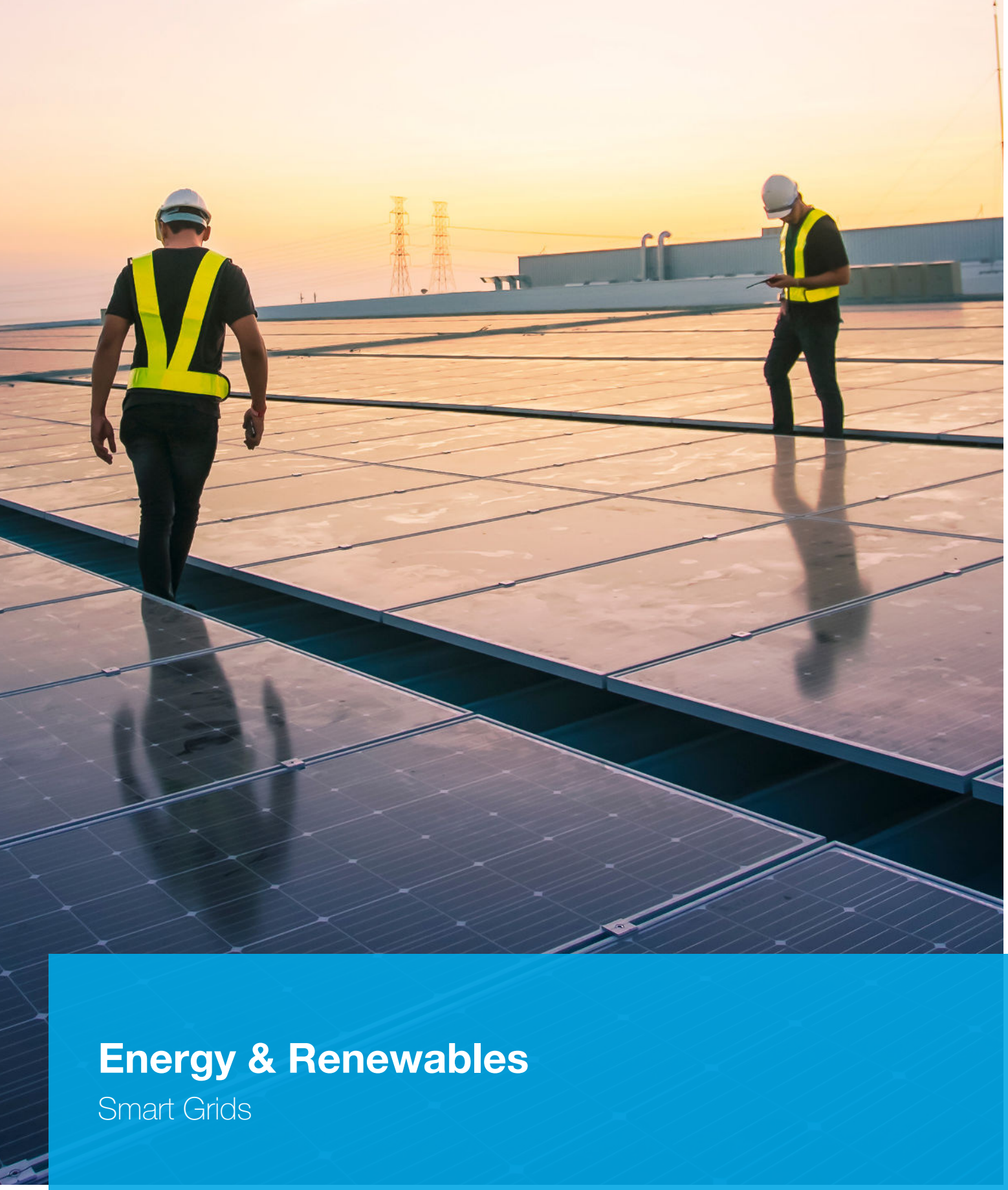

Energy & Renewables

Smart Grids

March 2024

PERSPECTIVES

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Introduction 1

The need for sustainable energy solutions is growing ever more urgent. Increasing concerns revolve not only around climate change, but also around energy security and the escalating demand for electricity from an ever-growing global population.

