Shaping Tomorrow's Energy Landscape:

Balancing Sovereignty, Affordability and Climate Responsibility

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06 THE CLIMATE BOTTOMLINE

CAN WE SAVE THE PLANET?

MIKE LEWIS
Global Vice President Energy Transition

We focus on climate in the chapter : What needs to be done to save the planet?

Earlier this year, the Intergovernmental Panel on Climate Change (IPCC) reported that there is insufficient pace and scale on climate action to tackle climate change. Unfortunately, this was no surprise to me, and I wanted to take this chapter to shine a spotlight on what needs to be done.

Energy continues to be the major emitter of greenhouse gases (GHGs). Here we look at how we can take steps to reduce these harmful emissions from energy production, as well as the three main pillars that consume energy: industry, transport and buildings.

How much will it cost to clean up our ever-growing demand for energy? Where would that funding come from? What will it take to develop the required clean energy capacity? And, as we transition to cleaner energy, how can we be certain that we are making significant progress in reducing carbon?

We also take a look at innovation for our most energy-demanding needs: heat production and industrial use of energy.

This chapter includes:

1. Funding the energy transition
2. Ensuring new energy is truly low carbon
3. Can we produce enough low-carbon energy globally?
4. How can heavy industry make the transition to low carbon energy?
5. Managing intermittency of low-carbon energy
6. Innovation for efficient ways to create heat
7. What needs to be done to create sustainable buildings?
8. How can we make better, "joined-up" decisions to progress climate action?

As stated by IPCC, we need to increase the pace and scale of our actions. There is hope and a business case.

We are now at a time for action.

06

HOW CLIMATE CHANGE WILL IT BE FUNDED? THE ECONOMIC CASE

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Because of recent significant global events, from COVID and Ukraine – Russia war to inflation and high interest rates, priorities, energy-wise, have been redefined and resulted in successive energy crises: it's urgent to accelerate on Energy Transition, while managing the Security of Supply, Sovereignty on energy production, equipment and resources and insuring energy affordability to avoid social and economy crashes. All these imperatives need to be successfully balanced considering the limited earth resources and their preservation.

Investments need to be massive, to save the planet. How to secure the funding required to deliver Energy Transition is covered within this article?

The Energy Transition investment case, ~$7tn per annum

Analysts, participants in the COP process, energy players, public authorities, economies stakeholders and populations around the world agree on the need to accelerate the transition. In particular:

- Phasing out as quickly as possible all fossil fuels. In 2022, the world continues to invest $1tn in fossil fuels (still growing, albeit net-zero by 2050 means reducing emissions 5% every year)[1].
- Electricity covers only 20.4%[2] of the growing energy demand. There is a consensus within the energy transition scenarios on the fact that electricity should represent 50% of the energy demand by 2050. Massive electrification of Transportation, Heating/Cooling and Industry is expected to abate significantly GHG emissions.
- Electricity must be almost carbon free, with nuclear generation (in the nuclear friendly countries) and renewables. End of 2022, the share of Renewables in Electricity Generation is only 29.4%, when wind and solar energies accounts only for 12.2%[3] (% highly variable from one country to another). Hydro remaining the first renewable source.
- Other investments are being required, like Grids modernization to meet a higher share of intermittent renewable in the electricity mix as well as transport and distribute more electricity. IEA reports a global climate technologies investment of $1.7tn in 2022, including Renewables, Grids, but also CCS, Biofuels, nuclear, EV, Energy Efficiency and other scalable clean energy fuels and resources. IEA speaks of clean energy.

1 Source: World Energy Investment 2023 report, IEA

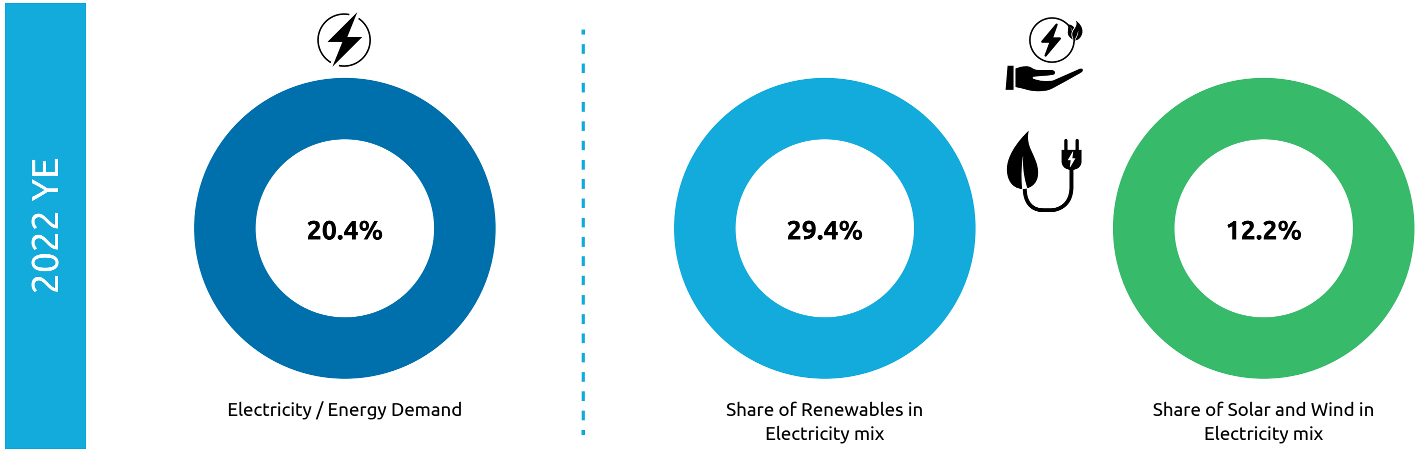
2 End of 2022 figure. Source: Enerdata 2023 yearbook
3 Source: Enerdata 2023 yearbook

- Accelerate investment into massive reduction of GHG emissions – through more intelligent energy use such as energy reduction, energy conservation, demand smoothing, material reuse and carbon absorption and extraction technologies.
- In 2022, with a GDP growth of 2.8%, CO_2 emissions have continued to grow (+2.5%) despite deployment progress in climate technologies and energy intensity per GDP units.

In the IEA NZS (Net Zero Scenario), the clean energy investment must triple (from now on and for the next decades up to 2050), from \$1.7tn to about \$5tn pa, and with additional costs on climate change adaptation, circular economy, or behavioral changes programs, we land on a consensus around **\$7tn required investment per annum,** about 7% of the world GDP. Huge, and far from actual levels. Is this huge funding gap, from \$1.7tn today to ~\$7tn pa the soonest realistic?

FIGURE 1

Some energy figures as of YE 2022



Eyes on the past and the present – what have we observed?

Recent government policies to secure supply of energy with sovereignty, while addressing climate concerns through clean technology has resulted in a complex range of funding incentives. Many of the incentives address very specific climate concerns from decarbonizing transport, making building more energy efficient, to decarbonising industrial processes. In many regions this has created a fragmented and complex portfolio – often resulting in increased pressure on electrification through banning carbon intensive fuels for these essential services (vehicle charging, heat pumps, industrial processes, etc.).

Many incentives have been relatively short lived and often complex to access the funds, while others are longer term and disrupted by changing political environments – not delivering the real cash as planned or intended to deliver a positive impact (i). This complex tapestry of incentives has made long term, strategic investment surprisingly risky for investors.

Some climate techs have matured and are now very competitive power generation options (Solar and Onshore Wind), enabling the cheapest way of generating electricity today. These technologies are now producing the Lowest Levelized Cost of Electricity (LCOE), with dramatic cost reduction from global competition and large demand of full-scale deployment.

Early subsidies to encourage creating this scale are now coming to an end, with tax incentives moving to power producers investing in renewables to deliver clean energy in the largest global markets (specifically China, USA, EU, Japan, Australia, UK, and Norway).

However, they also bring new challenges, requiring further funding – e,g, securing construction locations with approvals, connectivity to national infrastructure, managing intermittency, accurate forecasting of supply, storage of surplus supply.

More recently holistic funding incentives such as the Inflation Reduction Act in the USA, and the Green Deal Industrial plan in the EU, coupled with continued subsidies and tax incentives in Japan and China – has resulted in clearer investment opportunities. As a result, global spending in clean energy will increase by 24% between 2021 and 2023 to $1.7tn. Where new electricity generation capacity is concerned, an estimated 90% of spend from this category will be on Solar and Wind investments.

However, given the fact that spending in energy from fossil fuel continues to increase, surpassing pre pandemic levels, there is a clear need to find additional technologies which can scale to replace hard to abate industries, solve the challenges of intermittent generation from wind and solar and accelerate the path to Net Zero. Science also suggest that the time has passed where conversion to clean energy is no longer enough, and now there is additional need to support funding to scale innovation in technology that can remove GHG at source and from industrial processes.

Those incentives on "to be matured and scale-up fast enough technologies" are less clear, and not encouraging investment. Overall spending on clean technology is less than 5% of the traditional Oil and Gas upstream spend. Oil and Gas companies are well equipped to deliver new combustible gas solutions – and Low Carbon Hydrogen is seen to be a very promising fuel for hard to abate industries such as manufacturing aluminum, steel, cement & fertilizer. In 2022 this category of low carbon energy attracted only $1.1bn of investment. This is a 3X growth from 2021, however a long way to go to challenge traditional oil and gas investments.

Many global regions remain focused on Nuclear as the central source for low carbon, predictable electricity. With further investments in Small Modular Reactors – new nuclear options have been under review in recent years. Asia, Canada, USA, France, Sweden and UK have active studies into the safety and economic benefits of SMR's – and Russia having the first operational SMR in Yakutia.

Transformation, modernization and extension of the IEA suggest electricity grids in the USA, China, Japan the EU and India are attracting huge funding. This level of funding will not extend to countries who are less wealthy, and solutions to bridging these funding gaps have yet to be found. Concerns also on how the world can level up less wealthy countries, so they can also meet the global commitments to climate action – and fundamentally prosper from Energy Transition rather than be penalized by it.

Looking at decisions made from COP – in 2009 US$100bn per year was committed by developed countries for developing countries need to fight climate change. In a United Nations Climate Action report published this year, derived from 2020 data provided by OECD suggested only $83.3bn has been provided in total, with only 8% of that total going to low-income countries.

Creating clean power generation capacity takes time, even when the required funding is available. To bridge the time delay, investment has been flowing into innovations to enable smarter energy use. Essentially innovation to reduce energy need for existing services (energy efficiency), reduce energy and resources on new products (reuse, repurpose and recycle) and conserve energy through smart design e.g. (passive buildings).

Many of these innovations are "behind the meter" and installed for commercial consumers and homeowners by energy services organisation, and a growing trend of consumer installable devices (Google Home, Amazon Alexa, Apple Homekit,) enabling automation to reduce energy and move appliance use to time when energy is more abundant and potentially lower cost. Interoperability of behind the meter consumer appliances, and electric vehicles has helped grow the smart home space (according to Predence Research Smart Home market, excluding EV grew to US$98bn in 2023, expecting a CAGR of 21.88% to US$581bn in 10 years). This growth provides choice and more affordable solutions. However, harnessing this technology to deliver more intelligent energy systems in communities, regions &, cities, appears to be a difficult challenge to master.

In addition to innovation in energy saving devices, thermal enhancing solutions are constantly evolving and increasing opportunity to reduce the need for energy. However, these innovations can prove to be very difficult to retrofit into buildings and industrial processes. Efficiencies from high performing Insulation, heating appliances, windows and doors which significantly improved thermal properties of buildings can be very attractive for new construction – but costly, too long to payback, and disruptive for older property stock.

In recent times the fragmented incentives, energy crisis and increasing awareness of global climate events has secured investment in innovation and created new markets with economic benefits of new jobs creating and addition routes for taxes – delivering the beginning of broad clean energy market. Evidence does indicate where very large investments are needed, to deliver these significant benefits accessible and sizable incentives need to be offered and supported by major central government's policy (e.g. IRA, The Australian Government's Powering Australia plan, EU Green Deal Industrial Plan, etc.)

In recent times the impact of changing climate, disasters resulting from extreme weather is competing for funding. Data produced by NPR highlights that the USA registered 18 separate climate change disasters costing more than $1bn each, and a total of cost of $165bn in 2022 because of extreme weather, fueled by climate change.

At a global level - the World Meteorological Organisation produced a report in iiMay 2023 highlighted that the "most vulnerable communities bear the brunt of weather, climate and water-related hazards".

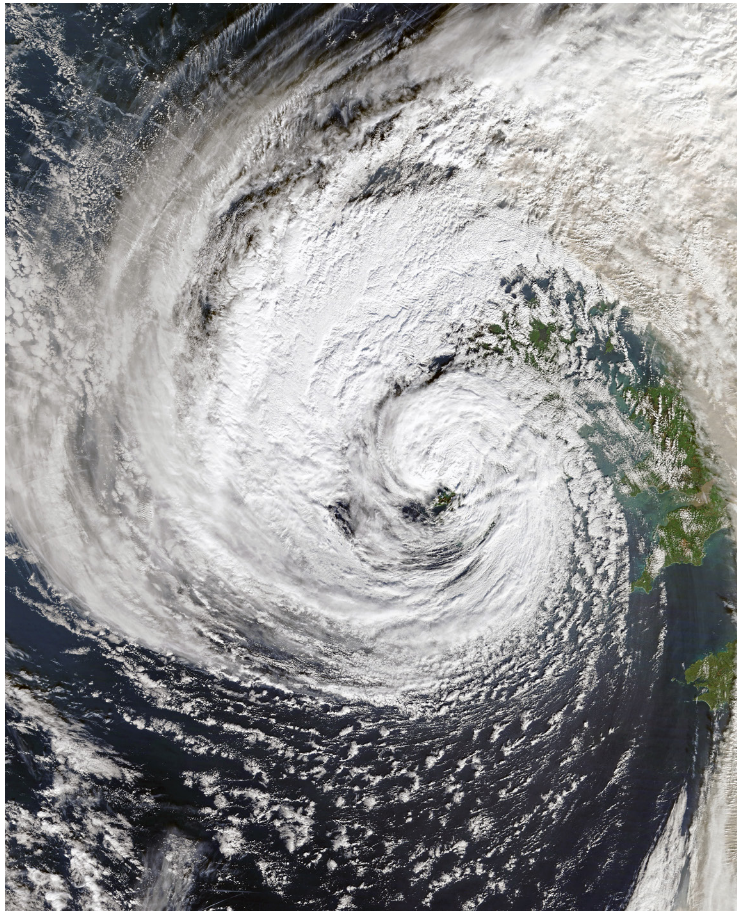
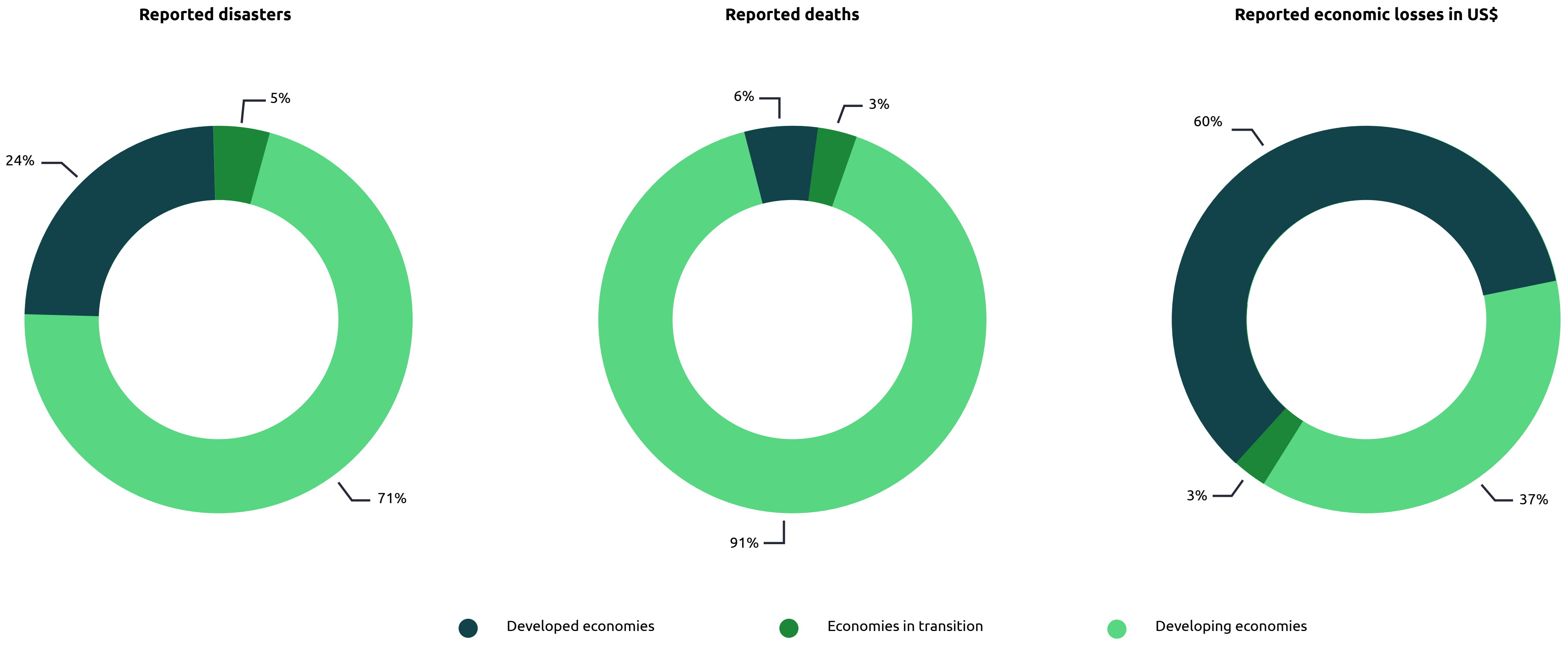


FIGURE 2

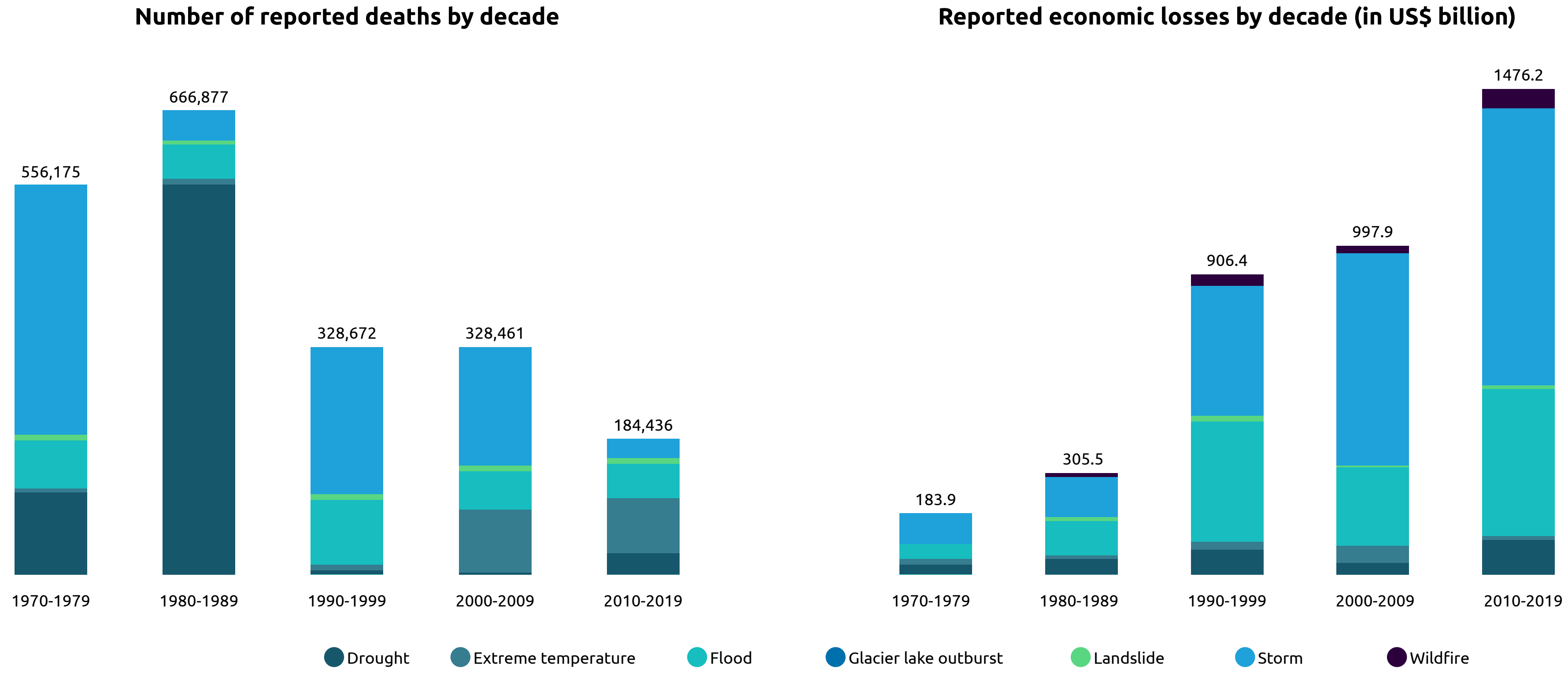
Most vulnerable communities bear the brunt of weather, climate and water-related hazards



The report highlighted decreasing mortality rates due to improvements in early warning systems and disaster management. However, increasing economic losses due to climate events:

FIGURE 3

Decreasing mortality rates and increasing economic losses due to climate events by decade



Big investments are needed

Clean utility scale technologies - renewables farms, nuclear plants, hydrogen production and transportation assets, batteries gigafactories, electric networks are large assets, taking 5 to 10 years to build (even more for 3rd generation nuclear plants, 15 years), and planned to operate from 25 and up to 100 years. With the required In the TCO of these assets, CAPEX accounts for 60% to 90%. It's big money and challenging in times of relatively high interest rates (because of the TCO CAPEX share), impacting long term profitability.

