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ENERGY – time for change

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Dear Reader,

In addition to causing anxiety over global food security, Russia's invasion of Ukraine has put the issue of energy security right at the top of the political agenda. In combination with a fear of supply bottlenecks, the dramatic fossil fuel price hikes have given new impetus to a transition to low-carbon energy sources – which is urgently needed anyway given global warming. In November last year, the International Energy Agency (IEA) announced that overall capacity of renewables is to almost double world-wide in the coming five years. Then these "clean" energy carriers could replace coal as the biggest source of electricity generation. From 2022 to 2027, the IEA is reckoning with power produced from renewable sources amounting to 2,400 gigawatts (GW) – a volume corresponding to China's total power generating capacity. China, the USA and India are set to be the biggest drivers of renewable energy development, the IEA continues. And they are precisely the countries responsible for the largest shares world-wide of CO_2 emissions (China: 33 %; USA: 13 %; India: 7 %).

But what about Africa? Today, the continent accounts for a mere 3.4 per cent of world-wide primary energy consumption. But its energy consumption is reckoned to double by 2040. Will hopes placed in leapfrogging – i.e. the notion that the continent can leave out the deviation via fossil fuel and directly enter the age of renewable energies – be fulfilled? At first glance, the conditions for this appear to be good. There are estimates that Africa could generate 60 per cent of solar energy world-wide. Wind conditions are sufficient to produce 250 times the electricity the continent now needs. Already today, countries like the Democratic Republic of the Congo, Ethiopia or Kenya are covering more than 80 per cent of their electricity demand with hydropower or geothermal energy. And according to statements by the International Renewable Energy Agency (IRENA), solar projects in Zambia, Senegal and Ethiopia were auctioned in 2020 at a price of just 25 USD per megawatt-hour, making them cheaper than fossil fuels.

All in all however, the continent's energy supply continues to rely almost exclusively on fossil fuels. And according to a 2021 survey by scientists at the UK's University of Oxford, this is how things are going to stay for the time being. Their forecasts predict that in 2030, two thirds of Africa's electricity will still be coming from "dirty" sources. Whether these forecasts are accurate indeed depends on the political will of African heads of state – who face the daunting challenge of 600 million people throughout the continent still having no access to electricity, which is strongly inhibiting the economy.

However, the way the Global North and the international community position themselves is an equally crucial factor in this context. Since Russia's attack on Ukraine, countries like Algeria and Mozambique, Nigeria and Angola have become increasingly interesting as oil and gas suppliers – an aspect which is also contributing to local investing in new crude oil refineries, gas pumping plants and pipelines. At the same time, the continent is to assist in promoting the energy turnaround in Europe while simultaneously benefiting from the production of "clean" energy. It can only be hoped that there will be no repeat of the mistakes made in the Desertec project, launched with high hopes but ending as a spectacular failure.

Wishing you inspiring reading, on behalf of the editorial team,

Patricia Summa Silvia Richter

Partner institutions of Rural 21

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INTERNATIONAL PLATFORM

Bridging the digital gender divide, empowering rural women

Inclusive access to digital technologies and education is crucial to reducing gender inequalities and empowering rural women and girls. This was the message three United Nations' Agencies, the Food and Agriculture Organization (FAO), the International Fund for Agricultural Development (IFAD) and the World Food Programme, announced on the occasion of their joint event marking International Women's Day 2023 on the 8th March. Digitalisation on its own cannot solve all the gender-related disadvantages women face. But if provided with equal access to digital technology and education, women could have a more active and effective role in our agrifood systems.

"Admittedly, it is discouraging to celebrate International Women's Day in a time when we are going backwards on gender equality and are seeing widening gender gaps in science, technology and innovation," said FAO Deputy Director-General Beth Bechdol, adding: "When we invest in rural women, we invest in resilience, in the future of our communities and in creating a more inclusive and equitable world – one where no one is left behind."

"Food security for households and communities is in the hands of the women. It is only through women's empowerment that we can build a world where no one goes to sleep hungry," said WFP's Deputy Executive Director, Valerie Guarnieri. Transfer of knowledge and skills including digital literacy could help these women realise their full potential.


An indian village woman giving training in laptop technology.
Photo: Neeraz Chaturvedi/ shutterstock.com

Despite the rapid proliferation of digital tools and services, women continue to face systemic and structural barriers in accessing and adopting new technologies, the organisations state. They say that globally, 69 per cent of men are using the Internet – compared with 63 per cent of women. In low- and middle income countries (LMICs), women are 16 per cent less likely to use mobile internet than men. And recent statistics show that this contrast is even starker in rural areas. As a consequence of constraints such as affordability, illiteracy, user capabilities, and discriminatory social norms rural women are particularly disadvantaged in terms of access to information and Communication Technologies (ICTs) and less likely to engage with ICT solutions. The organisations add that surveys have revealed that the ICT sector is both urban- and male-centric, ranging from the design of ICTs to the gender of sector employees and decision-makers.

The FAO has launched various initiatives to promote digital technologies which also specifically support women. Examples include the International Platform for Digital Food and Agriculture, the E-Agriculture Community of Practice and the 1,000 Digital Village Initiative. The Global Network on Digital Agriculture and Innovation Hubs aims to support its members to foster innovation within their digital agriculture ecosystem, with a special focus on women and young agripreneurs. By assisting women with digital and financial literacy trainings and working with community champions, WFP aims to help them to open their own banking, mobile money or other digital accounts, bringing economic benefits including food security to these women and, in turn, to their families and communities. *(sri)*

Rural tourism for community empowerment

At a meeting of the G20 Tourism Working Group in the Rann of Kutch, India, in February 2023, the World Tourism Organization (UNWTO) shared its recently launched Tourism for Rural Development Programme. The meeting explored the main challenges facing the sector, particularly with regard to digital and non-digital infrastructure, the empowerment of local communities and skills development. Representatives from Indonesia, Spain, Italy and Japan joined UNWTO, the UN Environmental Programme (UNEP), the International Labour Organization (ILO) and the South Asia Women's Network (SWAN) in discussing how tourism policy can support tourism's contribution to rural development.

Participants stressed that the sustainability of tourism in rural areas was dependent on a comprehensive planning strategy which was adopted and implemented based on a multi-action and multi-stakeholder participatory approach. Furthermore, it was noted that rural tourism required the support of regional and local governments, the private sector, industry associations, civil society, communities and tourists.

Recently, the UNWTO also announced "The Best Tourism Villages 2022". This initiative is the flagship project of the UNWTO Tourism for Rural Development Programme, which aims to reduce regional inequalities in income and development, fight depopulation, progress gender equality and women's and youth empowerment, advance innovation and digitalisation, improve connectivity, infrastructure, access to finance and investment, innovate in product development and value chain integration, and promote sustainable practices for more efficient use of resources and a reduction of emissions and waste and enhancing education and skills. It promotes multi-level governance and partnerships and the active involvement and empowerment of communities. Thirty-two destinations from all around the world have been named as Best Tourism Villages 2022 (for a list, see: rural21.com). A further 20 villages are to enter the Upgrade Programme. All 52 villages will also become part of the UNWTO Best Tourism Villages Global Network created in 2021, which from this date gathers 115 villages from the five continents. The Network provides a number of benefits, including onsite and online training, sharing of good practices and international brand recognition and awareness, the UNWTO states. *(ile)*

Optimising the use of eco-friendly biopesticides to combat Oriental migratory locusts

Locusta migratoria manilensis, commonly known as the Oriental migratory locust, is one of the most dangerous threats to crop production and food security in South-East Asia and China. Crops at risk include maize, rice and peanuts. Pastures can also be seriously damaged. Entomopathogenic fungi (EPF) have already been widely promoted in an effort to reduce the use of more harmful pesticides in tackling the pest. A new study has now found the best time to apply these biopesticides. It was carried out by MARA-CABI Joint Laboratory for Biosafety, a collaborative partnership between the Chinese Ministry of Agriculture and Rural Affairs and the UK-based CABI which also includes the Institute of Plant Protection at the Chinese Academy of Agricultural Science.

With their study, published in *Frontiers in Physiology*, the scientists sought to understand the behavioural patterns of different stages of hoppers (younger locusts) and adults of the Oriental migratory locust, as well as the environmental factors that modulated their body temperatures through field observation. The field samplings in two of the main breeding regions in China included recording the day and night body temperatures of 953 locusts as well as their morphological traits (stage, sex and size) and microhabitat. The results of the study revealed that locusts, particularly hoppers, preferred the ground as their main sub-habitat. Adults tended to move up in the reed canopy at two peaks – 10am to 11am and 2pm to 3pm. The body temperature of the locusts during the daytime increased with development stage and size, while the opposite pattern occurred at night-time.

According to the researchers, entomopathogenic fungi are more effective if the body temperature of the target pest is neither too high nor too low. The biopesticides should therefore be applied primarily on younger locusts – and sprayed in the morning or at dusk, when the locusts have lower body temperatures. *(wi)*

Treaty of the High Seas to protect the ocean

In early March 2023, global negotiations concluded on the landmark Treaty of the High Seas to protect the ocean, tackle environmental degradation, fight climate change and prevent biodiversity loss. "There is only one Ocean. Every State, every economic player, every community of people and every individual has a responsibility to conserve it and to use it sustainably," the treaty states. Areas beyond national jurisdiction cover nearly two-thirds of the world's ocean, comprising the high seas and the seabed beyond national jurisdiction. They contain marine resources and biodiversity and provide invaluable ecological, economic, social, cultural, scientific and food-security benefits to humanity. However, they are under mounting pressure from pollution (including noise), overexploitation, climate change and decreasing biodiversity.

The 'Biodiversity Beyond National Jurisdiction' (BBNJ) treaty enters into force once 60 States have ratified. The European Union stated that it will work to ensure this happens rapidly and help developing countries prepare for its implementation. To this end, the EU has pledged 40 million euros as part of a Global Ocean Programme and has invited members of the High Ambition Coalition to do the same within their capabilities. The new treaty will allow the establishment of large-scale marine protected areas on the high seas, which are also necessary to meet the global commitment of the Kunming-Montreal Global Biodiversity Agreement concluded last December to protect at least 30 per cent of the ocean by 2030.

For the first time, the treaty will also require assessing the impact of economic activities on high seas biodiversity. Developing countries are to be supported in their participation in and implementation of the new treaty by a strong capacity-building and marine technology transfer component, funded from a variety of public and private sources and by an equitable mechanism for sharing the potential benefits of marine genetic resources. This Implementing Agreement is the third of its kind following specific agreements on seabed mining in 1994 and the management of straddling and highly migratory fish stocks in 1995. *(ile)*

Biodiversity in our oceans is threatened by pollution, overexploitation and climate change.

Photo: Nico Faramaz/ shutterstock.com

GLOBAL ENERGY FLOWS IN TRANSITION

While the global energy world has already been witnessing radical change for some time, Russia's invasion of Ukraine has made this change more visible and tangible. Simultaneous climate, energy and political crises also bear a potential to accelerate global structural change in the energy sector – change towards bidding fossil fuel farewell and to ushering in climate-neutral and renewable energy sources.

By Roman Buss

The global energy supply is still based very solidly on fossil fuels: natural gas, coal and mineral oil. Traditionally, the bulk of these resources has come from the "strategic energy ellipse", an area stretching from the Middle East to the Caspian Basin and onwards into Russia's far north and containing around 70 per cent of the world's known conventional oil and gas reserves. Most members of the Organization of the Petroleum Exporting Countries (OPEC) are located in this region. Russia, not officially a member of OPEC, has also built up substantial oil and gas export capacities. Over the last two decades, the United States of America (USA) has emerged as one of the leading producers of oil and gas, mainly based on its adoption of fracking technology. The oil crises back in the 1970s led to energy-saving, the development of new technologies, efforts to reduce dependency on fossil fuel imports and, finally, the start of the expansion of renewable energies. As a result of all these factors, OPEC's significance declined. At the same time, the OPEC members have still managed to secure a substantial share of the market and generate revenue running into billions, not least due to the rise of the People's Republic of China, now established as a new player – with an ever-increasing demand for energy – on the world's economic stage.

The established model is in crisis

According to figures from the International Energy Agency (IEA), global energy consumption has more than doubled since the early 1970s, rising from 194 to 418 exajoules (EJ). The highly industrialised OECD countries in North America and Europe, but also Japan, are still the largest consumers of energy. However, in these regions, a stagnation or, in

Photo: Wojciech Wrzesien/ shutterstock.com

some cases, even a decline in primary energy consumption can be observed. The countries in them have made successful efforts, partly through improvements in energy efficiency, to decouple economic growth from energy consumption. This contrasts starkly with the situation in the emerging economies in South and East Asia (mainly China, India, South Korea and Indonesia). In the last four decades, a substantial proportion of global energy consumption has shifted towards these regions (see top Figure on page 8). Looking ahead, given its consistently high rate of population growth, over the coming decades, Africa is also set to become a significant factor in the global game of Energy Monopoly.

Fossil fuels – oil, gas and coal – are transported thousands of miles around the world by ship or pipeline before they reach the major hubs in Europe, North America and China where these resources are consumed. According to the IEA, Saudi Arabia, Russia, Iraq, Canada and the United Arab Emirates (UAE) are the world's largest oil exporters. China, India, the USA, Japan and South Korea are the largest importers in numerical terms. With natural gas, it is a rather different situation. The five largest exporters are Russia, Qatar, Norway, Australia and the USA. The largest gas importers – and heavily dependent on these imports in some cases – are China, Japan, Germany, Italy and Mexico.

Renewables – no longer a privilege of the rich countries

Since around 2000, a highly dynamic expansion of renewable energies (mainly wind and photovoltaics) has also been observed worldwide. According to *EurObserv'ER*, which monitors developments in this industry, renewable energies are already generating significant and positive socio-economic effects. In 2020 alone, renewable energy use in the 27 European Union States (EU-27) avoided 528 million tonnes of CO_2 emissions, substituted for 164.6 Mtoe (million tonnes of oil equivalent) of fossil fuel, saved 35 billion euros in imports, and created and maintained 1.3 million jobs in the renewable energy industry.

Energy analysts such as Bloomberg New Energy Finance (BNEF) have observed not only a change in trade flows but also noticeable shifts in investment (see bottom Figure on page 8). By far the major share of new investment in the energy sector is now channelled into renewable or low-carbon technologies instead of fossil fuel exploration. According to research by the energy advisory company Rystad Energy, investments in low-carbon energies reached 560 billion US dollars (USD) in 2022; the company is predicting a further rise to 620 billion USD in 2023. Solar and wind (onshore and offshore) will contribute the most by a sizable margin. Alongside hydropower, geothermal and hydrogen, Rystad classes nuclear power, but also carbon capture, utilisation and storage (CCUS), as low-carbon technologies.

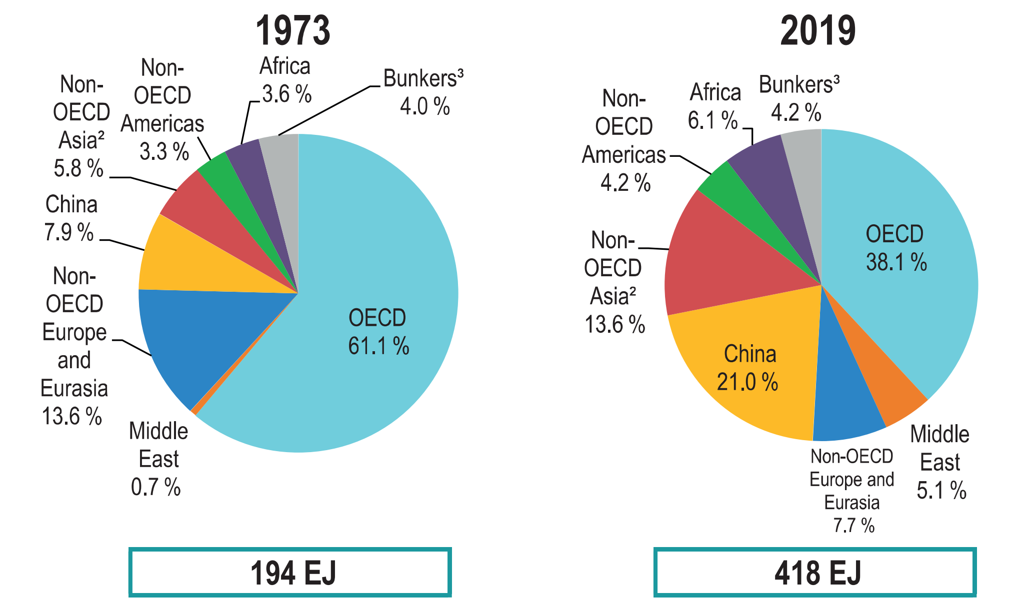
Renewable energies, then, are no longer a luxury enjoyed by privileged industrialised countries; they are now a hard economic factor and driver of innovation with commercial viability. Until now, however, renewables have largely been confined to the electricity sector. It is only recently that there has been any development in the electrification of transport – in the form of electric vehicles – and the domestic heat supply, e.g. with heat pumps. Wind, hydropower, solar and geothermal tend, by their very nature, to be available locally. Most of the electricity generated from renewables is fed into the European transmission grids and traded Europe-wide in a liberalised market. Unlike oil, coal and gas, renewables are not traded as a transcontinental commodity: there are no subsea power cables linking Europe with North or South America.

Russia's war on Ukraine driving global energy transition

For many decades, including the entire duration of the Cold War, Russia was a reliable supplier of affordable gas to Europe. The gas was transported by pipeline through Eastern Europe to the West and was an important pillar of the Western economic and growth model. With Russia's invasion of Ukraine, this model more or less imploded overnight. In response to Russia's war of aggression, the European Union (EU) imposed sanctions on Russian companies and individuals from the spheres of politics and business. This has affected the financial, energy and transport sectors. Since then, the EU has been attempting to break free from Russian energy imports as swiftly as possible. At the start of 2021, for example, more than 53 per cent of the gas consumed in Germany came from Russia, but within a matter of months, this had fallen to almost zero, according to figures from the German Association of Energy and Water Industries (BDEW). This was achieved by switching to other gas supplier countries and making significant energy savings in households and industry.

The dramatically accelerated diversification of the energy supply away from Russian gas, which began – not entirely voluntarily – in 2022, does not signify an immediate break with fossil fuel per se. Indeed, in Germany, disused lignite-fired power plants have been brought back into service in order to secure the electricity supply in winter and substitute for natural gas in the energy mix. Several EU countries are turning to the international energy markets to obtain liquefied natural gas (LNG) – which is not entirely free from controversy in terms of its environmental credentials, but is still a highly sought-after commodity. As a result, an LNG supply is now out of

Share of world total energy consumption by region (in exajoules, EJ)



1 Data for biofuels and waste final consumption have been estimated for a number of countries.
2 Non-OECD Asia excludes China.
3 Includes international aviation and international marine bunkers.
Source: IEA, World Energy Balances, 2021.

reach for the weaker economies. LNG is natural gas that has been cooled to a temperature of -162° Celsius, bringing it to a liquid state in which it occupies only 1/600th of its original volume and allowing it to be transported on tanker ships. These LNG tankers dock at floating terminals, known as Floating Storage and Regasification Units (FSRUs), where the LNG is brought back up to normal temperature and fed into the gas transmission network. The world's leading LNG exporters include Qatar, Australia and the USA. In the short term, the purpose of the new floating LNG terminals – which have undergone a fast-tracked approval process – is to contribute to energy supply security. In the medium term, the terminal infrastructure should be capable of handling carbon-free hydrogen instead of natural gas. This rapid and comprehensive reduction in the share of Russian gas, oil and coal imports appears to be irreversible, at least for now.

Russia is therefore attempting to compensate for this loss of revenue by redirecting its exports to countries such as China. India, too, is stocking up on cheap crude oil from Russia. However, pending the development and expansion of the necessary pipeline infrastructure, these exports currently amount to no more than a fraction of the previous levels. This has sometimes bizarre and environmentally harmful consequences. As gas wells, once opened, cannot be closed again immediately, Russia often resorts to flaring to burn off the residual natural gas exiting the wells. The *Handelsblatt* newspaper and other media have also reported on a quite extraordinary situation in which Saudi Arabia – one of the world's largest petroleum producers – has stocked up on low-cost Russian oil for power generation, thereby benefiting from falling market prices.

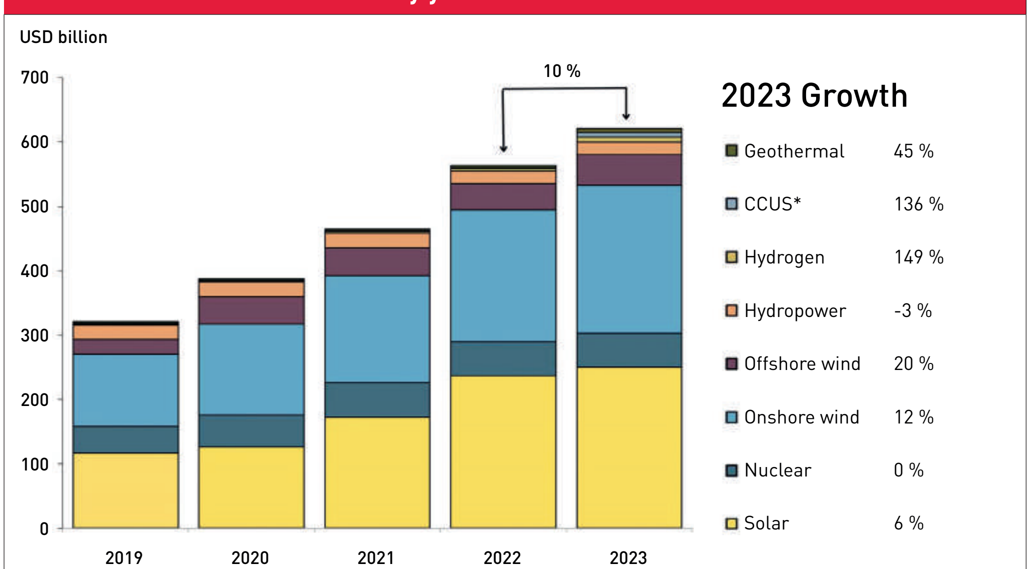
New energy sources and new trade flows emerging

Nevertheless, the notion that the heyday of fossil fuels is reaching an end is no longer wishful thinking on the part of environmental NGOs. In its latest *World Energy Outlook* 2022, the IEA also predicts that the era of fossil fuel growth may soon be over, with global demand for fossil fuels peaking, followed by a steady decline in the coming decades. The kind of energy system required for the future is now a largely uncontentious issue in politics, business and society: what is needed is a radically decarbonised, fossil fuel-free energy system which is substantially reducing its resource consumption and energy-related emissions, if not to zero but certainly to a level compatible with climate neutrality.

