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Energy transition and Covid-19 crisis: the role of engineers

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The presentations of the speakers and the videos of the symposium are available on: **http://www.wfeo.org/committee-energy/**

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I. Keynote address – Engineers: responsible for the energy transition, sustainable development, and building the world back better and wiser after Covid-19 – Gong Ke (China)

Gong Ke, WFEO President

I would like to welcome you all to this very important Symposium – very important because today's topic is a challenging one for all engineers around the world. I will be presenting my personal views on this topic.

1. Climate change data

A recent IPCC report released in August 2021, *Climate Change 2021: The Physical Science Basis*, tracks the change in global surface temperatures as observed, due to (a) human and natural factors, and (b) to natural factors only. The firmly report demonstrates the human impact on climate change, and UN Secretary-General, António Guterres, has called the report "a Code Red for humanity".

According to the IPCC, the primary sources of greenhouse gas emissions in 2013 were electricity and heat, which accounted for 31% of these emissions. That was followed by agriculture (11%), transportation (15%), forestry (6%) and manufacturing (12%). Energy production of all types accounts for approximately 72% of emissions. By 2019, the proportion of carbon emissions induced by electricity and heat production was still on the increase, and was far beyond the track specified in the Paris Agreement.

Another report by the Our World in Data organisation shows that the percentage of energy-related greenhouse gas emissions has increased to 73.2%. This warns us of the urgency of the energy transition. Engineers are responsible for implementing the energy transition in order to shape a net zero-carbon world. That is what we mean when we refer to "building back better and wiser from Covid-19".

On 24 September 2021, the United Nations convened a High-Level Dialogue on Energy. In his opening remarks, Secretary-General António Guterres stated that "without deep and rapid decarbonisation of our energy systems over the next 10 years, we will never reach the Paris Agreement goal of limiting temperature to 1.5°C… This will be fatal to the Sustainability Development Goals, to us all, and the planet. Science has shown us exactly how to avoid this. To limit temperature rise to 1.5°C, we must reduce emissions by 45% below 2010 levels by 2030 and reach net zero emissions by 2050."

2. SDG 7: Affordable and Clean Energy

The Sustainability Development Goal 7 – Affordable and Clean Energy – sets out 3 targets for 2030.

- Ensure universal access to affordable, reliable and modern energy services.
  - Today, energy poverty is extensive, with 840 million people lacking access to electricity, predominantly in Sub-Saharan Africa. More than 3 billion

people relying on polluting solid fuels for cooking, causing approximately 3.8 million premature deaths each year.

- Increase substantially the share of renewable energy in the global energy mix.
    - Energy-related greenhouse gas emissions reached an historical high of 33.1 gigatons in 2018. According to the IPCC, if these trends continue, renewables will need to supply 70-85% of electricity by 2050, compared to only 12.4% today. Under a business-as-usual scenario, that figure is expected to rise to only 22% in 2050. Therefore, decarbonisation of energy sources would need to be tripled to reach the target.
- Double the global rate of improvement in energy efficiency.
    - Going forward, improvements in energy efficiency will be crucial. The demand for energy is expected to increase by 25% in 2040 due to rising incomes and a growing population. The increase could be significantly higher if no improvements are made to energy efficiency.

In the Global Sustainable Development Report 2019, *The Future is Now*, a new model for the integrated implementation of the SDGs is proposed. The model refers to six entry points for transformation, including "energy decarbonisation with universal access". The model also sets out four levers for action, including "science and technology". The intersection between this entry point and this lever for action is the area in which engineers can play a critical role.

3. Achieving an energy revolution

We need to achieve a comprehensive energy transition – or energy revolution – towards very efficient and cheaper renewable energy; safe, reliable and efficient long-term storage; scalable and economic carbon capture and storage (CCS) technology and negative emissions technologies; smart, resilient and effective transmission, distribution and operation; widely and clean electrification of end uses and efficient usages; and much more. That means using all of the available tools to advance the transition.

The potential for progress is clear through a rapid scale-up of renewable energy. At the same time, new and improved technologies are also needed, especially with respect to smart grid management and flexible generation. Research and development should support the necessary infrastructures for key technologies, including for heating and cooling networks, charging stations for electric vehicles, and grids for distributed energy generation. Power stations need to allow high penetration rates of renewables. Digital technologies should also be used to improve the efficiency of distribution and availability of energy.

Another important aspect of this is gender equality. The Global Sustainable Development Report states that the 2030 Agenda will fail if we allow people to be left behind. 90% of the over 65 million people worldwide who have been forcibly displaced from their homes are living without access to electricity. The gender dimension of the energy transition is often overlooked, but it remains crucial to our future.

4. Conclusion

I will conclude with three key messages.

- The energy transition is imperative and of great urgency in sustaining both humanity and the planet.
- Engineers are responsible for this comprehensive energy revolution, on both the supply and demand sides.
- The WFEO unites all engineers – men and women – to engage in the energy revolution so that we can build a better and wiser world after Covid-19.

II. Introductory remarks – Jean Eudes Moncomble (France)

Jean Eudes Moncomble, Chair, WFEO Energy Committee

On behalf of the WFEO, I am pleased to welcome you all to this Symposium on the role of engineers in the energy transition and Covid-19 crisis.

The Covid-19 pandemic has disrupted our economies and our lifestyles, even if the climate or biodiversity emergencies are still with us. New health, economic, political and societal uncertainties complicate the fight against environmental damages and require more efficiency and realism, cooperation and solidarity. A little over a year ago, let's remember that there were many debates on the energy transition: the stakes were mainly environmental, with the fight against climate change or the loss of biodiversity at the top of the list. The composition of the energy mix, the capacity of our societies to evolve towards other modes of transport and the consequences of the emergence of digital technology were discussed, to name but a few of the debates that were very present in the "world before".

And then the Covid-19 pandemic struck, a shock of unprecedented violence that surprises us more and more each day by its power, its persistence and the extent, still poorly estimated, of its consequences.

Nevertheless, our societies demonstrated strong resistance and resilience. At the forefront of that resilience were the caregivers – those working in direct contact with the virus and those providing indispensable logistic services, among which figure many engineers. They have allowed the economy to continue to function, and have ensured access to vital services such as water and sanitation, waste treatment, energy, the food chain, internet and communications, transport and so much more. We also have all those who are mobilised to ensure continued access to information, education, culture, and assistance to the disadvantaged.

How could we have faced this health crisis if, in addition, our power plants had stopped functioning or we had suffered a shortage of fuel?

The health crisis is far from over although it is slowing down – perhaps temporarily – in some countries. For more than one year, our forces and resources have been focused on fighting the virus. However, our environmental challenges are still here and will become even more critical as the global economy recovers. More than ever, the transitions we had embarked on before the crisis are proving their importance in all their environmental and social aspects. In addition, these challenges will have to be addressed by a world impoverished and exhausted by the health crisis. With greater reason then, the notions of optimisation, resilience, and efficiency will form the cornerstone of the system we must rebuild – and that is the role of our engineers.

Has the Covid crisis modified, directly or through its numerous consequences, our perception of energy issues or of possible energy transitions? What will be the contribution of the engineers in building our new energy landscape?

Our symposium will first focus on the feedback from this period: how resilient were the energy systems to the Covid-19 crisis. All along the Covid-19 crisis, energy supply in all countries and world regions has been ensured at any time. Hence, on the one hand, the pandemic has highlighted that the underlying energy systems, technologies and transport systems are substantially resilient, although this has required a proactive engagement from energy utilities in this unpredictable context. On the other hand, the continuous and stable energy supply has enabled the sanitary sector to work on its gargantuan effort, by powering critical hospital infrastructures, as well as other crucial activities. How did this happen and what has been concretely been put in place to manage the crisis situation?

The Covid-19 pandemic disrupted our economies and lifestyles and, as previously said, the climate emergency or the loss of biodiversity are still with us. But health risks and cyber risks are examples of new threats to the resilience of energy systems. This should encourage us to move towards a broader definition of energy system resilience, based on a new understanding of risks. Have these "new" risks been sufficiently taken into account? How are they integrated into our thinking and how do they modify our understanding of the transitions we are experiencing?

The pandemic but also - and perhaps above all - the measures taken to combat it have had undeniable and important immediate consequences. Many people are wondering about the sustainability of changes in energy demand: can we see, in the longer term, signs of strong disruptions? The Covid-19 crisis included new threats linked to its easy transfer between humans and between materials and humans. This introduced social constraints affecting primarily either public transportation or safety requirements in building air-conditioning and maintenance. It introduced new or reverse trends, that might influence our societies beyond the Covid crisis itself. Examples are the preference for safer transportation or the trends towards decentralized greener and less dense habitats. The reliance on internet-based channels but also on new locally-based shopping venues has impacted the previous equilibrium, but does this mean that these changes will remain at the end of the crisis or that elasticity phenomena will bring back incumbent actors and behaviours?

On the supply side, two major questions concerning the behaviour of citizens will determine the paths of future transitions:

- Globalization has been identified as partly responsible for the current crises: will we continue along the path of what some describe as unbridled globalization, will we return to lifestyles refocused on the local, or will we find a more balanced path?
- Cooperation and solidarity are values that have returned to the public debate: once the crises are over, will we keep the memory of them in mind in order to build our after pandemic world?

In conclusion, it is essential to develop sustainable, resilient and inclusive energy systems. Reflections must be based on facts, rigorous and without preconceptions. To achieve these objectives, all energy options are possible, depending on national contexts.

- Engineers have a role to play in informing choices by adopting systemic approaches that put forward mature and immediately available technologies that contribute significantly to the fight against climate change and biodiversity loss.
- In the current context related to the Covid-19 pandemic, it is important to use simple and transparent economic criteria such as, for example about climate, the cost per ton of CO_2 avoided.

III. Session 1 – Resilience of energy systems to Covid-19 crisis: experience feedback

1. Covid-19 crisis: Engineering and engineers in Uruguay – Miguel Fierro (Uruguay)

Miguel Fierro, Vice President, Uruguayan Engineering Association

On 13 March 2020, after the detection of the first case of Covid-19 infection in the country, the Uruguayan government declared a sanitary emergency. On 18 March, a risk management protocol was established for the operations of the state energy company, UTE.

UTE: Uruguay's Energy Company

The National Administration of Electric Power Plants and Transmission (UTE) was created by law on 21 October 1912. It is the only energy company in the country, serving 99% of the population today and 100% of the population within the next 10 years. Its autonomy is determined by constitutional norms.