On top of this big money, others need funds to be developed and scaled-up, specifically CCUS and more efficient, new storage technologies, nuclear fusion.

~$7tn per year investment for the next 30 years at least, requires regulation with stability and predictability. This investment timescale is not compatible with political and national strategic decision-making timescales which are about 5 years, the impact of Energy Transition and global warming will concern many generations.

Clear economic signals are needed to secure these big investments, made generally by private investors, and publicly owned utilities.

Key points and challenges to stimulate the appropriate investment.

There is so much more to be done, to make massive funds available to pay for the assets and infrastructure required to clean up our global energy needs, and the increasing (huge) costs of climate events incurred from our slow progress to address climate change.

Should we prioritize the investments? Of course, every $ invested on Energy Transition must lead to results – GHG (Green House Gases) reduction. In the years 2000, the marginal abatement cost emerged as a measurement and decision-making tool. It is simply the cost of an intervention that will reduce GHG emissions by one ton[4]. But hard to abate emissions must also be considered to reduce emissions to almost zero in 2050.

So the question of prioritization is complex:

- Each measure cannot be considered individually since they interact with one another
- The question of velocity matters. But we can't wait that all electricity is decarbonized to start deploying electric vehicles. Industry and users need time to adapt
- Technology availability and associated cost that depend also on the demand…

Focusing on long term objectives, thus being more complex, integrates interactions between sectors and technological changes, with an objective to minimize the cost of the transition, rather than concentrating on the marginal cost.

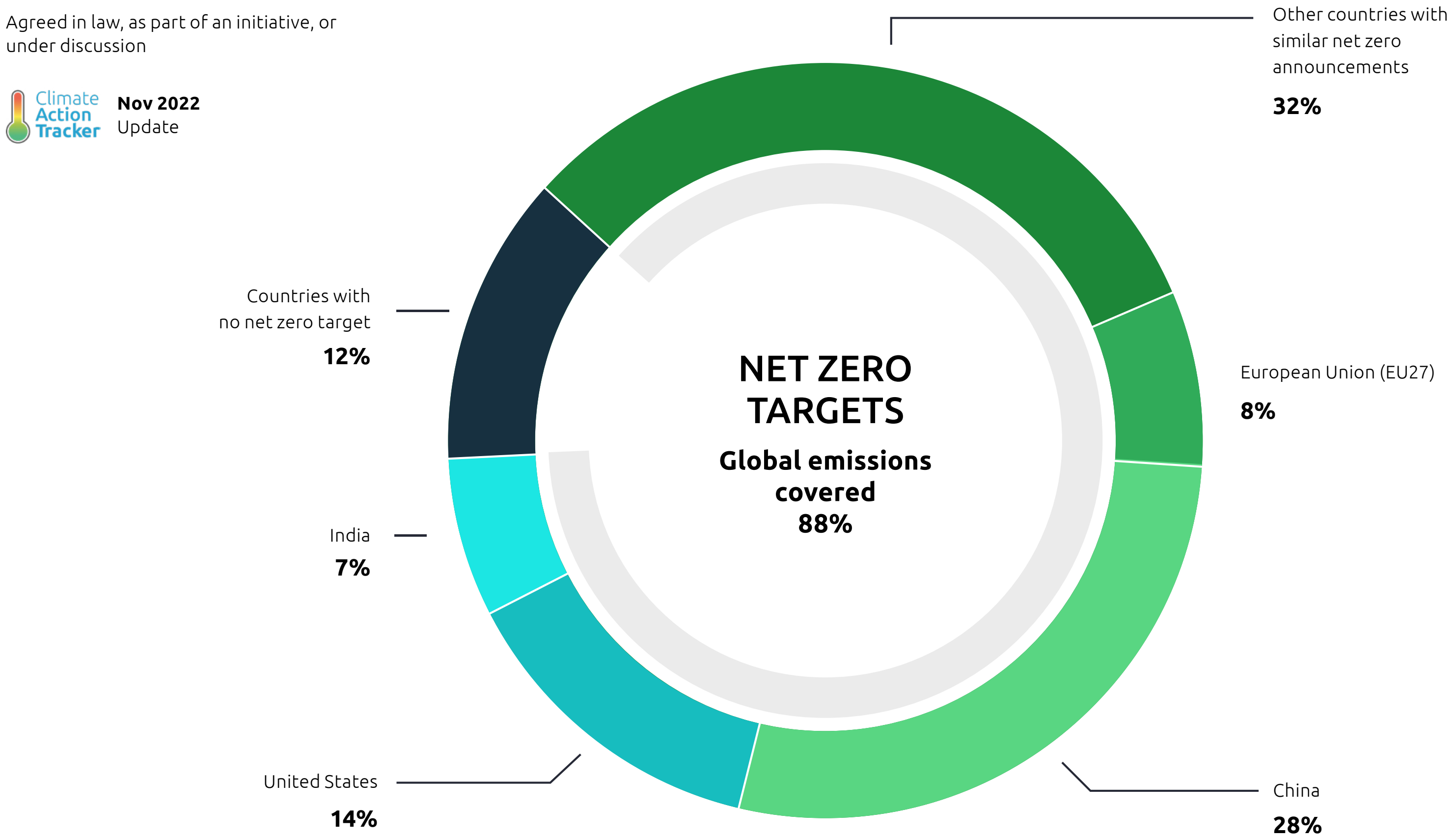
Certainty around real-world action for global investors is required, to enable them to come forward and co-fund massive projects with clarity of returns. This needs simplification of operating environments (regulation, access to low-cost funds, available supply chains, developed skills, etc.) through clear long-term policies for achieving Net Zero commitments. Not just from developed countries – but how to fund this transformation in developing countries.

Data tracked by the Climate Action Tracker consortium (climateactiontracker.org), suggests that 88% of the world have announced Net Zero emission targets, with detailed assessment of the policies to achieve each announcement.

4 Carbon emissions on the full life cycle that have to be considered.

FIGURE 4

Net zero emissions target announcements



Note: Share of GHG emissions covered by countries that have adopted or annouced net zero emissions target (agreed in law, as part of an initiative, or under discussion). Compilation based on Net Zero Tracker (2022) and WRI (2022) as of 8 September 2022 complemented by CAT analysis. The compilation includes countries that have joined the Climate Ambition Alliance announced at COP25. Emissions data excluding LULUCF for 2019 taken from PRIMAP emissions database (Gutschow et al, 2021)

Clarity over the business case, and commitment to the business case – why it makes sense for taxpayers, to move funds into this category of spending, needs to be accelerated. Climate taxes must be allocated to Climate actions. In WEMO 22, we demonstrated that less than half of carbon taxes were used for funding climate actions, the rest had diluted into general budgets. Value comes certainty from economic impacts, new job creation, carbon taxation, and GDP growth from scaling innovating clean technologies.

Increased taxation on profits from carbon intensive energy such as the UK Energy Profits Levy, and similar incremental taxes in other markets are additional vehicles to raise public funding. This level of taxation may help accelerate large oil and gas companies invest faster into low carbon fuels.

Funds raised from carbon markets have reached almost US$100bn according to reports published by the World Bank. Increasing additional taxation on carbon is a clear option to drive further acceleration to low carbon economies. For example – point of sale carbon taxes of carbon intensive products, would make them more expensive to buy, and therefore less competitive than low carbon alternatives. Levies and taxes to end use drives consumer demand and behaviour as seen in other end use taxation (tobacco, alcohol & sugar).

Establishing trust with taxpayers is also key – ensuring the funds raised through increased taxes are going directly to solving global climate problems must be demonstrable and transparent, as does the trust in the authenticity of carbon intensity in products. Efficient, scalable, independent testing and certification of carbon intensity would be required, along with transparent reporting of funds raised, and how they are dispersed.

Finally, the availability of funds and overall cost of money in recent times has caused some reluctance in the market to invest. Rising costs of borrowing, coupled with long permitting and approvals processes (often 4 years plus for renewables projects), has resulted in some market failures to secure bids. In September 2023 the UK Department for Energy Security and Net Zero suffered an absence of any bids for additional offshore wind generation capacity. The rising cost and complexity of supply chain, coupled with low offer price per MWh (£44) produced were among the reasons for bids not being tabled. These failed bids cause delays in progress to deploy renewable energy capacity, and lessons need to be learned about the changing market conditions, and what is required to attract a competitive – and achievable clean energy system.

Economic rationale

Obvious question, debated many times, without clear answer as of today: in terms of economics, what will be the result of the Energy Transition unavoidable massive investment? Comparing here required investment and economic impacts.

Investment and impacts tables below result from a high level approach by categories – quite impressionist, but relevant picture and definitely not a business modeling exercise.

Investments / Costs	Figures and comments
$7tn pa on climate tech development and deployment (for 30 years)	**~$7tn pa** (rationale: tripling climate tech efforts + adaptation measures + behavioral change programs + circular economy…)[5]
Adaptation measures such as… Floods, infrastructures relocation, wildfire and more generally weather events consequences protection. Covers crop changes to adapt to drought too…	**~$1tn**[6] (Derivated from a governmental evaluation in France, world representing roughly 20 times French economy) – included in the $7tn
Circular economy development	No real figures published on that dimension. Innovation and development required.

5 International Energy Agency, World Energy Investment 2023 report
6 I4CE on behalf French authorities

Contribution to the economy / payback	Figures and comments
Economy stimulation from clean energy development	**~$5.6tn** pa- Keynesian multiplicator effect ~0.8 out of climate tech development (~$7tn)
Jobs creation	**~50M new jobs for a decade (~5M/year)** reference: Up to 10M by 2030 (Fit for 55) at European level, considering Europe weights 20% of worldwide economy
Capping weather events impacts	**5% to 10% GDP** in the long term (IPCC statement)
Circular economy benefits • Economy global value creation	**$7.7tn** pa by 2030[7]. Potential economy gains from the WBCSD. Consistent with European assumptions[8], stating $1.8tn pa savings from circular economy, with $0.6tn only for primary resources.
• Jobs creation value	**$0.5tn pa**[9] (International Labour Organization assumption 2023 - $4.5tn / 2023 to 2030)
Energy costs contained	Not evaluated but significant
Insurance costs contingency	Not evaluated but significant

7 World Business Council for Sustainable Development – 2023, previous estimates by the WEF in 2020 were standing at $4.5tn

8 https://archive.ellenmacarthurfoundation.org/assets/downloads/Note-de-Synthese_FR_Growth-Within.pdf

No choice for the planet but investing on Energy Transition. Obviously, as demonstrated above, **the impact of this huge investment will be positive** (direct impact on economy and avoided costs). No brainer and no regret (on the economical dimension). The question being, how to secure the appropriate funding?

9 International Labour Organization statement - 2023

Conclusion

Getting the appropriate level of investment from all stakeholders is a complex equation, considering the variety of financial participants, and the level of required investment. We are dealing here with about 7% of the world GDP. It's massive. So, no final answer, but 6 key points out of the development made in this article.

- Politicians (governments) must commit their countries to mid- and long-term targets, related development objects (renewables and nuclear capacity, low carbon hydrogen, grids, carbon collection, energy efficiency…). It means public funding with money of course, but also clear and easy to manage financing mechanisms and vehicles. In a consistent overall framework with energy market design. Again, stability, predictability and easy to mobilize funding vehicles are absolute must haves.
- Public funding (countries and regions budgets) must make sacred the Energy Transition public investment. In the long term. Which is and will remain a significant challenge.
- Companies have to show the way since it becomes more and more obvious that the competition winners will be the most sustainable companies: profit, growth, image, attractiveness which applies to all business, employees, and financial markets (shareholders and banks).
- Financial institutions and markets, will naturally invest in projects and companies paving the way to a sustainable world, demonstrating balance sheet expected improvement. But without clear and immediate rules avoiding financing any fossil fuel or GHG emitting object (project or operations), no chance to get enough from the finance sector to fund the effort.
- Helping and motivating (with incentives) individuals to act upon Energy Transition, change their behaviors and consider their priorities.
- Financing enough developing countries on Energy Transition, the duty of wealthy countries. Climate change is a global thing. Being exemplary when your neighbor is not, is useless.

OPERATIONALIZING CARBON INTENSITY TRACKING

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Carbon intensity, the metric that captures the greenhouse gas emissions released per unit of economic output, is a crucial indicator in the fight against global warming. Monitoring energy consumption and emissions throughout a product's value chain enables the calculation of a quantitative environmental impact score. Moreover, the growing accessibility of high-frequency data now facilitates the assessment of carbon intensity down to the level of individual products at specific sites. In this article, we will explore the operationalization of carbon intensity tracking and the challenges associated with implementing comprehensive analyses that accurately capture this metric.

The importance of carbon intensity: the power grid as an example

Carbon intensity is the measure of the environmental impact of any process in terms of direct carbon and carbon equivalent emissions, as well as associated upstream and downstream emissions. It can also be referred to as emissions intensity, probably a better descriptor, but will be referred to herein as carbon intensity ("CI").

CI is determined through life cycle analysis (LCA), a method which evaluates the environmental impacts of a product, process, or service over its entire life cycle. There are different approaches to LCA analysis, with expressions such as "cradle to grave" which is used to capture the full environmental impact for products, "well to wheels" for transportation fuels, or, in the context of hydrogen, "well to gate" to describe the system boundaries or scope of measurement.

For example, the CI of power generation, expressed in grams of CO_2e per kWh generated, is principally driven by fuel type, but will also be affected by individual plant efficiencies, operating levels and ambient conditions. In addition, how fuel is produced and transported to a point of generation, and emissions associated with its manufacturing and construction are reflected in the LCA as well. Hence, even renewable generation with no direct emissions will have some associated emissions reflected in the CI. Therefore while the CI values shown in Figure 1 reflect averages emissions, the actual CI at the point of power generation will vary significantly from the single point estimates shown.

The resulting CI of a power grid will vary depending on generation mix, as shown in Figure 2 which demonstrates the geographic variability of the power grid during a recent month. In France, for example, 61% of power was from nuclear and 25% was from wind, with a resulting CI score of 21. In contrast, Poland was 61% driven by coal and 11% by wind, with a resulting CI score of 778 for that month.

FIGURE 1

The Carbon Intensity of Electricity Generation (g CO_2e/kwh)

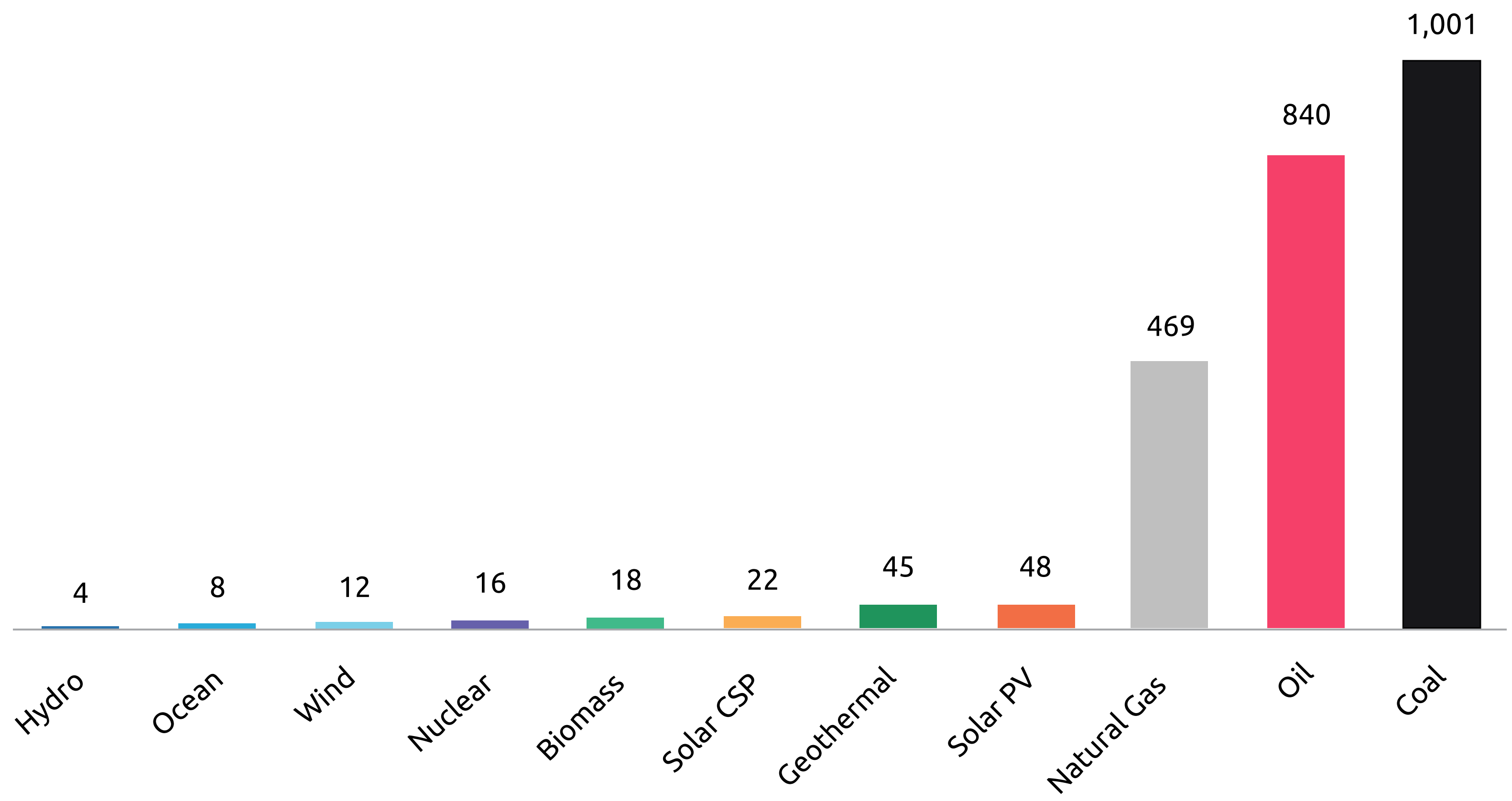
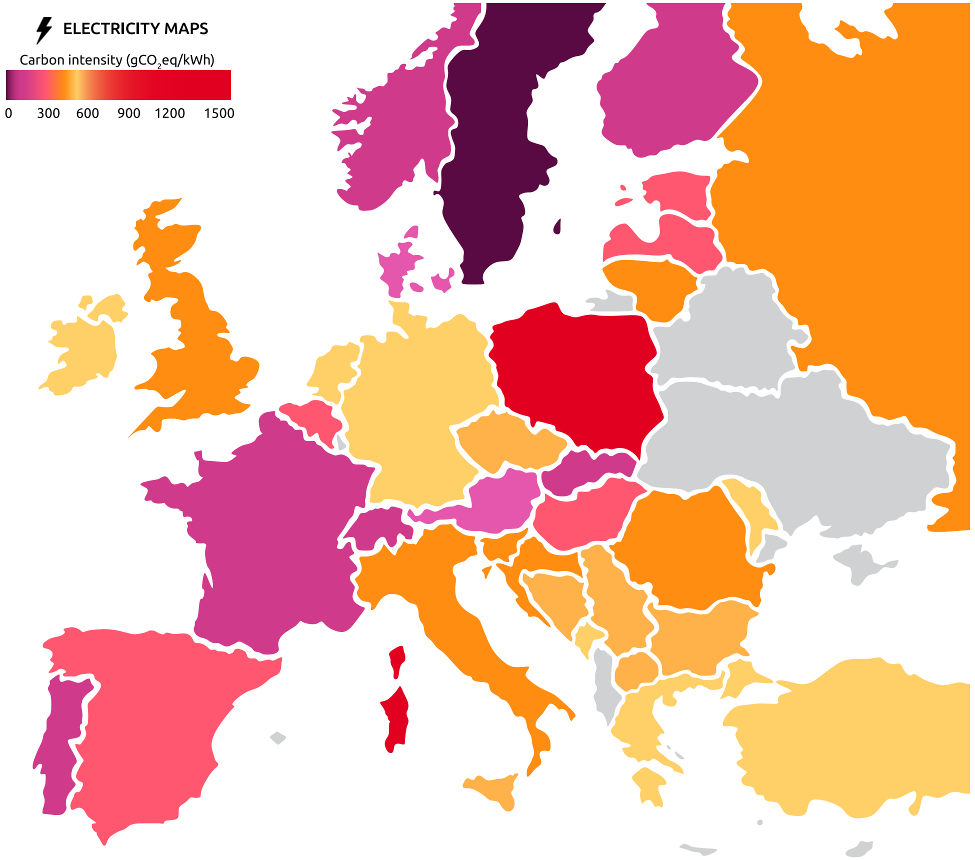


FIGURE 2

Carbon Intensity of the Power Grid in a Recent Month in the EU



Grid CI has a dramatic impact on the resulting carbon intensity of the products that require power. For example, if hydrogen was produced by electrolysis using grid power in any of the countries deep green in color, the corresponding CI of that hydrogen would be around 1.2-1.5 kg CO_2e per kg H2 produced. In contrast, if the grid in Poland was relied on for H2 production, the resulting CI would be 45, which would place it is as the dirtiest hydrogen in the world. By comparison, it would be more than twice as bad as hydrogen produced from coal without carbon capture and sequestration ("black" hydrogen) and four times worse than unabated natural gas ("grey" hydrogen).

