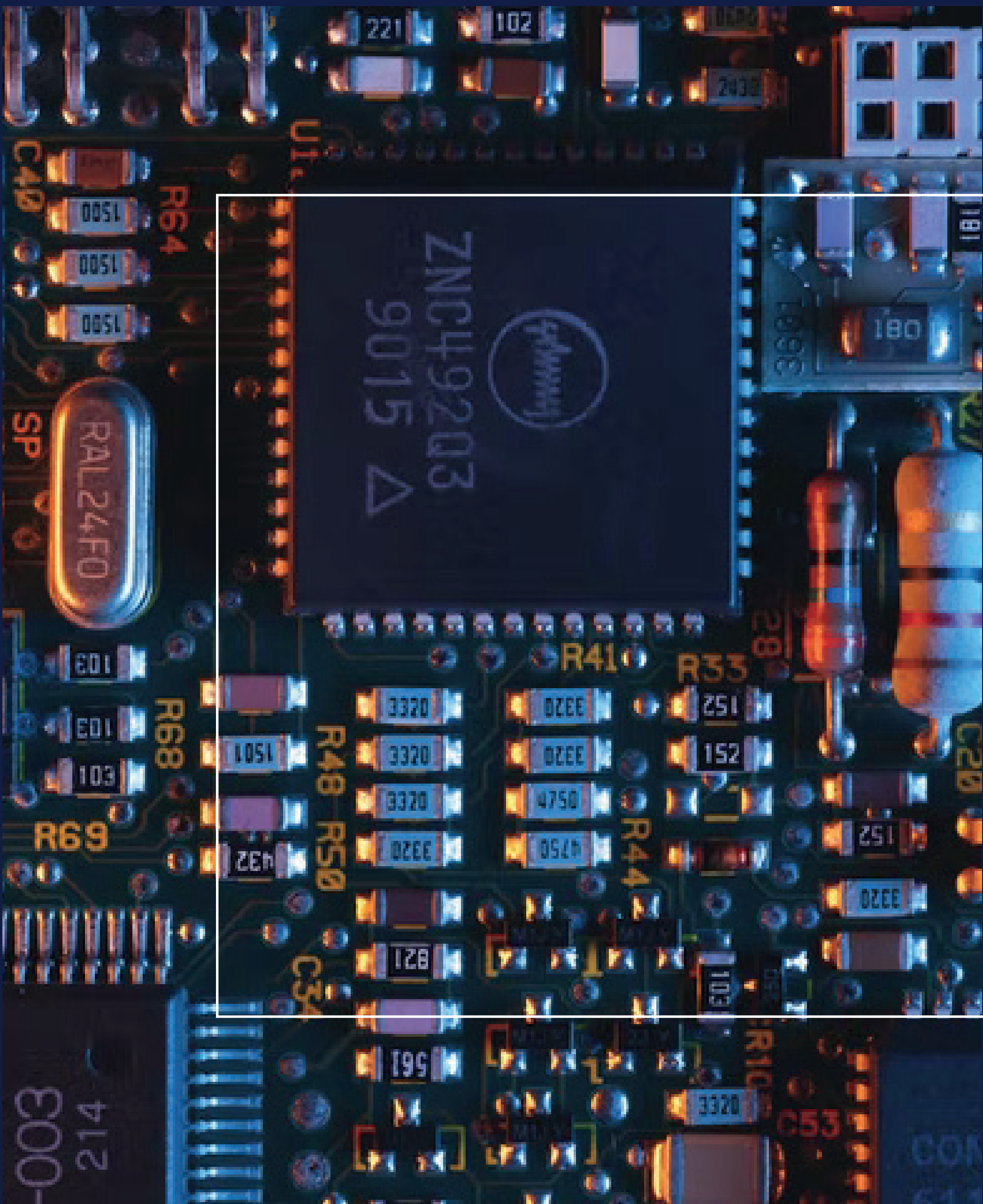
“LOS OBJETIVOS DE DESARROLLO SOSTENIBLE DEMANDAN MAYOR ELECTRIFICACIÓN Y MÁS ELECTRÓNICA DE POTENCIA”

PROF. FREDE BLAABJERG



En este número de In Genium dedicado a los Objetivos de Desarrollo Sostenibles (ODS) definidos por la ONU, desde la Sección de Ing. Eléctrica, Electrónica e Informática, invitamos al Prof. Frede Blaabjerg, de la Universidad de Aalborg en Dinamarca, a escribir un artículo para la revista. El Prof. Blaabjerg ha trabajado por más de 30 años en temas de Electrónica de Potencia aplicada a sistemas de energía y accedió gentilmente a escribir un artículo especial para In-Genium.