Recent developments in the electrical energy mix mean that 98% of Uruguay's energy supply is generated by renewable sources, and we are the second-largest producer of clean energy in the world. The company has hydroelectric, wind and photovoltaic power plants. It has 1.4 million users in Uruguay, and also exports energy to neighbouring countries such as Argentina (through the Salto Grande hydroelectric power plant) and Brazil (through converter stations located in Rivera and Melo). This strengthens the Uruguayan power grid and provides it with greater flexibility.

Covid-19: feedback on experience

The Covid-19 contingency protocol was implemented for both administrative tasks and field work. For administrative tasks, remote working was introduced in all offices in order to reduce the risk of infection. For field work, permanent teams were defined for operative tasks, with weekly rotations ensuring that the teams remained isolated from each other. In storage facilities, mixed measures were introduced to cover both administrative and operational tasks. A similar procedure was set up for the generator and transmission departments. In addition, restrictions were imposed on customer services: schedules were reduced, and an advertising campaign promoted the use of remote communication tools by customers, for example, WhatsApp, mobile apps, and SMS. Electric meter readings were only carried out in customer homes where this could be done without human contact. Only priority activities were carried out by the technical commercial teams, for example new customer connections or power increases.

These measures led to a 50% reduction in the daily workforce. Nevertheless, the electricity service and distribution network were not impacted.

The situation today

The preventive measures were modified several times due to changes in the country's sanitary situation, with a number of different decrees issued by the President and

Secretary of Health. After almost 18 months, the company has adapted to its new work modalities without any impact on the service provided to its customers.

Conclusion

Uruguay has approximately 5,500 engineers in activity today, compared to an overall population of 3.5 million. Over 1,300 engineers work at UTE, and 1,050 engineers are members of our Engineers Association, the AIU.

2. Covid-19 and Sub-Saharan Africa – Abubakar Sambo (Nigeria)

Abubakar Sambo, Chairman of the Nigerian National Committee of the World Energy Council, Professor at Usmanu Danfodiyo University

Covid-19 and Sub-Saharan Africa

Sub-Saharan Africa has been severely negatively impacted by the Covid-19 lockdowns for a number of reasons. The economies in the region that were already weak were pushed into recession by the crisis, and many people almost starved to death as the lockdowns deprived them of their daily incomes. The 30% of nations that rely on income from oil and gas, including Nigeria, were the most negatively impacted.

Most Sub-Saharan African nations have since come up with economic recovery and growth plans that are based on significantly strengthening their power sectors, in line with the need for an energy transition based on SDG 7 (clean energy) and SDG 13 (climate change). The plans will involve the promotion of agriculture and agro-allied industries, the setting up of mines and mineral processing plants, the creation of manufacturing industries, and significantly improving tourist sites.

This points to the critical role that will be played by engineers in the strengthening of African electricity supply, and in developing modern agricultural practices, mining, manufacturing, and tourist sites.

Access to energy in Africa

Africa suffers from the greatest levels of energy poverty in the world, with 680 million Africans living without access to electricity. According to the IEA, average electricity consumption per capita in the world today amounts to 2,600 kWh, compared to only 500 kWh for Sub-Saharan Africa. The world average for access to electricity is 87%, compared to only 43% for Sub-Saharan Africa.

Nevertheless, a number of countries are getting it right. For example, Mauritius and Tunisia have 100% access to electricity, Gabon has 92% access, and Kenya and Ghana have 85% access. However, the majority of Sub-Saharan Africa remains very poor, and Nigeria for example has only 62% access to electricity.

Paradoxically, while energy access is poor in Africa, it has significant potential in terms of renewable resources and the world's highest potential in photovoltaic power. In this context, the five major issues faced by Sub-Saharan Africa are: (a) inadequate energy infrastructures, (b) inadequate human and manufacturing capacities, (c) shortage of investment funds for energy development, (d) inadequacy of appropriate national energy pols, plans, laws and regulatory frameworks, and (e) a lack of good governance and mutual confidence among African nations.

However, Africa also benefits from a number of opportunities. The huge population of over 1 billion represents an enormous market for energy developers. Demand for energy will continue to rise due to the demand for improved energy services. This would require significant financial investments in energy infrastructures, providing many opportunities for businesses working in the energy sector. Finally, many opportunities exist for national and regional cooperation.

The way forward for Sub-Saharan Africa

In order to promote meaningful socioeconomic growth, Sub-Saharan African nations:

- Need to produce comprehensive, scenario-based energy demand projections using modern energy modelling tools.
- The tools should be used on the major economic sectors to project short-, medium- and long-term horizons. An example of this is the 2050 Pathway Calculator used by Nigeria's Energy Commission to determine the energy demands of country up to 2050.
- It is also necessary to develop a comprehensive energy supply strategy based on the UN Sustainable Energy for All Initiative, and to support trans-border projects as promoted by the African Union Commission under the NEPAD (New Partnerships for African Development).
- Regional energy projects should be supported, for example, ECOWAS, ECCAS, EAC, SADC and AMU.
- Reports of the World Energy Council such as *Issues Monitor* and *Energy Leaders Summits* should be relied upon.
- Elements of the Integrated Resource Plans (IRPs) should be embraced. These roadmaps can be used by large utilities to plan for their acquisition of power generation over the coming years and decades. They allow utilities to assess the cost effectiveness of supply options, and promote enhanced transparency. A good IRP should be prepared by a very wide range of stakeholders in the Sub-Saharan African countries.

The next step for Sub-Saharan African nations is for them to adopt the Global Energy Transition. The IEA has produced a roadmap to net zero carbon emissions by 2050, and this should be widely accepted during the upcoming COP26 conference.

We know that the combustion of fossil fuels is the principal cause of global warming which will lead to floods, droughts, disruption of agricultural production and a scarcity of drinking water. The African Union in 2013 agreed that climate change was also an African problem and it subsequently adopted Agenda 2063 mandating Member States to produce their nationally determined contributions (NDCs) for abating climate change. The NDCs focus substantially on renewable energy for electrification and the use of electric vehicles in the entire transportation value chain.

The African Business edition of September 2020 highlighted the fact that there is a very visible increase in the uptake of renewable energy projects in Africa. Nevertheless, this could be further improved, notably by adopting the South African auction-based renewable energy financing referred to as Renewable Energgy Independent Power Procurement Programme (REIPPP) which will enhance good governance and transparency in African project development.

With respect to the role of gas, it should be noted that Nigeria has the largest oil reserves in Africa. It has a clear policy on the continued use of gas, which has a 50% lower carbon footprint than that of coal. The Nigerian government has therefore declared that 2021-2030 will be the decade of gas. It has also just enacted the Petroleum Industry Act which is aimed at bringing greater benefits to Nigerian citizens from the sector. A recent policy declaration refers to maximising the domestic use of gas to power the economy. At the same time, the government is taking a proactive position on carbon reduction, driving a massive uptake in renewable investments and facilitating regulatory reforms. Nigeria has introduced significant fines for those companies that continue to flare gas.

The 13 other Sub-Saharan African nations that are well endowed with oil and gas are expected to take positions that are similar to those of Nigeria.

Electricity Generation Expansion Plan (EGEP)

The Nigerian chapter of the World Energy Council recently issued an Electricity Generation Expansion Plan (EGEP) as a pathway for the country's electricity supply industry to meet its demand projections to 2050. It will not be possible to stop the use of coal and gas completely but, by 2050, renewable energy will make up approximately 85% of power supply. We are therefore in favour of projects like the 50MW solar plant commissioned by Togo in June 2021 or the 310MW wind energy project commissioned by Kenya in July 2019.

The role of engineers

The post-Covid-19 economic recovery and growth plans of Sub-Saharan Africa will only come to fruition if engineers are fully involved in all the relevant steps. Engineers are needed to design electricity power plants and develop implementation roadmaps. Engineers will work with other specialists to design CCS plants and plant forests to act as carbon sinks. Engineers will be needed to design and construct modern agricultural projects and agro-allied industries. They will need to plan, design, and operate mines and mineral processing plants. Engineers will build and equip African tourist sites with round-the-clock electricity, water and internet services. Finally, engineers will head the manufacturing plants for the production of vaccines, personal protective equipment, and related items.

The role of engineers is crucial for Sub-Saharan Africa in the post-pandemic age.

Conclusion

I will conclude with a number of key messages.

The Covid-19 pandemic has highlighted the need for Sub-Saharan African nations to take serious measures to develop their economies so that future pandemics will not drive their economies into recession and lead to the near starvation of their populations.

A first priority is for nations to significantly expand their access to electricity in line with global energy transition trends and in line with the SDGs and NDCs.

The unstoppable global energy transition will lead to a gradual decline in demand for oil and gas. As such, the Sub-Saharan African nations whose income largely depends on oil and gas will have to tap into other income sources such as agriculture, mining, manufacturing and tourism.

Engineers will play a pivotal role in both strengthening the energy sectors and tapping into other sources of revenue, all of which is necessary for the better management of future pandemics.

3. Panel Discussion

Jean Eudes Moncomble

You referred to a number of Covid-19 contingency protocols. What were the main challenges you faced in implementing those protocols?

Miguel Fierro

We faced a number of challenges in implementing the protocols. First, when the emergency was declared, people rushed to buy face masks, gloves and sanitiser, leading to shortages. It was therefore difficult for UTE to buy the necessary stocks of these protective items for its 5,900 employees and almost 3,000 sub-contractors.

Second, we had to come to an agreement with trade unions on how to implement the protocols. There was some uncertainty around the world as to how the virus was spreading, and workers were therefore understandably afraid of being infected, especially those involved in visits to customer sites.

Third, when it came to remote working, not all employees had access to a computer or internet connections in the home. It took almost one month to get everyone connected to the company network.

Nevertheless, despite these challenges, we were able to continue working without any impact on customer services.

Manta Nowbuth

Renewable energy represents 98% of energy sources in Uruguay, an encouraging example for everyone here. How did you address the question of connectivity? Is the entire population on the same grid?

Miguel Fierro

Uruguay has only one electricity company, the UTE, which achieved connectivity for the entire country. Uruguay is a small country, with almost half of our customers located in the capital, Montevideo.

Gong Ke

First, what is the percentage of renewable sources such as hydro, thermal, solar, wind and biomass in your energy mix? Second, no mention was made of nuclear energy. Is this being considered in your countries?

Abubakar Sambo

Renewables represent approximately 30% of our energy mix today, with the aim of reaching 85% by 2050. Nigeria has no nuclear power plants for electricity generation, currently. However, the Nigerian government now has a nuclear power programme in place, and nuclear energy is expected to contribute 10% of the energy mix by 2050.

