliers and customers through shared value chain decarbonization initiatives or supplier performance programmes can help tackle these emissions. Suppliers can benefit from visibility on low-emission procurement standards, and customers from the unique engineering and technology expertise of another industry to decarbonize.

TABLE 1 | **Collaboration model examples between customers and suppliers**

Collaboration model	Short description	Example (collaboration names in bold, when available)
Supply and offtake agreement	Suppliers and customers can create long-term visibility on low-emission product offtake and delivery for each other	The **First Movers Coalition**[173] is a platform of over 35 companies enabled by the US State Department and the World Economic Forum. The Coalition was created through a partnership between the US State Department's US Special Presidential Envoy for Climate and the Office of Global Partnerships, and the World Economic Forum, in collaboration with the US Departments of Commerce and Energy. The coalition advocates for companies to harness their purchasing power and supply chains to commit to long-term demand and supply, creating early markets for clean energy technologies to be accessible and scalable, and to bring down costs.
		SSAB teamed up with Volvo to unveil the world's first truck made from 100% fossil-free steel. More vehicles are expected to follow in 2022 in a drive for Volvo to achieve net-zero value chain GHG emissions by 2040.[174]
Pre-commercial public procurement	Public buyers can pre-purchase low-emission products before they are made to provide the necessary visibility for suppliers to invest	**The Clean Energy Ministerial Industrial Deep Decarbonisation Initiative (IDDI)**[175] is a global coalition of public and private organizations committing to the purchase of low-carbon materials, particularly steel and cement. Coordinated by the United Nations Industrial Development Organization, the initiative brings together heavy industries and multilateral organizations, such as the Mission Possible Partnership, LeadIT, IRENA and the World Bank, as well as public entities, such as the Governments of the United Kingdom, India, Germany, Canada and United Arab Emirates.
Circular supply network	Suppliers and customers can establish circular supply networks to maximize the reuse and recycling of materials from one another in a near closed loop	Centro Rottami is supplying recycled aluminium to Indinvest's Italian foundry. Enabled by TOMRA's aluminium scrap sorting technologies, the partnership guarantees a constant supply of high purity aluminium (85% recycled content billet), essential to establishing trust with foundries. This collaboration contributes to Italy's rank of first in Europe for recycled aluminium production, achieving 70% recovery.[176]
		Novelis has implemented closed-loop systems with major automakers, including Volvo, Ford, Jaguar and Land Rover, working together to take back the car manufacturers' aluminium scrap and transforming it into the same high-quality products indefinitely. Novelis increased the amount of overall recycled aluminium in its products from 33% in 2010 to over 61% in 2019.[177]
Circular product development	Suppliers and customers can redesign end products together to maximize recycled content	The **EOCENE industrial research project**,[178] a consortium with Kimitec, Cosentino, Acciona, Omar Coatings, Aerotecnic, Reciclalia and SUEZ, aims to adopt a circular economy in the composites industry by creating a new generation of highly sustainable thermostable composites, procuring all components (resin, fillers, fibres) from renewable sources and developing sustainable technologies for controlled recycling processes and revaluation of waste at the end of its life cycle.
		Tata Steel and Bouwen met Staal (the Netherlands' national organization for the promotion, knowledge transfer and research of steel in construction) have collaborated on a project at Amsterdam's Schiphol Airport to demonstrate the reuse of steel in construction. They adopted building practices that promote high reuse rates of between 20% and 40%, reducing the environmental footprint of the steel used in the airport building by 18% to 36%.[179]
Joint value chain decarbonization	Suppliers and customers can leverage their respective capabilities and expertise to help each other decarbonize	Shell leverages its leading capability in system level modelling (used internally for years to deconstruct Shell plants and processes) to help Dalmia Cement, one of its customers and a leading Indian cement manufacturer, find pathways to decarbonize.[180]
		bp and CEMEX agreed "to develop solutions to decarbonize the cement production process and transportation". These solutions "include low-carbon power, low-carbon transport, energy efficiency, natural carbon offsets, and carbon capture utilization and storage technologies".[181]

TABLE 1 | **Collaboration model examples between customers and suppliers (continued)**

Collaboration model	Short description	Example (collaboration names in bold, when available)
Supplier performance programme	Suppliers and customers can co-design low-emission procurement standards and co-develop roadmaps to achieve new targets over time	Dow is directly engaging with suppliers to request climate-related information via the Carbon Disclosure Project (CDP) supply chain programme's platform.[182] The goal is to support suppliers in environmental reporting to track climate impacts and support the identification of collaborative decarbonization opportunities.
		With building and construction processes in Sweden estimated to generate around 10 MT CO_2e per year, the Swedish Transport Administration has set a target to reach close to net-zero carbon emissions from road construction by 2045. It is reinforcing carbon reduction requirements in the procurement of major project construction, materials used and future maintenance.[183]

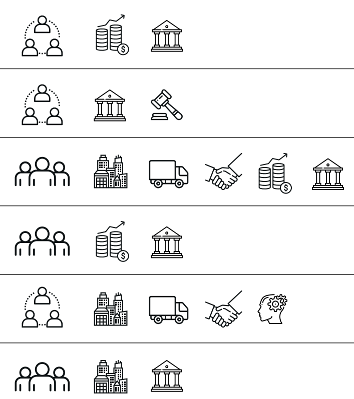


2.5 Net-zero collaboration between industry and cross-industry peers

Across heavy industries, companies face increasing pressure from governments, investors and society to decarbonize. This common ground strongly encourages new collaboration between peers within and across industries, particularly to address common needs in terms of capability, energy, infrastructure and capital.

FIGURE 15 **Collaboration model types between industry and cross-industry peers**

	Collaboration model	Potential collaboration partners	Targeted choke point
Collaboration between industry and cross-industry peers	Shared infrastructure development		Infrastructure access
	Industrial cluster infrastructure planning		
	Shared commercial projects		Scaling capital
	Cross-industry funding		
	Knowledge sharing		Transition capability building
	Reskilling the workforce		



Single firm · Cross-industry peers · Suppliers · Researchers · Non-profit and think tanks · Public authorities · Industry peers · Other businesses · Customers · Start-ups · Financiers (public and private) · Regulators

Source: World Economic Forum and Accenture

The transition of heavy industries is a new and fast-changing domain in which deep expertise is scarce but critical. Collaboration with peers through knowledge sharing initiatives, either forward-looking (e.g. net-zero roadmaps) or focused on existing technologies (e.g. methane management), or through upskilling/reskilling programmes for management and employees, can close a number of knowledge gaps while building the workforce of the future (Figure 15).

Heavy industry companies also typically require large amounts of capital to deploy their own or third-parties' promising technology at scale. Collaboration with industry or cross-industry peers through shared commercial projects/ventures or cross-industry funding can bridge capital gaps, reduce risks and overcome financiers' reluctance to invest in subeconomic or lower-return projects that are important to break new ground on the path to net zero.

Many solutions to decarbonize heavy industries involve the adoption of technologies[184] based on electrification, low-emission hydrogen, low-emission power, or carbon capture, utilization and storage, all requiring extensive infrastructure. Collaboration with industry and cross-industry peers through shared infrastructure planning and development can ensure that companies deploying new technologies will not be constrained by the lack of enabling infrastructure.

TABLE 2 | Collaboration model examples between industry and cross-industry peers

Collaboration model	Short description	Example (collaboration names in bold, when available)
Shared infrastructure development	Peers within and across industries can join forces to develop shared infrastructure at lower risk and cost	**Longship**,[185] a partnership project between the Norwegian state, Gassnova, HeidelbergCement, Fortum Oslo Varme (waste-to-energy plant) and Northern Lights JV (Equinor, Shell, TotalEnergies) aims to develop the first-ever full-scale cross-border carbon capture and storage value chain for industries to transport CO_2 from capture sites across Europe to a terminal in Norway for storage, before transporting for permanent storage in the North Sea.
Industrial cluster infrastructure planning	Cross-industry peers and public authorities can jointly plan infrastructure development for industrial clusters to realize synergies and ensure all parties' needs are met	The **Kwinana Industrial Area (KIA)**[186] is the largest industrial cluster in Western Australia and exemplifies industrial symbiosis with more than 150 products, by-products and utilities exchanged between facilities in the region. KIA produces industrial, agricultural and mining chemicals and refined materials for national and international markets. bp recently repurposed its Kwinana Refining site as an integrated energy hub that produces and distributes fuel for the future, such as the production of green hydrogen.
		Eight private-sector organizations are working on concrete solutions to achieve carbon neutrality by 2040 in the largest CO_2 emitting industrial cluster in the UK, **the Humber Industrial Cluster**.[187] The plan includes early projects aimed at accelerating industrial carbon capture and green/blue hydrogen production, such as Phillips 66 progressing Gigastack, a green hydrogen project that along with ITM Power, Ørsted and Element Energy seeks to produce green hydrogen and electricity from nearby offshore wind and electrolysis.[188]
Shared commercial projects	By merging a large set of different expertise, joint commercial ventures can create synergies and reduce risks and costs	**HYBRIT**[189] (Hydrogen Breakthrough Ironmaking Technology) is a collaboration between three mining, steel manufacturing and electricity companies – LKAB, SSAB and Vattenfall – to create the world's first fossil-free steel. "The HYBRIT technology involves replacing the blast furnace process, which uses carbon and coke to remove the oxygen from iron ore, with a direct reduction process using fossil-free hydrogen produced from water using electricity from fossil-free energy sources."[190]
		Holcim expands carbon capture projects through a consortium with Svante, Oxy Low Carbon Ventures and TotalEnergies.[191] The partnership has completed a "study to assess the viability and design of a commercial-scale carbon-capture facility at the Holcim Portland Cement Plant" in the United States.[192] With the confirmation of funding from the US Department of Energy, "the partnership has committed to the next project phase to evaluate the feasibility of the facility designed to capture up to two million tons of CO_2 per year".[193] Looking forward, Holcim continues to expand its carbon capture portfolio through new partnerships, such as recently signing an agreement with Eni for the utilization of CO_2.
Cross-industry funding	Collaborative funding can help industries meet the large demand for capital, while allowing them proximity to breakthrough innovation	TotalEnergies, Air Liquide and VINCI "are combining forces with other large international companies to sponsor the creation of the world's largest fund exclusively dedicated to clean hydrogen infrastructure solutions. The **Clean Hydrogen Infrastructure Fund** aims to reach €1.5 billion and has already secured initial commitments of €800 million. Its objective is to accelerate the growth of the clean hydrogen ecosystem by investing in large strategic projects and leveraging the alliance of industrial and financial players" to do so.[194]
		Clean Steel Partnership[195] was established in 2021 by the European Commission and the European Steel Technology Platform on behalf of the entire European steel value chain for the sustainable production of clean steel. The public-private partnership aims to facilitate the reduction of CO_2 emissions from steel production through the funding of research, development and innovation projects. The partnership will invest to develop the technologies necessary for industrial deployment.

TABLE 2 | **Collaboration model examples between industry and cross-industry peers (continued)**

Collaboration model	Short description	Example (collaboration names in bold, when available)
Knowledge sharing	Knowledge sharing can be relevant between peers sharing similar strategic or operational decarbonization challenges	The **Mission Possible Partnership (MPP)**[196] is an alliance comprised of the Energy Transitions Commission, Rocky Mountain Institute (RMI), We Mean Business Coalition and the World Economic Forum focused on supporting the decarbonization of the world's highest-emitting industries: the hard-to-abate sectors (steel, cement, chemicals, aluminium, shipping, tracking and aviation). The MPP has released sector-specific net-zero roadmaps, providing powerful and tangible examples of clear targets and strategies to keep the 1.5°C target alive with leading companies and business alliances.
		The **Global Methane Initiative (GMI)**[197] is an "international public-private partnership focused on reducing barriers to the recovery and use of methane as a valuable energy source. GMI provides technical support to deploy methane-to-energy projects around the world … and advances methane mitigation in three key sectors: oil and gas, biogas, and coal mines".[198] GMI partner countries account for approximately 70% of global man-made methane emissions.
		Ten major chemical sector companies around the world – BASF, Dow, DSM, Solvay, Clariant, Covestro, Mitsubishi Chemical, Air Liquide, SABIC and SIBUR – in partnership with the World Economic Forum have established the **Low-Carbon Emitting Technologies (LCET)**[199] initiative, a breakthrough, pre-competitive knowledge sharing development platform and implementation vehicle to accelerate net-zero climate technologies in the chemicals industry.
		The **Carbon Pricing Leadership Coalition**[200] promotes the successful implementation of carbon pricing globally by bringing together leaders from government, business, civil society and academia to strengthen the development and implementation of carbon pricing policies and enhance the sharing of data, expertise and lessons learned through various "readiness" platforms.
Reskilling the workforce	Partnering with peers, NGOs and knowledge institutions can formalize and accelerate capability building, while fostering a just transition for employees	The World Economic Forum launched the **New Generation Industry Leaders (NGIL)**[201] programme in support of designing and driving a responsible industry transformation, while building excitement about its future frontiers and opportunities for younger generations. The community actively engages in the Forum's work and agenda to share new ideas to transform and champion the industry to younger generations.
		Eni, Red Rock Power and the University of Strathclyde have signed a memorandum of understanding to develop and deliver a workforce transition programme to help professionals working in the Scottish oil and gas sector transfer their skills to renewable energy technologies.[202]

2.6 Net-zero collaboration between wider ecosystem stakeholders

In addition to suppliers, customers and peers, heavy industry companies also interact with a wider network of stakeholders, such as public authorities (e.g. central governments, regional and local authorities), regulators (e.g. policy-makers, industry regulatory agency), financiers (e.g. public investment funds, private funds, banks), researchers (e.g. academics, public or private labs) and NGOs (e.g. specialist NGOs, business alliances, think-tanks). These organizations, classified in this report as "wider ecosystem stakeholders", can also play prominent roles in the net-zero transformation of industries. Public authorities and regulators can be incentivized by national net-zero agendas, financiers by investor pressure to decarbonize portfolios, and researchers and NGOs by mandates to find and support new sustainable solutions. This common ground encourages new collaborations between heavy industry firms and wider ecosystem stakeholders, particularly related to technology, policy and regulation, carbon management and emission offsetting challenges.

