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February 11 – 13, 2023, Dubrovnik, Croatia

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Plenary 1

Usage of Non-toxic Materials and the Disposal Technology for Existing Hazardous Materials

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Summary

A wide range of materials treatments are feasible with plasma technology. Three different types of processes on the materials can be activated, depending on the peculiar physical properties of the plasma created by various ionization systems, in particular: (1) Destroying hazardous or dangerous materials; (2) superficially altering already-existing materials; or (3) developing new materials.

Thermal plasma can be used to create anti corrosion, thermal barriers, anti-wear coatings, as well as to eliminate toxic, halogenated, and dangerous solid, liquid, and gaseous compounds. Cold plasmas can be used to modify the topography of materials' surfaces as well as produce coatings and surface chemistry that are vastly different from those of the bulk material.

The weight of each of the three lines in relation to an immediate industrial transfer varies. The third one is still being investigated, while the other two are suitable for direct practical application of the techniques. The description of a few industrial procedures will be followed by a cost comparison of a few dangerous material treatments.

Two basic types of plasma are primarily used in industrial operations using plasma technology: the first type, called "thermal plasma," is created at high pressures (>10 kpa) using direct or alternating current (dc-ac), radio frequency (RF), or microwave sources. These devices, also referred to as torches, create plasmas with electron and ion temperatures of about 1-2 eV and very little gas ionization. DC and AC torches can be realized with power more than several MW and can be classified as transferred and non-transferred arc. The primary use of the generated plasma is to eliminate poisonous or dangerous compounds or, as in the case of the plasma spray, to create thick film coatings. The electron temperature of the second form of plasma, known as cold or non-equilibrium plasma, is higher than the ion temperature; it is created under vacuum conditions using low power RF, microwave, or DC sources. Plasma particle interactions with the materials result in surface modification that adds various functional qualities relative to the bulk material.

The majority of thermal plasmas utilized in the processing of materials are produced by high frequency induction discharges, dc or ac electrical discharges, or both. When there is a strong enough gas flow, the arc discharge creates a zone of high temperature and density between two electrodes, and the plasma can even jet out past one of the electrodes. The plasma-arc method seems to be one of the most intriguing new technologies for treating halogenated materials. Due to the achievement of greater temperatures and also reactivity in large quantities with a high process flexibility, the most current industrial procedures based on the utilization of thermal plasmas demonstrate a higher destruction efficiency.

PCBs, halo-methane, and other substances of a similar nature are included in this category of liquid or gaseous organic hazardous wastes, along with other compounds used in processing, such as paint solvent and cleaning agents. For the material destruction, there are two possible treatment concepts: (a) using the heat generated by the plasma jet to break the chemical bonds; and (b) combining the impact of energized plasma particles on molecules with heat to do the same. The first idea has the advantage of producing higher temperatures than the combustion effect. The second one can be used to treat materials that are directly injected in the plasma arc zone where the plasma density is highest, whether they are gases, liquids, or

solids (with non-transferred arc), or muddies and solids (with transferred arc). In the second scenario, the destruction effectiveness is stronger because thermostable molecules or high energy bonds can be broken apart by ion and electron bombardment.

Numerous projects are active and in varying stages of development. Westinghouse has developed the most comprehensive plasma method to date. A 1MW non-transferred plasma torch and a hot reaction channel with refractory lining that exhausts the reaction products into a bigger holding tank make up the reactor. In a scrubber, the acidic gases are neutralized and then released after being vented from here.

Since the plasma gas is essentially at room temperature, cold plasmas can be used to change the surface functional properties of any organic material. The treatment methods exhibit unusual benefits, few negative effects on the environment, competitive costs, and in particular, the ability to change the surface characteristics of any materials (also inactive). Radio-frequency radiation is used to excite and ionize gaseous products when they are in a vacuum and at room temperature. By colliding with the material surface (located in the plasma zone), the energetic plasma particles release free radicals on the surface, breaking the chemical bonds. Depending on the kind of plasma gas being employed, these are also vulnerable to other reactions. As a result, surfaces are created that are quite distinct from the material bulk in terms of their properties. Gas chemistry and plasma characteristics both affect how the plasma behaves on the surface. The pretreatment and makeup of the substrate, the kind and quantity of reactive gas, the total reactor pressure, the amount of RF energy used, and the process time all affect the type of alteration.

The need for proper toxic waste annihilation is becoming more crucial as a result of environmental contamination and the scarcity of natural resources. Storage or incineration might be quite dangerous. Due to the benefits of the plasma reactors, thermal plasma technology is a possible replacement for the traditional disposal methods. The plasma torch can be used to transform halogenated waste into non-toxic materials. The plasma technology allows unfathomable developments in the area of the surface alterations of the materials that the lone researcher scarcely manages to hypothesize. The operational promptness of the interested businesses plays a key role in popularizing the potential of plasma as well as the modern notion of its particular industrial uses. Therefore, it is becoming increasingly crucial for the full utilization of these new technologies that research and industry work together.

Key words: plasma treatments, surface modifications, toxic material destruction

Renewable Energy Management and Smart Grid in India

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Summary

The modernisation of the energy transmission and distribution networks is urgently needed due to the diminishing fuel resources, poor environmental circumstances, and rising power needs. In order to consistently provide power to consumers at the lowest possible cost, utilities must maximise their efficiency and optimise the network. Smart grid technologies are a promising solution for dynamic optimization of grid operations and resources, metering, distribution automation in response to demand, etc. This article provides a basic overview of the many elements that make up the smart grid architecture. A brief analysis of several current projects in India is provided, along with information on the smart grid policies implemented around the world and the standards set by the Indian government for the organisation responsible for implementing advanced metering infrastructure (AMI). In this paper, challenges and problems related to this development in India are also discussed.

Traditional grids need to be reengineered in order to be able to meet rising demand, be less prone to faults and power loss, reduce electricity theft and air pollution, extend equipment life, etc. This is because centralised generation and unidirectional communication make traditional grids less efficient. The term "smart grid" refers to this bidirectional grid with an integrated communication system, highly effective sensors and measurement units, advanced components and control methods, decentralised generation, and intelligent distribution. They reduce greenhouse gas emissions, have effective OMS, promote PQ improvement, and are self-healing. Their main goal is to make the best use possible of all resources. The following are the main attributes of the smart grid:

- It enables informed consumer participation, allowing them to adjust how they use and buy power and track their usage patterns.
- It permits the use of both distributed and centralised methods of generation and storage (incorporates renewable energy resources also).
- It opens up new markets, services, and goods.
- Offers price that is current.
- Self-healing, load forecasting, fault prediction, frequency control, and frequency monitoring help to improve power quality.
- By utilising the most recent technology, asset utilisation and operational efficiency are enhanced.

The bidirectional smart grid is made up of a sophisticated metering infrastructure with a highly effective metre data management system, as well as smart generating, transmission, and distribution systems. Smart producing plants automatically maintain voltage, frequency, and power factor while learning the behaviour of the power generating resources in order to maximise energy production. In a microgrid, real-time dispatch is carried out by controllable generators and energy storage systems. The phrase "advanced metering infrastructure" (AMI) refers to a broad set of technologies that are integrated into the architecture for measuring, collecting, transferring, and evaluating energy usage. Power factor performance, transformer performance, security, breaker status, and battery condition are monitored and managed by a substation. These renewable energy generating facilities must to be quick to react, have effective outage management systems (OMS), and be capable of black starting.

Transmission network congestion is decreased by distributed power from various residential-scale renewable generating systems. Remote control switches and smart metres are part of an active, networked smart distribution system. These metres have built-in load event switches and power event alarms that enable bidirectional data transmission between the supplier and the consumer. They also inform the user of energy consumption through in-home displays, making them aware of their HAN usage. HAN enables smart building automation, DER connectivity with the smart grid, and utility control of appliances with high power demands during peak hours. Smart metres have the ability to update their firmware and deliver readings as needed. The data measured at the smart metre is transmitted via NAN to DCU, which then gathers data from a group of smart metres and transmits it through WAN to MDMS. To convey the data securely, effectively, and reliably, it is crucial to select the right communication network for the exchange of massive amounts of data from metres and sensors. The power line carrier (PLC), broadband over power line (BPL), wireless (radio frequency), internet, copper or optical fibre, etc. are the major components of the highly secure bidirectional communication network.

The only way to meet the projected 2.2% annual increase in global energy consumption from 2012 through 2035, according to the International Energy Agency (IEA), is to upgrade the existing electrical grid. The notion of a "smart grid" varies across nations based on their needs and policies. Among the top CO_2 emitters, China, the United States, India, Russia, Japan, and Germany account for around 60% of global CO_2 emissions. These nations, as well as Italy, the United Kingdom, South Korea, Europe, and Australia, are attempting to produce electricity more intelligently.

India has the fifth-largest installed capacity for generating electricity in the world, or about 315.42 GW, of which 30% is made up of renewable energy. India still has an energy shortage of about 23522 GWh, according to the Central Electricity Authority of India's 2016 annual report. A programme dubbed "Power for All" has been initiated by the Indian government with the aim of providing families with uninterrupted power by the year 2020. India is looking for cutting-edge grid modernization solutions and ways to integrate renewable energy into the existing infrastructures in order to meet this requirement. As a result, India is moving toward more intelligent electricity generation, transmission, and consumption practises. Several initiatives were started by the Indian government, including 100 Smart Cities, 175 GW of renewable energy by 2030, and electric vehicles. Modernizing the grid is necessary due to numerous initiatives launched by the Indian government, such as 100 Smart Cities, 175 GW of renewable energy by 2030, electric vehicles to reduce air pollution, smart meters, etc. The National Smart Grid Mission (NSGM), which is 30% centrally funded and includes a number of projects, was launched in 2015 and has gained support at the national level from the ministries, institutes, and state governments. The following is a succinct description of these projects:

- Chandigarh Electricity Department, Chandigarh: The monitoring, substation automation, rooftop solar PV, and IT functionalities are all part of the EMS.
- Maharashtra State Electricity Distribution Corporation Limited (MSEDCL), Amravati, Maharashtra – It is implemented in Amravati with AMI, OMS and DR technologies.
- MSEDCL, Congress Nagar, Nagpur, Maharashtra – It is implemented at Congress Nagar Division of Nagpur with AMI, SCADA, OMS and DR functionalities.
- Kanpur Electricity Supply Company Limited (KESCO), Kanpur, Uttar Pradesh – It is implemented at Kanpur and the technologies involved are AMI, peak load management, DT monitoring and Distributed Generation.

Smart grid pilot projects are also being carried out around the nation in addition to the aforementioned NSGM programmes. The Ministry of Power is providing 50% of the funds for these projects (MoP). Making regulatory recommendations for future, more significant projects will be aided by these projects.

The modernization of the grid will result in the integration of better technologies into the grid, satisfaction of consumer demand for a continuous power supply, job creation with the inclusion of new research and development areas, increased asset life, improved power quality, increased security, reduction of forced power outages and blackouts, reduction of peak demands, energy efficiency, cleaner environment, new market for utilities, etc. Varied countries have different benefits from grid modernisation depending on their needs, and as a result, they have made the policies mentioned in this paper. The fundamental objective in India right now is to give everyone access to reliable power. The execution of the aforementioned projects will give practical insight into potential barriers to these technological breakthroughs and their associated advantages. For wider deployment, it is important to keep in mind the development's main obstacles. If these projects are effectively completed, they will support long-term objectives and offer the best means of supplying the nation's expanding energy needs.

Key words: renewable energy, smart grid, machine learning, grid integration

A Nonlinear-Multimode Piezoelectric Energy Harvester for Mems Application

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Summary

Energy crises, global warming, and environmental pollution have become global issues. Various alternative energy sources have been receiving attention owing to their sustainability and eco-friendliness. In recent years energy harvesting technologies, which scavenge the wasted ambient energy, such as vibrations, solar, heat, wind, and water, into electrical energy for low-power application devices. Further advancements in low-power integrated circuits (ICs), wireless sensor nodes, and mobile electronics have reduced the demands in power consumption requirements and increased the appeal of energy harvesting. Usually, these energy harvesting schemes could suffer from low, variable, and unpredictable ambient conditions. Among various ambient sources, mechanical vibration in form of direct human activities and structural vibrations from industrial machinery buildings, etc is abundant and versatile in our ambient environment. Most of the recent research works have focused on the design of these vibration energy harvesters based on three major transduction mechanisms i.e., piezoelectric, electromagnetic, and electrostatic transduction mechnisms. While each of the techniques has its advantage, piezoelectric energy harvesters have received the most attention due to their higher energy density, high conversion capability, and simpler designs as compared to their counterparts. In addition, piezoelectric material provides ease of scaling in micro and nanoscale devices and therefore is preferable technology in Microelectromechanical (MEMS) devices. Conventional piezoelectric harvester based on resonance of the structure has the drawback of high frequency, narrow bandwidth, and low output generation. They perform inefficiently in real-time practical use since the environmental vibration is low, broad, and varying with time. Considerable research has been focused on reducing the operating frequency, widening the operating bandwidth, and increasing the output power density of the piezoelectric harvester3. Nonlinear vibration energy harvester has become a recent popular choice owing to their lower resonant frequency and broad bandwidth. It is proved that introduction of nonlinearity in energy harvesting will broaden the operational bandwidth and show superior power generation.