As an increasingly wide variety of products are being evaluated by their environmental attributes--including their associated CI--the management of emissions will emerge as a critical issue for commercial reasons as well as environmental considerations.

Operationalizing carbon intensity tracking

Implementing the systems to monitor energy use and emissions allows cost-savings opportunities from energy efficiency as well as emissions reductions, and typically, the value of energy savings offset much more than the cost of the systems themselves. Further, the systems to collect and share this data are no longer optional; more companies are demanding data from their suppliers on the emissions across their value chains as they have their own environmental disclosures to manage.

Carbon intensity tracking influences decision-making at both strategic and operational levels. At a strategic level, it can help shape a company's overall approach to sustainability. By highlighting areas with higher carbon intensity, companies can identify where changes need to be made to reduce their overall emissions. At the operational level, it can help determine the most cost-effective economical solutions to carbon abatement, as well as differentiate products to be independently certified as low-carbon or net-zero.

A logical starting point would be to collect all available relevant site-specific data and assess the decarbonization options available using Capgemini's Low Carbon Navigator, a benchmarking tool that helps companies develop their decarbonization strategies. It covers 25 industries and has brought together decarbonization strategies from over 400 companies. It provides a peer comparison of carbon-abatement strategies, and provides a comprehensive assessment of the transition risks and opportunities, resulting in a tailored road-map for the best-cost decarbonization solutions.

Implementing the resulting strategy requires ensuring that a comprehensive corporate data collection and reporting functionality is in place. We have observed that much of the relevant data already resides at the plant-level in local process control systems (Scope 1) but may vary in what data is being collected, the frequency of collection, and how it is being maintained. The pain-point from a corporate perspective includes these inconsistencies, as well as off-site carbon associated with utilities (Scope 2) and other suppliers or, where relevant, customers (Scope 3). Ultimately there has to be a single place where all data resides to ensure consistent reporting and support independent certification.

We have identified four steps required for successful operationalization:

Data Collection

- Site-specific utility providers, across the valuechain

Data Analysis

- Life Cycle Assessment in conformity with various standards

Monitoring

- Plant-level and corporate-level systems

Certification

- Independent audit and certification

Data Collection

The first step in calculating carbon intensity is collecting the necessary data across all relevant steps of the value chain, using technologies such as infrared gas sensors, flue gas analyzers, and data from utility providers and upstream suppliers. In many cases, the bulk of the necessary data already resides in the process control systems at the production site; obtaining data from suppliers or customers may prove more challenging.

Data Analysis

Once the relevant data has been gathered, it is analyzed using various analytical tools and software. While historically many companies have relied on data collected manually and analyzed in Excel, this has been problematic for companies with multiple products and sites, as well as those operating across multiple jurisdictions with varying standards and regulations. Industry-leading organizations have moved beyond this approach to ensure data integrity and are currently using solutions from AspenTech, AVEVA, SEEQ, Microsoft Sustainability Manager, and SAP's Industry 4.0. These solutions can be tailored to provide a consistent approach to carbon intensity measurement relevant to a single product or allocation to a collection of co-products. The method of allocating carbon across co-products can be a matter of informed judgement and debate as there are multiple valid approaches, each with their advantages and disadvantages.

Monitoring

Once the process for calculating carbon intensity has been established, continuous monitoring and reporting can inform opportunities to adjust operations. Real-time carbon intensity monitoring can also enable a company to react more quickly to changes, thus enhancing their efficiency and reducing their carbon footprint.

Certification

While in the past carbon intensity has been disclosed voluntarily and taken on trust, it is increasingly being used as a measure for regulatory compliance or qualification for government incentives. For example, in May 2023, as part of the Federal Buy Clean Initiative, the US General Services Administration announced a pilot program for procurement of $2.15 billion of substantially lower embodied carbon construction materials for Federal projects. As part of this program, suppliers of construction materials including asphalt, cement, glass, and steel must disclose various product environmental attributes to qualify for purchase. Figure X shows an example of a possible form of an environmental product declaration for a particular grade of steel rebar. In addition to a carbon intensity score of 0.964, other attributes are reported as well and will be driven by similar site-specific data.

FIGURE 3

Example: Environmental product declaration for steel rebar

EVALUATION VARIABLE	UNIT PER METRIC TON	TOTAL
Primary energy non-renewable	MJ	13,200
Primary energy, renewable	MJ	868
Global warming potential	metric ton CO_2 eq.	0.964
Ozone depletion potential	metric ton CFC-11 eq.	6.53E-11
Acidification potential	metric ton SO_2 eq.	3.74E-03
Eutrophication potential	metric ton N eq.	1.94E-04
Photochemical oxidant formation potential	metric ton O_3 eq.	0.0444
Abiotic depletion potential, elements	metric ton Sb eq.	1.55E-07
Abiotic depletion potential, fossil	MJ	11,800

Source: Sustainable Facilities Tool, U.S. General Services Administration

Challenges in operationalizing carbon intensity tracking

Life cycle analysis is an evolving science, and the approach varies across industries. For products with complex, global supply chains, tracking every input can be especially challenging, as it can be hard to account for the environmental impacts of every component, especially when parts are sourced from different parts of the world with varying environmental standards.

We have identified seven challenges within life cycle analysis:

1. **Data availability:** One of the most significant challenges in conducting an LCA is obtaining the necessary data on materials, energy use, emissions, and waste at each life cycle stage. This data may be hard to find, particularly for complex products with supply chains spanning multiple countries. In some cases, data may be considered proprietary and therefore not publicly available.

2. **System boundary definition:** Defining the system boundaries for an LCA is a challenging task. The system boundary determines which processes and impacts are included in the analysis. However, deciding where to draw these boundaries can be complex and subjective. For example, should an LCA of a car include the impacts of building the factories where parts are made? Should it include the impact of disposing of the car at the end of its life?

3. **Assumptions and uncertainties:** LCA involves a range of assumptions, such as how a product is used or how long it lasts, which can significantly affect the results. Additionally, there are often uncertainties in the data used for LCAs, such as variation in energy use or emissions across different production sites. These assumptions and uncertainties can complicate the interpretation of LCA results.

4. **Allocation problems:** When dealing with multi-output processes it is challenging to allocate the environmental burdens across products. Various methods for allocation have been proposed, but there is no consensus on the best approach. For example, if the CO_2 from hydrogen production is sequestered the emissions associated with its disposal are transferred to the products from the process. This is simple when there is a single product, but what happens when the process also generates steam, power or other chemicals?

5. **Impact assessment:** There can be significant variability in the environmental impacts of a product, depending on how and where it's made and used. Additionally, the need to make assumptions and estimates can introduce uncertainty into the results. For example, methane is calculated to be approximately 80x more potent a greenhouse gas, at least in its first 20 years of release, but that value has varied over time, with significant results on reported carbon intensities.

6. **Time and resource intensity:** Performing an LCA can be time-consuming and resource-intensive, particularly for complex products with long and complicated supply chains. This can limit the feasibility of LCA, especially for smaller companies with limited resources.

7. **Lack of standardization:** While there are some general guidelines for conducting LCAs, there is a lack of standardization in the field. This can lead to inconsistencies in how LCAs are performed and how results are reported, making it difficult to compare results between different studies.

Continuous improvements in data availability, methodological approaches, and software tools are helping to overcome some of these obstacles. There is also an increasing call for harmonization of more standards globally in order to allow more direct comparison across products.

Multiple standards and methodologies create a complex landscape

As referenced above, there are multiple standards, guidelines, and methodologies available that guide how industries measure and report carbon intensity, including but not limited to:

Greenhouse Gas Protocol (GHGP):	Developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), the GHGP is a widely-used international standard for greenhouse gas accounting. It provides clear standards for calculating carbon intensity by defining direct and indirect emissions (Scope 1, 2, and 3 emissions) and providing guidance on emission calculation methodologies.
ISO 14064 Standards	These international standards developed by the International Organization for Standardization provide guidelines for the quantification and reporting of greenhouse gas emissions and removals at the organization level.
IPCC Guidelines	The Intergovernmental Panel on Climate Change (IPCC) has produced guidelines for national greenhouse gas inventories, which include methodologies for calculating emissions from various sectors, including energy, industrial processes, agriculture, and waste.
CDP (formerly Carbon Disclosure Project):	While not a standard in itself, the CDP sets out a comprehensive process that encourages companies to measure and disclose their environmental impact, including carbon intensity. The information CDP requests from companies is aligned with other standards like the GHGP and ISO 14064.
IEA (International Energy Agency) Guidelines	The IEA offers specific methodologies for tracking energy use and related CO_2 emissions in a range of industry sectors, from manufacturing to transport. These guidelines are used to help monitor progress in energy efficiency and carbon intensity.
Science Based Targets initiative (SBTi)	This initiative provides companies with a clearly defined pathway to reduce greenhouse gas emissions, in line with the Paris Agreement goals. Companies using SBTi are given access to methodologies and tools that can help measure and reduce their carbon intensity.
Task Force on Climate-related Financial Disclosures (TCFD):	TCFD provides recommendations for consistent climate-related financial risk disclosures for use by companies, which includes tracking and reporting on carbon emissions and intensity.

While these standards and guidelines can help provide a framework for measuring and reporting carbon intensity, the precise methodologies used can vary between industries and organizations. The choice of standard often depends on the specific requirements of the industry, region, or company. There is an increasingly acknowledged need for a global harmonization of standards and approaches to life cycle analysis in order to reduce confusion and allow for more comprehensive and verifiable reporting.

Conclusion

The need for high-integrity carbon intensity tracking systems which will inform regulators, customers, investors, and other stakeholders continues to grow. For many of our clients, we observe that much of the required data is already collected across the enterprise, but with significant variations--particularly across differing geographies--in what specifically is being collected, the frequency, and how the data is being maintained. Ultimately, there must to be a central corporate data repository and systems which will allow the calculation and certification of data, potentially across a variety of applicable standards. As the world strives to limit global warming, carbon intensity tracking will provide the data needed to help companies, industries, and economies reduce their carbon footprint and move towards a more sustainable future.

BUSINESS PLANNING IN A FINITE WORLD

ALAIN CHARDON, FRANCE

MATTHIEU MEAUX, FRANCE

Planetary boundaries increasingly impact the economy: Traditional business planning is no longer operational for long-term strategic investments

$11.6 trillion investments by the global industry, $1-100 billion single corporate tickets

To face the energy transition, the global industry will have to invest $11.6 trillion in the next ten years, representing $1-10 billion in investments for a typical international company. Regarding financial services, the risks and investment changes will be even more significant in the portfolios of equities, obligations, and loans.

Industries – including energy, manufacturing, steel, cement, aerospace, automotive, and shipping – want to make decisions about major product lines and process changes, transitions to clean energy supplies and low carbon assets, circularity of materials, and protecting physical assets from climate risks.

Banks, asset managers, and insurers want to know which future green technologies they should back, and step back from sectors and companies that contribute to climate change or whose assets, strategy, and investments are impacted by climate, planetary boundaries, and transition risks.

Except to take major risks, business strategy and investment planning can no longer rely on traditional off-ground economic modeling

As a strategist, can you trust the economic scenarios from economists, international financial institutions, and national governments invariably forecasting a steady 3-4% GDP growth rate for the next 30 years, as in the past 30 years? Can you trust plans such as the American Inflation Reduction Act (IRA) or the European Fit for 55 that promise clean energy and resources will be abundantly available for your industry in time?

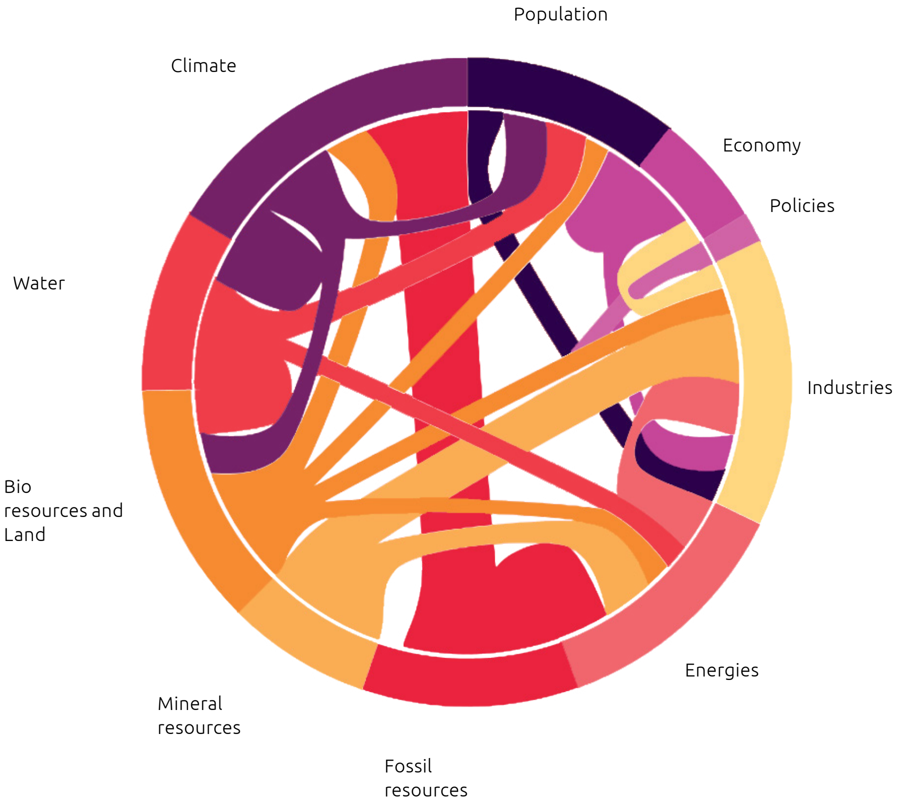
To make better decisions, strategists must understand how the changing world will impact technologies, assets, and business. Will there be a clean energy infrastructure (the blood of the economy) to power your business? Will there be sufficient materials (the skeleton) to make them in the future? Will there be enough agriculture, sea, forest, and biodiversity production (the flesh)? Will there be enough GDP (the aliment) to feed the funding of the infrastructures and techs needed by your company? How deep will climate damage GDP output and workforce productivity and affect the population's ability to consume your products? These questions are even more complex because they do not exist in isolation but are interacting and looping.

Integrated assessment models (IAMs) are the new tool for high-stake business planning

IAMs are models that consider all or part of the interactions between climate, economy, energy, resources, and regulations. Historically, public authorities have used them to plan short- and long-term policies. In the coming years, these tools will become state-of-the-art for corporate business planning in industry, energy, and finance. In particular, Capgemini's Business for Planet Modeling (B4PM) solves some of the limitations of the existing IAMs with a broader scope and increased flexibility for business purposes.

FIGURE 1

Can corporates plan long term investments and disconnect the impact of a finite world on GDP and business?



IAMs, long used by institutions, have only partial coverage of planetary boundaries, do not loop the impacts, and lack the flexibility to serve business needs

The history and usage of IAMs: Integrated assessment models have been developed over the past 50 years to account for intertwined economic, material, and sociologic interactions. They provide insights to international bodies, such as the United Nations, the Intergovernmental Panel on Climate Change (IPCC), World Bank, International Monetary Fund (IMF), and others, as well as national governments and financial institutions to develop strategies and policies.

The grandfather, World3, originally meant for planetary boundaries: World3 was the first IAM model. Developed by Denis Meadows and revealed in 1972 in the book The Limits to Growth, the model predicts the dynamic evolution of the human population depending on the level of pollution, food availability, resource availability, and economic conditions. World3 does not account for climate change, and progress in energy technologies cannot balance the overall predicted degrowth dynamics. The economic model may be considered too simplistic.

Modern neoclassic economy IAMs are disconnected from the finite world: Surprisingly, modern IAMs are less complete than the World3 model for the resource's limits. Often built for macroeconomic purposes, they use neoclassical considerations where the only limits are capital and workforce and cannot tackle the challenges of climate, energy, and resource transition.

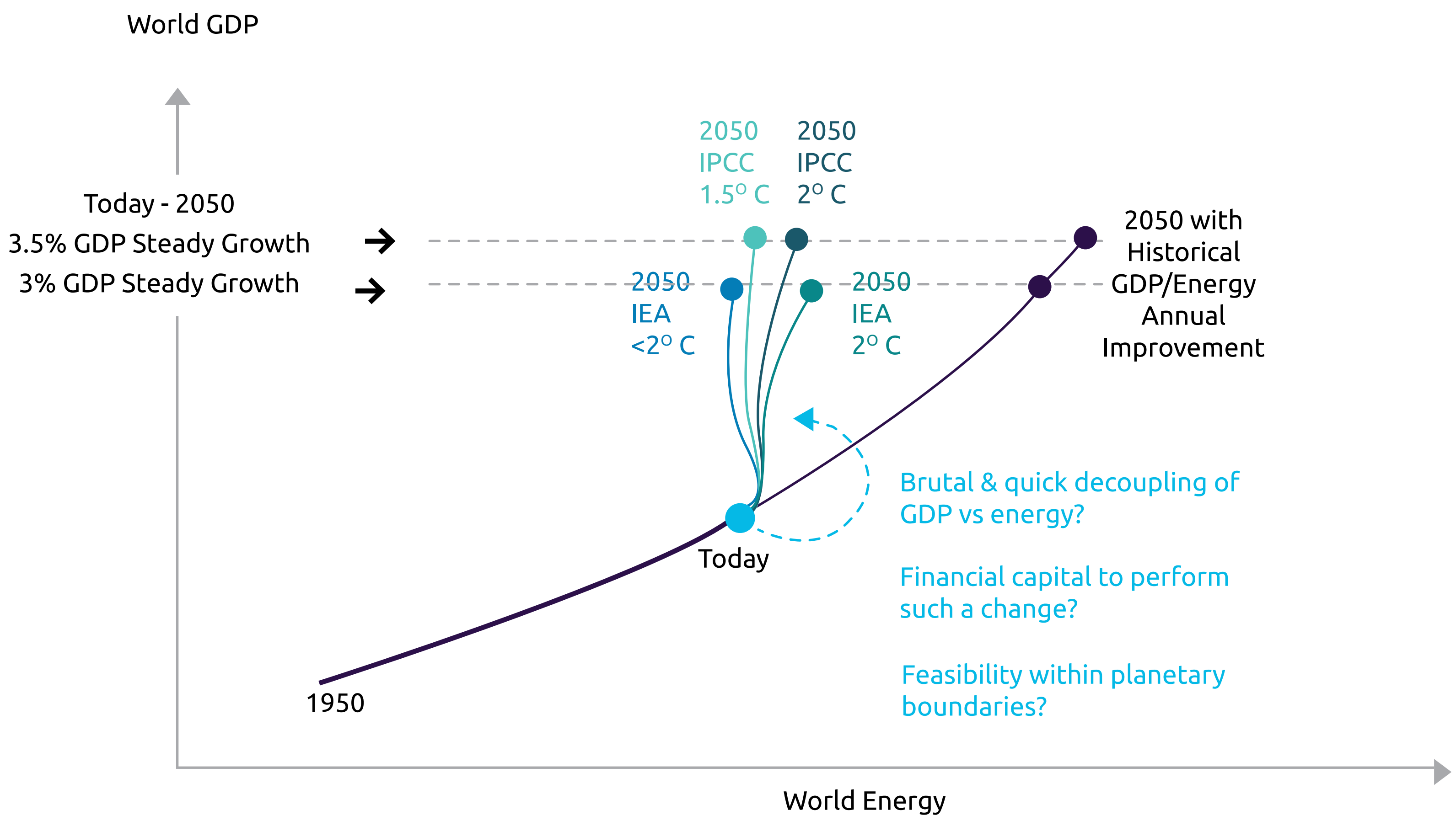
Climate damage is underrated: In most models, climate change does not damage GDP or population, which is a given hypothesis (it was an output in World3). William Nordhaus introduced the feedback of climate on population and GDP levels in his 1992 Dynamic, Integrated Climate and Economics (DICE) model. He received the Nobel Prize in 2018 for his work. Nevertheless, his initial damage functions are deemed underestimated today. At present, fires, droughts, and heatwaves have impacted the GDP and health in India, the U.S., Canada, Australia, Libya, Germany, and Greece.

Resources and circular economy are forgotten: Low-carbon technologies will dramatically multiply the need for raw resources. Few models cover raw materials, water, and land use, limiting economic development. Few models consider the circular economy, despite its potential to significantly impact the 55% of global upstream Scope 3 emissions related to converting primary resources into final products, in contrast to the 45% of emissions associated with running equipment on fossil fuels.

Technology and platform limits: These models are often rigid and built on outdated IT platforms, meaning they lack the transparency and flexibility to integrate additional features or adapt to existing ones. The "black-box" effect leads to a deficit of trust in the model's results. The lack of flexibility causes considerable reworking and cost to extend or tune models to explore specific scenarios. Models and languages are often proprietary, making collaboration more difficult on these highly transversal topics.