FIGURE 16 **Collaboration model types between wider ecosystem stakeholders**

	Collaboration model	Potential collaboration partners	Targeted choke point
Collaboration between wider ecosystem stakeholders	Public-private advocacy and collaboration	Cross-industry peers, Non-profit and think tanks, Public authorities, Regulators	Policies and regulations enablement
	Intergovernmental action	Cross-industry peers, Non-profit and think tanks, Public authorities, Regulators	
	Integrated research and innovation	Industry peers, Other businesses, Researchers, Public authorities	Breakthrough technology
	Start-up investment and incubation	Industry peers, Start-ups, Financiers (public and private)	
	Emission measurement standardization	Cross-industry peers, Other businesses, Non-profit and think tanks, Public authorities, Regulators	Carbon measurement and management
	Emission tracking and management	Single firm, Other businesses, Suppliers, Customers	
	Carbon offset supply	Cross-industry peers, Other businesses	Residual emissions offsetting
	Carbon offset quality	Cross-industry peers, Other businesses, Public authorities, Regulators	

Single firm · Cross-industry peers · Suppliers · Researchers · Non-profit and think tanks · Public authorities · Industry peers · Other businesses · Customers · Start-ups · Financiers (public and private) · Regulators

Source: World Economic Forum and Accenture

In addition to pushing their own R&D effort, heavy industry companies can collaborate with technology start-ups and research labs through private equity investments, incubation, research grants and joint facilities and teams to accelerate the technology readiness[203] of key solutions.

While not a silver bullet, policies and regulations can drastically improve the transformation business case of an industry and reduce first movers' risk by supporting technology adoption, creating demand and enabling access to capital. Collaboration with public authorities and regulators through public-private advocacy groups can help companies co-design the pace and shape of their journey to net zero (Figure 16).

Moreover, significant emission reductions could be achieved today on many industrial sites, provided companies are equipped with adequate standards, processes and tools to manage emissions. Collaboration with specialist NGOs and technology service companies can help heavy industry firms achieve state-of-the-art emission measurement and monitoring and identify impactful actions with today's available technologies.

Some heavy industry companies can reach zero Scope 1 and 2 emissions by fully electrifying their production processes and using renewable power (e.g. aluminium or ammonia industries). However, where structural long-term options are not available, some producers might rely on offsetting residual emissions to achieve net zero by 2050. Collaboration with specialist NGOs and offset providers can help companies secure the required certified offsets in the long run.

TABLE 3 | **Collaboration model examples between wider ecosystem stakeholders**

Collaboration model	Short description	Example (collaboration names in bold, when available)
Public-private advocacy and collaboration	Firms can join forces to ensure that common objectives, roadmaps and needs are adequately communicated to regulators, so the business environment evolves at a pragmatic and just pace	The **European Clean Hydrogen Alliance** "supports the large-scale deployment of clean hydrogen technologies by 2030 by bringing together renewable and low-carbon hydrogen production, demand in industry, mobility and other sectors, and hydrogen transmission and distribution. It aims to promote investment and accelerate the roll-out of clean hydrogen production and use" in line with the EU's climate change objectives to build industrial leadership and accelerate the decarbonization of industry.[204]
		The **Clean Energy Demand Initiative (CEDI),** led by the US Department of State's Bureau of Energy Resources, unites companies and governments to jointly achieve their clean energy goals by leveraging corporate commitments and catalysing investment and policy signals. Corporate demand for clean electricity, through corporate power purchase agreements, have the potential to drive significant investment in renewable energy and help the private sector offset its electricity demand. Thirty-nine companies from major sectors, including technology, manufacturing, retail and health, have signed letters of intent to procure renewable energy to offset their electricity demand.[205]
Intergovernmental action	Close collaboration with governmental entities working with foreign counterparts can help companies anticipate and co-shape change	**Mission Innovation**[206] is "a global initiative of 22 countries and the European Commission to catalyse action and investment in research, development and demonstration to make clean energy affordable, attractive and accessible for all" by 2030.[207] It brings together governments, public authorities, corporates, investors and academics and is the main intergovernmental platform addressing clean energy innovation through action-orientated cooperation that seek to create tipping points in the cost and scale of clean energy solutions in select areas.
		Germany and Namibia have signed a Joint Communique of Intent to establish a **Green Hydrogen Technology Partnership.** The Federal Ministry of Education and Research (BMBF) will fund the identification of suitable sites for green hydrogen production in Africa and The Federal Research Ministry will provide up to 40 million euros in funding to accelerate cooperation within the developed framework.[208]
Integrated research and innovation	Integrated R&D and innovation programmes between industry firms and research organizations can affect the net-zero technological race	The **Massachusetts Institute of Technology (MIT) Climate and Sustainability Consortium** convenes influential industry leaders from a broad range of industries (including, cement and chemicals) to work with MIT to accelerate shared solutions to address climate change.[209]
		As part of Institut Polytechnique de Paris's strategic partnership with TotalEnergies, the institute has "approved the creation of a new centre for innovation and research into carbon-free energy solutions". The newly developed innovation park brings together "private and public research centres, thus nourishing the ecosystem of Institut Polytechnique de Paris and more broadly the science and technology cluster of the Paris-Saclay region".[210]
		The Smart Energy Lab[211] is a green "factory" partnership bringing industries, academics and development partners together (e.g. EDP Comercial, Accenture, Instituto Superior Técnico, Faculdade de Ciências da Lisboa, Universidade de Coimbra, INESC TEC and INESC-ID) for "new or improved products, services or processes that contribute to accelerating energy transition, reducing transaction costs, through technology and user adoption".

TABLE 3 | **Collaboration model examples between wider ecosystem stakeholders (continued)**

Collaboration model	Short description	Example (collaboration names in bold, when available)
Start-up investment and incubation	Investing and incubating promising start-ups can help companies secure early access to the technologies and solutions of the future	The **Oil and Gas Climate Initiative (OGCI)**[212] brings competitors (led by CEOs) together to "accelerate the industry response to climate change". It currently includes 12 member companies, including Saudi Aramco, Eni, bp, Equinor and Petrobras. The OGCI Climate Investments team (with a $1 billion fund) brings industry experience and expertise to co-invest, pilot and deploy new technologies and projects that "accelerate decarbonization in oil and gas, industry and commercial transport", and other sectors. OGCI Climate Investments uses the know-how and global footprint of its members and network to support commercial adoption through pilots and global implementation of investments, to achieve scale at an accelerated pace.
Emission measurement standardization	Working jointly with NGOs and peers can accelerate the development of the necessary emissions standards for each industry	**The Carbon Disclosure Project (CDP)**[213] is a not-for-profit organization that "runs the global emissions disclosure system for investors, companies, cities, states and regions to manage their environmental impacts. The world's economy looks to CDP as the gold standard of environmental reporting with the richest and most comprehensive dataset on corporate and city action".[214]
		Pavilion Energy, QatarEnergy and Chevron jointly launched a GHG "quantification and reporting methodology to produce a statement of GHG emissions for delivered liquefied natural gas (LNG) cargoes". This methodology will be applied to sales and purchase agreements for wide adoption. Overall, "it aims to create a common standard for the measurement, reporting and verification of the GHG emissions associated with producing and delivering an LNG cargo to drive greater transparency and enable stronger action on GHG reduction measures".[215]
Emission tracking and management	Partnering with specialized NGOs and technology service companies helps to bring emission transparency to the required level for effective action	**The Climate TRACE** global coalition[216] aims "to make meaningful climate action faster and easier by independently tracking GHG emissions" across the supply chain of various sectors using "satellite imagery and other forms of remote sensing, artificial intelligence and collective data science expertise … The emissions inventory is the world's first comprehensive accounting of GHG emissions based primarily on direct, independent observation". Currently, over 50 organizations are collaborating across 38 industries and 10 sectors, from power plants and oil refineries to rice cultivation, cement production and shipping.[217]
Carbon offset supply	Partnering early-on with offset suppliers can guarantee long-term supply availability (the carbon offset market is expected to grow from $1 billion today to $550 billion by 2050)[218]	Oxy Low Carbon Ventures (OLCV) partnered with Carbon Engineering to produce renewable fuels in British Columbia by capturing CO_2 from the atmosphere using Direct Air Capture (DAC) and Air to Fuels technologies. The DAC to fuels facility is expected to be the first commercial-scale project of its kind. Overall, Oxy is pioneering the ways to leverage quality offsets, delivering the world's first shipment of carbon-neutral oil to India's Reliance Industries.[219]
Carbon offset certification	Partnering with NGOs specialized in carbon offset certification can ensure companies' permanent carbon removal is achieved with their investments	**Verra**[220] is a global non-profit leader developing and managing standards and frameworks to channel finance towards high-impact environment activities, including carbon offsetting projects.
		Gold Standard[221] is a global non-profit leader that was established by WWF and other international NGOs to "ensure that projects that reduce carbon emissions feature the highest levels of environmental integrity and contribute to sustainable development".[222]

The changes required for heavy industry sectors to reach net zero are vast and will be transformative for these industries. These changes will require not only new models of collaboration, like the ones presented in this report, but also a whole new level of collaboration across all stakeholder groups – a step change in collaborative activity.

Companies will have to enter into new collaboration with their suppliers and customers, with their industry peers and with their wider ecosystem. Indeed, when truly disruptive technologies are created, the risk-taking and commitment required are too great for a company to bear alone. Industry companies' innovative power and longstanding expertise will be key to the decarbonization challenge, but they will need their ecosystem to create the enabling environment, to jump-start demand and to create the financial conditions necessary to support private-sector innovation.

In addition, the boundaries of industries do not stop at national borders. International cooperation, including but not limited to groups like the G20, will be essential to pool risks and to create bigger markets for successful innovation and clean new products. International cooperation will also be needed to remove regulatory barriers, provide credible policy support internationally, and create compatible standards or joint investment declarations. This must not only happen in advanced economies; importantly, emerging and developing economies poised to see the biggest increase in energy demand and GHG emissions are in dire need of investments, technological solutions and infrastructure to transition their energy systems. Collaboration across advanced and developing economies will need to play a key role to achieve this.

These changes cannot and will not happen purely "top-down" through governments' orchestrated target setting or through industries' applying the right solutions independently. Public-private partnerships will be crucial, and the public sector will have an important role to play to provide the foundational capital or financial conditions necessary to encourage private-sector innovation.

In recent years, pioneer companies from the heavy industry sectors and their stakeholders have put great effort into exploring solutions to decarbonization choke points. Thanks to them, many inspiring "next generation" collaboration models already exist today. Other industry players can study, learn from, follow, improve, replicate these models in other geographies or industries, and invent more ambitious cooperation to progress the collective journey to net zero.

3 Conclusion

Recent environmental, macroeconomic and geopolitical events have affected the energy system in multiple ways and highlighted the complexities of the energy transition. In particular, energy market disruptions and subsequent volatility and knock-on effects on the global economy have demonstrated the need for the global energy transition to strike the right balance between energy affordability, security and sustainability. In essence, what is needed is to collectively drive a resilient energy transition that can keep the momentum moving forward in challenging times. Trade-offs between energy affordability, security and sustainability exist today and are expected to continue to evolve. Countries must manage them carefully to keep the transition going.

As the gap between climate pledges and implementation continues to widen, it is essential to accelerate the transition and mitigate the risks of a slowdown. Early signs of the transition's implications on equity and justice indicate the need for robust and well-targeted measures to protect vulnerable populations and businesses against the impact of possible future high energy prices. Additionally, as many countries' energy security concerns grow, it is key to note that the energy transition, which can help diversify energy supply with low-carbon energy sources, can be a source of energy security. Countries can engage in the dual energy supply diversification of import partners in the short term and energy mix in the long term. The energy crisis provides an opportunity to supercharge the transition by increasing clean energy investments at record pace and transforming consumers' energy consumption habits. It is too early to tell, however, whether the world will see a tipping point in the transition, which depends on the collective actions of governments, corporations and consumers.

This special 2022 edition stresses the importance of the industrial sector's transformation. This sector represents a significant share of global emissions, faces enormous challenges to decarbonize and is where demand is expected to grow significantly by 2050, partly due to the needs of the transition itself. Stark differences can be observed between countries with largely service-based economies and countries that have maintained relatively large shares of industrial activity. The former typically fare better with their energy transitions as the historical ETI trends reveal. Progress to decarbonize industry will be key in many countries, most notably in the G20 economies, which produce 85% of global industrial output.[223]

However, many industries are still refining their pathways to a low-carbon future and major challenges likely remain, particularly in heavy industries, which face complex decarbonization challenges in multiple areas, including low-emission technology, electrification, access to low-carbon energy infrastructure, demand for low-emission products, enabling policies and regulations, and access to capital, among others. Solutions to industry choke points are seldom found within a single firm or even industry and will require innovative partnerships between customers and suppliers, between industry and cross-industry peers and between the wider ecosystem of industry stakeholders. A step change in collaborative activity could be the key to unlocking the net-zero transformation of industries and keeping the net-zero by 2050 goal within reach.