Miguel Fierro

In terms of the energy mix, Uruguay does not have its own gas reserves; it imports gas from Argentina and Bolivia. It has one gas-fired plant but it is in fact fuelled by oil. Renewables currently represent 98% of the energy mix, and thermal plants are only used when renewable supply drops below demand. Uruguay does not have any coal-fired plants. With respect to nuclear energy, this is specifically prohibited by law in Uruguay. The country has only 1.4 million customers and it would not be possible to build a nuclear plant for such a small customer base.

Gong Ke

What is the situation in Uruguay with respect to electricity storage?

Miguel Fierro

Several private companies are working on building energy storage plants that can be used to store surplus energy. In addition, work is underway to try to use that surplus energy to produce green hydrogen.

Jorge Spitalnik

What is Nigeria doing to develop the petrochemical and gas chemicals industries in order to expand the use of fossil resources rather than simply burning them?

Abubakar Sambo

Gas flaring is now subject to very heavy fines in Nigeria, and many oil companies are trying to capture the gas for two purposes: (a) for the West African gas pipeline that will deliver gas to Benin, Togo, Ghana and Senegal, and (b) for electricity generation. In addition, the government is transporting gas from the Niger delta to central and northern parts Nigeria and it is called the Abuja, Kaduna Kano Gas Pipeline Project, forming the first segment of the much talked about North African Gas Pipeline Project that could, in line with the thinking of the African Union, send gas to Niger, Algeria and even to Europe. We are also urging the government to expand the use of oil and gas in the petrochemical, pharmaceutical and fertiliser sectors.

Fyne Ogolo

When the security situation improves in Nigeria, would you recommend the creation of solar and wind farms in northern Nigeria as a way of significantly increasing the percentage of renewable energy in the country's energy mix?

Abubakar Sambo

Nigeria has many security problems, including Boko Haram, banditry and what is referred to as "unknown gunmen". The government has taken measures recently to crush these criminal elements and this has already started showing positive results. It is believed that the Nigerian security problems will subside significantly in the next year or two and many energy practitioners are pushing on with our energy transition plans.

Liu Chang

What solutions are in place to ensure a secure electricity supply to computer servers and data centres?

Miguel Fierro

Uruguay has one major data centre in Pando. It is a new centre with a very secure energy supply, backed up by fuel generators that can be used in case of blackouts. We advise customers operating in isolated areas to install a UPS (uninterruptible power system) to guarantee their electricity supply. Uruguay is a small country with very secure energy distribution and service network. Two years ago, we had a major blackout due to an issue in Argentina, which lasted 3-4 hours in more than half of the country. However, we rapidly had the system up and running again.

Abubakar Sambo

All the major ICT facilities in Nigeria have their own uninterruptible power systems and many of them are installing off-grid solar power plants both of which make their data well protected.

AbuBakr Bahaj

All the fossil fuels should be left in the ground unless they contribute to the transition to net zero in order to achieve the 1.5°C target. Should engineers advise this and produce alternative plans based on Africa's plentiful renewable resources?

Abubakar Sambo

Nigeria's economy is heavily dependent on oil and gas which provides 90% of its foreign exchange income. The Government's position on energy transition is to use more gas along with renewable energy and it is attending COP26 to strongly seek for a "Just Transition" to enable the country to go ahead with its policy. Energy practitioners are advising the Government that while it is expanding the use of gas there will be need to adopt the circular carbon economy to manage the carbon from the new gas projects in addition to the development of forestry plantations that are known to be effective carbon sinks.

IV. Session 2 – A larger definition for resilience: a new understanding of risks

1. A systems approach to infrastructure delivery – Andrew McNaughton (United Kingdom)

Andrew McNaughton, Review Chair, Institution of Civil Engineers

I will be discussing the issues surrounding the delivery of complex infrastructure projects.

Infrastructure projects provide a service to the community and society. They increasingly involve an intervention into an existing, operating network with the aim of improving either the user experience or the efficacy of the network. That is the case whether we are talking about networks in power, transportation, healthcare, communications, and so on.

International studies into infrastructure show that 70% of major or mega-projects actually disappoint their owners either in terms of time, cost or performance in the outcome. All of that impacts on the business case that was initially agreed upon.

ICE Report: A Systems Approach to Infrastructure Delivery

In early 2020, the UK's Institution of Civil Engineers (ICE) embarked on a study into the issue of the lack of performance, and the possible improvements that could be made. The study, *A Systems Approach to Infrastructure Delivery*, is available on the ICE website. We not only looked at the portfolio of infrastructure projects, but we also started from the hypothesis of the nature of infrastructure projects in the future. That hypothesis was divided into three parts. First, infrastructure as a whole is beginning to become more and more dependent on technology. Second, if we effectively apply systems-thinking to infrastructure, that will make a real difference to the delivery of projects in operation. Third, there are lessons to be learnt from other industries.

The study came out in support of all three of those assumptions, particularly with the finding that technology is becoming steadily more prevalent and dominant in infrastructure.

When we look at the new infrastructure being developed, we are building in resilience to future issues such as climate change and carbon reduction. However, almost 90% of the world's existing infrastructure has been in place for years, if not decades. It is therefore necessary to consider the interventions that are necessary to make that infrastructure as resilient as new infrastructure.

Increasingly, infrastructure projects are based on upgrades using new or emerging technologies, and involve very little of no civil engineering or structural engineering activity. Alternatively, they are based on an evolution in the lifecycle of technology that has been put into operation. We therefore need to think very differently about how we implement such projects, where technology represents the primary interventions being made.

8 guiding principles

The study came up with 8 overall principles to guide such interventions.

- Think outcomes not edifices. We need to be more and more focused on the outcome of the infrastructure rather than just building the structure itself. We have to bear in mind the outcome that is expected, as articulated by our clients or asset owners. As decisions are made throughout the life of the project, they must be referred all the way back to the initial planned outcome. We have to ensure that a decision either aligns with the outcome or that the change is made in a deliberate manner and properly recorded.
- Close the knowledge gap with other industries. There are certainly ways in which we can learn from other industries. We concluded that we should look to close the gap of knowledge between other industries and bring those lessons learnt into infrastructure. Industries like aerospace and defence have for some time been further ahead in applying a systems approach.
- Owners must own projects. There are certain things that only a client or an asset owner can do, and they must give clear direction on the project. For example, we have to understand their appetite for new technology and how it plays a part in the development of the project. We also have to remember that there are different time constants in the development of a project: we normally focus most of our time on the civil engineering element, as opposed to the technology pieces, but these all need to come together at the same time.
- Future-proof projects. We need to have a much stronger focus on the implementation of systems engineering. Starting again with the outcome and working backwards through the project, this means that from the outset we can organise the project to be delivered in the right way. This applies not only in terms of procurement models and incentivisation for each party but also to the interaction and interface definition between the various parties. The ability to understand and manage the risks associated with those parties is crucial. In applying systems thinking, we need to fully appreciate the risks in terms of productivity, not only the civil engineering risks but increasingly those associated with emerging technologies. Despite infrastructure programmes spanning many years, we have to fully understand the R&D cycle for the technologies chosen to support the outcome, the interfaces between those different technologies, and the degree of pre-conditioning testing required for the whole system to function correctly.
- Think shovel worthy, not shovel ready. Being "shovel ready" is a phrase that is often used in infrastructure to refer to the moment when the project can be commenced. However, we prefer the concept of the "shovel worthy" which means that a project can commence once all of the elements that I have described come together. There has to be enough front-end engineering, front-end loading, or left-shift thinking in preparation for the project. And that has to be done in sufficient time before we commence projects on-site. That will ensure that the project outcomes are maintained and we can deliver on the customer's requirements.
- Bake in systems thinking. When we consider systems thinking, we also have to focus on systems integration which is rarely considered in sufficient detail in infrastructure projects. We need to think about the commissioning of complex

technology-dependent projects. The UK's Infrastructure and Projects Authority developed a route map in 2014 for major projects – a best practice guide for project initiation and delivery that now includes reference to systems integration. Systems integration processes help us to identify and effectively manage the interfaces between elements of the system. Focusing on systems integration will identify elements that require adequate modelling and testing.

- **Agile leadership**. Leadership is crucial in the delivery of any project, particularly complex ones. In terms of infrastructure, we still lead projects in the civil engineering domain in the way that we have done for decades and it is now time to think differently. In particular, we need to recognise the leadership capabilities and skills in the project management team, so that the entire team is able to understand the different technologies to be implemented. The leadership must also give sufficient "voice" to the various aspects of the projects at the right point in time of development. We also need to think about future leadership models. Do we have a single leader all the way through the life of the project or multiple leaders with baton changes at certain points in the project?
- **Data oils your project**. Once again, client or asset owners need to own the data architecture and requirements. With the ever-increasing availability of data to improve the effectiveness and efficiency of operations and maintenance, owners need to set out the key elements required. Ideally, they should define the common data requirements to be used throughout the life of the project, from delivery to operations. We therefore came up with the concept of the "golden loop". If an infrastructure project is an intervention into an operating system, then the data requirements flow out of the existing operating system into the project and then flow back into the augmented operating system. In that way, improvements to the network can be delivered and the desired outcome is realised by the owner.

Future work

Going forward, we are continuing to work on 3 specific areas. First of all, we are organising a series of briefings to industry leaders across the UK and elsewhere in the world, thereby creating a forum in which to share knowledge about the concept of system thinking. In addition, we are exploring the question of leadership competencies for complex projects. Finally, we are planning a follow-up report later this year that will present case studies on particular projects that should bring these principles to life.

Conclusion

Irrespective of the short-term issues we face today in a post-pandemic world, infrastructure is clearly an enabler of economic growth and mobility. That is the case all around the world. Our choice of infrastructure delivery must recognise and support the sustainability goals that have been set at the global and national levels. The mission of the ICE is to harness the powers of nature for the use and convenience of humanity – that assumes an enduring planet that is *harnessing* nature, not *destroying* it.

The technology used in infrastructure is advancing at speed. Projects are more complex today, with the physical infrastructure representing only one element in a system of systems. Managing all that requires a systems approach that considers all the elements of a project and their interfaces. Throughout the life of infrastructure, technology will continue to develop, and it is necessary to carefully plan for the implementation of those technological changes.

For example, the physical infrastructure of the UK's rail transportation network was built in the 1830s. It has continued to be used since that time largely as it was built. However, the technology has changed many times in the past 200 years. Leadership, the skills of project leaders and the culture of project organisations must evolve, recognising the role of technology in these projects. I therefore believe that the individuals and companies that embrace the concept of systems thinking for infrastructure projects will enjoy massive opportunities in the future.