To overcome the drawbacks of conventional linear Piezoelectric harvesters, we propose a novel nonlinear and multimode piezoelectric harvester design. A schematic diagram of the proposed harvester is shown in the figure. Tapered-shaped substrate spring with the piezoelectric film is combined with the concept of magnetic-bistability. The tapered shape of the harvester will have a more uniform strain distribution, which in turn results in efficient use of device structure for piezoelectric voltage generation while reducing the resonant operating frequency. Whereas, segmentation of piezoelectric film facilitates multimode operation of harvester segmentation at higher vibration modes and increases the generated output voltage by avoiding the cancellation of charge that occurs at strain nodes of higher vibration modes. The harvester induces bistable nonlinearity through repulsive magnetic arrangement at the centre of the tapered spring structure which administers a quartic potential profile. The analytical model of the proposed design concept will be developed. The comparative performance analysis is performed for the proposed nonlinear-multimode piezoelectric harvester with lower operating frequency, wider operating bandwidth, and increased output power density.

Key words: energy, models, preferable technology

Transport and Urban Air Pollution in India

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Summary

The rapid expansion of motor vehicle activity in India and other quickly industrializing low-income countries contributes to high levels of urban air pollution, among other negative socioeconomic, environmental, health, and welfare consequences. This study initially analyses the local, regional, and worldwide implications of air pollutant emissions caused by motor vehicle activity in India, as well as the technological, behavioral, and institutional reasons that have led to these emissions. The study then covers certain implementation concerns relating to various policy initiatives that have been implemented, as well as the challenges of the policy framework. Finally, the study gives insights and lessons based on recent Indian experience for better understanding and more successfully tackling the transport air pollution problem in India and similar nations in a way that is responsive to the needs, capabilities, and limits.

Rapid rise in motor vehicle activity in Indian cities has resulted in a slew of major social, environmental, health, and welfare consequences. Among these effects, those caused by urban air pollution, caused by emissions from motor cars and other sources, have received a great deal of public concern and policy attention. Because of the concentration of motor vehicles and other energy-consuming activities in these cities, as well as the high pollution intensity of these activities, such high levels of air pollution occur in Delhi and other large Indian cities. Acidification and ground-level ozone are becoming more prevalent in Asia. Globally, the rapid expansion of motor vehicle activity has serious implications for energy security and climate change.

Indian emissions inventories are untrustworthy and do not accurately reflect real vehicle populations or operating circumstances. In terms of emissions per passenger-kilometer, M2W and M3W vehicles have been a major issue. The majority of transport-generated particles are PM10, which has been strongly connected to morbidities and deaths related to respiratory and cardiovascular diseases (Shah and Nagpal 1997). Because lead in gasoline is primarily emitted in the form of PM10, it has become a major public health concern around the world. Lead concentration was extremely high until the mid-1990s, when considerable improvements in gasoline quality began to be adopted.

India has put in place a number of regulatory initiatives to mitigate the worsening air pollution in Delhi and other Indian cities. Some crucial measures are highlighted, as well as some implementation challenges. Except for Taiwan and Thailand, M2W vehicles have been characterized by high pollution levels. Exhaust emission requirements for the year 2000 are the harshest in the world. Catalytic converters require steady spark ignition to function properly, but spark plugs in M2W and M3W vehicles may be subject to malfunctioning due to unclean operating conditions and insufficient air filtering and maintenance. Frequent catalyst replacement would be costly and difficult for both vehicle owners and manufacturers, who would be held accountable in the event of a failure in service. To compensate for lead removal and benzene reduction, methyl tertiary butyl ether (MTBE) has been added to gasoline in several Indian states. India's capital, Delhi, is the only city in the world to have converted its entire public vehicle fleet to run on CNG. Financial incentives were provided to facilitate conversion; in the case of M3W vehicles, for example, sales tax exemptions and subsidized loans were provided. Road infrastructure measures to alleviate traffic congestion and reduce per-vehicle emissions are being implemented in various Indian cities.

A multitude of government agencies and private actors at the national, regional, and local levels is responsible for the various roles and functions that have important implications for air pollution from urban transport—the development and implementation of vehicle emission and fuel and oil quality standards vehicle licensing, registration, and inspection; certification and licensing of fuel dispensing and service stations to test in-use vehicle emissions and repair noncomplying vehicles; fuel adulteration control; transport system management and traffic control transportation planning, road construction and maintenance; and land use. In the case of many of these important functions, agency roles and responsibilities are fragmented, overlapping, and conflicting. In addition to this jurisdictional complexity, interactions between the various agencies and actors have been characterized, at least until recently, by conflict. Also, an important barrier to rapid and effective action has been the fact that many of the key actors, being government agencies, are difficult to regulate effectively. Addressing transport air pollution is challenging enough because, as in other contexts, this problem in India is complex and multidimensional; it involves a variety of pollutants from a range of motor vehicles and other sources, the daily travel and vehicle purchasing, operation, and maintenance choices of millions of vehicle users, and a multitude of actors and affected groups. This challenge is made more daunting in the Indian case, because of the restricted financial, technological, and administrative resources for effectively fulfilling the above important functions.

India's transport air pollution is becoming more severe in metropolitan areas as motor vehicle activity increases. Poor vehicle maintenance is a result of vehicle users' low affordability, but it is also a result of a cumbersome and ineffective in-use emissions monitoring and control regime, as well as hefty spare parts taxes. More broadly, system-wide policy consequences should be considered from the perspectives of many actors and groups affected by policies. In Delhi, financial incentives were used successfully to stimulate the conversion of M3W vehicles to CNG. By taking into account in-use realities, implementation concerns, and vehicle user views, institutional mechanisms can be put in place to predict and address problems.

This approach would also enable robust policies that are insensitive to poor operating conditions and that minimize reliance on expensive institutional support mechanisms. And since these policies are determined by or affect multiple actors governments at various levels, vehicle and fuel manufacturers and retailers, the vehicle servicing industry, and vehicle users all of these actors should ideally be involved in policy development and implementation.

There has been no significant improvement in Delhi, particularly in terms of particulates. A system to buy back old vehicles and sell them after reconditioning would make emissions performance-based scrappage more attractive Given that providing for motorization and mitigating its effects can necessitate significant resources in a context of resource constraints and a plethora of urgent demands, and given that the vast majority of city dwellers are poor and benefit little from motorization, it would be preferable for countries such as India to develop transportation systems that take into account their unique needs and priorities, as well as their capabilities and constraints, to acclimate to the changing world. With specific reference to M2W vehicles, public policy should address their air pollution impacts, while not adversely compromising the considerable benefits these vehicles afford many.

Key words: renewable energy, smart grid, machine learning, grid integration

Sustainable Development Issues & Issues in Sustainability Perspective

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Summary

We occasionally hear the term "sustainable development" used to emphasize our idealized future, which is devoid of all the issues that Earth's inhabitants face now natural resource depletion gender disparity a wealth distribution that is unfair. These are only a few, but they perfectly capture the problems that we are working to resolve. Although many view sustainable development as an abstract, impractical concept, often considering the horrifying images of overly polluted oceans or the hopelessness of their life situation as a result of being born female, this is due to the term's inclusiveness and the gravity of the situation it seeks to solve. However, in our modern world, having a solid awareness of this sector and its difficulties is quite important and can aid in leading a more conscientious and selfless life. In essence, sustainable development is a long-term strategy for planning future growth without harming the environment in order to ensure that future generations can live in a safe environment while also developing their economies, societies, and environmental stewardship with the same goals in mind. It meets our wants without impeding other people's chances. The idea encompasses a wide range of topics, including environmental, social, and economic development, which keeps demonstrating how important it is to our lives because it has an impact on every part of them. In order to serve as recommendations for the best possible conscious growth in the future, the United Nations has established a number of Sustainable Development Goals and goals. Since our industries are investing in and depending more and more on technology, if rare earth metals were to gradually disappear, prices would soar, inflation rates would rise, and it would be hard to function—at least for a while. In order to ensure stable development in this field without placing an undue reliance on exhaustible resources, new options and developments in the tech sector are crucial to sustainable development. Another major concern is the potential for future food shortages due to our population growth, which is anticipated to reach just under 10 billion people by 2050. Deforestation is reducing the extent of currently available arable land, which affects the supply of local food for those living in locations close to forests, particularly for the inhabitants of Southeast Asia and South America. Formerly fertile terrain is frequently rendered unusable for agriculture due to soil erosion, which typically happens after forest land is transformed into agricultural land for cultivating cash crops like coffee, tobacco, or cotton. This happened to the Brazilian Cerrado. The way livestock is raised and the frequency with which it is consumed are two more changes that will need to be made in the future. Around 30% of the earth's surface is being used for livestock, and as a result of the increasing demand for meat and dairy products, more and more land is being converted into grazing pasture or just industrial livestock production. In conclusion, as shown by the examples above, sustainable development is a problem that needs to be taken extremely seriously because it has an impact on everyone. Many do not see a stable future for the planet if things continue as they are now. Every single person and organization need to start reflecting on their own lifestyle choices and raising awareness about the problems that afflict this planet in order to slowly start enforcing real changes. Only then will we be able to provide a safe environment for our future generations.

The idea of sustainable development has been subject to various interpretations and critiques since its inception. According to the Brundtland Report, the phrase "sustainable development" has many distinct definitions and refers to long-term sustainable development, ecological planning, heritage preservation, and biodiversity (WCED, 1987). Dobson (1996) noted more than 300 definitions and interpretations of the idea of sustainable development a few years after the Brundtland Report. The definitions largely adhere to the primary idea outlined in the WCED's fundamental definition. According to these definitions, sustainable development primarily refers to a socioeconomic system that meets human needs, but it can also refer to long-term improvements in well-being and overall quality of life that take into account environmental restrictions.

According to theory, the term "sustainable development" refers primarily to growth that creates the environmental circumstances required for life to exist at a given standard of well-being for both current and future generations. This is a comprehensive strategy that places environmental protection and sustainable development together and within a larger ecological, socioeconomic, and political framework. Certain human demands deriving from quantitative economic values can be met through sustainable development (Ulhoi & Madsen, 1999). It provides a chance to fulfil various social requirements, including those related to tradition, culture, and other social values and traits. This strategy emphasises the equality from a cross-generational perspective while also taking ecological considerations into account.

Due to their reformulation and reinstatement in Agenda 2030, some of the earlier Millennium Development Goals (MDGs) established in the year 2000 were partially achieved. The complexity of the situation on Earth and the rising demands and challenges represented by new ambitions. The new development goals cover topics like ensuring access to clean energy and water, building infrastructure, fostering innovation and industry to create jobs, addressing economic disparities between nations, promoting sustainable cities and communities, protecting the ecosystem on land and in the oceans, promoting world peace, etc. The Brundtland report, published by the United Nations thirty years ago, introduced the idea of sustainable development. Even though many strategies and plans for managing sustainable development have been adopted, the current issue with its execution persists. According to Holden & Associates' (2014) analysis, the majority of nations have not succeeded in achieving sustainable development. The concept's execution is greatly influenced by the level of socioeconomic development, the availability of funding and technology, as well as the diversity of global political and socioeconomic objectives and interests (Drexhage & Murphy, 2010). According to Holden & Associates' (2014) research, most countries have failed to achieve sustainable development, and some are far from it (preserving long-term ecological sustainability, addressing basic human needs, and achieving equality between current and future generations). This is based on a sample of 167 countries.

The authors make note of the fact that some of the fundamental pillars of sustainable development can only be met at the expense of the second pillar; in other words, while one pillar of sustainable development becomes sustainable, others may not remain so, particularly if it has an adverse effect on ecological sustainability. The writers make note of the fact that several of the fundamental tenets of sustainable development can only be met at the expense of the second tenet. Locally, the idea has undoubtedly been put to good use, but globally, it hasn't produced any notable outcomes. The Brundtland report stated 30 years ago that sustainable development "proven to be one of the more challenging difficulties with which we wrestled," and current challenges to the idea are more demanding and complex.

Meeting fundamental human needs, integrating environmental development and conservation, establishing equality, safeguarding social self-determination and cultural variety, and protecting ecological integrity should all be addressed by sustainable development. Although the idea of sustainable development has changed in the past, its core tenets and objectives have helped people behave more conscientiously and adapt to environmental constraints. This is the rationale behind the concept's adoption in various spheres of human endeavor. While the concept has found positive application locally, several international organizations have been involved in its implementation; yet, it has not had a substantial worldwide impact. This statistic demonstrates that environmental issues still exist today, 30 years after the notion was first introduced. The United Nations Millennium Development Goals, which are focused on a complex global scenario including population expansion, hunger and poverty, wars and political instability, and additional environmental deterioration, provide a contemporary interpretation of the notion of sustainable development. The gap between wealthy and impoverished nations has widened and many nations are not even close to sustainable development. The degree of socioeconomic development that many countries have not yet attained, linked to a lack of financial resources and technology, as well as the diversity of political and economic goals on a global scale, are fundamental obstacles to the implementation of the concept of sustainable development.