Advancing the global energy transition at the required pace will depend on the world's ability to intensify, replicate, scale and further improve the collaborative efforts across countries and sectors. Working together will allow us to achieve the structural change necessary to underpin our collective transition journey to 2050 and beyond. wn

A look into Carbon Offsets - is Africa ready?

As countries commit to reaching net-zero by 2050, carbon offsets will significantly reduce emissions. How?

When the Australian Prime Minister, Scott Morrison, made an implied commitment in a speech in February at the National Press Club that "net-zero by 2050 was likely to become government policy", the Australian carbon offset price spiked three days later and closed 3 per cent higher, at a 12-month high of $17.15 a tonne, according to carbon market analyst RepuTex.

The words of the Minister triggered an investment splurge in carbon credits (Carbon credits are generated by projects that reduce, remove, or capture emissions from the atmosphere, like tree planting or replacing fossil-fuel generators with renewable energy). By September, the spot price had increased to $26 a tonne.

Imagine trading in the absence of something you do not want...welcome to the world of carbon offsets. While general offsets trade in tangible commodities, carbon offsets involve paying someone else to reduce your emissions to enable you to remain carbon-neutral and maintain an acceptable carbon footprint. Broadly, it refers to a reduction in greenhouse gas emissions (GHG) or an increase in carbon storage (e.g., tree planting), used to compensate for emissions that occur elsewhere.

How does it work? Company A pays Company B a certain fee per ton of 'avoided emissions', which allows Company B (the offset provider) to channel the money paid by Company A into an activity or technology that keeps greenhouse gases out of the atmosphere. But one primary concern is whether Company A, as the offset buyer, is getting the value he paid for.

How can the value be ascertained and determined considering that the commodity is absent in the real sense?

Offsets are either regulated or voluntary. Regulated offsets are operated within the compliance framework for cutting emissions under the auspice of the Clean Development Mechanism (CDM), which is an offshoot of the Kyoto Protocol, whereby signatories agreed to cap greenhouse gas emissions generated by participating countries.

Within the CDM, offsets (otherwise known as 'certified emission reductions' or CERs) count toward compliance with the legally binding emission reduction targets within the Kyoto protocol. Companies bound by the Kyoto Protocol can purchase offsets from projects in developing countries, considering the low carbon footprint across the region. Offset projects vary, ranging from landfills that capture methane to renewable energy installations such as wind farms.

However, four conditions have been posited for such projects to be considered viable:

(i) They must be 'additional', in the sense that they must come from

activities that would not happen in the absence of an offset incentive, i.e. are such projects already required by regulation and would thus proceed even without offset funding or will such offset purchased contribute nothing to further emissions reductions because no additionality was implemented based on the intention to sell offsets (essentially, has the technology been in place well in advance of any likely intention to sell offsets?).

(ii) They must be 'quantifiable', meaning they must measurably reduce emissions.

(iii) They must be 'permanent', so the GHG kept out of the atmosphere would not be released later.

(iv) They must be 'real', so third-party inspectors can verify them.

On the other end of the spectrum is called 'voluntary offsets', nonregulated 'over-the-counter' markets accessible by any person, business or group seeking to minimise their carbon footprint. Voluntary offsets do not count towards compliance with mandated emissions reductions, like those required by the Kyoto Protocol.

Offsets typically support projects that reduce the emission of greenhouse gases in the short- or long-term. A typical project type is a renewable energy, such as wind farms, biomass energy, biogas digesters, or hydroelectric dams. Others include:

- Energy efficiency projects like efficient cookstoves.
- The destruction of industrial pollutants or agricultural byproducts.
- The destruction of landfill methane.
- Forestry projects.

Some of the most popular carbon offset projects (from a corporate perspective) are energy efficiency and wind turbine projects.

According to Terrapass, Emission reduction projects reduce the number of greenhouse gases in the atmosphere in one of three ways:

(1) By capturing and destroying a greenhouse gas that would otherwise be emitted into the atmosphere. An example of this is a methane gas capture project at a landfill.

(2) By producing energy using a clean, renewable resource that eliminates the need to produce that same energy from fossil fuels, the burning releases greenhouse gas into the atmosphere. An example of this is wind power.

(3) By capturing and storing (or "sequestering") greenhouse gases to prevent their release into the atmosphere. An example of this is a project that promotes the healthy growth and maintenance of forests.

Some projects include more than one of these activities at the same time. For example, gas capture projects at landfills prevent the release of methane gas into the atmosphere and use the captured methane to generate electricity that would otherwise be generated by burning fossil fuels such as coal or natural gas.

The risks and concerns associated with carbon offsets include- lack of 'additionality,' fraud as it relates to double-counting whereby developers sell multiple offsets for a single project, and lack of regulatory control and accountability for the 'over-the-counter' offset market. However, market-based standards are deployed, etc.

Although it has been acknowledged that offsets alleviate the burden and support the ability of stakeholders to deal with climate change, the workability of offsets beyond global regulatory obligations is dependent on individual state policies, thorough due diligence, certification standards, etc. In addition, numerous schools of thought have questioned the viability of offsets, positing a preference for Carbon Tax.

In the words of Alison Reeve, deputy director of the energy and climate program at the Grattan Institute, 'offsetting should not be a substitute for avoiding cutting emissions, but it has a place when dealing with emissions-heavy industries, like cement production.

Another view from the Institute for Applied Ecology is that 'Offsetting has tried, and failed- to pursue this as a solution now is nothing more than greenwashing and would blow a massive hole in the Paris agreement.

But based on the Carbon Offset Guide, Carbon offsetting is possible because climate change is a non-localised problem. Greenhouse gases mix throughout the atmosphere, so reducing them anywhere contributes to overall climate protection.

CAN AFRICA BENEFIT FROM THE CLIMATE MITIGATION STRUCTURES AND MEASURES?

Africa accounts for only 2% of the trading in the global carbon market, with South Africa and North Africa enjoying the larger share benefits of the projects under the CDM.
The African Development Bank (AfDB) in the Carbon Markets and Africa Quick Facts recognised climate change as a driver for change to realise new value for businesses and institutions in Africa for the benefit of local economies and people.

Whether directly or indirectly, countries that emit greenhouse gases can take action to reduce the emissions and pay for the costs partly by generating emissions reduction credits that are tradable assets.

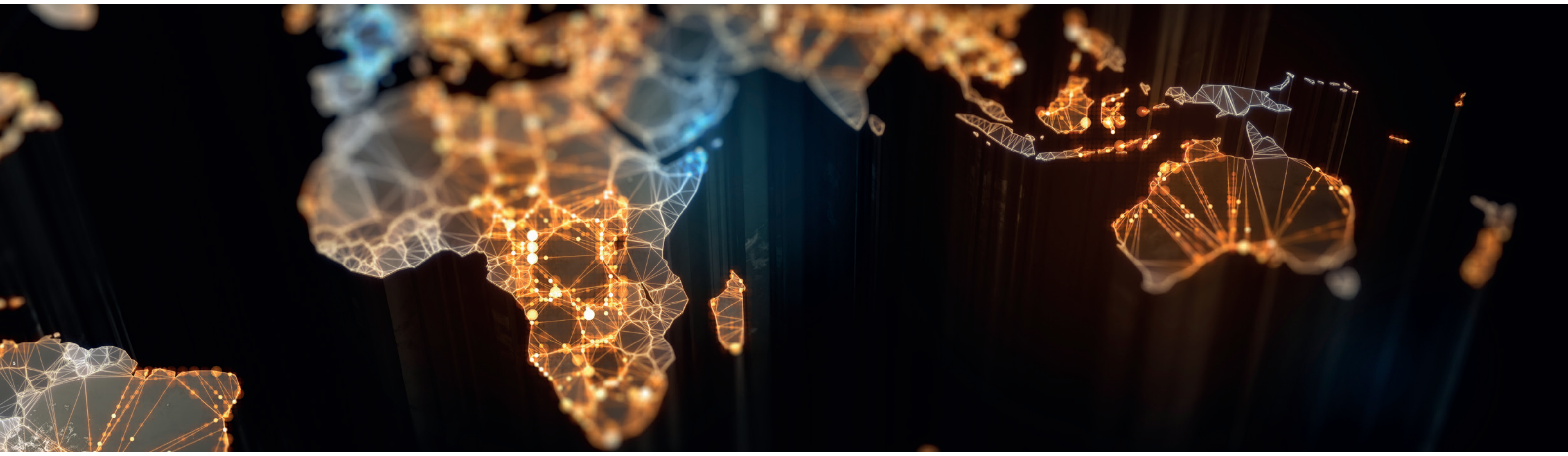
For small-scale activities such as decentralised waste management by SMEs, it is posited that carbon credits can provide additional revenue streams far into the future, thus augmenting the viability and sustainability of the business models.

A study revealed that the annual and cumulative investment in registered CDM projects in Africa amounted to 4496 between 2004-2012, thus revealing clear signs that the African carbon market is starting to take off, with over $4.5 billion invested in registered African CDM projects.

In South Africa, introducing a carbon tax has revived keen interest in the offset market. Nevertheless, suitable projects must be invested in and delivered at scale. Furthermore, regulatory systems will need to be put in place, and the region will need to develop its climate and carbon finance strategy.

Africa requires US$52-68 billion annually by 2030 to meet the climate change challenge. These investments will come through innovative models within the CDM framework backed by donor support. Otherwise, the reality remains that the investments may come from existing investments in fossil fuels through cleaner mechanisms, particularly natural gas, which has been posited to be the cleanest of all fossil fuels.

At COP26, it has been reported that one of the most complex tasks facing negotiators is how to agree on a market-based mechanism that will allow countries to use international carbon credits to meet their emissions reduction goals in the Paris agreement. wn



Green Ammonia

There is a genuine reason for an erudite analysis and study of grey, blue, and green ammonia, respectively, and diesel (grey, and blue diesel, and biodiesel) due to their energy densities by volume and mass, carbon capture, carbon emission, environmental pollution, and techno-economic considerations.

By | AD Asiegbu

The need for sustainable and environmentally friendly energy sources is crucial if future generations are to be spared from the misdoings of past generations. Climate change, environmental pollution, radiation pollution, and altering the balanced ecology of the green planet earth is now a significant challenge. If not mitigated, some island nations will disappear in future due to human activities energised by the unsustainable fossil fuels that cause a rise in sea level.

Based on these facts, ammonia, which has a 1.5 energy density more than hydrogen, boiling at -33 degrees Celsius (hydrogen boils at -253 degree Celsius), need to be carefully compared with diesel, the most flexible liquid fossil fuel with the optimum energy density and low energy cost, to reveal opportunities to reduce Green House Gases (GHGs), carbon footprint, environmental pollution, energy transportation and optimum storage cost, improved efficiency, and overall improvement on the human quality of life. Germany has taken concrete and necessary steps to stem the tide of this ill wind by embracing the Green Hydrogen and Green Ammonia system. This is more obvious in the transport system that produces more than 40% of (GHGs) in Europe. Germany, an industrialised European nation, has introduced the Green Hydrogen and Green Ammonia for transportation and long haulage transportation (containers transportation via the high seas and oceans).

Also, Chile has commenced ammonia and hydrogen production and transportation to Japan in a profitable manner beneficial to both countries based on a mutual agreement that mitigates GHGs and other issues. Thus, this paper provides a clear and concise academic scholarship in the detailed but comprehensible analysis and implementation of Green Ammonia from green Hydrogen (GH) energy in the smart energy system and its comparison to diesel fuel. The paper compares ammonia and diesel in terms of energy densities, energy production, energy storage potentials, sustainability

Diesel

(GHGs, carbon footprints, ecological impacts etc.), and transportation in three sections, namely, Geographical, social, and economic aspects, respectively. The last section of this paper is the discussion of results from cost/feasibility analysis, energy model based on proton vector-based power system from green hydrogen and green ammonia, electron vector-based power system, and the dual or combination of liquid fuel and electron/proton vectors-based power system, with an educated conclusion and recommendations made at the end of this research.

1. INTRODUCTION

The comparison between green ammonia and diesel is made by considering each chemical substance on its merits, demerits and associated or relevant facts. Ammonia is a chemical substance consisting of three hydrogen atoms and one nitrogen atom. Fritz Haber (German) patent in 1908 the synthesis of ammonia, and in 1918, he received a Nobel Prize in Chemistry for this discovery. Named after him, the Haber process is a synthetic method of manufacturing ammonia, a chemically reactive, highly usable form of nitrogen and hydrogen production or associated derivatives. Above -33.3 °C, ammonia is a pungent-smelling and colourless gas with a density of 0.86 kg/m^3.

Below -33.3 °C, it is a colourless liquid with a density of 681.9 kg/m^3 and a colourless and transparent solid with a density of 817 kg/m^3 at about -80 °C. The molecular mass of ammonia is 17 grams per mole. At room temperature, ammonia is a gas with a strong pungent, suffocating, and irritating smell. When anhydrous (dry, without water), it is very poisonous and dangerous to health. In addition, it has alkaline, corrosive, and hygroscopic properties.

It readily dissolves in water to form a caustic weak base solution. It can be compressed under high pressure and transported in steel containers. Although it is not highly flammable or combustible, it can explode when exposed to high temperatures. The human body, animal species, and some plant species produce and metabolise ammonia. It is easily detected by its pungent odour. However, if present in high concentration and prolonged exposure, it is toxic and can cause injury to the eyes, skin, respiratory tracts etc. There is a probability or propensity that after prolonged exposure to ammonia, a threshold smelling sense is reached, where the smell of ammonia appears natural to the affected person. Thus the exposed person might be inhaling the intense and dangerous gas without being aware. Thus, employees in an ammonia facility should undergo regular medical check-ups, and special ammonia leak sensors should be fitted in that plant and premises. Ammonia produced from fossil fuel with low or no carbon capture is called grey ammonia. If carbon capture is fully realised, then it is called blue ammonia. The ammonia produced from water electrolysis and powered by renewable energy sources like solar, wind, and hydro kinetics is called green ammonia.