If we are to limit our impact on the environment, we must meet our commitments to reach net zero emissions by optimising the production and consumption of energy, including limiting the use of fossil fuels.

This goes hand in hand with energy security: where once it was easy to rely on cheap imports of energy from external parties, current geopolitical tensions have cast a pall over international relations, calling into doubt the agreements enjoyed previously.

And as the world's population continues to grow – it is estimated to reach approximately 10 billion people by 2050[1] – electricity demand will grow with it, a trend that will only be exacerbated as populations increasingly urbanise .

Against this backdrop, smart grids emerge as essential components of our future energy framework. These advanced networks seamlessly integrate digital technology with renewable energy sources, revolutionising the generation, distribution, and consumption of electricity.

This article dives into the world of smart grids, exploring their capabilities, the investment landscape, the benefits they offer, and the hurdles that must be overcome to move toward a resilient and sustainable energy future.

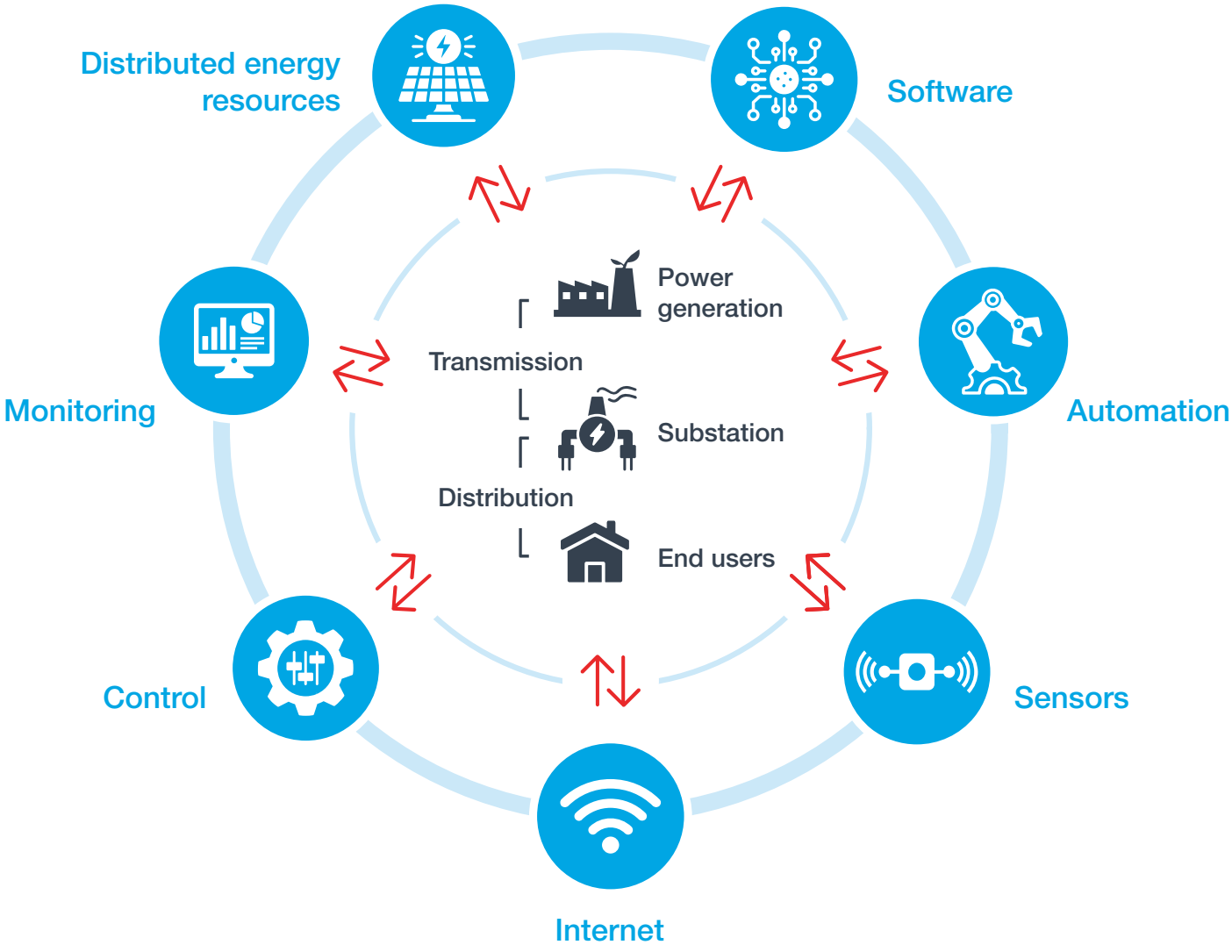
> "Electricity networks are the linchpin of secure and reliable power systems. In the next decade, transmission and distribution grids are projected to garner an increasing share of total power sector investments in the [Net Zero] Scenario."
>
> International Energy Agency

