Digital Solutions and Knowledge Transfer for Energy, Water and Agriculture

*The **Global Forum on Sustainable Energy (GFSE)** is a neutral multi-stakeholder platform which is facilitating international dialogue on energy for sustainable development by taking into accounts the special interests and challenges of developing countries. GFSE aims at the establishment of a sustainable world energy system from a social, economic and environmental perspective.*

GFSE contributes to both international discourse and information dissemination on sustainable energy. The multi-stakeholder platform plays a crucial role in facilitating sustainable energy projects by bringing together donors, investors and project developers. Their interaction creates new opportunities and enhances existing initiatives in the field of sustainable energy.

Introduction

Decarbonization, decentralization and digitalization are rapidly transforming the energy sector. Energy systems, which are increasingly based on a combination of decentralized renewable energy, energy efficiency, communication and information technologies, and smart and flexible infrastructure are materializing. These emerging energy systems have the potential to empower new entrants and prosumers, substantially decrease carbon emissions and enable access to clean energy for low-income populations, among others. New energy and digitalization technologies are changing markets and thus allowing the emergence of new business models for energy services and industrial activities. However, companies in the decentralized renewable energy business in developing countries face barriers to access technology as well as finance. They often also lack business and technical skills. Digital innovations are well-poised to help provide more affordable and accessible renewable energy and energy efficiency services to a wide range of consumers. As such, the energy sector will continue to be largely shaped by digital transformations going forward.

To achieve the Sustainable Development Goal (SDG) 7 (ensure access to affordable, reliable, sustainable and modern energy for all) and SDG 13 (take urgent action to combat climate change and its impacts)[1,2] by 2030, the energy access gap needs to be eliminated, energy efficiency must be substantially increased and renewable energy technologies deployed at a much larger scale. This will require the rapid transformation of energy systems by embracing digitalization and decentralizing (renewable) energy production. Innovation and digitalization play a crucial role in driving economic growth, creating employment opportunities, building resilient societies and achieving the Sustainable Development Goals (SDGs). As important enablers of future development, efforts need to be scaled up to enable everyone to benefit from the benefits of digitalization.

Digitalization is currently facilitating a smooth integration of renewable energy sources and could also facilitate the implementation of improved energy efficiency services particularly in the built environment. Using these new technologies requires skills, knowledge and of course the respective infrastructure. Integrated approaches to capacity building are necessary, which cover different actors from governments to entrepreneurs, technical professionals and civil society, and address different segments of the value chain to foster networked entrepreneurial ecosystems. Capacity building for developing countries must include the development of business and technical skills to make the most appropriate use and reap the benefits of incoming clean energy, water, agriculture and climate technologies, and capital support to allow businesses enter partnerships in cleaner production businesses.[3]

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A cross-sectoral and multi-level approach to build a sustainable ecosystem for innovative entrepreneurship is necessary to support climate, clean energy, water and agriculture innovation in developing countries and emerging economies. Such a multi-level approach requires sound legal and regulatory frameworks both for clean technologies and innovative enterprises, facilitating access to finance, business support through incubators and accelerators, support to technology development as well as early-stage technology validation and market development, among others.

Renewable energy technology-based solutions, which are not yet affordable, should be supported by access to financing. Through innovative business models, major unexploited market potentials for renewable-based solutions can be further exploited. However, in order to do so, actors must address the related existing challenges, including the economic viability of projects in developing countries, financing and up-scaling beyond pilot projects, and the lack of appropriate incentives to step up investments in renewable energy solutions.

Early-stage support to start-ups through the provision of capital and risk-sharing mechanisms is necessary to sustain these businesses. At later stages, growth capital and debt are required for companies to expand their business scope. There is also a real need for project developers and young businesses to receive coaching and mentoring in order to develop sound business plans and financial structures for renewable energy business models that incorporate digital technologies.

Renewable energy and energy efficiency technologies can play a significant role in the water and agriculture sectors. For instance, they can have an impact on key blue economy sectors (e.g. fisheries and aquaculture, desalination and freshwater production, coastal protection and waste treatment, biotechnology, ocean intelligence and observation, costal and maritime tourism, shipping and ports) in Small Island Developing States (SIDS). They also have potential in cultivation, irrigation, harvesting, animal husbandry, crop drying, food processing and other applications along agri-food chains in developing and industrialized countries alike.[4]

In order to facilitate the transition towards sustainability and the achievement of SDG2 (food security), SDG6 (water), SDG7 (energy) and SDG13 (climate change), clean technology diffusion must be accelerated, in particular in developing and emerging economies. For this purpose, technology cooperation, transfer and adsorption must become more effective. This requires substantial knowledge transfer and exchange as well as regional and international cooperation. Digitalisation can increase the effectiveness of clean technologies in the energy, water and agriculture sectors and make technologies more flexible and tailored to local needs and conditions. Digital solutions can also support knowledge transfer to increase the capacity of developing and emerging countries to deploy clean technology in the energy, water and agriculture domains.