Climate neutrality cannot be achieved with the current level of fossil fuel use. The mitigation targets set forth in the Paris Agreement can only be reached if there is a rapid change of direction in many countries' energy and climate policies, based on carbon-neutral energy use. In recent years, hydrogen has therefore been hailed by many decision-makers as a potential energy source and great hope for the future. Several dozen hydrogen strategies or roadmaps now exist world-wide, and the number of hydrogen projects being announced is steadily increasing. The proclaimed technological and environmental benefits of hydrogen lie in its characteristics as a local carbon-free energy source and its numerous potential applications, including electricity storage and use as a fuel or input in industry and transport.

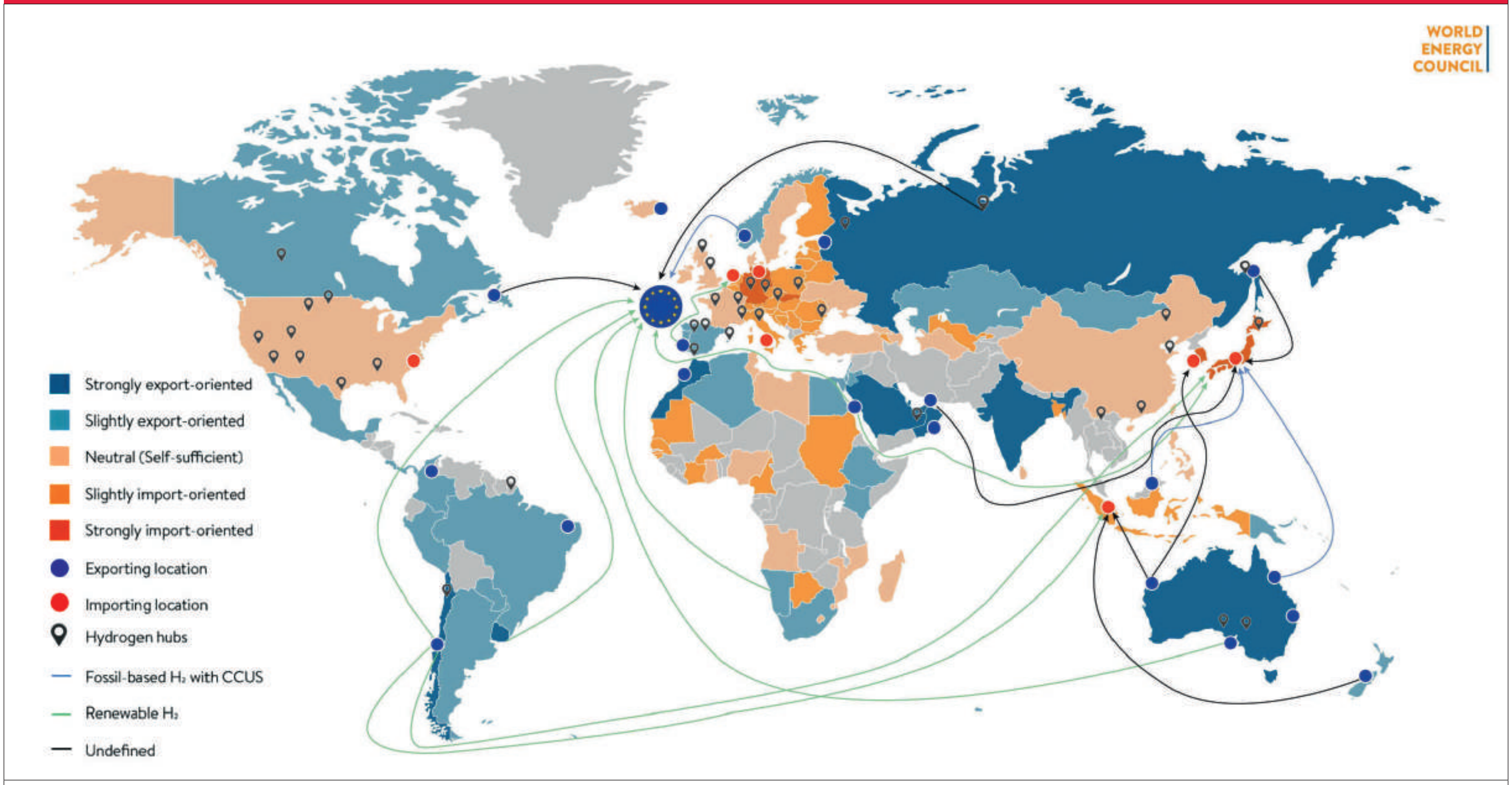
Low-carbon production of hydrogen derivates such as ammonia, methanol and synthetic fuels is theoretically possible. Currently, however, production of hydrogen and its derivates is

Global low-carbon investments by year



*Carbon Capture and Storage
Source: Rystad Energy, 2022.

Map of potential low-carbon hydrogen import-export dynamics in 2040



Source: World Energy Council, 2022.

usually an energy- and therefore emissions-intensive process. The production of renewable hydrogen is most affordable and efficient in the sun-drenched and windswept regions of the world, in theory offering untold economic development opportunities for regions and countries around the world which were never previously thought to have abundant energy resources at their disposal. Indeed, new countries are now appearing on the geopolitical world map and featuring in energy policy debates: alongside the current fossil fuel-exporting countries – Saudi Arabia, Qatar and the UAE, which will have to adapt to a post-fossil world – new actors are positioning themselves with their megaprojects in the prospective hydrogen arena, such as Australia (previously an exporter of coal, now solar power and hydrogen) and Chile (positioning itself as an exporter of hydrogen and silicon as a raw material for batteries and e-mobility). India, South Africa, Morocco, Namibia, Colombia, Mauritania, Oman and Egypt are also moving into position as potential hydrogen producers and exporters – to mention just a few of the countries with new energy and hydrogen ambitions. A "race to hydrogen" can also be observed at present. Through agreements and energy partnerships, the major energy consumers in America, Europe and East Asia are keen to secure access to countries with good climatic conditions for hydrogen production and export.

This creates both opportunities and risks. Becoming an exporter of clean but still rare and therefore valuable renewable hydrogen offers a great development opportunity for previously marginalised economies in the Global South, for it holds out the prospect of growth, employment, prosperity and innovation. At the same time, there is a risk of neocolonial energy extractivism and the "resource curse", which has afflicted many countries engaged in oil and gas production: the vast export earnings and tax revenue generated by multinational corporations have often ended up in the hands of a small and corrupt elite without significantly improving the living standards of the population at large. Furthermore, it is still unclear which modes of transport for hydrogen will prevail in the medium to long term: hydrogen as a gas, liquefied or in the form of ammonia or methanol, or, alternatively, the use of new storage methods and molecules, known as liquid organic hydrogen carriers (LOHCs). It is likely that several technologies and markets will develop at the global scale, each serving specific applications and industries.

The future energy system will probably be based largely on renewable energy sources and a far higher proportion of temporarily stored energy. But what should this system look like? Should it be centralised or local? How will it be organised (based on market economic principles, or reliant on a high degree of state control and taxation)? How much of a share will accrue to individual energy sources (proportion of renewables, natural gas or nuclear)? Which technologies should – or should not – be utilised to achieve compliance with the Paris climate targets (carbon capture and storage, fracking, geoengineering, or other measures to achieve negative emissions)? Can overall energy and resource consumption be reduced with energy efficiency measures, and if so, how? And what about funding? These pressing energy, climate and technology policy issues are the subject of intense debate in politics, business and society world-wide, and their solutions at the national level will vary widely.

Roman Buss is a political scientist who has been observing the expansion of renewable energies and the hydrogen ramp-up in Germany, Europe and world-wide for many years. He is a Senior Manager at Weltenergierat – Deutschland e.V., the national member representing the Federal Republic of Germany at the World Energy Council, the world's largest energy body covering all energy resources and technologies.
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References: **www.rural21.com**

ENERGY NEWS ROUNDUP

Investments in energy transition – glaring disparities

Global investment in energy transition technologies – including energy efficiency – reached 1.3 trillion US dollars (USD) in 2022. This is a new record high, up 19 per cent from 2021 investment levels, and 50 per cent from before the pandemic in 2019. However, these investments are way short of what is needed to achieve the international climate and sustainability goals. This is referred to in the report *Global Landscape of Renewable Energy Finance 2023*, launched by the International Renewable Energy Agency (IRENA) and the Climate Policy Initiative (CPI) on the sidelines of the Spanish International Conference on Renewable Energy in Madrid in February 2023. While investment in renewable energy reached an all-time high, at 0.5 trillion USD, in 2022, this still represented less than 40 per cent of the average investment needed each year between 2021 and 2030, according to IRENA's 1.5°C scenario. Neither are investments on track to achieve the goals set by the 2030 Agenda for Sustainable Development, the report says. As decentralised solutions were key to reach universal energy access, efforts had to be made to scale up investments in the off-grid renewables sector. But although exceeding 0.5 billion USD in 2021, investment in off-grid renewable solutions fell far short of the 2.3 billion USD needed annually in the sector between 2021 and 2030.

Furthermore, the authors criticise the concentration of investments in specific technologies and uses. In 2020, solar/photovoltaic alone attracted 43 per cent of the total investment in renewables, followed by onshore and offshore wind at 35 and 12 per cent shares, respectively. Preliminary figures might suggest that this concentration has continued up to 2022. But to best support the energy transition, more funds needed to flow to less mature technologies as well as to other sectors beyond electricity, such as heating, cooling and system integration.

38 countries plus the EU have roadmaps for hydrogen production

366 billion USD was invested in renewables in 2021

156 countries have renewable power regulatory policies

Renewables 2022 Global Status Report

Disparities have increased

Comparing renewables financing across countries and regions, the report shows that glaring disparities have increased significantly over the last six years. About 70 per cent of the world's population, mostly residing in developing and emerging countries, received only 15 per cent of global investments in 2020. For example, less than 1.5 per cent of the amount invested globally between 2000 and 2020 went to sub-Saharan Africa. In 2021, investment per capita in Europe was 127 times that in sub-Saharan Africa, and 179 times more in North America. Recognising the limited public funds available in the developing world, the report calls for stronger international collaboration, including a substantial increase in financial flows from the Global North to the Global South. "For the energy transition to improve lives and livelihoods, governments and development partners need to ensure a more equitable flow of finance, by recognising the different contexts and needs," IRENA Director-General Francesco La Camera said presenting the report.

Fossil fuels getting more support again

Achieving an energy transition in line with the 1.5°C scenario also required the redirection of 0.7 trillion USD per year from fossil fuels to energy-transition-related technologies. But following a brief decline in 2020 due to Covid-19, fossil fuel investments are now on the rise again. Some large multi-national banks have even increased their investments in fossil fuels at an average of about USD 0.75 trillion dollars a year since the Paris Agreement. In addition, the fossil fuel industry continues to benefit from subsidies, which doubled in 2021 across 51 countries. The phasing out of investments in fossil fuel assets should be coupled with the elimination of subsidies to level the playing field with renewables. However, phasing out subsidies needs to be accompanied by a proper safety net to ensure adequate standards of living for vulnerable populations.

(IRENA/CPI/sri)

Photo: Oliver Knight/ World Bank

Carbon dioxide levels at all-time high

Global energy-related CO_2 emissions grew in 2022 by 0.9 per cent, or 321 million tonnes, reaching a new high of more than 36.8 billion tonnes. This is stated in the report *CO_2 emissions in 2022*, which the International Energy Agency (IEA) presented in Paris early in March. "The impacts of the energy crisis didn't result in the major increase in global emissions that was initially feared – and this is thanks to the outstanding growth of renewables, electric vehicles, heat pumps and energy efficient technologies. Without clean energy, the growth in CO_2 emissions would have been nearly three times as high," said IEA Executive Director Fatih Birol at the presentation of the Report. "However, we still see emissions growing from fossil fuels, hindering efforts to meet the world's climate targets." International and national fossil fuel companies were making record revenues and needed to take their share of responsibility, in line with their public pledges to meet climate goals. "It's critical that they review their strategies to make sure they're aligned with meaningful emissions reductions," Birol demanded.

The report covers CO_2 emissions from all energy combustion and industrial processes – and also includes information on methane and nitrous oxide emissions, providing a complete picture of energy-related greenhouse gas emissions in 2022. Some of the main findings:

> We still see emissions growing from fossil fuels

- Of the 321 Mt (million tons) CO_2 increase, 60 Mt CO_2 can be attributed to cooling and heating demand in extreme weather and another 55 Mt CO_2 to nuclear power plants being offline.
- Emissions from coal grew by 1.6 per cent or 243 Mt as the global energy crisis continued to spur a wave of gas-to-coal switching in Asia and, to a lesser degree, in Europe. While the increase in coal emissions was only around a quarter of 2021's rise, it still far exceeded the last decade's average growth rate. The increase in emissions from coal more than offset the 1.6 per cent decline in emissions from natural gas as supply continued to tighten following Russia's invasion of Ukraine and as European businesses and citizens responded with efforts to cut their gas use.
- Emissions from oil grew by 2.5 per cent, but are still remaining below pre-pandemic levels. Around half of the year-on-year increase in oil's emissions came from aviation as air travel continued to rebound from pandemic lows.
- The biggest sectoral increase in emissions in 2022 came from electricity and heat generation, whose emissions were up by 1.8 per cent or 261 Mt. In particular, global emissions from coal-fired electricity and heat generation grew by 224 Mt or 2.1 per cent, led by emerging economies in Asia.

> Without clean energy, the growth in CO_2 emissions would have been nearly three times as high

- CO_2 growth in 2022 was well below global GDP growth of 3.2 per cent, reverting to a decade-long trend of decoupling emissions and economic growth that had been broken by 2021's sharp rebound in emissions.
- China's emissions were broadly flat in 2022 as strict Covid-19 measures and declining construction activity led to weaker economic growth and reductions in industrial and transport emissions.
- Excluding China, emissions from Asia's emerging and developing economies increased by 4.2 per cent, reflecting their rapid economic and energy demand growth.
- The European Union's emissions fell by 2.5 per cent, thanks to record deployment of renewables helping ensure the use of coal was not as high as some observers had anticipated. A mild start to the European winter and energy savings measures in response to Russia's invasion of Ukraine also contributed.
- In the United States, emissions grew by 0.8 per cent as buildings increased their energy consumption to cope with extreme temperatures.

(IEA/sri)

ENERGY NEWS ROUNDUP – A look at Africa

Germany intends to intensify the climate and energy partnership with SASSCAL and WASCAL

Southern and West African Climate Change Ministers have signed a "Joint Declaration" with Germany's Federal Government to further strengthen the climate and energy partnership of the Southern African Science Service Centre for Climate Change Adaptive Land Management (SASSCAL), the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) and the Federal Ministry of Education and Research, Germany (BMBF). In addition to expanding the centres, the Declaration stipulates establishing green hydrogen and renewable energy as a new strategic focus. "SASSCAL and WASCAL are door-openers in creating a global supply chain for Green Hydrogen. Africa is especially suitable for this," said Germany's Federal Research Minister Bettina Stark-Watzinger, signing the "Strategic Climate and Energy Partnership SASSCAL, WASCAL, BMBF" in Berlin in mid-February. A total of 68 million euros had already been provided to develop this cooperation scheme. SASSCAL and WASCAL, which are now international organisations, were initiated by the BMBF together with partner countries in West and South Africa in 2012. With these centres, regional research on adapting to the impacts of climate change is to be promoted. In addition, cross-country programmes on capacity development and the setting up of a common data and research infrastructure are on the agenda. *(BMBF/sri)*

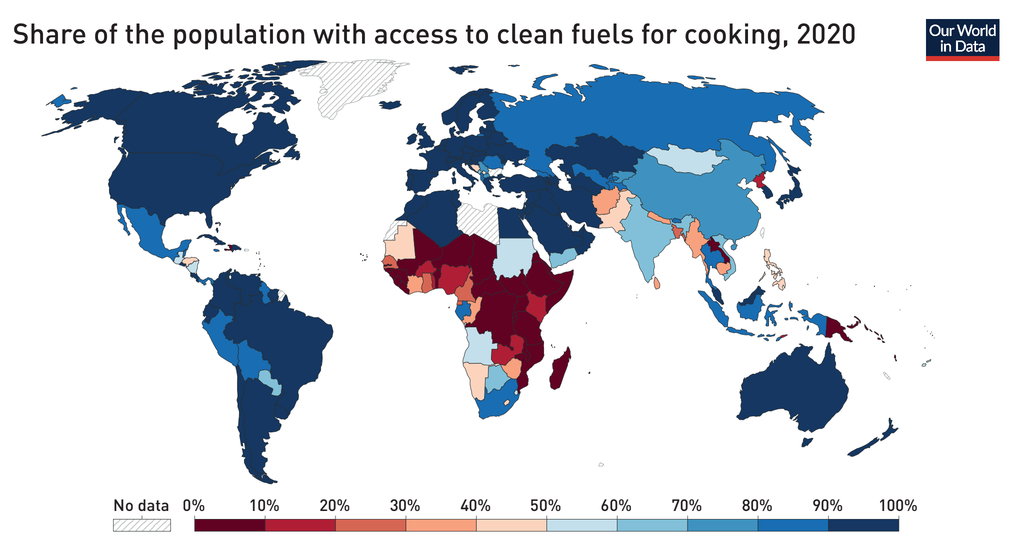
AU seeks to raise efforts to achieve universal energy access by 2030

On the side-lines of the 36th Ordinary Session of the Assembly of the African Union in mid-February, a presidential roundtable called for the acceleration of financing for energy access in Africa with clear targets and steps for ensuring the achievement of universal energy access by 2030. Here, the Chairperson of the African Union for 2023, the President of the Union of the Comoros Azali Assoumani, shed light on the irony of energy poverty on a continent that is richly endowed with vast energy resources which remain untapped. Assoumani also highlighted the energy situation in most African island nations and noted that continental approaches could complement national initiatives to boost energy access. He referred to the example of the Geothermal Risk Mitigation Facility (GRMF), a fund that was established in 2012 to finance, facilitate and accelerate geothermal development in Eastern Africa.

The African Single Electricity Market (AfSEM) was noted to be a key strategic element of facilitating energy access and enhancing energy security in Africa and, therefore, the AU Member States, regional economic communities and their specialised institutions were urged to play their part in facilitating its operationalisation. Launched in June 2021, this continent-wide energy trading programme is meant to interconnect all 55 African Union Member States through an efficient, affordable and sustainable electricity market. The President of the Republic of Madagascar Andry Rajoelina emphasised the need to invest in clean sources to fast-track universal energy access in Africa. "Addressing energy access is not negotiable for any leader, and we need now to move from words to action," he said, adding that Madagascar aspired to achieve 100 per cent energy access in the shortest possible time, mainly by harnessing renewables.

African Union Commissioner for Infrastructure and Energy Amani Abou-Zeid stressed that Africa's key priorities and initiatives including industrialisation, the African Continent Free Trade Area (AfCTA), agricultural development, food security, poverty alleviation, job creation and regional integration, as well as the achievement of the SDGs, were all dependent on modern and universal energy access and services. According to the AU, Africa needed 25 billion US dollars in investment annually to meet its energy targets. Partnerships in the area of finance, knowledge and technology transfer were required to help speed up existing and new initiatives to overcome constraints that African countries were facing in their quest for energy development. *(AU/sri)*

Share of the population with access to clean fuels for cooking, 2020



Source: WHO, Global Health Observatory, 2022.

How global energy and fertiliser markets impact on food security

The world is currently facing three parallel shocks: an oil/gas price shock, a fertiliser price shock and a food price shock. For governments, the private sector and civil society, it is important to understand how the markets for these commodities work and how they intermesh. Only then will they be able to draw the right conclusions for sensible policies and solutions, our author maintains and explains the context.

By Heinz Strubenhoff

Global food insecurity reached record highs in 2022. It is a result of many events and developments interacting with one another – including the impacts of the Russian war of aggression against Ukraine, conflicts and droughts in Africa, global climate threats, the corona pandemic and rising prices of energy, fertiliser and food. The interplay of the drivers of energy, fertiliser and food markets is reversing recent trends, making it unlikely to eradicate poverty and reach zero hunger in 2030. According to the World Food Program, the number of people facing acute food insecurity has risen from 135 million to 345 million since 2019. Food price spikes increase social tensions, and may lead to more conflicts and fragile situations in the Global South.Global commodity markets for energy, fertiliser and food are highly correlated. The drivers of these markets cannot be influenced by single decision makers, but thorough assessment may facilitate development of strategies to cope with these shocks and to mitigate social and economic risks.

Global food commodity prices will most likely remain elevated for a certain period if energy and fertiliser remain costly and food market supplies are reduced because of additional threats.