At present of this research, grey ammonia appears to be the cheapest means of ammonia production due to its development over time and strong use in agriculture and other industrial uses. However, it contributes significantly to GHGs emissions, climate change, ozone layer depletion, and environmental pollution. Blue ammonia is encouraged by various governments like the government of Germany, which will be used as an example throughout this research. However, it is still relatively expensive, with overall benefits and savings in mitigating the environmental issues and health problems associated with grey ammonia production. The best and safest production of ammonia is green ammonia. Green ammonia is an alternative, or an additional energy carrier, transport medium for energy and raw materials for industrial processes, and means of storage produced from green hydrogen liquid energy and other renewable energy sources (MacFarlane et al., 2020).

Green ammonia has net-zero emissions. Since green ammonia is 1.3 times in energy density (energy per unit mass or energy per unit volume) compared to green hydrogen, it presents more opportunities than the ones present in green hydrogen (Wang et al., 2018). This makes green ammonia very suitable for long-distance travel, like the shipment of containers through the oceans (90% of worldwide trade go through this route) and high seas (Aziz, TriWijayanta and Nandiyanto, 2020). The existing hydrogen transport infrastructure in Germany, which is also analysed in this paper, can be used to distribute and supply green ammonia from renewable sources to consumers.

Diesel: In 1892, Rudolf Diesel discovered and patented diesel fuel. Petro-diesel (grey diesel) is produced from crude oil, but biodiesel (green) is produced from biomass. Diesel chemical composition is C10H20 to C15H28, with carbon forming 86% of the total mass. The CO2 emitted by diesel (73.25 g/MJ) is slightly lower than that of gasoline (73.38 g/MJ). It has significant sulphur content, which results in emissions of sulphur dioxide or sulphur monoxide and GHGs. It has a boiling point of around 180 °C to 360 °C, with high volumetric energy density and slightly higher heat value compared to gasoline and ammonia. Diesel efficiencies and performance can be increased with hydrogen-assisted atomisation of diesel droplets, increasing the flame radius and shortening ignition delay (Cernat et al., 2021). This makes diesel more efficient and a better option than gasoline, but not green ammonia and green hydrogen.

2. GEOGRAPHICAL FEATURES

The geographic features can help reveal the technology, economic forces, and infrastructure to make an optimum and geographical comparison between (green) ammonia and (Improved/hydrogen atomised) diesel. Germany is used in this regard as a template due to its efforts to reduce carbon footprint, implement green hydrogen/green ammonia, and migrate to a sustainable energy future following the European Union (EU) policy on sustainable and renewable energy aimed at reduction of GHGs, climate change, and carbon footprint reduction. The Federal Republic of Germany (FRG) has a well-structured democratic federal republic form of government with its capital in the metropolitan city of Berlin as the national capital. The official language is German, the national currency is the (continental) Euro, the total geographical area is 349,223 square kilometres, and the major rivers are Danube, Rhine, Main, and Elbe. The population projected growth rate is 200000 per year starting from 1985, and currently, the population is 80,457,737 ('GERMANY (Federal Republic of)', 2020).

Germany has various landscapes and primary energy sources, like wind energy, hydropower, biomass, solar energy, and other renewable, environmentally friendly, and sustainable primary energy sources. Because of the rise in demand or consumption of energy over time, which results in climate change, ozone layer depletion, environmental pollution, and the increase of Green House Gases (GHGs) like Carbon (IV) Oxide (CO2), Sulphur (IV) Oxide (SO2), Carbon (II) Oxide (CO), Nitrogen (IV) Oxide (N2O), Hydrofluorocarbons, Perfluorocarbons, Sulphur hexafluoride (SF6), the government of Germany seeks to discourage generation of energy from fossil fuel sources like coal, crude oil, natural gas, and fuel wood. However, it supports renewable energy sources which are environmentally and economically sustainable, primarily the green hydrogen and green ammonia energy sources (Schill, 2014).

Transportation activities produce an average of 28% of CO_2 emissions in the European Union (EU) (Thalmann & Vielle, 2019). Germany being the largest economy, the wealthiest and a post-industrial nation in continental Europe, produces more CO_2 than the average value in Europe. Thus, it is crucial to change primary energy sources that will change the geographic, social, economic, and salient features of the world and the German nation. To reduce the exploration of the land, atmosphere, and the earth's biosphere from fossil energy primary sources, the geography and geology of the green planet earth need to be balanced and maintained by switching to renewable energy sources like solar energy and wind energy. These primary sustainable energy sources fluctuate seasonally, making reliable energy storage inevitable. One such long-lasting and reliable energy storage and mix, especially in the distributed generation, is the green hydrogen energy and green ammonia renewable energy source. However, green ammonia presents many advantages over green hydrogen and diesel. Also, green hydrogen is better than diesel.

Green ammonia has three times more hydrogen atoms than a green hydrogen atom in terms of the produced hydrogen atoms during dissociation in electrolysis, chemical reactions, and photo-mediated dissociation. Thus, green ammonia has a high volumetric energy density and heat value (1.3 times) in the liquid matter phase, is half the infrastructural cost, is easily compressible at ambient temperature, has a higher production rate (100 million tonnes/year) than green hydrogen (Avery, 1988), but not diesel.

However, green ammonia is renewable, produces less GHGs, has a low carbon footprint, and can use Germany's current green hydrogen transport and storage facilities optimally than green hydrogen. In these dimensions better than diesel, which emits more GHGs and is significantly less efficient (conversion efficiency of 50%) and not as environmentally friendly as ammonia, with conversion efficiency up 100% theoretically. Also, with the downward trends in renewable energy technologies, the cost of electrolytic green ammonia will decrease and eventually become cheaper than the cost of diesel (Fasihi et al., 2021).

In the classes of hydro-fuel, ammonia stands out because it has a boiling point (-33°C) higher than propane (-42°C). Propane is a liquid petroleum gas (PLG) under pressure in the cylinder. It is easily compressible compared to green hydrogen. Heavy transport vehicles are not required but required in the case of green hydrogen, unaffected by a cold climate, unlike diesel gel-like phase in a cold climate, which impedes flow and transportation.

During handling, storage, transportation, and production, leaks can be easily detected by the strong, pungent smell of ammonia, as an early warning, unlike odourless green hydrogen and slippery diesel fuel. Just like green hydrogen, it follows upward delivery in the laboratory test tubes if it is anhydrous and reduces ammonia's toxic effects on the lower atmosphere when released into the atmosphere. It goes through photodissociation into nitrogen and hydrogen in the upper atmosphere, then the nitrogen enters the nitrogen cycle, and hydrogen reacts with earth-abundant oxygen to form water vapour. Thus, it is environmentally friendly and sustainable, unlike the CO_2 and other GHGs emissions of diesel that present climate issues and environmental problems.

Transportation is a significant energy consumer and is considered a standard for implementing green hydrogen energy, referred to as the Green Hydrogen (GH) for transportation, using Germany as a case study or template. Green Hydrogen is the splitting of a water molecule to yield one molecule of hydrogen (two atoms of hydrogen) and one atom of oxygen when direct current electricity is passed through water.

The GH produced can be stored as Liquid Hydrogen (LH) or Compressed Hydrogen (CH). It can be transported in pipelines or tanks using trucks and used as a primary energy source for direct heating, electrical energy, and industrial or commercial purposes when the wind energy, solar energy, and other renewable sources are not available or in short supply (Hake, Linssen and Walbeck, 2006). Significantly it can be electrochemically processed to yield green ammonia.

The oxygen atom is very reactive, solely responsible for combustion (an example of oxidation reaction) and must be paired to form diatomic (O_2) gas, heavy oxygen molecules that descends through the downward delivery displacement. A hydrogen atom is also reactive, and the only atom that loses an electron forms a proton (an example of a reduction reaction) that must be paired to form the lightest chemical element (H2 gas), ascending through the upward delivery displacement. The two half (electron) reactions are collectively known as redox (reduction-oxidation reaction), with water as the product. O_2 is abundant in the atmosphere, but H2 is not, making it a limiting chemical reagent whose capture represents a primary renewable green energy source geographically.

Similarly, ammonia gas can be split by electrochemical means to yield three protons against two protons produced from the green hydrogen above. The nitrogen atom left behind then combines with oxygen to form nitrogen dioxide, a GHG. This GHG can then be captured naturally by reacting with ammonia gas and water to form liquid ammonium hydroxide. This weak base needs a weak acid like citric acid to be neutralised entirely and easily managed.

This green ammonia is the future primary or intermediary energy source and an essential part of Distributed Energy Resources (DERs), Smart Energy (SE), Distributed Generations (DG), and most importantly, a reliable energy-efficient storage and transport. This forms part of the energy modelling and blockchain technology, a bitcoin technology that is extremely important in energy trading in today's digital world.

Theoretically, the hydrogen fuel-powered by green ammonia by electrochemical (recovery of green hydrogen from green ammonia) can achieve 100% conversion efficiency from chemical energy to electrical energy transduction. However, the currently designed plant achieved 65,8% efficiency (Makhloufi & Kezibri, 2021) compared to diesel's 40 to 50% conversion efficiency/heat value to power (Rosero et al., 2020). Hence, by 2050, green ammonia will represent 20% of global energy use and an in-depth decarbonisation pathway (Salmon & Bañares-Alcántara, 2021).

3. SOCIAL ASPECTS OF GREEN HYDROGEN

The GH produced (from green ammonia) should be acceptable, socially and economically appealing, strategically located, and must pass through some market and economic routes before getting to the energy consumer (Households, Industries, commercial users, and Building energy users) in the society. The cost of GH transportation using a truck will be reduced using four different strategies and at high compressed pressure of 250 Bars and 350 bars in the year 2030 (Lahnaoui et al., 2018).

Thus, modern infrastructure must be in place, or the old infrastructure must be upgraded to accommodate the peculiar needs of GH storage, transportation, and end device direct use as a clean energy source. The green hydrogen and green ammonia transportation infrastructure in Germany, projected/modelled for the year 2030, is shown in figure 1.

International Renewable Energy Agency (IRENA) has identified the need for a green world, as summarised below:

a. Decarbonization of the global economy
b. Transition to Renewable energy should be done urgently
c. Because 90% of global trade is via ocean, liquid green ammonia energy is needed for long-distance haulage and net-zero emissions
d. Complete decarbonisation of maritime sector by 2050
e. Limiting earth temperature increase by 1.5°C (global warming)
f. Reducing Green House Gases (GHGs) to zero by Mid-century
g. Energy efficiency and renewable energy sources are crucial
h. Advanced Biofuel (short-term measures) and green hydrogen (long-term measures) integrated with solar, wind, and hydrokinetic energy sources will yield sustainable Distributed Energy Resources (DERs)
i. Maritime transport sector needs 183 million tons of NH3 to decarbonise completely

To realise these aims and objectives, an extensive transport network and supply chain or upgrade/overhaul of the current hydrogen transport in Germany is inevitable. The current hydrogen/ammonia supply network is a model for the EU and the rest of the world.

Through energy modelling of green ammonia and e-diesel, blockchain technology can be implemented in the energy sector. As depicted above, green ammonia is socially compatible and can be readily integrated with the existing green hydrogen supply chain network across Germany. Similar countries with established green hydrogen production facilities, transport and distribution networks, can take advantage of green ammonia in managing the agelong problems of pressure, relative easy liquefaction of green ammonia, electrochemical synthesis of ammonia instead of the traditional Haber process, and fuel cell-powered by green ammonia with theoretical 100% efficiency, and 65.8% efficiency currently.

This digital e-energy trading is called energy blockchain technology, like cryptocurrencies technology, a modern social cohesion and integration tool, with the aims and objectives of optimising energy resources in a renewable and sustainable manner, creating thousands of professional, modern and clean jobs in the process (Miller & Campbell, 2019).

Renewable energy sources power the whole energy conversion process. E-diesel is an economically sound technology developed and tested by Audi cooperation, used by the Germany ministry of education and research by using carbon dioxide, water, and electricity to synthesise carbon-neutral fuel, in this case, known as e-diesel. This fuel is called blue crude oil because of the carbon capture, relatively zero net GHGs and radiation emissions.

The process involves heating water to a high temperature (220°C) and splitting it into a proton (hydrogen radical) and oxygen radical. This product reacts with CO_2 to form water, CO and H_2 gas.

Finally, through the Fischer–Tropsch (FT) chemical process, first developed by German chemists Franz Fischer and Hans Tropsch in 1925 (Abdollahinejad et al., 2020), yields the blue crude oil that can be refined to produce e-diesel and other desired products with an advantage of net-zero GHGs and radiation emissions, economically feasible, most importantly socially acceptable by people and specifically environmental activist.

Regarding the social features of green ammonia and e-diesel, the comparisons and techno-economic features offer the potential to mitigate issues around fossil fuel. Since they are renewable and can be used to store and transport energy, even digitally, as in the blockchain energy model, thus, both represent modern, clean energy for a sustainable

Figure 1: The GH transportation infrastructure for 2030 (Ochoa Bique & Zondervan, 2018).

and blissful future here on the green earth. Since the crude oil produced is in the blue category, it is still below green ammonia. Thus, green ammonia offers the overall best deal, considering environmental impacts, climate change and pollution. However, in society, the smell of diesel is not as pungent as the green ammonia.