The transition towards low-carbon, climate resilient energy, agriculture and water systems is urgent and necessary to both mitigate greenhouse gas emissions and overcome short- and long-term impacts of climate change. Food insecurity, drought, desertification and flood vulnerability, poor access to energy, among others, and related negative economic impacts must be reduced.

The COVID-19 crisis has led to substantial disruptions in the global supply chains, for example for renewable energy, and made evident that strengthening of local value chains is required to keep these systems operating properly and increase their resilience. Nurturing of local know-how to increase the capacity of developing countries to manufacture, install, repair and maintain clean energy, agriculture and water technologies is required to make these systems more resilient and guarantee energy, water and food security of supply. Developing countries can proactively address current technology gaps by strengthening their domestic capacities to absorb, assimilate and deploy clean energy and climate technologies.

Technology absorption capacity is a critical element and can be strengthened, among others, through targeted access to information and training about technologies and improvement in the capacities to build, install and maintain clean energy and climate technologies in addition to enabling legal frameworks.[5] Knowledge platforms and initiatives to support the sharing of knowledge will continue to gain importance in all economies around the world. The following sections will explore the benefits that digitalization can bring to solve the existing energy, water and agriculture challenges with focus on possibilities for knowledge transfer.

Digitalization and Climate Technology Dissemination

Technology Transfer and Adsorption of Climate Technologies

Technology fulfils a dual role in society: on the one hand it influences all economic sectors worldwide, and on the other hand it has a disruptive effect on societies and the environment. Climate change increases and exposes vulnerabilities, especially in least developed countries and small island states, undermines economic development, competitiveness and trade, which in turn worsen access to basic services and the quality of life. Technologies can exacerbate or mitigate the social and environmental impacts of human activity. Technological innovation can be seen as a process, which connects a set of actors and institutions that are in the position to shape the transformation cycle. In the context of climate change and mitigation efforts, technological innovation and their relation to national and international regulations is of utmost importance. Improving the development, transfer, deployment and dissemination of climate technology is a key pillar of the international response to climate change and the mechanisms for technology development and transfer of the UNFCCC have the potential to support the creation of climate relevant innovation-systems.

However, a number of obstacles to technology transfer still exist, uncertainty about the costs and benefits of adoption, lack of information on the value of the innovation, lack of financing, lack of skills, externalities, and regulatory barriers.[6] Building national or regional systems of innovation that enable domestic innovation and increase absorption capacity to acquire technology from abroad requires long-term efforts on policy, financial support and coordination of different actors (business, academia, governments, civil society etc.) and must be accompanied by international efforts to develop a supportive environment for technology transfer.[7]

In 2015, the Paris Agreement acknowledged the crucial role of technologies in mitigation and adaptation efforts in developing countries. Technology Needs Assessments (TNAs) - a mechanism of the Paris Agreement - emphasize enhanced support to developing countries in conducting and implementing effective TNAs and further implementing Technology Action Plans (TAPs) to boost implementation of the Agreement.[8]

Article 4.5 of the United Nations Framework Convention on Climate Change (UNFCCC) also requires developed countries to “promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, especially developing country Parties”[9]. At the conference in Cancun in 2010, the Parties to the UNFCCC set up a Technology Mechanism to facilitate enhanced action on technology development and transfer, which consists of a Technical Executive Committee and the Climate Technology Centre and Network (CTCN). The **Climate Technology Centre and Network (CTCN)** is hosted by the UN Environment Program (UNEP) and the UN Industrial Development Organization (UNIDO). CTCN is engaged in more than 150 countries and promotes the accelerated transfer of technologies through three core services:

- At the request of developing countries, providing technical assistance to accelerate the transfer of climate technologies;
- Creating access to information and knowledge on climate technologies; and
- Fostering collaboration among climate technology stakeholders.

The service is provided free of charge (with a value up to USD 250,000) at the local, national or regional levels to academic, public, NGO, or private sector entities at all stages of the technology cycle. Through these services, CTCN aims to address barriers to the development and transfer of climate technologies and create an enabling environment for a reduction in greenhouse gas emissions and climate vulnerability, improvement of local innovation capacities and further investment in climate technology projects. CTCN has already implemented 297 technology transfer projects[10] and provides five types of technical support: technical assessments, technical support for policy and planning documents, trainings, tools and methodologies, and implementation plans.