FIGURE 2

Transition scenarios from international institutions



Source: Michel Lepetit, Global Warning, The Shift Project, Capgemini analysis

Capgemini's Business for Planet Modeling (B4PM): Pivot your business in a finite world thanks to WITNESS, one of the widest IAMs, and the SoSTRADES platform – both open-source

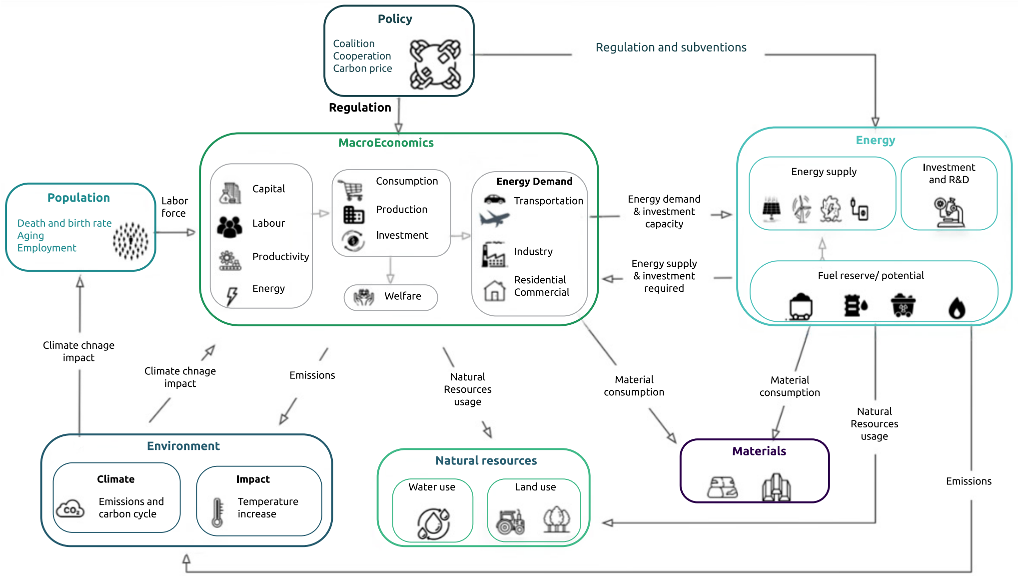
FIGURE 3

B4PM IAM WITNESS ⟺ **B4PM COMPANY STRATEGIC USE CASE MODELING**

WITNESS is one of the IAMs that covers the most disciplines and interactions:

- Climate,
- Population,
- Economy,
- Policies,
- Energy,
- Resources,
- Land use…

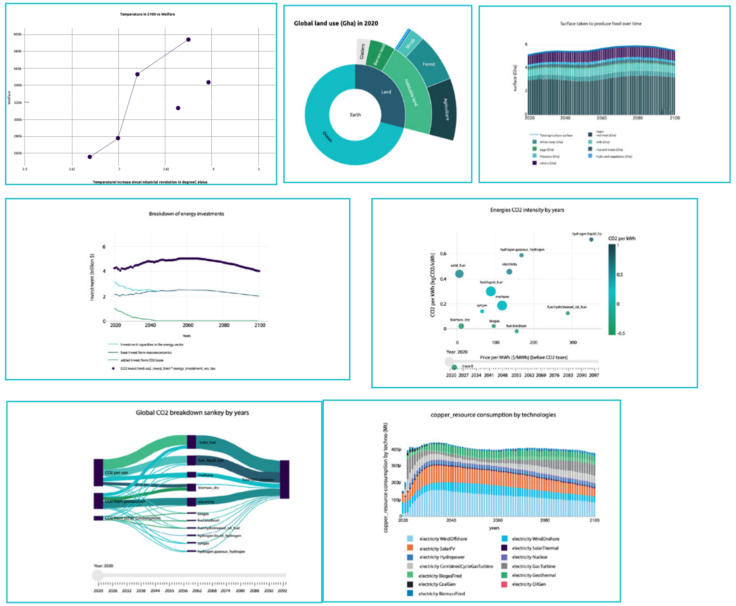
100+ models
300,000+ variables
WITNESS is flexible and expandable thanks to the SoSTrades platform



Stress-test and secure the company strategy and investments.
Model your product / process / asset /services portfolio.

Plunge them in the future of the world (WITNESS scenarios or IEA, IPCC, NGFS scenarios…).

Get all the required financial, operational or emissions results.



B4PM PLATFORM SOS TRADES

GEMSEO
Multidisciplinary Design Optimisation
Multidisciplinary Design Analysis
Design of Experiments
Sensitivity Analysis
Uncertainties Quantification

SoSTrades is a « System of Systems » cloud-based collaborative simulation platform with easy-to-use user-interface, allowing experts to work together.
SoSTrades automatically links models from various origins and runs them together without additional coding using Multi-Disciplinary Analysis (MDA).
Its advanced mathematical algorithms (MDO, DOE, UQ…) allow to solve complex optimization problems or quantify uncertainties on a large panel of models.
SoSTrades articulates WITNESS with the modeling of the strategic use case of the company and solves its business challenge optimally?

B4PM WITNESS is an open-source, transparent, and flexible IAM designed to allow companies to develop models that explore how their plans, assets, and investments play out under different future scenarios. This helps them understand the associated risks without compromising the confidentiality of their business assumptions and data.

WITNESS combines all best-of-breed climate-relevant models in one place, including models on climate change, climate impacts (people, assets, etc.), the global economy, capital flows, demographic change, energy tech, infrastructure (availability, aging, etc.), and resources.

B4PM SOSTRADES is the potent open-source platform that runs and provides all the flexibility and power to B4PM WITNESS. This advanced climate data and IT platform, with libraries and calculation tools, allows all models to operate together and for new models to be added. They can be switched on or off at will. With minimal data naming, the platform makes links between models automatically. Its advanced MDA features solve the looping interactions between population, economy, regulations, energy, resources, and climate. Its MDO tools help to fix constraints, find the optimal path within high uncertainties, and to derisk the company's transition choices.

Companies can build a strategic twin model of their business issues. They can generate infinite options. Users build their scenarios by combining models from the database, which can be clicked together like building blocks to simulate the world. They plug them into WITNESS, the B4PM model of the world. The underlying platform, SoStrades, loops the interactions between the company's business and the global model. The users can stress-test the choices they are considering in a wide range of possible future scenarios.

They can tweak inputs and visualize how future decisions (their own, competitors, or governments) would affect economic flows, climate impacts, resource availability, and therefore, risk levels. This enables the company to derisk its transition decisions and roll out a profitable business plan in a finite world farther and better than the competition. This helps strategists make informed decisions about the least risky path to success, including where to invest, how quickly to progress new technologies, how to evolve supply chains, where to build or move factories and assets, and what insurance and risk-mitigation policies to pursue. All of these help derisk decisions, build resilience, and chart a profitable course through the energy transition.

Mixing a private and open-source approach for WITNESS and SoStrades carries many benefits

One benefit of WITNESS and SoStrades being at least partly open-source is increasing the transparency and, therefore, the trust from third parties in the model's results and transition paths proposed by the company. A second is that joining a community facing the same climate and data challenges creates a shared experience. This approach prevents duplicating research and data capture, establishes common data standards for processing the climate and economy data, and enhances the model's integrity and evolvability.

Once the first results are reached and momentum builds for the company's transition models, the question of maintaining the data and codes will arise. The third benefit of open source is the ability to collaborate with other companies to maintain, share, validate, and update data of common interest.

This would give the companies valuable data to steer their strategy, which would be costly or impossible to maintain alone.

Capgemini is a member of Open-Source Climate (OS Climate) - Why not join us? We facilitate the transition scenarios working group with WITNESS and SoStrades. The purpose of OS-Climate – part of the Linux Foundation – is to gather a community around these topics, with several high-profile members, including banks, tech giants and industries. Capgemini joined OS-Climate as one of three premium members (alongside Goldman Sachs and BNP Paribas). Why not join us?

Capgemini's Business for Planet Modeling (B4PM): Pivot your business in a finite world and solve a wide variety of practical use cases (potential non-exhaustive list)

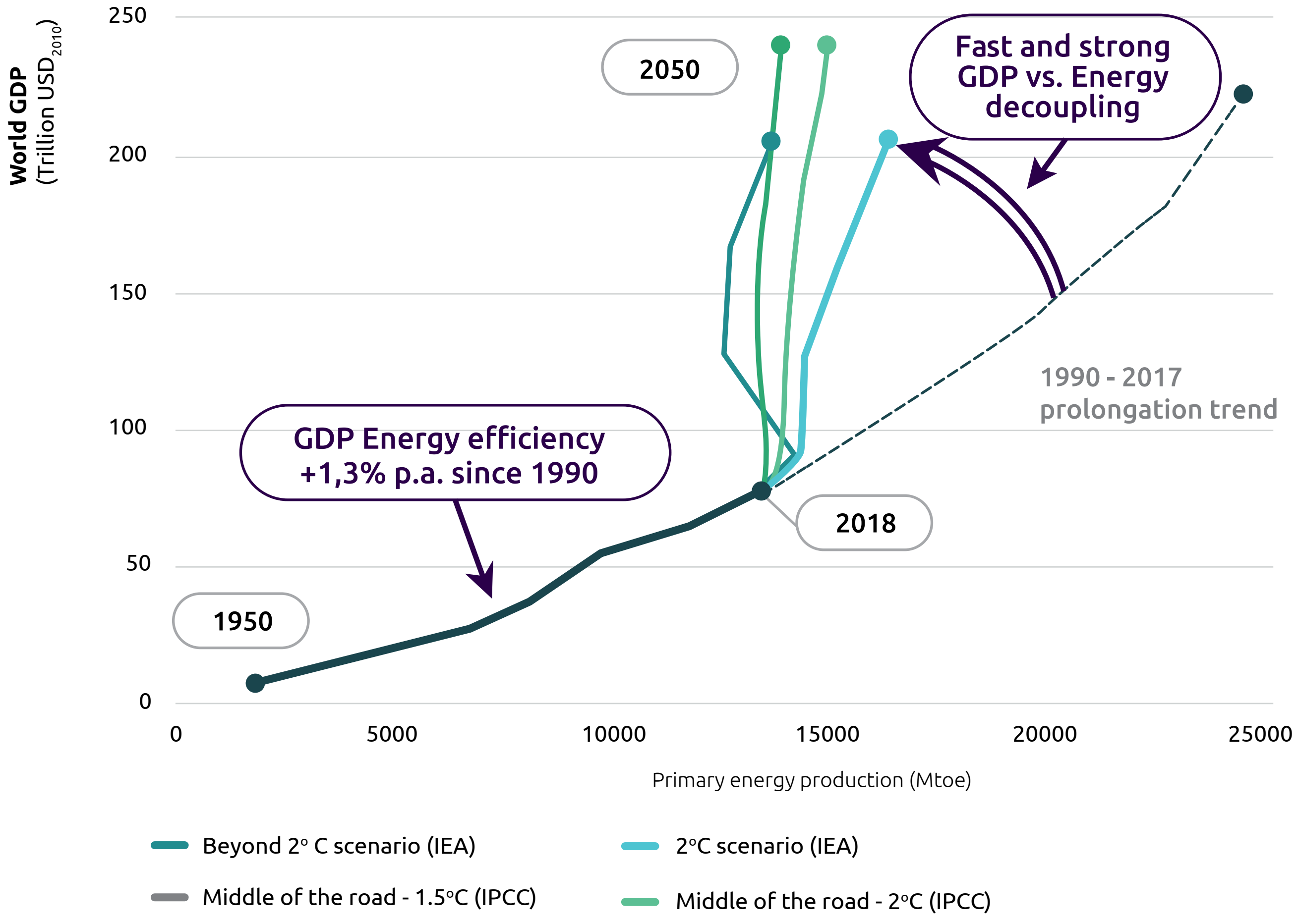
FIGURE 4

INDUSTRY & ENERGY	1st TRANSFO INDUSTRY Steel, metals, plastics, glass, cement, …	2nd TRANSFO INDUSTRY Intermediary components & chemicals	3rd TRANSFO INDUSTRY Final goods Auto, CPRD, Hightechs…
CONSISTENT TAYLORED INPUT SCENARIOS FOR STRATEGY	●	●	●
PRODUCT INVESTMENTS & PORTFOLIO TRANSITION			●
PROCESS INVESTMENTS & PORTFOLIO TRANSITION	●	○	
INDUSTRIAL ZONES & PORTS H2, CO2, HEAT, CIRCULAR ECO	●	○	●
SCOPE 3 / CIRCULAR ECONOMY WITH TIER 1 2 3 SUPPLIERS	○	○	●
MANUF & ENERGY FLEXIBILITY, SCARCITY PLANS 8760 Hrs/Yr	●	●	●
ENERGY INVESTMENTS IN PLANTS & AT GROUP SCALE	●	●	●

FINANCIAL SERVICES	ASSET MANAGERS	INSURERS	BANKS
CONSISTENT TAYLORED INPUT SCENARIOS FOR STRATEGY	●	●	●
CLIMATE STRESS TESTS & WHAT IF ANALYSIS	●	●	●
DEBT DEFAULT, COLLATERALS & EAD TRANSITION RISKS			●
EQUITY & BONDS VALUE TRANSITION RISKS	●	●	
NON-LIFE TRANSITION RISKS		●	
LIFE, PENSION & HEALTH TRANSITION RISKS		●	
FINANCED EMISSIONS & PORTFOLIO TRANSITION	●	●	●

FIGURE 5

GDP versus energy production evolution | 1950 - 2050



DECARBONISING ENERGY.
ARE WE MOVING FAST ENOUGH? LIGHTS AND SHADOWS

DAVID PEREZ-LOPEZ, SPAIN

Current decarbonization path is the under 2.5°C average temperature increases but far from 1.5°C Paris Agreement goal. The arctic will be ice-free in a time between 2030 and 2050.

Energy transition is off-track. According to international institutions under current decarbonization path will rise of 2.5 °C in global average temperature far from 1.5°C Paris Agreement goal. Current pledges and plans fall well short of 1.5°C pathway and will result in an emissions gap of 16 gigatonnes (Gt) in 2050 representing more than 40% of total current emissions to be abated.

CO_2 emissions path to 2050 under STEPS and even APS scenarios are far from Paris Agreement temperature rise goal, encourage policies and pledges are key to reach a NZE path.

2023 will surely be the hottest year ever recorded, last July 6 was the hottest day in recorded history reaching 17.2°C global average.

Every fraction of a degree in global temperature change will trigger significant and irreversible effects in biodiversity losses, droughts, food security, fires, extreme heat and weather events, floods sea level rise, or coral reefs disappearance.

A recent study based on NASA and ESA latest satellite observations and IPPC climate model predicts that between 2030 and 2050 will arrive an ice-free Arctic even under a low emission scenario path, and by 2100 the Arctic region will be ice-free for almost half a year. Nature Observationally-constrained projections of an ice-free Arctic even under a low emission scenario.

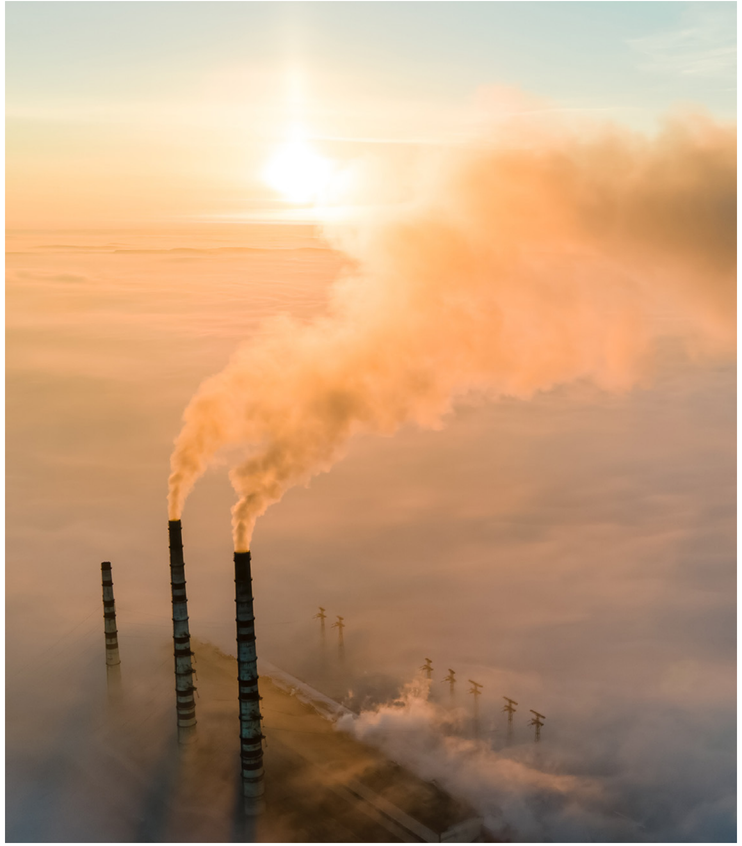
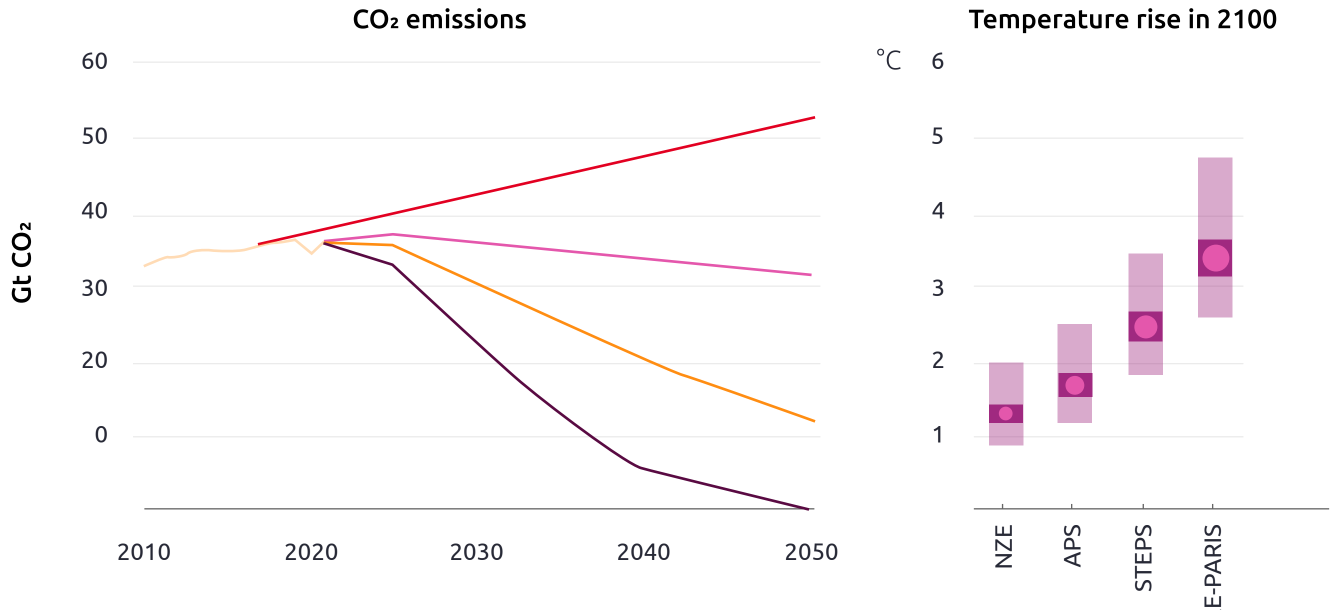


FIGURE 1



CO_2 emissions paths to 2050 under STEPS, APS and NZE and temperature rise in 2100

Climate change is the largest humanity risk.

The world is experiencing multiple crises but climate change in the long-term are the largest global risks , and extreme damages were caused by climate change over for 2022 with thousands of deaths, environmental disasters, and billions of economic losses.

The need for the energy transition has become even more urgent. The recovery from the Covid-19 pandemic and the global energy crisis have provided a major boost to global clean energy investment.

In the next 5 years solar and wind will be installed as much as to date and by 2030 will double or triple the current annual capacity installed. This is not enough.

Renewable energy growth is accelerating due to the energy and gas crisis context where countries seek to strengthen energy security as main part of the solutions to be addressed accelerating its hypergrowth. Wind and solar avoided €11bn to EU in gas costs for 2022 lowering the inflation.

Several progresses are being made, especially in the electricity sector, where renewables is representing 83% of the new capacity additions globally by 2022 and expected to be more than 90% of global new additions in the next 5 years. By 2027 solar energy will account becoming the largest source of electricity.

Although global investment across all energy transition technologies reached a record high of USD 1.3 trillion in 2022, annual investment must more than quadruple to remain on the 1.5°C pathway . By 2023 an increasing push anticipated spending up to a record USD 2.8 trillion, with renewables, and EVs leading the expected investment. This momentum behind clean energy investment stems from a powerful alignment of costs, climate and energy security goals, and industrial strategies, but remains heavily concentrated in advanced economies.

There are positive signs they are still not enough, even during 2022 worrying signs occurred: gas use has declined, but not enough, we have gone from the golden age of gas to the golden age of LNG., coal investment is higher than pre-pandemic levels, low carbon fuels are only a small portion, energy efficiency is not under expected pace specially in a period of high energy prices, critical minerals could be a constraint for energy transition goals, slow permitting and bureaucratic processes that projects cannot be developed at the speed expected, NIMBY social position movements.

Renewables alone isn't enough. Energy transition is also about storage, heat pumps, hydrogen, grids, CCUS, energy efficiency, flexibility.

Storage strategies and business models for front-of-the-meter and after-the-meter in short, mid and long duration storage are moving slowly by specific regulations and the difficulty to monetize getting clear returns, usually together renewables plants and stand-alone grid-scale uses are being a promising growing year to year.

About 50% of all energy consumed in OCDE countries is used for heating and cooling and more than 70% still comes from fossil fuels. Heat pumps are a mature technology that is much more energy efficient than boilers would nearly double their share of heating in buildings by 2030 at current growth rates. New applications of electric water heaters could also work as household batteries, storing energy and saving billions in full-electric homes powered by renewable energy.

Grid infrastructure, especially in weak grids, is being a limiting factor for renewable deployment constraining the grid access capacity and starting to see the first global awareness about curtailments situations due to this grid issue.