Key words: sustainable development, food safety, energy consumpsion

Biomass Gasification for Decentralized Power Generation: The Indian Perspective

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Summary

This article makes an effort to highlight the technical and financial concerns surrounding biomass gasification-based decentralized power generation in India. Biomass-based energy is the best renewable energy alternative for India since it has a number of specific advantages, such as widespread availability and uniform distribution. In India, the potential for generating electricity from renewable sources is projected to be 85 GW, with biomass power accounting for about 20 GW of it. Biomass gasification-based power generation, in particular in the remote regions and hilly terrains of India, offers a highly viable solution for satisfying the energy needs of small villages and hamlets, which would not only give them independence but would also lessen the burden on state electricity boards. The many technical alternatives for low-, medium-, and large-scale power generation using biomass gasification are reviewed in this work. We essentially talk about the advantages and disadvantages (operational and other issues) of various systems. Additionally, we analyze the economics of these systems and the key variables affecting the viability of biomass-based power generation. Finally, we examine a few case studies of biomass-based power generation used to supply thermal and electrical energy needs.

India's energy demand is rapidly increasing across a range of industries, including agriculture, manufacturing, transportation, commerce, and residential. The generation capacity is now far insufficient to satisfy the demands. Peak demand estimates place the average difference between electricity supply and demand at roughly 14%. India's development has also faced significant obstacles due to rural electrification. In contrast to urban areas, the primary uses of electricity in rural areas are for domestic lighting, irrigation pump operation, and small-scale commercial activities like flour mills and other rural industries. Rural electrification has been given top priority in the National Electricity Policy (NEP) that the Indian government just unveiled. NEP insists on using both traditional and renewable electricity generation methods, provided that they are commercially feasible. Decentralized energy generation using renewable sources offers a workable solution in very remote places where a wide infrastructure is not practical. In order to close the gap between supply and demand, it is urgently necessary to exploit the enormous potential of renewable energy sources. Unlike coal, which is dispersed unevenly across the nation, India's estimated annual potential for biomass-based power generation is 200 million tons. This is equivalent of 20 GW of installed capacity. In addition, agro-residues and woody bio-refugee land could add another 100–300 million tons for power generation.

All of the aforementioned renewable energy sources have the potential to be used in India thanks to its abundant natural resources. Solar energy, wind energy, minor hydropower, biomass, biogas, and energy recovery from waste from businesses and municipalities are the main renewable energy sources. Even in metropolitan settings, decentralized electricity generation from renewable sources provides a workable answer to the lack and rising cost of electricity. The Government of India's Ministry of New and Renewable Energy (MNRE) has put in place extensive programs for the growth and application of diverse renewable energy sources in the nation. The first renewable energy plant in India was a tiny hydropower project with a 130-kW capacity that was put into place at Sidrapong, Darjeeling, in 1897. Then, in 1902 and 1911, respectively, two further hydro projects with a combined capacity of 40 and 50 kW were installed at Chamba and Jubbal. Since there were no transmission lines available at the time, the power produced by these plants was mostly used to satisfy local energy needs.

All organic material derived from plants, including all land and water-based vegetation like trees, algae, and crop leftovers, is referred to as biomass. More than 70% of the population in India depends on biomass for all of their energy needs, accounting for 32% of the nation's total primary energy consumption. With the production of more than 700 billion units of electricity annually, biomass-based power generation in India draws investments of Rs. 1000 crore. In India, the biomass gasification initiative began primarily as a combined R&D project between MNES, numerous academic institutions, and private businesses. Research conducted in these facilities made a significant contribution to the creation of prototype technologies and the transfer of technology to industrial enterprises. For a variety of uses, more than 25 gasifiers based on I. I. Sc. technology have been deployed in India and overseas. In the industrial sector, significant R&D efforts for technology development have also been made. For the installation of gasifiers in India, MNRE has provided financial assistance in the form of capital subsidies. Fixed bed and fluidized bed are the two basic categories for biomass gasifiers. Updraft, downdraft, and cross-draft gasifiers are the sub-categories for fixed bed type gasifiers depending on the relative directions of biomass and air movement. Additionally, entrained bed gasifiers (like those for coal gasification) were created for biomass, however these turned out to be ineffective. The primary components of the pre-treatment biomass are drying and particle size reduction. For gasification, biomass must have a moisture content in the range of 10% to 15%. Higher moisture content causes the gasifier's combustion zone to heat up less slowly. Additionally, it lessens the combined heat of H_2 and CH_4 combustion, which lowers the producing gas's calorific value.

There are over 24,500 isolated villages in different Indian states where it is not practical to extend the grid's electricity. With the use of renewable energy sources like photovoltaics, micro hydro, wind, and biomass gasification, these settlements could be powered. In the case of India, biomass-based electrification is more advantageous due to the uniform distribution of biomass throughout the nation. In the Karnataka villages of Hosahalli and Hanumanthenagara, the Indian Institute of Science Bangalore erected 20 kW gasifiers in 1987 and 1994, respectively. The primary uses of electricity were for flour mills, irrigation, street lights, and residential lighting. The gasifiers were overseen by the village committee and run by locally trained personnel. Two Indian villages, Odanthurai and Nellithurai, have erected biomass gasifiers to produce energy for water pumps for the supply of potable water. In the West Bengal Sundarbans, two distant islands have been electrified using biomass gasifier plants. About 84 people have been employed directly and indirectly by this operation, with a total capital investment of Rs. 9.5 million. In the town of Chottomollakhali in the Sundarbans, four gasifiers with a combined capacity of 125 kilowatts (kilowatts) were installed in June 2001. For Rs. 500,000, 10 acres of land were planted in order to supply the gasifiers' fuel requirements.

The technical and financial elements of decentralized power generation by biomass gasification in the Indian setting have been covered in this review. The demand for power in India's rural areas is increasing at a pace of 7%, while there is a total peak hour electricity shortage of about 20,000 MW. It is decided how much power India can produce. However, coal reserves in India are largely confined to the country's eastern and northeastern areas, where coal is used in thermal power plants. There are compelling arguments for why biomass gasification is preferable to alternative decentralized power choices including wind, solar, and micro hydro projects. Practically any community with an annual supply of biomass adequate to assure efficient operation can install a biomass gasifier. In rural locations, low loads and poor capacity utilization present additional challenge for the operation of a renewable energy system. Due to the relatively variable operating hours of biomass gasification-based systems, this issue can be resolved. The creation of a "energy system package" would improve manufacturing, installation, use, and maintenance. By including additional commercial and industrial activity in the gasifier load, the load factor or capacity utilization factor is improved. For the gasifier to operate, additional working capital finance (in the form of soft loans) is also necessary. To educate the rural populace on the benefits of gasifier-based generating, regular informational campaigns should be run.

Key words: biomass gasification, biomass gasifiers, rural electrification, decentralized power generation

Overview of the Renewable Energy Sources Structure in Croatia

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Summary

Currently, the renewable energy sector in Croatia has been developed and structured by the Act on Renewable Energy Sources and High-Efficiency Combined Heat and Power, while various other regulations determine specific segments of the sector itself. These legal acts were also drafted in accordance with the European Union guidelines and legal acts. In particular, the Green New Deal, the EU Climate and Energy Framework 2030 and the EU Long-Term Strategy 2050 are fundamental documents that guide Croatian legislation and industry. However, recent events in the energy market in Croatia, Europe and the world have led to drastic changes that require an efficient response. The European Union is currently experiencing a severe energy crisis as a result of market and consumption disruptions caused by the COVID - 19 pandemic, but also due to unforeseen and significant disruptions in the geopolitics of the European Union and the world. These events had an immediate and unavoidable impact on the entire energy market in the EU, as well as on the supply of natural gas, an indispensable source of energy for daily life. As a political and strategic response to these problems, greater and stronger attention was paid to the implementation of previously adopted energy and economic policies and frameworks, such as the Green New Deal and proposals like REPowerEU. In addition, the EU Commission proposed a "market correction mechanism" at the end of 2022. This is a time-limited and targeted mechanism that automatically intervenes in gas markets in the event of extreme gas price increases. With the introduction of the Energy Price Toolbox, Member States have also taken numerous measures at national level to reduce price pressure on consumers and industry. Through policy initiatives and regulations, the EU is also investing in and drastically rebuilding energy infrastructure to prevent such scenarios in the future and reduce the EU's dependence on existing energy supply models. In line with the development of the renewable energy sector and the fact that the EU is a world leader in their deployment, the situation will eventually encourage an increased use of renewable energy sources and a more effective use of electricity. The aim of this research was to gain insight into the structure of the renewable energy sources sector in Croatia, assess the stages of development of certain technologies to date, and provide recommendations and guidelines for further steps to increase renewable energy production.

In Croatia, the transition of the energy sector to renewable sources is achieved through incentives. In this way, the development of new technologies is encouraged to the extent that they become capable of operating independently on market principles. There are two incentive models for renewable energy sources, feed-in tariffs (FiT) and feed-in premiums (FiP). The main difference is that in the FiT systems, compensation is allocated administratively, while in the FiP system it is allocated through tenders. From the mid-2000s until 2020, Croatia, as in Europe, was dominated by the FiT system, which was necessary in order for investors to be willing to take risks in new markets. After identifying and finding solutions for the initial barriers, the competition system was a logical sequence to reduce the costs of renewable energy sources. In May, 2020, the Croatian government adopted the Regulation on quotas for encouraging the production of electricity from renewable energy sources and high-efficiency cogeneration, with which the application of the premium model for renewable sources and the new investment cycle begins. This system is a more transparent, improved transition model, with stronger market influence. It is primarily intended for the gradual integration of renewables into the market, which is the ultimate goal of the energy transition. The market of energy produced from renewable sources is controlled by the Croatian Energy Market Operator (HROTE), which operates as a public service under the supervision of the Croatian Energy Regulatory

Agency (HERA). HROTE is responsible for organizing the electricity and gas markets in accordance with the law. It collects levies for the promotion of electricity generation from RES from electricity suppliers, who collect these levies from electricity consumers. It concludes contracts with eligible generators for the purchase of electricity and pays them the guaranteed support price, as well. As such, the company covers the majority of the profile of renewable sources in Croatia, and its annual reports provide insight into the technological and business structure of the sector. By the 2022, there was a total of 1,442 registered RES power plants in Croatia who concluded a purchase agreement based on the tariff systems with HROTE, of which 85.16 % are solar power plants. Thereof, there were 54 biomass, 47 biogas, 20 hydroelectric, 26 wind, 5 cogeneration and 1 geothermal power plant. In the tariff models, there was a total of 716.80 MW of wind, 113.26 MW of cogeneration, 106.52 MW of biomass, 53.13 MW of solar, 46.92 MW of biogas, 10.00 MW of geothermal and 6.37 hydroelectric power plants, i.e., a total of 1055.50 MW. As part of the Incentive System, those within FiT model were total of 68, where 88.23 % refer to solar power plants, with power capacity of 14.11 MW. Also, three biomass power plants with a power capacity of 1.35 MW and five hydropower plants with a total power capacity of 1.27 MW were present with this form of contract. On the other hand, there were 9 of those within FiP model, of which five refer to biogas power plants with a total power capacity of 7.74 MW and four biomass power plants with a total power capacity of 5.80 MW.

Renewable resources in Croatia are available in significant amounts through all technologies. The country has great potential to reduce energy imports by increasing the use of renewable resources. This is supported by geographical and climatic advantages, which enable a high degree of utilization of solar and wind energy in the coastal and mountain areas above all, but also energy from biomass, biogas, and geothermal sources in the interior and continental part. However, the diurnal and seasonal fluctuations in the use of solar and wind energy make it necessary to encourage and support the development of other energy sources, such as biogas and biomass power plants, which can be used continuously and independently of weather conditions. This form of utilization makes it possible to ensure a constant supply. However, the fact is that in Croatia corn silage in co-digestion with manure is almost exclusively used as a raw material for biogas production. Such a model of production and dependence on the availability of raw materials involves certain risks. The availability and predictable price of raw materials are crucial for long-term planning and investments. Recent events on the market have disrupted the price of these raw materials, which directly affected the profitability of operations and the price of produced energy. As such, care must be taken to diversify the range of raw materials used by these plants so that dependence on the choice of monocrops and food raw materials does not lead to undesirable disruptions in supply, i.e., to an increase in the cost of the energy produced.

Key words: renewable energy sources, country profile, energy structure

Offshore Solar – The New Frontier in Renewable Energy

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Summary

The growth of renewable energy and in particular, solar energy over the last decade or so is undeniable. At the time of writing the global installed PV capacity is probably already over one Terawatt. Installations are increasing every year with hundreds of Gigawatts added each year and if worldwide renewable energy targets are to be met, rate of installations will have to accelerate. New solar farms in the hundreds of megawatt size range announcements have become routine. However even with this impressive growth in solar energy, this renewable resource only accounts for a tiny fraction of the world's electricity needs. Moreover, the goal is to replace all energy by renewable sources, not just electricity, so the need for renewable energy is even bigger. Of course, solar is not the only source of renewable energy – there is also wind energy, hydro-electric, bio-energy and other renewable energy sources. However, most of those, other than wind and solar, have limited growth potential due to the resource.

