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REVIEW

Circular economy: national and global policy—overview

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Abstract
The motivation for this special issue on circular economy, and national and global policy, originated during the international stakeholder meeting (Ochoa 2019) for our SUNRISE flagship project (Abbott 2019; Kupferschmidt 2019) in Bruxelles in June 2019. At the same day, one mile away from our meeting, Deutsche Energie Agentur (DENA) held a panel round table meeting on regulation for renewable fuels (Powerfuels 2019), at which the author could participate. The SUNRISE flagship is a European initiative for the sustainable production of solar fuels and base chemicals. The yet to be developed technology is based on the chemical reduction of carbon dioxide (CO_2) from concentrated sources and from the atmosphere, and solar water splitting for hydrogen production. Hydrogen and carbon dioxide will be synthesized to hydrocarbons for industrial use. When the synthetic hydrocarbons are consumed, carbon dioxide will be generated and fed back in a circular process, powered by renewable energy. In this extended carbon cycle (Calvin 1961), CO_2 is a valuable asset and remains part of the global biogeochemical cycle and becomes part of the circular economy. CO_2 concentration in the atmosphere will be reduced to an acceptable, climate neutral value once the cycle is in operation (Faber et al. 2020).

Keywords Circular economy · European Commission · Flagship · Paris Agreement · Carbon dioxide · Renewable fuels

SUNRISE has a trans-European component in as it has supporters in Africa, Asia, Australia, and the USA. The European Commission welcomes participation of non-EU partners in their programs. However, other countries may have different energy goals, policies and regulations, irrespective their researchers in participating in our projects. We have therefore solicited a dozen international contributions on the matter of renewable energy and circular economy. There may be common goals, differing goals and even contradictory goals. These goals may be rooted in the different settings and situations of the nations. Countries rich in coal have a cheap and valuable asset to use for their own industry and economy, or as a trading good. The decision to not further tap this resource, see Germany for example, is a big economic sacrifice which other countries maybe are not considering for understandable reasons. South Africa, in contrary, is a coal country, is a noble metal catalyst country, and a wine growing and wine exporting country. Countries good for growing wine should be also good for producing solar energy.

At a diplomatic reception at the Future Africa Campus at University of Pretoria on July 30, 2019, South Africa chemistry professor Egmont Rohwer, pointed out that their country, rich in solar energy, could be a future exporting country for solar fuels, either by pipeline or by ocean vessels (Rohwer 2019). We may think this is a far-fetched and wild idea. But three months later, German government announced in a press conference their future hydrogen strategy, acknowledging Germany was using more energy than it would be able to produce by renewable means, and thus

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would consider large sunny countries in Africa and Australia as future solar hydrogen supplier, in return for renewable hydrogen technology (Phoenix 2019). However, even for a region like West Africa, which has large potential for renewable energy harnessing from wind and solar energy, and a political will to exploit these, there may be still lack of industrial interest in investing there, as Ackah and Graham point out in their paper (Ackah and Graham 2020) "Meeting the Targets of the Paris Agreement: An Analysis of Renewable Energy (RE) Governance Systems in West Africa (WA)".

Researchers, Engineers, Technologists, Policy Makers, and Investors worldwide are now working towards a renewable energy landscape and economy. Virtually every nation has at least one research group working on this matter. From South Africa, we have a contribution, which covers the technical principles and economic consequences of atmospheric carbon dioxide reduction and conversion (Roduner 2020).

The first author of this Introduction paper had the pleasure of doing his various business travel across Europe with a hydrogen fuel cell car Hyundai ix35; a 30,000 km in total (Braun 2019). South Korean car manufacturer Hyundai has its hydrogen cars operating since 2015 on the roads in many countries. Also, Japan's Toyota and Honda produce hydrogen fuel cell cars. There is currently no other company manufacturing and selling fuel cell cars for the consumer market, including Auto nation Germany. However, Germany has currently around 100 public gas stations for hydrogen mobility in operation (H2live 2018).

Rechsteiner gives a portrait and analysis of "The German Energiewende (Energy Transition) and what to learn for Environmental and Climate Policy" (Rechsteiner 2020), and Telli et al. (2020) compare this Energiewende with the efforts and status of the energy transition in Turkey.