Carbon capture, utilization and storage (CCUS) technologies have entered into a new era offering a strategic value tackling emissions in sectors where other technology options are limited expecting to abate 20% of total current CO_2 emissions in 2050.

Time matters and carbon budget is running out.

Hydrogen. Hype or hope?

Hydrogen is still in the early stages but has the potential to be one of the most technologies capable of accelerating the energy transition in heavy industry and long-distance transport uses, living an undisputable momentum strengthened by energy crisis and expecting to be the next 1trn business.

1.5°C energy transition pathway will require the use of all technologies and a massive change in how produce and consume energy. Many of technologies are currently fully available as renewables, heat pumps or energy efficiency, and another will need to be developed, improved or optimized as storage, EV, carbon capture or hydrogen. Despite some progress we are far from being on energy transition track and multiple actions are needed to be on the right track.

FIGURE 2

IRENA Tracking progress of key energy system components to achieve the 1.5°C scenario

	Indicators	Recent Years	2023	2050	Progress off/on Track
RENEWABLES	**ELECTRIFICATION WITH RENEWABLES**				
	Share of renewables in electricity generation	28%	67%	91%	
	Renewables power capacity additions	295GW/yr	975GW/yr	1066GW/yr	
	Annual solar PV additions	191 GW/yr	551 GW/yr	615 GW/yr	
	Annual wind PV additions	75 GW/yr	329 GW/yr	335 GW/yr	
	Investment needs for RE generation	468 USD billion/yr	1300 USD billion/yr	1382USD billion/yr	
	Investment needs for RE generation	274 USD billion/yr	548 USD billion/yr	790 USD billion/yr	
	DIRECT RENEWABLES IN END-USES AND DIRECT				
	Share of renewables in final energy consumption	19%	34%	83%	
	Solar thermal collector area	746 USD million m^2/yr	1700 USD million m^2/yr	3700 USD million m^2/yr	
	Modern use of bioenergy (direct use)	1.5EJ	44EJ	56EJ	
	Geothermal consumption (direct use)	0.4EJ	1.3EJ	2.2EJ	
	Renewables based district heat generation	0.9EJ	4.3EJ	12EJ	
	Investment needs for renewables end uses and district heat	13 USD billion/yr	269 USD billion/yr	216 USD billion/yr	

	Indicators	Recent Years	2023	2050	Progress off/on Track
ENERGY EFFICIENCY	Energy intensity improvement rate	0.6%/yr	3.5%/yr	2.9%/yr	
	Investment needs for energy conservation and energy	295 USD billion/yr	1772 USD billion/yr	1493 USD billion/yr	
ELECTRIFICATION	Share of direct electricity in final energy consumption	22%	29%	51%	
	Passenger electric cars on the road	10.5 million	355 million	355 million	
	Investment needs for charging infrastructure of EV's and EV addoption support	30 USD billion/yr	141 USD billion/yr	364 USD billion/yr	
	Investment needs for heat pumps	64 USD billion/yr	266 USD billion/yr	258 USD billion/yr	
HYDROGEN	Clean hydrogen production	0.7 Mt/yr	21.4 Mt/yr	518 Mt/yr	
	Electrolyser capacity	0.5 GW	233 GW	5722 GW	
	Investment needs for clean hydrogen and derivatives infrastructure	1.1 USD billion/yr	80 USD billion/yr	170 USD billion/yr	
	Clean hydrogen consumption industry	0.04 EJ	2.4 EJ	40 EJ	
CCS AND BECCS	CSS/CCU to abate emission in industry	0.01 $GtCO_2$ Captured/yr	1.0 $GtCO_2$ Captured/yr	3.0 $GtCO_2$ Captured/yr	
	BECCS and other to abate emissions in the industry	0.002 $GtCO_2$ Captured/yr	0.7 $GtCO_2$ Captured/yr	1.0 $GtCO_2$ Captured/yr	
	Investment needs for carbon removal and infrastructure	6.4 USD billion/yr	18 USD billion/yr	107 USD billion/yr	

EMPOWERING YOUR SPACE: EFFECTIVELY LEVERAGING BUILDING EFFICIENCY TECHNOLOGIES

JOANNE SIU, UK

CHARLOTTE WARD, UK

Accelerating zero-carbon buildings

Buildings account for almost 40% of global energy-related carbon dioxide emissions – more than the global transportation sector. To achieve net zero emissions by 2050, all new buildings, as well as 20% of the existing building stock, must be zero-carbon ready by 2030.

Innovative technology makes it possible to achieve a 60% energy efficiency improvement at present. But to be on track for zero-carbon buildings by 2050, an 80% efficiency savings by 2030 is needed. This is possible only with significant investment in R&D and vast electrification implementation.

Upgrading buildings will unlock a huge sustainability benefit, as well as long-term cost savings. Those using the buildings will also experience improved comfort and productivity. People can make a significant impact on old and new builds through passive strategies, active technologies, data and analytics, and renewable energy solutions (RES).

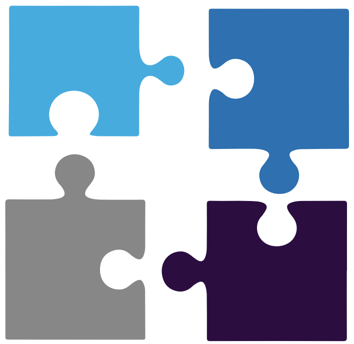
26% of energy-related emissions are directly or indirectly caused by building stock. About 20% of these emissions are accounted for in the construction process and the embodied carbon in building materials. However, 80% of these emissions are caused by the direct and indirect emissions produced throughout the building's lifecycle, which will be the focus of this article.

Emissions are only growing year on year. Population growth, combined with an expectation for more space per individual through declined household sizes around the world, is intensifying pressure on the energy system. In fact, total building footprint has increased by approximately 70% since 2000 (80% of which is residential), while the energy use per square meter has declined by only 20%. Combine this trend with improved access to energy, especially in developing nations, increased heating and cooling appliances due to more extreme weather, and higher ownership of energy-consuming appliances, and the average energy used in buildings could increase by 70% by 2050 without targeted energy efficiency improvements.

More stringent policies, supportive financing, improved consistency in design standards and tools, upskilling programs across construction, and better use of data and analytics technology is needed globally. In addition, without an improvement in collaboration at a local, regional, and global level, zero-carbon buildings will remain a pipe dream.

FIGURE 1

Strategies for energy transition



Who's winning in the race for energy efficiency?

Despite the significant carbon impact figures we face today, there is optimism for the future in Europe, parts of the U.S., and China, where the goal of achieving zero-carbon, energy-efficient buildings by 2050 is promising.

The American Council for an Energy-Efficient Economy's (ACEEE) 2022 building energy efficiency ranking provides insight into how close the countries' building stock, on average, is to achieving zero carbon for both retrofits and new builds.

The Netherlands is leading the way with strong building regulation across both residential and commercial, closely followed by France, Spain, and Germany. China comes in fifth, having comprehensive energy use reduction, building code regulation, and appliance labelling despite an overreliance on coal.

The most energy efficient countries act as pathfinders globally. Similarly, individual projects can showcase and inspire scalable solutions.

Country case study: Iceland's 85% renewable power mix. In the 1970s, the United Nations Development Programme (UNDP) classified Iceland as a developing country with no integrated grid system, inexperienced institutions, and a sparse population. By fostering cooperation among municipalities, government entities, and actively engaging the public, local communities gained a sense of empowerment. This enabled the country to transition to geothermal and hydroelectric power sources, harnessing the potential of its natural environment.

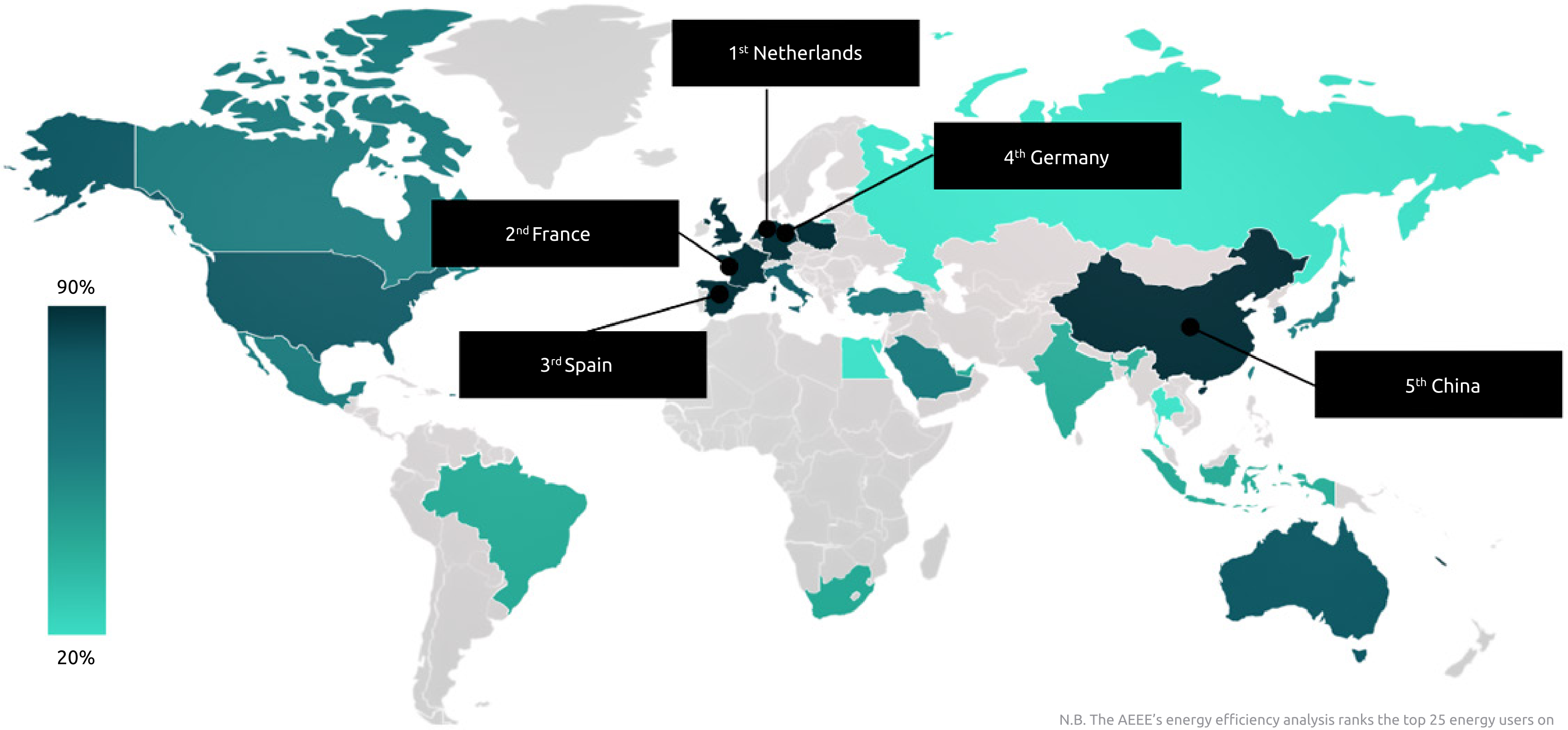
City case study: Milan MIND Project. A €4 billion project transformed the 2015 World Expo grounds into Europe's largest testbed for innovation, exploring green architecture and urban living. Milan Innovation District (MIND) aims to become a sustainable smart city tying together housing, offices, and municipal buildings. E.ON ectogrid™ supplies the heating and cooling requirements for all 32 buildings in one system. This results in a circular energy system that intelligently distributes energy for heating and cooling.

Building case study: Energy Command Center (ECC). Next-generation technology plays a critical role in increasing building energy efficiency. Capgemini has introduced the Energy Control Center (ECC). Established in India at its facilities and structured around an IoT-based architecture, this framework enhances resource management and facilitates the efficient monitoring of energy assets within the designated location.

Since the launch of ECC, energy efficiency has increased by 25% and maintenance costs have been reduced by 20%. This solution is available to customers for similar site needs.

FIGURE 2

Energy Efficiency rankings (including policy measures and performance metrics)



N.B. The AEEE's energy efficiency analysis ranks the top 25 energy users on 36 efficiency metrics including policy measures and performance metrics

Zero-carbon buildings: Capitalizing on energy efficiency across the building spectrum

> *When people move house they are more likely to make improvements to their bathrooms and kitchens, but why not the efficiency of their houses, which can save them money - as well as emissions?"*
>
> **Baroness Neville-Rolfe,**
> Former Minister of State (U.K. Cabinet Office), 2016

Zero-carbon homes produce 75-80% fewer carbon emissions. This figure is based on improvements to energy intensity and renewable electricity provision, as well as minimized active emissions produced by the building and embodied carbon in the materials. This is achieved primarily by improving the building envelope's effectiveness and the heating and cooling systems.

To achieve the full potential, integrated building energy management systems must be implemented and utilized to manage all appliances, equipment, and technological innovations across the building ecosystem.

The opportunity is clear, but the realization of such a task is daunting for every economy. Both new builds and retrofitting need sizeable amounts of work done so that they can reach zero-carbon ready buildings standards.

This is especially true of retrofitting since each historic building has unique needs. One of the benefits of a deep energy retrofit (DER) over a conventional energy retrofit is that, instead of viewing items in isolation, the building is flexibly upgraded as an entire system. **This marks a transformative shift, elevating the standard 20% isolated energy savings to a significant enhancement in energy efficiency, reaching up to 60% or even more – a substantial leap forward.**

On top of retrofitting existing buildings, governments and individuals should ensure all new-build homes are net-zero emissions ready. Architects and construction firms must analyze the full process from start to occupancy to deliver a low-carbon home fit for the future as well as today. Energy-efficient designs consider factors from embodied carbon in materials to current and future energy consumption, a principle equally crucial in comprehensive renovation initiatives.

To attain the crucial goal of retrofitting 20% of existing buildings by 2030, every market must sustain an annual deep renovation rate exceeding 2% from the present day through 2030 and onwards. Furthermore, all newly constructed homes should be zero carbon-ready by 2030.

Europe is leading the way with multiple retrofitting projects since 2021. However the rate is around 1%, well below what is needed. This started with the least efficient buildings, followed by promotion of large-scale renovation programs and future targets of passive hospitals and passive schools by 2025.

The market value potential for retrofitting in Europe, totaling €245 billion (comprising turnover and investments) annually by 2030, along with its substantial carbon impact, is significant.

A study published by the Buildings Performance Institute Europe (BPIE) also states that for every €1 million invested in the energy renovation of buildings, an average of 18 jobs are created in the EU economy.

However, this market value will only be realized through creative new financing schemes. Government tax credits and rebates can help catalyze short-term uptake, but financial institutions need to continue to support energy companies' as-a-service propositions, which spread the cost and capitalize on the long-term savings, despite current high interest rate conditions.

With the investment in deep renovations, there are millions of job opportunities possible.

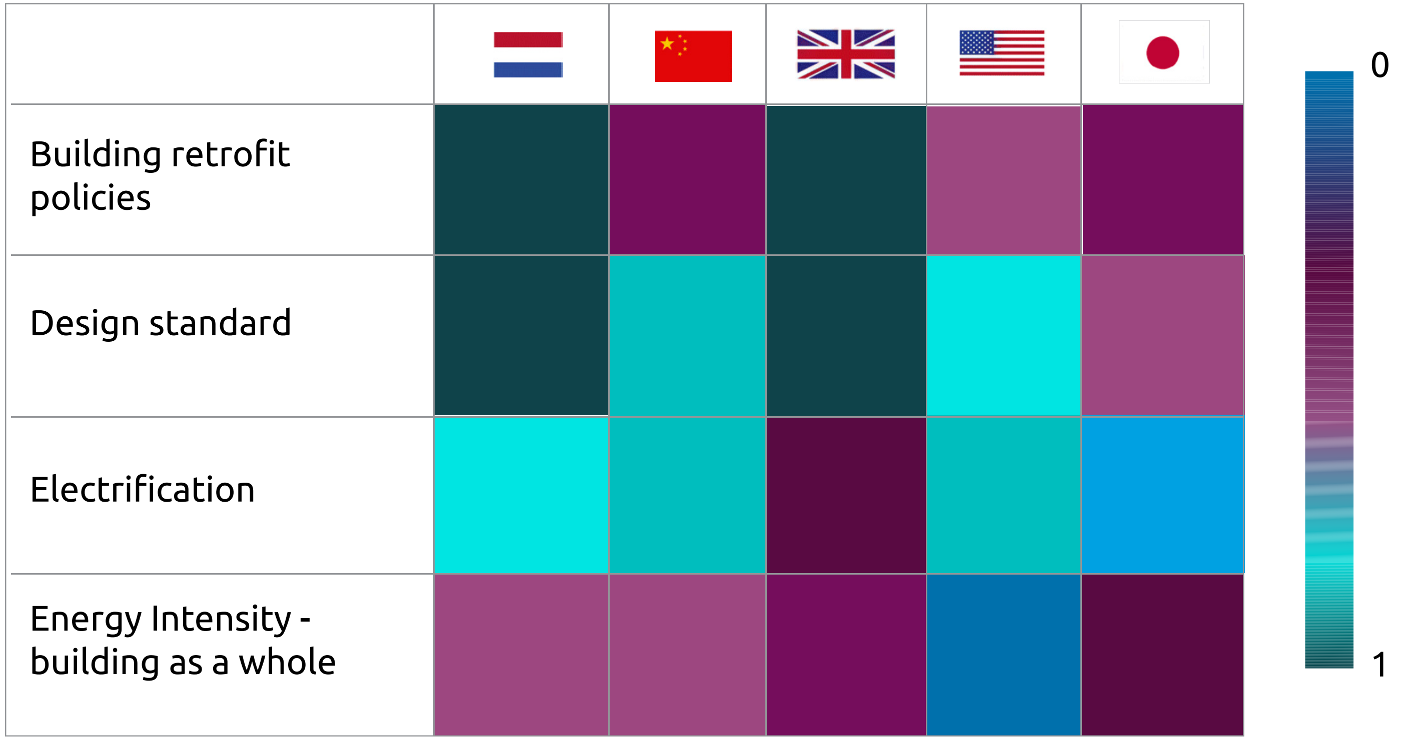
The power of proactive change

Effective policy positions were a key enabler to change throughout Iceland's successful renewable electrification journey. In fact, the AEEE's energy efficiency analysis places government policy positions as the principal factor in comparing the country's energy efficiency levels.

Despite some countries having similarities in their building stock footprints, each has taken a different route in their policy. When comparing five well-known countries in their advancements in energy transition and construction, the outcomes are surprising.

Japan, despite being one of the most innovative construction markets in the world in earthquake technology, falls short across the board for energy efficiency policy, as does the U.S. for whole building energy intensity. The Netherlands performs well in most of the areas, setting a benchmark. This country has set thorough policies, ambitious standards, and requirements, but still relies on fossil fuels for too much of their energy mix. Across the board, these countries are struggling to apply fully-integrated electrification systems (Figure 3).

FIGURE 3



> *We've discovered that the cost of 'deep retrofit' [on a Nottingham council house] …is at least double the expected amount – averaging around £69,000."*
>
> **Professor Lucelia Rodriguez**
> Professor of Sustainable and Resilient Cities
> University of Nottingham

Financial support is the key – especially for the lowest-income communities. These communities inadvertently exhibit lower indirect emissions because of their limited financial resources. However, they still face substantial direct emissions since they lack the necessary support to invest in energy-efficient technologies and home upgrades.

Situation highlights the importance of finding inclusive solutions to alleviate the economic burden on communities.

Governments need to work with financial institutions, as well as commercial and residential stakeholders, to balance the financial costs in the short-term and achieve long-term carbon and cost savings. Examples include Weatherization Assistance Program (WAP) in the U.S. and Affordable Warmth Grants in the U.K.

Financially supported policies are not the sole drivers of change. Figure 4 outlines additional key factors for facilitating change.

Upskilling	Demand response (DR) programs
The European Commission and the construction industry successfully joined forces to upskill and reskill three million workers (25% of the workforce) in the next five years through an initiative called the Pact for Skills. Other markets must follow suit.	Demand response programs are important to attaining decarbonization within the construction industry and beyond. These efforts have yielded notable electricity savings in Australia, the EU, and South Korea. In the case of the Auto DR pilot program in South Korea, there was a remarkable 24% increase in electricity savings.
Cross-party collaboration	**Energy efficiency standards and labelling programs (EES&L)**
Policy makers, financial mechanisms, the construction sector, and consumers all need to work together to achieve this goal.	Appliances and equipment are critical to achieving decarbonization and can result in energy reductions of 10-30% over 15-20 years in most regulated products across all countries.

Passive strategies enabled by active technologies and renewables are the key to acceleration

FIGURE 4

- Governments must make urgent reforms to the planning process for all types of renewable generation.
- Innovation to improve the energy generation potential of each asset (e.g. solar PV or wind turbines) must continue, with existing assets upgraded strategically to maximize energy output.
- Trade of renewable energy reserves is key to balancing the enrgy mix, just as it is with fossil fuels.

- Traditional electricity grids are not robust enough to support the needed electrification. data-driven prioritization is needed to strategically upgrade the physical infrastructure.

The management of renewable power generation differs significantly from that of fossil fuel power stations. To effectively handle grid outages and surges, it's essential to make smart grids and virtual power plants the standard approach.

- More effective collaboration is needed through universal labels across Building Information Modelling (BIN) and related tools for embodied carbon and energy modelling. This will enable immidiate insight n the effect of their design choices.
- Upskilling of the existing workforce in the cnstruction industry is needed to embed zero-carbon building ready practices by default into new building designs.