[1] https://www.un.org/en/desa/world-population-projected-reach-98-billion-2050-and-112-billion-2100

2 Smart grids explained

Traditional electricity grid infrastructure comprises two main components: transmission and distribution networks. Transmission grids are responsible for the high-voltage transportation of electricity from generation facilities to substations over extensive distances, effectively minimising energy loss during transit. When the electricity reaches a substation, its voltage is reduced via step-down transformers to ensure safe distribution to end users.

Subsequently, the distribution grid facilitates the delivery of this lower-voltage electricity to consumers, maintaining a predominantly unidirectional flow of power and information from generators to consumers. This conventional model has served as the backbone of electricity supply for decades, yet it inherently lacks the capacity for real-time interaction and adaptability to fluctuating demand patterns.



The transformation from conventional electricity grids to smart grids is driven by the integration of advanced technological components and digitalisation. At the core of this evolution is the deployment of sensors across the grid, playing a critical role in monitoring electrical flows in real time. These sensors enable the precise measurement of electricity supply and demand, facilitating the optimisation of energy output to closely match consumption patterns.

Central to the architecture of smart grids is the implementation of advanced monitoring systems. These systems aggregate data collected by sensors, providing a real-time overview of the grid's performance. Such central monitoring capabilities are instrumental in enabling utility operators to make informed decisions, ensuring the efficient distribution of electricity, and the rapid identification and resolution of any grid anomalies or failures.

A good example of this technology being put to use is the Danube InGrid project. Initiated in 2020, it aims to integrate the electricity markets of Slovakia and Hungary, improving cooperation at both the transmission and distribution levels. As part of the effort to modernise the grid, smart elements are being added and interconnected with an upgraded communication network to achieve more efficient management and network control. The implementation of new IT solutions will also enable the processing of larger data volumes and the optimisation of network operations.

Another advantage of smart grids is their ability to incorporate distributed energy resources, such as wind and solar power, directly into the grid's energy mix. This integration is made possible through sophisticated software platforms that manage the variable output of these renewable sources. By adjusting for fluctuations in wind and solar energy production, smart grids can maintain a steady supply of electricity, even when renewable generation is inconsistent.

Furthermore, local storage solutions can be integrated within the smart grid to capture excess energy during periods of high production but low demand. This stored energy can then be redistributed during peak demand periods, enhancing the grid's ability to dynamically balance supply and demand. The Energypolis initiative in Switzerland serves as a tangible demonstration of the integration of distributed energy resources and storage into smart grids. The campus boasts a range of technologies including solar panels, battery storage, flexible electric charging, heat pumps, fuel cells, advanced monitoring and control systems, and power-to-gas facilities to convert solar electricity production into hydrogen and methane. It proves that the application of smart grid technology for a community is not only possible but also increasingly economically viable.