The irritating smell and, to an extent, poisonous ammonia fume is a disadvantage and not well received by people in most social circles. Another significant merit of e-diesel social is the

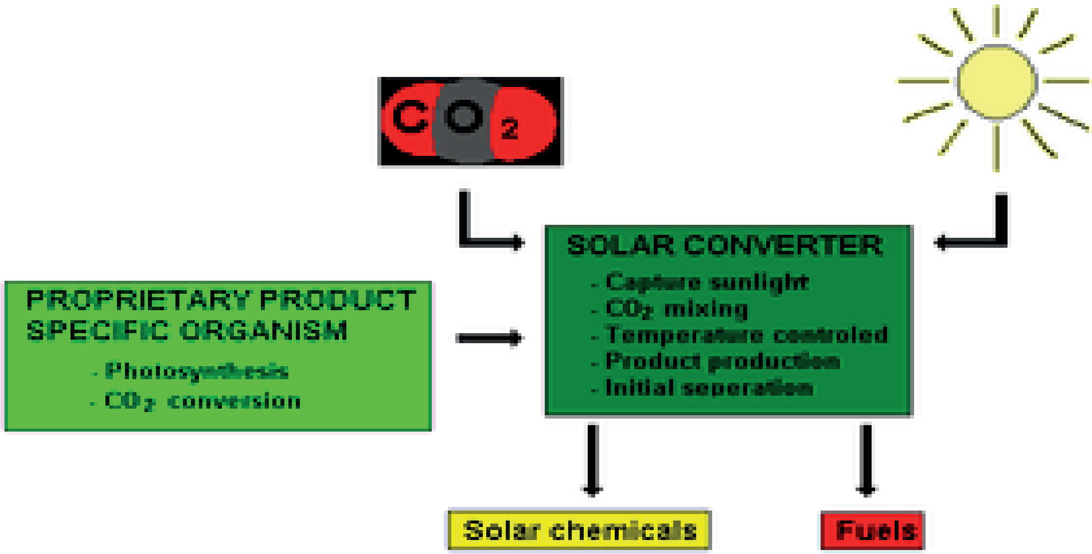


Figure 2: microbes (algae) in green biodiesel production

numerous diesel filling stations, transport mechanisms and storage facilities already in place in most countries and the ease with which it is poured into the car or machines at lower pressures and average ambient temperature (Avinash, Natarajan and Mahalakshmi, 2015).

Green ammonia does not leak easily compared to green hydrogen (the lightest atom known to man). Thus, rubber tubbing and caps are sufficient to prevent leaks in green ammonia transportation. Diesel tends to be slippery when in contact with the ground, even after lightly cleaning it out, which presents hazards to people and skidding cars in contact with these surfaces, which is a demerit for diesel. Another demerit of diesel social appeals is slow starting in cold climates. Another advantage of using liquid energy fuel

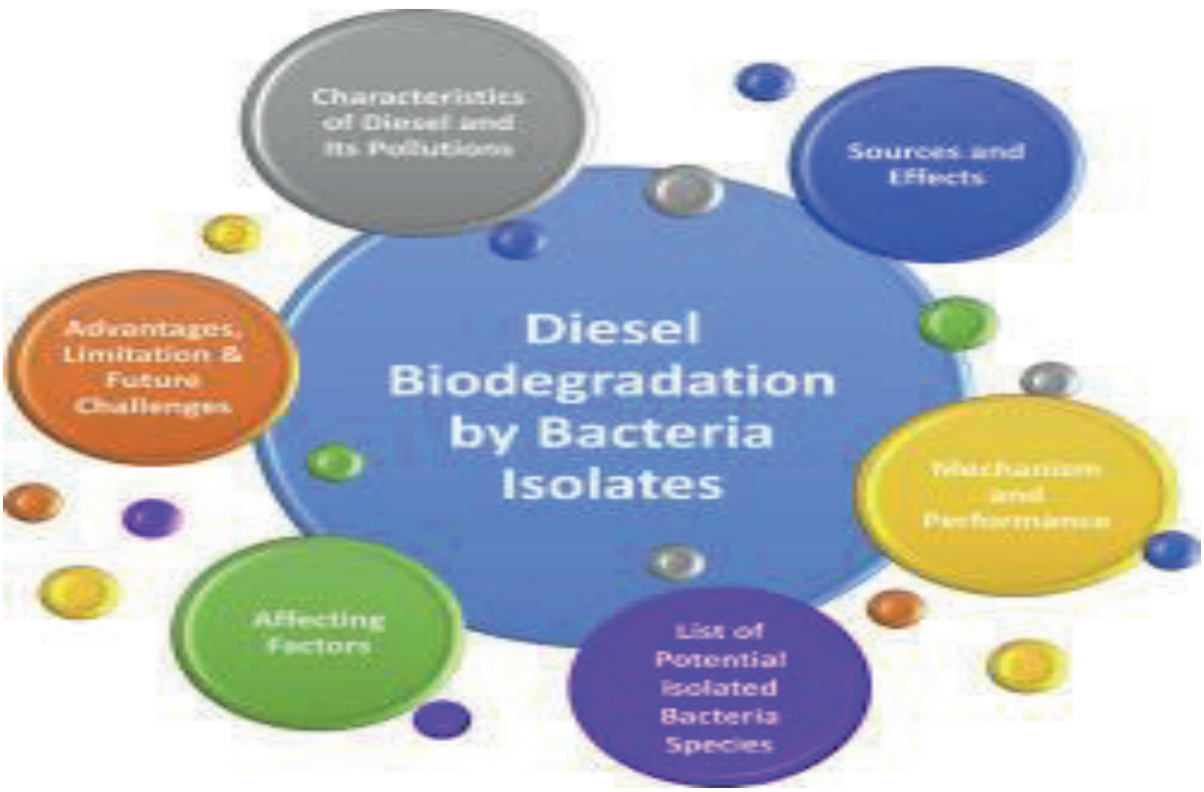


Figure 3: Biodegradation, bioremediation of diesel by microbes.

in Germany is producing e-diesel from microbes, as shown below. It can also be biodegradable (Fernandez, Stocker and Juarez, 2019).

Figure 2 and figure 3 clearly show that e-diesel is a game-changer and can be made environmentally friendly, with net-zero GHGs, radiation emissions, and little or no impact on climate change. Compared with green ammonia, green ammonia is a reasonable and better choice after all the considerations have been done.

4. ECONOMIC FEATURES OF GREEN HYDROGEN/GREEN AMMONIA AND E-DIESEL (BLUE CRUDE OIL) ENERGY SOURCE

To encourage the use of GH and green ammonia, the German government introduced a pilot program for the use of Fuel Cell Electric Vehicles (FCEV) and Hydrogen Supply Chain (HSC) (De-León Almaraz et al., 2015).

Based on the current trend in energy demand, savings from using high energy equipment or energy system, saving from avoiding health issues resulting from GHGs, and environmental pollution, implementation of the distributed energy system, advancement in technology, and future research breakthroughs, the cost of generating GH will decrease and GH/green ammonia/energy access will increase. There is a policy that discourages the use of fossil fuels in Germany, especially the use of diesel as a primary energy source, as part of the European Union policy on decarbonisation.

However, the federal government of Germany, through the ministry of education and research, has partnered with Audi miracle of synthesising blue diesel (e-diesel), owing to diesel's high energy density, liquid form at ambient temperature and pressure, and existing storage and transport network to conduct techno-economic analysis and feasibility studies of this beautiful innovation. It will also be noted that the oxygen by-product will be used soon to convert methane (natural gas) into ethene gas (reformation of methane gas to make it more environmentally friendly and reduce its carbon content from C4 to C2), which has a high bond energy and combustion energy being a double bond with sigma and pi bonds respectively (Mosinska, Szynkowska and Mierczynski, 2020).

Analysis based on these techno-economic and future technology features shows that e-diesel is still emerging and could represent a generation of sulphur-free diesel, high-performance diesel, digital diesel suitable for blockchain technology and energy modelling comparable to green hydrogen and green ammonia.

Thus, considering additional infrastructural diesel facilities in place and the declining cost of renewable energy sources like photo-voltaic cells, wind turbines, and hydro dams, both have an equal rating, in my opinion. All the green hydrogen parameters and statistics shown below can be replaced and even made to perform better using green ammonia. Thus, there is no need to change the green hydrogen and diesel infrastructure in Germany to accommodate green ammonia and e-diesel, respectively.

Geographic tools, like the geographic information system (GIS), can be used to model the supply chain management

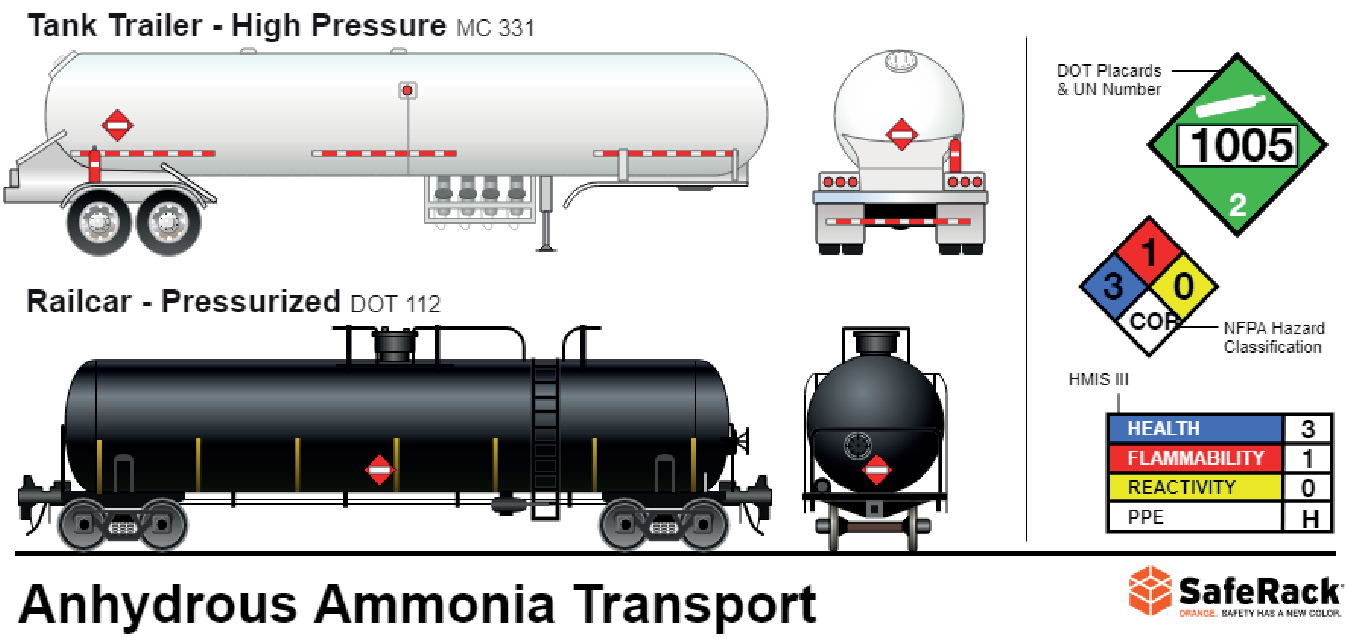


Figure 4: Anhydrous ammonia transport from SafeRack transport and logistics company

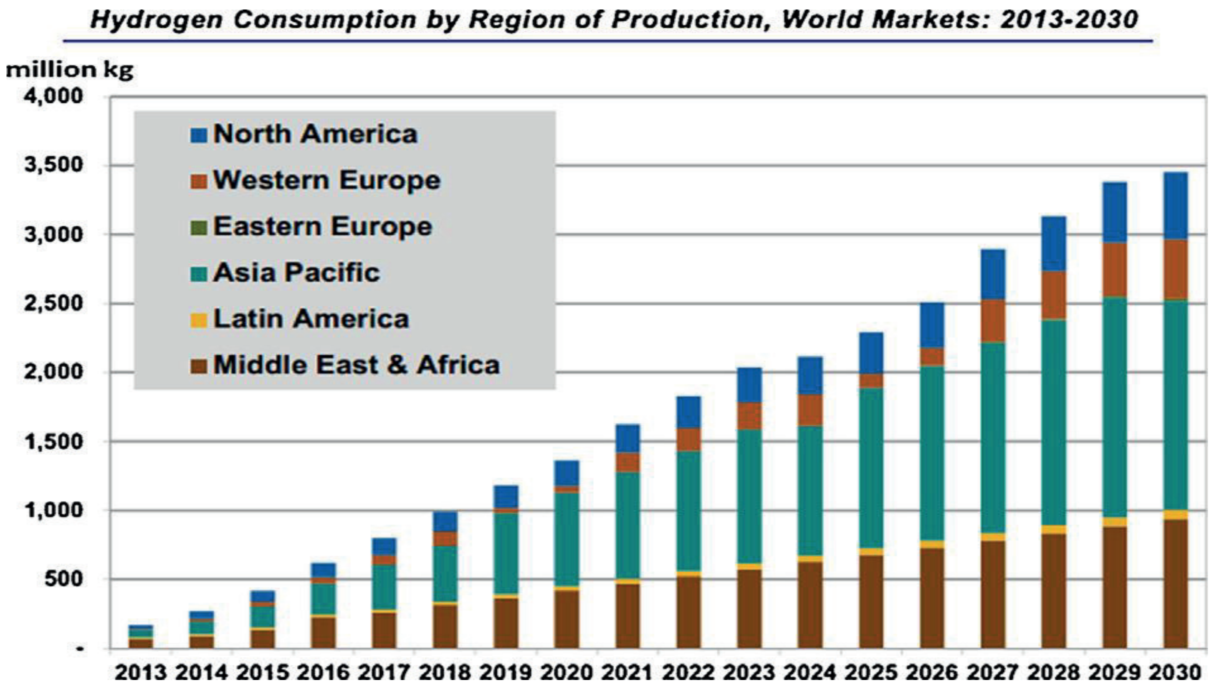


Figure 5: World Hydrogen needs and demand (Ogumerem et al., 2018)