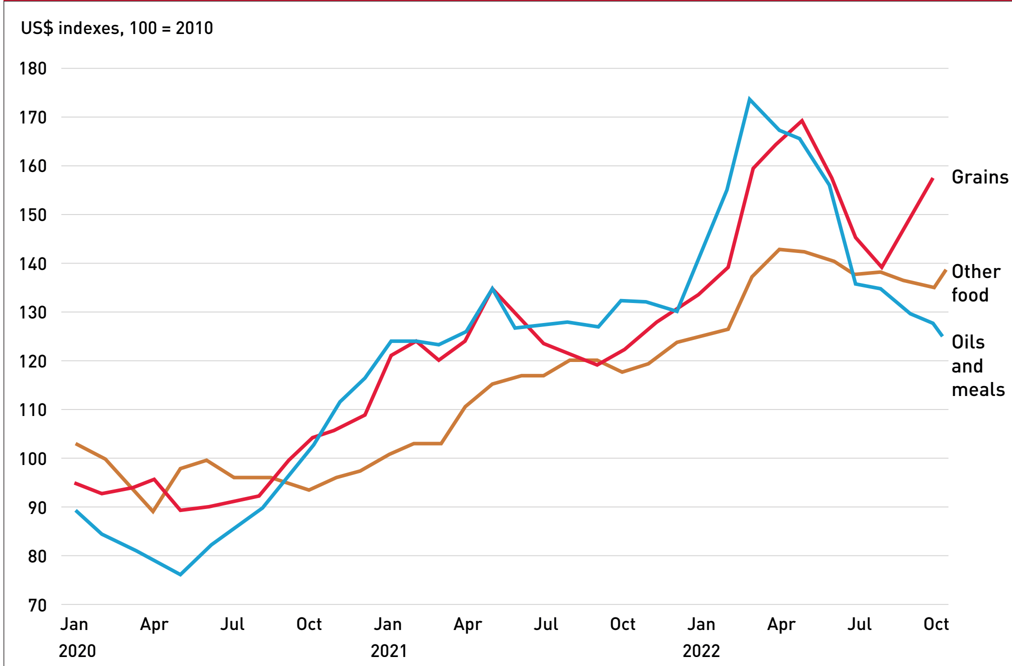
Photo: Jörg Böthling

Food prices and fertiliser affordability

Ukraine and Russia provide almost 20 per cent of globally traded cereals; Ukraine supplies more than 50 per cent of globally traded sunflower oil. After the Russian invasion of Ukraine and its blockade of Ukrainian Black Sea ports, food prices reached their peak in April/May 2022 (see top Figure on page 14). At the beginning of the war, traders anticipated that Ukraine's fertiliser, cereals, and oilseeds exports would remain blocked for some time, and Russia's exports would be constrained by sanctions. As a consequence, prices have almost doubled compared to the previous year. The blockade of Ukrainian Black Sea ports triggered interventions to avoid a global food catastrophe from various international actors from the African Union to the United Nations. Brokered by Turkey's President Recep Tayyip Erdogan and the UN's Secretary General António Gutierrez, the Black Sea Grain Initiative was launched, allowing Ukraine to export food commodities under special control mechanisms. Russia's fertiliser and food exports were not sanctioned. This initiative – and EU countries' support to ease Ukrainian exports using other routes – had an immediate impact on global cereals and oilseeds markets. As a result, in summer 2022, prices went down by about 10 to 15 per cent. Although Russia threatened to derail this initiative several times through lengthy controls and rocket attacks, the deal has held so far. In the same period, fertiliser prices have also doubled. Various factors, including surging input costs and supply disruptions due to Covid-19, had already caused prices to rise from 2020 to 2021. The war in Ukraine amplified supply problems. Russia, Belarus and Ukraine provide about 20 per cent of global nitrogen, potassium and phosphate fertilisers. Nitrogen fertiliser production is very energy-intensive, and rising gas and coal prices (see bottom Figure on page 14) led to widespread production cutbacks. Higher nitrogen prices have also driven up phosphate and potassium prices. Fertiliser prices are expected to stay at historically high levels if gas and coal prices remain elevated. The outlook also depends on the supplies coming from Russia, Ukraine and Belarus to global markets.

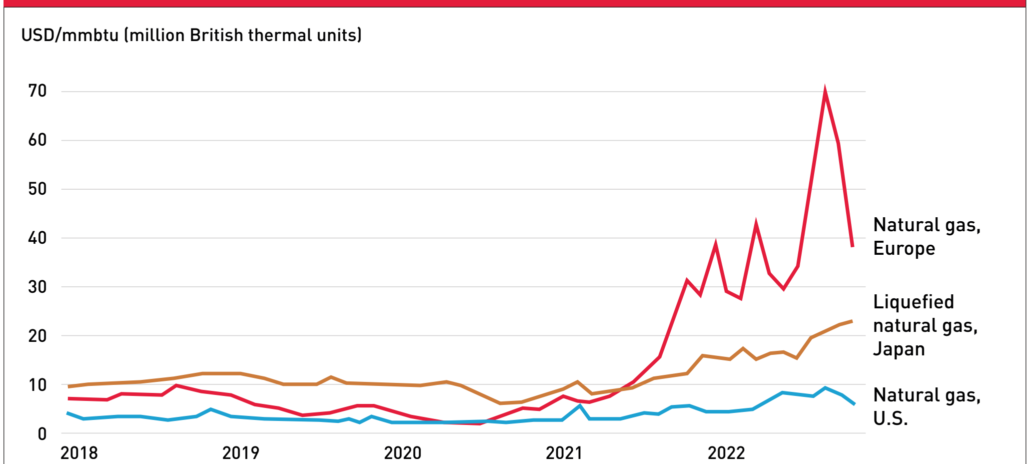
Global cereal and oilseed markets were tight even before the crises, the reason for this being shrinking stocks in 2021 because of fewer supplies from large exporters, including Canada and Russia, and record-high imports from China. Inelastic demand causes a small drop in global harvests to result in cereals and oilseeds prices rising by a large margin. People must eat. That's why global traders look attentively at monthly international harvest forecasts and the ratio of global stocks and global consumption. If the stock-to-use ratio falls under certain thresholds, food prices react quickly and violently. But if fertiliser prices increase even more than food prices, producers must cut back on input levels they can no longer afford. The World Bank's fertiliser affordability index measuring the ratio of fertiliser to food prices is at historical high levels and shows this current situation (see Figure on page 15).

Food price indexes



Note: last observation is October 2022. Source: World Bank

Natural gas prices



Note: monthly data, last observation is October 2022 for natural gas, EU and natural gas, US and September 2022 for LNG Japan. Source: World Bank

Price fluctuations in food and energy markets may further be accelerated by capital markets. If interest rates are low, speculative money is betting on increasing prices at Future Stock Exchanges. Research shows that this significantly amplifies price fluctuations on food markets. Oftentimes, traders of food commodities are not interested in buying or selling the product itself but in realising profits on market trends. Biofuels markets also impact on food commodity markets. The amounts of corn in the USA, rapeseed in Europe and sugar in Brazil that are being transformed into biofuels are huge and impact on food markets. Biofuels demand is very inelastic. Mandates need to be filled at any price. In times of high food prices, biofuels mandates that are set politically should be revisited and if necessary be reduced to lower the pressure on food commodity markets. In times of low prices, the opposite could be done in order to help to reduce food price volatility.

A further known threat to food markets is the weather. The El Niño oscillation in the Pacific is currently in a La Niña phase. Although La Niña has a milder influence on agriculture production than El Niño, it may cause droughts and floods in countries of the Southern Hemisphere, leading to less food production. As climate change is progressing, we may expect more extreme weather conditions leading to droughts and floods adding more risks and volatility to agriculture and food markets.

What must we reckon with?

Higher global food commodity prices will most likely remain elevated for a certain period if energy and fertiliser remain costly and additional threats of climate change, war and conflicts reduce food market supplies. Previous crises suggest a period of about two to three years before higher prices again lead to higher supplies. But this time, it may last longer. With stricter climate action, we may enter a period of longer transition to renewable energy. Expected climate action investments in the energy and fertiliser industries are huge and take time. But even if gas and fertiliser prices do go back to previous levels, food prices may stay elevated. The reason is that the war in Ukraine will continue to reduce supply from the Black Sea region significantly for some years. If Ukraine exports only 20 million tons of cereals annually instead of 50 million tons, food consumers in the world will feel it. To put this into perspective, imagine that one ton of cereals may feed a family of six for a year if based on cereals diets. Thirty million tons less from the Black Sea would thus affect about 180 million people in poor importing countries.

Cereals are particularly important for the poor. Wheat, barley, maize, sorghum and rice account for at least 50 per cent of global nutrition, and as much as 80 per cent in the poorest countries. Global stocks of these crops have been shrinking during the last few years, as demand has outstripped supply. Prices increased sharply from 2020 to 2022. The impact of price spikes on the poor in the Global South is much higher than in industrialised countries for two reasons. First, the share of food in total consumption is much higher. Poor people's purchasing power goes down, and price increases are felt immediately and violently. Second, the value of public budgets for food security programmes shrinks spectacularly with rising food prices.

Which strategy to choose?

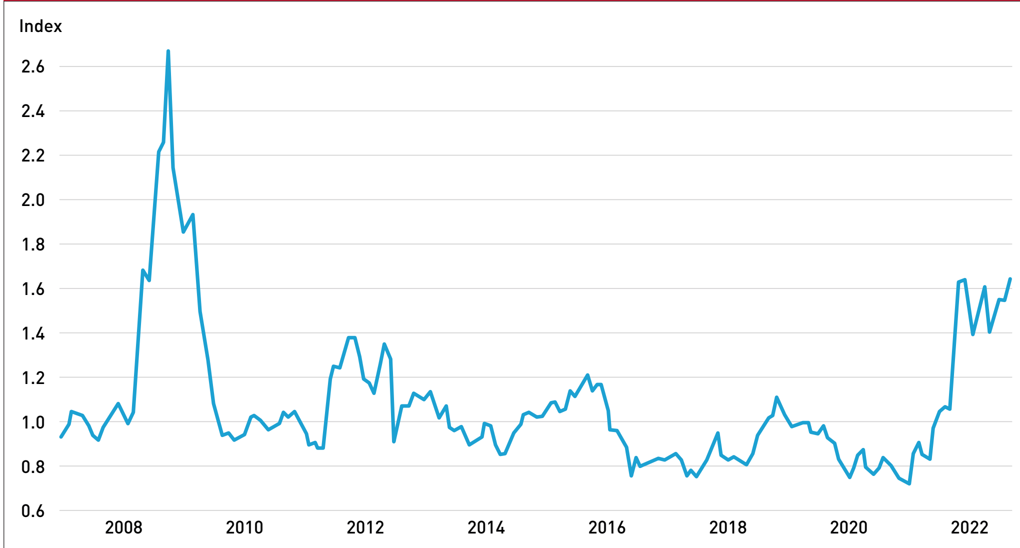
To mitigate the risks of the above triple shock driving inflation and rising costs of capital governments of poor countries must make difficult choices. Budgets are shrinking and need to be invested wisely. Would it make more sense to help consumers in cities to get affordable food, or should this crisis be used to promote producers to increase local production? These are difficult decisions, and solutions will vary from country to country according to priorities, demography, and local production potential. As a rule of thumb, from an economic viewpoint, it is more sensible to help local producers to get affordable seeds, fertilisers, and other inputs than to subsidise products for urban consumers based on imported food commodities. However, policy-makers must also consider social and political consequences – bread prices in cities are highly sensitive to social unrest.

As the area for new farmland is limited in many countries and rules for biodiversity become stricter, more production for growing populations will mainly have to be achieved by climate-smart intensification. Climate-smart agriculture is an approach that helps to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. Mitigation of climate change risks can be achieved by reducing carbon emissions by improved farm practices, keeping more organic matter in the soil (carbon sequestration), reducing methane emissions by improved manure management and improved paddy rice cultivation. Adaptation to climate change can be accomplished by fostering resilience for example by developing drought-resistant seed, water-saving technologies and improving land use efficiency. Investments in climate-smart agriculture may offer development and employment opportunities for rural areas.

To avoid confusion, climate-smart doesn't necessarily mean organic fertiliser only. Sri-Lanka's recent ill-conceived import ban on mineral fertiliser led to riots and a 30 per cent drop in crop yields forcing the Government to change the policy quickly for good reasons. To feed the world, both organic and mineral fertiliser are necessary. There is simply not enough organic matter available to fully replace mineral fertilisers. In many African countries, governments help farmers to use more fertiliser to increase productivity. Kenya and Rwanda are examples of countries which have increased fertiliser use significantly during the last few years. In future, investments in fertiliser production on the African continent may be considered to ease difficult supply chains and reduce transport costs. It would help to facilitate trade between African countries, which is now lower than with Asia and Europe.

The caveat of fertiliser production, in particular the production of ammonia based on gas, is that it produces a lot of carbon emissions. Ammonia production accounts for around 420 million tonnes of carbon dioxide emissions annually, which together with hydrogen production, responsible for 830 million tons of carbon emissions, create around two per cent of the annual global greenhouse gas emissions. So in future, technology partnerships to produce "green" ammonia and hydrogen will become very important in lowering the climate impact of food value chains.

Fertiliser affordability



Note: Ratio of World Bank's fertiliser price index to food price index. A higher ratio represents lower fertliser affordability, and vice versa. Last observation is September 2022. Source: World Bank

Higher prices for energy, fertiliser and food create market problems and lead to higher food insecurity, but at the same time present opportunities and incentives to invest in importing countries. Local production gets more competitive. Production of renewable energy, including solar, hydro, wind and bioenergy become more profitable. Incentives to produce organic fertiliser may lead to farmers using more organic matter. Investments in market infrastructure to link local farmers to markets become more attractive. Local food processors may be inclined to replace imported commodities by locally produced agricultural products. Investments in market infrastructure, including transport, storage and processing make importing countries less vulnerable to global shocks.

I would also like to draw attention to solutions to avoid food waste. About one third of global food production is wasted, in industrial countries mainly at the end of the food chain, in households, and in agrarian countries mainly at the beginning of the food chain, on farms. Under tropical conditions in Africa, with bad storage and insufficient transport infrastructure one third of perishable farm produce is rotting away after farmer's hard work. A transition to off-grid, solar-powered cold storage systems can reduce food waste and make more food available for subsistence and sales, ensuring food security and economic development while minimising the adverse effects of conventional, fossil fuel-based agricultural value chains.

To fend off price hikes and allow food and fertiliser to be supplied to those who need it most, countries need to be encouraged to keep their borders open. Any attempts to constrain exports of food commodities and fertilisers should be avoided. Where possible, trade barriers should be lowered and idle production capacities be used to deliver more food to the world. Joint action helps to keep markets open and prices under control.

Heinz Strubenhoff has worked as a consultant in East Africa and Eastern Europe. For over ten years, Strubenhoff, who holds a PhD in agricultural economics, lived in Ukraine, where he also headed the German-Ukrainian Agricultural Policy Dialogue for Germany's Federal Ministry of Agriculture and worked for the World Bank's International Finance Corporation (IFC). He currently lives in Hamburg/Germany, where he is a consultant for KfW and Deutsche Bank.
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References: **www.rural21.com**

Green hydrogen – new opportunities for sustainable development in the Global South?

International observers link many hopes for global sustainable development to the use of green hydrogen – i.e. hydrogen whose production releases no emissions. It is regarded as an important building brick for the development of zero carbon economies. Several countries in the Global South are in the process of positioning themselves as exporters of this new energy carrier. But what potential does the new technology really hold? And who benefits in the end?

By Andreas Stamm and Rita Strohmaier

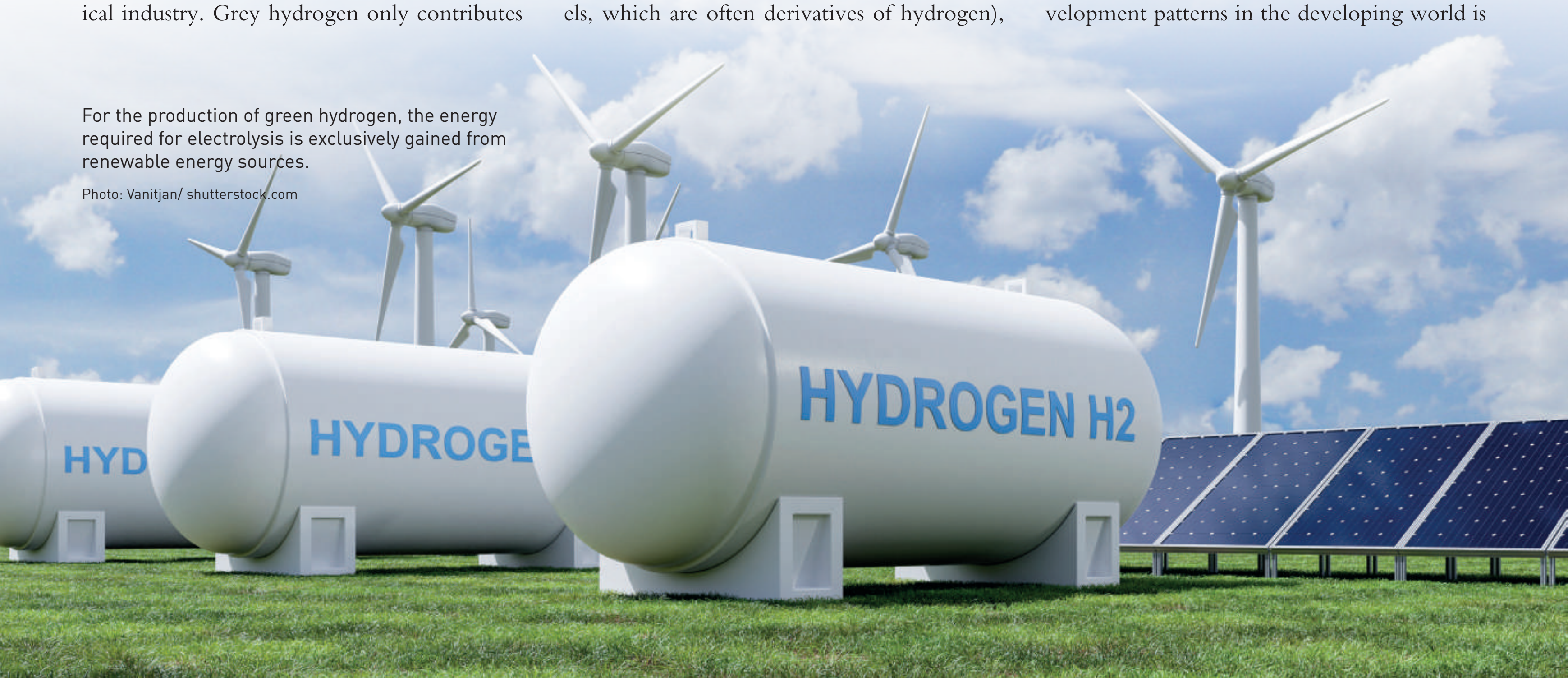
Hydrogen is the lightest and most common element in the universe. However, most of the hydrogen on Earth is bound up with oxygen, as part of water. To be used as an energy carrier, free hydrogen molecules are needed. Traditionally, and at very large scale, free hydrogen – used in the chemical industry, including ammonia production and in refineries – is obtained through a process called steam methane reforming (SMR), which uses hydrocarbons – most often natural gas – and extracts hydrogen in a series of chemical reactions. This method requires large amounts of energy, as the reforming reactor has to be kept at very high temperatures to keep the chemical processes running. The high energy demand adds to the carbon dioxide produced from the natural gas reactions and makes SMR a heavy emitter of greenhouse gases. It is estimated that 9.3 kilograms (kg) of CO_2 are generated per kg of hydrogen produced with SMR, more than an equivalent amount of gasoline, which produces 9.1 kg of CO_2 when combusted. The hydrogen obtained in this way is called grey hydrogen. In Germany, 55 terrawatt-hours (TWh) of grey hydrogen are annually processed, mainly in the petrochemical industry. Grey hydrogen only contributes to decarbonising industries and other societal processes if the CO_2 produced is captured and not emitted into the atmosphere. The hydrogen coming out of this low-carbon process is labelled as blue hydrogen.

The vision of an international green hydrogen economy

For some years now, hope has rested on hydrogen produced without emissions – also called green hydrogen (GH_2). Here, the starting material is simply water, and the splitting into its two components is done by electrolysis, a process of which the chemical principles have been well-known for more than 200 years. In producing H_2, the energy required for electrolysis is exclusively gained from renewable energies. Against the background of international commitments to rapidly reduce greenhouse gas emissions (GHG) and achieve zero carbon societies in a few decades, a steep increase in low-carbon hydrogen demand in the industrialised world is expected.

In addition to using hydrogen (or synthetic fuels, which are often derivatives of hydrogen), there is also the option of direct electrification as a way to decarbonise industrial processes. With regard to some applications, the two approaches are competing to become the dominant technology. It is, however, very clear that hydrogen will play a crucial role in all industrial processes which require high amounts of process heat, e.g. the steel- and metal-processing and glass industries. This demand arises mainly in the Global North. It is expected that Europe, Japan and South Korea in particular will have to import a great deal of green hydrogen in order to achieve their climate targets. They host many emission-intensive industries but lack renewable energy potentials and space to generate high amounts of green hydrogen.

At the same time, the transition towards green hydrogen is seen as a potential for sustainable development in the Global South. Many developing countries in Africa, Latin America and Asia are endowed with very large potentials of solar radiation, wind and – sometimes – geothermal energy. These comparative advantages could help to open market opportunities in the North. Whether and how these opportunities can in fact trigger more sustainable development patterns in the developing world is



For the production of green hydrogen, the energy required for electrolysis is exclusively gained from renewable energy sources.

Photo: Vanitjan/ shutterstock.com

still "work in progress". We will come back to this later. First we must analyse some uncertainties and risks which may hamper or at least delay the ramp-up of a green hydrogen world economy.

Techno-economic and systemic uncertainties of scaling up GH_2

In the past two to three years, the hydrogen topic "went viral" across the globe. More than 20 countries and the European Union approved national hydrogen strategies since 2020. Taking together, these combine more than 50 per cent of the world's economic output. More policy papers are in the pipeline. Some of these strategies are extremely ambitious, with regard to hydrogen production, trade and usage. The EU, for instance, projects 40 gigawatts (GW) of electrolyser capacities to be up and running already by 2030, producing around 10 megatons of hydrogen per year. A simple comparison makes the level of ambition clear. Since 2021, Europe's largest electrolyser has been operated by the Shell company at its chemical park in Wesseling, close to Cologne in Germany. It has a capacity of 10 MW (= 0.01 GW) and is expected to annually produce 1,300 tons of green hydrogen. Thus, for achieving the ambitions of green hydrogen strategies it has to be assured that electrolysing capacities can be scaled up from pilot scale facilities to large industrial plants in a few years. This includes establishing supply chains for raw materials, sometimes of scarce supply on the world markets, e.g. iridium in the case of Proton Exchange Membrane (PEM) electrolysers.

Iridium is an extremely rare metal. Annually, not more than seven metric tons is extracted, mostly as a by-product of nickel and copper mining or, alternatively, while isolating platinum from its ores. There is a concentration of iridium production in South Africa, which holds 70 per cent of the global market. For the very steep increase in electrolyser manufacturing, global production must be rapidly expanded and/or the iridium context of PEM electrolysers reduced via technological innovations. Alternative technologies, such as alkaline electrolysers, provoke fewer bottlenecks, but are less suited to work with intermittent renewable energies.

The next logical, but often neglected, question is how hydrogen, produced thousands of kilometres away from Europe, Japan or South Korea, can be internationally transported in a safe, environmentally friendly and cost-efficient way. One relatively low-cost possibility is transportation via pipelines. This option is, however, only open to countries within a radius of no more than 5,000 km from the buyers. It excludes locations like Namibia in Africa and Chile in Latin America, which are positioning themselves as export locations for green hydrogen. If the very high import needs in the Global North become reality, it is obvious that current vessel capacities will not suffice to transport these huge quantities. It must also be added that vessels transporting a low- or zero carbon material should better not be powered by high-emission fuels, like heavy oil and marine diesel fuel. However, this contradiction can be technically solved. In early 2022, the world's first ammonia-ready vessel

Photo: Dragon Claws/ Adobe Stock

was put into service in Greece. In the future, this type of tanker may transport ammonia, as a derivative of hydrogen and also to use it for its own engines. But considering the quantitative dimensions of a green hydrogen world economy, many more of these ships will have to be built and put into service in the next years and decades.