Offshore solar will likely never be as cheap as solar on land. However, countries are now prioritizing energy security as much as cost of supply, especially after the recent wild fluctuation in prices and insecurity of supply caused by the war in Ukraine. Installing large solar farms requires a lot of space. There are places where large suitable tracts of land are not available. Many islands certainly fall in this category. However, so do many large cities where it is difficult to find large areas for solar farms within or close to the city. Typically, solar farms would therefore have to be built many kilometers away from the city center with the associated costs and power losses of long transmission lines. Luckily, many of these cities are coastal and therefore another option is to put a solar farm at sea, very close to shore and the city center where most of the consumption is happening.

Floating solar installations on lakes and reservoirs have been established in many places around the world with the first systems appearing around 2007-2008. There are several multi-megawatt installations, and the market is already in the Gigawatt range with a forecast to grow to close to 5 GWp by 2026. The main motivations for these installations are a lack of space for large solar farms where they are installed but also a reduction in water evaporation and algae growth and they are typically close to where the electricity is being used.

The motivation for offshore solar systems is similar. The sea provides almost endless space and very often in close proximity to where the consumption is happening. Moreover, in some cases, as in the case of densely populated islands or large coastal cities it could be the only option. Furthermore, system's performance installed on water, while already performing better than a land-based system could be further enhanced by actively cooling the system using the endless supply of cool water. Other secondary advantages are the absence of shading objects, the relatively clean environment and the ability to rotate the system relatively easy if this is a requirement. In theory, a system at sea could also be moved to a new location if it becomes redundant or is needed more elsewhere.

There are also of course key challenges. The sea is a corrosive environment and any structure built for a solar farm would have to withstand the waves and wind for a period of 20 years or more including mooring. The system would also have to be built relatively cheap to make it competitive with land-based systems. The location of the system must be chosen not to interfere with other marine uses such as shipping and fishing, and to make it easily connected to the grid. There are also environmental concerns related to the effect of the structures on vegetation on the sea bottom especially in shallow waters.

Our research group started tackling this problem over 10 years ago. Malta being a small densely populated island, it was logical that we look at offshore. From the beginning we kept cost considerations in mind when exploring different designs. Our target for the project, which we named Solaqua, was to produce solar farms which had a lifetime of at least 20 years and a LCOE like land-based systems in land constrained locations.

In the first of three funded projects (2012-2016) we tackled the issue of design, size shape and materials. The designs considered varied from large rafts to individual floating panels. Various materials ranging from wood to concrete to steel pipes and polymers were considered for two main parameters – durability and cost. Several rafts and floats were also constructed and tested in open sea in an open bay in the north of Malta. The first two rafts (made of polystyrene over a steel frame and covered in thermoplastic polyolefin) were launched at the end of 2014. These first two platforms, which had thin film panels on them, were tested at sea for almost three years. Similar panels were also installed about a kilometer away on land to act as controls. Several other designs including two frame structures, self-floating panels and panels floated on light material were also tested.

This first project yielded several interesting results including that the panels at sea performed almost 4% better than similar panels on land. While at the start of the project there was concern about salt deposits on the panels, it was found that the impact of these was in fact minimal. The rafts also performed well in some very severe weather which hit the Maltese islands while they were at sea.

In this first project, and in the following funded project (2016-2018) in addition to cost and material considerations we also considered size and shape, i.e. whether a larger or a small raft would perform better and if there is an optimal size and shape. This was done primarily through modelling in Ansys Aqwa. What we found was that larger is better as the force of the waves does not increase linearly with size, but tapers off and therefore the force per square meter decreases for larger rafts. In the first project we had also determined that a light concrete raft would probably be the cheapest to construct while also having the necessary strength. In the second project we determined that the optimal configuration would be hexagonal shaped rafts with an area of at about $40m^2$ or larger, hinged to other rafts to form a honeycomb of rafts. This would not only provide the opportunity to expand the area indefinitely, but also performed well under mediterranean wave conditions in simulation and the rafts would be small enough to construct on land and transport if needed.

Finally in the most recent project models of the design were constructed and tested in two wave tanks. A 1:50 model tested in a small 1m deep wave tank and a 1:25 model tested in a larger facility. In both cases the tests simulated mediterranean wave conditions of up to 5-6m wave height. The results validated the previous predictions obtained in simulation that the rafts would have limited overtopping only in the worst wave conditions and that the raft structure would flex with the waves in an acceptable way that would not jeopardise the panels on top of it.

A patent has been filed covering the design of the raft and we are currently planning the deployment in open sea using a set of full size rafts. Funding permitting, this should happen in 2023-2024.

Key words: renewable energy, solar energy, offshore

Green Hydrogen Production and Use of Waste Heat from Agro-Solar Power Plants

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Summary

Hydrogen is a chemical energy carrier, which is produced by consuming energy that is transferred afterwards in molecular form. Energy carriers allow energy from an external energy source to be stored, transferred and released over time. Today, most hydrogen is produced from natural gas. Renewable hydrogen is identical to fossil-based hydrogen, but it is produced through electrolysis from water, which involves the separation of the water molecule in hydrogen and oxygen by applying electricity from renewable energy sources, such as wind and solar. It can also be obtained from biomass as raw material. Accordingly, renewable hydrogen's production is almost emission-free. Currently, hydrogen is mostly used as an energy feedstock in industrial processes, but it could also contribute to producing other gases and liquid fuels. Thanks to its energy density properties, it can also carry and store energy, which makes it particularly suitable for long-distance and heavy-goods transport. Another aspect that could accelerate its production is the fact that existing infrastructure in gas transport and storage can be repurposed for hydrogen. The REPowerEU plan foresees a "hydrogen accelerator", which sets objectives for 10 million tons of domestic renewable hydrogen production and 10 million tons of renewable hydrogen imports by 2030. It includes measures to scale up hydrogen infrastructure, which highly relies on the deployment of renewable energy and port infrastructure, and its connection to industrial and transport users. Within the plan, the Commission also identifies a series of actions to accelerate the uptake of renewable hydrogen and its derivatives in hard-to-decarbonise sectors, particularly in transport and industry. For instance, it is estimated that around 30% of the EU's primary steel production could be decarbonised on the basis of renewable hydrogen by 2030.

In accordance with the Croatian Hydrogen Strategy 2021-2050 and the EU Green Plan Guidelines on the decarbonization of industry and transport, the Hydrogen Energy Park - "Banovina" 50 MWe meets all modern requirements that are set in the long term for the production of RES from a solar power plant, the use of green energy for production renewable (green) hydrogen as an energy source for industry decarbonization Particular attention is paid to the decarbonization of cement, wood, chemical, petrochemical, industry, shipyards, central heating, trucks, ships, public bus transport, heating of public institutions and households. Green transition without fossil fuels means, the need for the production of green hydrogen, that requires an increase in the construction of solar power plants, also using agricultural plots on which agricultural crops can be grown that require thermal energy in order to increase their growth. The process of obtaining hydrogen by electrolysis of water with renewable electricity releases sufficient waste heat from the electrolyser.

This heat is used to heat greenhouses where vegetables are grown. The construction of the agro-solar power panels are placed diagonally high enough above the greenhouse so that they do not obscure the insolation of agricultural crops in the greenhouse.

Thermal energy-heat can be used for the food processing industry for the production of ketchup, juices and another products at site, or can be transported via warm water pipelines to nearby production facilities. For Example, from a 5 MW electrolyser you get about 1,25 MW of waste heat which can be distributed to green houses. Additional there is sufficient production of waste oxygen $H_{20} = H_2 + O_2$. By installing electricity storage (batteries) of higher power or fuel cells (as electricity production), a reliable system enables additional work of electrolyser to get more hydrogen and if needed quick response for obtain the secondary and tertiary grid balancing of the Croatian energy system. In addition by gasification of biomass or bio waste above of 1150 °C a synthetic gas or hydrogen is produced, which is also used in the decarbonization of industry and

transport. To move the hydrogen economy 'from niche to scale', the Commission announced in September 2022 the creation of a European Hydrogen Bank that aims to support investments to connect hydrogen supply and demand during its scale-up phase and to enable cost-efficient and predictable purchase and sales of renewable hydrogen from within and outside the European Union. The bank will be able to invest EUR 3 billion to help building the future market for hydrogen.

Key words: greenhydrogen, solarpowerplants, agrosolarpowerplants, electroliserwasteheat, eugreendeal, repowereu

Renewable Energy Atlas and Optimization Tool for Power-to-Gas Hubs – case Croatia

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Summary

Future energy systems are all but not cheap. In order to make a smooth transition to fully decarbonized energy systems by 2050 very important is to properly (i) size, (ii) schedule operation and (iii) real-time control their constituent individual systems and coalitions.

The lecture will focus on the developments performed within the Interreg Danube project DanuP-2-Gas: Innovative model to drive energy security and diversity in the Danube Region via combination of bioenergy with surplus renewable energy, with focus on the territory of Croatia. Two main results from the project will be presented: the Renewable Energy Atlas and the Optimization Tool. The Atlas shows data collected along the entire Danube region, including Croatia, regarding different assets important for power to gas technology – data on biomass sources, infrastructure for electricity, gas and transport, renewable energy plants and industrial plants. The Optimization tool is used to optimally size and schedule operation of a power-to-gas hub based on data for a certain location that can be pulled from the Atlas or entered manually in the tool. The Atlas and the Optimization Tool can be both reached on the platform danup2gas.eu.

Power-to-gas (P2G) hubs are parametrizable conversion points of biomass, biochar, electricity, water, gas and heat into gas, electricity, hydrogen, biochar and heat. They consist of properly parametrized: i) subunits for conversion processes, like e.g. gasification, methanation, anaerobic digestion, combined heat and power (CHP) production, electrolysis, biomass-to-biochar (B2BC) conversion, etc., and ii) storages for different chemicals, like e.g. methane, hydrogen, biochar, etc. With a right parametrization of the subunits and storages they can be adapted to different local contexts regarding availability and costs of needed inputs/outputs and grids connections, as well as the subunits/storages costs. The parametrization can lead to the situation that just some of the inputs are used and just some of the outputs are produced – in the case that some parts do not contribute to the economic benefit of the whole plant these can be designed with zero-size. This means that also pure biogas plants (anaerobic digestion + CHP production) as well as pure B2BC conversion plants or pure electrolysis plants, where other processes are not present, are considered also P2G hubs in the context of this general free parametrization. One may note a misaligned general name of P2G hub with the final plant outlook for the case of a pure biogas plant or a pure B2BC conversion plant and should consider them as truncated P2G hubs. An illustrative graphical representation of possible mass and energy conversion paths is presented in Figure 1.

Within the DanuP-2-Gas project [1], the problem of deciding on the location and parametrization of P2G hubs is tackled by designing a series of tools that approach the problem from the organizational, technical, ecological, legal and financial side. These tools are meant to be used by stakeholders interested in P2G hubs investment, by stakeholders in supply or consumption chains of the prospective P2G hubs, and by the policy makers to direct the parametrization and localization of P2G hubs in the best national, regional and local interests.

The important tools developed within the DanuP2Gas project and presented here are: Danube Energy Platform, Transnational Renewable Energy Atlas and Optimization Tool.

Danube Energy Platform [2] is a web platform where all the stakeholders interested in P2G hubs can interact on the transnational level and easily reach the tools developed within the DanuP-2-Gas project.