El artículo está dividido en cuatro partes. La primera de ellas está dedicada a dar una visión global del rol de la electrónica de potencia para dar cumplimiento a los ODS establecidos por la ONU. Los dispositivos de electrónica de potencia son aquellos encargados de convertir una forma de energía eléctrica en otra, ya sea en Corriente Continua (CC) o corriente Alterna (AC), con distintas frecuencias, o niveles de tensión y/o de corriente. Estos dispositivos permiten una fácil integración de las fuentes de energías alternativas a la red eléctrica existente.

Las Naciones Unidas, con la participación de la Conferencia de las Partes (COP), que abarca a 196 países y la Unión Europea (UE) firmantes de la Convención Marco de las Naciones Unidas sobre el Cambio Climático (CMNUCC); acordaron 17 objetivos comunes para lograr un planeta mucho mejor para vivir en él, es decir los ODS. Estos son muy amplios, y la tecnología de los convertidores electrónicos de potencia puede contribuir con muchos de ellos: por ejemplo, proveer energía eléctrica a más de 1 billón de personas que hoy no la tienen, en forma mucho más económica que extendiendo la red eléctrica existente. Relativo a este punto el Prof. Blaabjerg destaca que la Power Electronics Society de IEEE (Institute of Electrical and Electronics Engineers) está realizando una competencia internacional buscando soluciones técnicas innovadoras para mejorar la calidad de vida de la mayor cantidad de gente posible alrededor del mundo, en particular aquellas con una pobre provisión de energía eléctrica. (https://www.ieee-pels.org/programs-projects/empower-a-billion-lives)

La segunda parte del artículo, está dedicada a las direcciones claves para lograr un futuro sostenible. La primera clave es satisfacer la demanda de energía creciente, la segunda es desarrollar una producción de energía sostenible a largo plazo, de modo de obtener la necesaria descarbonización del planeta. Es imprescindible un uso más eficiente de la energía, la electrificación del transporte es un ejemplo de ello; la cual a su vez contribuirá a disminuir la polución de las ciudades tanto en lo referente a emisión de gases como a la contaminación sonora. También es necesario desarrollar sistemas de generación de energía, renovables y sostenibles, En ellos juega un rol esencial la electrónica de potencia así como la digitalización de los sistemas, para su mejor comunicación y control. Hoy los combustibles fósiles proveen el 60% de la energía consumida en el mundo, mientras se desea reducirlos a un mínimo para 2050, para lo cual es imprescindible un aumento de la generación con fuentes renovables y alternativas. Hay que reconocer que incorporar una tecnología novedosa en el sector energético es costoso y difícil de llevar a cabo desde su idea inicial hasta el producto final, especialmente si el precio de la energía por unidad es generalmente bajo.

La tercer parte trata de la modernización y digitalización de los sistemas energéticos. Estos sistemas deben ser capaces de acoplar diferentes fuentes de energía (no sólo eléctrica) y ser capaces de tener una operación robusta. Para ello es necesario el almacenamiento de una gran cantidad de datos (big data). Entre otras cosas el uso de inteligencia artificial permitirá modernizar los sistemas de energía. Esta modernización conlleva el incremento de nuevos consumos, como la electrificación del transporte y el crecimiento de los centros de datos. Un concepto importante es cómo lograr mayor capacidad de almacenamiento de energía, no sólo en forma eléctrica (baterías de distinto tipo), sino su conversión en otros combustibles (Power to X o PtX), por ejemplo el hidrógeno. Éste último prevé la conversión del excedente de energía eléctrica en otros combustibles que ofrezcan mayor facilidad de almacenamiento a largo plazo. Dentro de la modernización de los sistemas de energía, las regulaciones y los Estándares juegan un rol esencial para lograr los objetivos deseados en forma global.