For producing countries, the transport issue has an additional difficult dimension, especially for developing countries with limited investment and financial capacities. To date, it is unclear in which chemical and aggregate state hydrogen will be internationally shipped. The only certainty is that it will not happen in the gaseous state for technical and economic reasons. Currently, three options are intensely discussed: liquefied hydrogen (LH_2), ammonia (NH_3) or liquid organic hydrogen carriers (LOHC). Ammonia is gradually gaining acceptance as the technology of choice, but without certainty. A developing country wishing to position itself as GH_2 exporter might have to invest in plants and infrastructure for the conversion of hydrogen into one or several of the three derivatives. Associated risks of lost investments are high.

Equally important is the question of the offtake of hydrogen once it is produced, and how to coordinate supply and demand in a technically and economically feasible way. While hydrogen can be used for storing energy in small to medium quantities in pressurised or ultra-cooled form, it cannot be produced in stockpiles in the dimensions required e.g. by industry. Only a coordinated scaling-up of supply and demand can, thus, assure a lasting market ramp-up.

Towards a dual and gradual GH_2 strategy

Under the given uncertainties, it is obvious that most developing countries should not rely exclusively on an export strategy. Even if the technical and systemic uncertainties can be overcome, establishing green hydrogen export enclaves will not contribute to solving the most pressing socio-economic problems in the Global South. Most of the potential producing countries are struggling with high (youth) unemployment levels. Employment effects of large renewable energy facilities and electrolysers may be relevant during their establishment, but not so once the systems are up and running. Sector coupling and linkages to local industries have to increase value addition and high quality employment. Societies may also benefit in other ways: Green hydrogen can be used as a storage option in mini-grids in remote areas, fed by intermittent renewable energies. Fuel cells can power heavy transport vehicles and long-range buses, lowering GHG emissions and reducing local air pollution.

Chile and Costa Rica's green hydrogen strategies and South Africa's green hydrogen roadmap sketch a gradual building-up of a hydrogen economy. The first steps foresee investing in facilities to produce green hydrogen and use it on the domestic market, e.g. for the transport sectors (mainly heavy duty transport and long-range buses) and for the local industry (cement, explosives for the mining sector in Chile). Gaining experience and building up human capacities can position domestic stakeholders in the driver's seat of the green hydrogen economy. Risks of lost investments can be lowered.

Using GH_2 as feedstock for fertiliser

One all too often overlooked role for sustainably produced hydrogen is as a feedstock in the production of nitrogen fertilisers (also see article on page 36). The Haber-Bosch process is key to the elaboration of fertilisers. It uses hydrogen (from different sources) and nitrogen (e.g. from direct air capture) to synthesise NH_3, ammonia. NH_3 is then converted into fertiliser. The core technology to produce hydrogen is through SMR. A fossil fuel (most often natural gas) is used to extract hydrogen. This mode of H_2 generation is rather inexpensive but entails huge emissions of CO_2. Substituting hydrogen from SMR by green H_2 offers a triple-win option for farmers, especially in the developing world:

- It would make fertiliser production rather independent from fluctuations in natural gas prices. Even before Russia's war of aggression against Ukraine started in February 2021, fertiliser prices had increased very significantly, linked directly to the rises in natural gas prices. Fertilisers became increasingly out of the reach of farmers, above all smallholders in the Global South.
- Linked to this, it would make developing countries less dependent on a small number of autocratically governed countries. In the past several years, the Russian Federation has been the largest supplier of fertiliser to Latin America, and the second-largest to Africa. China is the most important supplier to India, followed by Saudi-Arabia.
- It could contribute to significantly lower GHG emissions; recent research concludes that nitrogen fertiliser production alone is responsible for 0.84 per cent of global greenhouse gas emissions.

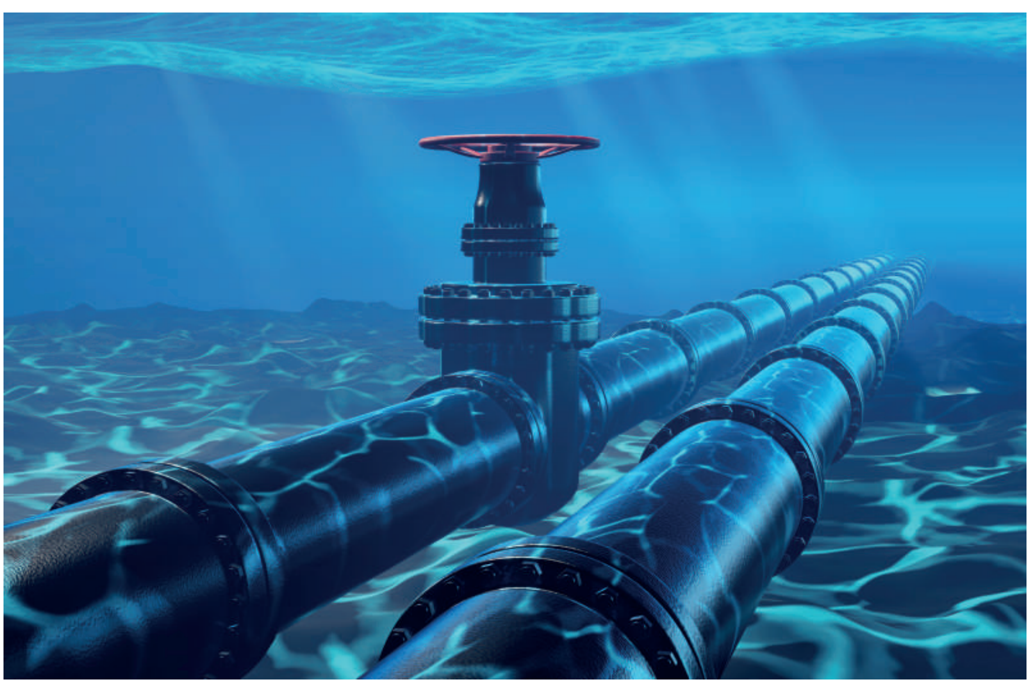
Producing nitrogen fertiliser from green hydrogen is technically feasible. Several large companies have dedicated projects in the pipeline, e.g. Yara from Norway and Fertiberia from Spain. To date, the main obstacle to a fast roll-out of hydrogen-based fertiliser production is the high costs of hydrogen generation. It is, thus, not surprising that Fertiberia has very ambitious plans for producing low-carbon fertiliser in the Northern Swedish region of Luleå-Boden. The project, announced in 2021, includes 600 MW of electrolysers and a green ammonia plant producing 1,500 tons per day as well as an annual production of more than 500,000 t of low-carbon fertilisers and industrial products. The locational advantage of Northern Scandinavia is the availability at very low costs for renewable electricity. These are only a fraction of the costs in other parts of Europe and also many developing countries.

In most developing countries, fertiliser production based on green hydrogen is not competitive with imported fertilisers produced on a large scale and based on natural gas as feedstock. This can change in the future, if the negative externalities of GHG emissions are fully internalised and the prices for renewable energies and electrolysers decrease. Considering the mentioned "triple-win" options, there might be good reasons for international cooperation to promote dedicated pilot projects. These could be situated in sub-Saharan Africa, as this is the world region most affected by the current food crisis. In addition, farmers in Africa tend to use – on average – very low amounts of fertilisers: in 2020, around 22.5 kilograms/hectare land, compared to 197.3 kg/ha in South Asia, 211.3 kg/ha in Latin America and 288.8 kg/ha in East Asia. This implies that increases in nitrogen fertilisers applied – in combination with responsive varieties, proper application of the right amounts at the right time and good soil management – may lead to more elastic increases in yields compared to other world regions. At the same time, the risks of eutrophication of water bodies may be lower.

Production of green ammonia and fertiliser would require scaling up of renewable energy generation. In many countries in sub-Saharan Africa, this might be seen as conflicting with the universal access of the local population to electricity. Thus, if international investors consider building green ammonia/fertiliser plants in Africa, they might also think about some kind of benefit sharing with the local population, e. g. building "oversized" renewable energy plants and feed parts of the electricity into the grids which supply households and small businesses. Internationally financed pilot projects might be located first in countries which have achieved relatively high percentages of electricity access.

Final considerations

Green hydrogen has come to stay. It provides important opportunities for global sustainable development. Significant research still has to be done to carve out strategies for long-term mutual benefit of actors in the Southern and Northern hemisphere. Reducing the role of developing countries to exporters of a (green) commodity is inadequate. A partnership-oriented approach implies involving researchers and other actors from the Global South in the search for innovative ways towards a global green hydrogen economy.



It is still unclear which modes of transport for hydrogen will prevail in the medium to long term. Transportation via pipeline is low-cost, but only open to countries within a radius of no more than 5,000 km from the buyers.

Photo: Dragon Claws – stock.adobe.com

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Members of a group belonging to the Turkana community closing a steel ring kiln to prepare charcoal next to their village in Morungole, Turkana County, Kenya. The group has substantially transformed its livelihood, hacking down the invasive trees called Mathenge and turning them into charcoal.

Photo: Luis Tato/ FAO

Biomass for energy and forest landscape restoration

Especially in rural communities, millions of households rely on firewood or charcoal fires for heating and cooking. However, these so-called traditional bioenergy value chains are not sustainable, one of the many consequences of which is land degradation. Modern bioenergy is a solution to satisfy affordable energy demand while restoring forest landscapes. Exploiting this link provides several opportunities for energy and income generation, but the transition is not easy.

By Matteo Milani, Constance Miller and Maria Michela Morese

In some parts of the world, traditional wood energy remains the primary energy source for many households. In sub-Saharan Africa (SSA), more than 80 per cent of households in urban areas depend on firewood and charcoal (called woodfuel) for heating water and cooking, and wood energy value chains provide employment to millions of people. Woodfuel demand is expected to grow further because of population growth.

Traditional wood energy is unsustainable

Traditional wood energy value chains are not sustainable. Increasing energy demands have resulted in overharvesting and unregulated sourcing, leading to deforestation, loss of biodiversity and consequent landscape degradation. What's more, there is not only the problem of unsustainable harvesting of wood and other forest biomass, but also the inefficient conversion and final use of the fuel itself. The latter can cause a number of environmental and socio-economic problems, including higher greenhouse gas (GHG) emissions than other, 'cleaner' energy alternatives, indoor air pollution and related health repercussions, and limited access to modern energy that restricts development opportunities. Illegal logging of wood, unsustainable land management and conversion of forested areas to other uses are among the major drivers of forest land degradation, which is defined as a decrease in the vitality of the forest, which lowers its ability to provide goods and services. Such degradation affects forest-dwellers, Indigenous Peoples and those directly dependent on natural resources, and fuels climate change through increased GHG emissions and reduced carbon sinks. Degraded land is more exposed to wind, rain and floods, and may be unable to provide precious resources, compromising food security. In SSA, the registered deforestation rate is five times higher than the world average, severely endangering the resilience of lands and communities to climate change, while conditioning forest ecosystem productivity and biodiversity conservation.

Modern wood energy and forest landscape restoration

Reforming unsustainable woodfuel practices is one of many necessary measures towards forest landscape restoration (FLR), an activity designed to regain the ecological functionality of deforested or degraded forest landscapes. The process addresses ecological, social and economic functions of landscapes and related ecosystem goods and services, with the main purpose of increasing health and number of trees while restoring landscapes and their biological productivity.

Modern bioenergy generation offers multiple opportunities to contribute to and benefit from FLR. The dedicated use of woody biomass for energy can stimulate demand for products from forest plantations and agroforestry. Several species of plants and trees such as poplars and willows, precious biomass energy sources, are even able to grow on marginal or unproductive lands, which can restore idle areas while sequestrating and storing CO_2, reducing soil contamination and improving soil health and crop yield. Such restorative solutions have tremendous energy potential. In SSA, 75 million hectares to be restored under the African Forest Landscape initiative could yield around six exajoules of primary bioenergy per year – according to the International Energy Agency (IEA), this amount would correspond to 23 per cent of Africa's total final energy consumption in 2019.

Modern wood energy supply chains apply circular economy principles to forest management, creating value from by-products, residues and waste at the last ring of the chain. For instance, forest and wood residues may be used to produce improved feedstocks for energy production such as pellets, briquettes and chips. In turn, biochar, a by-product of woody biomass gasification (the burning of biomass in limited oxygen at high temperature) can be used as organic fertiliser and CO_2 storage in the soil. This serves as soil amendment, offering a soilless substrate component for forest seedlings and recycling nutrients back into the soil, thus 'closing the loop' by enhancing the ecosystem on which the value chain depends.

Overall, securing supply for modern wood energy through restoring forests is a sustainable land management practice that avoids issues of land-use change and fosters food security and socio-economic development in unproductive areas. Benefits for FLR are direct, such as improved soil fertility, but also indirect, as modern wood energy reduces pressures on forest resources by embracing alternative feedstocks like food, crop or wood waste. Further advantages include reduced indoor air pollution through more efficient heating and cooking solutions, creation of income and job opportunities for farmers, and enhanced energy security and climate change resilience. Modern wood energy pathways tackle the main causes of forest landscape degradation while fighting its consequences and providing solutions for FLR.

While traditional wood energy value chains may have direct or indirect repercussions on forest landscapes, eradicating them abruptly is both difficult and inappropriate given that millions of people rely on them for both their energy needs and their livelihoods; the transition

Conventional use of fuelwood is frequently associated with indoor air pollution and related health repercussions.
Photo: Jörg Böthling

towards modern sustainable pathways must be gradual. One essential starting point is to tackle the general lack of awareness on the availability and benefits of modern wood energy value chains, beginning with information and aware-

> The transition towards modern sustainable pathways must be gradual

ness campaigns on social, economic and environmental potentials. To do so, different communication tools are crucial to inform various target groups including a technical audience, the general public and youth. In turn, local, national and international dialogues may stimulate collaboration and exchanges on a broad vision for the energy transition. The forestry sector and wood energy practitioners have often been drawn towards diverging priorities, with the latter focusing on issues of reliability and affordability of wood energy supply, and the former seeking investments towards restoration and sustainable management of forest landscapes. In fact, the two interests are synergistic. Establishing multi-stakeholder platforms – of public sector authorities as well as on-the-ground actors including NGOs, civil society and organisations of workers and academics – is a solution for uniting stakeholders with material resources and knowledge. This allows joint learning, training and capacity building activities to fuel informed, scientifically valid and sustainability-oriented interventions.

Successful policy and practical interventions require proper data on the state-of-the-art and potentials. Therefore, initiatives for creating this knowledge are also fundamental; for instance, campaigns to collect comprehensive georeferenced databases mapping domestic woodfuel supply potential, natural resources as well as all domestic enterprises, highlighting the most successful operations and technologies. Moreover, assessments of the current sustainability and potential for wood energy to contribute to FLR are key to comprehensively supporting legislators to make informed policy decisions. A number of frameworks exist for this purpose, such as the Global Bioenergy Partnership Sustainability Indicators, used to assess economic, social and environmental impacts of bioenergy.

A plurality and diversification of wood energy practices is an asset to manage forests sustainably and to meet demand increases. One way to accomplish this is to promote technological innovation for more efficient energy production methods such as pyrolysis and micro-gasification, where novel feedstocks, such as agricultural and forestry residues, are fully burnt and used for cooking energy, avoiding energy and income losses. This can be spurred by the creation of entrepreneurship programmes, stimulating the market through financial incentives and generating socio-economic opportunities. Furthermore, subsidising the diffusion of locally-produced upgraded cooking stoves would fuel an internal market for improved feedstocks, generating additional income flows. Financial barriers could be further reduced by developing short wood energy value chains to reduce the number of intermediaries between consumers and producers.

Opportunities for producers and best practices

Producers certainly play a pivotal role in the transition towards modern wood energy value chains in synergy with forest landscapes. While policy interventions may help stimulate the transition, in many cases, wood energy practices that are positive for FLR can already be financially viable solutions for producers. For example, in Sri Lanka, smallholder farmers produce wood fuel from *Gliricidia sepium*, a nitrogen-fixing leguminous shrub that grows alongside food crops, dramatically increasing crop yields. Surplus wood is sold to power plants while the foliage is transformed into livestock feed and fertilisers, creating energy and income while regenerating the land. In Lebanon, pruning waste is usually burned on the spot, a cause of frequent forest fires. Instead, the waste can be used for energy production, while its collection reduces the risk of forest fires and resulting degradation. Moreover, excess wood and residues can be turned into compost, thus providing fertilisers as well as economically viable energy from waste. One example of this is a project implemented by the Al Shouf Cedar Society (ACS), an organisation set up in collaboration with the Lebanese Ministry of the Environment to manage the Shouf Biosphere Reserve. The project backed setting up a local bioenergy plant for the production of briquettes for cooking and heating from local waste materials from olive oil pressing, olive and fruit tree pruning, as well as the thinning and pruning of oak and pine forests. For the same heat volume, the cost of energy has been reduced by more than two thirds in comparison with fuel – the main energy source in the local households. This also has positive effects on the consumption and savings of the local population, and leads to less pollution and health problems through the use of diesel.

Even invasive species can become useful energy sources for producers, as the example of *Prosopis juliflora*, an invasive small tree in Kenya, locally known as 'mathenge', shows. To control the spread of Prosopis, it was excluded from a government ban on timber harvesting in all public and community forests. The tree is now used to produce firewood and charcoal, reducing pressure on indigenous woodlands and allowing their regeneration, increasing standing biomass, resilience and income of farmers. Improved kilns allow charcoal to be produced with lower costs and wood consumed, with a four times higher recovery rate compared to traditional methods. Prior to the ban, which was aimed at alleviating widespread drought, local communities in Baringo had produced charcoal from indigenous species, mainly *Acacia lahi*.

Summing up

Traditional wood energy value chains are unsustainable and have environmental, social, economic and health repercussions. However, they remain crucial to millions of people, and the dependence of rural economies on traditional wood energy will likely persist in the near future. Thus, a long-term vision is needed to facilitate a gradual transition towards modern wood energy supply chains aimed to restore rather than burden forest landscapes. The process starts by increasing awareness of the mutual benefits of sustainable wood value chains and FLR, highlighting their energy and income potentials. Relevant stakeholders should be brought together to align perspectives and share best practices. Hereby, collective trainings and capacity building activities are crucial to transmit long-lasting knowledge and science-based tools to measure and address sustainability concerns, and to provide technical support to policy-makers. Further interventions should stimulate technological innovation, to improve and diversify energy sources and practices, increasing socio-economic opportunities in the sector and motivating producers to adopt some of the countless wood energy processes that act in symbiosis with forest landscapes.

All in all, forest landscapes provide tremendous opportunities for income and modern energy generation, which, in turn, reduces pressure on natural resources and increases biodiversity and soil fertility, enhancing forest landscape restoration and creating value from by-products and waste.

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References: **www.rural21.com**

The Global Bioenergy Partnership

Founded in 2006, the Global Bioenergy Partnership (GBEP) has been making efforts towards bringing together stakeholders, and facilitating capacity building and stronger technological innovation. Supporting a transition towards modern wood energy and FLR is one of the Partnership's priorities. In SSA, GBEP organised three dialogues on "Wood Energy and FLR", covering both the international (Global Landscape Forum Accra 2019) and the national level (National Dialogues in Togo and Ghana), with active contribution by the UN Food and Agriculture Organization (FAO), the International Renewable Energy Agency (IRENA) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Extensive trainings and cross-cutting knowledge were delivered together with practical demonstrations on modern technologies and FLR strategies suited to the region. GBEP provided Togo and Ghana with tailored assessments of their FLR and wood energy sectors as well as ready-to-implement actions, strategies and take-home messages. Involved stakeholders played a crucial part in the holistic dialogues, which stimulated them to establish a permanent National Multi Stakeholder Working Group for continuous coordination and policy support.

Boosting food system energy efficiency with private sector innovations

Small and medium enterprises play a crucial role when it comes to putting innovative ideas and technologies into practice. They are being assisted by the "Water for Energy and Food Grand Challenge" initiative.

By Noémie Topklen, Sten Schurer, Kilian Blumenthal and Matteo Jaeckels

Today's food production consumes 30 per cent of the global energy resources and is responsible for more than half of the greenhouse gas (GHG) emissions. To feed the growing world population, food production would have to be increased by 60 per cent until 2050, consequently requiring a significant increase in energy consumption. Agricultural food systems and energy are strongly intertwined, and therefore, there is an urgent need for innovative approaches to produce more food with fewer resources. In this context, the role of the local private sector is crucial to disseminate integrated solutions for a fair transition and sustainable development. Small and medium enterprises (SMEs) play a significant role here. Through the dissemination of innovations, they can enhance options for actions to foster sustainability, boost development, dynamise the regional economy and increase resource use efficiency.

A SunCulture customer fixing an irrigation pipe in her garden.

Partnerships for sustainable agri-food systems transformation

SMEs in the water-energy-food nexus in Africa and Asia are bursting with innovative technologies and ideas. Their innovations range from solar-powered irrigation and cooling technologies to organic fertiliser and inclusive business models. The companies are also directly connected to the end-users of their innovative products – they maintain strong links to smallholder farmers and understand their concrete challenges and needs. Therefore they have the potential to boost a path towards sustainable agri-food systems transformation. By using smart innovations and climate-friendly practices, farmers and food companies can enhance climate resilience, reduce CO_2 emissions and support the goal of limiting global warming to 1.5 degrees Celsius.

However, SMEs often have too little access to finance and opportunities to develop their capacities and business plans. At the same time, they frequently lack appropriate institutional and political framework conditions which could help them to grow up and extend their services and products. This is where the Water and Energy for Food (WE4F) initiative (see Box) comes in. It supports innovative approaches at all levels of the water-energy-food nexus (local, national, regional and global) and connects farmers, businesses, investors, governments, researchers and other stakeholders to open dialogue and communication between the development and the private sector.

Through the work of two Regional Hubs (see Box), the programme assists innovators via partnerships and a range of different activities, such as improving access to finance, investor matching, technical advice, results-based financing, knowledge dissemination and co-creation. At the same time, the programme supports capacity building for the end users of the innovations, the creation of appropriate finance options for access to innovations as well as the improvement of institutional and political framework conditions. Through the involvement of different stakeholders, barriers hindering the adoption of innovations are to be eliminated and a vibrant local economy and environment for the innovators to thrive in is to be created.

