UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION
Progress by innovation

A2D Accelerate to Demonstrate Facility

# MARKET ASSESSMENT ON SMART ENERGY INNOVATION IN DEVELOPING COUNTRIES

## Technology innovation in smart energy in developing countries

Innovation in smart energy (SE) not only plays a vital role for the sustainable development of developing countries but is also essential for decarbonizing heavy industry sectors. SE solutions have the potential to significantly enhance energy efficiency and to reduce costs. Technologies like smart grids, energy storage, and electric mobility are pivotal in accelerating clean energy transitions, improving energy access, and driving economic growth while addressing pressing environmental challenges. Initiatives such as the "Accelerate-to-Demonstrate Facility" (A2D) are instrumental in supporting these efforts by facilitating the adoption and development of advanced technologies.

A comprehensive market assessment covering all 141 countries on the list of Official Development Assistance (ODA) recipients was undertaken to examine five core areas of analysis which are key for the evaluation of opportunities for accelerating smart energy technology innovations: 1) stakeholders, 2) markets, 3) technologies, 4) projects and initiatives, 5) SDGs and impacts.

## Stakeholders

Six critical stakeholder groups essential for advancing SE technologies can be identified: innovators, adopters, controllers, funders, advisors, and influencers.

Innovators, including think tanks, academia, research organizations, startups, and tech companies, are pivotal for initiating and driving the development of new technologies. Adopters, such as end users, SMEs, corporations, and service companies, bring innovations to market. Controllers, including government and regulatory bodies, set policies and provide initial funding. Funders, such as banks and investment funds, provide capital for R&D and technology deployment. Advisors, including NGOs and industrial associations, engage communities and share best practices. Influencers, including media and social media platforms, raise awareness and drive engagement.

Among the main beneficiaries are local communities and SMEs. Decentralized renewable energy solutions can contribute towards reducing energy poverty and improving living standards and economic opportunities especially for underserved groups and women in rural areas. Large industrial users can also reap great benefits – improved energy access, cost savings, and enhanced operational efficiency – from SE technologies.

**TABLE : Stakeholder groups**

| Stakeholder Groups | Innovators | Adopters | Controllers | Funders | Advisors | Influencers |
|---|---|---|---|---|---|---|
| Role | Develop new technologies, perform data analysis and provide technical expertise | Bring innovations to market, invest in technology development and scale up solutions | Set policies and regulatory frameworks, provide initial funding and facilitate demo projects | Provide capital for R&D and technologies deployment, and mitigate risks | Engage communities, provide on-the-ground support and share best practices | Raise awareness, facilitate collaboration and driving engagement through their platforms |

## Markets

The assessment focused on 28 countries which were identified as providing suitable enabling environments for investment in SE technology innovation.

The selection of these countries considered representation of different regions and income-levels. India, Brazil, Thailand, South Africa and Mexico provide strong policy frameworks that advance the adoption of clean energy technologies and display a commitment to leverage technological advancements with global sustainability and climate objectives. However, few policies specifically address the development and implementation of innovative technology solutions.

Interventions are likely to have the most transformational impacts in countries with well-established relevant policy frameworks, large or rapidly growing populations (e.g. India and Indonesia), high rural population rates (e.g., Kenya and Nigeria), and a strong economic dependence on energy-intensive sectors (e.g., Thailand and Vietnam).

**28 focus countries**

| Africa | Asia | Americas | Europe | Oceania |
|---|---|---|---|---|
| Malawi | Cambodia | Domin. Republic | Moldova | Papua New Guinea |
| Rwanda | India | Costa Rica | Serbia | |
| Tanzania | Jordan | Mexico | | |
| Senegal | Kazakhstan | Panama | | |
| The Gambia | Indonesia | Brazil | | |
| Kenya | Malaysia | Ecuador | | |
| Egypt | Thailand | | | |
| Morocco | | | | |
| Ghana | | | | |
| Nigeria | | | | |
| Mauritius | | | | |
| South Africa | | | | |

## Projects and initiatives

Various national and regional initiatives such as the “REnovables in Latin America and the Caribbean” in the Americas and 24 relevant projects were identified across the 28 focus countries. An analysis of these projects shows that most of them focus on smart grids, are driven by private organizations and utilities, and are largely financed through grants.

- Utilities emerge as key players in SE projects as they are the key adopters and implementers of technologies such as smart grids, and virtual power plants (VPPs).
- The highly innovative nature of the technologies involved has implied that most projects face technological constrains, as well as political and legal constraints which are prompted by privacy and security concerns related to these technologies.
- Many SE projects are supported by government grants as governments seek to promote lighthouse projects which would then attract further interest and investments from other stakeholders.
- Smart grid technologies, especially market enabling mechanisms such as VPPs, attract attention and funding due to their cost effectiveness and enabling character for renewable and distributed technologies. Further, there is a noteworthy degree of activity related to smart grids, which is catalyzed by an increasing need for flexibility and integration of renewables into the grid.