La cuarta y última parte del artículo, destaca la necesidad de algunos avances disruptivos para lograr la modernización deseada. Por ejemplo es imprescindible mejorar fuertemente los rendimientos de los sistemas de conversión PtX. Es posible pensar en cables superconductores para la transmisión de energía? Es imprescindible lograr una gran flexibilidad y conexión entre las distintas fuentes y transportes de energía.

Es muy importante tomar conciencia y tener medida de cómo cada uno está contribuyendo al logro de los ODS. El Prof. Blaabjerg nos comenta que en Dinamarca el ranking de Universidades incluye una medida de los esfuerzos que ellas realizan para el cumplimiento de los ODS (https://www.aau.dk/digitalAssets/1096/1096663_aau-sdg-report-2021.pdf)

GLOBAL GOALS FOR A BETTER AND MORE SUSTAINABLE WORLD DEMANDING ELECTRIFICATION AND POWER ELECTRONICS

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I.GLOBAL VIEWS - GLOBAL GOALS

I have been working with energy for more than 30 years in my profession and even longer time as it has been a major interest of my life. The engagement comes from that we need energy as it is a fundamental condition for the world to be modernized and bring better life to human beings on the planet. Professionally speaking, I have been working with electrical power conversion where power electronic devices are able to handle high voltages and currents for converting electrical power from one level to another, and thereby controlling an energy process. It can be from alternating current (AC) sources/voltages to direct current (DC) sources/voltages and opposite. Today it can be done with a very high efficiency – typically higher than 96 % and in some cases even above 99% with the newest power devices. In the research we have been applying those principles for renewable power generation and large scale energy saving applications in the society, and using power electronics made an easy integration into the existing electricity power grid. An example of a modern energy system is shown in Fig. 1 – where all the bricks illustrated are power electronic conversion units (AC to DC or DC to AC).