2. Mapping the spatial vulnerability of the elderly to a health pandemic – Manta Devi Nowbuth (Mauritius)

Manta Devi Nowbuth, Head, Civil Engineering Department, University of Mauritius

In my presentation, I will be challenging the engineering community to develop more resilient cities. Worldwide casualties due to Covid-19 show that the elderly were the most at risk of the disease. We therefore undertook a study to understand how the pandemic affected the day-to-day lives of one of the most vulnerable groups in our society.

Social vulnerability mapping

The study aimed to capture the challenges faced by the elderly during the Covid-19 pandemic, in order to be better prepare for any future pandemics. Field surveys were conducted with the elderly, and vulnerability indicators were extracted from census data. That allowed us to develop vulnerability maps at the district, ward and village level in Mauritius.

Four main health risk factors were identified: age, gender, co-morbidity, and immune system response. These factors placed the elderly in the category of most at risk to the pandemic. The three main risk reduction strategies implemented in most countries included full or partial lockdowns, vaccination programmes, and investments in the health sector. In addition, social vulnerability maps, which help support risk reduction strategies, and are to be encouraged.

Field surveys were carried out in 2 different villages: Chemin Grenier (a middle-sized village in south Mauritius with 940 elderly in a total population of 12,223), and Reduit (a small village in central Mauritius with 831 elderly in a total population of 8,846).

23 questions (or indicators) were used to assess the coping capacity of the elderly, focused on access to basic needs, living conditions, health conditions, mobility, support facilities, and communication facilities. For the most vulnerable group, the elderly, access to all of these indicators is very important in ensuring safe living conditions.

Key findings

The key findings of the survey included the fact that certain indicators reflected a low level of vulnerability: having children, having access to running water and electricity, having access to telephones and internet, having social support. Other indicators reflected a higher level of vulnerability: education levels, comorbidity, access to basic food, poor housing conditions. Overall, 44% of those surveyed said that they found it difficult to cope with the pandemic.

The field survey data was further analysed using geospatial and a multivariate analysis. The vulnerability indicators were grouped into 4 categories: living conditions, access to basic facilities, mobility, and economic conditions. Those four factors were translated to the secondary data of the 2011 census. A total of 14 indicators were extracted from the census data, and they were weighted and combined. The highly vulnerable areas identified in the study were found to be spread throughout the country.

A comparative study showed that although there may be sufficient facilities at the district level, not everyone at the community level had access to those facilities.

The challenge for the engineering community

The study raised a number of questions for the engineering community.

- Is the current development model of cities addressing the needs of the elderly, the needs of ageing societies, and the needs of other vulnerable groups?
- Are the relevant authorities able to rapidly locate vulnerable groups in order to provide support?
- Is the healthcare system adapted to reaching those with limited mobility?
- What have we learnt from the full lockdowns that were implemented during the pandemic?

The study highlighted the need to re-engineer support systems in cities. More IT and connectivity are required in order to build more resilient systems. Businesses that address the needs of the most vulnerable groups in society should review the way they are operating. Healthcare systems have to reinvent themselves in order to reach out to vulnerable groups. The transport system has to be adapted to facilitate access for those with reduced mobility. The most vulnerable groups should be at the core of city design. Our societies will become more and more energy intensive in the future, requiring R&D investments to be focused on the development of renewable energy.

Conclusion

I will conclude with 4 key messages.

- For a country to flourish, no one should be left behind.
- Many countries have ageing populations and we need to be more prepared and roll out a different development model.
- We need more efficient systems to reduce additional stress on limited resources.
- Climate change impacts must be mainstreamed in order to develop resilient infrastructures for the welfare of all, in particular for vulnerable groups.

3. Panel Discussion

Gong Ke

During the epidemic in China, smartphones were used to track infections but the elderly did not have smartphones or were not able to use the relevant apps. What percentage of elderly people in the Mauritius survey had access to the internet?

Jean Eudes Moncomble

A similar issue arose in France during the vaccination campaigns where people could make appointments online. In some parts of France, there was a lower rate of vaccination due to people's lack of access to the internet.

Manta Devi Nowbuth

67% of all those surveyed in our study had internet access. However, while this means that their building has internet connectivity, they are not necessarily the ones using it – it may be that their children are accessing internet.

Jean Eudes Moncomble

You have proposed a systems approach to infrastructure delivery. Is that applicable to all types of infrastructure?

Andrew McNaughton

Systems thinking is indeed applicable to all types of infrastructure and even to all parts of our societies. All infrastructures can be broken down into a series of interconnected elements, and the risks often lie at the interfaces between those elements.

Jean Eudes Moncomble

What are the greatest concerns of the elderly, and how can the engineering community address those concerns?

Manta Devi Nowbuth

One of the greatest concerns for the elderly is access to healthcare facilities. When attending such facilities, the elderly face the risk of being contaminated. That is why it is so important that the healthcare system is able to reach out to the elderly during difficult situations, allowing them to access their medications and the support they need. That is also why the engineering community has to rethink the way it designs cities, placing elderly and vulnerable groups at the centre of the system.

Jean Eudes Moncomble

Would you provide some examples of how IT and other technologies can be integrated into the design of cities?

Manta Devi Nowbuth

Smart cities make much use of the internet of things. They recognise the importance of being able to readily access information through connectivity between transport systems, communication systems, health systems, and so on. That can be done when retrofitting our existing cities – it is not a luxury but a necessity.

Question from the audience

What can the engineering community do to ensure that the elderly can access the healthcare services they need without the risk of contamination?

Manta Devi Nowbuth

Mauritius has a vaccination programme that involves healthcare workers going house-to-house to vaccinate people. The fact that there is a risk of contamination means that communications should be facilitated, both from the healthcare centre and from the community more generally. Vulnerable people should have access to direct and interactive communications with the healthcare system.

Gong Ke

To what extent have digital technologies like big data, the internet of things, or artificial intelligence been used to improve the UK's energy infrastructure?

Andrew McNaughton

The UK is still in the early days of being able to transform existing data into intelligent decision-making. That is the case in all sectors of infrastructure. There is therefore a move in the UK to transform the large amounts of available data into proper management information, predictive maintenance, and so on. The role of the engineering community is to help asset owners understand the tools they need to do this.

Jean Eudes Moncomble

How will leadership models need to change within the systems approach? Does that apply throughout the entire supply chain?

Andrew McNaughton

We are still leading infrastructure projects in a very traditional manner. The skill sets that allow individuals to have an understanding of complexity and of how systems operate can be found in many different domains and not only in civil engineering. We often look to asset owners for that leadership. However, the leadership model has to pass through the entire supply chain – everyone has to understand how complex the environment is. That is particularly the case when we are concerned with emerging technologies. We will therefore see a new leadership model emerging in the future.

Question from the audience

Should our engineers receive an education in much wider domains?

Manta Devi Nowbuth

We are talking about multidisciplinary groups today, and having both a vertical and horizontal education. Without multidisciplinary training we will not be able to reach our goals.

Andrew McNaughton

We have to plan for the future in order to deliver the projects that we need.

Jean Eudes Moncomble

It is, of course, important to take a holistic approach to these issues. However, given the complexity of the world today, we cannot expect that our engineers will be able to deal with every single aspect of a problem.

V. Session 3 – Energy demand: evolution or disruption?

1. Effects of Covid-19 on mobility: causes and solutions – Vincenzo Antonucci (Italy)

Vincenzo Antonucci, Research Manager, National Research Council of Italy, Institute of Advanced Technologies for Energy

Covid-19 changed our lives, our habits, the world of work and the mobility sector. Starting from March 2020, we saw the closing of gyms, swimming pools, museums, cinemas, exhibitions, schools, universities, flights and general travel. We also saw an interruption of production activities in the world, which had a significant effect on energy, as did the lockdowns that were eventually put in place by most countries.

The impact on the energy sector in Italy was an 8% reduction on the consumption of carbon-sourced energy, a 5% reduction in oil, a 2% reduction in gas, and a significant increase in the use of renewables. At the global level, there was a 10% reduction in demand for electricity, the greatest reduction since World War II. Even during the 2009 economic crisis, demand went down by only 6%.

Why did the consumption of renewables increase in this scenario? Fossil fuels suffer more from the reduction in demand because of their low efficiency: if they are not working at 100% of their capacity, plants will be closed down in some cases. In that context, the move towards renewables as the principal source of energy addresses the issues of capability, flexibility, and resilience in electricity networks as compared to traditional fuels.

Impact of Covid-19 on the mobility sector

The effects on the mobility sector were even more significant, with the consumption of automotive fuels (petrol and diesel) reduced by approximately 18%. There was also a significant reduction in road accidents.

There was a drastic reduction in the use of public transport during the pandemic, with a drop of approximately 25%. In parallel, there was a major increase in individual transport, and also increased use of bicycles, motorcycles and on-foot travel. 60% more bicycles were purchased in May 2020 than in May 2019, and Italy saw the introduction of 200 km of "light" cycle paths in 2020. This also had benefits in terms of consumer spending and health, a reduction in pollution and a reduction in traffic.

The pandemic also had a positive effect on pollution, with drastic reductions in NO_2 and CO_2 emissions in Italy and at the global level.

The recovery phase

The recovery phase has now begun in most economies, with a phasing out of remote working and a return to daily commuting. Flights and trains have returned to almost normal operations, as have sports activities, cinemas, concerts, etc. In short, the transport system is back on track. This is an opportunity to re-think our mobility ecosystem.

Mass urban transport is the only possible solution for avoiding the congestion and pollution in cities caused by the use of private cars. It is my view that the solution to the problem of mobility lies in avoiding a massive return to the use of individual cars and avoiding a return to our old habits before the pandemic began. We can use this crisis as an opportunity to unleash the potential of new technologies.

Future actions

The real challenge going forward is to adapt our transport systems so that they ensure safe mobility without losing efficiency. This could be done in a number of ways.

- Re-thinking traffic flows within cities in order to reduce peaks, for example by having staggered working hours in offices.
- Introducing mobility on demand or mobility as a service, which means that public transport becomes more flexible.
- Promoting pedestrian and cycling mobility. This "micro-mobility" within the urban environment is absolutely fundamental to the reduction in congestion.
- Increasing efficiency or inter-modality by providing many different options: public transport but also car-sharing, bicycles, scooters, and so on.
- Creating appropriate infrastructures such as inter-modal hubs, in particular in connection with railways, and digital platforms that make everything more user-friendly.
- Maintaining safety measures such as the cleaning of shared cars, measuring temperatures, green passes, and so on.
- Further developing eco-sustainable mobility through the greater penetration of electric or hybrid cars and buses. This would have a significant impact on the flexibility of electricity networks, which could become a major issue in the coming years.