**TABLE: Distribution of identified smart energy projects across key parameters**

| Primary Stakeholder | Primary market constraints | Funding mechanism | Technology category |
|---|---|---|---|
| IGOs 4% | Social constraints 0% | Multiple 4% | Digital technologies 8% |
| Foreign government 4% | Economic constraints 17% | Subsidies 4% | Automation technologies 8% |
| Research institutions 8% | Political and legal constraints 29% | Crowdfunding 4% | Smart grid enablers - Infratech 13% |
| Government owned enterprise 8% | Technological and environmental constraints 54% | Incentives 8% | Smart grid networks 25% |
| Government 13% | | Loans 13% | Smart grid enablers- market mechanisms 46% |
| Private organization 29% | | Equity 25% | |
| Energy utility 34% | | Grants 42% | |

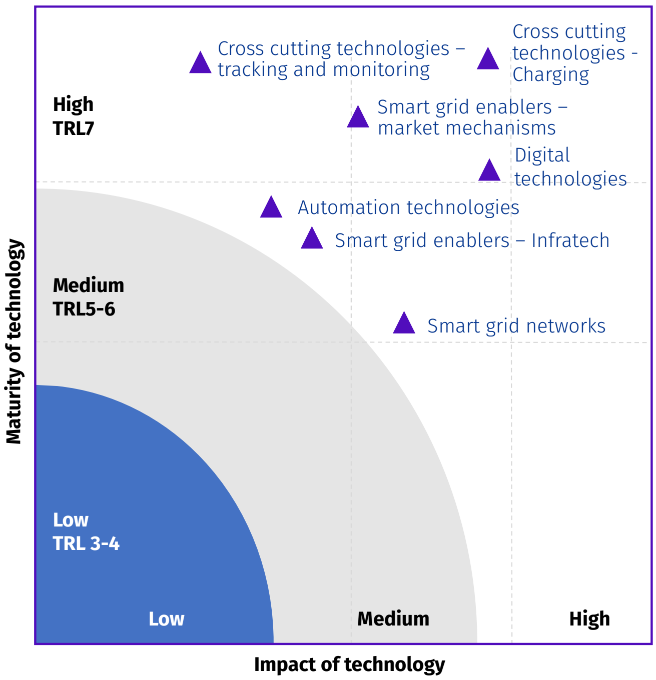
## Technologies

Key technologies include smart grid enabling technologies, market efficacy enhancing mechanisms such as demand response and virtual power plants, as well as digital technologies like Artificial Intelligence (AI), Machine Learning (ML), Blockchain, and Internet of Things (IoT).

- AI optimizes energy usage, predicts maintenance needs, and facilitates renewable energy integration.
- ML improves demand response, detects anomalies, and enhances overall energy efficiency.
- IoT enables real-time monitoring, smart grid management, and remote control of energy systems, ensuring optimized energy use in buildings and across the grid. Together, these technologies drive significant advancements in decarbonizing sectors with high energy demand, promoting sustainability and efficiency.

These technologies are increasingly integrated into energy systems to enhance productivity and improve energy efficiency.