Promoting energy efficiency in agriculture

Energy is a driver of economic growth and social development. Harnessing the potential of sustainable energy is a prerequisite to achieving inclusive green growth and strong agri-food value chains. In 2021, the WE4F Regional Innovation Hubs (RIHs) organised regional and national Calls for Innovations to create new partnerships with local SMEs requiring support in scaling their sustainable and innovative solutions. Around 45 innovators were selected and are now carrying out different activities with the RIHs to promote energy-efficient agricultural practices in the respective regions. Some examples:

In East Africa, WE4F supports the acceleration of Kenya's progress to net-zero emissions and the deployment of renewable energy, enhancing the resilience of the agriculture sector to the effects of climate change. One innovator contributing to this commitment is SunCulture. This Kenyan company develops and commercialises solar irrigation systems in both East and West Africa, where currently only three per cent of the agricultural land is irrigated. SunCulture provides smallholder farmers an affordable and climate-friendly way to increase their yield, cultivate more profitable crops and adapt to the changing climate and corresponding droughts. In addition, the company uses a PayGo Model that allows smallholder farmers to pay in instalments, giving them a chance to acquire a pump with less upfront payment.

Another good example is Kenya's Mace Foods, a women-led company producing, processing and marketing chilies and traditional African leafy vegetables. Mace Foods aims to bridge the demand and supply gap between the rainy and dry seasons with its own processing plant, using solar-powered processing technologies. It is collaborating with a majority of women farmers and also employs women in production, as Mace Food's Production Manager Peter Okello emphasises: "Being a woman-owned entity, we make conscious decisions to have more women employees." As the company occasionally runs into shortages of vegetable, Mace Foods and SunCulture decided to collaborate to cope with each other's challenges. SunCulture farmers are now producing high-quality chilies on six hectares of land, which Mace Foods then purchases to process them with a solar drying technology.

In West Africa, the WE4F Regional Innovation Hub joined forces with Cold Hubs, an innovator from Nigeria that offers solar cooling solutions. In many parts of Nigeria, refrigeration is uncommon because of unreliable local power grids. This is where Cold Hubs come in with their 100 per cent solar-powered cold rooms suitable for farms, processing units and food markets. Cold Hubs offer a 24/7 off-grid storage and preservation of perishable foods with a flexible pay-as-you-store subscription model. Cold hubs are installed in major food production and consumption centres (in markets and farms) where farmers store their produce in clean plastic crates for which they pay a daily flat fee. This extends the freshness of fruits, vegetables and other perishable food from two days to about 21 days. Hence, post-harvest losses are prevented and greenhouse gas emissions will be reduced, while energy is being saved.

The walk-in solar-powered cold room containers help preventing food losses.

Photos: WE4F

The Regional Innovator Hub South East Asia, operated by USAID, employs a similar approach and supports a variety of SMEs including Husk Power Systems in India. Husk innovators discovered that biomass gasification – utilising biomass waste, such as rice husks, maize and cobs – can deliver reliable and 100 per cent renewable energy to rural households and agricultural enterprises. By combining the biomass gasification system with a solar photovoltaic system, the innovation powers a mini-grid that produces electricity for residential as well as agricultural needs. Husk Power offers customers a flexible "pay-as-you-go" energy service, using a mobile-enabled smart metering system. In this way, the company allows rural, off-grid communities to benefit from more productive hours in the day, creating choice and improving their quality of life.

An enabling environment is key

The dissemination and scaling up and out of climate friendly water, energy and food nexus innovations requires an enabling environment and long-term partnerships. Innovative enterprises are invited to participate in different events and alliances and share their solutions. This allows them to promote their innovations and learn from each other, build networks and partnerships and access information. While raising awareness for the transformation needed in our food systems, the events enable the activating of different partners and stakeholders in the water, energy and food nexus. The topics addressed include solar-powered technologies as game changers for a just energy transition, the transformation towards climate resilient food systems, food and water security and the importance of access to finance for the private sector in sub-Saharan Africa.

Since the Initiative started in 2020, through innovative solutions in East and West Africa nearly three million litres of water and 30 million kilowatt-hours of energy have been saved. And in future, together with its international partners WE4F will be driving change towards fairer and sustainable development.

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BioCNG made in India – not a flash in the pan!

The use of biogas made from animal dung and kitchen scraps is widespread in India. What is new, in contrast, is the notion of producing bio-methane out of straw. The first such plant was recently inaugurated in India's north-eastern Federal State of Punjab. With a threefold purpose, for in addition to generating sustainable fuel, air pollution caused by burning off the stubble is reduced. And valuable fertiliser is created as a residue from the process.

Continuous beeping is coming from the telescopic wheeled loader in the grounds of the brand new biogas plant. The driver takes one large round bale after another from a twelve-metre-high straw stack and drives them to the fermentation line. Several of these 100-metre-long stacks are on the eleven-hectare site of Verbio India, a subsidiary of the German biofuel manufacturer Verbio AG. The plant is located near the town of Lehragaga in the Indian state of Punjab. The bales contain rice straw as well as wheat straw, although the latter is under-represented. According to Plant Manager Pankaj Jain, the company has collected roughly 40,000 tonnes of straw from about 1,000 farmers in the local area – and in the case of sugarcane bagasse, also from further afield – since operations commenced a few months ago. That is a huge volume, which is why the bales are not only deposited directly beside the plant's eight digesters. An additional four interim storage sites have been established where the plant's feedstock is stacked and covered with tarpaulins. An enormous amount of logistics is involved in ensuring that the straw and bagasse is collected dry from the fields and has retained its quality by the time it reaches the fermenter. This is certainly one of the key factors in ensuring that the first straw fermentation plant of its kind in India, which was inaugurated in the presence of many political celebrities in October 2022, can achieve sustained success.

"Welcome into the Greenzone" says a sign at the entrance to the bioenergy plant, which employs 80 people and required a whopping 25 million euro investment. Production at the plant has not yet been fully ramped up; the 10 MW capacity limit will only be reached with a feedstock intake of around 100,000 tonnes of straw and bagasse per year. But expectations are already high, on the part of both Indian politicians and farmers in the region. On a day-to-day basis, no-one is more aware of this than Pankaj Jain. On this foggy morning, the chemical engineer is constantly moving between the digesters, the feedstock storage site and the growing digestate store to keep an eye on operations. As deliveries of straw arrive, the purified and compressed methane, filled in standard gas cylinders, departs from the plant. Digestate is taken away with lorries and small waggons drawn by tractors. It is brought back to the fields as high-value fertiliser.

Well-established logistics for gas distribution

Roughly 60 tonnes of straw or bagasse per day is fed into the digesters. The compressed BioGas or CBG – a somewhat misleading term used in India because it is actually Compressed Natural Gas (CNG) – is filled directly into the standard 75- to 150-litre gas bottles that are permanently installed on truck trailers. Once a trailer's cylinders are full, it is picked up by a truck and taken to a filling station within a radius of 25 to 100 kilometres. Like Vivek Singia's filling station, for example, which is located on the main road between Sangrur and Patran. As is customary, not only diesel and petrol are sold there, but also gas. The latter is a commonly used fuel in India. However, drivers filling their tanks at Singia's petrol station are not aware that a quarter of the motor fuel they purchase is CBG (bioCNG), as CBG is not offered separately from fossil fuel.

When the CBG load runs out, the trailer with the empty gas cylinders is taken back to the biogas plant – a cycle that did not take long to run smoothly. Sales are going well too, says Jain. Even if the volume of production were to rise threefold, CBG distribution would not present any logistical problems. Logistics for straw and digestate are more complex. "Various models are still being tested. The straw can be dealt with via hired companies or with a plant's own logistics," says Ashish Kumar, Managing Director of Verbio India. Kumar works in Chandigarh, the state capital of Punjab, where Verbio India's head office is located. He has come from the capital for a few days to conduct on-site discussions with individual farmers and entire village communities about the issue of straw collection. After his military service in the Indian Navy, Kumar, who is now in his late forties, studied Interna-

Since the plant was put into operation, the company has collected roughly 40,000 tonnes of straw from about 1,000 farmers.

Ashish Kumar, Managing Director of Verbio, is convinced that straw fermentation will have a great future in many Indian regions.

tional Business in Leipzig/Germany and then worked for management consultancy EAC in Munich for some time. He is fully convinced that straw fermentation will be very successful in many Indian regions in the future. Why? “The mere fact that the post-harvest burning of rice straw over wide areas, which regularly plunges the whole Punjab into toxic plumes of smoke, will come to an end with our form of utilisation. This aspect is very important to us,” he emphasises. Moreover, straw fermentation creates many jobs in rural areas. One example is Manseet Singh, who drives a wheeled loader at the external straw storage facility 3.5 kilometres away. “My family has a small two-hectare farm in Bhutal Kalan village,” says the 27-year-old, standing in front of a pyramid of straw bales. His income eases the economic pressure on the smallholder family.

Market transparency still lacking

Another important argument is that of sustainable energy production, even though the issue is still far from being afforded the same significance by society at large as it is in Europe, for example. Although biogas production for the fuel sector is economically secured with fixed tariffs within a flexible price corridor, market transparency is still lacking. Anyone filling up a natural gas vehicle in Punjab does not know whether the gas comes from Qatar, Russia or elsewhere, or whether it has been produced from the straw harvested in the region. Consequently, the bioCNG does not fetch a higher price at the pump. Nevertheless, according to the clear commitments made by the Indian central government and the responsible Ministry for New and Renewable Energy in New Delhi, biogas is an important building block on the path towards more climate-friendly, and ideally, carbon-neutral energy production.

Biomass plays an important role in India's overall energy sector, with about one third of the supply being based on renewable raw materials. The hundreds of thousands of mini biogas plants that have been installed in recent decades from Cape Comorin in the South to the mountains of Darjeeling, and whose energy is mainly used for cooking, are not at odds with the large-scale plants for electricity generation and fuel production that have primarily been built in recent years. Both systems exist side by side, as can be seen on Darshan Singh's farm. Singh's family has been fermenting the manure from their ten cows and their offspring for many years, using a simple, small biodigester designed for small-scale farms; the amount of gas they produce easily covers their energy needs for cooking. Singh, who farms roughly 18 hectares of land with his family, is therefore already familiar with biogas generation. This is one of the reasons why he welcomes the large fermentation plant that was built a mere three kilometres away from his farm. “I like to take our rice straw there. Our cattle don't like to eat it anyway because of the high silica content. I almost always used to burn it in the field right after the harvest to keep a clean seedbed for the wheat crop to follow,“ says Singh. But he would not want to give away his own wheat straw. “I need some of it for my animals, and for the rest of it I can get a good price in the marketplace,“ Singh continues. But what about his soils’ humus content if he harvests two crops a year and burns or removes all the biomass? In fact, the organic matter content of his soils is not satisfactory, Singh admits. This is the case for many fields in the Punjab region, the “Land of the five rivers”, which after all is well supplied with water throughout the year from canals and the farms’ own wells. "But then there is also the government-subsidised mineral fertiliser," says Singh. Irrespective of this, he would be happy to accept digestate from Verbio and use it as fertiliser for his fields – “provided I can get it for free”.

“Our nutrient economy is still dominated by NPK,” criticises Verbio manager Kumar. The fertiliser lobby continues to have a great influence on Indian agricultural policy and is blocking more sustainable farming. This is why the Indian Biogas Association recently called for a programme under which the purchase of mineral fertilisers would have to be linked to the purchase of digestate. Such a demand meets with Kumar's instant approval, because the lack of appreciation for digestate means that at present it is very cumbersome and costly for many biogas plants to get it distributed. “In the long run, we need a closed cycle of straw, energy generation and digestate to revitalise Punjab's soils, which have been badly degraded by intensive cultivation over the past decades, ”Kumar maintains. S. S. Gosal, vice chancellor of Punjab Agricultural University in Ludhiana, fully agrees with him. “Humus levels have been declining in recent years, and dramatically dropping groundwater levels caused by widely dominating rice cultivation are forcing a rethink,” Gosal says in his office on the university's huge campus. “In the past, we always focused on the plant; now we focus more and more on the soil and the systems’ interactions in general.“ The change in mindset is also an opportunity for biogas in India – as an integral component of a sustainable farming sector.

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The compressed biogas is filled directly into gas bottles and taken to a petrol station.

Darshan Singh has been fermenting the manure from his cows and their offspring for many years.
Photos: Jörg Böthling

The Tehri hydropower dam in Uttarakhand, India.
Photo: Ravi – stock.adobe.com

Sinking houses in the Himalayas – hydropower projects to blame?

The sinking of over one hundred houses in Joshimath, a pilgrim township high in the state of Uttarakhand in the Indian Himalayas, has caused considerable outrage. And more and more villagers in this Indian federal state are complaining of damage their houses have sustained, some of which have become unfit to live in. New road-building projects as well as construction measures for large-scale hydropower projects are being made responsible for this.

By Athar Parvaiz

“We're going to pay a very heavy price for cutting down our forests and bulldozing our landscapes,” Ravi Chopra, a prominent environmental activist and scientist in the Himalayan state of Uttarakhand, told me during a conversation at his office in Dehradun last year in April. “It is so painful to see swathes of bare yellow earth dotted with road-building materials and construction workers on landscapes where thick forests stood until a few years ago,” he said. “It's driving us crazy.”

What Chopra was apprehensive of has finally started happening in Himalayan villages where not only railway tracks are being laid by blasting mountains and road widening is being carried out in sensitive landscapes but also a number of hydropower projects are being constructed, often without caring about the environmental consequences, according to environmental activists. Early in February 2022, the news agency Reuters reported that houses of villagers in places near construction areas had developed cracks and were at risk of facing total damage in several villages. “Nine residents from three villages along the 125 km rail route stretching from Rishikesh to Karnaprayag showed Reuters damage to their homes they said had started appearing soon after blasting or other work for 104 km of tunnels began near their villages,” the news agency stated.

What has brought the danger facing the homes of villagers in Himalayas into sharp focus is the sinking of over a hundred houses in Joshimath, a pilgrim township high in the Himalayas, in January of this year. Several houses have sunk, and many more have been declared unsafe with red marks even as thousands of residents have been evacuated from the town. Interestingly, only days after the sinking of houses in Uttarakhand was reported, hundreds of villagers had to be evacuated from Nai Basti, a village in another Himalayan region in India's northern state of Jammu & Kashmir. "I had spent all my savings building that house. But then it has suddenly collapsed. I have no clue what can I do now," said Tariq Ahmad, a villager whose house has suffered complete damage. "We had been living in this house for years. But, suddenly we lost it," Shah Din, who works as a labourer, recalled, appealing to the government to help the villagers. The district administration had to evacuate 25 families. Din and several other families have been moved to makeshift housing while some families have been accommodated by their relatives and friends in their own homes.

A villager in Kashmir Himalayas showing the crack in the outer wall of his house.

Photo: Athar Parvaiz

The causes are obvious

In March 2020, residents of Dalwas, on the Srinagar-Jammu highway in Ramban district in the Kashmir Himalayas, had to flee their homes before the village was struck by landslides. The villagers blamed use of heavy machinery for the construction of the highway passing through their village. Experts say that they had repeatedly warned that haphazard construction amid new climate-driven vulnerabilities in the form of frequent extreme weather events and disasters was making the entire Himalayan region unsafe. In recent years, the Indian government has implemented dozens of hydropower construction projects and road construction projects leading to pilgrim sites high in the Himalayas.

Digging inside mountains with tunnel-boring machines, experts say, has not only multiplied the threats of land sinking and landslides, but has also disrupted the aquifers (groundwater sources), resulting in the drying up of Himalayan springs. As of today, said Sunita Narian, Director General of the New Delhi-based Centre for Science and Environment, some 7,000 megawatts (MW) of hydroelectric projects are either operating or being constructed in the fragile mountainous region of Uttarakhand with back-to-back dams and no respect for the river or its need to flow naturally. "The issue is not about the need for energy or development. It is about the carrying capacity of the fragile Himalayan region, which is even more at risk because of climate change", she insisted.

"The era of hydropower dams is over"

"There is no question that we are going to see more of this, not less, unless we change the way we do business with the environment. But more importantly, it will happen until we take better studied decisions on the projects and on mitigating their impacts," Narian said. "Our fragile mountains and the people living there are being put at risk for constructing these projects," said Ravi Chopra, the environmentalist. He claimed that the blasting and digging operations were making the earth in the mountainous regions prone to subsidence and landslides. "In this time and age, hydropower makes no economic – and environmental – sense. For example, in Uttarakhand, to produce one unit of electricity, you need to spend seven to eight rupees for it. Now, tell me, who is going to buy it when solar power is produced at two-and-a-half rupees a unit?" Chopra noted. "The era of hydropower dams is over – in fact, it ended in the last century."

After the devastating floods and landslides in Uttarakhand in June 2013, a Supreme Court-appointed committee which Chopra was part of had recommended that no dam should be built above an altitude of 2,000 metres. "But, despite that recommendation, infrastructure creation for those projects continued under one or the other pretext and one of those projects got damaged in the February 6 disaster – it was being built by a government company," Chopra explained.

Sharachchandra Lele, of the Centre for Environment & Development at Ashoka Trust for Research in Ecology and the Environment (ATREE) said that the government definitely needed to rethink its development strategy for the Himalayas. "Climate change is aggravating environmental risks of the already environmentally fragile Indian Himalayan region. Damming of rivers, tunnelling for power generation, and indiscriminate road building are magnifying these risks and their impacts," Lele claimed, insisting that indiscriminate building of dams had to stop.

When the issue of developmental projects in the environmentally sensitive Himalayan regions was recently raised in the country's parliament, the Indian government didn't comment about the details of construction activities in the Himalayas and what steps would be taken to stop the disasters in the Himalayas in future. It only told the parliament that the Himalayas were "unstable", having a "dynamic geology" which "is leading to land subsidence".

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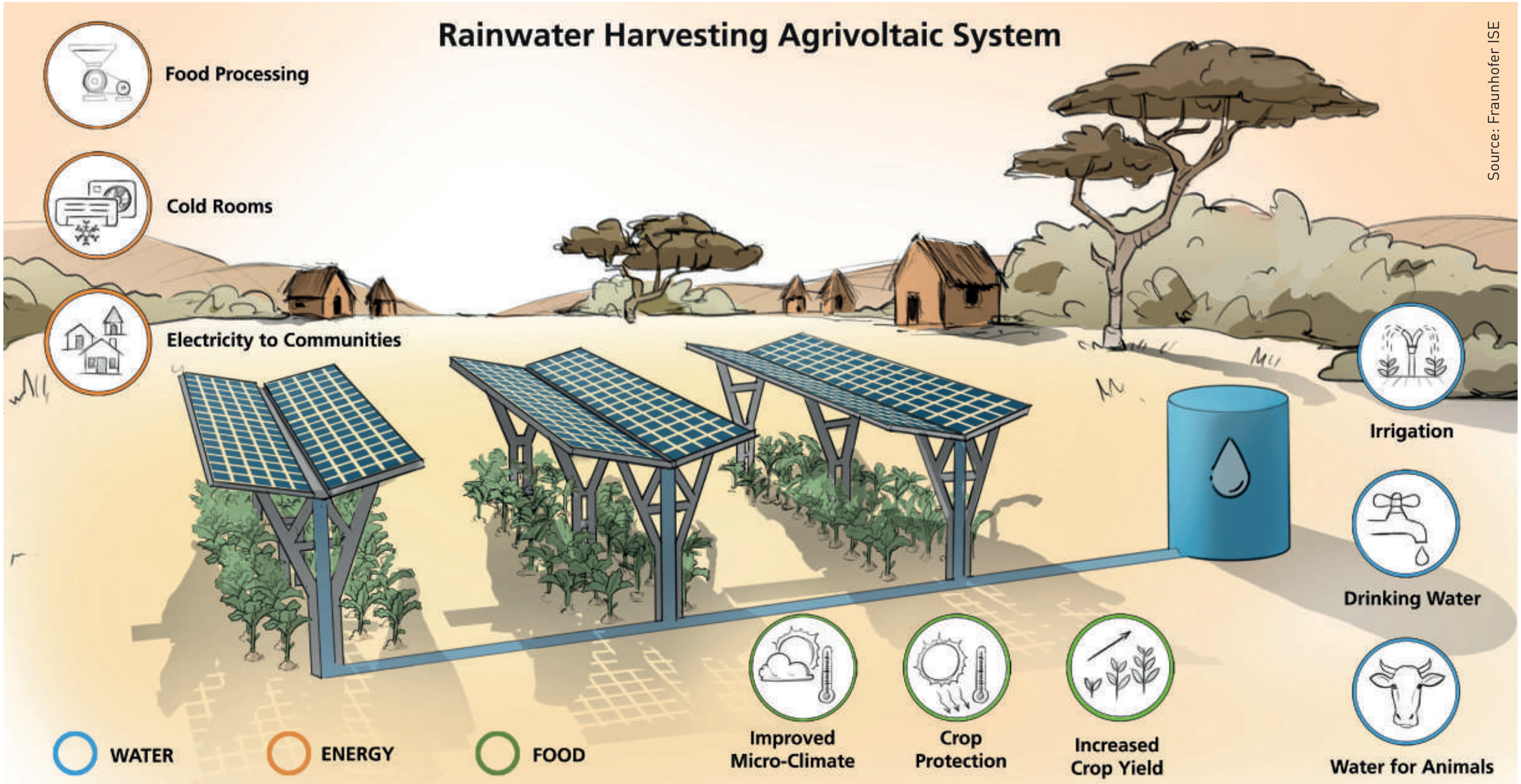

Unlocking the potential of agrivoltaics

Agrivoltaics is a concept that combines photovoltaic electricity generation and agricultural production, providing the opportunity for a more efficient land use and contributing overall to the integration of food, energy and water systems. This can be particularly interesting for countries in the Global South, where rural electrification rates are often low and food security needs to be improved. A research project in Mali and The Gambia is to explore the potential of the system, with a focus on community integration and integrative funding.

By Henriette Stehr, Nora Adelhardt, Brendon Bingwa and Susanne Wolf

Agrivoltaics is a concept based on dual land use, where a single area is used both for agricultural production and photovoltaic (PV) power generation. Although first mentioned in 1982, development has gained momentum only in recent years. As of 2021, there are 14 gigawatt-peak (GWp) of installed capacity world-wide. In agrivoltaic systems, PV panels are mounted on a substructure on the agricultural land and generate sustainable electricity, while agriculture production takes place underneath or between the PV module rows. When installed above, the increased height of the installation provides enough space for farming activities underneath. This has many potential advantages, including higher land-use efficiency as well as shading and physical cover provided by the panels altering the microclimate and protecting crops and soils, possibly leading to higher crop yield and quality. A field trial conducted by the Fraunhofer Institute for Solar Energy Systems in Germany has shown that the simultaneous use of land can increase land-use efficiency by up to 84 per cent (depending on the crop type) and can therefore be considered as a resource-efficient way of improving land productivity and enhancing food security.