In the current global context, the CTCN is focusing its technical assistance on green recovery issues as follows:

- Creation of national innovation systems
- Developing circular economy roadmaps and introducing circularity in updated versions of the Nationally determined Contributions (NDCs)
- Introducing transformative technologies, including digital technologies
- Building resilient communities through adaptation technologies and nature-based solutions (e.g. hotspot mapping[11] to identify risks and vulnerability assessments)

International cooperation could bring forth a number of benefits such as information exchange, research activities, consulting, education and training, and access to financial instruments, as well as promotion of domestic industry. One of the key players in international cooperation efforts related to knowledge and technology transfer is the European Union. In the framework of the **Horizon 2020 Program,** innovation and research are strongly supported in and outside the EU: the program allocated a significant share (EUR 80 billion) of its 2014-2020 budget for developing countries and made it available under three different programmes: (a) excellent science; (b) industrial leadership; and (c) tackling societal challenges (including climate change).

Support activities enable cooperation with institutions such as science parks, accelerators or clusters. As an example, within the industrial leadership component, international cooperation on developing and strengthening of digital innovation hubs in Africa is being undertaken. Cooperation activities encompass, among others, development and establishment of Pan-African networks of Digital Innovations/Tech Hubs through strengthening local digital innovation and startup ecosystems through[12]:

- “capacity building and technology transfer to SMEs, local governments and projects on digitalisation and the uptake of digital innovations such as open data, artificial intelligence, cybersecurity and blockchain technologies;
- fostering the development of an enabling environment for digital start-ups through establishing networks between fast growing companies, startup founders, local governments, academic institutions, early stage investors and corporates;
- capacity-building programmes focusing on digital and entrepreneurship skills targeted to marginalised youth, women and vulnerable groups”.

Information and Communication Technologies

The costs of renewable energy technologies have decreased significantly over the past years (e.g. solar home systems) and information and communication technologies (ICTs) have disseminated quickly. Information and communications technologies facilitate the integration of renewable energy technologies (automated sensors, data capture, performance measurement or other mechanisms) that enable the production of electricity, heat and fuel from solar, wind, hydro, wave and tidal power, heat-exchange/geothermal and bioenergy.

The rapid expansion of ICTs has impacted developing and emerging countries quite differently. Least developed countries have experienced the most dramatic effects, especially in the telecommunication and data sectors, where technological leapfrogging enabled going beyond traditional ‘land-lines’ and made mobile solutions widely available. Mobile money increases security of financial transactions and allows companies to collect payments in a more efficient way. In addition, it enables the supply of energy services to customers, - for instance in rural areas -, who may otherwise not have had access. Such services particularly address customers at the bottom of the pyramid and lower the risk for suppliers through greater payment security. Mobile phone enabled pay-as-you-go (PAYG) models offer not only flexible payment terms (on a daily, weekly or monthly basis) for customers, but they also establish credit history. PAYG addresses larger markets and helps build consumer trust by offering payment methods that require minimal upfront costs.

The potential of ICTs has an influence on all of the economic sectors, but it is also a double edged sword: it can either improve the lives of individuals through socio-economic and environmental changes, but it can also reinforce prior existing inequalities among and within societies.[13,14] Technological innovation is a process that takes place in “technological innovation systems”, which is connected to a set of actors and institutions that shape the innovation processes. Depending on the intervention of technology, it impacts the labour market, productivity, competitiveness and trade and wealth. To help identify, mitigate and, where possible, reverse the effects of climate change, frontier technologies offer some potential. Leveraging these technologies to engineer new solutions to address climate change represents an opportunity to accelerate efforts to achieve the Paris Agreement. The following list provides a brief overview of some emerging digital developments:

Artificial Intelligence (AI) autonomously simulates human intelligence processes (ex. learning, reasoning and self-correction) in computers and machines. AI has a potential to be an essential tool in decoupling economic growth from rising carbon emissions, by influencing consumer behavior related to GHG emissions. For instance in the water sector, applications of AI have been growing and include: “i) predictive maintenance of water infrastructure, ii) forecasting water demand and consumption, iii) monitoring the health and environmental impacts of water reservoirs and dams, iv) tracking water quality, and v) monitoring and predicting water-related disasters.”[15] These applications contribute to achieving water related SDG targets. Artificial intelligence is also being applied to data analysis and modelling of interactions between water and energy systems and, specifically, to the handling of large data sets being collected through digital technologies.