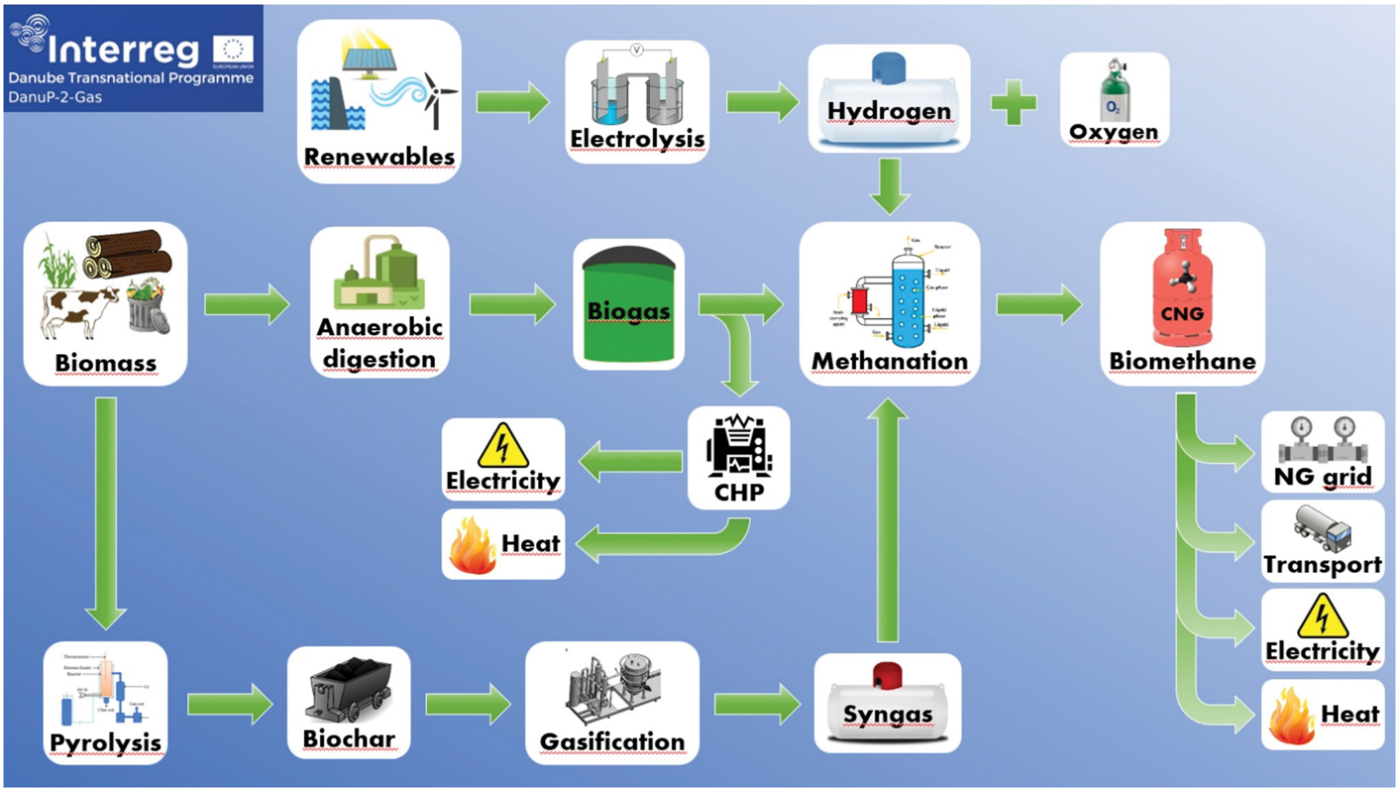

Figure 1. Simplistic graphical representation of a Power-to-Gas hub

Transnational Renewable Energy Atlas [3] is an on-line web geo-information system (GIS) tool, available from the Danube Energy Platform, for showing different interesting assets for P2G hubs planning across the entire Danube Region, i.e. for the following countries: Germany, Czech Republic, Slovakia, Austria, Slovenia, Hungary, Croatia, Serbia, Romania and Bulgaria. These assets are: i) biomass sources with prices, available quantities and classification regarding moisture content, ii) transport hubs used for biochar transportation over rail or water, iii) electricity, gas and water grids connection points, iv) renewable energy plants with types, power sizing and yearly yields of electricity, gas and/or biochar as well as with heat production/consumption, (v) industrial plants with power sizing and yearly gas and electricity consumption as well as yearly heat production/consumption. Also, the information about nationally relevant prices for electricity and gas, as well as respective grid fees and grid connection prices is contained in the Atlas. The Atlas is further meant for interacting with the users in a way that they can select a range of biomass sources on the map that they would like to consider for exploitation in a P2G hub, and then select a point on the map where they would like to localize a P2G hub which can be a greenfield investment or can be co-located with a renewable energy plant or an industrial plant. Based on these entries a description file of the assets with respect to the selections performed, including the national-level data on energy prices, grid fees and connection prices, can be downloaded and then further used within the Optimization Tool, described next.

The Optimization Tool [4] provides the optimal suggestion for a P2G hub investment in the selected point in the Atlas such that it provides the economically optimal solution for its parameterization, for the given amount of maximum-allowed investment pay-off time and investment size. The tool is meant to be downloaded from the Danube Energy Platform and consists of the user interface implemented as an Excel file and the computation algorithm files. It is used off-line on the end-user's computer such that the user is ensured that the data he/she uses as a baseline for investment planning is kept private. The parametrization consists of sizing of conversion units and storages in a P2G hub as well as grid connection capacities for it. Together with the parametrization, the user is suggested with the optimal operation recipe for the P2G hub, i.e. timings and amounts of consumptions of resources, internal processes running as well as P2G hubs products push to consumption chains. The user starts the optimization and reviews its results through a user interface which can be initialized by using the description file regarding the selected location on the Atlas. The user is able to change all important inputs of the optimization if he/she knows it better from the local context compared to the data available on the Atlas, e.g. different prices of inputs/outputs of the hub or available quantities. The user can also select in the user interface to merge the P2G hub with a local renewable energy plant and/or an industrial plant. All the inputs to the Optimization Tool can be done manually from scratch without using the Atlas, for an arbitrary location in the world.

The user interface for the Optimization Tool is implemented as an Excel file. It consists of several sheets for entry of the required data for the P2G hub parametrization and for previewing the obtained optimization results. Figure 2 shows a sample sheet with displayed P2G parametrization results after the optimization is performed.

Interreg Danube Transnational Programme DanuP-2-Gas

RESULTS

Investment specifications

	Element	Cost		Size	
Processes	Dry anaerobic digestor	0,00	€	0,000000	kg/s
	Wet anaerobic digestor	1.222.294,06	€	0,058204	kg/s
	Dry biomass to biochar plant	0,00	€	0,000000	kg/s
	Wet biomass to biochar plant	0,00	€	0,000000	kg/s
	Combined heat and power (CHP)	0,00	€	0,00	kWe
	Carbon capture plant	0,00	€	0,000000	mol/s
	Gasification + water gas shift plant	2.910,22	€	0,002910	kg/s
	Methanation reactor	751.240,26	€	1,767624	mol/s
	Electrolyser	2.672.756,86	€	1.069,10	kW
	Demineralizer	0,00	€	0,000000	mol/s
	Precipitation collector	2.000,00	€	1.000,00	m²
	Heat exchanger	53.401,33	€	534,01	kW
	Gas compressor station	21.142,89	€	26,4286	kWe
	Total for processes	**4.725.745,63**	**€**		
Storages	Dry biomass storage	0,00	€	0,00	kg
	Wet biomass storage	25.006,93	€	5.001,39	kg
	Biochar storage	0,00	€	0,00	kg
	Biogas storage	0,00	€	0,00	kg
	Hydrogen storage tank	0,00	€	0,00	kg
	Oxygen storage tank	0,00	€	0,00	kg
	Methane storage tank	0,00	€	0,00	kg
	Syngas storage tank	0,00	€	0,00	kg
	Carbon dioxide storage tank	0,00	€	0,00	kg
	Water storage tank	8.340,93	€	379,13	m³
	Total for storages	**33.347,87**	**€**		
Connections enlargement	Electrical connection	0,00	€	0,00	MW
	Gas connection	0,00	€	0,00	MW
	Water connection	0,00	€	0,00	m³/h
	Total for connections	**0,00**	**€**		
	Total investment	**4.759.093,50**	**€**		
	Payoff period	**19,63**	**years**		

Operational costs for selected period

		Cost		Amount	
Electrical energy	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	20.982.000,00	€	90.000,00	MWh
	Net consumption without investment	20.982.000,00	€	90.000,00	MWh
	Mean peak power without investment	431.506,85	€	10,27	MW
	Consumed by P2G	2.565.995,62	€	11.006,56	MWh
	Net consumption with investment	**23.547.995,62**	**€**	**101.006,56**	**MWh**
	Mean peak power with investment	**484.422,99**	**€**	**11,53**	**MW**
Heat	Produced by REP	0,00	€	0,00	MWh
	Produced IP	0,00	€	0,00	MWh
	Net production without investment	0,00	€	0,00	MWh
	Consumed by P2G	0,00	€	-2.262,66	MWh
	Net production with investment	**0,00**	**€**	**2.262,66**	**MWh**
Gas (methane) to/from the grid	Produced by REP	0,00	€	0,00	MWh
	Consumed by IP	2.495.391.027,56	€	6.057.529,54	MWh
	Net consumption without investment	2.495.391.027,56	€	6.057.529,54	MWh
	Produced by P2G	2.724.379,00	€	6.215,39	MWh
	Net consumption with investment	**2.492.203.060,44**	**€**	**6.051.314,15**	**MWh**
Water	Water from the grid consumed by P2G	0,00	€	0,00	m³
	Collected precipitation consumed by P2G	n/a	€	841,40	m³
Input materials	Dry biomass bought	0,00	€	0,00	t
	Wet biomass bought	6.228,49	€	915,25	t
	Biochar bought	0,00	€	0,00	t
	Total cost of input materials	**6.228,49**	**€**		
Additional sales	Hydrogen sold (in bottles)	0,00	€	0,00	t
	Oxygen sold (in bottles)	0,00	€	0,00	t
	Methane sold (in bottles)	0,00	€	0,00	t
	Biochar sold	0,00	€	0,00	t
	Total revenue from additional sales	**0,00**	**€**		
Residues	Residue from dry anaerobic digester	0,00	€	0,00	t
	Residue from wet anaerobic digester	0,00	€	137,29	t
	Tar from gasification + water gas shift plant	0,00	€	4,58	t
	CO2 emitted	0,00	€	0,00	t
	Total cost of residues	**0,00**	**€**		
	Total operational cost without investment	**2.516.804.534,41**	**€**		
	Total operational cost with investment	**2.516.241.707,55**	**€**		
	Savings with introduction of P2G	**562.826,86**	**€**		

Figure 2. Sample of the Optimization Tool Excel interface Results sheet after a performed optimization

The mathematical background of the Optimization Tool is explained in the appendix to the user manual, available for download from [4]. Essentially the optimization within the tool is reduced to solving a convex optimization problem in the form of a Linear Program. This means that no heuristics is involved in the optimization procedure and that the true optimal configuration and operation schedule of the P2G hub is computed with the Optimization Tool.

The talk will focus on the usage of the Atlas and the Optimization Tool and examples of optimal P2G hubs parametrization for several locations in Croatia will be shown.

Key words: future energy, optimization tool, renewable

Plenary 2

A Way Out: Community Based Livestock Breeding Programs for Low Input Systems

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Summary

Over the last 80 years, breeding operations have changed the performance of many livestock populations dramatically. Hybrid laying hens are now laying more than 300 eggs a year and convert 2 kg of feed into 1 kg or egg mass, modern pigs convert 2.4 kg of feed into 1 kg of body weight gain. Milk production of cows in Austria and most other "developed" countries has more than doubled in the last 50 years. For small ruminant species (sheep and goat), changes have not been as dramatic but productivity improved substantially. Those changes, sometimes called livestock revolution, were based on similar procedures as those driving the green revolution with improved crops. They are essential in view of food security and the still dramatically growing human population.

Definition of complex breeding objectives based on the relative economic importance of traits is the starting point, routine recording of those traits is the next step and use of the data in complex statistical analyses aimed at ranking animals from genetically best to worst, termed genetic evaluation, provides the basis of the breeding operations of selecting and mating animals to be parents of the next generation. Nowadays, high throughput genomic data are routinely collected for very many animals and sensors of motion, rumination, methane emission and various other features produce huge amounts of data, all related to traits in the breeding objectives. Livestock breeding has become a biotech operation, and many scientists work of tools and methods related to breeding. Note that while poultry and pig breeding is often in the hands of international companies, cattle and small ruminants are mostly still bred by farmer cooperatives, but with similar sophistication.

The situation is dramatically different in many "developing" countries where breeding with its formalities and technicalities has not been successfully implemented. A breeding nucleus at a governmental center and distribution of best male animals form there to smallholder farmers is often considered a viable option, mostly because on farm recording of animals is deemed unfeasible. Nucleus breeding have been failing consistently, often due to mismanagement but also because the centers produced animals not preferred by the local farmers.

This failure has led part of the scientific community working on animal breeding in developing countries of Africa, Latin America and parts of Asia to a shift of paradigms. The central theme of this shift is to put the farmers in the center of breeding operations. This includes accepting perceptions and goals of farmers rather than only considering the relative economic importance of traits. Based on the experience of the authors of this presentation, farmers have a good understanding of the biology and heritability of traits, much better than generally assumed. Teaching farmers how to apply their knowledge when selecting best animals is crucial. Awareness of the importance of choosing very good male animals for breeding in generally lacking. While famers typically favor big animals in their herds, they typically sell the fast-growing male animals for quick cash income and keep slow growing animals in the herd for mating.

Community based breeding programs (CBBP) are a bottom-up approach to breeding programs, with scientists and governmental officials agreeing and working with communities (typically villages) of farmers. Breeding objectives and relative importance of traits are established with participatory approaches. Simple on-farm recording, typically with enumerators form the community, is established, recording data are entered using specific apps developed for the purpose, data are analyzed externally by scientists linked to the CBBP, using genetic evaluation procedures, and ranked lists of animals are transmitted back to farmers. Best young male animals, i.e. the next generation of breeding males, are selected by committees of farmers in the framework of an event, combining the ranking information from the genetic analysis with their own perception.

Starting from 2010 in Ethiopia, we and others have established a range of community based breeding programs for local sheep, goat, cattle, lama and alpaca populations in various countries. Positive genetic change for several local sheep CBBP populations has been evaluated in Ethiopia, and the national government has made CBBP the breeding method of choice for small ruminants in the country and farmer led breeding associations have been formed in most instances. While CBBP are only the start to national recording and breeding programs, they have created enormous awareness about the importance and feasibility of breeding programs with on-farm recording and farmer-led selection decisions for the choice of male breeding animals.