- Data monitoring and management systems should be mandatory across all buildings, rather than being left t the discretion of private landlords.

Just as phone app management optimizes energy demand and supply, building energy management systems should automatically adjust energy use, activate energy-saving mode for underutilized appliances, and offer proactive guidance on energy-saving opportunities.

Conclusion

Zero-carbon buildings are the key to building energy efficiency

Accelerating the deployment of zero-carbon technology across the construction sector is crucial. Deep-retrofitting of the hardest-to-abate buildings must be prioritized today to create the step-change needed. Further, zero-carbon building methods must become the norm in both developed and developing countries.

- **Governments:** Governments should follow the lead of the most energy efficient markets, which have set aggressive targets to boost deployment. In the Netherlands, all office buildings will be required by law to have an energy rate of C or higher by 2023; there is also a target to achieve an energy rate of A by 2030. The U.K. is on a similar path, targeting an EPC rating of C or above for all rented properties by 2028. With more support from governments in terms of policy setting and financial backing, there is a chance to set a more aggressive target, aiming for an EPC rating of B or above for all buildings by 2030.

Consumers: It is crucial to invest in preparing your residential or commercial property for zero-carbon standards today. Adopting a comprehensive deep renovation approach is essentia

- **Renewables developers, grid operators, and energy suppliers:** Focus less on 'quick wins' and accelerate where the largest opportunities lie. Ensure that upgrades today are future-facing as technology improves.
- **Financiers:** To achieve this, government, energy companies, and financial institutions must support business models which capitalize on the new market opportunity. Spreading the high upfront costs over time will accelerate uptake while providing long-term stable interest opportunities like mortgages today. This will ensure that the poorest in society are not left behind.

DO WE HAVE MINERALS AVAILABLE TO REDUCE THE IMPACT OF CLIMATE CHANGE?


JEAN-MICHEL CHARETTE, AUSTRALIA


NEELAM YADAV, AUSTRALIA


JOHN WAREING, AUSTRALIA

Turning our net-zero ambitions into reality

It has become a necessity for the world to move towards renewable and clean energy sources sooner rather than later.

Are we on track to decarbonize our society in time to mitigate the severe impacts of climate change?

Decarbonization can be achieved through operational efficiencies, use of renewable energy, electrification and adoption of new technologies. To build the new technologies, raw materials must be provided by the mining industry.

Do we have enough minerals to achieve this?

What role will geo-political forces play?

How can we come together to make the required minerals available to bring the energy transition to life?

The solutions coming to the energy market to enable and support decarbonization efforts continue to grow. Whilst we have seen increased adoption of corporate power purchase agreements (PPAs), we have observed growth in technology solutions becoming available, including wind turbines, advanced batteries, electric vehicles, metal recycling, carbon capture and storage, solar photovoltaics, hydrogen related fuels, artificial intelligence, etc.

There will continue to be a range of factors that will influence decarbonization efforts, such as customers, regulators and investors, and the impact of differing geographies.

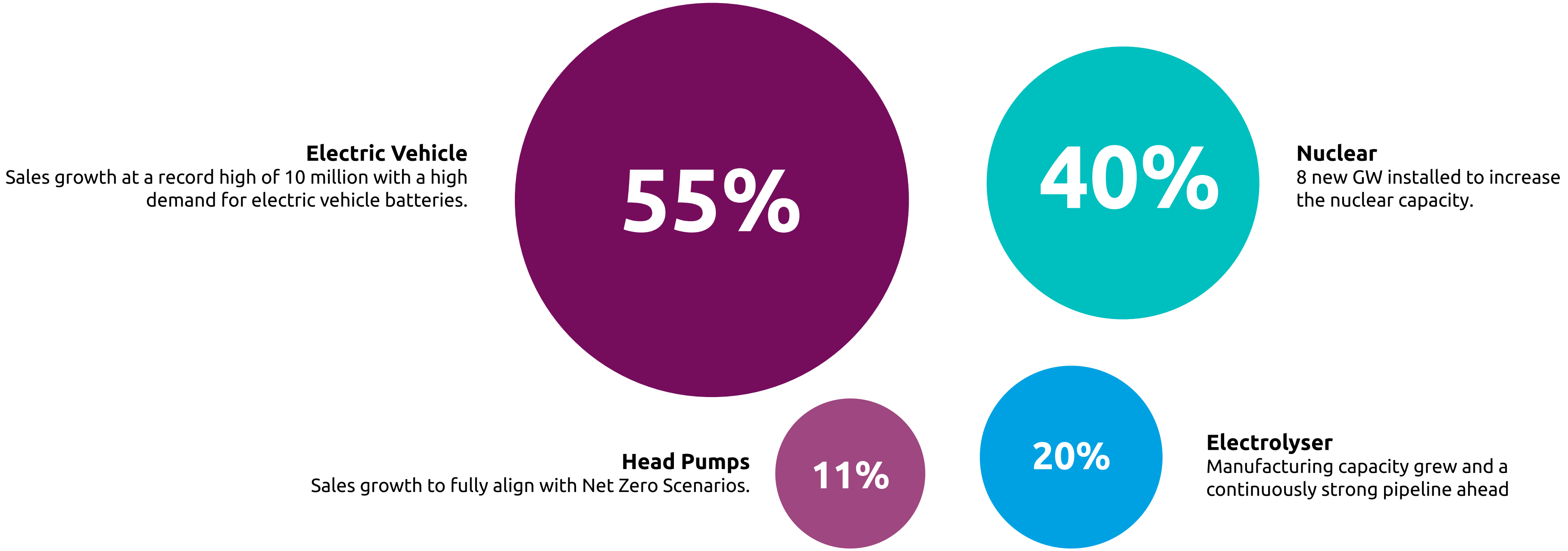
The availability of these technologies has improved over recent years, however, there is still a requirement to utilise a vast amount of minerals to create and scale the new technologies. For example, electric vehicles are dependent on lithium, meaning greater amounts of lithium will need to be mined and / or extracted.

We can realise our net-zero ambitions. It will require everyone to work together, to re-invent our future.

The fight against climate change continues, however the world must work together to refresh the way we use energy, make resources available, and review our policies, economics and behaviors. Let's deep dive into understanding how the availability and location of minerals will play a vital role in the energy transition.

FIGURE 1

The progress on clean energy technology deployment in 2022 has grown
Clean Energy Economy in 2022



Source: IEA (2023), Tracking Clean Energy Progress 2023, IEA, Paris https://www.iea.org/reports/tracking-clean-energy-progress-2023, License: CC BY 4.0

The race against time for clean energy technology deployment and rapid growth in 2022

The progress across the globe for clean technologies has been quick in some countries, however in others it's off track. Several steps have been taken towards Net Zero Scenarios which has led to the deployment of low emission technologies in the four areas over the years.

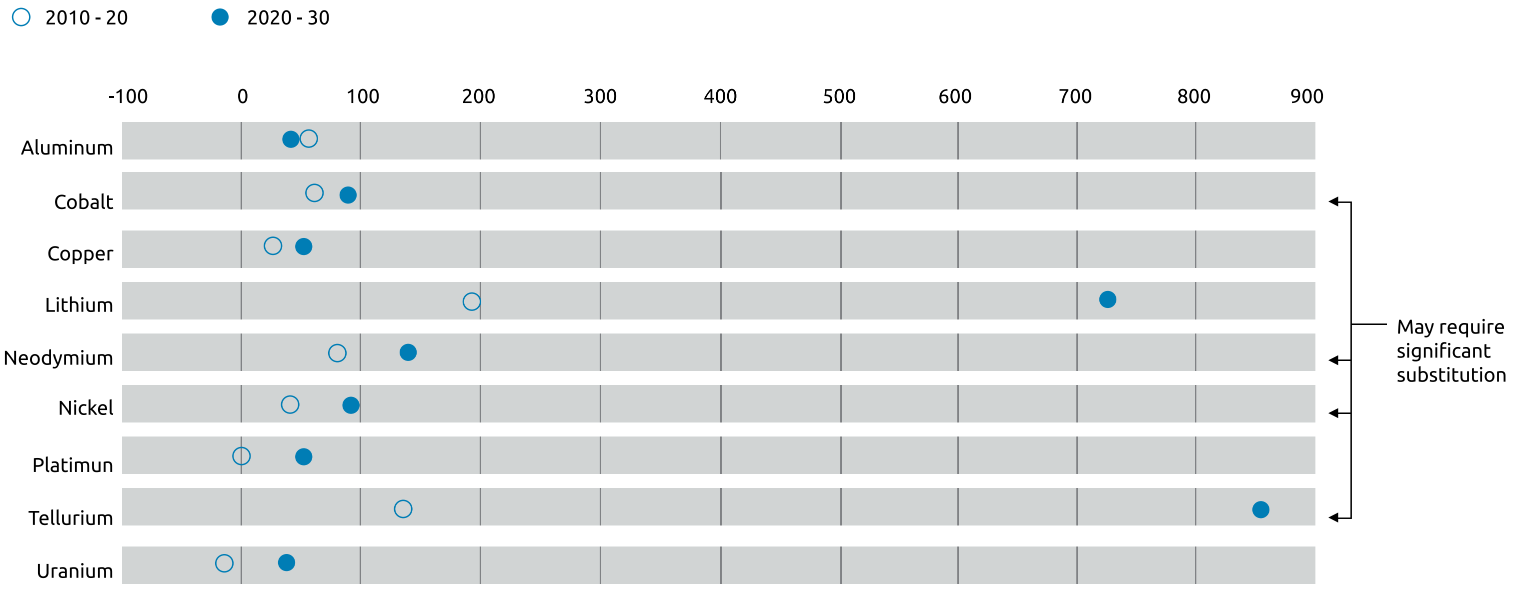
Mineral and raw materials will be at the centre of decarbonization initiatives and electrification of the economy as we transition into a low-carbon economy.

Mineral and raw materials are poised to play a pivotal role in the ongoing efforts to decarbonize our industries and drive the electrification of our economy, particularly as we steer towards a low-carbon future. As the world seeks to reduce its carbon footprint and transition away from fossil fuels, these essential resources are at the heart of the transformation. They are the building blocks for the renewable energy infrastructure, electric vehicles, and various sustainable technologies that will underpin the eco-friendly economy we are striving to achieve.

For the technology transition to occur as forecasted, the raw-materials growth will need to advance at a rapid pace, as compared to earlier calculated rates. The demand for minerals has exceeded the calculated historical rates and will continue to grow in the coming years. As shown in the visual above, the forecast for minerals like cobalt, copper, lithium, neodymium, nickel, platinum and tellurium has exceeded the historic usage in the last decade.

FIGURE 2

Forecast of consumption of rare minerals and a comparison from last decade



Source: McKinsey and Company, January 2022, https://www.mckinsey.com

How quickly can the mining industry meet the demands?

Steel is a crucial metal and infrastructure enabler across all elements of the low-carbon economy, however specific elements will be playing a vital role in technology transitions. Below is a view of essential materials required for the shift toward a sustainable, low-carbon economy, categorized by their respective technology types.

Consideration #1: Location

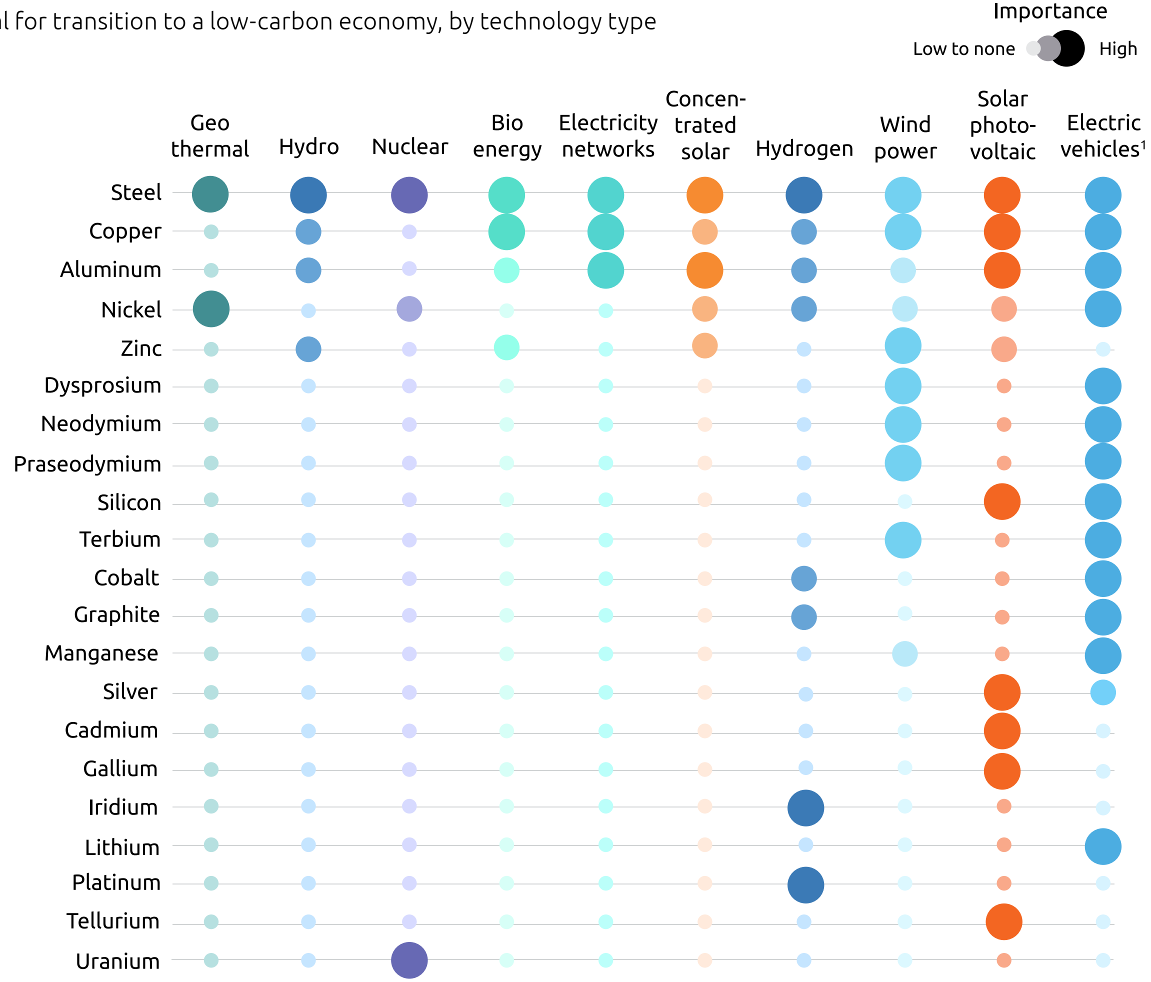
The world's mineral raw materials are known to be of great economical value and are vital in our modern and emerging society. For example, minerals are crucial to battery performance, longevity and energy density, as well as for wind turbines and electric vehicle (EV) motors, as stated by the International Energy Agency.

Mineral reserves, such as iron, copper, nickel, cobalt, graphite, rare earths and lithium, are spread across the globe. The top producing countries in extraction vary by mineral type, however China is one of the largest producers of many of the world's critical minerals. Following China, the United States, Australia, Russia, India, Brazil and Canada are recognised as key producers. Other countries such as Chile and the Democratic Republic of the Congo are large producers of specific minerals, lithium and cobalt respectively.

Location of minerals plays a key role in solving for decarbonization, as it can present a different set of challenges per geography, such as physical change to climate increasing the risk of assets.

FIGURE 3

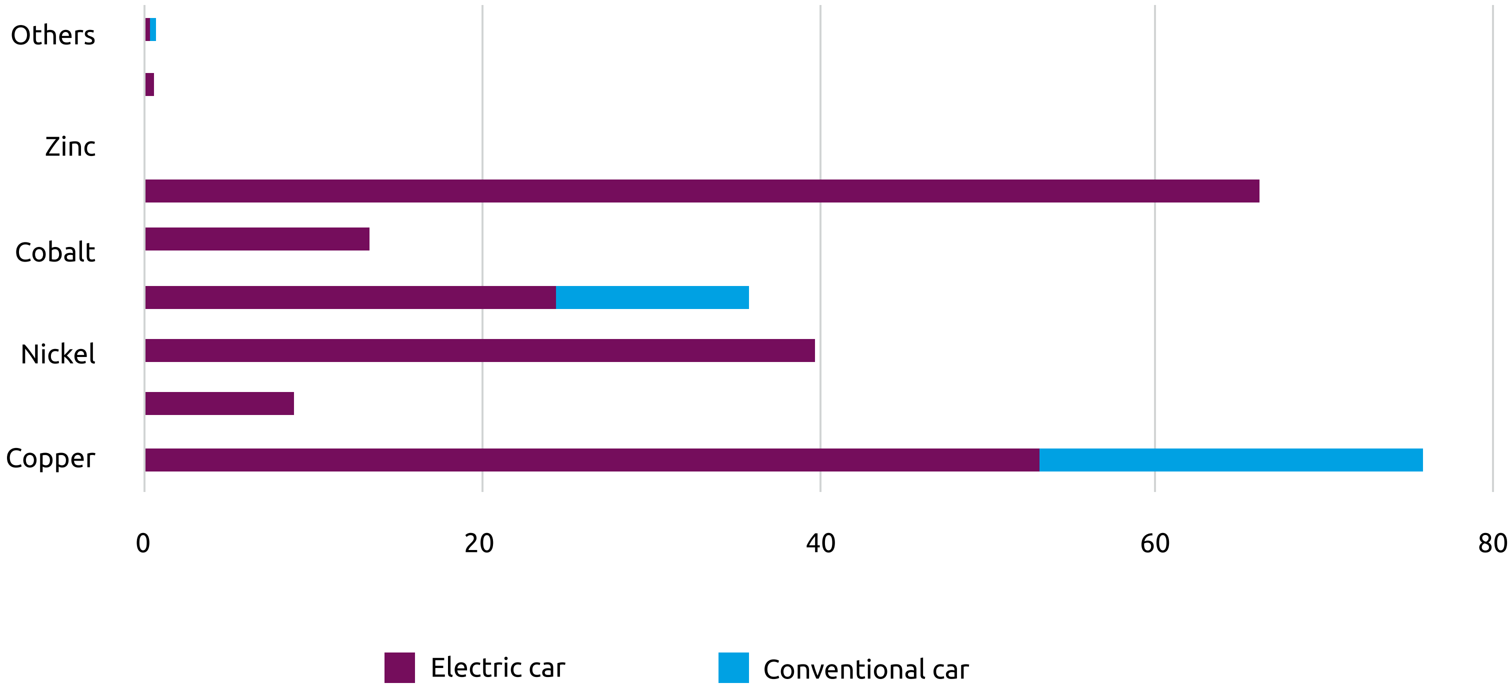
Materials critical for transition to a low-carbon economy, by technology type



Source: McKinsey and Company, January 2022, https://www.mckinsey.com

FIGURE 4

Minerals used in electric cars compared to conventional cars (kg/vehicle)



Source: IEA

Consideration #2: Geo-political factors

The last 18 months has shown us the impact that conflict between two or more countries can have on the world, the flow-on effect to global businesses and the influence on our societies and practices.

The ongoing conflict between Ukraine and Russia, the increasing tensions between USA and China, and rise in resource nationalism are felt by miners as they continue to be under pressure to resolve supply-chain challenges and transform rapidly.

Geo-political influences can have further implications for countries with emerging policies. For example, countries looking to nearshore critical minerals under new policies or legislation may result in inclusion of some but not all countries. Where countries are not aligned on new policies, this opens the door for other players, introducing increased competition.

Periods of geo-political instability increase the risk of disrupting or reducing interdependencies between countries, particularly those that have standing agreements in place.

Amidst these rising challenges, how can we work together to make the required minerals available for decarbonization technologies?

With challenges, comes opportunity. There is a large focus on energy transition, and 'going green', meaning there is an increase in scope for investment in geographies that are rich with critical minerals. Further, countries can take advantage of changing geo-political environments to advance trade agreements and increase collaboration across mining extraction and production. Governments also have a key role to play here, by building stronger ties with other countries and industry / sector groups, and in turn developing shared policies, behaviours, and methods to safely transition.

G20 Nations Summit are the driving force for leading the brighter path for humanity and the 2023 summit focussed on three themes:

1. Climate Change

2. The Blue Economy

3. Resource efficiency and circular economy

Consideration #3: Nationalization/sovereignty of resources

In late April 2023, Chile's government announced a major policy change to its lithium mining industry. The new policy will require private organisations to partner with the Chilean government for the development of all future lithium mines. Some have termed this as a 'nationalization' effort, others see this as a balancing act retaining involvement from the private sector.

The Chilean government has proposed to create a new state company, National Lithium Company, and will follow the existing model of Chile's state-owned copper company, Codelco.

The policy change will set a precedence for the rest of the world, particularly as critical minerals become a key focus for many, such as lithium. Whilst Chile falls behind Australia as the leading producer of Lithium, they are still a significant contributor to the global lithium supply chain.

The national approach will likely require private companies to agree to new terms, focusing on reducing or eliminating environmental damage, providing improved conditions for workers, increasing consultation and engagement with Indigenous and local communities, and utilising new technologies. Regarding the concept of exporting raw materials versus producing the finished product within a country, it's important to recognize that the worth of the end product, such as a battery, can significantly surpass the value of the initial raw material, like lithium, often by a factor of 100 or more.