Additionally, automation plays a pivotal role in the operation of smart grids, streamlining the process of adjusting flows and managing distributed energy resources. Through automation, actions such as rerouting power to avoid overloaded circuits or integrating renewable energy sources into the grid can be executed with minimal human intervention. This not only improves the efficiency and reliability of the grid but also significantly reduces the potential for human error.

3 Benefits of smart grids

Smart grids are revolutionising the energy sector, surpassing the capabilities of conventional grid systems and offering a range of advantages:

Efficiency and reliability

Smart grids minimise energy loss and optimise grid operations by significantly enhancing the efficiency of electricity distribution. Advanced monitoring systems play a pivotal role in improving reliability, swiftly identifying and rectifying faults to expedite service restoration following outages.

Integration and management of renewable energies

Smart grids facilitate the seamless integration of renewable energies, such as solar and wind power, managing their intermittent nature. This contributes to a more sustainable energy mix, thereby reducing greenhouse gas emissions. Enhanced grid management tools provide utilities with better visibility into their networks, allowing for more efficient load balancing and voltage control. They also pave the way for greater use of electric and hybrid vehicles by streamlining their integration and charging within the grid infrastructure.

Cost saving and resilience

By optimising grid operations and enabling demand response programmes, smart grids can result in cost savings for both utilities and consumers. Furthermore, the instrumental role of smart grids in the growth of microgrids enhances the resilience of local energy networks, enabling them to operate autonomously and providing robustness against larger grid disruptions.

With these advances, smart grids emerge as a key enabler of the shift towards a more efficient, sustainable and resilient power system for future generations

Key challenges 4

However, there are challenges facing their global implementation, which can be broadly categorised into three main groups:

Technology

Smart grids, being digital infrastructures, are vulnerable to cybersecurity threats. Achieving compliance with standards and regulations for risk mitigation requires comprehensive technical solutions. Challenges also extend to the integration of microgrids, necessitating advanced algorithms for grid automation and the establishment of effective data management to fully leverage the generated data.

Regulations

Regulatory bodies play a crucial role in grid modernisation. For instance, they mandate utility companies to submit their strategic plans to achieve efficiency, reliability, and sustainability. Regulatory bodies must ensure the alignment of technological advances with existing standards, including data privacy and cybersecurity. Establishing interconnection standards is also critical for the seamless integration of various technologies, as demonstrated by the E4S alliance, a partnership of 21 utilities collaborating to develop an open and interoperable smart grid architecture. Governing entities can facilitate this process by determining and enforcing those standards.