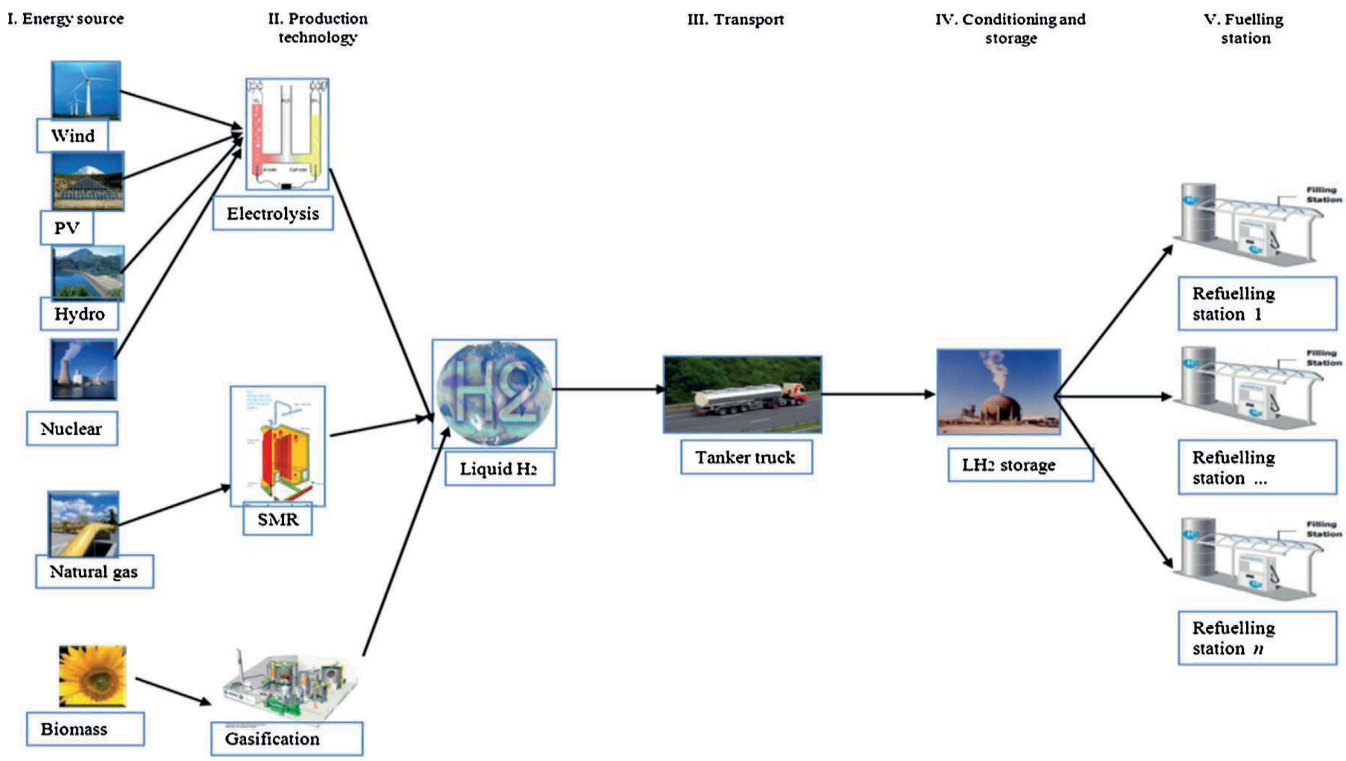


Figure 6: Hydrogen Supply Chain (HDC) (De-León Almaraz et al., 2014)

systems like the Hydrogen Supply Chain (HDC) and ammonia supply chain systems. Model for Optimisation of Regional Hydrogen Supply is used to do geographic analysis (and economic feasibility) of the German HDC (Ball, Wietschel and Rentz, 2007).

The Fuel Cell Electric Vehicles (FCEVs) will be sustainable since it is an example of (hydrogen) gas to (renewable) energy technology that is reliable (can travel long distance without the need to recharge batteries or refuel the car).

It can be integrated into the distributed generation system, use green ammonia as an e-fuel, and capture wind and solar energy directly from a natural energy-rich environment.

The e-diesel has some other economic value besides serving as an energy source. For example, ammonia can be synthesised from steam reforming of natural gas and reacting the product with the nitrogen in the air. Green ammonia can be synthesised by water/Alkaline/PEM electrolyser, water desalination, air-cryogenic distillation and Haber-Bosch Process (fertiliser production of NPK), all of which are powered by solar voltaic cells and onshore/offshore wind farm (renewable energy sources) (Nosherwani & Neto, 2021). Nevertheless, the other economic values of blue and green ammonia outweigh that of blue diesel.

This will make the land filled with well-nourished plants, which will even reduce the amount of GHGs in the atmosphere to natural values, reducing the greenhouse effect, climate change reduction, erosion reduction, humidification of the atmosphere, soil moisture retention, soil structure maintenance, and soil aeration. Thus, the economic and ecological gains from using grey, blue, and green ammonia is outstanding and can turn the world into green planet earth in terms of energy supply, geography, ecology, and, most importantly, the climate and atmospheric equilibrium or balance.

Since ammonia can be metabolised by the liver in small concentrations, by some plant/legume crops, thunderstorms (nitrogen cycle and nitrogen fixation), and some other animals, despite being toxic and having a strong, pungent smell, it is more natural to the biosphere and the social environment than the grey, blue, and biodiesel respectively. This is an economic and technological advantage over diesel.

The new cost of using green hydrogen/green ammonia energy will change

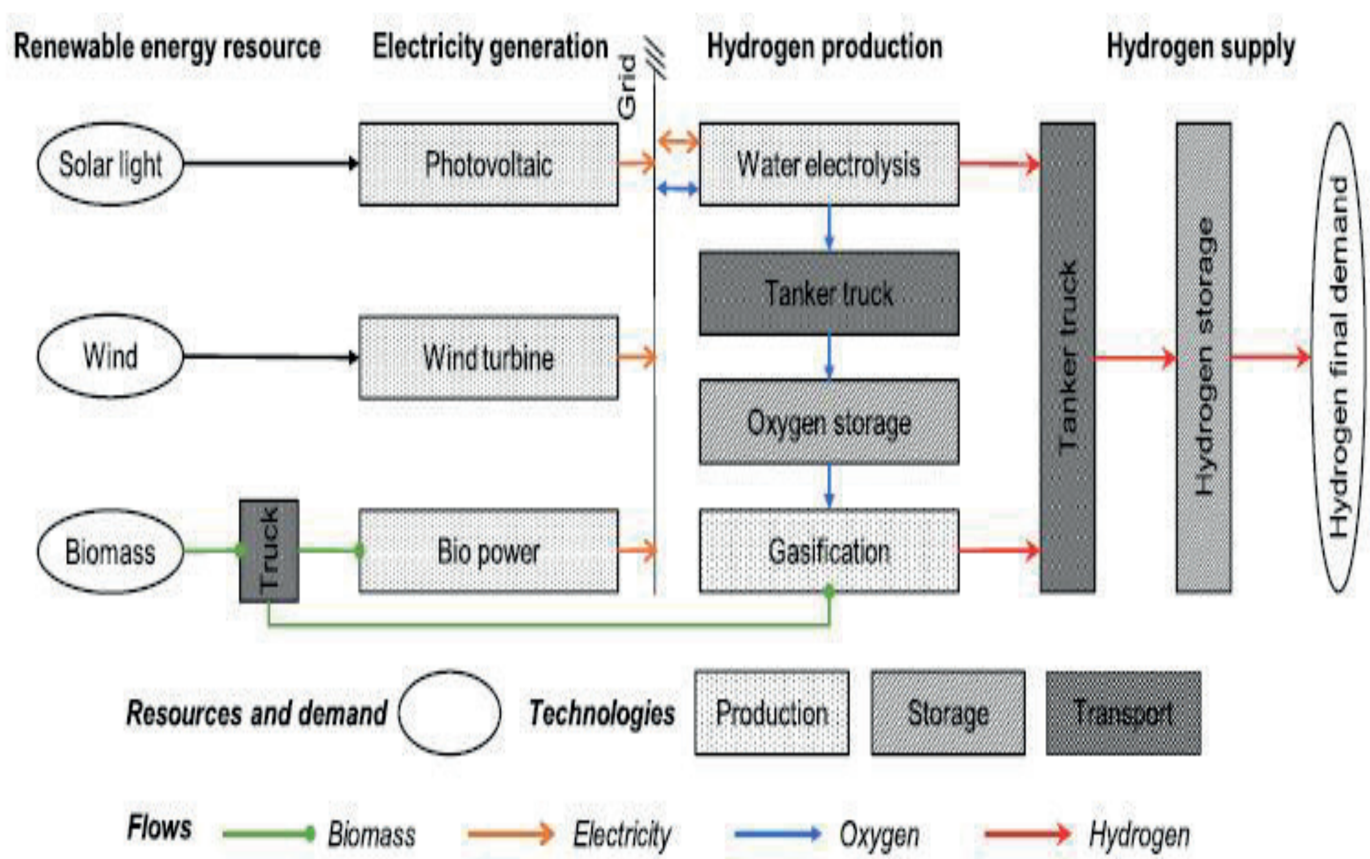


Figure 7: An integrated renewable energy system with hydrogen playing a pivotal role.

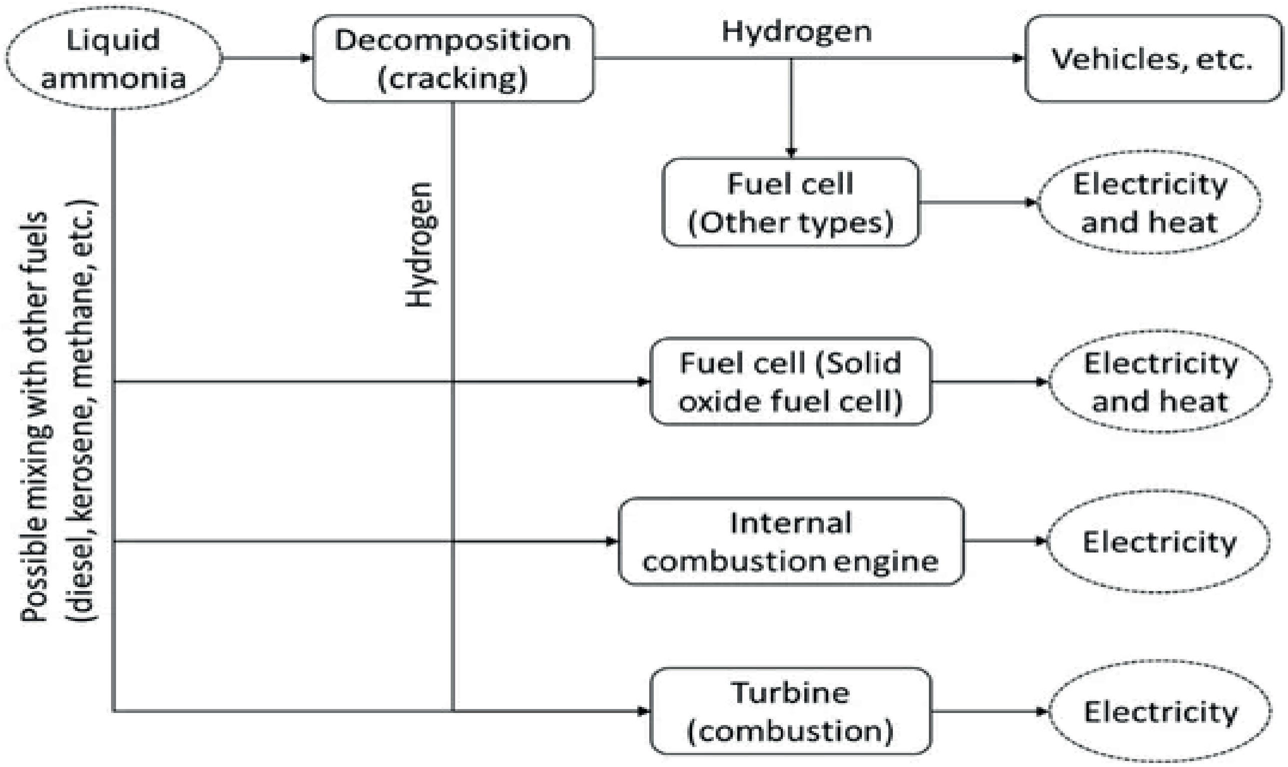


Figure 8: Transport and Utilisation of green hydrogen and ammonia.