The APV-MaGa project – combining traditional and non-traditional research

Most current agrivoltaic systems are located in the Global North, with the first pilot plant in Germany being installed in 2016. However, the potential for agrivoltaics in the Global South is extremely high as the potential advantages and opportunities could be especially significant in these regions (see upper Box). Against this background, the APV-MaGa project (see lower Box) was launched in 2020. In its context, five agrivoltaic systems will be installed in Mali and The Gambia, two countries with which the project partners are already cooperating in the context of the water-energy-food nexus. Both of them are located in the Sahel Region, one of the areas most vulnerable to climate change, and at high risk of droughts. High solar radiation levels and the population's dependence on agriculture put even more stress on the need for sustainable water management, especially with fertile arable land becoming increasingly scarce. Because of the increasing impact climate change is having on agriculture and growing energy demands, both countries need innovative and sustainable energy solutions and improvements in food security. The agrivoltaic systems are to provide food, water and electricity to local communities and simultaneously increase the resilience of the agricultural sector to climate change effects.

There are plans for the construction of one 200-kilowatt-peak (kWp) system in Mali by the end of 2023 and four smaller systems, up to 62.5 kWp, in The Gambia, by the end of the first quarter of 2024. While in Mali the system will be installed in the grounds of the Rural Polytechnic Institute of Training and Applied Research in Katibougou, the systems in The Gambia are intended to be set up at the University of The Gambia, a small private farm and two community farm sites. The mix of different farm types will allow both traditional scientific research, in which conditions are more strictly controlled, and non-traditional research, where community involvement will require flexibility in the scientific approach (e.g. local farming practices will be implemented, social interaction with the system will be considered, etc.). The photovoltaic (PV) modules are to be installed at a height of 2.5 metres to enable the use of farming machinery underneath the system and to obtain a higher energy gain from the used bifacial PV modules, which also generate electricity from their rear side. Some of the demonstrators include a rainwater harvesting system, with the rainwater being collected in a gutter between the modules and stored in tanks at a height of about five metres. Solar pumps will be used for the distribution to the target areas.

The electricity generated by the systems is planned to power supplementary equipment such as cold-rooms, post-harvest processing equipment and irrigation systems, which will be built as part of the project. The crops underneath the agrivoltaic systems are to include those already commonly cultivated by local farmers, such as onions, tomatoes, potatoes, okra and green beans, as well as high economic value crops that may not have previously been possible to cultivate because of the harsher climatic conditions, such as strawberry and broccoli. Research data will be collected and supplied by the local partners beyond the life of the project, providing long-term data, which is essential to accurately assess the impact of the agrivoltaic systems in the local climatic and socio-economic conditions.

What effects are expected?

Economically, multiple short- and long-term effects are to be expected. For instance, farmers' income may be increased in general through the sale of higher yields and higher quality crops, as well as better timing of the market allowing crops preserved through cold storage to be sold at higher prices at times of high demand/low availability. Also, the more efficient irrigation and the increasing availability of self-generated electricity lower the expenses needed to run the farm. In the long run, additional income may lead to investments and enable the expansion to non-local markets. The additional equipment connected to the agrivoltaic system also allows farmers and farming communities to diversify revenue streams and increase income through the sale of services to the surrounding communities.

One important aspect of the project is the realisation of a community-based approach, especially in The Gambia. This has multiple implications, starting with an active communication with local partners and community members. Participatory schemes and acceptance studies are used to evaluate this exchange. Secondly, the project team plans group discussions with local farmers and other potential smallholders, to be able to understand and consider individual needs and ideas. Thereby, technical know-how and engagement of the farmers can also be integrated into the project. A co-design workshop with important stakeholders will be organised to ensure that the system is adapted to regional factors. The focus lies on developing a sustainable business model for the long-term success of the agrivoltaic systems. Additionally, a local organisation will be established in both countries to include financial stakeholders and community members in the decision-making process. These organisations will take care of the long-term maintenance of the systems.

The challenge of sustainable funding

While the project is still in its planning phase, funding has proven to be a significant challenge. One of the goals is to include local partners' own financial contributions. The idea is to include both public and private funding and move away from the traditional model of donor funds with little input from local partners, as this often leads to long-term problems or failure of projects. In-kind contribution (labour, equipment, use of existing infrastructure, etc.) by the local partner is also considered a form of funding. But as APV-MaGa is a research & development project, it is hard to secure the investment of private companies. These conflicting interests between private and public funders require a lot of communication. The project aims to bridge the gap between these two interest groups for a new, more integrative and sustainable financing approach in accordance with the overall goal of the project. Based on their experiences with previous failed projects, the local partners agree that this approach could be a way to mitigate the problems and are therefore keen to also explore ways to secure their contributions, either in cash or in-kind.

Water, energy, food, income: agrovoltaic's potential

Over 759 million people, most of whom live in rural sub-Saharan Africa, do not have access to persistent and affordable electricity. In these rural, off-grid locations, agrivoltaics can provide access to electricity and thereby improve energy security. The solar electricity can be used directly for self-consumption on the farms, lowering the costs associated with use of alternative forms of energy (e.g. diesel generators), or used to provide energy services and thereby increasing income diversity.

In addition, globally, about 2.3 billion people live in water-stressed countries, and most countries in the Global South are not on track to fulfil the UN sustainable water management goals. Also, 72 per cent of all water withdrawals comes from the agricultural sector, demonstrating the need of increasing water-use efficiency. Agrivoltaics offer the option to integrate a system to collect rainwater from the solar panels; additionally, through the shading caused by the PV panels, water losses through evapotranspiration by the plants can be decreased. In this manner, water use can be lowered and collected rainwater can be used for a more efficient irrigation, such as drip irrigation or other farm-related purposes. This alternative water supply and water-use reduction can therefore reduce the overextraction of groundwater resources.

Savings on irrigation costs, an increase of crop yield through drought protection, sale of electricity to nearby communities and higher income through improved crop quality are among the financial assets offered by agrivoltaics.

Agrophotovoltaics for Mali and The Gambia: Sustainable Electricity Production by Integrated Food, Energy and Water Systems (APV-MaGa) was launched in August 2020. The four-year project is being funded by the German Federal Research Ministry in the context of "Client II – International Partnerships for Sustainable Innovations" and comprises 15 partners from research, politics and the private sector. It incorporates five agrivoltaic systems with a total capacity of between 400 and 450 kWp installed.

While the potential of agrivoltaics for the Global South is high, much research data is still required. In the crop-farming sector, this applies to the impact of shading on the micro-climate below the PV modules, the subsequent effect on the crops and the most suitable crops that can be grown under these altered conditions. As the upfront costs of the systems may be a barrier to their wide-scale implementation in the Global South, further research is also needed on solutions that could reduce costs and/or provide a positive return on investment. Suitable finance and business models have to be examined, with some of them possibly being transferrable from other settings. For the African context, the models described e.g. by Horvath ("host-owned" or "community-owned", but also "pay-as-you-go", to name some) could be appropriate. The use of alternative construction materials (such as bamboo and wood) and material use-efficiency through innovations including the integration of rainwater harvesting into the substructure are further examples of current and future research focus. Higher upfront costs and uncertainty over the effect of shading on crops serve as the main points against agrivoltaic systems in the target regions. It is difficult to justify higher system costs, given the extremely low electricity access rates, while not all crops respond positively to shading and changes in micro-climate, hence crop yield could be reduced, rather than being increased. And last but not least, one of the key factors for the success of the system is to gain more insights on its acceptance among the local population.

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Brendon Bingwa is Project Manager in the Agri-PV group at Fraunhofer ISE and is focused on agrivoltaic research projects in Africa.
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References: **www.rural21.com**

"We want to create training and employment opportunities for the coming generations"

The German provider of solar systems SUNfarming has set up agri-PV systems in various countries in Africa, Asia and Latin America in public-private partnerships. For Edith Brasche, director of international projects, the potential of these dual-use systems is far from being exhausted. The sticking point, however, remains financing, she maintains.

Edith Brasche is Managing Director for Project Development of the SUNfarming Group for German and international projects. Previously, she worked for a business consulting group for 25 years, where she was a member of its board of directors.

Ms Brasche, SUNfarming has already been developing agri-PV plants for almost 20 years. What makes the concept so interesting for you?

All across the world, agri-solar plants can considerably contribute to energy and food security. The raised solar plants generate renewable energy on farmland while fruit and vegetables or even grapes for wine can be cultivated below them. Livestock can also be kept in pastures with agri-solar systems, where they are protected from the weather or attacks by birds of prey. Especially in countries with high solar radiation, where climate change is increasingly destroying harvests, agricultural solar plants – also known as food & energy plants – can help secure harvests and minimise famine. Farmland and livestock grazing thus receive multiple benefits for agriculture, energy production, and animal welfare, but also to provide an economic and social base for people to live in regions they would otherwise have had to leave in the wake of climate change impacts.

So it's a holistic concept ...

Yes – very much unlike the ground-mounted solar plants, which generate renewable energy in a one-dimensional way, but cover or even seal the land, ruling out any further use.

What do your plants feature?

The plants' steel substructure is rammed straight into the ground, and only the transformers stand on concrete foundations, resulting in less than two per cent of the ground being sealed. The tables for the modules are mounted on pillars, with the lowest point of them at a height of 2.10 m and the highest at 3.60 m. The semi-transparent double glass modules have a light transmission of 15 per cent. The mounting profiles for the modules serve as a rainwater distribution system underneath. They are designed to evenly distribute the rainwater under the module tables. Together, these two aspects protect the soil from erosion and promote optimum plant growth. In addition, the modules are resistant to hailstorms and can also withstand cyclones, as our plants in the Bahamas, the Dominican Republic and Madagascar have proven for many years.

Is 15 per cent of daylight sufficient for the plants to thrive?

Yes, because the 15 per cent goes straight through the modules and additional light comes in from the sides of the module rows; plants sensitive to light or those requiring an especially high amount of sunlight cannot be cultivated so well below them. That is why we are concentrating on growing vegetables, herbs and fruit, which works very well.

You set up the first Food & Energy plant in the Global South in South Africa in 2012. What was important to you in this context?

A main part of our concept is to integrate the people in the areas where we build our plants. You always need to involve the local people and see what their needs are. Most countries want to have renewable energy, but in most cases there are more fundamental things on the priority list – education, unemployment, water and food shortages. Within our Food & Energy concept, we can provide appropriate countermeasures for all these challenges. With our partially shaded systems equipped with water-saving drip irrigation, food is produced with minimal water use, with the harvest protected by the structure even in extreme weather conditions. Our plants are operated in cooperatives by local people who have previously been trained by us.

What exactly does this training look like?

With our subsidiary SUNCybernetics, we have created a recognised and certified training programme for electricians and community service staff as well as people from poorer rural areas. In cooperation with regional educational institutions, certified trainers train people on site in the planning, installation and operation of solar plants as well as sustainable agriculture. This train-the-trainer principle promotes knowledge transfer and thus creates access to education and training in the respective region. Various programmes have been developed for this purpose, lasting between four and twelve weeks; the trainees are selected via local scouting processes in cooperation with local cooperation partners as well as cooperating NGOs.

You also collaborate with universities for this purpose ...

In 2014, on the Potchefstroom Campus of North-West University in South Africa, we set up a SunFarming Food& Energy Training centre. It serves both as a production unit and a nodal point for interdisciplinary research and development projects with the University's agriculture and electrical engineering departments as well as with external partners from the food sector. Currently the Potchefstroom plant consists of three greenhouses with netting areas, where together with vegetables – tomato, cucumber, cabbage, spinach and others – and medicinal herbs such as *artemisia annua* being grown, sustainable energy is generated by means of roof-integrated photovoltaic modules. The facilities are also being used for research purposes and nurseries to identify what kind of crops can be grown best under the structure. The Training Project provides knowledge transfer in train-the-trainer programmes for master trainers and students. Moreover, workers from local communities are trained as foremen in special food production under greenhouse conditions and gain a basic knowledge in PV solar production. Around 500 trainees are being trained each year, and so far, roughly 4,000 people from all over the country have been trained. In addition, 3,600 kilograms of food is produced there each year.

What about women's participation?

Around half of the trainees are women. We want to give them the opportunity to become self-employed in agriculture and thus generate a – second – income for their families. To achieve this, local companies in the food production sector are also involved. The women are also trained in energy production, but primarily in sustainable agriculture.

South Africa is a popular cooperation partner regarding renewable energies. Does the concept also work in other countries?

It does, although the focus of course varies according to local needs. For example, our Food & Energy facility in Turkey has been producing food with refugees from the neighbouring camp since 2019 and supports the development of social contacts between the refugees and the local population through joint business activities that focus on the sale of products from fruit and vegetable cultivation and poultry farming. The initiative thus contributes to a better integration of people and to the sustainable maintenance of livelihoods. In Madagascar, the products grown under the agri-PV plant are intended primarily to ensure the survival of the bitterly poor population, providing them with healthy food and medicinal herbs to strengthen their immune system.

You mentioned the drip irrigation system – is it also part of your offer?

Yes, we develop the respective irrigation systems in addition. For this purpose, we take a look at the individual local water situation, at what cultures are grown, etc. In Madagascar, for example, we are at the moment developing a second plant for which our engineers have worked out a special water management concept.

Agri-PV plants are more expensive than ground-mounted solar plants. How are they financed?

Via our company's own investments and also in co-financing schemes with development cooperation funds from the German Federal

Greenhouses with roof-integrated photovoltaic modules at North-West University's Potchefstroom Campus in South Africa. Vegetables and medicinal herbs are cultivated in them.

Photos: SUNFarming

Government, with the aid of international development banks or also internationally operating charitable organisations campaigning for climate protection and food and development cooperation. Furthermore, we closely work together with the respective governments of the countries in public-private-partnership projects. The F&E Centre in Potchefstroom, for example, is a partnership with North-West University and the Deutsche Investitions- und Entwicklungsgesellschaft, DEG.

What about the economic viability of the plants?

In economic terms, the green electricity generated and fed into the national grid must be remunerated at a rate of at least 0.10 eurocents per kilowatt-hour. However, the remuneration is often much lower – if it is granted at all. The minimum purchase price has been calculated to ensure that with a subsidy of around 350,000 euros from the communities or the government, we can create up to 24 new jobs and 50 training places per megawatt-peak (Mwp) of plant output and year.

And what if there is no guaranteed purchase?

If the countries are not bankable, in other words, if government guarantees of payment of renewable energy are not recognised by international financiers as secure and not accepted, then the holistic plant concepts can only be put into practice by private investors purchasing the electricity at the minimum purchase price. These are companies who want to achieve CO_2 neutrality and energy security independently of government grid infrastructures or that are seeking to produce green hydrogen or ammonia with renewable energy or ammonia together with us and make it available to the European market.

Given your experience in different countries throughout the world, what are the biggest problems you face in implementing the schemes?

Now and then, major investment ventures fail because of a lack of financial feasibility in politically unstable countries or also owing to the monopoly position of the grid operators, who are usually government-run, which block the feed-in of renewable energy in order to use their grids for fossil energy, which they generate, for example, with obsolete power stations. Here, we would very much desire changes in the framework conditions and having the opportunity to feed agri-PV electricity into the grids. Even in African countries in which blackouts are part of everyday life and renewable energy could be optimally generated with agri-solar plants and wind power, ventures are thus delayed or even rendered impossible. And of course, in addition, there are countless regions without any grid infrastructure. Here, agri-solar plants operating independently from the grid could not only secure power supply for companies or even entire villages but could also safeguard agricultural yield below the plant.

Have you got an example of this?

One example is the installation of a Food&Energy system with a rated power of 13 kWp to supply electricity to a small outpatient health clinic in the community of Suwareh Kunda in The Gambia. This facility was constructed in March 2022 and is equipped with a battery storage system and a backup generator. On average, the plant produces more than 56 kWh per day. Most of this goes directly into the operation of the health station. During the day, the surplus electricity is used to charge the battery storage system, which even covers the energy demand during peak daytime hours or when solar yields are poor during the rainy season. To make the system fail-safe, a 6 kVa diesel generator is also available as an emergency generator, which is automatically switched on when demand is high or the battery charge is low. In the dry season, the area under the solar modules is used as a chicken coop or to provide shade for the staff and patients, while in the rainy season, local vegetables are grown there.

What is local acceptance of the F&E plants generally like?

As a rule, both the governments and the locals are very enthusiastic because they can see for themselves that the plants provide a solution to many of the existing problems. But of course they can also see the cost – and understandably, they try to lower them by awarding contracts to the most favourable bidders in calls for bids. Of course, a standard ground-mounted PV-plant can be built at a very low cost – and it may work for some years. Our agri-solar plants have a guaranteed life span of at least 30 years. We try to convince the regions and local communities that it makes more sense to invest a little more but in return get a high macroeconomic effect. We want to create training and employment opportunities for the coming generations with sustainable agriculture and energy production.

How do you assess the prospects of agri-solar plants for the future energy mix in the Global South?

I see enormous potential here. Due to the strong solar irradiation and the simultaneous high availability of arable and pasture land, for example in sub-Saharan Africa, large solar parks can be developed which, when coupled with existing wind energy parks, can make the use of electrolysers significantly more economical than in Europe. In South Africa or Brazil, for example, green hydrogen can be produced much more cost-effectively than in Germany. If ammonia is produced on site from green hydrogen, a solid energy carrier with high economic potential is created that can be used as a chemical feedstock, as fuel in shipping or for stationary power generation plants. Both Brazil and South Africa are currently in the process of developing large marine terminals as hydrogen hubs for loading ammonia to ship the locally produced ammonia to customer markets, including Europe. Biomethanol, on the other hand, which is also produced from green hydrogen and preferably green CO_2, such as from sugar cane production, can not only store green hydrogen, but also significantly reduce CO_2 emissions from road transport as a biofuel.

Interview: Silvia Richter

SUNFarming and FEED

Founded in 2004, SUNfarming GmbH is seated in Erkner, in Brandenburg, close to Germany's capital of Berlin. This family enterprise with its own research and development department operates in 15 countries and has so far installed roughly 1,300 PV plants with an output of 650 MW. In 2020, company founder Peter Schrum initiated the charitable association Food, Education, Energy & Development, reg. Ass. (FEED). Donations are used to train people from the South African townships in cultivating fruit, vegetables and medicinal herbs below agri-solar plants for their own needs but also for regional sales. The medicinal herbs are sprinkled into a pre-cooked maize porridge and processed as "Vitality Porridge", which is then handed out to school and kindergarten children. Every day, more than 15,000 children join the Vitality Porridge meals; in 2022, over 600 women were trained in sustainable agriculture by FEED in cooperation with partners in South Africa.
More information: www.sunfarming.de; www.feed-ev.de

Photo: Ibrahima Kebe Diallo/ IFAD

The global rush for green energy shouldn't undermine rights of pastoralist communities

Africa's drylands seem to be predestined for generating solar and wind power – especially given the current hype over green hydrogen. However, pastoral communities are often put at a disadvantage in this respect. Our author describes the arising conflicts and what successful coexistence of green energy projects and the communities could look like.

By Hussein Tadicha Wario

According to the 2021 Africa energy review by Price Waterhouse Coopers, since 2013, Africa's renewable energy capacity has grown by 24 gigawatts, with wind energy and solar power volumes noted to have increased by 14 and by 13 per cent respectively. Renewable power is forecast to grow in Africa from a current 1.79 exajoules to 27.3 exajoules by 2050 – a tremendous increase.

Especially in Africa, more interest in green energy has brought the drylands into the limelight as governments and investors recognise these areas as an excellent site for generating wind and solar power. But the drylands are important livelihood assets for diverse pastoralists peoples, hunter-gatherers and crop farmers, who utilise it as common pool resources. The rediscovery of dryland potentials counters longstanding prejudice that these are wastelands needing to be reclaimed for better economic ventures. The persistent narrative of drylands being "idle" and "empty wastelands" continues to be used to justify land acquisition in the current drive to establish solar and wind power. While green energy can potentially support the resilience of communities to the changing climate, the disregard with which land is acquired will instead exacerbate their vulnerability.

How land acquisition for green energy projects impacts on pastoralists' livelihoods

In most of Africa's drylands, the tenure rights remain largely communal and not recognised as a legitimate form of land ownership by the governments. As a result, during planning of the energy investment projects, the pastoralist land users are not sufficiently informed about the plans and their own rights, so that they cannot defend them. Lack of recognition and registration of their land ownership also means that communities are denied compensation for the land as well as benefits, except perhaps for a few employment opportunities and some meagre corporate social responsibility projects. In essence, such acquisition constitutes land grabbing depriving local land users of resources such as pastures and natural energy sources (firewood), and often they are not even granted access to the electricity produced on their own land.

Thus, some green-energy projects have led to land and energy dispossession resulting in reduced access to pastures and interruption of adaptive migration practices, which is the main production strategy in the highly variable environments. This negatively impacts the resilience of the pastoral land-users to the already changing climatic factors. In most of the countries, the generation of renewable energy has reinforced historical marginalisation of the pastoralists. Affected communities often try to resist such projects, sometimes violently, resulting in serious conflict, but rather than regarding it as agitation for their rights, governments label such resistance as anti-developmental. This results in project delays and at times even project failures, the consequences being missed economic potentials for the people, investors and the country.

Despite these challenges, there are some recent positive developments in pastoralists' agitation against green energy projects. In a case in Kenya, against the largest wind power scheme in Africa, the Lake Turkana Wind Power Project (LTWP; see box on page 35), the community successfully challenged land acquisition where the land courts declared the process of acquiring 150,000 acres of land for the wind power establishment illegal. The courts however, did not grant the communities the power to have the company operations suspended pending resolving the land issues. This is nevertheless an unprecedented and historic victory because it is rare for such small and marginalised communities to have won a legal case against international business firms involved in a project backed by the government. The case is also instrumental as it sets benchmarks for communities lacking recognised legal claims to their lands and facing similar threats of dispossession. In this case however, with the wind power project complete and already contributing to the national power grid, the extent of benefit or restitution for the community remains to be seen. It can be assumed that with continued increasing interest in land in the rangelands, unless the human rights principles and legal recognition for tenure rights to common land are strengthened, a growing number of pastoralists will lose their land to large-scale renewable energy projects and become poorer.

Green-energy technologies and their impacts

Solar power/photovoltaics (PV) requires a relatively large land area to harness energy, thus interfering with existing land use (grazing, recreational activities, conservation, etc.). The construction of panel stands necessitates land clearing and levelling, which may lead to erosion. As solar panels contain hazardous chemicals and recycling systems have not yet been developed, the disposal of the old panels poses a future challenge. Some water for PV manufacturing and cleaning the panels is needed.
Wind power has only a small footprint in terms of land and access roads. In principle, it is compatible with grazing; there are no relevant water needs. In some countries, however, the entire land area of the wind park is acquired without compensation for local land users, who feel that they have lost control of their ancestral lands.
Green hydrogen production needs significant amounts of water but little land. It can be sited some distance from where green electricity is generated, as this can be transported by power lines. Production is possible with desalinated seawater, and a technology is being developed for the direct electrolysis of seawater. As energy for electrolysis usually comes from wind or solar parks, green hydrogen benefits from falling costs of solar and wind power.