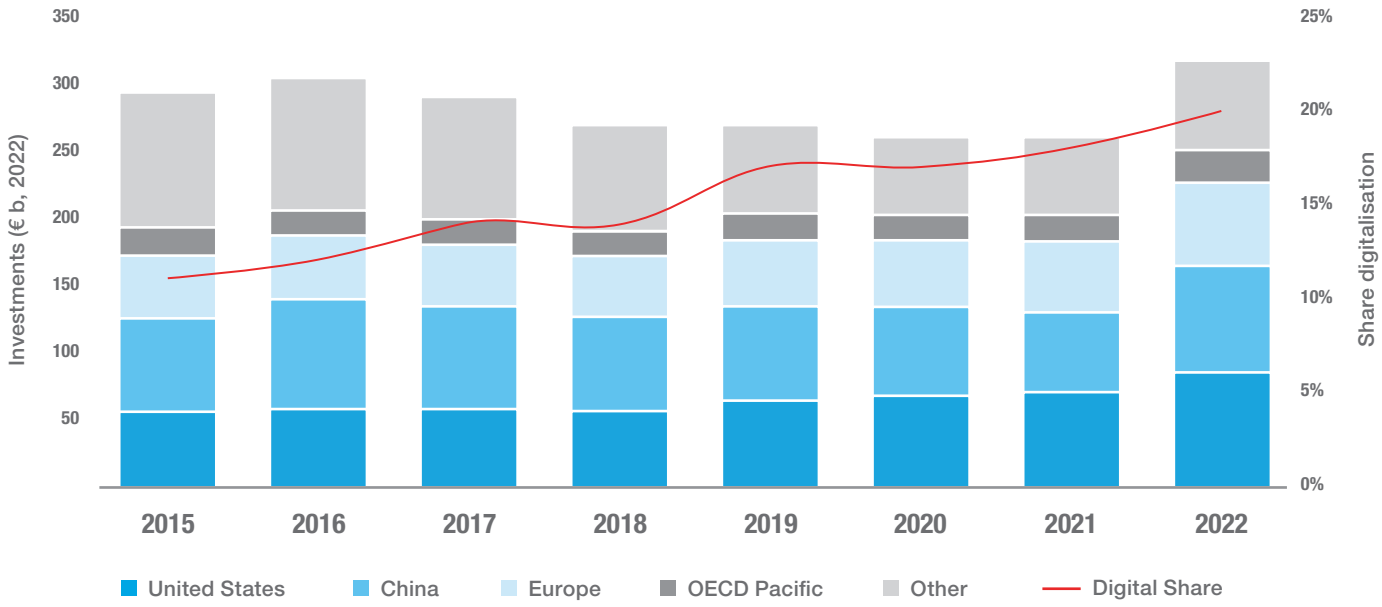
Economics/Costs

The transition to smart grid systems involves a substantial investment in modernising existing infrastructures and adopting new technologies. The long-term return on these investments, coupled with potential economic downturns and budget limitations, poses significant financial challenges. Forming strategic partnerships, such as the Global Smart Energy Federation (GSEF), which promotes collaboration between the public and private sectors, offers a pathway to overcoming these obstacles

5 Understanding investment trends

Let's take a closer look at the investment trends in electricity grids. We can classify them into three main themes: (i) regional differences, (ii) a growing digital focus and (iii) expanding capacity:

Investments in electricity grids



Sources: IEA, DNV, BloombergNEF

There is a noticeable regional disparity in spending. According to the IEA, advanced economies, including China, account for 80% of the total expenditure. In the upcoming years, the European Union is expected to invest €584 billion, followed by Japan, China, and India at a combined €593 billion. The United States and Canada are expecting to spend €10 billion.

Investment in digital infrastructure for smart grids has surged, marking 8% growth from the previous year and highlighting the urgent need to modernise distribution systems that lag in terms of digitalisation. While transmission grids have achieved a high degree of digital maturity, globally the focus is now shifting to enhancing distribution grids, which concentrate 75% of upcoming infrastructure projects.