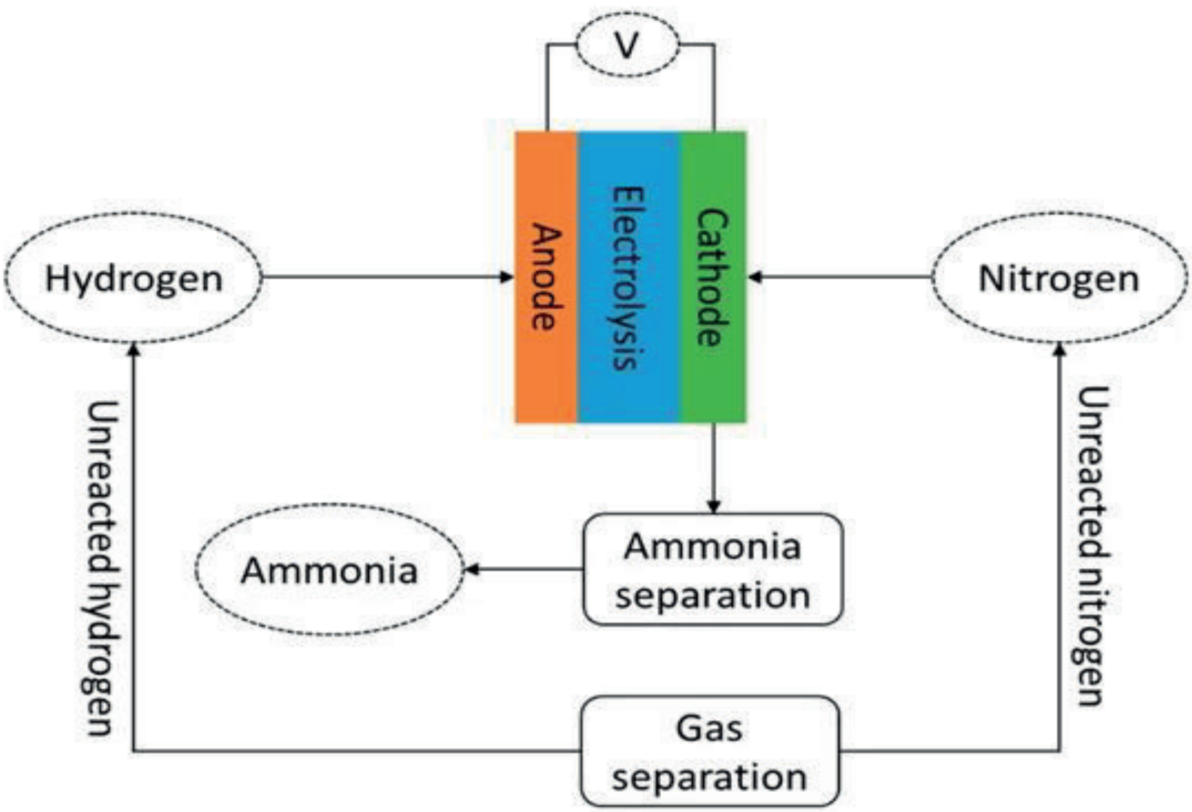


Figure 9: Green ammonia renewable energy source.
(Aziz, TriWijayanta and Nandiyanto, 2020)

according to the equation: the **New Cost = the reference Cost X (New Capacity /Reference Capacity) ^ Power Low Factor** (Kim & Kim, 2016), where the low power factor is assumed to be 0.6 for Green Hydrogen (GH), transported through pipelines. The capacity of GH in Germany is 960000kg/day, the capital cost of production is R29,249,472,600, and the production unit cost is R98,01. Due to the increase in demand for GH in Germany, the new expansion cost of the current capacity, which will double the original capacity (1920000kg/day), is calculated as R58,498,945,200 and a new unit cost of R196,02.

This shows that if the demand is doubled, the cost tends to double if the present infrastructure is not modernised. Green ammonia cost (Net Present Value (NPV)) with a confidence of 95% return on investment, the NPV = +76.1% of occurrence.

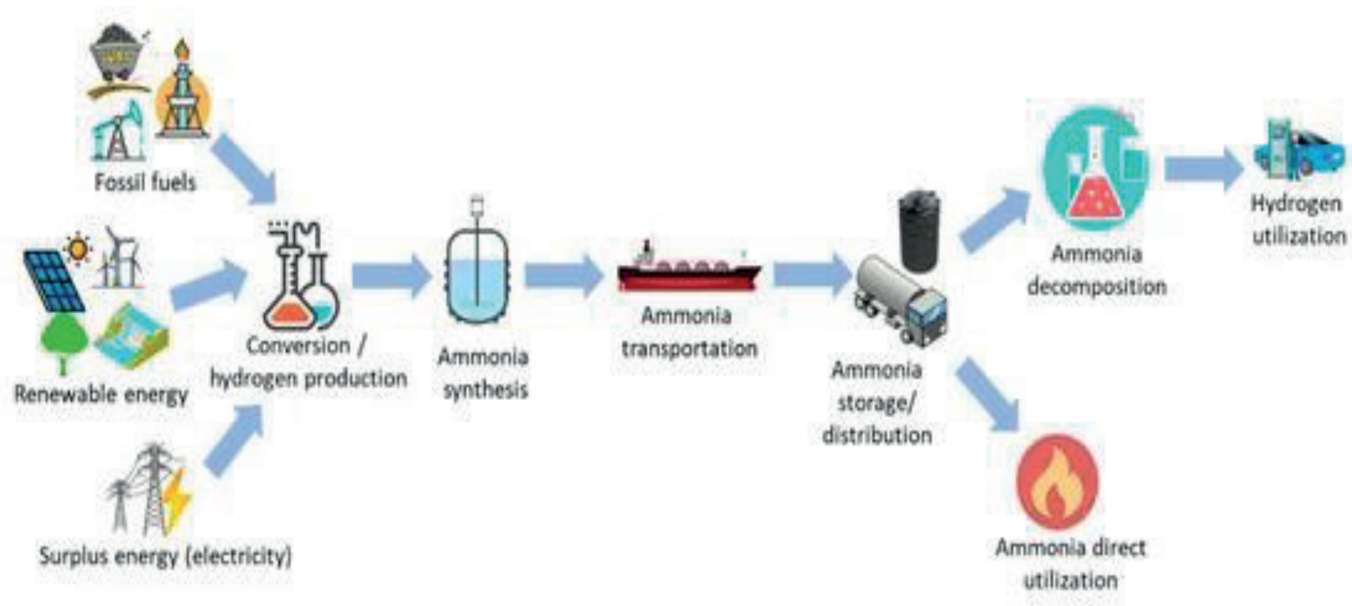


Figure 10: Ammonia synthesis and usage in green Distributed Energy Resources (DERs)(Aziz, TriWijayanta and Nandiyanto, 2020)

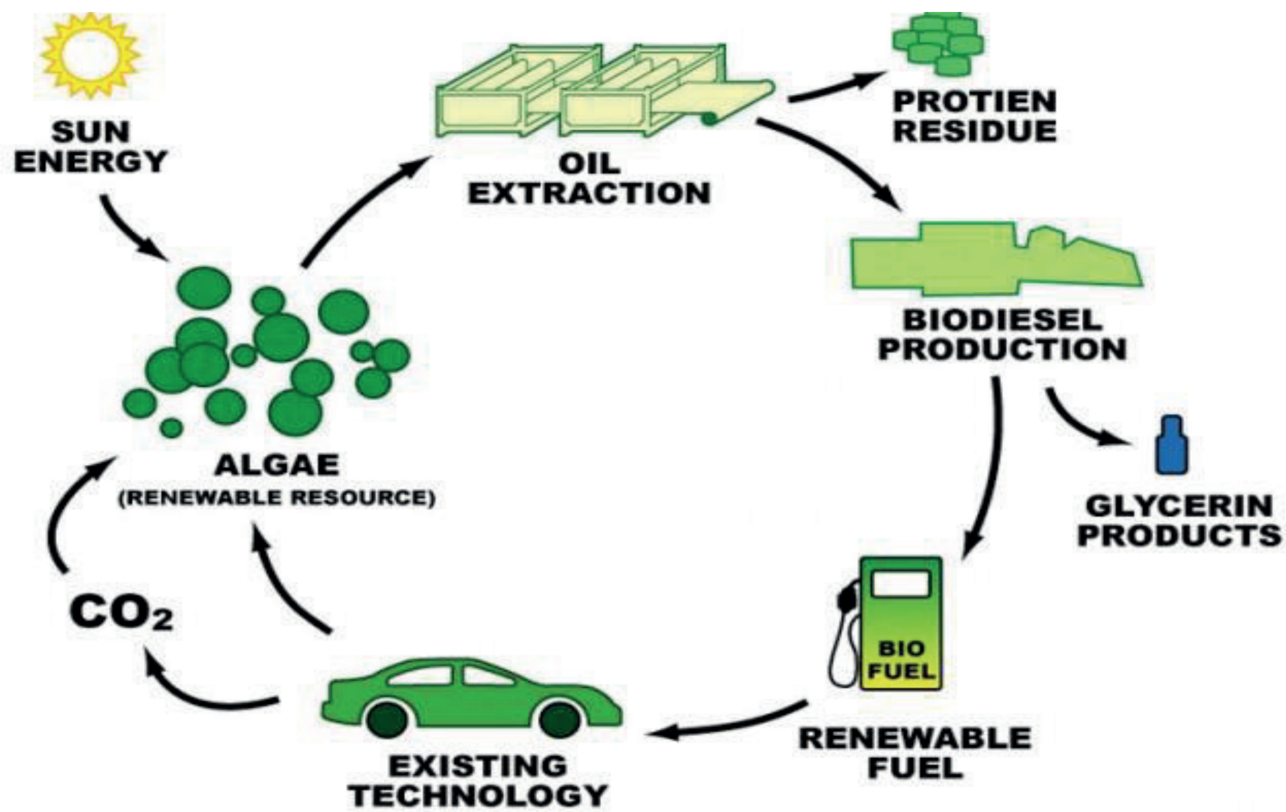


Figure 11: Green biodiesel energy model

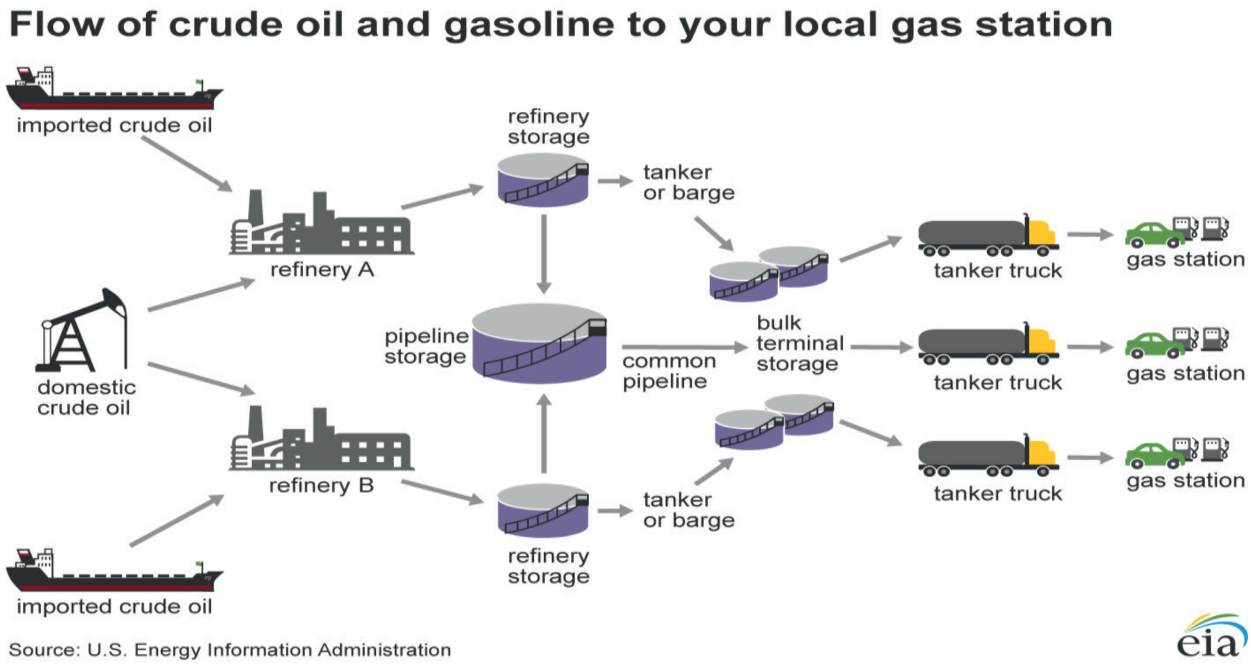


Figure 12: Crude oil fuel flow and supply model in the USA.