Conclusion

New technologies will be key to emerging from the Covid-19 crisis. As we recover from the crisis, we can either go back to the way things were before, or try to build a better future.

Resilience is the ability to face a traumatic event by re-organising in a positive way. One way of doing that is to promote the idea of electric mobility, and integrate the energy sector with the electric mobility sector. However, that requires a solution for energy storage that goes beyond the use of traditional batteries.

In this context, hydrogen is a key technology: renewable energy produced at peak times can be stored as compressed hydrogen for use when demand increases. In that way, the fluctuations in the supply and demand of renewables can also be addressed, and that can be used as a source of energy for cars, buses, trains, and planes.

2. Impact of a respiratory infection pandemic on the ventilation industry – a paradigm shift – Benoît Olsommer (Switzerland)

Benoît Olsommer, Managing Director, Swegon

I will provide an insight on the impact of the Covid pandemic on the ventilation industry, outlining where the future lies and the need for a paradigm shift in this industry.

History of ventilation

Ventilation was recognised as a necessity as long as 500 years ago, when manual ventilation was introduced in mines or heat-driven ventilation was used to produce a chimney effect in high towers. Mechanical ventilation began to be introduced only 150 years ago to replace draught ventilation in buildings. Progressively it became obvious that ventilation was a necessity for the well-being and health of people in buildings. Since the 1950s, mechanically activated ventilation by extract fans became a standard while people spent always more time inside buildings, spending 90% of their time indoors. It is therefore no exaggeration to say that good air quality has a real value. This is recognised by most people around the planet.

This history of ventilation shows that the relevance of air quality is quite recent, having emerged in the last 30 years. I will therefore focus on the quality of this indoor environment, a concept which has come more and more popular in the community.

Indoor environment quality (IEQ)

Why is it important to have a good quality indoor environment? For a company, it means that its employees will be more productive and also more likely to remain with that company. Studies show that employees working in a good environment are up to 20% more likely not to change jobs. In addition, companies with a good indoor environment are considered 30% more attractive than companies that do not.

Most people would indeed recognise this in theory but how do we get from theory into practice? There are a number of issues at stake here: temperature, air quality, relative humidity, and acoustics. All of these indicators are typically used as metrics that define a good indoor environment.

- **Temperature**. When we talk about environment quality, the first thing we think about is, of course, temperature. It has been proven that office productivity is at an optimum at a temperature of approximately 21°C. If a building is too hot – or too cold – it is difficult for people to concentrate and they are less productive.
- **Air quality**. A quality environment is also as matter of air quality which is most often measured in terms of CO_2 levels. One study has shown that people's cognitive functions drop drastically when CO_2 levels reach 1,000ppm, which can happen quite quickly in a poorly ventilated office. Once again, this will lead to a reduction in productivity.
- **Humidity**. It is also important to consider relative humidity. A certain level of humidity is necessary to prevent cracks in building materials and decors, and a level of 30-60% relative humidity appears to be an optimum for buildings. Humidity is also important for humans. Below 30% relative humidity the human

body will be more prone to allergies, eczema, dry eyes, and so on. That is of particular importance in winter in northern countries where the air will be very dry inside.

- <u>Acoustics</u>. We can also talk about acoustics. Everyone would agree that noise is very disturbing for concentration.

A study on the impact of IEQ in schools has shown that a better airflow – from one litre per second and per person to 8 litres per second and per person – leads to a 3% improvement in reaction times by students, an 8% improvement in their visual memory, and a 14% improvement in word recognition. Similarly, poorly-ventilated rooms with over 1,000ppm of CO_2 lead to a 10-20% increase in absences for reasons of sickness. It is therefore quite clear that a good IEQ has a direct impact on the quality of information absorbed by students.

Ventilation today

In 2021, on average for the EU27, approximately 30% of commercial buildings (non-residential) are not equipped with any ventilation at all, despite the fact that we have known the importance of ventilation for the past 20 years. The good news is that the number of buildings equipped with ventilation is on the increase.

We still have commercial buildings today that are equipped with some kind of ventilation, but with no heat recovery which obviously does not make a lot of sense. Again, the use of heat recovery is on the increase as part of the European roadmap to a zero carbon 2050, although that will create another challenge on the energy side.

When it comes to residential buildings, there are huge disparities between countries. In Scandinavia, for example, 80% of new constructions are equipped with heat recovery and ventilation. In Germany the figure is 25%, and the rest of the EU is below 20%.

We understand the importance of IEQ. Technology is available. But the reality looks quite different. A study of 2,000 people in Sweden with respect to their workplace showed that many were experiencing symptoms such as headaches, irritated mucous membranes, difficulty in concentrating and fatigue. All of which could be avoided through the use of ventilation. Why did we, as an industry, not succeeded in this area? There are a number of reasons at play here.

First, the complexity of the problems which require the control of many different parameters at the same time. It is also necessary to master the technology, and deal with multiple suppliers and owners: in some cases, the tenants are not the same as the owners or the investors. Ignorance is also an issue: many people simply do not understand that, for example, CO_2 has an impact on performance. Finally, there is a lack of visualisation. All this means that we are operating in a very difficult paradigm.

Impact of Covid-19

The first learning from the pandemic is that the ventilation industry (and society as a whole) was largely unprepared for such a crisis. While there were laws and regulations on ventilation in many countries, they were quite weak or even absent, or they were not being enforced.

Early on in the pandemic, it was not clear that Covid-19 was primarily propagated by the airborne emission of pathogens from the nose and mouth. This was despite the fact that a 2017 publication had already explained the need for a 1.5 metre distance from the infection source, a recommendation that only came out in April or May 2020. The same 2017 publication showed that sufficient ventilation could mitigate the risks of transmission. Despite this, at the start of the pandemic, some people were arguing that ventilation should be turned off.

After the first few months of initial confusion, the root causes of the pandemic became quite clear. As well as the pharma industry, the engineering community was fully engaged in developing a basic understanding of the propagation of pathogens inside the air, providing guidelines and recommendations for existing ventilation systems. It took only a few months for the scientific community to reach a consensus on the main mode of propagation, and on the fact that proper ventilation was key to limiting the indoor transmission of the virus. Organisations such as ASHRAE and REHVA developed very pragmatic guidelines for ventilation, but legislation and enforcement were still lacking.

Last year, REHVA published very precise and detailed guidelines. It includes pragmatic guidelines, some obvious such as stopping recirculation, some less obvious such as conflicting controls between temperature, humidity or CO_2 levels. The guidelines extend to protecting those responsible for maintaining or cleaning the ventilation ducts. The guidelines take a very pragmatic approach and are very well documented.

Ventilation: investment, energy

It is estimated that the Covid-19 pandemic has cost the global economy approximately $1 trillion per month. At the same time, ventilation accounts for only 1% of building investment costs, but energy consumption by buildings represents over one-third of global energy demand. HVAC represents a fifth of the building direct electrical energy consumption or up to 45% when space heating and water heating are thermally activated by heat pumps.

Depending on the fresh air volume flow and on the ratio of heat recovery of exhaust air, the electrical energy needed for ventilation and to compensate for thermal loss is far from negligible. An estimated that 11 to 43 TWh of electrical energy per year would be required to ventilate the EU27 countries. That would require 1 to 5 1 GW power plants.

IEQ and ventilation: a paradigm shift

What did we learn from the Covid-19 crisis? We learnt that airborne transmission played a dominant role in respiratory infections. As such, IEQ cannot be limited only to matters of comfort (such as temperature or noise) but must also include airborne pathogens. We also learnt the key role of state-of-the-art ventilation systems in limiting the indoor transmission of infection.

Going forward, therefore, engineers face a huge challenge and responsibility. It will be necessary to strengthen the legislation on ventilation to better account for airborne transmission – that is a must-have – and that legislation has to be enforced. Engineers will have to master increasingly complex systems with conflicting multi-parameter requirements. That will require more cross-disciplinary work, working with scientists, architects, builders and investors. It will be necessary to develop new technologies, for example sensors to enable the real-time measurement of pathogens. The environmental impact of IEQ systems in new and existing buildings will have to be minimised, as will the cost impact of all of these actions. Finally, it will be necessary to convince investors about the relevance of IEQ versus investment costs. That will probably be our greatest challenge.

The IEQ and ventilation systems of the future will have to cope with this increasing complexity. State of the art chillers, air handling and air diffusors will be required. Those products will be integrated in systems and operated with smart controls, reacting to all sort of sensors (temperature, CO_2, occupancy, noise, etc) and able to optimally master multi-parameters (all of this in real time) with often conflicting objectives (e.g., CO_2 or room temperature levels). Our industry is now working on having these systems "talk" to each other. At the same time, we are working on developing systems and algorithms that optimise, for example, the temperature set points of cooling and heating systems in order to meet the IEQ needs. These systems and algorithms will make it possible to drastically reduce energy consumption while maintaining a good level of IEQ.

We are only at the beginning of these developments, and such systems are starting to be implemented around the world. This is where our technological input will be required in the future.

3. Panel Session

Daniel Favrat

Will we see the end of the rotary heat recovery wheels in these ventilation systems?

Benoît Olsommer

No. The wheels are more energy efficient: if they are well-designed and manage leakage there is no risk of pathogen contamination. The REHVA guidelines confirm that.

Virna Gooreeah

What projects have been implemented since the Covid-19 pandemic to encourage a more eco-friendly system?

Vincenzo Antonucci

Italy's National Recovery Plan includes a major section on infrastructures for public mobility and on the hydrogen economy, both of which are aimed at a more eco-friendly system.

Donald Dhondee

In the context of Covid-19, have any studies been conducted on ventilation systems in aeroplanes and airports?

Benoît Olsommer

Aeroplanes are indeed very challenging as they are closed systems, or at least they do minimize the level of fresh air in order to reduce the drag of the aircraft. Not being directly connected to this industry segment any longer, the aerospace industry had been working in the past on UV-based technologies to prevent the spread of pathogens. The situation in airports faces similar challenges but has the difference that it is not a closed system.

Jean Eudes Moncomble

What has been the impact of Covid-19 on rural transportation systems as opposed to urban ones?

Vincenzo Antonucci

The impact is quite different on rural and urban transportation systems. However, the thinking and the approach remains the same.

VI. Session 4 – On the supply side: the demands of citizens

1. Implications of Covid-19 for China's electricity sector – Haiwang Zhong (China)

Haiwang Zhong, Department of Electrical Engineering, Tsinghua University

Impact of Covid-19 on the electricity sector

The impact of Covid-19 on China's electricity sector is multifaceted, and its impact on power supply and demand is as follows.