With the shift, there is an inherit risk for Chile and other countries that follow this pathway – Foreign investors and mining companies may look to other countries for lithium opportunities, if Chile is regarded as less attractive. This may open the door for Argentina and Bolivia, who make up the 'lithium triangle' together with Chile. On the other hand, opportunities exist for countries to enter into treaties and agreements. For example, the US-Chile tax treaty that has been recently approved by the US Senate, in turn resulting in tax rate reductions and other benefits, enabling greater US involvement in Chile's lithium industry.

Consideration #4: Recyling

With the need for critical metals accelerating, there is a need for recycling and sustainable practices across the value chain. Recycling will also support the need to reduce carbon emissions. The carbon footprint of recycled material is much lower than the original material.

New legislation, such as the **European battery passport**, are making recycling compulsory. The industry needs to come together to ensure recycling is standardised across the value chain.

"Black mass" is obtained when dismantling batteries and it is made up of many recoverable rare metals and separated into ferrous and non-ferrous materials. The S&P Global launched regular pricing of this material in 2023 and the carbon footprint of recycled materials has a much lower carbon footprint than the original material itself.

The graph below shows the Ni and Co Black Mass calculated prices in $ per metric ton for Europe and US, and Yuan per metric ton for China.

Technology progress and the mineral recycling process can bridge the gap and create a balance between rare mineral consumption and the high cost of such materials.

FIGURE 5

Recycling process for Li-Ion batteries

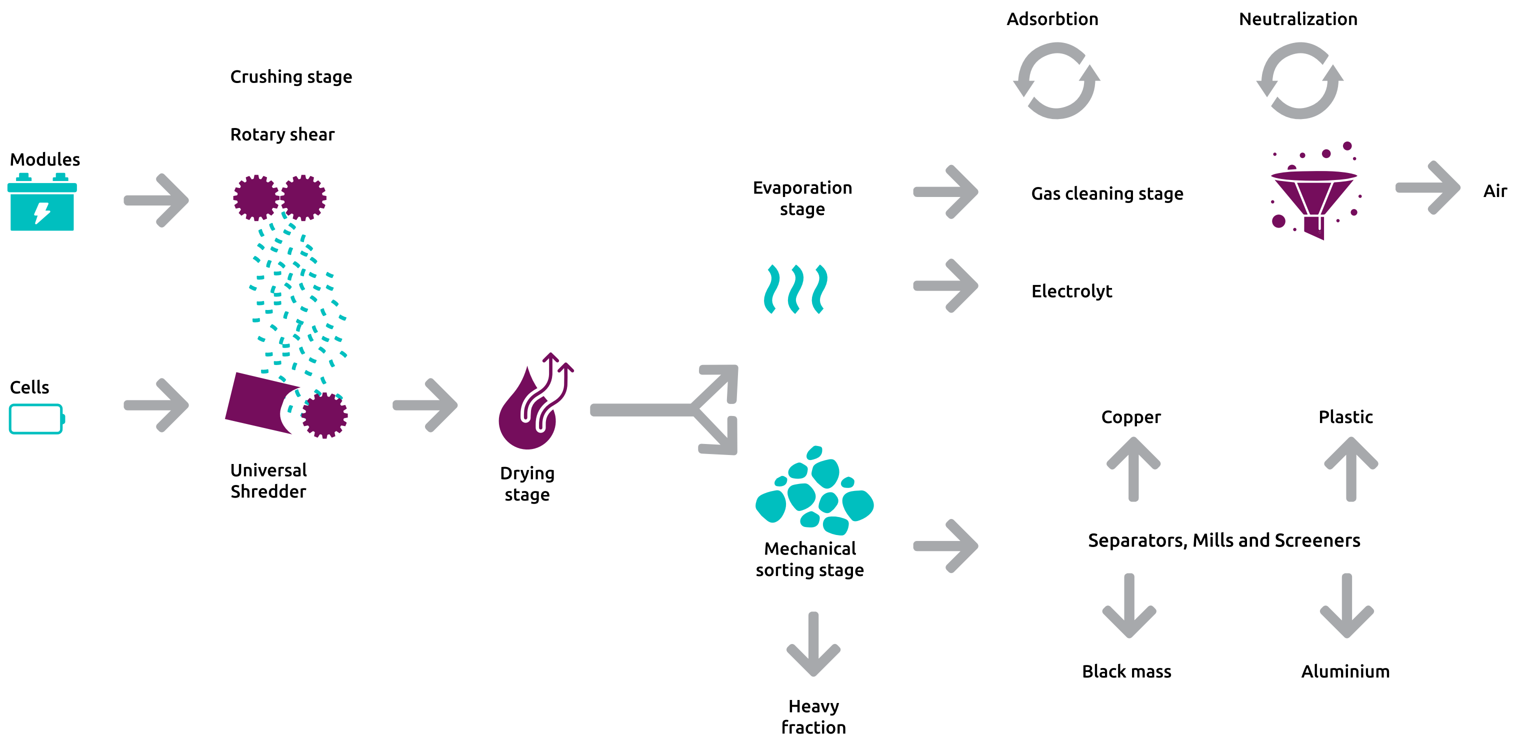
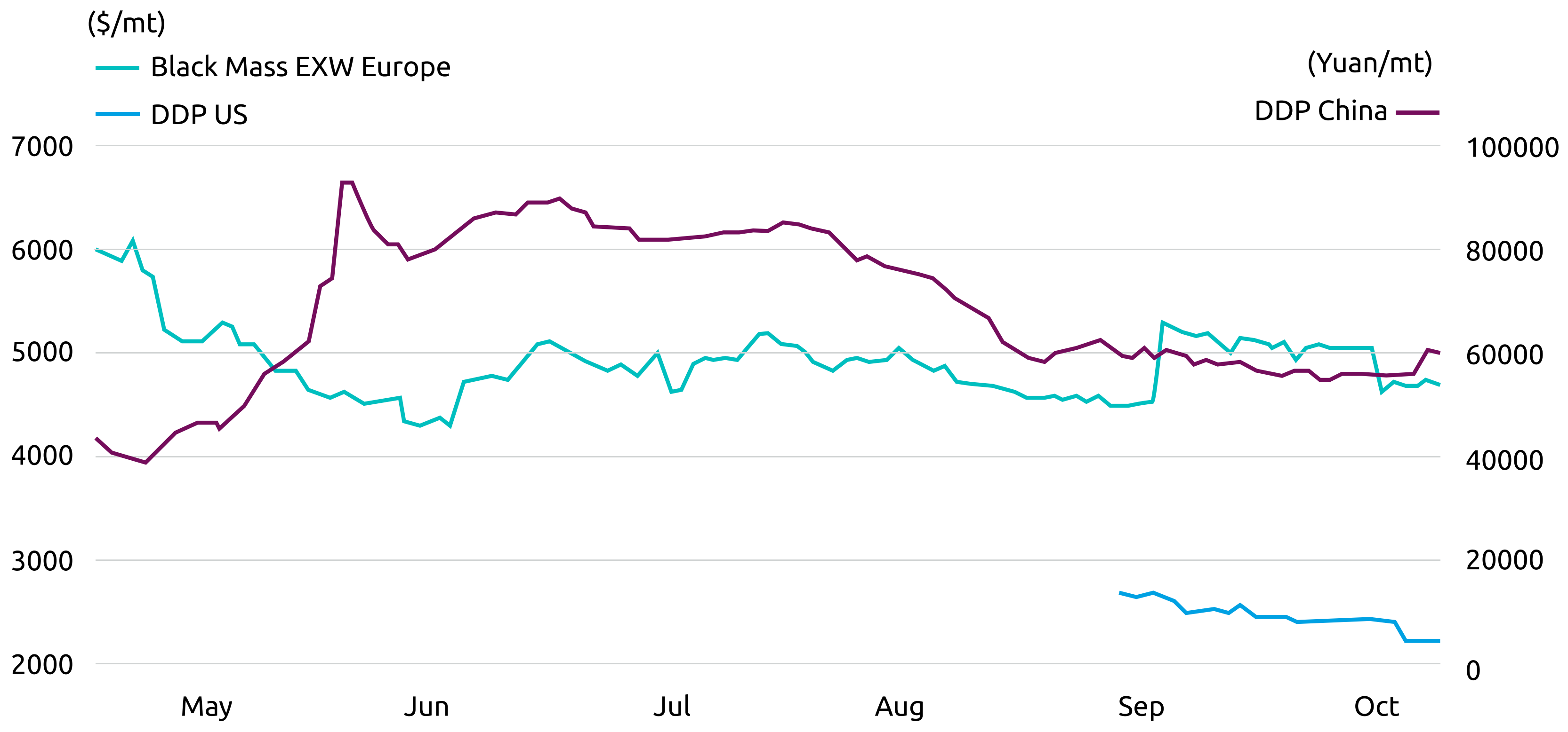


FIGURE 6

Platts global Ni-Co Black Mass calculated prices



Conclusion

These considerations must be explored to increase availability of critical minerals to reduce the impact of climate change around the world. We should acknowledge the complexity and scale of the challenge at hand, noting this cannot be solved for in isolation.

It is understood that we must mine additional minerals to create the technologies we need to decarbonize. We have started to see examples of increased collaboration between countries to support this, however further work is required to establish practical consortiums and working groups.

We've gone past the stage of simply setting and forgetting goals, we must re-visit and bring them to life through action. We must also remember that whilst this is a global effort, we must continue to engage with local communities to minimise impact from a people, and biodiversity perspective.

We can only ascertain the minerals we have available on earth if we work together, to build the future we want for ourselves and those that come after us.

We recommend starting the conversation now.

Call to action

- **Government and policymakers –** Designing the policies and processes from the nation's ability to maximise the resources for the change we are experiencing around energy transition, to add the most impactful value. Invest in value creation for the respective country.
- **Miners and refiners –** Collaborate and engage across industries to drive meaningful change and ensure that the critical mineral resources we need are available to produce the technologies to reduce the impact of climate change. Moving away from the traditional approach and harnessing the technology for the benefit of future generations.
- **Industrial consumers -** Manufacturers in the clean energy and automotive sectors have a range of choices within their supply chain when it comes to sourcing minerals. They have the capacity to strike a harmonious balance between ethical considerations and economic value, thereby ensuring both the sustainability of their industry and the well-being of their organization.

FINDING OPPORTUNITY IN THE HEAT TRANSITION

SIMON BROD, NETHERLANDS

Energy use in buildings is a major source of CO_2 emissions worldwide, representing 27% of global energy and process-related emissions. Buildings used 135 EJ of energy in 2021. Space and water heating is responsible for a little under half of this (62 EJ), producing around 2.5Gt of CO_2 as direct emissions from burning natural gas, oil, or coal consumed on site. A further 1.5 Gt was emitted from district heating plants and power stations serving buildings with heat and electricity for heating. The amount of energy used in space and water heating is equivalent to roughly 60% of the electrical energy consumed worldwide.[1]

Some 40% of the world's human population lives in areas where some kind of space heating is needed. Residential heat load is expected to remain stable in coming decades, while the number of large buildings needing heating is expected to increase. Of the world's energy consumption for space and water heating, some 50 to 60% is in advanced economies. Around half the heat load is represented by households.[2]

This article focuses on heating rather than heating and cooling. While cooling load is expected to increase, and will bring its own challenges, most cooling systems are electrical, with no CO_2 emissions at the point of use. In contrast, a large share of heating systems burns fossil fuels directly. This is where decarbonisation efforts are urgently needed.

1 All based on IEA, 2021 data and https://www.iea.org/reports/the-future-of-heat-pumps
2 https://www.iea.org/reports/the-future-of-heat-pumps
3 https://www.iea.org/reports/the-future-of-heat-pumps

Electrification is essential

Many approaches have been proposed for the heat transition. There are overwhelming advantages to tackling it through electrification:

- **Most countries already have a goal of increasing the penetration of renewable energy sources (RES) in their energy mix.** By making heat load electric, decarbonisation will take place along with the rest of the electricity system. A desirable side-effect is reduced dependence on imported energy. Countries with a high penetration of zero-carbon energy (such as Norway and France) already use electricity for space heating, as this was historically their cheapest option. This situation will become widespread around the world over the next few years, as almost all countries increase the share of renewables in their electricity mix.

- **Efficiency will increase.** Electrification enables deployment of heat pumps which are much more efficient than direct heating, thus reducing load on the energy system as a whole. Heat pumps can provide as heat two to five times what they consume as electricity, enabling significant amounts of heat load to be electrified without a corresponding increase in electricity generation and transmission capacity. Currently, heat pumps provide around 8% of heating worldwide. This will rise to over 50% by 2050, according to the IEA's 'net zero' scenario[3]. Each year, more than 1% of heating systems worldwide will need replacing, representing tens of millions of installations per year.

- **Demand flexibility from heating will be available to the electricity system.** Deploying millions of electrical heating devices offers the potential to modulate electricity demand (for example, by allowing indoor temperature to vary within certain limits, or by storing energy in the form of hot water), helping the grid manage large amounts of variable RES generation cost-effectively. Such smart technology can be used to reduce the need for capital-intensive grid strengthening.

There are technologies which can help decarbonise heat supply without electrifying – such as green or blue hydrogen, biomass, biogas or geothermal. These can be attractive if they reduce the need to invest in new infrastructure (for example, some countries such as the UK and The Netherlands are considering repurposing existing gas networks for hydrogen). None of these technologies is suitable beyond niche applications. For example, using biomass as a fuel can make sense in areas which already have a heat distribution network and access to properly sustainable biomass. Using green hydrogen as a fuel can make sense in areas that already have a large surplus of renewable electricity at all times which can be used to generate hydrogen. Producing biogas at scale competes with food production, which limits its availability. Geothermal heat can only be safely accessed in certain places. Blue hydrogen might provide a temporary step towards decarbonisation but is only a partial, costly solution, and its use will delay measures which can fully decarbonise our energy system.

Waste heat from industry, water treatment, data centres, and the like, is a large, potentially cheap resource. In Europe, some 2.5 to 9.8 EJ/year of such excess heat may be recoverable[4], while space and water heating demand is 13.1 EJ/year[5]. In areas where a district heating grid already exists, such heat sources should be used where possible. Areas without a heat distribution network will need to carefully consider the costs, risks, and benefits of investing in one. District heating currently supplies some 10-15% of Europe's heat load.

The heat transition will be accomplished largely through electrification. In certain places, local conditions will make it cost-effective for electrification to be combined with other technologies.

4 https://heatroadmap.eu/wp-content/uploads/2019/04/Urban-Persson_Halmstad-University.pdf
5 https://heatroadmap.eu/wp-content/uploads/2018/09/STRATEGO-WP2-Background-Report-4-Heat-Cold-Demands.pdf

Multiple challenges and opportunities must be addressed

At the level of the individual house or building, the optimal solution varies widely, even within the same neighbourhood. For example, in the Netherlands city of The Hague, only 50% of housing units are suitable for a heat pump without other modifications[6]. Those that are not suitable may need insulating first or may need to modify their heating system in other ways. Innovations such as high-temperature heat pumps extend the range of homes which can easily be upgraded. But many homes face the cost and disruption of a major refurbishment. A typical ground source heat pump retrofit for a house costs US$10,000 or more. Costs can be far higher when combined with other modifications to the heating system or the building. The wealthiest households can afford this, but for a mass roll-out to take place, financing needs to be provided. Large buildings will see lower specific costs than individual households, thanks to economies of scale.

If large numbers of houses are to convert to electrical heating the electric grid will need strengthening. This can partly be mitigated through local energy storage in batteries or as hot water, enabling the neighbourhood to smooth its demand over time and even absorb surplus energy at times of high wind and solar electricity production. Coordination at a neighbourhood or city level also opens new possibilities to reduce system costs - for example, making the complex trade-off between running larger, central, heat pumps combined with a heat distribution network, and having a separate heat pump for each building.

In tandem with electrification, in some neighbourhoods it will be possible to use other sources of zero-carbon heat. Geothermal sources are accessible in some areas. And certain waste heat streams from industry can be recovered. For example, Meta's hyperscale Tietgenbyen data centre in Odense, Denmark is donating waste heat into the local district heating grid, providing energy to warm more than 11.000 homes[7]. Such use of waste heat is a good way to decarbonise but requires homes to be connected to a (local) heat grid. In specific situations building such a grid can make economic sense.

The economics today are marginal

Subsidies are needed. The US government has earmarked USD 8.8 billion for home energy efficiency and electrification projects, aimed at low- and mid-income homes[8]. In Europe, subsidies vary per country, and are typically in the range of Eur 3.000 – 10.000 per heat pump installation[9]. Subsidies come mostly in the form of one-off grants, and are not explicitly linked to CO_2 emissions reductions. Estimates of payback times for a typical single-household heat-pump project in The Netherlands[10] are:

Without subsidy	12 to 18 years
With current level of subsidy	8 to 13 years
With current level of subsidy and with CO_2 emissions reductions priced at 100 Eur/tonne	7 to 10 years

Experience with rooftop solar panel deployment in Western European markets indicates that, where financing is available, a 5-to-7-year payback time is sufficient for households. Large buildings will see better returns as the specific capital costs are lower for large systems, but business owners will have more stringent return requirements for making an investment.

6 Capgemini analysis, 2022

7 https://datacenters.atmeta.com/wp-content/uploads/2023/05/Denmark-Odense.pdf
8 https://www.energy.gov/scep/home-energy-rebate-programs
9 https://www.ehpa.org/wp-content/uploads/2023/03/EHPA_Subsidies-for-residential-heat-pumps-in-Europe_FINAL_March-2023.pdf
10 Based on: https://www.verbeterjehuis.nl/verbeteropties/volledig-elektrische-warmtepomp/

What can be done?

Given the marginal economics, it makes sense to seek to reduce costs. There are many opportunities to capture economies of scale in carrying out the heat transition:

- **Standardisation:** if a whole city settles on a limited number of equipment choices, it will be able to negotiate better with equipment makers. There will also be savings in training installation and maintenance staff, in the time taken to install, and in the quality of the work.
- **Labour efficiency:** if building upgrades can be coordinated, then installation programs can move from district to district, carrying out upgrades as a well-structured industrial process.
- **Lower specific costs:** whatever technology is chosen, a general rule is 'the larger the equipment, the lower the capital and operating costs per unit of heat supply'. Pooling heat demand can make the difference between a marginal project and an attractive one.
- **Financing:** if large numbers of upgrades can be packaged together as one program, run by a reputable entity, it will be easier to attract debt finance.
- **System-wide cost-effectiveness:** if the energy system of a whole neighbourhood or city can be considered, rather than each building making an independent decision, optimal choices can be reached with respect to how central or distributed heat production should be, how much energy storage to include, whether to build electricity or heat microgrids and at what scale, and any additional energy sources to use.

To roll out new heating systems on a large scale, it will be necessary to mobilise households. What can be done to increase people's willingness to invest and to endure disruption? The most important driver is the extent to which homeowners perceive tangible benefits. For example, a study in rural India found that owners of homes that were not connected to a water supply were willing to pay a higher price than expected to get access to piped water. Willingness to pay was above the regulated price of water and was sufficient to justify the necessary investments in infrastructure[11]. When the benefits are as obvious as those of having clean water on tap, people want to pay. Conversely, a study in France of homes at risk of flooding found that most homeowners were reluctant to invest in even modest flood protection measures (such as installing non-return valves in sewage pipes), or to rearrange their home to reduce risk (for example, moving a kitchen from the ground floor to an upper floor). By far the most important determinant was the homeowner's perception of risk. Many felt the risk was remote or non-existent. Those that did feel at risk were willing to make the necessary changes.[12] Against this background, climate change emerges as a weak driver for most people. The risks seem remote and uncertain, and the benefits of decarbonising will be felt in the relatively distant future. Perhaps, with growing evidence of climate change making news headlines, more people will take the risks seriously.

Experience in the energy retail market suggests only a limited section of the population is prepared to pay more for renewable energy – perhaps 5% to 10% of households. This group can be increased by creating a sense of belonging and by giving people something to be proud of – being seen to be doing the 'right thing'. For example, Powerpeers created an energy sharing community with tens of thousands of members in The Netherlands. An important success factor was to find and mobilise local 'champions' to spread the message and act as trusted ambassadors. Such enthusiastic, intrinsically motivated community leaders can help create a feeling of belonging and re-set people's ideas of what is normal, boosting participation even when there is no financial return.

11 https://documents1.worldbank.org/curated/en/439161468034759169/pdf/447900PP0P09411413B01PUBLIC10PAPER1.pdf

12 https://onlinelibrary.wiley.com/doi/10.1111/jfr3.12696

What might change the game for the better?

Certain events will help the heat transition, if they take place:

- **Technical innovation** around equipment such as heat pumps, and around smart system controls, could bring costs down and performance up. The world will more than double its fleet of heat pumps in the next 10 years[13]. Such large-scale deployment is likely to stimulate innovations that yield significant improvements.

- **Dramatically higher fossil fuel prices,** relative to electricity prices, will give project returns a boost. Barring geopolitical shocks, there is little prospect of this in the short-to-medium term. Long-term electricity prices are expected to fall, as the share of low-marginal-cost generation (such as wind, solar, or nuclear) increases.

- **A turning point in public sentiment,** caused by increasing climate-related disruption, would signal a step change in willingness to invest.

- **More decisive government action,** such as mandating the deployment timetable rather than relying on the market, could increase progress dramatically. While some western governments are starting to ban fossil-fuel technologies for home heating (for example, The Netherlands[14]), it is inconceivable that they would impose on citizens a centrally planned program of building upgrades. Autocratic regimes such as in China may make this possible.

Any of the above could significantly accelerate the heat transition.

What steps should local communities and governments take?

Collective action is essential, otherwise heating system upgrades will be deployed piecemeal. By orchestrating the roll-out of upgrades and carrying them out at scale, the transition can happen faster and more cheaply. What does that require?