For example, AI can be used to understand energy related water use and water related energy use and related vulnerabilities. This is useful in the assessment of the impacts of shocks on infrastructure security and sustainability for both energy and water supply systems.[16] Artificial Intelligence is also starting to be used in digital platforms for knowledge transfer and educational purposes.

Internet of Things (IoT) enables the wide proliferation of information and communication technologies by building a global infrastructure for societies at large. It can come up with interconnections based on existing and evolving interoperable information and communication technologies, both physically and virtually. In the energy sector, for example, there are a variety of applications of IoT including smart cities, smart grids, smart buildings, and intelligent transportation. However, a number of challenges still remain for the effective application of IoT technologies, including big data management, integration of subsystems and compatibility, privacy, security and standardization.[17] In the water sector, IoT technologies can help utilities address challenges, including extending the life of assets, reducing leakages in the distribution network, improving water quality monitoring, service levels and reliability of supply, promoting water conservation, or increasing revenue through improvement of operational efficiency.[18]

5G is the newest generation of cellular and wireless connectivity that is expected to offer faster speeds and greater coverage, in addition to longer battery life for devices, larger data transfer capabilities and more reliability. Due to the fact that 5G is more directional and efficient, it consumes less energy and power. It therefore has the potential to leave a smaller environmental footprint than current technologies. 5G has the potential to foster the intertwining between energy and telecommunication technologies, for example supporting the implementation of smart technologies for demand response, which allow prosumers to reduce or increase their electricity demand when required, to match the production of variable renewable electricity and thereby, participate in the energy markets.

Digital Twins: a digital twin is the virtual representation of a physical system or object across its life cycle. By using real-time data and enabling learning, decision making and reorientation leads to improved decision making. In the context of climate change, they are particularly useful for urban areas that have rapidly growing population, size and increasing energy consumption, therefore require efficient, agile and responsive management to maintain their systems.[19] Digital Twins can also be used for knowledge transfer and training.

Digital Platforms for Knowledge Exchange: Digital platforms have emerged as important enablers for private and public actors to distribute knowledge. They offer new ways for organizations to collaborate on technologies and knowledge transfer.[20,21]

Artificial Intelligence in Building Energy Management Systems

As an example, here the role of artificial intelligence in energy efficiency and demand response in the build environment is highlighted. Buildings are at the center of a decarbonized energy system. Smart buildings can play a leading role in transforming the energy landscape into a more decentralized, renewable-based, interconnected system that maximizes efficiency and ensures the optimal use of resources. A smart-ready built environment can enable energy-system-responsive buildings, which at the same time provide a better indoor environmental quality and comfort for the occupants.

Artificial intelligence in Building Management Systems (BMS) can improve building operations. AI can contribute to make buildings more energy efficient, help them participate in energy markets, improve comfort control, and enable predictive maintenance. [22]

AI algorithms in BMS can optimize commercial building energy use and allow buildings to participate in demand response markets, decreasing the demand for electricity when there is insufficient electricity supply or increasing it when there is a surplus of electricity, for instance when there is a surplus of variable renewable electricity from solar PV and wind power. In this way, buildings can provide much needed flexibility to the electricity market and be rewarded by the market for this flexibility.

AI-based energy management platforms can identify opportunities to optimize building operations through models of building thermal characteristics that allow steering the cooling of the building throughout the day, increasing demand when the electricity prices are low and vice versa.[23] AI can also be used to analyze data from various systems and Internet-of-Things (IoT) devices within a building to identify anomalies and generate a diagnosis, supporting building managers with predictive maintenance and fault detection. Still, AI cannot replace the expertise of the human operators.[24]

Artificial Intelligence is starting to be used in digital platforms for knowledge transfer and educational purposes. AI is also being applied to data analysis and modelling of interactions between water and energy systems and, specifically, to the handling of large data sets being collected through digital technologies.

Digital-water.city

It is a major challenge for cities to manage urban water systems in a sustainable way, because of the over-exploitation of groundwater and surface water bodies by the agricultural industry and citizens as well as the growing effects of climate change. The quality of water services can be increased by the deployment of smart digital water technologies, such as real time sensors, mobile devices, cloud and artificial intelligence solutions that enhance the integrated management of water infrastructures.