On the demand side, the closure of factories and shops resulted in a decline in power demand, which is a direct result of Covid-19. Government restrictions on travel and social gatherings, the need for social distancing, and regional lockdowns led to a sharp decrease in travel abroad. That resulted in a reduction in industrial demand and an increase in residential demand.

On the supply side, there was a decrease in total generation volumes, leading to an increase in the proportion of renewable generation. Power grids also faced difficulties, with an increase of peak-to-valley differences in the daily load profile. This highlighted the need for more flexibility in generation dispatch to cope with fluctuations in demand and the supply of renewable energy. This can be addressed by having greater elasticity in the smart grid through energy storage and demand response.

Covid-19 also led to challenges in the operation and maintenance of the power grid. Dispatchers and maintenance workers were subject to increasingly strict physical quarantining between teams. The pandemic highlighted the importance of new contactless technologies in the operation and maintenance of power systems, for example, AI-assisted dispatch and unstaffed substations.

Most importantly, the change in the energy mix on the generation side had environmental impacts. There was an 8% decrease in the first quarter of 2020 in China, which appears to have had a positive influence on carbon emissions and other pollutants such as NO_x and PM2.5 (Particulate Matter). However, this may be a short-term effect only. Data from Carbon Monitor, a platform developed by Tsinghua University, shows a rebound in CO_2 in 2021 at the same time as the economy began to rebound. As such, we can see that a transition to clean energy is more effective in protecting the environment than placing restrictions on human activities.

Carbon neutrality and emissions peaking

China's annual CO_2 emissions rank first in the world, and its energy mix has long been dominated by coal and thermal power plants. The task of optimising China's energy mix and moving towards carbon neutrality is therefore a major task for the country.

The goal of the 2016 Paris Agreement is to limit global warming to well below 2°C and preferably to 1.5°C, as compared to pre-industrial levels. To achieve this goal, countries aim to reach the global peaking of greenhouse gas emissions as soon as possible, leading to a climate neutral world by the middle of the 21st century.

In its 2020 meeting of the Central Committee for Financial and Economic Affairs, a host of measures were mapped out to help China peak its carbon emissions by 2030 and attain carbon neutrality by 2060. In this way, China will establish a clean, low-carbon, secure and efficient energy system that limits the overall use of fossil fuels. A new type of power system based on renewable energy will be promoted.

According to the study *China's Long-Term Low-Carbon Development Strategy and Pathway*, China's CO_2 emissions and energy consumption in the next 30 years will by largely influenced by its environmental targets. China's CO_2 emissions and energy consumption will decline under all the 4 scenarios set out in the study: the policy scenario, the strengthened policy scenario, the 2°C target scenario, and the 1.5°C target scenario.

The study also predicts that carbon emissions from the power sector will not increase in the next 30 years, and energy storage capacity will rise sharply by 2035. Cross-regional power exchanges will be widely used in the future, and electricity supply costs will begin to decline by 2030.

A power system based on renewable energy

In order to achieve such ambitious goals, China will have to promote an energy transition towards a new power system with renewable energy as its mainstay.

Electricity generation has been increasing in China since 1990. At the same time, there has been a non-negligible growth in the share of renewable energy generation in the energy mix since 2012. That growing proportion of renewable energy will lower the share of coal-based generation, and consequently reduce CO_2 emissions. China is therefore building a new power system with renewable energy as the mainstay.

Such a new power system will require changes in all parts of the system, including generation, network, load and energy storage.

Revolution on the generation side of the system is key. Controllable energy sources such as hydro, nuclear and thermal power plants will make it possible to cope with intermittent power sources such as wind or photovoltaic power. At the same time, centralised and distributed renewable generation should complement each other, and the two together will ensure the security of the energy and power system.

In contrast, the network should be more distributed and elastic in the future. In order to promote large-scale access to the power system of distributed renewable generation, the conventional distribution network needs to evolve to become more active. Future grid developments will be based on the efficient coordination and interaction of transmission and distribution networks. By connecting gas and heating networks, the active power distribution network will form a comprehensive energy system. That will improve the efficiency of energy distribution and supply, resulting in a low-carbon energy supply.

Load will have to be more flexible in the future. Unlike conventional fixed demand, future demand will introduce a system of responses determined by the grid. Thanks to the use of ICT, massive amounts of data can be collected, transmitted, stored and processed on a large scale in real time; industrial and commercial loads and residential users can effectively participate in demand response.

Multi-energy integration allows different energy sources to replace each other, with air-conditioning systems, for example, being used for virtual energy storage in the grid.

Finally, several energy storage patterns are likely to be implemented in China. As wind power peaks at night and photovoltaic power peaks at noon, the excess energy can be stored in energy storage units and released when demand exceeds supply. The significant reduction in storage costs will solve the challenge that uncertain and volatile renewable generation brings to the power system.

Power system coupled with hydrogen energy

Hydrogen energy can be used to meet the growing demand for storage in the long-term. By coupling power systems with hydrogen energy, the volume of storage capacity can be extended. On the one hand, the electricity distribution system has low cost and high reliability, but it requires instantaneous balancing between power generation and consumption. On the other hand, hydrogen energy has a high energy density and is an efficient carrier for large-scale electric energy storage, providing flexibility for balance between power generation and consumption. As such, both electric and hydrogen energy have their pros and cons.

China's western provinces are richer in wind and solar energy resources but its eastern provinces have a higher population density. Energy demand in the east is therefore considerably higher than that in the west, and resources must be transported across long distances. This raises an important question: should China transport hydrogen energy or electricity?

Hydrogen transport means that hydrogen would be produced in the west and then transported to the east to generate electricity. However, hydrogen production requires huge amounts of water and water is scarce in the west. This would therefore not be sustainable in the long-term. Even without that issue, it is very difficult to transport hydrogen over long distances – it requires temperatures below –170°C and raises many security concerns. As a result, long-distance and large-scale hydrogen transport is not an ideal solution; it is neither low-cost nor low-risk.

Transmitting renewable electricity from the west to the east is another option, with hydrogen power playing the role of energy storage. When the supply of renewable energy generation exceeds demand, the excess energy can be stored in the form of hydrogen. When demand exceeds supply, hydrogen power can be used to generate electricity. Such a system has a number of advantages.

- There is no need to worry about the use of water resources in central and eastern China.
- The existing thermal power plants can be used to generate electricity with hydrogen.

- Hydrogen production can improve the utilisation rates of UHV (Ultra-High-Voltage) transmission lines through peak shaving and valley filling; it can also reduce wind and PV (photovoltaic) curtailment.
- The system is economically feasible costing 0.46 yuan per kWh as compared to 0.49 yuan per kWh for hydrogen transport.

We therefore believe that this is a promising concept for the future.

Conclusion

The new power system is based on a reconfiguration of the power grid, with renewable energy as its mainstay. It will create a new physical form with electricity at the foundation, hydrogen coupled with electricity as energy storage, and an interaction between generation, networks, load and energy storage. On the basis of internet technology, it will create an open, shared, competitive and win-win energy ecosystem.

2. Is green hydrogen becoming a demand of the citizens? – Carsten Ahrens (Germany)

Carsten Ahrens, Professor Emeritus, ZDI Jadehochschule Oldenburg

Globalisation and cooperation remain major questions, not only with respect to the Covid-19 crisis but also with respect to many other local and global crises. The Covid-19 pandemic was able to rapidly expand due to the high volumes of international movements of goods and people. Staying at home and living under strict lockdown measures could have stopped the pandemic. At the same time, the distribution of masks was only possible thanks to our international transportation and trading systems. However, the costs and shortages experienced in relation to masks led to a reversal in the interest in internationalisation, and a return to local production and national value chains. Nevertheless, the future will not be an "either-or" situation but a mix of both possibilities.

The general demands of citizens relate to items such as food and clean water, cars and fuels, peace and welfare, buildings and accommodation, clothing, energy – especially electricity – and so on. Overall, they want to have access to all goods at any time through global or national supply chains.

Demands during the Covid crisis changed quite remarkably, with masks, vaccines and sanitisers now at the top of the list, together with ventilation systems, hospital beds, and even toilet paper. People also wanted rapid internet connections in the home to facilitate working-from-home and home-schooling. At the same time, their traditional demands for food, clean water, cars, fuels, accommodation, and so on continued.

The role of the engineer

What is the role of the engineer at a time of Covid-19? One role is involved in the production of masks, vaccines, sanitisers, and ventilation systems for hospitals, schools, workplaces, homes and transport. Engineers are also expected to provide quick internet connections for home offices and home-schooling, and to continue to supply machines, cars, buildings, and so on. All of this has to be done while also providing an uninterrupted supply of energy, in particular electricity.

Of course, the problem during the Covid-19 crisis was the interruption of global supply chains, leading to shortages of masks, vaccines, sanitisers. There were great disparities and unfairness in the distribution of supplies, and a high risk of bribery and corruption. Keeping up supply chains involved a great risk of infection and high numbers of non-traceable contacts. Lockdowns disrupted the production of goods, and lead to disruptions in energy supply or bottlenecks in internet connections.

The post-Covid situation

What can we expect in a post-Covid world? Above all, we can expect greater political, ideological, religious, cultural and academic borders. The American Society of Mechanical Engineers has written that "Covid-19 is reshaping the engineering world."

China was the first country to be hit by Covid-19, and the government introduced a series of lockdowns that brought industry to a halt. As a result, electricity demand in the country underwent a sharp drop in China, as it later did in Europe and India, for example, with reductions in demand of 10-20%.

People will not quickly forget the crisis, and cooperation and solidarity will remain important values going forward in all fields. It will still be necessary to find a response to the questions of the pre-pandemic world, especially with respect to climate change and reaching the 1.5°C target. That question has to be addressed by the engineering community, in particular the members of the WFEO and our Standing Committee on Energy.

Achieving the energy transition

As energy will be totally electrified by 2050, we have to explore how we can succeed in our energy transition on the basis of green hydrogen. The Lappeenranta University of Technology in Finland and the German Energy Watch Group estimate that 90% of global primary energy will be fuelled by electricity in 2050, with only 4% fuelled by thermal energy and 6% by bioenergy fuels. Fossil fuels and nuclear will represent only a very small part of the mix.

In March 2020, the EU adopted a proposal for a European Climate Law aimed at achieving net-zero greenhouse gas emissions in Europe by 2050. This proposal is part of the European Green Deal. It aims to make Europe the first climate-neutral continent while also boosting the competitiveness of European industry and ensuring a just transition for the regions and workers affected.

In April 2021, Germany's Federal Institutional Court made a historic decision: that the country's current climate law was insufficient to effectively protect future generations from climate change. As a consequence, the German government must adapt its current targets and provide clear measures from 2030 onwards. That ruling provides enormous momentum for the national climate movement, and its impact will spread far beyond Germany's borders.