In conclusion, the concept of community-based breeding programs (CBBP) aims at increasing the productivity and profitability of indigenous breeds without undermining their resilience and genetic diversity, and without expensive interventions. This concept is very important for combatting hunger in economically disadvantaged societies. Very frequently, people claim poor performing local animals to be locally adapted.

***Locally adapted* is not an excuse for *poor performing*. Go for *locally adapted and well performing*, by breeding.**

Key words: animals, production, livestock breeding, programs

Importance of Crop Residue Management in Conservation Agriculture

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Summary

Climate Change (CC) today represent one of the most important and challenging existential threats at the local, regional and global level. These negative influences, which arise from drastically changing climate, are visible in all humans and natural aspects and sectors. One of the most important aspects, which is strongly connected with climate change and which is inevitably in a causally consequential relation relationship with it, is agriculture. To prevail these negative influences, many platforms strive to found some valuable and adequate sustainable approaches, measures and techniques. Many techniques (such as soil tillage, seeding/sowing, crop/plant protection, crop residue management) in crop and plant production, which is usually called "conventional", they are no longer adequate. They should be promoted/updated/renovated/upgraded/adapted into sustainable techniques. According aforementioned "many platforms", Conservation Agriculture (CA) belongs to the one of these and represent very successful platform in adaptation and mitigation strategy to CC. CA is highly adaptive concept and with relative very easy applicative measures on different levels; on local, regional and global scale.

CA as measure of adaptation to CC is based on three basic principles:

- Minimal soil mechanical disturbance,
- Permanent soil surface cover (with crop residues and/or growing crops),
- Crop rotation (species diversification).

All three basic principles are interconnected by crop residues, as one of the most important factors of CA, on different ways and levels, as it: way and intensity of soil tillage, mass and type of crop residue, type of crops, biological yields, harvesting quality, activity of soil biology, soil chemical and physical quality, agroecological conditions, crop residue management, etc. Most often definition of CA is according amount of crop residues on soil surface. According this criterion CA is defined as a crop production system where at least 30% (up to 100%) of the soil surface is covered with crop residues after all tillage treatments and sowing/seeding are performed. In comparison to CA, and using same criterion, conventional soil tillage with plowing has up to 15% and reduced soil tillage up to 30% (usually from 15-30%) of crop residues on soil surface.

Crop residues and their retention on the soil surface or near the soil surface have multiple and significant mostly positive, but in some cases conditionally negative impacts, especially in soil conservation tillage systems. Different effects of crop residues (positive or negative) on soil conditions and crop production (current and next growing crops) resulted from many factors, such as: amount, type and fragmentation of crop residues, different soil conditions in residues management, type of climate (dry or wet conditions), type of mechanization, intensity of crop rotation (short or intensified), etc. Generally, negative effect is mainly expressed through intensified development of disease and pests, slower soil surface warming and potential difficulties in soil preparation and sowing (large amount of residues). As the most important positive effects can be highlighted next: reduction of water and wind erosion, reduction of evaporation, better water infiltration, better water preserving, reduction of weed infection, intensification of soil biota etc. It is clearly visible from the definition that crop residues play a very important role in CA, and for this reason special attention is paid to this issue.

Measuring/assessment of the amount of crop residue can be performed in several different ways, with prescribed appropriate methodology for each method. The basis of each measurement method is that it is carried out after the sowing of the next crop, and the measured values are expressed as a percentage of the soil surface coverage with crop residues. There are three basic methods for measuring of crop residues:

a. line transects method (most popular and easy to use),
b. Photo comparison method (more possibilities: photo camera, drone, remote measurement – satellite, radar polarimetry),
c. Calculation method (complicated, demanding and time-consuming in creating but very easy to use).

There are number of modifications and adaptations of these based methods and it is important to emphasize that each method has its advantages and disadvantages, and that accuracy of the results depends on a large number of parameters (e.g. precision/calibration of the method, data collecting method, agroecological and agrotechnical conditions). But whichever method of measuring/assessment is used, it is essential for conservation soil tillage to ensure the best possible coverage of the soil surface with the crop residue.

Case study: The field experiment with different conservation tillage systems, different fertilization and soil conditioners, and different crops in rotation was conducted in 2021 in two different agroecological region in continental part of Croatian. Tillage treatments were: ST (standard tillage; plowing up to 30 cm and different number of secondary tillage treatments), CTD (conservation deep tillage; loosening up to 30 cm with a minimum of 30% of crop residues on the surface) and CTS (conservation shallow tillage; tillage up to 10 cm with a minimum 50% of crop residues on the surface). Method for estimation of residue cover (in %) was line-transect method, and it was performed after all soil tillage operations and after sowing next crop. Already in early stage of research, after second experimental year (maize was grown in first and soybean in second year) percentage of crop residue was higher than is expected, but in expected distribution on both experimental sites. Higher soil covering was measured in western part of Croatia and lower in easter part. As it expected, highest soil covering was on CTS on fertilization according recommendation with application of liming and lowest on ST with decreased fertilization without liming. Generally, soil surface covering with crop residues according treatments were as follows: CTS>CTD>ST.

Key words: conservation agriculture, conservation soil tillage, crop residues, maize, soybean

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Multiscale Imaging Approaches for Understanding and Crop Root Responses to Soil Environmental Stress

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Summary

The biophysical structure of the rhizosphere, the crucial zone where roots and soil interact, has a significant impact on how plant root systems develop to capture water and nutrients. Understanding these interactions has never been more important with respect to issues such as maximising inputs from the available land and potential issues associated with its degradation. With a rapidly increasing global population and the challenges modern agricultural practices face against climate change, maximising plant productivity and developing sustainable soil management strategies are vital for food security.

Understanding how plants respond to unfavourable environmental conditions can have many benefits to crop breeding programmes, for example, by the identification and selection of adaptive traits that confer stress resilience. Imaging based phenotyping methods are showing great promise to collect spatial and temporal information on both above and below ground components of plants. Until recently, investigation of the plant roots within their natural soil environment has mainly been limited to the use of destructive methods, such as direct observation following excavation and washing the soil from the roots. Although, these methods are simple and relatively quick to perform, information on the 3D structure of both the rhizosphere soil and the roots are typically lost. In recent years, non-invasive techniques such as X-ray Computed Tomography (CT) have shown great promise to overcome these challenges allowing visualisation and quantification plant roots in the undisturbed soil environment in three dimensions (3-D). Moreover, as the technique is non-destructive, if multiple scans of the same plant are made then it also is possible to quantify the temporal development of the plant root systems in response to their environment.

The Hounsfield Facility at University of Nottingham brings together a series of multiscale imaging platforms to capture the 3D structure of the soil, plant roots, leaves and canopies. The Facility currently has three X-ray Computed Tomography systems which allow detailed information of the 3D shape of the roots systems and how the develop over time to stress with the goal to discover resilience traits for the plant. To complement this technology, Laser Ablation Tomography (LAT) allows imaging of anatomical scale root traits and multispectral imaging allows measurement of plant canopies. This presentation will focus the use of these multiscale imaging techniques to provide insights into the influence of biotic and abiotic factors on both root system architecture and soil structural development. The importance of the volume of soil surrounding roots i.e. the rhizosphere, is well established particularly in terms of the complex microbiological and chemical gradients that exist there. Recently we have shown that imaging of the rhizosphere can shed new light on important mechanisms such as how a root responds to soil compaction. Previously it was considered that the strength or hardness of the soil was the major limitation to root development in soils with a high bulk density. However, we have shown that root growth is supressed by the hormone ethylene and that plants with ethylene insensitivity are capable of growing in soils at a high compaction offering new options for plant breeding. Understanding the complex interactions and interfaces in soil is vital for future efforts to maximising inputs from the available land and for developing sustainable soil management strategies that are urgently needed.

Key words: plant root phenotyping, environmental stress, sustainable agriculture, multiscale imaging, computed tomography, rhizosphere, soil

Crop Production, Climate Change and Data Galore: Where are We Now?

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Summary

Smart agriculture driven by large data sets allows prediction of phenotypes more precisely by training a model using data collected from multiple sources. Although data-driven agriculture evolves fast in terms of experience, applications, good practices and computation power, actual solutions to real-life problems are still limited. This is particularly true in the context of climate change. The aim is to demonstrate large data applications in crop research exemplified by genomic, phenomic, and enviromic maize data collected in Croatia.

First large data sets were generated in the field of genomics where high-throughput techniques were best developed comprising routinely hundreds of millions of DNA data points: 1872 maize inbred lines from two genotyping panels included 572 accessions of the historical inbreds were genotyped using the Axiom 600k array, and 1300 modern inbred lines which were genotyped by Illumina MaizeSNP50 technology with 56000 polymorphic SNP markers. High-density genotyping technologies offer a good representation of genomic physical maps, but with certain extent of redundancy due to the linkage disequilibrium dependent of population size and structure, as well as ascertainment bias caused by infeasibility to capture full scope of allelic diversity in diversity panels used to anchor genotyping arrays. Due to these constraints, generated genotyping data are pruned (regarding their informativeness) and filtered (based on the positional scoring quality).

On the other hand, generating large data framework in phenomics and enviromics started only recently with rapid developments in proximal and remote sensing, and the Internet of Things (IoT). Firstly, a high throughput multispectral proximal sensor was newly developed for real-time monitoring of plant physiological status in field conditions. The sensor is based on a 6x1 diode array with spectral response peaks at wavelengths representing the plant-emitted fluorescence and other important reflectance/emittance features. The reads are further arranged to obtain normalized difference vegetation indices (NDVIs). Secondly, weather data were collected using proximal sensors for real-time monitoring as well as using open satellite data collected from the platforms Agri4cast and Copernicus. Continuous and dense monitoring of crop physiological status and environmental parameters in field conditions using various IoT devices created large datasets.

However, it is challenging to develop a large-scale system that integrates a variety of heterogeneous data sources to provide farmers and agronomists with simple and usable tools, such as assessing current field conditions, estimating crop stress levels, or determining the best time to apply certain cultivation practice. Out of the large data most important characteristics (volume, velocity, variety, veracity), volume, velocity and veracity were best represented in genomic studies. Characteristics of phenomic and enviromic data were velocity and variety. Maturity of the large data solution using technology readiness levels (TRL) scheme started at lab environment and prototype stage and aims at a technical maturity of real-world small-scale deployment. Predicting maize phenotypes via statistical inference or machine learning, crop growth modelling and seasonal climate forecast will be discussed. Knowledge-based and data-driven approaches will be compared. In further development of data-driven agriculture, the key principles include understanding the ecosystem, collaboration, using open data and open sources. This can help to narrow the divide between agricultural research and practice.

Key words: climate change, crop production, large data, phenotype prediction, smart agriculture

Enhancing Resource-use Efficiency in Food Production

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Summary

Sustainable production of food for increasing world population (8 billion in November 2022) is a significant and multi-faceted challenge. Supplying crops with optimal amounts of resources required for growth (e.g. water, nutrients) is increasingly problematic because of intensifying severity and duration of droughts in many food-producing areas, greenhouse gas emissions during manufacturing as well as after application of nitrogen fertilizers, scarcity of non-renewable nutrient sources (e.g. phosphate rock) and environmental pollution associated with use of mineral fertilizers (e.g. nitrogen and phosphorus).

A recently discovered symbiosis between fungi and crops that has some similarities with mycorrhiza (hence, called 'nearly mycorrhiza', in Latin: feremycorrhiza) improves phosphorus nutrition of mycorrhizal crops such as wheat and barley as well as non-mycorrhizal ones (canola/oilseed rape). Feremycorrhizal fungus *Austroboletus occidentalis* has lost most of its saprotrophic capacity, thus relying on supply of simple sugars (hexoses) exuded by roots. Hence, it lives near roots, but does not enter/colonize them. Feremycorrhizal fungus solubilizes phosphorus-containing minerals in the crop rhizosphere through exudation of organic acid anions, enhancing phosphorus uptake by crop roots. Feremycorrhiza also improves drought tolerance of these crops.

Biological nitrogen fixation is used in agricultural practice to improve nitrogen supply to leguminous crops that can form symbiosis with various rhizobial bacteria via root nodules, but that option is not available for non-legume crops such as cereals and oilseeds. Feremycorrhizal fungus synergistically enhances biological nitrogen fixation by free-living soil diazotrophs in the crop rhizosphere, improving the supply of nitrogen to cereal and oilseed crops.

Feremycorrhizal fungus is used in developing biofertilizers to improve phosphorus and nitrogen nutrition and drought resistance of various crops, contributing to improved resource-use efficiency and enhanced sustainability of food production.