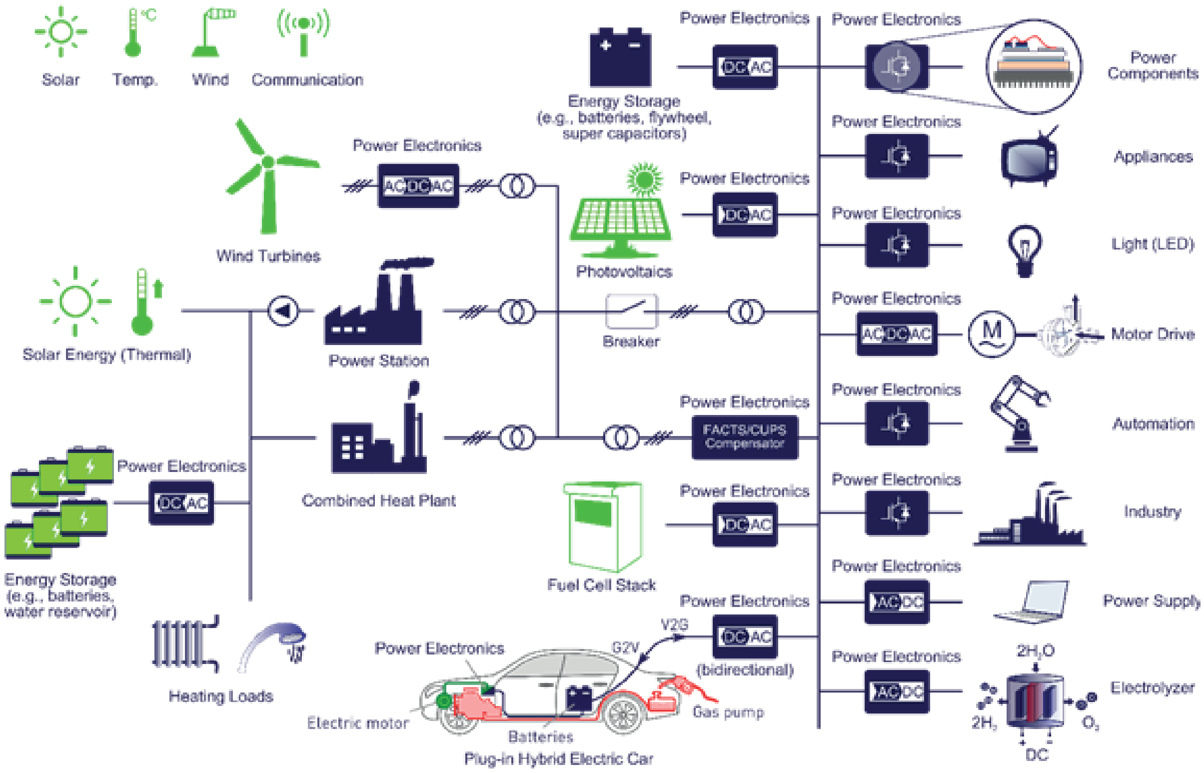

Fig. 1. A modern energy system from power generation to consumption – and many power electronic units are applied in different parts of the energy system (FACTS – Flexible AC Transmission Systems; CUPS – Custom Power Systems; LED – Light-Emitting Diode). Energy can typically be carried in the form of electricity, gas or heat.

Some of the pioneering work has been focusing on developing such energy systems and today many are working with this and a large-scale implementation in all aspects of energy stages is seen. For example, today more than 1500 GW of installed renewable generation capacity are done, and as illustrated in Fig. 1, the interface between the grid and the renewable generation source is done by power electronics. Not only has the generation involved many power electronics, but also do the modern power transmission systems use a big amount of power electronics and converters, e.g., offshore wind parks using high-voltage DC (HVDC) transmission technologies to improve the long-distance transmission efficiency.

The world has today realized that the use of fossil fuels giving emission of carbon is heating up the planet and will result in significantly sea-level rise already in this century (and with no point of return), further leading to large areas that are not livable anymore. Therefore, global goals have been defined and tried to be reached through consensus on reducing carbon emission to become almost zero by 2050 – and also with mid-term goals already in 2030. For instance, Denmark will reduce its carbon emissions significantly by then – and such agreements are continuously being reviewed and updated through the COP-meetings around the world – e.g., the latest was COP26 held in Glasgow and organized by the United Nations (UN) in 2021.

Energy is not the only element to make the planet much better to live on – many other elements are significant and essential, e.g., to ensure health, water, and food. That has been the main motivation for the UN to define 17 common goals for the human being on the planet, which are named the Sustainable Development Goals (SDG) and they are all shown in Fig. 2.

The goals are very broad – but all important for a better and sustainable life on the pla-

Fig. 2. United Nations 17 Sustainable Development Goals (SDG) for a better planet.

net where power electronic conversion technology will contribute significantly to many of the SDGs. It is, for example, the technology enabler for areas without electricity today – which still counts more than 1 billion people. The technology can provide a small electrical grid by the use of photovoltaic (PV) sources in remote areas in combination with energy storage devices, and then providing energy for lighting, cooking, communication, basic transportation, water-pumping, and etc. In this context, the IEEE Power Electronics Society, where I have been the president for 2019 and 2020, have also been running a global competition (Empower a Billion Lives, EBL) to find and innovate technical solutions about how to empower as many people around the world as possible, especially those energy-poverty areas. Existing grid-extension strategies are far expensive and can cause negative impact in terms of carbon emissions if more widely implemented – and instead new approaches that offer lower-cost and higher-value are clearly needed to help those living in energy poverty areas. The new solutions should be viable even for the lowest income customers by applying new and robust technologies such solar PV, batteries, microgrids, power electronics, cloud-computing, smart phones, and mobile-money. To come up with the best solutions, the thinking has been holistically in the activity to simultaneously address issues of not only technology, social impact, but also business models to accelerate the adoption and scaling – the latter might even be the biggest challenge. Electrical power conversion and electricity will also help other SDGs (See Fig. 2) like

SDG 6: Clean water and sanitation – power electronics have enabled efficient pumping and access of water as well as supplied by renewables in millions of places.