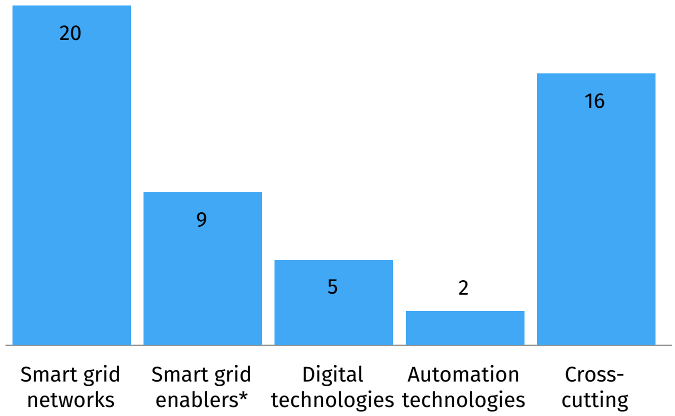
**TABLE: Technology maturity map**



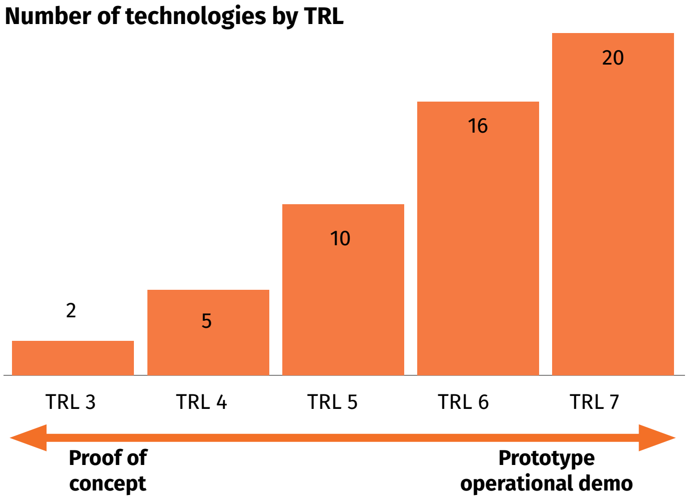

Approximately 50 relevant smart energy technologies within the Technology Readiness Level (TRL) range 3 to 7 were identified and assessed. Most of these technologies are currently in the post-conception phase, with nearly 50% at the prototype or pilot testing stages.

**TABLE: Technology types and distribution among TRLs**

**Number of technologies by tech type**




**Number of technologies by TRL**




Regional analysis indicates varied adoption patterns.

In **Africa**, the focus is on partial grid upgrades and market mechanisms due to limited infrastructure and capital, with key projects such as smart grid networks in South Africa and grid stabilization in Tanzania.

**Asia** shows higher adoption of innovative technologies due to better infrastructure and supportive policies, with ongoing projects including smart grid networks in India and Indonesia.

The **Americas** demonstrate significant activity in smart grid networks and market-based mechanisms, with projects in Brazil and Panama focused on smart grids and fast charging infrastructure.

## Impacts and promotion of SDGs

SE technologies hold substantial potential for promoting SDG 1 (No Poverty), SDG 9 (Industry, Innovation, and Infrastructure) and SDG 13 (Climate Action) by enhancing energy access and reliability, improving living standards, driving economic growth, increasing efficiency and sustainability of industrial processes and infrastructure. The integration of digital technologies such as AI, ML, and IoT into energy systems amplifies these impacts by optimizing energy distribution and consumption.
The promotion of SDGs occurs at both the country level, where governments establish enabling environments for adopting smart energy solutions, and the technology level, where technological innovations optimize energy efficiency, integrate renewables, and reduce emissions.

| Key Technologies | 1 No Poverty | 9 Industry, Innovation and Infrastructure | 13 Climate Action | Co-Benefit SDGs | Rationale for Co-Benefit SDGs |
|---|---|---|---|---|---|
| Smart grids | ✓ | ✓ | | 7, 11 | Enable better integration of renewable energy sources, improve energy efficiency, and enhance the sustainability and resilience of urban energy systems. |
| Digital twin | | ✓ | | 4, 8 | Promotes quality education through advanced learning tools and improves industry processes |
| Virtual power plants | ✓ | ✓ | ✓ | 7, 11 | Fosters affordable clean energy access and helps cities manage energy more sustainably and efficiently |
| Supercapacitor in hybrid storage | | ✓ | ✓ | 7, 11 | Enhances clean energy use and enhances the resilience and efficiency of urban energy systems |
| Cloud and edge computing | | ✓ | | 4, 8 | Supports quality education with better data management and creates new job opportunities |
| Distributed ledger technology (DLTs) / Blockchain | | ✓ | | 8, 16 | Streamlines business processes and facilitates secure and transparent transactions |
| Cell-to-chassis battery technology | | ✓ | ✓ | 7, 11 | Enhances sustainable energy use and supports industry innovation and the development of greener cities |
| Rail-to-grid energy storage system | | ✓ | ✓ | 7, 11 | Stores and manages renewable energy and supports sustainable cities manage energy more efficiently |

VPPs provide an example of how innovative systems can enhance energy reliability and sustainability by integrating distributed energy resources such as solar panels, battery storage systems, and smart grid technologies into a decentralized network. Utilizing advanced IoT, AI, and real-time data analytics, VPPs optimize energy production and consumption, supporting various SDGs.

VPPs address SDG 1 by providing access to affordable and reliable electricity to underserved communities, thereby reducing energy poverty, and facilitating economic activity. They contribute to SDG 9 as they enhance the resilience of energy infrastructure using innovative technologies. SDG 13 is promoted through the optimized use of renewable energy and improved energy efficiancy which lead to significant reductions in greenhouse gas emissions.

There are also co-benefits for other SDGs. VPPs support SDG 7 (Affordable and Clean Energy) by ensuring access to sustainable energy sources, and benefit SDG 11 (Sustainable Cities and Communities) by enhancing the sustainability and resilience of urban and rural environments.



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