1. **Form a broad group** to evaluate and come up with a plan. Include citizen representatives, and local government, real estate, construction/refurbishment/installation industry, energy grid, energy supply, and finance sectors.

2. **Run educational campaigns** to inform people about climate change and about the benefits of decarbonising their homes. Find community leaders eager to champion the cause.

3. **Map the building stock** and evaluate solutions appropriate at neighbourhood level. Ask the following questions: How well insulated are buildings? What kind of heating system do they have? Are they suitable for a heat pump, and if so what kind? How much local RES is there? What are the constraints of the electricity grid? How much disruption will citizens accept for what reward? What opportunities are enabled for job creation and re-skilling? Consider different possibilities systematically, taking into account the costs and benefits for the whole system. Seek optimal solutions at a neighbourhood or city level.

4. **Standardise solutions** where possible for economies of scale, but make sure solutions work for all. Some buildings may simply be uneconomic to upgrade; focus on what can be easily achieved.

5. **Create a plan which addresses citizens' needs.** Ask the following: how will disruption be kept to a minimum? What benefits will they get?

6. **Take the time to publicise the plan and engage citizens.** Slow and thorough at this stage saves effort and delay later.

7. **Set up a competent body to oversee the program,** once you decide to go ahead and execute.

13 https://www.iea.org/reports/the-future-of-heat-pumps
14 https://www.rijksoverheid.nl/actueel/nieuws/2022/05/17/hybride-warmtepomp-de-nieuwe-standaard-vanaf-2026

Around the world, examples are multiplying where local communities have gone through some version of this process. Here are two examples which illustrate different approaches:

- **Republica microgrid, Amsterdam, The Netherlands –** The community consists of 74 apartments, office space, a large hotel, leisure facilities, a parking structure, and a restaurant space. Republica has become its own private grid operator, with both heat and electrical microgrids. Heating is provided by central heat pumps. A central battery enables the community to minimise its demand on the regional electricity grid while maintaining comfort for community members. The community benefits from consuming locally generated energy, lower tariffs, and lower energy costs.[15]
- **Heat the Streets scheme, Stithians, England –** hundreds of homes are being connected to a shared network of underground pipes which provide ground source heat. Individual households are spared the cost of this element, reducing the cost of their home heat pump installation by nearly two-thirds, and eliminating the need to modify their home heating system. In return, participants pay a fixed monthly fee for being connected to the network. This concept was initially championed by local residents and was awarded a GBP 6.2 million grant by the European Regional Development Fund (ERDF).[16 17 18]

15 https://spectral.energy/project/republica-microgrid/
16 https://www.kensautilities.com/
17 https://heatthestreets.co.uk/
18 https://www.theguardian.com/uk-news/2022/jun/22/cornish-village-to-pilot-communal-grid-to-source-low-carbon-energy

What is likely to happen in practice?

In the advanced economies, political will is growing (not least because electrification of heating also increases energy independence). It is expected those economies will reach perhaps 30-40% of what's needed for net-zero in 2050. For this group of countries, the task is largely one of retrofitting existing buildings with new technology. The heat transition will progress fastest:

- **In places with environmentally minded populations and wealthy governments** (think Austria or Denmark). Here it will be easier to align all stakeholders and provide sufficient subsidies.
- **In places with large amounts of government-controlled social housing** (for example, Denmark or The Netherlands). This is often owned and managed at scale already, removing a big hurdle to systematic roll-out of new heating systems.
- **Among wealthy households.** This segment can afford the necessary investment and is more susceptible to wanting to be seen to 'do the right thing'.
- **Among commercial buildings.** Professionally managed buildings will upgrade whenever there is a competitive return on investment. They will act quickly to take advantage of (perhaps temporary) fluctuations in energy prices, or advantageous subsidies.
- **Among communities of residents.** Community schemes will proliferate wherever citizens feel motivated. Gradually citizens' groups and local governments will acquire the skills needed to execute the transition.

Developing countries will likely not have much appetite to invest in retrofits. But as growing economies, their building stock is increasing. If new buildings are fitted with zero-carbon systems, this group of countries will succeed in gradually reducing the carbon intensity of heating.

Opportunities will fall to those who combine a careful choice of which countries to do business in, with know-how in community leadership and in operations. Systematic deployment of heating upgrades is a challenge, but the potential scale makes it worthwhile to become expert at it, bringing together the interests of residents, building owners, equipment makers, energy suppliers, energy grids, financiers, and government. This is the biggest value add.

In conclusion, while it is unlikely the world will progress as fast as required to reach 'net-zero' in 2050, some optimism is justified. Technology to decarbonise exists and will improve. Electricity will be cheaper in the long term, making electrical heating more attractive. And, with luck, early success of some large roll-out programs will help shift public sentiment, boosting demand and creating a virtuous circle.

Get in touch with the author at simon@circulusworks.com. Circulus Works brings a commercial mindset to sustainability and the energy transition. We support leadership teams in
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- *executing those strategies through fit-for-purpose change, innovation, and go-to-market processes.*

TRANSITION TO RENEWABLE ENERGY: PROGRESS AND CHALLENGES

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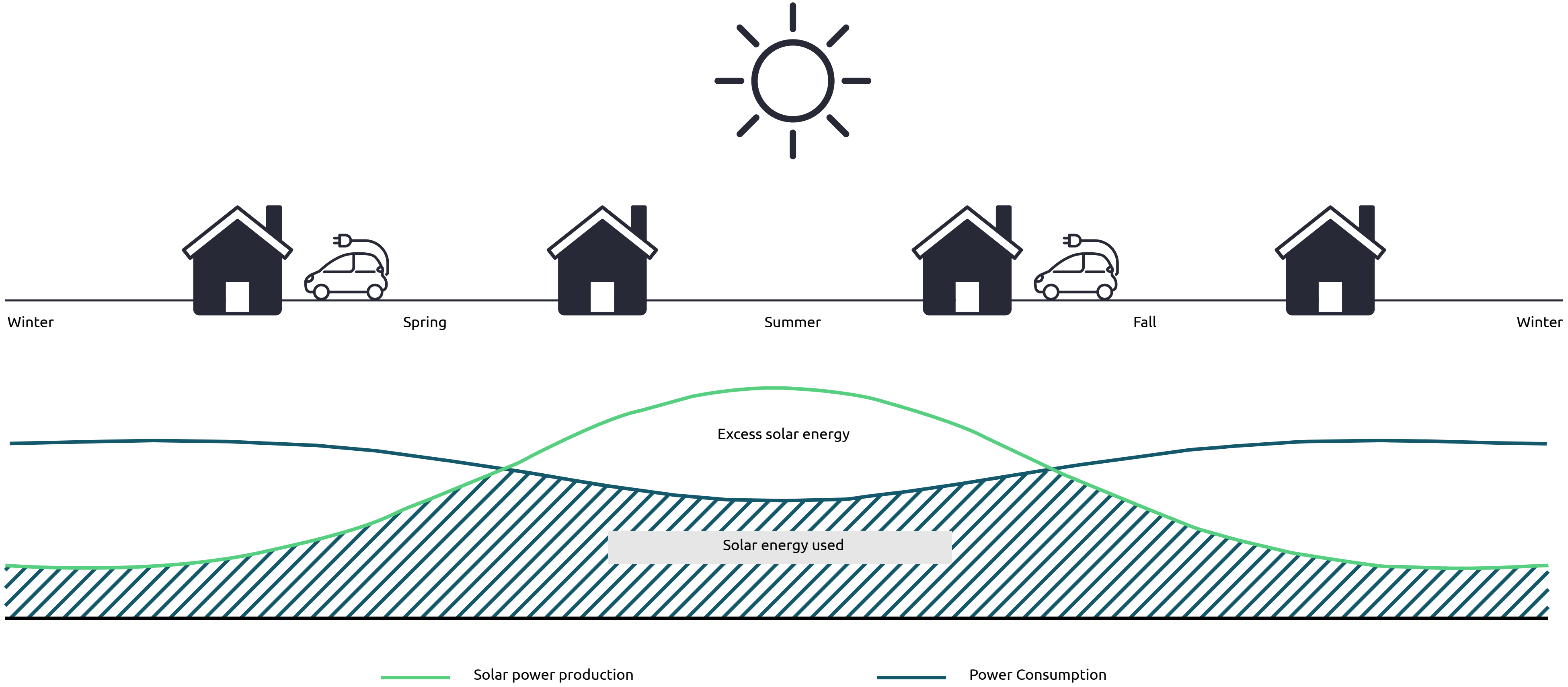
The need to switch to renewable energy production has become increasingly evident as we face the pressing challenges of climate change and environmental degradation. Renewable energy sources, such as wind and solar power, offer a sustainable and clean alternative to traditional fossil fuel-based energy generation. However, the transition to renewable energy is not without its obstacles. In this article, we will explore the progress made so far, the challenges we face when the wind doesn't blow, or the sun isn't shinning and the new business models and technologies that can help mitigate supply and demand gaps.

The energy transition worldwide has been marked by a significant increase in the penetration of renewable energy sources. By the end of 2022, renewable energy sources accounted for approximately 34.7% of global electricity capacity. Concurrently, there has been a phase-out of baseload capacity, such as coal and, to a lesser extent, nuclear power. While this transition is commendable, it presents grid operators with new challenges. As renewable energy deployment increases and fossil fuel baseload generation is phased out, there will be periods of overproduction but also periods of underproduction. In Figure 1, we observe a summer day characterized by abundant solar energy production, surpassing the corresponding demand, resulting in a noticeable mismatch between the two.

Renewable energy generation is inherently volatile and intermittent, unlike traditional power plants that provide constant and stable generation. This volatility can lead to imbalances between production and consumption, jeopardizing grid stability and the security of energy supply.

FIGURE 1

Different production and consumption profiles



Unseen Challenges – behind the curtain

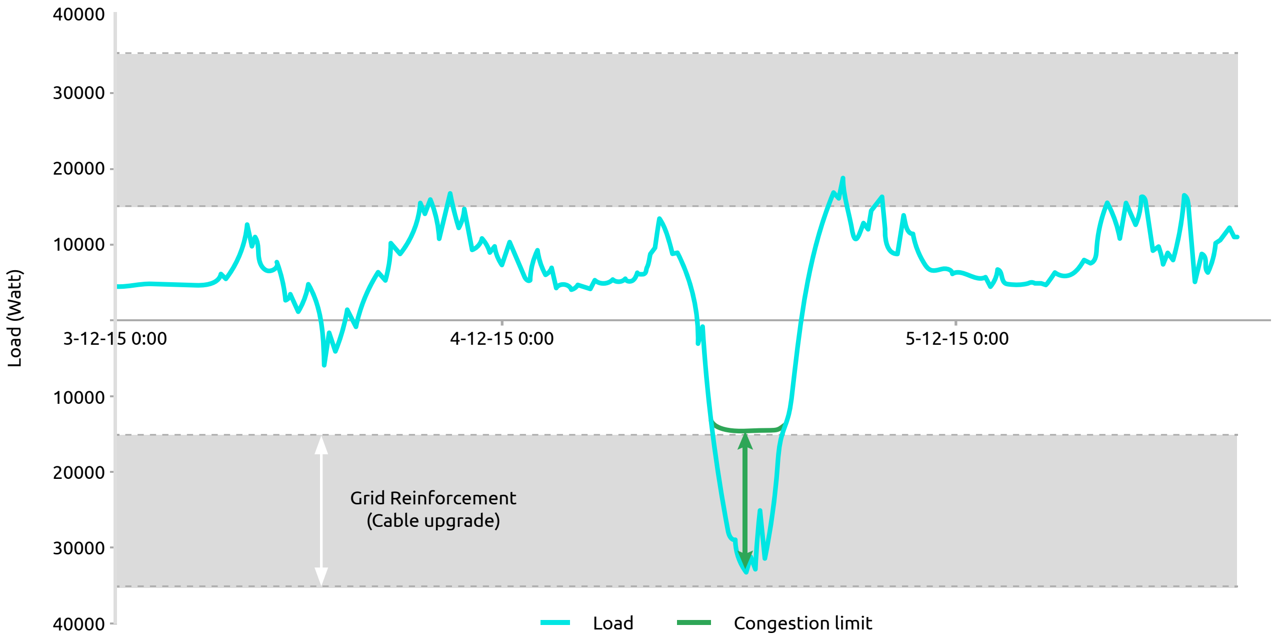
Unlike thermal power plants, which can provide constant generation, renewable sources are dependent on weather conditions. This unpredictability requires accurate forecasting and efficient balancing of supply and demand. When there is an imbalance, several issues can arise. Short-term imbalances can lead to frequency deviations, affecting the lifespan of appliances and causing power failures. Long-term imbalances, resulting from prolonged periods of limited renewable generation, can threaten the security of electricity supply.

The traditional unidirectional flow of electricity from centralized power plants through the grid is evolving. The surplus electricity generated from sources like solar panels now flows back into the grid, resulting in a bi-directional flow. This, along with the increased electrification of mobility and heating, brings forth certain challenges, including grid congestion. Congestion occurs when the load on the grid exceeds its capacity, leading to asset deterioration, higher transportation losses, blackouts, and voltage fluctuations (Figure 2). Connecting new renewable energy sources to the grid is also becoming a challenge in some areas due grid congestion.

Merely reinforcing the grid's capacity is not a cost-effective or sustainable solution in the long run. Reinforcing grid asset implies increasing the capacity of the cables and transformers to ensure the load fits within the capacity of the assets (figure 2). Increasing the capacity of the electricity grid is one way to alleviate strain, but it has limitations. The cost of this endeavor is significant, estimated at …... Also, the process of obtaining licenses and permits for infrastructure upgrades can be time-consuming, leaving the grid susceptible to interim congestion. Moreover, since congestion is temporary and sporadic, relying solely on grid reinforcement is not a cost-effective long-term solution.

FIGURE 2

Grid reinforcement to increase grid capacity and mitigate congestion



However, these challenges also bring opportunities for more efficient grid management through flexibility sources. Flexibility can be achieved through demand-side and supply-side management, such as controlling appliances and industrial processes, decentralized generation sources, and storage. For example, scheduling a heat pump to use excess solar energy during the day helps distribute the load and reduce congestion during peak hours. Embracing flexibility can help alleviate the need for extensive grid reinforcement and support the integration of decentralized renewable energy.

We all have a role to play – the power of large numbers

Customer engagement plays a crucial role in smoothing potential supply/demand gaps. Encouraging consumers to adjust their energy consumption patterns through load shedding and demand-side management can reduce stress on the grid during peak demand periods.

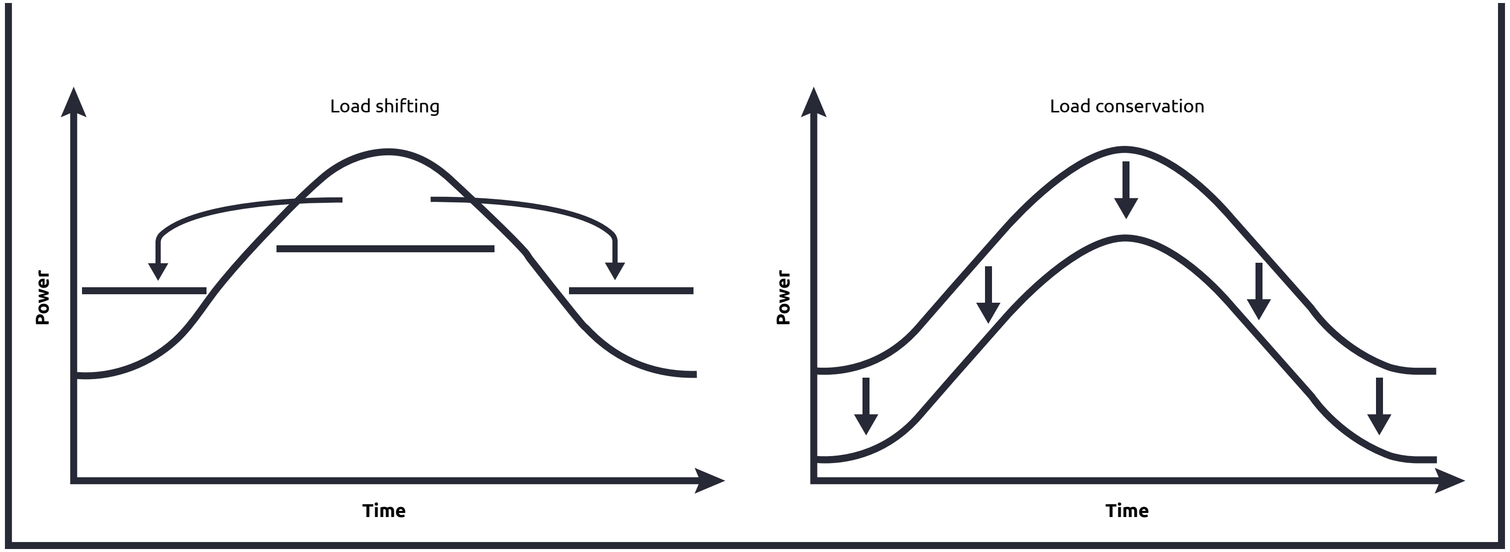
As individuals, it is essential for us to recognize that we can no longer take electricity for granted. For decades, we have enjoyed the luxury of accessing energy whenever and in whatever volume we need, often without questioning its availability. However, it is crucial to understand that traditional power sources are finite and environmentally damaging. If we truly want to transition to more sustainable sources of power, we must fundamentally change our relationship with electricity.

This means adopting a mindset of conscious consumption and recognizing the impact our energy demands have on the environment. We have a role to play in changing our demand patterns to align with renewable energy integration. By adjusting our energy consumption habits and being mindful of peak demand periods, we can contribute to a more balanced and efficient grid. This may involve simple actions like using energy-intensive appliances during off-peak hours or implementing energy-saving measures in our homes and workplaces (see Figure 3).

Furthermore, it is essential to embrace a proactive approach to renewable energy adoption. This can include exploring opportunities to generate our own renewable energy through rooftop solar panels or participating in community energy projects. By becoming active participants in the energy transition, we can help drive the demand for renewable energy solutions and accelerate their adoption.

FIGURE 3

Demand side management techniques



The digitization of power:

Customer engagement is not possible without the digitization of power. Digital technologies have various benefits for the power sector. They enable better monitoring of assets and their performance, allowing for more efficient operations and real-time control. These technologies also facilitate the implementation of new market designs and the emergence of innovative business models.

The widespread adoption of smart meters has already reached over 700 million installations globally, with China alone accounting for around 400 million. Additionally, the Internet of Things (IoT) is expected to connect around 75 billion electrical appliances worldwide by 2025, providing valuable information to consumers, manufacturers, and utility providers.

An example of how digitalization is being utilized is the case of Sonnen, a battery solutions company in Germany. Sonnen has aggregated 30,000 networked home storage systems, allowing them to provide grid services and participate in the country's electricity balancing market.

The role of data and analytics

To address these challenges, new technologies and business models are emerging. Advanced forecasting techniques, powered by artificial intelligence and advanced analytics, can improve the accuracy of renewable energy forecasts. This helps grid operators better anticipate supply and demand fluctuations and take proactive measures to balance the grid.

By leveraging historical data, weather patterns, and real-time information from various sources, AI-powered forecasting models can provide grid operators with valuable insights into future energy generation levels. For example, by analyzing wind speed data, solar radiation patterns, and historical generation data, these models can forecast the expected output of wind and solar farms with a high degree of accuracy.

This improved forecasting capability allows grid operators to anticipate periods of high or low renewable energy generation in advance. Armed with this knowledge, they can take proactive measures to balance the grid and mitigate potential supply and demand gaps. For instance, if a forecast predicts a period of low wind energy production, grid operators can make arrangements to ramp up alternative generation sources or activate energy storage systems to ensure a continuous and reliable power supply.

Furthermore, advanced analytics can help grid operators optimize the utilization of existing renewable energy resources. By analyzing real-time data on energy consumption patterns, they can identify opportunities for load shifting or demand response initiatives. For example, during times of high renewable energy generation, grid operators can incentivize consumers to shift their energy-intensive activities, such as charging electric vehicles or running heavy machinery, to take advantage of the excess energy supply.

Bridging the Gap with Storage Technologies

Investment in energy storage is another key solution. Storage technologies, such as batteries and pumped hydro storage, can store excess renewable energy during times of high generation and release it during periods of low generation. This helps bridge the gap between supply and demand, ensuring a reliable and continuous power supply. Behind-the-meter solutions, including home energy storage systems, can empower individual consumers to become more self-sufficient and reduce their reliance on the grid.

As shown in the graph, there has been a substantial increase in the deployment of battery energy storage systems globally. This growth is driven by factors such as declining battery costs, supportive policies, and increasing renewable energy penetration.

Behind-the-meter solutions, including home energy storage systems, have gained traction as they offer consumers the ability to store excess energy generated from rooftop solar panels or during off-peak hours and utilize it when needed. The graph below shows the growth in residential energy storage installations….

Conclusion

Looking ahead, it is crucial to consider our perspective on the future of renewable energy and whether we are doing enough to achieve a sustainable energy system in time. The transition to renewable energy is a journey filled with challenges and opportunities for efficient grid management. To navigate this path successfully, engaging consumers, embracing flexibility, and harnessing digital technologies are paramount in addressing supply-demand imbalances. With advanced forecasting and cutting-edge energy storage technologies, like batteries, empowering consumers, we have the tools to bridge the gap between supply and demand. By boldly embracing these innovative solutions, we can accelerate the transition towards a sustainable energy future that powers our world.

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