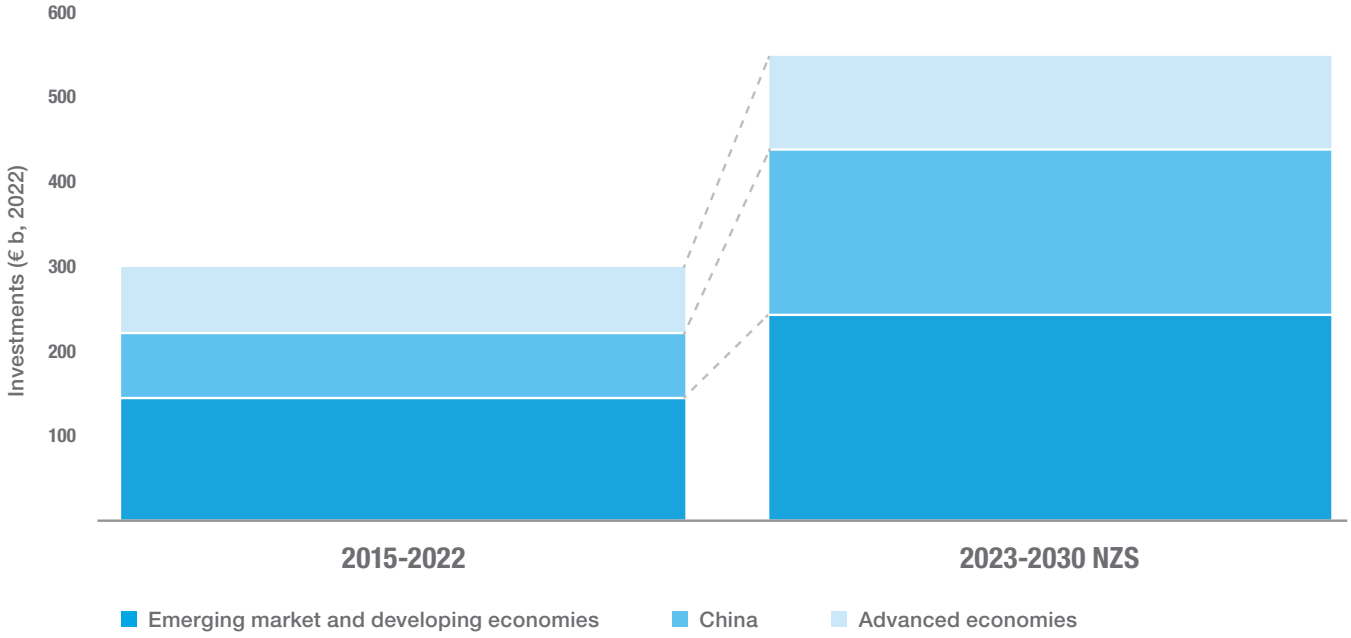
Increasing grid capacity is imperative, given the growing electricity demand, projected to constitute 50% of the global energy mix by 2050 (up from 20% in 2023). To meet this demand, global electricity grid capacity would need to double compared with current levels. The anticipated expansion, reaching 205 million circuit kilometres by 2050, underscores the crucial role of investments in smart grids in shaping a resilient and sustainable energy future.

According to the International Energy Agency, investment in smart grid technologies is expected to increase significantly. This growth is driven by the necessity for more secure and resilient power systems, coupled with the global transition towards renewable energy sources.

Note: [1] As smart grid technologies mature, investment spending serves as a reliable indicator of actual deployment

Indeed, to achieve the goals of the Net Zero Scenario as outlined by the International Energy Agency, a substantial increase in global grid investments is essential.

Required investments to reach net zero



Source: IEA

The current figures indicate that to stay on course, investments must average €560 billion annually until 2030 – a substantial increase from the current €280 billion. Most of this financial commitment is expected from advanced economies and China, projected to contribute approximately €430 billion each year.

However, the investment landscape is volatile. Investment in the electricity grid in advanced economies declined by one-third during 2019–2022 due to the economic impacts of the COVID-19 pandemic. Although a rebound was anticipated post-2022, a yearly shortfall of €100 billion persists, presenting a significant challenge in maintaining momentum towards achieving net-zero emissions. Similarly, China faces a €115 billion annual investment deficit against its required spending under the IEA's Net Zero Scenario, and emerging markets encounter a €31 billion gap.

Note: [1] Advanced economies include OECD countries, Bulgaria, Croatia, Cyprus, Malta, and Romania

7 Conclusion

As we navigate through the complexities of the energy transition, the importance of smart grids is becoming increasingly apparent. By facilitating the integration of renewable energy, enhancing efficiency and bolstering grid resilience, smart grids play a crucial role in guiding us towards a sustainable and carbon-neutral future.

Despite the challenges, strategic investments in and the deployment of smart grid technologies are essential steps in realising the vision of smart cities and a sustainable global energy system. As such, the collective efforts of policymakers, industry stakeholders and communities are vital in harnessing the full potential of smart grids to meet our energy needs while mitigating environmental impacts.

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Contacts

Bianca VAN ZIJDERVELD
Senior Manager

Tel: +31 6 264 618 46
Mail: bianca.vanzijderveld@accuracy.com

Sven VAN WIJK
Associate

Tel: +31 6 453 663 01
Mail: sven.vanwijk@accuracy.com

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