SDG 7: Affordable and Clean Energy – today power electronics are used for more 1500 GW installed renewables – as well as a high efficiency increase is seen in the process of energy. As mentioned above, micro-grids are based on power electronics and renewable resources, which in the end will give power to billions of people.

SDG 12: Responsible Consumption and Pro-

duction – the power electronics technology is making the society more efficient – e.g., LED lights are essentially power electronics; Electrical Vehicles (EVs) are fully power electronics based; and adjustable speed drives are used for heating, ventilation and air-conditioning – with huge energy saving as the operation process can be adjusted seamlessly according to the demand.
But other SDGs also need the power electronics technology – e.g., Sustainable Cities, which is heavily based on electricity (SDG 11) and Climate Action (SDG 12), as electricity is the most efficient way to obtain carbon-free electricity generation – just to mention some.

II.KEY DIRECTIONS FOR A SUSTAINABLE FUTURE

To achieve the goals – both seen from a climate perspective and from the SDG visions - the modern energy field is challenged and needs new solutions - at least into two main directions. The first one is to be able to supply and meet a growing demand for energy, which is needed on the planet; the second is to develop a long-term sustainable energy production in order to obtain the necessary decarbonization of the world. Therefore, we need to use the energy more efficiently, and in that way, to reduce the consumption growth which means to electrify as much as possible. One significant area is the fast-growing transportation sector which gives us mobility in life. An electrified transportation sector will make it much more efficient compared with today. It will also enable a significant reduction of the pollution of cities – both in terms of air quality and noise and making it a better place to live. An electrified transportation sector demands a substantial amount of power electronics for charging EVs and also for driving the EVs where energy is taken from batteries – so all will be electrified.
Also, we need to develop the renewable/sustainable power generation to become even cheaper so all can invest in the technology for supplying their need. Here, the scaling of power matters and power electronics is a key technology for doing the electrical power conversion in a very efficient way and interconnecting the renewable generation to the power grid.
Moreover, energy has become "digitalized" in many applications due to the use of power electronics and low-cost digital controllers. In this context, large bit- and watt-flows co-exist in today's energy systems. Power converters enable efficient and flexible conditioning of energy, and at the same time, the process of an increasing amount of data consumes much energy, which should also be efficient through advanced and innovative power electronics solutions. For example, data centers are major energy consumption points in many places, where efficient converters should be used, but also new energy management solutions/business models should be developed.
In general, the energy consumption is today typically divided into electricity (1/3), cooling/heating (1/3) and transportation (1/3) – and fossil fuels are covering more than 60 % of the whole energy consumption, as seen in Fig. 3. An expected scenario of the energy consumption and source by 2050 is also illustrated in Fig. 3. Both a slight reduction in energy consumption is expected as well as electricity will be dominating – more than 60 % – while fossil fuels will more or less be being taken out. The electricity share from renewables is also illustrated in Fig. 3.

As indicated in Fig. 3, renewable will be significantly increased in the future. Among those, one of the leading technologies is wind power. Wind does not need any fuels to produce energy – except wind! And therefore, it is a sustainable energy source for any country and the technology does not make any carbon emissions once the wind turbine is manufactured. One representative example of wind power technologies is Denmark where wind will make Denmark independent