In close cooperation with utilities, municipalities, researchers and innovators, digital-water.city develops solutions and integrates them in a guiding protocol to cover existing gaps in interoperability, cybersecurity and governance. Among others, new remote-controlled sensors for real-time bacterial measurements, early warning systems (EWS) for safe water reuse is a risk based management tool for sanitation systems, sewer flow forecast toolboxes, and platforms for integrated management of sewer networks and wastewater treatment plants are being implemented etc. Digital-water.city is active in five European cities, namely Berlin, Copenhagen, Milan, Paris and Sofia.

More information can be found here: https://www.digital-water.city/

Examples of Knowledge Transfer Initiatives

Digitalization for Agriculture (D4AG) and Knowledge Transfer

Due to the rapidly increasing population in Africa, agricultural production needs to increase to meet the demand. However, the income of farmers still remains low due to the fact that many of them only work on small plots (under 2 hectare) that usually do not have access to high quality seeds, machines or irrigation systems. The sector is also susceptible to the effects of climate change (ex. rainfalls, droughts or pest infestations). Digitalization for Agriculture (D4AG) solutions support and accelerate agricultural transformation across Africa. All these smart solutions comprise of digital technologies, innovations and data that can bring positive change to the agriculture sector (increased productivity, engagement, improved access to market or finance). D4AG technologies are able to provide more information about weather conditions, markets, prices and cultivation methods. It is expected that hundreds of millions of small framers will use these smart digital services.[25]

One example of D4AG is the platform **Wefarm**, a farmer-to-farmer digital network that allows farmers to connect with one another for free to solve problems, share ideas and innovations through SMS or internet. Through machine learning technology, crowd-sourced information helps farmers increase yields, gain insight into pricing, tackle the effects of climate change, source quality seeds and fertilizer, identify favorable loans and diversify agricultural activities in a peer-to-peer learning platform.

However, although significant potential is available, D4AG solutions are still under development and there are a number of challenges to overcome, among other related to profitability of the services, scalability of solutions, proliferation of apps, lack of transparency, and integration of several services in one platform. Digital applications can support decision making and productivity increase by farmers and other actors in the agriculture sector, but they need to be embedded in a comprehensive strategy and accompanied by developments in transportation infrastructure and logistics to bring products to the market, access to financing, adaptation of legal frameworks (e.g. for land tenure) and last but not least market creation. Otherwise, long-term positive impacts in the agricultural sector cannot be achieved.

Knowledge Transfer in the Domain of Water and Climate Change

An example of a knowledge transfer project in the domain of water and climate change is the **AfriAlliance project**, which is bringing African and European stakeholders together to better prepare Africa for such challenges. AfriAlliance has launched ten demand-driven “Action Groups” across Africa, on a number of topics related to science and water stewardship, ranging from citizen science based water resource monitoring, efficient and innovative small scale irrigation, planning for drought in semi-arid Africa to Integrated Water Resource Management (IWRM) and ethics.”[26] AfriAlliance also built a community of diverse stakeholders from academia, business, non-profit sector, youth and agricultural groups, public authorities, platforms and projects and has also created a knowledge hub, providing relevant reports, water and climate updates and online learning opportunities offered by AfriAlliance and other institutions.

A further example in the same field is the DAFNE project[27] which brings together partners from Europe and Africa to facilitate collaboration for the management of the water-energy-food nexus and its implications for the environment. DAFNE advocates an integrated and adaptive water resources planning and management approach from a participatory and multidisciplinary perspective. Planning and management solutions based on the cooperation of public and private stakeholders to enhance understanding of the nexus are designed and implemented in pilot cases in the Zambezi and Omo-Turkana river basins.[28,29]

Knowledge Transfer in the Sustainable Energy Field

An example in the clean energy field is the EU project DiBiCoo (digital biogas cooperation). DiBiCoo facilitates cooperation on adaptable biogas technologies and related financing opportunities among relevant stakeholders in the biogas industry from Europe, with stakeholders from developing and emerging countries. Development and implementation of investment biogas projects is being facilitated through digital and non-digital support tools for capacity building, networking and an online information system to support project development and business between companies in Europe and developing countries that lead to the introduction of appropriate biogas technologies.30
In Ghana, for example, a mapping of relevant actors in the sector including project developers, municipalities, industries, feedstock processors, feedstock producers, technology providers and financial institutions allows profiling them on the platform in order to connect them to European partners.31 The project collaborates with the Private Finance Advisory Network (PFAN) managed by UNEP and UNIDO.[32]

Digital Platforms for Networks of Incubators and Technology Accelerators

Cleantech-focused incubators and accelerators contribute to bridge the knowledge gap for start-ups, provide professional services that may not be available or affordable, assisting them from conception to commercialization. They typically provide shared office space with similar start-ups, promote collaboration between them or with other companies, offer financial and marketing services, and facilitate contacts to venture capitalists and angel investors, and enable networking with local businesses, experts and mentors.