We are indeed dealing with a huge problem. The IPCC, for example, estimates the remaining carbon emissions budget from 2018 onwards as 420 Gt CO_2, which would provide a 66% chance of remaining below the 1.5°C target. That budget will be used up in the next 8 years if emissions are not reduced. What then should we be doing in political and technical terms?

We need to review the current distribution of global carbon emissions. Asia is responsible for over 50% of those emissions, and China alone accounts for approximately 27% of global emissions. The US makes up almost half of the remaining emissions (15%), followed by the EU (10%), India, Russia and Japan.

If we look at global investments in new power capacity, we can see that renewables represent almost 75% of all investments – equivalent to $282 billion. In 2019, the investment in renewables was three times higher than combined investments in coal, natural gas and nuclear.

Green hydrogen

In technical terms, it seems that the most likely way forward for the energy transition lies in the very deep electrification of all sectors through green electricity in combination with green hydrogen. However, that will only occur if the cost of production of green hydrogen is comparable to, or lower than, that of hydrogen from natural gas. Green hydrogen produced by electrolysis is likely to become the cheapest clean production route in the long-term, and could be competitive with blue hydrogen in the 2020s. Production prices should reach their lowest level in about 2040, although this should occur even earlier in locations such as Chile.

We can thus see that the penetration of electrical energy into other energy sectors can best be achieved by green hydrogen. 56 countries have already started national hydrogen activities since 2017, and the EU alone will invest €470 billion in the hydrogen economy by 2050. 31 of the 56 countries are located in Europe, 11 in Asia, 6 in South America, 5 in the Middle East and 3 in North America. Of these, 9 have national hydrogen strategies in place (including Norway, Germany, Netherlands, France, Spain, Portugal, Japan and Australia) and a further 11 have such strategies in preparation (including Canada, Morocco, Russia and China). 14 countries have provided support for pilot and demonstration projects in hydrogen, and another 17 have started initial policy discussions. 5 countries still have no relevant activities underway.

Conclusion

I will conclude with an example from north west Germany, which has embarked on a large scale hydrogen economy platform. That platform is based on strong sector coupling, bringing together electricity, street traffic and logistics, trains, steel mills, cement factories, buildings, and heating systems. A new project, "Aquaventus" is located on the island of Helgoland in the German Bight of the North Sea. It will involve the construction of offshore wind parks with a capacity of 10 GW by 2035, producing 1 million tons of green hydrogen per year. That will be transported onshore through pipelines for use and storage in the existing salt caverns in Germany that have a capacity of over 100,000 cubic metres.

Green hydrogen is the key to the long-term fulfilment of both citizen demands and the 1.5°C target.

3. Panel Session

Abubakar Sambo

How did you determine that demand for renewable energy increased during the Covid-19 lockdowns?

Haiwang Zhong

I showed that overall demand decreased due to Covid-19. However, the *proportion* of renewable generation within the mix remained the same. Mathematically, therefore, the level of renewable energy increased as a proportion of that overall volume.

Daniel Favrat

Given that seasonal storage is considered the most difficult challenge, how important are the seasonal variations in China?

Haiwang Zhong

Seasonal electricity demand is quite different in China, with peaks occurring in summer and winter, and troughs occurring in spring and autumn. The rainy season, for hydropower, occurs during summer and spring. Seasonal energy storage is therefore very important for China and that is why we have proposed a coupling of the power system and hydrogen energy. Hydrogen energy is a potential solution for long-term energy storage, and has a much higher potential than battery storage.

Daniel Favrat

If SOFC (solid oxide fuel cell) water from hydrogen oxidation could be recovered, would this technology be of interest to China in the future?

Haiwang Zhong

Many local governments in China are promoting the hydrogen economy and building hydrogen production plants. For example, during the 2022 Winter Olympics in China, buses powered by hydrogen fuel cells will be used throughout the Olympic Park.

Virna Gooreeah

Is electrolysis not a very expensive way of producing hydrogen?

Carsten Ahrens

Electrolysis is indeed an expensive method for producing hydrogen. However, the energy content of hydrogen is much, much greater than batteries, for example. The IEA's Executive Director, Fatih Birol, has stated that "governments need to take rapid actions to lower the barriers that are holding low-carbon hydrogen back from faster growth, which will be important if the world is to have a chance of reaching net zero emissions by 2050".

Jean Eudes Moncomble

However, Fatih Birol refers to low-carbon hydrogen and not renewable hydrogen. Low-carbon hydrogen can be produced using fossil fuel combined with CCS or by using nuclear.

Carsten Ahrens

We can use the peaks in wind or solar power generation to generate hydrogen. However, in intensive industrialised countries like Japan or Germany, we will not have sufficient green energy to produce green hydrogen.

Virna Gooreeah

Would you elaborate on the use of HVAC for virtual energy storage?

Haiwang Zhong

In power systems, generation and consumption should be balanced instantaneously. However, thermal energy is a slow process, and thermal energy can be stored inside a building. We can, for example increase the temperature setting in a building via the HVAC system in order to decrease electricity demand from the perspective of the grid operator. The HVAC system therefore acts as a virtual energy storage device.

Jorge Spitalnik

Would you explain how China will adapt its existing fossil fuelled thermal plants for the use of hydrogen?

Haiwang Zhong

If China is to meet its carbon neutrality goals before 2060, it will have to close many of its thermal power plants. We are therefore working on a proposal to repurpose those decommissioned thermal plants for the production and storage of hydrogen. Hydrogen can also be mixed with natural gas to generate electricity in these plants. However, there are no pilot projects underway on this proposal today.

Daniami Etire

What sort of incentives could be used to boost national or regional investments in hydrogen energy?

Carsten Ahrens

Producing green hydrogen is relatively easy in Germany's coastal areas that have sufficient water resources.

Jean Eudes Moncomble

I understood that Germany was considering importing green hydrogen from the Mediterranean because it did not have the surface area to produce sufficient volumes of green hydrogen in Germany.

Carsten Ahrens

We are at the very beginning of this work on green hydrogen, and the projects that have been announced are not yet stable or confirmed. This will all come down to a question of cost, and the amount of water and other resources that will be required.

VII. Roundtable – Lessons learnt so far: the role of engineers

Moderator: Jean Eudes Moncomble, Chair, WFEO Energy Committee (France)

1. Abubakar Sambo (Nigeria)

Abubakar Sambo, Chairman of the Nigerian National Committee of the World Energy Council, Professor at Usmanu Danfodiyo University

The Covid-19 pandemic has taught us many lessons. As a member of Sub-Saharan African countries, Nigeria has been most negatively impacted by the Covid-19 pandemic for two main reasons: (a) because the economies of these nations are already weak, and (b) because many of these countries rely on the sale of oil and gas for their foreign exchange earnings and development. Without that income from oil and gas, the countries went into economic recession.

In addition, many of these economies are not developed, and their populations rely on their daily incomes for survival. Similarly, the countries do not have well-developed healthcare systems. Fortunately, however, African infection rates did not follow the trends in Europe and countries like India or Brazil, and the number of Covid-19 deaths remained comparatively low in Africa.

As a result of the pandemic, all countries have now realised the important role played by engineers in improving the economy – shifting it to new revenue sources such as mining, large-scale agriculture, or tourism.

However, the common requirement in all this is electricity. Today, Sub-Saharan Africa is very backwards in terms of electricity with only 43% of the population having access to electricity compared to 87% as the average of the world. Average electricity consumption per capita in the world is 2,600 kWh, whereas in Sub-Saharan Africa the average is only about 500 kWh. Therefore, in order to strengthen the economies of this region, engineers have to be at the forefront of designing electrification systems based on the energy transition. Many of these countries are moving in that direction, although those countries with large oil and gas reserves are planning to continue using the gas which has lower carbon footprint than oil. In such cases, it is necessary to introduce abatement procedures such as carbon capture and storage or planting forests that act as carbon sinks. Engineers will also have to play an important role in such developments.

Engineers will, of course, also be involved in building more hospitals, and in manufacturing vaccines, face masks, sanitisers, and so on. Once again, all of this will require a significant expansion of electricity systems on the basis of renewable energy.

During the African Union meeting of 2013, all African countries agreed that climate change was a major problem for the continent, even though Africa only contributes 2% to climate change as compared to 18% for the developed world. African nations have therefore adopted Agenda 2063, and engineers will be at the forefront of the implementation of their countries' NDCs.

Jean Eudes Moncomble

Do you have a sufficient number of engineers in Africa?

Abubakar Sambo

No, we do not. However, in developing their NDCs and other action plans, many countries are looking at their human resource needs in the overall energy sector, and developing plans to increase those resources along the entire value chains. They are asking how many engineers, technicians and artisans are needed for existing and future power plants. The International Labour Organisation has published an excellent study on the human resource requirements of the energy sector, and we are using that report to show the government where we need to focus attention on.

2. Massimiliano Capezzali (Switzerland)

Massimiliano Capezzali, Professor, Institute of Energy and Electric Systems – IESE

I will take the opportunity to speak about the lessons learnt from the Covid crisis in terms of generation, networks, and public services.

First, what did we learn about the **generation** capacities of energy? Power generation was ensured even during the worst moments of the crisis. Small, decentralised plants as well as large installations worked well and there were no major power generation failures anywhere in the world, whether they be industrialised countries or developing countries. That required very careful management of specialised staff that cannot be easily replaced, for example in nuclear power plants or hydropower plants. IT security was increased, and communications continued to work well. Finally, decentralised power generation such as PV panels on rooftops were not affected by Covid. Overall, then, power generation worked very well, although some measures had to be taken, in particular in hydropower plants and nuclear power plants.

Second, what did we learn in terms of **networks**? Energy supplied to territories by way of very large international physical networks, or regional distribution networks, did not suffer from any major interruptions – even during the worst months of the lockdowns. This was the case for electricity transport and distribution, district heating and cooling networks, and natural gas transport and distribution. Once again, the careful planning of maintenance activities was key, and this presented a challenge for human resource management, especially during the cold months of the year. Storage capacities were available, and were used very efficiently for natural gas in particular, and the networks were managed very well overall.

Third, what did we learn in terms of **public services**? I have come to the conclusion that energy has been one of the backbones of the response capacity of our countries and communities. This relates to hospitals and emergency centres, but also essential industrial services, shops, telecommunications, homes, and the internet. All of that made it possible to rely on home-working, online shopping, and all of the remote services that were used during the lockdowns and semi-lockdowns. Those services led, in fact, to the development of new business models in some cases.