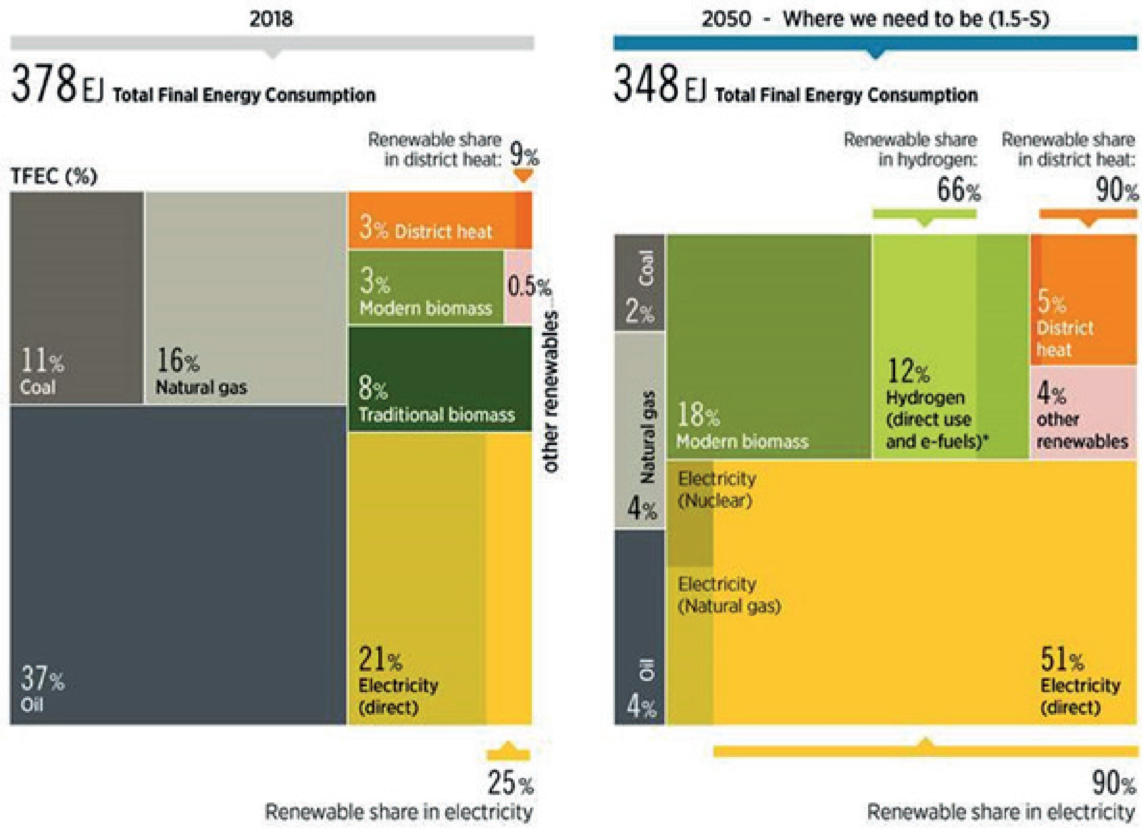

Fig. 3. Energy consumption by 2018 and predicted in 2050 in order to meet the need for carbon emission reduction on the planet proposed by IRENA, where the expected renewable share is also shown [5].

on importing energy by 2050 – it is even expected to be an energy exporter. Pricewise, the wind turbine technology has been very competitive due to its possible scaling. Today, wind is fully competitive with any other fossil-based energy sources. Naturally, wind has to be available, where the wind turbine is installed, and for example, in the case of Denmark, there are a lot of wind resources. Today more than 60 % of all electricity is coming from wind. In this case, we also need to have solutions to use electricity when we produce more than needed, where storage is important to consider as well as flexible loads.

Also, the ability to couple different energy sectors (electricity, heat, gas) is of importance – the key to that is energy digitalization – where a very close and on-line interplay between source and usage is implemented through control and communication. This development is on-going in many parts of the world where thermal energy storage, gas produced by electricity, and flexible loads are used to control the overall energy flow in combination with strong electrical interconnections to neighboring countries. Countries like China, Germany and the US have made it possible to implement the technology at a very large scale and thereby push down the prices of the wind power technology and also the PV power generation. It is now seeing the largest capacity growth for the moment as well as the largest price reduction in terms of cost per produced kWh. The advantage with this technology is that its power scale ranges from 0.4 kW up to GW – so most people have the possibility to invest for their own usage. This technology demands heavily power electronics for the interface to the grid as well as enabling to optimize energy capture from the sources.

However, in general, a completely new technology in the energy sector is expensive to realize from the very simple idea to a final product – where much investment is needed – as today the price of energy per unit is in general low and it can be difficult to compete in terms of being a newer technology.