A contribution on the South Korean efforts for the transition to the hydrogen economy is provided by Stangarone (2020) from Washington D.C. *Nota bene*, Korea's President drives on hydrogen and has a Hyundai NEXO as presidential car (Moon 2019). The Winter Olympics in Korea were served by a fleet Hyundai H2 fuel cell cars.

India, a sub-continent with over a billion population and approaching a five trillion dollar economy, is struggling with energy poverty. Dependent on foreign oil and coal, India has plans to make the transition to full electrification of the country using clean energy by 2030 in line with the Paris Agreement. The complete study "Striving towards a Circular Economy: Climate Policy and Renewable Energy in India" by Sawhney (2020) from Jawaharlal Nehru University is published in this special issue.

The inclusion of CO_2 "waste" in the circular economy is as natural as one can think of, given that primary production by photosynthesis is based on the carbon cycle since over 3 billion years (Braun 2020; Calvin and Benson 1948; Calvin 1961). The waste that best describes the twentieth century civilization is the electronic waste (e-waste). This waste, rich in metals and noble metals, is increasingly being included in the circular economy, as outlined in the paper by Chakrabarty and Nandi (2020).

Turkey, a nation with over 80 million population and a steady economic growth of around 3% for 30 years, is in the geographically comfortable and geopolitically perhaps uncomfortable position of being located between oil and gas exporting countries. Turkey is thus looking for a diversification of its energy mix by renewable energy and also by nuclear power (Aydın 2020). Turkey being a large country with a good agricultural industry is well suited for harnessing solar power (Uyan 2017). A paper by Erat et al. (2020) provides an overview of Turkey's energy transition towards 2030.

The largest coal producer and consumer on the globe is China. It has the largest CO_2 foot print. But the country is walking large leaps towards a renewable economy (Mathews 2017), but there are many leaps to be walked before the goal is reached. Much of the waste material of China is construction waste, most of it not being accounted for by regulatory measures. Li et al. (2020) show how the lack of waste management for construction waste. Li et al. (2020) show how the lack of stringent waste policiesfor construction waste, which can be up to 30% of municipal waste in chinese cities, pose a particular burden on these cities waste management.

China is an industry motor of the world and exporting to an extent that it considered re-opening long extinct trade roads, which is now coined as the One Belt and Road Initiative (Constantinescu and Ruta 2017; Kim 2017). Neighbour Pakistan is also rich in coal and deemed to develop its China Pakistan Economic Corridor with fossil fuels, for the time being. Chang et al. study the potential ecologic risks by this mega project and provide recommendations for corresponding regulations (Khan and Chang 2020).

A somewhat more exotic example for regulations on renewable energies is found in a second paper by Chang et al. (2020) which covers the regulatory landscape by the USA concerning their efforts in protecting the sea shores at the Atlantic and Pacific Oceans, and the utilization of marine renewable energy in the form of mechanical energy from tidal waves, and thermal, or thermoelectric energy from the temperature difference of water layers. Note that such renewable energy as any other renewable is the driving force for the completion of the aforementioned circular economy.

It was important for us to have in this special issue contributions from scientists, engineers, economists, and law faculty, political scientists, policy makers, and politicians. For an energy transition towards renewable and circular economy to materialize, engagement of citizens is important. This is because the transition may affect economy, ecology, landscape, human settlements, traffic and

mobility, and patterns of consumption of goods. Schönwälder (2020) presents an article about engaging citizens to boost climate neutrality and greater circularity.

The idea of a circular economy is certainly not entirely new, as Editor-in-Chief Subhas Sikdar has pointed out in a recent editorial (Sikdar 2019). Repairing, refurbishing, revamping, recycling are partial expressions of the spirit, which finds their completion in circular economy. The original rational for this human behaviour was an economic one. The new motivation for circular economy has its roots in the debate over climate and environment. Economy and wealth are affected by the realization of a circular economy. Policies will play a substantial role in this matter.

In the connected world of the twenty-first century ("The world is flat", Friedman 2005), more and more citizens become aware of the mutual dependencies of worldwide flow of resources, products, and services, and also waste. Circular economy needs waste. Circular economy, to work worldwide with efficacy, requires appropriate policies and regulations to bring the global cycle into motion. We hope this special issue helps in pointing this out.

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