A regionally or globally connected network of incubators and accelerators supported by digital knowledge transfer and exchange platforms could facilitate contact between entrepreneurs, investors and companies looking for cleantech solutions, support knowledge exchange regarding skill development and facilitate access to new funding sources.

Currently, accelerators and incubators typically focus on specific clean technology categories. However, given the complexity of the challenges associated with the energy-water-agriculture nexus and climate change, a variety of interrelated technologies is needed and synergies between them should be exploited. Thus, in the future, accelerators and incubators could shift their focus towards impacts on sustainability challenges related to the nexus energy, water and agriculture rather than specific technology categories, and promote clusters of technologies and related entrepreneurship ecosystems able to address relevant climate, environmental and social challenges that require the interlinked perspective between the three sectors. Digital solutions can help foster a fruitful, interdisciplinary exchange, break silo thinking and facilitate regional and international cooperation between cleantech incubators and accelerators.

E-Learning Solutions

Digital technologies are also starting to play an important role in boosting education and training of the workforce. Going forward, such technologies can provide flexibility on time, place and costs of the delivery of education. For example, focused online and blended learning programs (combining face-to-face interaction in the classroom and online learning) as well as learning platforms can facilitate market growth and contribute to reduce the deficit of skilled workers in the renewable energy and climate change area. This section explores a number of initiatives that use digital technologies to stimulate knowledge transfer especially related to climate change:

Knowledge Transfer and Digitalization for Youth Empowerment

The Organisation for Economic Cooperation and Development (OECD) has looked into the topic of green industrialization and the role rural youth can play in developing countries. "Rural youth constitute over half of the youth population in developing countries and will continue to increase in the next 35 years. Without rural transformation and green industrialisation happening fast enough to create more wage employment in a sustainable manner, the vast majority of rural youth in developing countries have little choice but to work in poorly paid and unstable jobs or to migrate."[33] Agro-food industries and production lines can help create a vast number of jobs in rural areas, while also helping to ensure food security.

The main drivers behind the rural transformation process are innovation and technology. Technology can significantly expand the opportunity space for rural youth, because they are best positioned to take advantage of new ICTs that improve competitiveness of rural communities.[34] However, rural areas in most countries of the Near-East, North-Africa, Europe and Central-Asia (NEN) region do not have access to the internet. As a result, rural youth are not provided with the skills they need to effectively use technology to access information and build networks. Furthermore, the lack of available content in local languages (especially Arabic) makes it more difficult for them to access educational material.

New communication technologies play a key role in economic growth as innovations in the mobile phone sector have shown. A concrete example is the **SCARA project**, which has carried out activities measuring the societal impact innovations have had. The realization of technology heavily depends on the capacity and accessibility of the younger generation. Therefore, the Egerton University and the BOKU partnered together to strengthen these capacities in agriculture through education, research and adaptation in Kenya. Involving multiple stakeholders, a Youth Council was set up to inform policy makers about the needs of the younger generation in these sectors. Moreover, Egerton University uses an e-learning platform (blended learning), which provides access to employees and people, who are not on the university campus. It also requires faculties to make at least one program available in an e-learning format. The experiences from the SCARA project demonstrated the significant role of the public educational sector in capacity building and in providing services to involved stakeholders. The project finds that communication technologies and e-learning will provide great opportunities for the development of African countries in the future.[35]

Melbourne Water's Smart City Model

The Water Smart City Model was developed by Melbourne Water to raise awareness of the benefits of the Blue-Green Infrastructure (BGI) in managing surface runoff and storm water quality. BGI is a planned multi-functional network of natural and semi-natural areas, including gardens and green streets, which is designed and managed to deliver environmental, economic, and social benefits including improved water quality. Blue-Green Infrastructure solutions enable cities experiencing climate change extremes to enhance climate resilience and restore the health of ecosystems. BGI also provides multiple economic, social, and environmental benefits.

This model is an educational activity suitable for all ages and involves bigger audiences at community events. It involves building city models from LEGO building blocks and making audiences (especially children) familiar with BGI. Features such as pollutants, rain garden, rainwater tanks and rooftop gardens can be also added rainfall can be also simulated in the model.