Key words: crop nutrition, free-living diazotrophs, feremycorrhiza, fungus, mutualism

Sessions

Circular Bioeconomy Model for Biofuel Production from Aquaculture Waste

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Summary

Constant growth of the human population, increasing demand for high-value protein food and increased consumption of the so-called "healthy foods", have caused a significant increase in the demand for aquaculture products, which has resulted in a continuous growth of aquaculture production over the last decades. Estimates show that global production will reach 109 million tons by 2030, which is an increase of about 25% compared to the production achieved in 2020. The increase in production, necessarily accompanied by an increase in processing and preparation of products for the market, inevitably leads to an increase in the amount of waste, or by-products, which in some cases can reach 70% of the basic mass of raw material. Until recently, most of it was thrown away or tried to be disposed of as worthless waste. The development and implementation of complex modern processing technologies has attracted the attention of scientists since by-products are recognized as a significant source of biologically valuable substances and can be considered as secondary raw material to produce various marketable products. The various uses of the by-products obtained during the processing of aquatic organisms are determined by their technological potential, which is estimated by the general chemical composition, as well as the biological value of proteins, lipids, etc. Most often, they are used in the production of feed for livestock and fish, serve as raw materials to produce biofuel, are for the extraction of chitin and collagen, or become valuable ingredients in human nutrition. This paper presents the latest trends and possibilities of utilizing aquaculture by-products created during production and processing as a source for biofuel production. In addition, the basic systems for the production of biofuels from aquaculture waste, which in addition to socio-economic and environmental, can also increase energy sustainability of aquaculture production are described.

Key words: aquaculture by-products, biogas, biodiesel, energy sustainability

The New Role of Integrative Plant Physiology in Agricultural Research in Term of Sustainability

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Summary

Within biology, the various fields of science investigate living organisms from different points of view. The study of the essence of plant life from operational/functional view, the life processes behind life phenomena, is the task of physiology. Plant physiology therefore studies the life processes reflected in the life phenomena with the aim of understanding them, by learning about their laws and discovering the interaction between the plant and its environment, it can develop the possibilities of influencing and controlling the life processes in a planned manner in order to achieve more and better crops. Therefore, plant physiology in agricultural research is not a science by itself, but is closely related to agronomy and combines and conveys the results of other sub-sciences of plant science, as well as biochemistry, biophysics, soil science and agrochemistry to practice. During the solution of the problems raised by the production and cultivation practice, plant physiology, based on the results of the mentioned related sciences, reaches the conclusion through their synthesis and special re-evaluation, which raises new ideas - often directly - for the practice. Plant physiology is a synthesizing and integrative science, which has more and more role in plant production in terms of sustainable. The application of results derived from plant physiology research has resulted in significant technological advances, mainly in plant production during the last decades. Primarily thanks to the fast development of *in vivo* plant-measurement technical solutions, nowadays basic plant physiology measurements are even more useful for plant production. For example, by validating the results of remote sensing, we can react more effectively to plant responses, which are key to the effects of climate change, both in terms of agro-environmental protection and food production.

Key words: future agriculture, smart plant production, validation, ecophysiology, stress physiology

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Evaluation of the Impacts of Stressors on Crops in the Context of Climate Change

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Summary

Climate change affects agricultural lands and crops most noticeably. Any unfavorable conditions or substances that have impacts on a plant's metabolism, growth, and development are regarded as stress factors. Plant stresses can be divided into natural and anthropogenic stress factors or biotic and abiotic stresses. The goal of this study is to summarize my team's work related to the effects of various stress factors on crops. The impacts of different abiotic and biotic stressors were examined during the last years. Soil pH and aluminum stress are among the most important abiotic stresses which affect plants' metabolism and can induce oxidative stress and reduced growth, and yield quality. The examinations of the impact of biotic stressors on plants' morphological, physiological, biochemical, and quality parameters are as important as the examinations of the effects of abiotic ones. In addition, the application of different fertilizers - like fertilizers containing amino acids or microelements - and industrial by-products, such as sewage sludge or compost, also can act as a stressor. A high amount of nutrients acts as a stress factor after a short time of foliar fertilizer application. Sometimes stresses have no visible symptoms on plants and the effects of stressors are only reflected in yield parameters. This can be explained by a correlation between increased antioxidant enzyme activity and yield quality and quantity.

Key words: abiotic stress, antioxidant enzymes, biotic stress, climate change, crops

Assessment of Water Footprint for Milk Production in Zebu and Crossbred Cattle, and Buffaloes at Organized Farm Conditions in Northern India

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Summary

The present study was performed to assess the water footprint to harvest the first kg of milk after initiation of lactation and per kg of milk production in Tharparkar (N=94), Sahiwal (N=61), and crossbred cows (N=177), and Murrah buffaloes (N=137) under organized farm conditions in Northern India. Drinking water intake of the individual animals and water required to grow feed and fodder were taken into account. The water demand for washing of sheds, washing of animals, water usage thorough sprinklers, and water usage at the milking parlor were measured using water meter. Results revealed that water required from birth to the day of first calving in Tharparkar, Sahiwal, crossbred cows and Murrah buffaloes was 2862083 L/animal, 2552742 L/animal, 2801903 L/animal, and 3846955 L/animal, respectively. The average daily water usage from birth to initiation of lactation in Tharparkar, Sahiwal, crossbred cows and Murrah buffaloes was 2456 L/animal/d, 2441 L/animal/d, 3024 L/animal/d, and 3117 L/animal/d, respectively. The lactating crossbred cows (6559 L/animal/d) required significantly ($P<0.001$) higher water than Murrah buffaloes (5512 L/animal/d) followed by Tharparkar (4446 L/animal/d) and Sahiwal cows (4318 L/animal/d). The water footprint for milk production was significantly ($P<0.001$) higher in Sahiwal cows (881 L/kg milk) followed by Tharparkar cows (868 L/kg milk), Murrah buffaloes (833 L/kg milk), and crossbred cows (658 L/kg milk) under organized farm conditions.

Key words: water footprint, milk, zebu cattle, crossbred cow, Murrah buffalo

The Role of Sustainable Energy in Development of Rural Tourism in Slavonija and Baranja Area

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Summary

Sustainable energy is an energy-efficient way of producing and using energy with little environmental harmful impact. In order to determine the possibility of its application on family farms in the Slavonia and Baranja area, a survey research was performed on 172 agricultural producers wich part of their products sell through the tourist gastronomic offer. Gastronomy is one of the key elements for development of rural tourism, in which the continuous fresh food supply is important. It was found that 50% of respondents use solid fuel, 28% gas, 19% electricity, and 2% oil on their farms. Of renewable energy sources (RES), 70% of respondents believe that the sun has the greatest potential for application, 10% biofuels, 6% biomass, 1-2% wind, geothermal and hydropower, and 9% of respondents consider this sources unsuitable. In terms of investing in the use of RES, 85 respondents have positive opinion, of which 72% would invest in solar energy, 12% in biofuels, and 4% in wind. 92 respondents would not invest in RES and as the reason they primarily state finances (22%) and insufficient education (19%). On the other hand, respondents believe that the use of RES is very important for the creation of new jobs and improved quality of life (118 respondents), reduction of fossil fuel consumption, dependence on oil and improved energy safety (83 respondents). The smallest number of participants consider that the mentioned facts for the use of RES are not important, which indicates a high awareness of the importance and use of sustainable energy in their activity.

Key words: rural tourism, sustainable energy, renewable energy sources

Development of the New Method for Frost Detection in Croatia

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Summary

The rise in temperature in recent years has significantly affected the entire biosphere, including the beginning and duration of the growing season. The earlier start of the growing season is visible in many crops and trees. Although an increase is generally visible in all temperatures (minimum, maximum, and mean daily), this does not exclude the occurrence of extreme weather conditions that can damage crops. In particular, a special danger is related to frost. Since there is no unequivocal method for determination of the occurrence of a frost event, many studies try to determine the risk of its occurrence using different criteria. This study aimed to determine the best method for predicting the frost event in the study area. In that matter, several already introduced methods, were tested on data and observations from meteorological stations all over Croatia. Also, a new approach has been tested, in which frost day is described with the criterion: $T_{min} < 3$ °C and dew point temperature (calculated using the minimum temperature) $T_d < 0$ °C. It was this method that showed the best results. The probability of detection for this method is higher than 90%, and the probability of false detection was around 15%. Also, all methods were subjected to the Signal Detection Theory. The new approach showed the best results again with a high accuracy index and not showing bias to over or under predicting.

Considering all that, this new approach to frost prediction has proven to be very good and provides the possibility provides the ability to predict frost in the future as well as forecast frost a few days ahead which can be significant for the protection of crops.

Key words: frost, dew point temperature, minimum temperature

Tackling the Climate Change Through Collaborative Approach

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Summary

According to European Environment Agency, 32 EU member suffered loss of €450-520 billion as direct result of natural and technological disasters occurring in the period from 1980 to 2020. Therefore, the EU and the rest of the World are forced to produce a systematic assessment of the risks caused by natural disasters due to increasingly widespread climate changes and to adopt global guidelines for reducing environmental pollution and protecting the climate and environment. Through the intensification of public investment and the redirection of capital, World is being steered towards sustainable development and inclusive growth.

Key words: climate change, legislative, emission reduction, climate policies

Introduction

For the past three decades, the World's economy has been confronted by the large-scale economy losses as a result of the uncontrollable climate change. According to a study by the European Environment Agency in 2010, more than 11 mill. people were directly affected by natural and technological disasters, with the highest percentage of human casualties resulting from the large earthquake in Izmit, Turkey in 1999 (17,000 victims) and the heat wave occurring in 2003 over the European continent (70,000 victims). Members of the European Economic Area (EEA) experienced a loss around €150 bill. in the period from 1998 to 2009. Other hazardous events led to further overall increase to as much as €200 bill. The biggest natural disasters recorded in Europe are the floods in Italy, France and the Swiss Alps in 2000 (€12 bill. loss), floods in Central Europe in 2002 and 2007 in the United Kingdom (€20 bill. loss), the earthquake in Turkey 1999 (€11 bill. loss), the earthquake in Italy in 2009 (€2 bill. loss), the winter storms in Central Europe in 1999 (more than €18 bill. loss) and 2007 (€8 bill. loss). The biggest technological disasters, such as oil spills from tankers in France in 1999 and Spain in 2002, toxic poison spills in Spain in 1999 and Romania in 2000, caused an additional loss around €50 bill. and ecological disasters of immeasurable proportions. According to estimates, Europe is affected by as many as 70000 forest fires every year, especially in the Mediterranean area where 70% of fires occur, and the total damage is immeasurable (Skov and Svenning, 2004), as 0.5 mill. hectares of European forests have been destroyed. Other significant natural disasters that should be highlighted are volcanic eruptions, the most significant of which was in 2010 in Iceland, when air traffic in Central and Western Europe was completely blocked by clouds of volcanic dust and smoke (EEA, 2010). According to the report of the Intergovernmental Panel on Climate Change (IPCC) from 2007, the most significant impact of climate change will be expressed in the form of an increase in the number of incidents related to natural disasters (IPCC, 2007). A study from 2013 predicts an increase in vulnerability due to natural disasters for as many as 47 European regions. According to Lung and his colleagues, the most threatened countries of central Europe, are the ones most threatened by the recurrence of large forest fires and floods. The consequences of such natural disasters are greatly aggravated by the demographic picture of Europe, where the average age of the population is increasing (Lung et al., 2013). Summer of 2022 showed that the horror of our past laid-back attitude towards the pollution has finally taken its toll. European territories were hit by intense heat waves, with the average recorded temperatures being the highest in history of measurements and going over 40 °C. This substantially led to droughts and forest fires, burning down as much as 700000 hectares in the European Union (EU). In Asia, rapid Himalayan glacier melting caused flood in one third of Pakistan, major typhoon caused major casualties in South Korea, while USA has been struck with wildfires (Bruyninckx, H., EEA, 2022). If we continue with such a vast deforestation, green house emission, atmosphere pollution and land destruction, small island and miles of coast line will be submerged, leaving millions of people homeless. Due to Artic ice melting and the rising temperature in oceans, as much as 90 % of coral reefs will be lost. All of the above, leads to extinction in thousands of animal and plant species. Although attempts have been made for decades to replace the systematic impoverishment of the planet earth by depletion of fossil fuels, and the introduction of the renewable and alternative energy sources, the use of alternative energy sources in everyday life have not been adopted. Negative economic indicators, social insecurity and natural disasters are an inevitable consequence of climate pollution, and a secondary indication is the increase in violent conflicts on European soil (Tol and Wagner, 2010). Therefore, the EU was forced to produce a systematic assessment of the risks caused by natural disasters due to increasingly widespread climate changes and to adopt global guidelines for reducing environmental pollution and protecting the climate and environment in the form of the European Green Deal (European Green Deal, 2019). At COP26 Climate Summit in Glasgow held at the end of 2021, pledges were made by 200 countries, but all of the crucial questions were left inconclusivly answered. All signing nations agreed on the agreement, however without clear agenda on how to solve global warming, under what terms and what are the crucial guidelines to cut emission in the next decade. The language used to outline this agreement was also softened, from phasing out the coal consumption to phasing down on coal consumption. From September 2009, when G20 leaders pledged to deliver more than $100 bill. to supplement emerging market and developing countries and to take globally coordinated action, such as climate change and food security, at the Pittsburgh Summit, the pledge was left mostly unresolved, at least in the sense of helping developing countries in implementing the renewable energy harvesting and fighting the climate change. To accomplish the net-zero emissions by 2050, all governments are required to forcefully and coherently work together to strengthen and implement their energy and climate policies.