III. MODERNIZATION AND DIGITALIZATION OF ENERGY SYSTEM

The energy system needs, as mentioned above, to be more modernized and digitalized in order to provide a more robust operation due to the variation in energy production and having the possibility to couple different energy carriers. Here is the communication system – wired or non-wired are very important for the digitalization – but also having the ability to handle a large number of data (big data) – as we sense more and more signals in the energy system. Fig. 4 shows in a simplified way the digitalisation of the grid as well as some of the key drivers to modernize the energy system – where also artificial intelligence (AI) is expected to be an enabler of the modernized energy system. Fig. 4 shows also the major growing areas in terms of energy consumption – beyond the electrification of transportation, data-centers are fast growing consumers as well as technologies for converting electricity into fuels through Power-to-X technologies, where the basic first step of conversion is to make hydrogen by using the electrolysis technology and afterward processing it (e-fuel, e-gas) – and thereby have a more long term storage available. The largest challenge now with the Power-to-X technologies is its total system efficiency – but it will give a large amount of flexibility in the system with multiple energy vectors. Energy storage based on batteries is also an important contributor to the digitalization and modernization of the power grid – as this will provide an efficient storage component which can convert and store with a high efficiency. Standards and regulations are the key to glo-

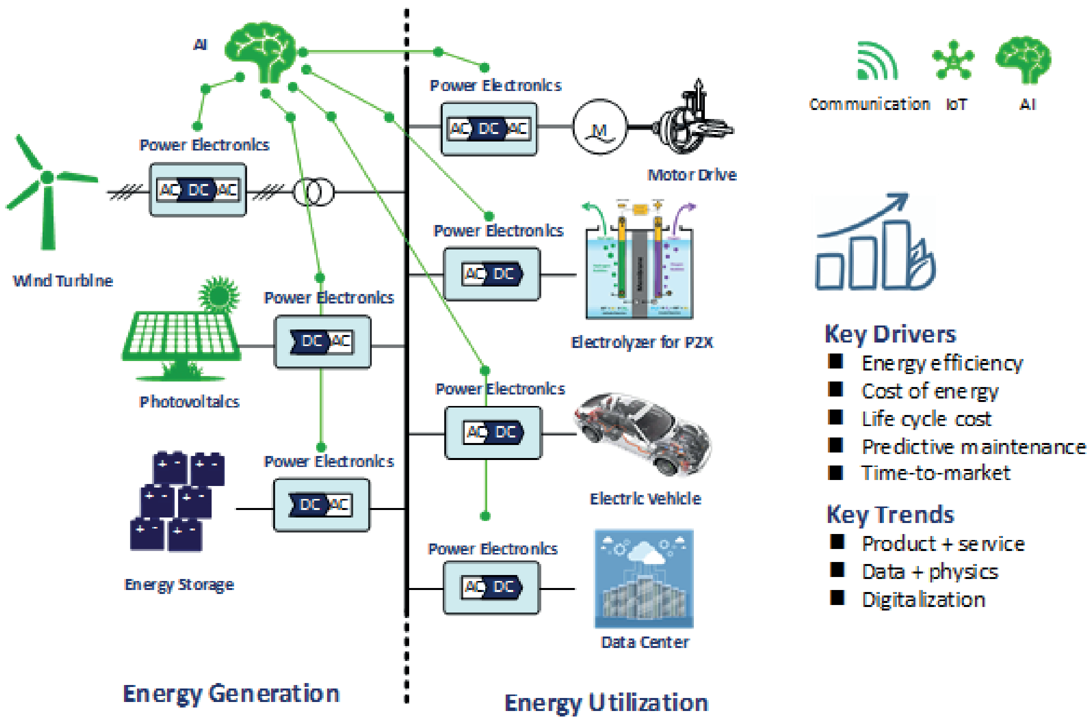

Fig. 4. A modernized, digital energy system using artificial intelligence in its operation.

bal transitions according to global goals and it should be done at an international level. This has already been a tradition today – but needs to be more intensified for the overall digitalization. The SDGs do also concern sustainability and re-use of resources. Here standards could give companies the responsibility to recycle or reutilize old and used products in order to be more sustainable.