When it comes to the future, we could say, "No energy, lots of cry". We have learnt the need for sustained investments in the development and maintenance of energy networks in cities and elsewhere. Where it is possible, having multi-energy supply for territories based on centralised and decentralised generation is key. We have also seen how security and the existence of backup systems are important.

In all of these aspects, the role of engineers, physicists, and other technicians is crucial and must receive our full support. That applies to everything from education to greater inclusiveness. Without people in these key roles in the energy sector our overall reaction and capacity for resilience would be greatly diminished. This means that engineers and technicians are in the forefront of our response to any major crisis, and we will hopefully be able to cope with future crises even better.

The energy system performed very well during this crisis. We have to learn why it performed well, and ensure that we can do even better in the future.

3. Ruomei Li (China)

Ruomei Li, Women in Power Chair, Power and Energy Society, Member of WFEO Executive Council

I will cover the challenges that are faced by engineers in the energy sector, in the context of both Covid-19 and natural disasters.

The Covid-19 pandemic, which broke out in Wuhan, lead to the emergence of four main challenges. First, the power load dropped by 35-38%, and the share of hydropower and new energy generation increased rapidly. As a result, the grid regulation capacity became a major issue. Second, due to the quarantine and isolation measures that were introduced, it was not possible to maintain electricity power plants, which led to increased safety risks. Third, electricity demand rose due to the construction of temporary hospitals and wards, but the number of field staff were in fact reduced by 30-50%, with engineers at a high risk of infection. Fourth, transportation problems led to a lack of raw materials, a lack of people, and security issues.

In July 2021, this was further exacerbated by the fact that the Henan province suffered a major flood disaster, leading to further challenges for power grids. The reliability of these grids in extreme weather conditions is, of course, critical. We had not prepared sufficiently for the potential risks and our infrastructures were found to be vulnerable. A number of sub-stations were closed due to the flooding, and it was not possible to repair or monitor underground cables in a timely manner. Switching rooms in residential areas were flooded, leading to major blackouts.

We therefore realised that it was necessary to further develop the primary and secondary equipment in sub-stations, and use smart or intelligent units on transmission lines. Real-time monitoring technologies are not yet fully mature, and the quality of monitoring equipment in particular had to be improved. IoT also has to be further developed to play a more effective role during extreme events.

How can engineers continue to perform in such unprecedented circumstances? First, when designing systems and maintenance processes, engineers have to be skilled at envisaging risks and developing counter-measures. Second, they have to be able to react and continue to perform in all kinds of extraordinary circumstances. Third, at all times, the safety and needs of people should be put first. This applies both to the safety of customers and the safety of engineers themselves. Fourth, advanced technologies are not necessarily reliable, and engineers should base their work on actual testing and data.

Digitalisation and artificial intelligence are the way of the future. However, as the situation in Wuhan and Henan showed, there is still a long way to go before they can be considered as reliable and practical.

4. Roundtable Discussion

Abubakar Sambo

Many Sub-Saharan African countries are interested in building large-scale hydropower plants. How was China's Three Gorges Dam, the largest hydropower dam in the world, impacted by the Covid-19 pandemic?

Ruomei Li

Of course, demand overall was reduced during the pandemic, but the Three Gorges Dam continued a steady supply of energy throughout the crisis.

Virna Gooreeah

How does your role as an *electrical* engineer in this situation differ from that of general engineers?

Ruomei Li

My role is to provide reliable electricity to our customers. In the past 10 years, we have been focused on reducing CO_2 emissions by bringing in more renewable energy. That is challenging in a country where power systems are highly centralised.

Jean Eudes Moncomble

Before the pandemic, we were developing a certain concept of the energy transition mainly focused on climate change issues but not only. During 2020 we focused all our attention on fighting the Covid-19 virus and we were no longer talking about the energy transition. In 2021, we are now coming back to the energy transition. What has changed in our energy transition thinking from before and after the crisis?

Ruomei Li

Pre-Covid, we believed in the energy transition as a way of achieving a more sustainable world. Post-Covid we have seen that a decentralised power systems based on renewable energy are more resilient and more flexible in the case of major crises. We also saw the need to recognise the important value of engineers. That will further motivate them to work on improving our systems.

Massimiliano Capezzali

The main difference is that we feel more vulnerable in the post-Covid world. We never thought that something so severe and dangerous could happen to us. We therefore feel the urgency of the energy transition much more than before, and we take that energy transition even more seriously today.

Abubakar Sambo

The pandemic has opened the eyes of many African nations to the critical role played by electricity in developing and strengthening our economies.

Ruomei Li

We are very clearly feeling the impact of climate change today, in particular in Beijing where I am based. As China experiences more and more natural disasters, people are starting to understand the reality of climate change.

Abubakar Sambo

France depends largely on nuclear power for its electricity production. Did the drop in demand during the pandemic have an impact on electricity generation from nuclear power plants?

Jean Eudes Moncomble

There were no disruptions to electricity supply in France during the pandemic, although there was, of course, a significant reduction in electricity demand. Priority attention was given to preserving the health and safety of those working in nuclear power plants to avoid any issues with the maintenance of the reactors. Due to the reduction in demand, maintenance cycles could be pushed back and this did not prove to be an issue.

Do we need to re-think the way we train engineers so that they are better able to face difficulties and crises in the future? What subjects would you add to their curricula?

Ruomei Li

We clearly need to provide training to engineers and technicians so that they are better prepared for the future. We need to increase the resilience and reliability of our systems, and of ourselves. We could also better share our experience of how we dealt with broken lines and collapsed towers during the recent floods in China.

Abubakar Sambo

The pandemic highlighted the need for more open and distance learning using ICT in our teaching. That is quite a paradigm shift for us. At the same time, when it comes to treating patients, we need to do more in the area of biomedical engineering, and I would encourage our engineering students and researchers to focus on that area.

Massimiliano Capezzali

I would not revolutionise our curricula but I would add more elements on risk analysis. It should also be possible to motivate students to enter the fields of energy engineering and environmental engineering – energy is not only a way of making money but is crucial for the overall functioning of society. Energy can really save lives, as we have seen in the pandemic.

Jean Eudes Moncomble

What is the key message you would like to share from this Symposium?

Abubakar Sambo

Our engineers should be more prepared to develop schemes and systems that significantly expand electricity supply in African countries, and they should do so while also fulfilling their energy transition plans. For the African nations relying substantially on the income from sale of oil, it is time they adopt other serious sources of revenue like agriculture, mining, manufacturing and tourism.

Ruomei Li

We need to better recognise the contributions that engineers make to our societies. We have to place humanity at the centre of all our priorities.

Massimiliano Capezzali

I am in favour of the market economy but, even within the market economy, it is important to think about resilience. We should be proud – and also very humble – of our role as engineers. The Covid-19 crisis demonstrated that everyone has an important role to play in our societies, be they nurses, taxi drivers, or Amazon workers. We should therefore humbly play our role in our society along with everyone else.

Jean Eudes Moncomble

Our discussions have shown that the role of engineers has been highlighted by the pandemic. Many outlandish ideas emerged during the crisis, and the role of the engineer is to guard against such ideas by proposing realistic and pragmatic solutions to society.

We have also seen that no one engineer can solve these problems alone. Instead, they must work in teams, taking a systemic approach to all of these issues – as was demonstrated, everything in our society is linked. To succeed as a team member, it is important to be humble. We also have to shift from a "how to do" mindset to a "how to be" one.

I would like to thank all our speakers for their contributions, and all our participants who provided such insightful questions. I would also like to thank the organising committee, and all those working behind the scenes to bring you this Symposium.

World Federation of Engineering Organizations

The World Federation of Engineering Organizations is an international, non-governmental organization representing the engineering profession worldwide.

Founded in 1968 by a group of regional and national engineering organizations, under the auspices of the United Nations Educational, Scientific and Cultural Organizations (UNESCO) in Paris, the World Federation of Engineering Organizations (WFEO) brings together national engineering organizations from some 100 nations and represents more than 30 million engineers from around the world.

WFEO's work is mainly performed through its Standing Technical Committees (STCs) and Policy Implementation Committees (PICs), hosted by its national members institutions. The Energy Committee is currently hosted by Ingénieurs et Scientifiques de France (IESF, WFEO's French National Member) with the support of the Conseil Français de l'Énergie (French member of the World Energy Council).

More information on **www.wfeo.org** and **@wfeo**

WFEO-CE - Committee on Energy

The Committee on Energy's objective is to become the engineering reference for assessing the feasibility of current and cutting edge energy technologies for sustainable development. And also to be the engineering reference for energy sustainable development based on engineering criteria and actively participate in sustainable energy programs around the world by providing subject matter experts.

Launch and complete studies for Solar power, Nuclear power, Energy Internet, Carbon Capture, Utilization & Storage (CCUS), Energy Storage, Hydrogen and Electrification.

The Committee on Energy has about fifty members from all five continents and is led by a Chairman and six regional Vice-Chairmen representing North America, Asia/Pacific, Latin America, Europe/Russia, Middle East/South Central Asia, and Africa. Committee Officers are appointed by their respective National Member organizations.

To download the Symposium proceedings: **http://www.wfeo.org/committee-energy/**

Contact: energy@wfeo.org

Ingénieurs et Scientifiques de France

The French Society of Engineers and Scientists (IESF – Ingénieurs et Scientifiques de France) is an association that brings together associations of former students of engineering schools, scientific, technical and professional associations.

Its Repertoire lists over a million of Engineers and scientists and it has been recognized of public interest since 1860.

Its experts, organized in committees by sector of activity or by profession, develop a whole range of actions aimed at the public authorities, the teaching profession, the political world and businesses: white papers, conferences, events ... Through that, they highlight the important role of engineers and scientists in the economic and sustainable development of France.

More information on **www.iesf.fr** and **@IESFfrance**

Conseil Français de l'Énergie

The Conseil Français de l'Énergie is an association that aims to promote the sustainable supply and use of energy for the greatest benefit of all people.

Founded in 1923, the Conseil Français de l'Énergie is the French member committee of the World Energy Council and represents its members in all international activities of the World Energy Council.

The Conseil Français de l'Énergie brings together key players in the French energy sector (companies, administrations, professional organisations or universities) involved in discussions that focus on the accessibility, availability and acceptability of energy from a global perspective; all energy resources and technologies are represented.

The Conseil Français de l'Énergie participates in energy debates, notably through publications, participation in various events and the organisation of seminars and forums, but also through the publication of *La Revue de l'Énergie*, a bimonthly review which for more than 70 years has been one of the places where energy issues are debated in France and throughout the world, at the interface of the academic, political and industrial worlds.

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