Past

On September 16th 1987, *the Montreal Protocol on Substances that Deplete the Ozone Layer* was signed by 46 countries and entered into force on January 1st 1989. This international treaty was designed to protect the ozone layer by phasing out the production of numerous substances, responsible for ozone depletion. It regulates the production and consumption of the ozone depleting substances (ODS) in thousands of applications across more than 240 industrial sectors and has undergone six revisions. This protocol is the only United Nations (UN) treaty ever to be ratified by every country on Earth - all 198 members (Montreal Protocol, 1989). The Montreal Protocol has succeeded in eliminating nearly 99% of ODS. On December 11th 1999, *the Kyoto Protocol* to the UN Framework Convention on Climate Change was signed as another international treaty, counting to as much as 84 signatories. Currently, there are 192 parties to the Kyoto Protocol, and every one of them has committed to limit and reduce greenhouse gases (GHG) emissions in accordance with agreed individual targets. The UN Framework Convention on Climate Change entered into force on March 21st 1994, with 198 countries as Parties to the Convention. The main goal of the Convention and the Kyoto Protocol is to stabilize the GHG concentrations interfering with the climate system. In 2015, *the Paris Agreement on Climate Change* was adopted within the framework of the UN Convention on Climate Change. It was the first general legally binding global climate agreement and a binding historic document on climate pollution prevention after the Kyoto Protocol. The Paris Agreement highlighted the need to introduce more environmentally friendly energies in our everyday life. The possibility of increasing the number of the nuclear power plants and the greater substitution of fossil fuels with nuclear energy was highlighted due to the low emission of carbon gases, which make up a third of the GHG emission released into the atmosphere. The main goal of the agreement is to keep the increase in the global average temperature at a level that is significantly lower than 2 °C, ensure food supply and strengthen the capacities of countries in the fight against the consequences of climate change in a way that encourages the development of new green technologies and helps weaker, less economically developed members in the realization of its national plans on reducing GHG emissions. Also, it encourages the ability to adapt and fight against the negative impacts of climate change and to increase resilience to climate change. By cultivating economic development with low levels of GHG emissions in a way that does not jeopardize food production and harmonizing financial flows, the Paris Agreement was set to stop the negative trend in environmental pollution (IAEA, 2019; Paris Agreement, 2016). In 2017, the President of the United States of America (USA), Donald Trump, announced that he would withdraw from the implementation of the Paris Agreement on climate change if the Agreement would not allow the USA to reopen negotiations, wanting to protect the fossil fuel industry, especially coal mining industry, on American soil. The ratification of the Paris Agreement on climate change and the adoption of all the set goals has been seriously shaken. President Joe Biden however, re-entered the USA into the agreement during his first months in office.

Present

At the end of 2019, *the European Green Deal* (EGD) was adopted. The EGD seeks to initiate the necessary changes in the social and economic trends of Europe, in order to protect the population from the increasingly devastating consequences of natural disasters and reduce pollution environment. Through the intensification of public investment and the redirection of capital, Europe is being steered towards sustainable development and inclusive growth. The EGD mandates the increasing inclusion of renewable energy sources in the development of the energy sector. Further improvements are proposed through implementation of new industrial policies based on a sustainable circular economy, greater investments in energy-efficient construction, the reduction of greenhouse gas emissions by restructuring European roads and encouraging the use of alternative fuels in transportation. Another main objective proposed by the EGD is solely ecological, by encouraging biodiversity and investment in afforestation and protection of sea and watercourses, encouraging investment in ecologically acceptable agricultural production and introducing a zero-tolerance approach for air, water and soil pollution (European Green Deal: Summary, 2019). According to a study by the International Energy Agency (IEA), energy demand by 2040 will require $60 trill. in investment to ensure global energy supply. Almost 40% of these investments are still projected to deplete fossil fuels (oil, natural gas, and coal) or build fossil fuel-powered power plants. Although this study predicts a reduction of as much as 30% of investments compared to the previous period from 2000 to 2015, as much as 70% of investments were spent on the depletion of fossil fuels, the numbers are still devastating. Just for example, an average 1,000 MW coal-fired thermal power plant needs a supply of 8,600 tons of coal every day (World Energy Outlook 2018, 2018). In accordance with the recommendations of the EGD, Europe is introducing the decarbonization of energy systems and the elimination of the risk of energy poverty. Thanks to this initiative, in the period from 1990 to 2018, GHG emissions were reduced by 23%.

The main goal of the deal is the development of the energy sector based on renewable sources with the gradual abolition of the use of coal and the decarbonization of gas, and the energy supply must be safe and affordable for consumers and companies. The problem of large investments, which are often required by plants with alternative and renewable energy sources, is also sought to be solved by this draft. This would enable the creation of a global European infrastructure and regulatory framework through the Regulation on the Trans-European Energy Network TEN-E, which would encourage the production of environmentally friendly energy at more affordable prices (European Green Deal, 2019). The strategy of the EU also includes large investments in digitization and the implementation of new innovative technologies. The EU intends to increase its competitive advantage in the field of clean technologies by applying innovative technologies and sustainable solutions, not only in the industrial but also in the food sector. The restructuring of the current industrial branches, overloaded by non-investment in new technologies and the use of fossil fuels, would ensure the creation of a sustainable model of inclusive growth. Through digital transformation, the circular economy and the transition of all sectors to more climate-neutral energy sources, it is planned to achieve an industrial revolution more in line with the needs of the labour force and environmental requirements for reducing pollution. Economic entities in Europe will be connected in cyclical chains whose primary goal is to encourage sustainable production with maximum recycling of raw materials and their reintroduction into production processes. In the proposals of the Commission for the common agricultural policy for the period 2021-2027, it is prescribed that at least 40% of the total budget of the common agricultural policy and at least 30% of the Maritime and Fisheries Fund should contribute to climate action (European Green Deal, 2019). From October 31st to November 13th 2021, the United Kingdom hosted the 26th UN Climate Change Conference of the Parties (COP26) in Glasgow. The COP26 summit was made with the intention that all of the Paris Agreement parties revisit their climate pledges made in the 2015. Currently, the world is not on track to limit global warming to 1.5 °C. The COP26 Glasgow Climate Pact is set to deliver 4 crucial goals: 1) Mitigation - reducing emissions; 2) Adaptation - helping those already impacted by climate change; 3) Finance - enabling countries to deliver on their climate goals, and finally 4) Collaboration - working together to deliver even greater action (COP26 Glasgow Climate Pact, 2021). All of the Conference of the Parties

(COP) in Glasgow agreed to fulfil the pledge of providing $100 bill. annually to developing countries; to collectively work in reducing the gap between existing emission reduction plans and requirements needed to limit global warming to 1.5 °C; and last but not least, all of the signing nations are called upon to phase down unabated coal power and inefficient subsidies for fossil fuels.

Future: Creating the legislative framework that works

Despite everything, the year 2020 also brought a series of problems in the implementation of positive economic changes aimed at reducing environmental pollution, primarily due to the Covid-19 pandemic. More than 6.5 mill. have lost their lives to Covid-19 so far (Bruyninckx, H., EEA, 2022). In the light of recent events, EU imposed sanctions on Russia, which is forcing EU members to look for new energy sources in order to cut dependency on natural gas from Russian territory. Consequently, the EU is not only dealing with the aftermath of the Covid 19 but also with the emerging energy crises forcing delays in the EGD implementation. According to EGD, the aim is to transform the EU into a prosperous society, with net zero emissions (NZE) of GHG in 2050. But is this scenario even possible in the light of this new events, and was overly ambitious in the first place? In 2021, emissions rose record heights by more than 6% or by 1.9 Gt to reach 36.6 Gt, due to the post-pandemic economic growth, slow progress in improving energy intensity and a surge in coal demands. According to IEA, the scaling up of clean technology supply chains to meet the surge in deployment projected in the NZE scenario are possible by deploying low emissions sources, such as modern bioenergy, wind and solar energy, rising by around 35 EJ and 28 EJ respectively to 2030. Extra focus should be added in deploying hydrogen-based fuels in heavy industry and long-distance transport to reach around 10% share in total final consumption by 2050, while bioenergy should reach around 15% of total final consumption in 2050. According to IEA, new jobs in emerging clean energy industries could reach 40 million by 2030, thus outweighing job losses in the fossil fuel-related industries (World Energy Outlook 2022, 2022).

Maybe new UN Climate Change Conference of the Parties, set to be held in November 2022 in Egypt, will yield with more explicit and straightforward actions on climate change deceleration and finding more ecologically acceptable solution to energy harvesting. In order to make a smooth transition to renewable and “greener” energy sources, few disadvantages of renewable energy utilization will need to be cleared. Not everything is as perfect as one could imagine when discussing alternative energy. The renewable energy sources have their shortcomings just as any other energy source. First of all, the renewable sources are location and weather dependent and have large daily oscillations in the availability. Second of all, their volatility and unpredictability impose significant limitations in electricity generation. Third of all, the renewable energy sources such as wind or solar plants have a lower ratio of produced energy to the area occupied by the power plant, compared to fossil fuel power plants. Renewable energy plants require larger areas to produce the same amount of the energy compared to the traditional fossil fuel plants and achieve relatively lower energy efficiency as seen in Table 1.

Table 1. Area occupied by single power plant in accordance with of fuel type (Mihelić-Bogdanić, 1985)

Type of energy	Power	Necessary construction area (m^2)					
		Nuclear power plant	Fossil fuel power plant	Solar power plant	Wind turbine power plant	Geothermal power plant	Biomass power planr
Thermal	100 MW_t	9800	25392	$1.7*10^6$	-	$33*10^6$	$46*10^6$
Electrcal	100 MW_e	45206	116520	$5.8*10^6$	$36.28*10^6$	$142*10^6$	$138*10^6$

For comparison, energy efficiency of the oil-fired thermal power plants is 38 to 44%, coal-fired is 39 to 47%, gas thermal up to 39%, gas thermal power plants in a combined process is up to 58%, nuclear power plant has a relatively low energy efficiency of 33 to 36%. Renewable energy power plants can reach relatively lower energy efficiency, with biomass and biogas power plants of 30 to 40%, waste power plants from 22 to 28%, wind power plant has an energy efficiency of about 35% to 45%, while photovoltaic and geothermal power plants have the lowest energy efficiency of 15%. The only exception considering efficiency can be seen in large hydropower plants with the highest energy efficiency of 95%, however they are not classified as renewable energy sources and they affect the biodiversity in the area located. The renewable sources generally operate shorter at maximum utilized capacity in one-year span comparing to traditional fossil fuel power plants. The coal-, gas-fired and nuclear power plants operate on average up to 7500 h/year at full power, while renewable energy plants on average operate at only about 2000 h/year at maximum power (Maradin, 2021). Fifth reason to tackle renewable energy usage are monetary nature, and those are of primary concern for less developed countries. Most renewable energy sources, except the biomass plants, yield higher capital costs, management and maintenance costs. On the other hand, the biomass plants require large amounts of raw materials, making it doubtful on the ecological acceptability of cultivating vast area of quick growing timber (often genetically altered or atypical for specific ecosystem). Last but not least, recycling the renewable-capturing technology is still in it's infancy. Widely used solar photovoltaic (PV) panels tend to create large amounts of electronic waste at the end of their 25-year lifecycle. New PV technologies are increasing cell efficiency and lowering production/installation costs, but are produced from toxic materials or materials with unknown health and environmental risks. Most of the renewable energy harvesting technology hasn't solved the problem in securely producing or disposing supplying batteries, wind turbine blades, worn out PV cells, etc. The wind turbines often produce noise up to 100 dB or low-frequency noise from 20 to 200 Hz (noise pollution), which also brings to spotlight concerns on electromagnetic interference. Flashing lights installed at the top of the turbines alarm planes but also create light pollution. Many birds, bats and other flying animals are often struck down by rotating blades of wind turbines. When installing wind turbine fields, kilometres of access roads and power lines should be built and kilometres of land deforest. Using hydrogen fuel cells in transport systems also shows few shortcomings. Although theoretically clean energy, hydrogen should be supercooled to liquid state below -253 °C or contained as compressed gas, which is energy intensive. Liquefaction requires insulated vessels and massive refrigeration power, and when placed into cars showed problems such as explosive gas build up and water leakage (Zehner, 2012). As seen from the above examples, the renewables are not the cleanest energy on the planet as long as the shortcomings aren't solved. However, by being aware of the problems, all of us can join in solving those shortcomings, to create better, safer and greener future.

Conclusion

The Montreal Protocol, Kyoto Protocol, Paris Agreement on Climate Change, COP26 Glasgow Summit and the European Green Plan mandate the increasing inclusion of renewable energy sources in the development of the energy sector, the encouragement of a new industrial policy based on a sustainable circular economy, greater investments in energy-efficient construction, the reduction of greenhouse gas emissions by restructuring roads and encouraging the use of alternative types of fuel in transport, encouraging biodiversity and investment in afforestation and protection of sea and water courses, encouraging investment in ecologically acceptable agricultural production and introducing a zero tolerance rate for air, water and soil pollution. However, all of those efforts will remain cold facts on paper until there is a strict consensus in finding workable solution to burning problem of climate change, forcing unified approach from both developed and undeveloped countries around the globe to find environmentally friendly way of producing and harvesting enough energy.

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