In May 2022, Germany's Heinrich Böll Stiftung and the relief organisation Brot für die Welt (Bread for the World) published the survey "Pastoralism and large-scale renewable energy and green hydrogen projects – potential and threats", of which Hussein Tadicha Wario is co-author. The survey looks at renewable energy projects in Canada, India, Kenya, Mexico, Mongolia, Morocco and Norway. The above is an excerpt from this publication.
More information: www.boell.de/en/publications

What about due diligence?

This is all the more tragic since the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) and Convention 169 of the International Labour Organization (ILO) have adopted Indigenous Peoples' having a say in taking decisions concerning their lives and livelihoods as human rights principles and should really protect them. According to these declarations, governments and investors are expected to use the principles of free, prior informed consent (FPIC) to ensure that the communities understand the proposed project and provide consent in a way that is appropriate to them. But despite these provisions, investors do not provide full disclosure of projects with governments, often compromised by larger economic benefits to the nation, failing to enforce the requirements. For this reason, most companies involved in green energy do not observe FPIC as a form of due diligence and their own human rights policies, particularly in countries that are weak in protecting human rights. According to the Business and Human Rights Resource Centre, out of 50 renewable energy companies surveyed, only five were found to observe FPIC. In Kenya, a country which is not a signatory to the UNDRIP, the above-mentioned Lake Turkana Project did not follow FPIC, citing the flimsy excuse that there are no Indigenous Peoples in the area where the project was established. In reality, the application of FPIC should have been followed regardless of whether or not the communities were identified as Indigenous Peoples.

For just transition to green energy, the customary systems of the communities, including their land tenure, culture and the overall value of their land-use systems, have to be recognised. With such recognition, the value of the land can be defined in project development as contribution by the communities. This will enable the community benefits to be included in a sustainable way, e.g. as having equity in the project and a community trust that manages the benefits. Such an approach is exemplified by the Kipeto Wind Power Project in Kenya (see Box on page 35), which provided annual lease payments to landowners for land where turbines were erected, an annual share of gross revenue from each wind turbine, and a five per cent equity to the community and revenue share managed by a community trust.

Finding ways for successful coexistence

Further, coexistence of the pastoral communities and green energy projects is an important possibility that needs to be explored before exclusions are decided on. The trade-offs between producing energy and producing food can guide designing of co-existence between the two. This involves minimising the area of

The Lake Turkana Wind Power Project
The Lake Turkana Wind Power Project (LTWP) started operating in 2019. It is the largest wind power project in Africa. Located in Loiyangalani District, in Marsabit County in north-western Kenya, the wind farm covers about 160 square kilometres and has a capacity of 310 megawatt (MW), which, according to the operators, accounts for approximately 17 per cent of the country's installed capacity and guarantees energy supplies for around a million households. The wind farm comprises 365 wind turbines, each with a capacity of 850 kilowatts. Energy is purchased at a fixed price by The Kenya Power and Lighting Company PLC and is fed into the national grid. The land, which is used by pastoralists, was given to the investor in 2009, on a 33-year renewable lease. LTWP is registered as a Clean Development Mechanism under the Kyoto Protocol, which allows for carbon trading. It is owned by a consortium of six stakeholders. According to the operators, LTWP is the largest private employer in Marsabit County and has employed approximately 3,000 people to date. Currently, LTWP has a staff of 329. Investments totalled 625 million euros.

The Kipeto Wind Power Project
The Kipeto Wind Power Project is the second-largest wind farm project in Kenya. Located in Kajiado County in south-western Kenya, it started operating at the beginning of 2021. The wind farm covers an area of approximately 70 square kilometres and has a capacity of 100 MW, providing power to around 250,000 households, according to the operators. The project's 60 wind turbines have a capacity of 1.7 MW each. As with LTWP, the energy generated is purchased by the Kenya Power and Lighting Company, under a 20-year power purchase agreement. Investment costs are reported to be at 344 million euros.

land used for green-energy installations and allowing land use for grazing livestock and crop farming. This multifunctional land use approach, where for instance the space below and between solar panels or wind turbines can be used for grazing of livestock or harvesting of other natural products, can provide a win-win situation resulting in higher overall economic efficiency. Grazing under solar panels can improve animal welfare, which is all the more relevant as climate change leads to higher temperatures. Regarding solar versus wind power, the former is more challenging for livestock grazing unless it is mounted at a height providing ample space for grazing underneath. However, adjusting the designs and raising the panels adds to the investor's costs of the solar installation, but the benefits from the dual use of land may compensate for these extra costs, particularly in areas of high grazing value.

While positive examples of coexistence from Africa are difficult to come by, a number of opportunities have been observed in other continents. For instance, field experiments in Brazil showed that grazing animals preferred shade from solar panels to shade from cloth, while ranchers in the United States and Australia observed livestock gathering in the shade of wind turbines. Also, in several countries in Europe, animals are grazed on land accommodating wind and solar installations, which provide shade protecting livestock against intense solar radiation while offering society a low-carbon energy source and additional income for the farmers with rights to the land. One further benefit of raised solar panels could be that water used to clean the panels would not be wasted but could drip to the ground and irrigate (albeit in a small way) the vegetation below. Although these coexistence examples are enlightening, they may not be relevant for pastoral areas in Africa, where much of the land is common property with overlapping use rights held by different user groups. However, from the perspective of the possibilities of multifunctional land use, the example serves a good learning point.

Ensuring an inclusive approach

There is therefore a need for inclusive participatory design of energy projects to support primary functions of the land to produce food and to provide other services such as conserving biodiversity, supporting rural economic activities in addition to generating electricity. Towards ensuring this inclusive approach, there is need for the tenure rights of the traditional users of the commons to be recognised within policy and legal governance systems. For instance, a number of countries such as Kenya, Uganda and Tanzania have put in place legal frameworks for the recognition and registration of communal tenure rights. However, the implementation of the said laws has not been adequate to prevent unlawful dispossessions by other land uses. Further, there is a need for government policies promoting collectively owned and managed community energy projects to provide local energy and also feed into the national grid.

Energy companies and investors have to adhere to global standards and international agreements that have already been developed, such as the UN Guiding Principles on Business and Human Rights, the International Finance Corporation Performance Standards on Environmental and Social Sustainability (World Bank) and the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests (VGGT) of the UN's Food and Agriculture Organization (FAO), among others. These standards advocate for the recognition of the local communities' rights, applying the FPIC principles and recognising their customary systems, including land tenure culture, and the overall value of their land-use systems. Overall, when the livelihoods are protected and adequate and just compensation is provided where land is acquired for green energy projects, then benefits from such projects can support pastoral livelihoods to withstand crises such as the current droughts, and provide avenues for recovery.

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Photo: author

Producing nitrogen fertiliser with net-zero CO_2 emissions

Decarbonising the production of synthetic nitrogen fertilisers can have the twin benefits of reducing both the industry's CO_2 emissions and its reliance on fossil fuel imports. But is such a process at all possible, and if it is, at what price? Considering the importance of nitrogen fertilisers for global food production, our authors have examined this question applying a country-specific analysis. Their findings, published in a recent scientific study, are summarised below.

By Paolo Gabrielli and Lorenzo Rosa

For centuries, nitrogen has been a bottleneck limiting global agricultural productivity. Despite its abundance in the Earth's atmosphere, nitrogen is generally not immediately available for human use, being present in the unreactive N_2 form. In 1908, the Haber-Bosch process to industrially produce the chemically reactive compound ammonia (NH_3) was invented, enabling an abundant supply of nitrogen fertilisers to boost agricultural productivity. While synthetic nitrogen fertilisers have a key role in global food production, excess reactive nitrogen has caused several environmental impacts, including groundwater contamination, eutrophication of water bodies and associated biodiversity loss, air pollution, greenhouse gas emissions, and stratospheric ozone depletion.

Anhydrous ammonia is transferred and stored as a liquefied, compressed gas.

Photo: Jon Rehg/ shutterstock.com

Fertiliser production and consumption, trade and food security

Synthetic nitrogen fertilisers are used to produce food for 3.8 billion people world-wide. According to the UN Food and Agriculture Organization (FAO), in 2019, 107 Mt of synthetic nitrogen fertilisers were used in agriculture globally. With 27 million tons of nitrogen (Mt N) per year, China is the largest consumer of synthetic nitrogen fertilisers, followed by India (19 Mt N) and the USA (12 Mt N). But considering country-specific nitrogen use efficiencies (i.e. the fraction of nitrogen lost in the field and not used to produce food), nitrogen waste and losses in crops from farm to fork, and country-specific per capita nitrogen intakes in diets, we found that India is the country feeding the largest number of people with synthetic nitrogen fertilisers, 646 million people, followed by China (530 mill.) and the USA (480 mill.).

In 2019, synthetic nitrogen fertiliser exports equated 38 per cent (47 Mt N per year) of global production. Exports are concentrated in just a few countries (see Figure, upper part), with Russia being the largest net exporter (9.2 Mt N per year), followed by China (5.6 Mt N) and Egypt (3 Mt N). However, some net exporters of synthetic nitrogen fertilisers are large importers of natural gas, which make these countries vulnerable to energy shocks – as highlighted by the current energy crisis. Accounting for natural gas imports lowers the number of countries that can produce synthetic nitrogen fertilisers self-sufficiently. The lower part of the Figure shows that while a number of countries, including China, Germany and Poland, have become net-importers of synthetic nitrogen fertilisers (via natural gas imports), major fossil fuel producers like Russia and Saudi Arabia remain net exporters.

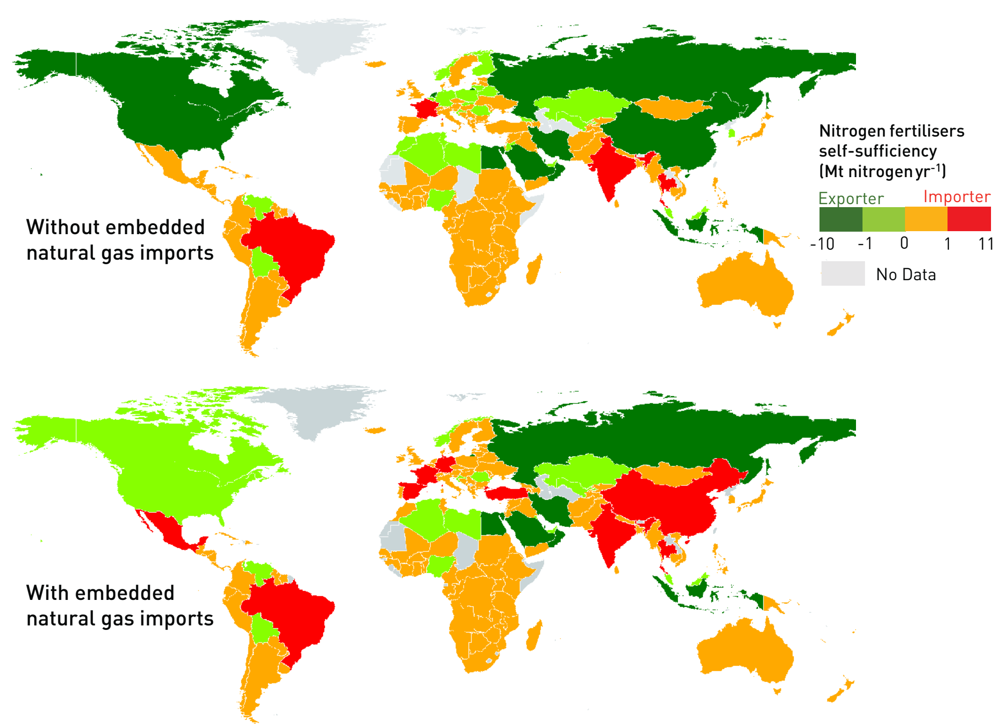
The reliance of synthetic nitrogen fertiliser on international trade makes global food security and food systems vulnerable. According to the FAO, food security is achieved "when all people, at all times, have physical, economic and social access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active healthy life". Considering safe physical access to proteins, we found that 1.07 billion people a year consume food reliant on fertiliser imports. But an additional 710 million people depend on natural gas imports used to produce synthetic nitrogen fertilisers. Thus, globally, 1.78 billion people per year are fed from food reliant on imports of either fertilisers or natural gas. So without trading of these commodities food shortages would spread, having devastating impacts on millions of people.

Carbon emissions embedded in ammonia production

NH_3 is the precursor to most synthetic nitrogen fertilisers, and NH_3 production accounts for roughly 90 per cent of the nitrogen fertiliser industry's total energy consumption and CO_2 emissions. Therefore, achieving net-zero CO_2 emissions in NH_3 production would represent a major step towards net-zero fertilisers. The global production of NH_3 is about 183 Mt per year, roughly 70 per cent of which goes into synthetic nitrogen fertilisers, whereas the remaining fraction is used for plastics, explosives and textile production. NH_3 synthesis is energy- and carbon-intensive. The global greenhouse gas emissions from NH_3 production are about 450 Mt CO_2 a year. However, country-specific carbon emissions from synthetic nitrogen fertiliser production have been overlooked until recently. Our analysis shows that 310 Mt CO_2 per year are emitted globally by ammonia production to produce synthetic nitrogen fertilisers. China is responsible for the largest amount of CO_2 emissions (117 Mt CO_2/year), followed by India (45 Mt CO_2/year) and the USA (31 Mt CO_2/year).

Conventional production of NH_3 via the Haber-Bosch process uses natural gas (70 %), coal (26 %), oil (1 %), and electricity (4 %) as feedstock. This is a highly integrated process, but can be divided into two main steps: hydrogen production from fossil fuels and NH_3 synthesis from the Haber-Bosch reaction. In most countries, hydrogen is currently manufactured through steam methane reforming (SMR) of natural gas, although China applies coal gasification. While improvements in energy efficiency and carbon intensity are underway and have reduced the emission intensity of NH_3 production by 12 per cent over the last 15 years, net-zero NH_3 production requires a fossil fuel phase-out.

Global nitrogen fertiliser self-sufficiency with and without embedded fossil fuel imports



Source: Gabrielli and Rosa, 2023.

Three net zero production routes and their energy-land-water implications

Net-zero CO_2 emissions in NH_3 production can be achieved through a) the production of hydrogen from fossil fuels integrated with carbon capture and storage, b) water electrolysis using low-carbon electricity, and c) biomass gasification, such as wood chips from crop and forestry residues. In the carbon capture and storage route, NH_3 is still produced from fossil fuels via the conventional Haber-Bosch process. Carbon dioxide emissions generated during NH_3 synthesis are captured, transported, and permanently stored in suitable underground geological structures. In the electrification route, hydrogen is produced from water electrolysis via low-carbon electricity, which also powers the Haber-Bosch process. In the biomass route, CO_2 is captured from air via photosynthesis during biomass growth and then emitted upon synthesis and disposal of the biomass-based product, thus resulting in net-zero CO_2 emissions. Biomass contains both the carbon and hydrogen atoms, as well as the energy required for the synthesis of NH_3.

While all net-zero routes described above are technically feasible, and some allow avoiding reliance on fossil fuels, a holistic approach is needed to quantify their environmental feasibility and avert unintended environmental consequences. The table on page 38 reports the reference values of global CO_2 emissions, energy requirements, land use, and water consumption. For example, decarbonising NH_3 production with the electrification route will require about 1,200 terrawatt-hours (TWh) of electricity (or 5 per cent of global total electricity consumption in 2019), compared to the 48 TWh currently used under a business-as-usual production pathway. All in all, net-zero routes are more land-, energy- and water-intensive than the business-as-usual route; this is the price of achieving net-zero emissions. Overall, the biomass route is the most water- and land-intensive one (mostly through the high water and land intensity for growing the biomass feedstock), while the electrification route is most energy-intensive (mostly because of the electricity amount required to produce hydrogen via water electrolysis). Let's look at this a little closer:

Being more energy-intensive, net-zero NH_3 production will not necessarily decrease vulnerability to energy shocks. For example, net-zero NH_3 production based on the electrification route could reduce vulnerability to shocks on commodity markets, at least in terms of oil, methane, and coal, but would be still vulnerable to electricity prices. The deployment of processes to synthesise nitrogen fertilisers from renewable energy (i.e. electrification and biomass route) can reduce CO_2 emissions while averting reliance on imports of fossil fuels. In contrast, whereas carbon capture and storage promotes net-zero emissions, it does not reduce the reliance of the food system on fossil fuels; still using an average of 77 Mt of carbon from fossil fuels per year, it makes the global food system vulnerable to energy shocks. In addition, carbon capture and storage would require a widely spread infrastructure to transport and permanently store the CO_2 captured at the production site. Whereas recent assessments indicate that between 7,000 and 55,000 Gt CO_2 can be stored world-wide, CO_2 storage still faces issues concerning the actual availability, accessibility, and acceptance of storage sites.

Importantly, our assessment accounts for natural gas leaks along the supply chain, here assumed to be 1.5 per cent of the required natural gas. However, it is worth noting that natural gas leaks affect carbon emissions, hence land, energy, and water consumption required to achieve net-zero emissions of the carbon capture and storage route only. Arguably, the carbon capture and storage route would find a better use for carbon-rich chemical products, such as methanol and plastics, which, contrary to NH_3, contain the carbon molecule in the final product, as we have shown in previous research. Unlike carbon capture and storage, the electrification and biomass routes can achieve net-zero emissions while avoiding fossil fuels. However, the electrification route would require 25 times more energy than the business-as-usual route. The biomass route would require 1,000 times more land and water than the business-as-usual route, using 26 million hectares of land and 255 billion cubic metres of water. To grow this vast increase in biomass, further nitrogen inputs as well as transport and processing facilities would be needed. In addition, both biomass and electricity would be required to achieve net-zero emissions in other sectors, and competition for these limited resources could constrain their use for NH_3 production. To avert unintended impacts on natural resources and biodiversity and additional land, water, and fertiliser use, biomass should be sourced sustainably from waste biomass, and forestry and crop residues.

While net-zero nitrogen production routes could solve energy and food security issues present in business-as-usual NH_3 production, they could also create inequalities in NH_3 nitrogen fertiliser production, with more technically advanced economies continuing to dominate the sector.

Global energy, land, and water required to achieve net-zero emissions in synthetic nitrogen fertiliser production

	CO_2 emissions (Mt CO_2)	Electricity requirements (TWh)	Land use (Mha)	Water consumption (km³)
Business-as-usual	310	48	0.03	0.04
Carbon capture and storage	0	76	0.06	0.13
Electrification	0	1,219	0.9	2.03
Biomass	0	49	26	255

How to reduce global ammonia demand

By emitting 310 Mt CO_2 per year, business-as-usual NH_3 synthesis for synthetic nitrogen fertilisers production commits humanity to emissions levels not compatible with the net-zero targets required to keep global warming below 1.5 °C. An additional 30 Mt CO_2 per year are estimated to come from NH_3 transport. Although NH_3 is not a greenhouse gas, its overuse leads microbes in the soil to convert it into nitrous oxide, a greenhouse gas 300 times more powerful than carbon dioxide and responsible for stratospheric ozone depletion. It is estimated that each year, nitrogen fertilisers emit 2.3 Mt of nitrous oxide, equivalent to 670 Mt CO_2 emissions, bringing global total emissions (direct and indirect emissions) from synthetic nitrogen fertilisers to 1,010 Mt CO_2 per year when accounting for emissions from NH_3 synthesis for nitrogen fertilisers, or 2 per cent of global greenhouse gas emissions.

Economic and population growth are expected to double global food demand by 2050. So, synthetic nitrogen fertilisers are envisaged to continue to be a major and growing component of agricultural productivity this century. While the net-zero routes analysed here can abate emissions on the supply side, demand-side measures can lower future NH_3 demand and significantly ease the task of achieving net-zero emissions while considering environmental trade-offs and socio-political shocks (e.g. related to food and energy supply). Encouraging diets with low nitrogen footprint or less meat, reducing food losses and waste, and improving nitrogen use efficiencies can reduce future NH_3 demand. First, global average nitrogen use efficiency – the share of applied nitrogen incorporated in food production – is estimated to be around 46 per cent, meaning that more than half of synthetic nitrogen is dispersed in the environment and not used to grow crops. Precision agriculture can increase the efficiency of nitrogen fertiliser application to crops. Second, nitrogen losses from farm to fork are put at between 41 per cent and 44 per cent and are mainly due to harvesting and distribution losses, and food waste. Such losses can be reduced by reducing food waste and improving efficiencies in food supply chains. Third, a dietary transformation to less nitrogen-intensive diets can reduce nitrogen demand. While the recommended per capita daily protein intake for a healthy diet is estimated to be roughly 50 g (or about 9 g of nitrogen), today the global median intake is 84 g of protein. Moderating the consumption of animal-based food can reduce nitrogen demand. Importantly, while average protein intake is above the recommended value for healthy diets, one billion people still suffer from protein deficiency world-wide, indicating inequalities in our food systems.

Considering losses, inefficiencies, and waste, it is estimated that only approximately 20 per cent of produced synthetic nitrogen fertilisers feeds global population. Therefore, roughly 80 per cent of synthetic nitrogen fertilisers is lost through inefficiencies in our food systems. Transitioning from a linear to a circular economy capturing and recycling nitrogen from waste can moderate the use of resources and energy required to produce synthetic nitrogen fertilisers. Promoting the use of organic fertilisers such as manure or compost can reduce NH_3 demand. Animal manure nitrogen outputs are a major source of nitrogen recovery and recycling globally. The digestate produced from anaerobic digestion of livestock manure can be spread over croplands to recover nitrogen. However, organic fertilisers are often more expensive, slower in releasing nutrients and presently not capable of supporting the demands of current or future generations. While promising scientific developments are underway for alternative fertilisers, many of these approaches need further development. Bioinformatics and plant genomics can both reduce fertiliser usage. Electrochemical synthesis and plasma activated processes are other promising approaches that could be deployed as an alternative to the Haber-Bosch process.

Conclusions

Going beyond the status quo and investigating the interplay between food security and climate targets, we have analysed alternative routes that are already available today to abate the carbon footprint of fertilisers via net-zero CO_2 emissions in NH_3 production. These net-zero routes hold the potential to align food system with global climate targets, while increasing food and nutrient security by reducing the reliance of the food system on fossil fuels. However, they will require more land, water, and energy than business-as-usual production. This highlights the relevance of location-specific analyses to determine optimal net-zero routes for producing fertilisers based on technical, environmental, and geo-political circumstances.