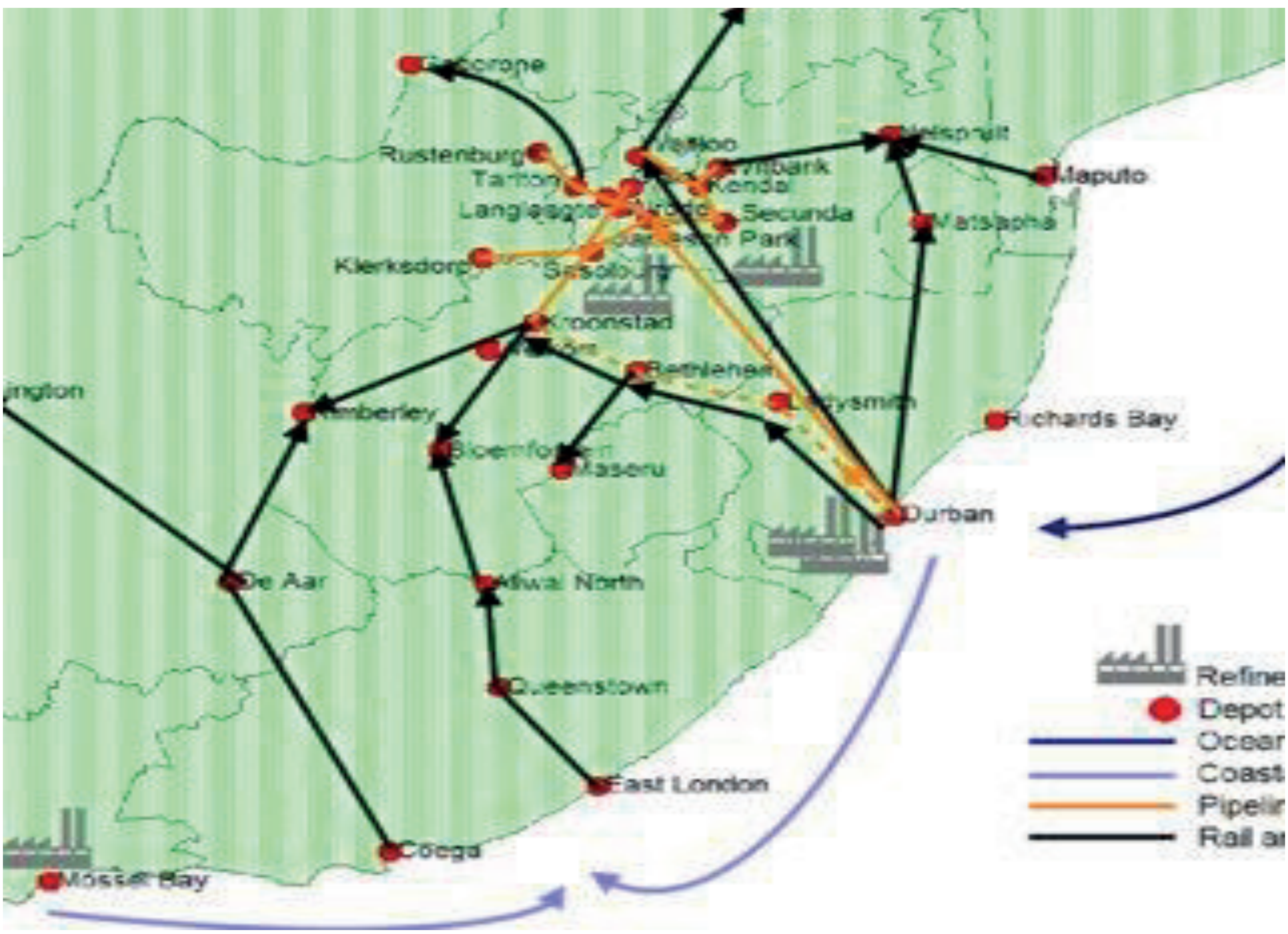


Figure 13: Crude oil refined fuel distribution in South Africa (Paelo, Robb and Vilakazi, 2019)

The optimisation process and energy model shows a stack of 164.21MW gives the best electrolyser dimension of the stack, estimated by taking into account the investments risk, operational expenditure, and capital expenditure, making the production and transportation of ammonia from Chile to Japan techno economically feasible and profitable, which also is R1,362,461,577,61 (1.4 Billion Rand) with a payback value of 7.62 years for Republic of Chile (Fúnez Guerra et al., 2020), and would be significantly lower for the Republic of South Africa, which has tremendous grey, blue, and green hydrogen and ammonia potential because of the significant potential of platinum, shale gas, SASOL oil giant infrastructure, ArcelorMittal steel giant, large deposit of coal in Mpumalanga, and precious group of transition (metals) catalyst, naturally found in South Africa, and demonstrated by the Federal Republic of Germany and Republic of South Africa partnership on green energy and renewable energy revolution.

In a nutshell, even though diesel has a well-developed infrastructure and network, careful modelling and implementation of ammonia green energy are feasible in South Africa, with a significant payback period of at least eight years. Thus, hydrogen energy production and supply are feasible in South Africa, even wind energy (Ayodele & Munda, 2019).

5. CONCLUSION

Considering the logical pathway and ideal fuel characteristics mentioned in this erudite research paper, which includes:

a. Energy production from coal, wind, solar, biodiesel, and e-diesel (green ammonia is preferred over diesel because it has a low carbon footprint and zero emissions)
b. Cost-effectiveness and NPV (Net Present Value) of green ammonia versus diesel (green ammonia has high NPV over diesel, but maybe at par with e-diesel if produced from solar energy as shown above)
c. Transportation and storage facilities already present (currently, diesel has more transport and storage network than green ammonia, but this is likely to change by 2050 in favour of green ammonia)
d. Carbon footprint, GHGs emissions, radiation emissions, etc. (green ammonia and green e- diesel are at par, but diesel from fossil fuel is far below green ammonia)
e. The practical application and compatibility of green ammonia in diesel-powered engines. (Green ammonia can be readily made to work with standard diesel engines, with fewer issues associated with diesel fuel)
f. Safety and health history of green ammonia versus diesel. (Green anhydrous ammonia is very toxic and should be handled more carefully than diesel. Diesel is slippery and can cause skidding of vehicles, but it is safer than its rival in terms of toxicity but lags in terms of flammability). They are both at par.
g. Local production capacity of green ammonia compared to diesel production in South Africa (green ammonia and green hydrogen is the winner)
h. Sustainability of green ammonia versus diesel fuel. (Green ammonia,

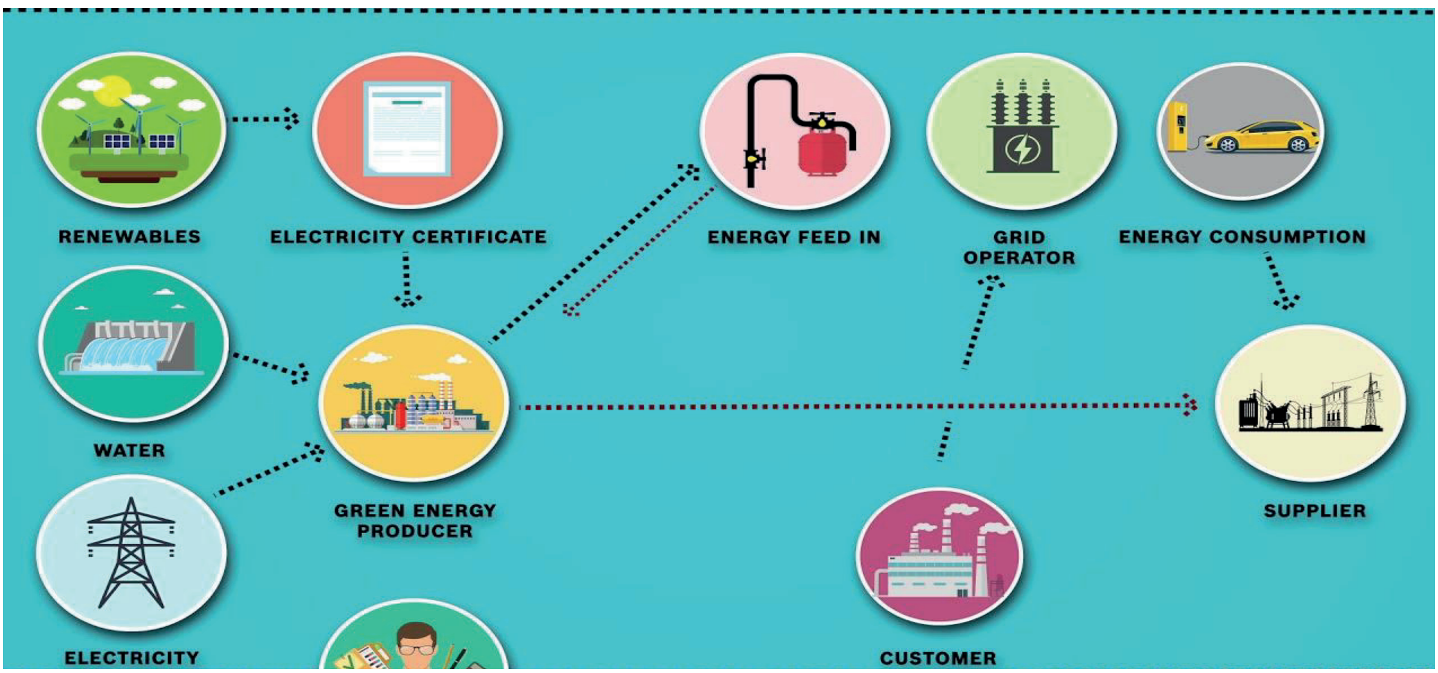


Figure 14: Distributed Energy Resources (DERs) Blockchain.

hydrogen, and e- diesel are more sustainable than diesel).

After careful analysis and consultations, the ideal fuel candidate of the future is green ammonia, also called the other green hydrogen, with additional benefits of low cost and high NPV, short payback period, overcoming the barriers encountered in the storage and transport of green hydrogen. In terms of flexibility of the ideal fuel, green ammonia in the United States, for example, has a network of production and distribution in place used for refrigerant supplies, fertiliser supplies etc., that can be used for green ammonia energy supply.

The e-diesel liquid energy vector combined with the electron/proton sub-atomic particle vector, known as the dual-energy vector, is recommended for the best energy production, transportation, accessibility, and sustainability. Thus, it can be more readily implemented than hydrogen in the United States of America. Regarding availability, the USA has about 20 billion kg of ammonia, which can be converted and utilised for various uses.

In terms of the geographical features, green ammonia is environmentally friendly, produces net zero GHGs, and supports the agriculturally based industries that make the environment aesthetically green and beautiful. It also humidifies and purifies the air and the soil, reduces carbon footprint, and eradicates forestation and soil erosion.
Sustainability, green ammonia can be synthesised from solar energy, wind energy, or any other existing and new method. Some of this development is in infancy and will mature over the years. There is a promise of reduced production and running costs with optimum Net Present Value (NPV) and Return on Investment (ROI).

From the German perspective, diesel is not preferred over green ammonia. Even there are taxes and other discouragements from the government towards the used diesel in Germany. However, there is also research and significant development in producing synthetic blue diesel called e- diesel. This is environmental diesel fuel with no net GHGs, carbon footprint, or other environmental pollution. This is comparable to green ammonia but a bit lower than green ammonia. However, green ammonia and the high energy density e-diesel fuel are growing and receiving attention from the Germans.

The government has incentivised and prioritised decarbonisation of the environment, prevention of pollutant emission, toxins (Mercury), and GHGs into the atmosphere and biosphere. Modern and efficient energy equipment should comply with energy standards and policies by energy users or consumers and through constant research in energy. Green Hydrogen (GH), green ammonia, and e-diesel from Audi is fully embraced in Germany as a way of energy storage from variable energy input from various renewable energy sources like wind and solar energy.

This GH and green ammonia electrolysis technology provides fluidity and reliability to the distributed generation in German Smart Grid (SG) and Smart Energy systems. The GH, green ammonia, and e-diesel primary energy sources can function as a battery, direct heater, direct boiler, and for other residential, commercial, and industrial purposes. From the results retrieved from this research paper, the cost of GH, green ammonia production, and e-diesel will reduce in the time provided efficient energy equipment is used and a modern and reliable energy transmission system is in place, like efficient pipelines and smart grid. wn

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South Africa's energy mix

Looking at the current power crisis in South Africa, there can be no doubt that alternative solutions to coal and diesel generation need to be found. Renewable and green energy is the ultimate end goal, but this is many years away.

By Viren Sookun, MD of Oxyon

In the interim, Liquified Natural Gas (LNG) and other gas options like helium and hydrogen can ease the transition. As we move away from fossil fuel power generation and toward a greener future, gas will remain an integral part of the energy mix. This is an enabler for creating sustainable employment opportunities in South Africa.

Gas is an integral part of our energy mix LNG is used in domestic settings to fuel appliances, specifically stoves and heating solutions. However, it is set to become a more significant part of the energy mix for the future of South Africa, and much investment is going into developing this.

Transnet is poised to send a Request for Quotation to develop an LNG terminal at their Richards Bay port. Total Energies is planning on drilling off the southwest coast, and globally there is a contract to drill off the northwest coast of Nigeria. More drilling licenses are being awarded in the Middle East.

The number of developments in the pipeline, specifically a dedicated port for LNG, shows that South Africa is indeed gearing up to incorporate this fuel source in a more significant way. While domestic use will undoubtedly remain a substantial proportion of its use, there are many applications for LNG as an alternative fuel source and a long-term transition fuel as we move increasingly toward renewable energy.

A FOUNTAIN OF OPPORTUNITY

There are numerous developments around gas in South Africa. In addition to the increased use of LNG, other gases also have energy applications. The recent discovery of helium in Virginia in the Free State has multiple uses, and carbon capture and green hydrogen production are also options that are being explored.

This is an opportunity and an enabler for employment, from fixed-term contracts around the construction phase of infrastructure, pipelines, ports and terminals to long-term maintenance and operations.

For those working in the development of gas in South Africa, finding the right

people to fill all these positions from the outset is critical to ensure projects run smoothly and prevent costly delays. From project managers and supervisors to general labour to high artisans, the quality of construction and development needs to meet the highest standards while complying with all relevant health and safety regulations.

A 360-DEGREE PARTNER IS KEY

Recruitment and employee management are seldom core competencies for organisations that specialise in constructing and developing gas pipelines, which is why the right partner is crucial. Recruitment is about more than just placing bodies in jobs, especially when lives could be at stake. In addition, while we may not have a skills gap as such, the reality is that, while the skill sets are available, many people in South Africa with these skills are currently working offshore where the opportunities are.

Finding the right skills and bringing them home will be essential to success. A structured, diversified employment solutions partner with the relevant skills, experience in the industry and access to a broad database of potential employees can be an invaluable asset. wn

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23/06/2022	SAIEE Mpumalanga Centre I Presidential Address and Panel Discussion
28/06/2022	KZN Centre webinar: Greenhouse gas-free High Voltage Products for Sustainable Power Grids
29/06/2022	Legal Liability: Occupational Health and Safety Act (OHS Act)

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05/07/2022	Photovoltaic Solar Systems
05/07/2022	Design Thinking and Innovation for Engineering Professional
07/07/2022	Anatomy of Wind Turbines
11/07/2022	Fundamentals of Power Distribution
12/07/2022	KZN Centre: Engineering and Patent Law
12/07/2022	Select, Maintain & operate your Rotating Electrical Machines like a Pro
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