Source: https://www.ourfuturewater.com/2018/11/17/blue-and-green-cities-the-role-of-blue-green-infrastructure-in-managing-urban-water-resources/

WBG Academy

In partnership with the Republic of the Korea, the World Bank developed and launched an open learning campus, called WBG Academy, where participants from across the globe can learn and share their experiences. The platform facilitates finding answers and solutions to climate change through learning. Among others, courses on climate change are offered ranging from the basic concepts to high level planning tools, and are attended by national level policy makers, economists, sector specialists, research scholars and NGOs alike. The curriculum is continuously adjusted to address the growing and changing demands of market instruments, low emissions development, and climate finance.[36] In addition, the platform offers e-learning courses on 'Digital Agriculture' that enables farmers and entrepreneurs to increase their productivity, efficiency, and competitiveness as well as enhance resilience to climate change. Digital agriculture provides a wide range of technical solutions, for example mobile apps, digital identities for farmers, solar applications for agriculture and portable agriculture devices. These technologies are in the process of becoming indispensable and it is therefore important to provide an opportunity to study digital agriculture technologies in further detail.[37]

International Education and Resource Network (iEARN)

The iEARN[38] is the world largest educational network that fosters global collaborative teaching and learning. It is comprised of 140 countries, 30 languages, 50,000 educators and 2 million youth. The global network with the help of other global education partners aims to realize the 17 Sustainable Development Goals (SDGs).[39] Teachers create global communities of practice through technology that enable students to collaborate with them around the world. Technology enables collaborative teaching regardless of geographic location, as demonstrated by the global nature of the Solar Cooking Project that aims to help people cook on their own with the help of solar cookers.[40]

Community Tablet

To empower rural communities through education and promote digital inclusion, Community Tablet was created by the Mozambican entrepreneur, Mr. Dayn Amade. In order to close the digital divide in Africa, the Mozambican company works with NGOs, governments and other corporate partners and serves as a vital bridge to increase the effectiveness of aid programs and empower individuals to make more informed choices.[41] Community Tablet is the first digital school that runs on four to six large LCD screens, powered by solar panels and transported by a trailer. Aligning with the Sustainable Development Goal 4 (ensure inclusive and equitable quality education and promote lifelong learning opportunities for all), the focus of the education materials displayed on the screens is to provide affordable access to digital context and close the widening gap in the delivery of education in rural and disadvantaged areas. It also provides communities that lack digital skills with internet access. Knowledge is converted into short animated cartoon videos, ending with quiz question, which is monitored and provides a direct feedback on the progress to the teacher. 35% of the users are women and children, who are encouraged to bring back the knowledge to their communities and teach others. The company aims to scale up to tool in the region and internationally with the support of interested partners and contribute to the achievement of the 2030 Agenda.[42]

Asia Pacific Adaptation Network (APAN)

The Asia Pacific Adaptation Network is a regional program for facilitating the dissemination of knowledge about adaptation strategies in the region. It supports governments and other organizations working on adaptation, by emphasizing the management of knowledge and capacity building. APAN aims to raise awareness and step up efforts to facilitate knowledge on the adaptation to climate conditions, enhance capacities to apply knowledge to assess technologies, access finance, and design and implement actions on adaptation, including technology adsorption. It strengthens the ability to integrate adaptation into development policies, strategies, and plans by equipping key actors in Asia and the Pacific Region with adequate knowledge for designing and implementing climate change adaptation measures, building capacity to access technologies and finance in support of climate change adaptation through online sourcebooks and exchange series. Sub-regional nodes and thematic nodes of APAN carry out sub-regional activities in Central Asia, South Asia, Southeast Asia, Northeast Asia and the Pacific. The sub-regional nodes operate with the help of national implementing partners located in the countries falling within each sub-region.[43] The APAN network has underscored the importance of transferring scientifically sound and policy relevant information to stakeholders, especially local stakeholders, in order to accelerate climate change adaptation and of regional partnerships for linking information platforms and capacity building organizations for development of adaptation projects.[44]

E-Genius

E-genius is a multilingual open-content platform managed by the scientific association “e-genius – Open Education Initiative on Technology & Natural Sciences” that facilitates education in technology and science. The materials are created by experts and teachers and meant for schools and colleges as well as for adult education. The platform provides interested parties with four learning modules, such as energy efficient buildings, thermal building renovations, insulation materials and façade systems and urban development and communities in ten languages.[45]

Africa Cloud

The German Technology Cooperation (GIZ) is implementing the Africa Cloud project on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The project aims to make innovative e-Learning solutions available through Learning Management System (LMS) to enable digital learning in Africa. It provides access to a wide range of learning courses with the aim to reach a broader target group of people with diverse educational backgrounds. In the future, the Africa aims at supporting additional learning alternatives, such as web-based-trainings, mobile learning, blended learning, tutor-supported learning and massive open online courses (MOOC).[46,47]