Paolo Gabrielli is a Senior Scientist at ETH Zurich/Switzerland and currently a Visiting Investigator at Carnegie Institution for Science at Stanford, California/USA. His research deals with the optimisation and assessment of net-zero energy systems, focusing on the assessment of energy storage technologies and the optimal design of integrated energy and chemical systems and supply chains.

Lorenzo Rosa is a Principal Investigator at Carnegie Institution for Science at Stanford. His research aims to assess the potential benefits and unintended climate and environmental consequences of innovations engineered to satisfy the increasing global demands for energy, water and food.

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References: **www.rural21.com**

Do import restrictions really benefit the local poor in West Africa?

Protectionist policies like tariffs supposedly protect domestic producers if they cannot compete with cheaper imported products. Some African countries have therefore opted to impose such import restrictions for a number of products. For the case of chicken imports in Ghana, this study analyses whether restrictions would lead to overall positive or negative welfare effects among households.

By Isabel Knößlsdorfer

Over the last 20 years imports of chicken have increased in many West African countries. Since local production cannot keep up with the growing demand, imports are used to close that gap in supply. In the case of chicken, those imports mainly come from the European Union (EU), but also from the USA and Brazil.

However, cheap imports of chicken to West Africa are discussed controversially. Developing countries may benefit from such cheap imports, as they help to keep domestic prices low and improve access to nutritious foods for the poor who might otherwise not be able to afford much protein. Nevertheless, critics point out that local producers, including smallholders, may struggle to compete with the lower prices of imported chicken and thereby lose one of their sources of income.

Critics of free trade claim that local producers in West Africa may struggle to compete with the lower prices of imported chicken.

Photo: Jörg Böthling

In the past, to protect the local industry and with it producers and farmers, a few African countries have imposed policies that restrict such imports. Referred to as protectionist trade policies, they have been implemented e.g. in Nigeria and Senegal, either by increasing import tariffs or banning chicken imports altogether. Although different trade agreements such as the Economic Partnership Agreement (EPA) as well as regulations by the World Trade Organisation (WTO) govern such trade policies, exceptions exist under specific conditions. Health concerns or disease control allow for different regulations. For instance, Ghana recently imposed a partial import ban on poultry products from five European countries following an avian influenza outbreak. In order to analyse the effects of such protectionist trade policies, we designed two scenarios – a 50 per cent import tariff for chicken and a prohibitive import tariff that would lead to zero imports, equivalent to an import ban for chicken. Taking Ghana as an example, we analysed the effects of these two hypothetical import policies on domestic households' chicken sales, consumption and overall welfare. By focusing on household consumption and production instead of larger commercial farms while also distinguishing between poor and non-poor households, the study helps to draw conclusions on whether or not import restrictions would be a pro-poor policy.

Ghana's poultry sector

The poultry sector in Ghana is characterised by large and medium-sized commercial farms which focus mainly on egg production as they have gradually been pushed out of the market for chicken meat by the cheaper imported competition. Most of the local broilers in Ghana are reared by small- and medium-scale farms for home consumption and selling on the market. Reasons for the lower competitiveness of local producers include lower productivity, high energy and transport costs, as well as high feed costs. In Ghana, much regionally grown feed is used, which of course costs more than the cheap soy imports chicken in the EU are often fed with. For comparison, farmers in the EU benefit from subsidies, and European consumers have a strong preference for certain chicken parts only, such as breasts, meaning that other parts are often exported at low prices.

To increase productivity and competitiveness in the local poultry sector, the Government of Ghana has implemented various support programmes, including input subsidies and trade restrictions, over the years. In 2015, import tariffs for chicken and other types of meat were raised to 35 per cent in accordance with the Common External Tariff (CET) regulations of the Economic Community of West African States (ECOWAS). However, this did not lead to long-term decreases in imports, and imported quantities still remain high (see Figure on page 40).

In 2019, average annual per capita meat consumption in Ghana was 9 kilograms. This is well below the world-wide average, partly because the majority of the animal protein consumed stems from fish. However, consumption levels are rising steadily, and chicken meat in particular is popular among private households but also restaurants and hotels.

Most of the chicken consumed in Ghana is imported from abroad; imports accounted for three-quarters of the total poultry supply in 2019. Next to that, imported chicken is about 40 per cent cheaper than domestic products. The two product types also differ in terms of freshness, taste, convenience and other attributes, as imported chicken is sold mostly pre-cut and frozen, whereas local chickens are sold fresh, as whole birds and often live. Ghana, South Africa and Angola are the biggest importers of chicken in sub-Saharan Africa.

Trade discussion

Trade liberalisation describes the reduction or abolition of trade protectionist policies, such that countries can trade goods with each other more freely. The existing literature on trade suggests that trade liberalisation has mostly positive effects on incomes and can reduce poverty in general. In theory, liberalising trade by reducing trade barriers decreases prices for consumers and increases market opportunities for producers. Protectionist policies like tariffs or other trade barriers, on the other hand, can lead to higher prices and profits for domestic producers but at the same time increasing costs for consumers, because imported products increase in price and decrease in quantity supplied. Trade barriers can also have unintended side-effects. In Nigeria, for example, a complete ban on poultry imports is now leading to rising incidents of border smuggling, thereby undermining domestic price targets as well as food safety.
Since poor people spend a larger share of their income on food, higher prices hurt them much more than others. Whether a total welfare effect of a policy is positive or negative depends on the specific situation of the country or household. Net producers benefit from higher profits, while net consumers are hurt by higher consumer prices. In the African context, many smallholders, accounting for a large share of the poor, are net consumers of food – they buy more food than they sell. Higher tariffs on food imports are therefore not expected to benefit them.

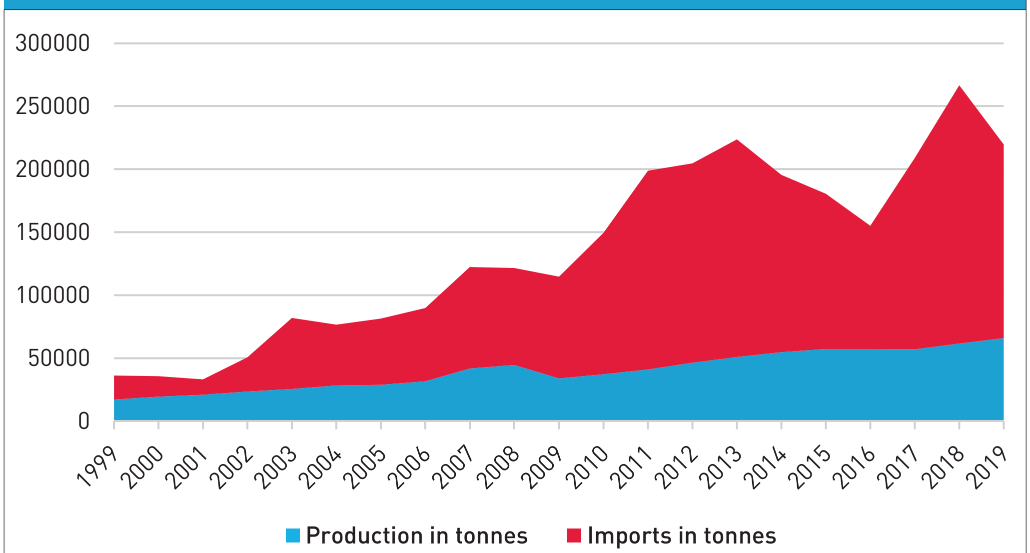
Household consumption and production

Our study (see Box on page 41) draws on data from the 7th round of the Ghana Living Standards Survey (GLSS7) from 2016/2017, a nationally representative household survey with about 14,000 household observations. The data includes information on chicken consumption and production, while distinguishing between consumption of fresh and frozen chicken. Based on market reports and other literature, it is fair to assume that the frozen chicken meat is imported, while the fresh meat is domestically produced. Additional local market price data were also collected in 2016/2017 as part of the GLSS7 and used to compute regional chicken prices.

Descriptive statistics show that around 43 per cent of all households consumed any chicken in 2017. At 36 per cent, frozen chicken consumption is much more common than consumption of fresh chicken (6 %). Around 15 per cent of all households owned chicken, either for the production of eggs or meat. Only 4 per cent sold any chicken during the 12-month survey period. The proportion of households hurt directly by cheap chicken imports is therefore rather small.

Regarding the distribution across rural and urban areas, rural households are more likely to own chicken and to sell any chicken than urban households, where only seven per cent own chicken. Consumption-wise, urban households are more likely to buy chicken from the market – either frozen or fresh – than to consume their own chicken. In both rural and urban areas, poor households are more likely to sell chicken and consume their own chicken than non-poor households. To identify poor households, we used the official poverty line, as defined by the Ghana Statistical Service (2018) for the GLSS7 data. A household is defined as poor if its consumption expenditures are below 1,761 Ghanaian cedi per adult equivalent and year.

Total supply of poultry meat in Ghana, domestic production, and imports



Source: FAOSTAT, 2021

Effects of higher import tariffs on households

In the first scenario, with an increase of the import tariff on chicken from the current 35 per cent to hypothetical 50 per cent, prices for chicken meat would rise by about 11 per cent for imported and 6 per cent for domestic chicken, respectively. In the second scenario, with a prohibitive tariff, prices for imported chicken would increase so much that this market segment would cease to exist, and imports would drop to zero. Prices for domestic chicken would then rise by 34 per cent. These new prices would affect consumption and production of chicken in Ghana as follows.

On the consumption side, only those households who purchase chicken products from the market would be affected. In the first scenario, consumption of imported chicken would decrease by 6 per cent, whereas consumption of domestic chicken would decrease by 3 per cent. In the second scenario, the changes are more drastic, as consumption of imported chicken would decrease by 100 per cent and consumption of domestic chicken by 17 per cent. While consumption would decrease, as expected, market supply levels among those households that sold any chicken would increase. In the first scenario domestic chicken sales quantities would increase by 3 per cent. In the second scenario, sales quantities would rise by 17 per cent. Accordingly, average incomes of these households would increase by

22 per cent and 74 per cent in the two scenarios, respectively. While these are large effects, they only affect a small proportion – about four per cent – of all households as the rest are not involved in chicken sales.

Study framework

To analyse the effects of the two hypothetical policy situations, a 50 per cent import tariff and a protectionist import tariff, we use a partial-equilibrium model of imported and domestic chicken supply in Ghana, assuming that other sectors of the economy would be unaffected. This simplified approach comes with a few limitations (see below) but still offers the possibility to examine welfare and distributional effects at the household level. The model assumes that higher import tariffs would increase the price of imported chicken while decrease or completely stop imports – depending on the scope of the tariff. Although imported chicken and domestic chicken are not perfect substitutes and differ in a few characteristics, demand for domestic chicken will nevertheless increase by a certain factor. This factor depends on the tariff, import price and quantity changes, and the elasticity of substitution between imported and domestic chicken products. Based on the shift in demand for domestic products, we compute price changes for chicken using own-price elasticities of demand and supply.
The changes in market supply and consumption for both scenarios are calculated for each individual household. The changes in household consumption and chicken sales are then added up to get the overall welfare effect using the equivalent variation (EV). It measures the amount of money transfer that would be needed to lift the household to the new level of utility at the initial price levels.
Limitations of the analysis include, first, the simplified assumption of fully separable market and household decisions, which may in reality not be the case – especially in semi-subsistence settings. Second, price elasticities of demand and supply are point estimates, which are usually not optimal when modelling larger price changes. Third, the results presented here can probably best be interpreted as medium-term effects of higher import tariffs, whereas short- and long-term effects may possibly differ. Finally, this study looks at household production only. Price effects also affect commercial poultry enterprises, which could affect household welfare through labour markets and wages. Results should be seen as tentative estimates of effects that can be expected from import restrictions for chicken in Ghana, but should not be over-interpreted as precise measurements.

Welfare analysis

As expected, higher import tariffs would lead to welfare losses on the consumption side and to welfare gains on the supply side. The proportion of households that would gain from additional import restrictions – those who produce chicken – is much smaller than the proportion of households that would lose as consumers.

Thus, the average consumption losses would be much bigger than the average gains from additional sales, meaning that the overall welfare effects of higher import tariffs would be negative. The total negative welfare effects would be much larger with a prohibitive import tariff than with a 50 per cent tariff, as with a prohibitive tariff, the market for imported chicken would cease to exist. Overall effects in both scenarios would still be relatively small. This is true for all household types, poor and non-poor, as well as for those living in rural and urban areas. There are however differences in the scope of gains and losses. It should be kept in mind that the proportion of households selling chicken might potentially increase in the long run with consistently higher market prices.

Effects on poor, non-poor, urban and rural households

Non-poor households would suffer more from chicken import restrictions than poor households, as non-poor households in all groups tend to purchase more chicken from the market. That means they depend on the price of chicken more than those households who consume a larger share of their chicken from their own production. However, the role of food prices is not the same for poor and non-poor households. Therefore, we also express welfare effects relative to households' total food expenditure. In both scenarios and for all groups of households, the total welfare losses would account for less than 2.3 per cent of total food expenditures. The main reason for this relatively small effect size is that chicken consumption, production and sales quantities are small for the average household in Ghana. For comparison, we also analysed the welfare effects when considering only households that consumed or produced any chicken. In such a case, the welfare effects increase in magnitude, but the direction of the effects remains unchanged. This means that at least in qualitative terms, our results may also hold if chicken consumption in Ghana continues to rise. This is also an important notion for those other African countries where the consumption of chicken meat plays a larger role than it currently does in Ghana.

Are import restrictions pro-poor?

Given the negative welfare effects of both hypothetical scenarios, additional import restrictions for chicken cannot be considered a pro-poor policy in general. Import tariffs do not seem to be an appropriate way to protect producers of chicken in Ghana from cheap imports, because only a small proportion of households are involved in production and the majority of them are net consumers who would be negatively affected. Targeted support measures, for example through technical assistance or direct income transfers, could be a better strategy. Overall, cheap chicken imports do not seem to be as harmful for poorer Ghanaian households as often claimed, and without access to alternative protein sources, cheap imported chicken products contribute to improved nutrition of income-restrained households. Furthermore, policies to strengthen local infrastructure, technologies, and institutions are better suited to promote sustainable development than import restrictions.

An additional question is also whether it would really make economic sense for countries in Africa to foster a commercial broiler sector for which developing international comparative advantage will be very difficult under current conditions. Fostering other agricultural sub-sectors for which African countries have stronger comparative advantages (including mostly raw and unprocessed products, like cocoa and its derivatives) would probably make more sense economically and socially.

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Activating rural voices for effective implementation of tobacco control policies

Just like many other African countries, Malawi, one of the world's top ten exporters of tobacco, is increasingly experiencing the consequences of tobacco-related death and diseases. However, as yet it lacks public health-related control policies. One reason for this is a lack of data, our authors believe. With their action research project, they seek to change this state of affairs – and here, they particularly have the voices of rural communities in mind.

By Mariam Kadzamira, Harriet J. Gausi, Tamara Phiri and Eta Elizabeth Banda

Chronic non-communicable diseases (NCDs) are becoming significant causes of morbidity and mortality in sub-Saharan African countries. But local, high-quality data to inform evidence-based policies are often absent. This also holds true regarding the impacts of tobacco in Malawi. There is little or no evidence of the economic costs of smoking, and the disease burden associated with tobacco usage is difficult to quantify. In order to fill this gap, the social enterprise Youth Enterprise Services (YES) Malawi implemented an action research. Their work also aimed to give a platform for 'hidden rural voices' – those that are often not included in policy formulation processes. In Malawi, according to World Bank estimates, rural communities account for roughly 82 per cent of the population.

"Should the government put in place regulations/laws banning/prohibiting tobacco use in this country? What approaches ought to be followed in order for these laws to be put in place and enforced?" These questions were addressed in the focus group discussions.

Photo: Development Initiative Network (DIN) Malawi

The World Health Organization (WHO) reckons that globally, more than eight million deaths are caused annually by tobacco use. Seven million people die as a result of their tobacco consumption, while 1.2 million non-smokers lose their lives through involuntarily inhaling tobacco smoke from others. Of these deaths, 80 per cent are projected to occur in low- and middle-income countries. Tobacco consumption is on the decline world-wide, but sub-Saharan African countries are witnessing more tobacco use resulting from improved economic conditions, a large and growing young population and the tobacco industry's intensive marketing efforts.

Malawi is one of the world's top ten tobacco producers. Nearly all tobacco leaves are exported, and only a small quantity is processed locally, mainly in cheap low-quality tobacco products. The production, buying and exportation of the tobacco leaf is governed by the Malawi Tobacco Act (1970, last amended in 1990) and the Tobacco Industries Bill (2012). The country is the world's most tobacco-dependent economy, and its government owns a major share of tobacco companies. But Malawi is not a signatory to the WHO's Framework Convention on Tobacco Control (FCTC), the international legal framework developed in response to the global tobacco epidemic which entered into force in 2005. It is thus not surprising that no specific public health-related tobacco control policies exist with restrictions on smoking indoor and/or in public places, tobacco advertising and packaging, and sale restrictions (e.g. minimum age for the purchase).

Reliable data is scarce

Recent official data shows that in Malawi, more than 5,700 people are killed each year by tobacco-related diseases, with over 5,000 children aged 10-14 years and about 920,000 adults using tobacco every day. But this data is most likely an underestimation, one of the reasons for which is how patient data is captured in the public healthcare system. Upon an illness, at facility level, this is done in three ways. Patients' files, with details of their health history, symptoms and their management, remains with the hospital. Health passports, briefs mainly capturing diagnosis, presenting symptoms and treatment/management, are meant to be carried by patients every time they visit a hospital to ensure continuity of care. Finally, there is the web-based District Health Management Information System (HMIS). It can be easily accessed by policy-makers for research, but it only captures a patient's name, age, gender, complaint, diagnosis and treatment. Key information such as a patient's history of smoking or family is only contained in the patient's hospital files.

National population-based data on the prevalence of smoking in Malawi is sparse, too. The most recent statistics come from the 2015-2016 Malawi Demographic and Health Survey which included 26,361 households. The figures indicate that approximately 12.4 per cent of all men aged 15-54 smoke cigarettes, the majority of them on a daily basis, but that a mere one per cent of women aged 15-49 are smokers. Tobacco usage is prevalent in both rural and urban Malawi. Whereas specific statistics on the type of consumption are hard to find, it can be assumed that tobacco-growing communities tend to 'roll their own' tobacco from their green leaf, while cigarette smoking is more prevalent in urban areas as it requires cash purchases. All in all, smokers are likely to be older, poorer, less educated and living in rural areas of the country.

Socio-economic costs and spill-over effects to family and community members

In the context of our action research, two in-depth case studies were developed, based on the life of two male smokers who had each been smoking for 30 years or more and whose life had been affected by smoking. This helped us to identify and document the direct and indirect socio-economic costs of disease burden associated with smoking. The case studies were augmented with six focus group discussions conducted to determine community knowledge on effects and impacts on smoking, and to gather public perceptions of the enactment of public policies to control smoking in Malawi. Sixty rural communities from various locations (Chikwawa, Salima, Nkhatabay and Kasungu Districts) and two peri-urban areas on the outskirts of the cities of Lilongwe (the capital) and Mzuzu (in the Northern region of Malawi) were engaged, with women making up a third of all participants in each focus group discussion on average. Findings from the case studies and the focus group discussions showed that illness related to smoking results in three impacts for smokers and their families: the smoker's ill health, the economic burden for the smoker, their family and the community, and mental health effects. Resulting from a lifetime of smoking, the smokers had to be hospitalised and stopped bringing income, which led to a loss of economic independence. In the case studies, the affected smokers indicated feeling 'helpless' and depressed, having been the main breadwinner in the family.

When a smoker gets sick in Malawi, the relatives, friends, workmates and other community members step in to provide cash for day-to-day needs. Relatives provide in-hospital support during hospitalisation, meaning that the smoker's close relatives and community members incur losses of income and time. This is true for other diseases as well, but illnesses associated with prolonged smoking are long-term in nature, e.g. hypertension and then a stroke, requiring relatives to give more time and money over a longer period. So costs associated with disease from tobacco usage spill over to an affected person's family and community, often eroding the individual and their family's finances, and pushing them below the poverty threshold – or further down, if they were already poor.

Rural voices as a basis to formulate policies

In our surveys, the rural communities referred to the following aspects alongside health issues as reasons to curb tobacco use in public places, and government enforcement of the same:

- Smoking contributes to air pollution and litters the environment with cigarette stubs.
- Smoking in public violates the human rights of non-smokers and creates conflicts between smokers and non-smokers. Furthermore, it sets youth and children a negative example.
- Public funds must be spent on treating tobacco-related illnesses. Income lost through smokers getting ill results in poverty, while money spent on cigarettes could be used for household needs.

There is much anecdotal evidence that children are often sent to groceries to buy cigarettes for their elders, and also light up the cigarette from the fire. This becomes an unintended initiation. Worse still, children pick up haphazardly discarded stubs and smoke them. Currently, Malawi law does not specify a minimum age for the purchase of tobacco products, which could explain why 3.5 per cent of Malawian youth aged 13–15 smoke cigarettes.

Rural communities consulted also provide insights on specifics that must be included in any policy aimed at curbing public smoking, and they offer insights on how these can be enforced in rural communities. They include the following:

- All businesses and government offices should designate smoking areas. This should go hand-in-hand with the enactment of penalties, stringent monetary fees, for anyone smoking in non-designated areas.
- Sale of tobacco products should be restricted to adults, with businesses selling tobacco products to under-age persons having their business license revoked.
- Government should involve the existing youth groups in communities to engage in advocacy campaigns. Community health talks and the arts could contribute to discouraging tobacco use, encouraging cessation and sharing information on support for quitting.

Our counterparts also called on the government to raise taxes on tobacco and cigarettes, with higher prices then perhaps discouraging people from smoking. These policies must be enacted along with budgetary support for on-going civic education and awareness-raising on the dangers of smoking for the public. The education system should also include anti-smoking messaging as part of the normal curriculum. Finally, the youth must be engaged in public health policy processes to ensure that their voice is heard, and that policies are developed.

The development of tobacco-related diseases shows the need for public policies to control smoking. Incorporating views from traditionally excluded communities – like rural communities – will ensure that their voice is heard, which could be the key to success of policy implementation. In addition, any policy that is formulated will only be effective if it is consistently implemented, has budgetary commitment and is enforced via local stakeholders such as traditional chiefs, who are the gatekeepers of rural communities in Malawi. Furthermore, there is need to put in place nation-wide initiatives aimed at preventing smoking initiation, supporting smoking cessation and sensitising the public on smoking risks. A national databank on smoking statistics has to be set up which includes occurrence of diseases linked to smoking. In addition, medical practitioners should be trained to provide advice on smoking cessation as part of regular health screenings.

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