IV. NEED FOR DISRUPTIVENESS

It is important to do research to synergize different energy carriers so they can operate together, e.g., through widespread digitalization. In this context, improvement of the energy storage possibilities for more long-term duration storage is important, and thereby enabling the faster and smoother transition for renewable generation. We need disruptiveness here. Battery as well as power-to-gas technologies are important for those matters.
As it has been illustrated in this article – the fossil fuel will be playing a minor role in the future energy system – which on the other hand also means that its resources may last more decades longer before it is exhausted on the planet, which will give a very high value for the society. Still many applications can hardly be operated without hydrocarbons – e.g., airplanes, large ships but also in many different chemicals/materials. It is assured that Power-to-X technologies will come but need better system efficiency before really being a competitor – and we are looking for strong disruptiveness here. A vision that the world should try to save highly valued fuels for as long time as possible and instead generate energy by renewables makes sense in terms of SDGs – where regions should strategically make plans to do a transition according to their abilities. Also, when large cities are becoming electrified and "fueled" by renewables - it will reduce their noise and pollution levels– which will make cities much better to live in – also highlighted in the SDGs.

When the energy production is going to be weather based and day/night dependent – a strong interconnection of electrical infrastructure is on demand having a high transmission efficiency. The power electronics technology is a key enabler again to convert electricity with a high efficiency. A further technology improvement can be super-conducting cables operating at higher ambient temperature – but here is more basic science needed to implement such a disruptive technology. This could make a large difference in terms of energy flexibility and efficiency and contribute to both climate goals and UN SDGs at the same time.

Awareness to measure and achieve the SDGs is important and even university rankings are considering this as a benchmark between universities. One example of such awareness can be found from Aalborg University, Denmark – as they do an annual report to summarize their efforts towards achieving the goals [10].

The general conclusion is that global goals for a better and more sustainable world demand electrification and much more power electronics - we need to devote a big amount of research efforts into achieving the ambitions.

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Frede Blaabjerg es un miembro destacado del Instituto de Ingenieros Electricistas y Electrónicos (IEEE Institute of Electrical and Electronics Engineers) donde comenzó como miembro estudiante en 1986 para alcanzar el máximo grado de Fellow del IEEE en 2003. En 1995 obtuvo el Doctorado en Ingeniería Eléctrica de la Universidad de Aalborg en Dinamarca. Desde 1992 se desempeña como docente en la misma Universidad donde obtuvo el cargo de Profesor Titular en 1998. Desde 2017 él es Villum Investigator de la Aalborg University, Ha obtenido distinciones honoris causa de la University Politehnica Timisoara (UPT), Rumania y de la Tallinn Technical University (TTU) en Estonia.
Sus actividades de investigación incluyen Electrónica de Potencia y sus aplicaciones tales como generación eólica, sistemas fotovoltaicos, confiabilidad, harmónicas y accionamientos eléctricos. Ha publicado más de 600 trabajos en revistas de la especialidad, 33 de los cuales han recibido IEEE Prize Paper Awards. Es co-autor de 4 monografías y editor de 10 libros en el área de electrónica de potencia y sus aplicaciones. Entre 2014 y 2020 ha sido nominado anualmente por Thomson Reuters como uno de los 250 investigadores más citados en Ingenieria en el mundo. Se ha desempeñado como Editor-en-Jefe del IEEE TRANSACTIONS ON POWER ELECTRONICS (2006 - 2012). Ha sido Conferenciante Distinguido de la IEEE Power Electronics Society (2005 – 2007) y de la IEEE Industry Applications Society (2010 – 2011 y 2017 – 2018). Durante 2019 y 2020 fue Presidente de la IEEE Power Electronics Society. Ha sido Vice-Presidente de la Danish Academy of Technical Sciences.
A lo largo de su Carrera ha recibido numerosos premios como por ejemplo: IEEE PELS Distinguished Service Award en 2009, el EPE-PEMC Council Award en 2010, el IEEE William E. Newell Power Electronics Award 2014, el Villum Kann Rasmussen Research Award 2014, el Global Energy Prize in 2019 y el IEEE Edison Medal en 2020.