Artificial Intelligence in e-Learning

Artificial Intelligence is making inroads into e-Learning. AI can act as a virtual tutor and answer questions for fundamental courses and/or basic notions. It can also help overcome language barriers and improve the learning process of persons with disabilities (e.g. narrating text to blind persons and helping convert spoken language into transcripts).[48] AI allows tailoring learning materials to the needs and performance of a particular individual, thus facilitating personalized learning.[49] AI can also be used to enhance e-learning management systems and free time for teachers to focus on the more crucial aspects of their work. For instance, the grading tasks that contain multiple tests can be automated by using AI-powered programs. AI technologies can also be implemented to reveal gaps in the curriculum and to uncover the weaknesses of the students and suggest the content for improving a particular area.[50]

However, although AI applications in e-learning are quickly evolving, AI cannot replace person-to-person interactions, which are relevant to the learning process and particularly for tasks that require creativity and imagination and the support of students that require encouragement and careful guidance. Therefore, a balance between human interactions and the use of AI for learning must be found. It is expected that in the future, AI will play a more significant role in knowledge transfer in a number of sectors, including energy.

Conclusions

Clean technology allows for a paradigm change as it enables pursuing industrial development and achieving structural transformation with a reduced environmental footprint, higher resource efficiency, reduced waste and lower GHG emissions. **Digitalisation can contribute to better advance decarbonisation and lessen climate change impacts in the energy, water and agriculture sectors. In addition, digital solutions can support the knowledge transfer required for the effective deployment of low-carbon, climate resilient technologies in these sectors and materialise the nexus approach, which takes into account interlinkages between them**. For instance, digitalisation can lead to enhancements in the ability to collect and analyse relevant data to better coordinate planning, investment and operative decisions across sectors. In its turn, capacity building and knowledge transfer about digital solutions is necessary.

For inclusive and sustainable development to materialize in developing and emerging countries, a healthy entrepreneurial ecosystem in the fields of clean energy, sustainable water and agriculture technologies is necessary.

For a clean technology entrepreneurial ecosystem to thrive, governments must develop supporting policies nurturing enterprises, building markets, introducing technology performance standards, strengthening capabilities, removing infrastructural bottlenecks, and providing finance. Moreover, instruments in these areas must be properly interlinked to effectively nurture entrepreneurial ecosystems for climate, clean energy and sustainable water and agriculture (nexus) technologies.

Developing and emerging countries experience significant barriers with the transfer and uptake of climate technologies and thus have to rely predominantly on the help from more developed countries. **In order to deploy zero and low-carbon innovation, technology adsorption capacity must be substantially incremented** and a large range of non-technical barriers need to be overcome, including behavioural and acceptance hurdles. **Strong partnerships and cooperative initiatives on the local, national, regional and international level can help support this transition**. Forging new partnerships between the public and private sectors is essential to carry out this approach.[51]

Building up the necessary structures requires substantial knowledge transfer in all of these areas and solutions that allow connecting people with each other through networks. Digital solutions can contribute to improve knowledge transfer between actors and bringing them together for the development and implementation of holistic solutions for clean energy, water and agriculture independently of their geographical location.

The number of e-learning tools and digital platforms implemented in crucial sectors of developing countries can be used to bridge the gap and tackle barriers by transferring knowledge, supporting project development and enabling business deals to materialise. Information and communication technologies can facilitate the global energy transition, the advancement of sustainable agriculture and sustainable water resources management and the shift to a circular economy.

Besides the possibility of enhancing knowledge transfer, digitalisation has the potential to enhance the impact of clean technologies in the domains of energy, water and agriculture, making them more flexible, tailored to local needs and enabling innovative business models. Frontier technologies, however, need to be closely monitored and it essential to make sure that they are leveraged in a best possible way to contribute to the achievement of the Sustainable Development Goals (SDG) and the objectives of the Paris Agreement.[52] Governments should further explore the nexus between climate change and technology development by building resilience at household, community, business and nation-level and by ensuring that the necessary skills and knowledge are in place to accelerate the transition towards climate-resilient, low-carbon societies and enable them to cope with short-term crisis and long-term climate change trends[53]. Digital solutions can contribute to make knowledge transfer and clean technology adsorption more effective by supporting the strengthening of local value chains and the transition towards climate-resilient economies in developing countries and emerging economies. The Global Forum on Sustainable Energy (GFSE) can play an important role in this regard by furthering the international discourse and information dissemination on sustainable energy and climate change solutions.

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