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KONCEPT NULTE EMISIJE
ZERO EMISSIONS CONCEPT

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Izvod

U vreme kada predloženikoncepti za smanjivanje, ponovno korišćenjeirecikliranjeotpada generalno nisu dali očekivane efekte na smanjivanje negativnih efekatanaživotnu sredinu, pojavljuje se koncept nulte emisijei. Terminnulte emisijeprivukao je posebnu pažnju, lako je razumljivi nezahtevaprevod. Ovajkoncept privlači povećano interesovanješiromsveta. Imajući u vidu da je poslednjih nekolikogodina količinaotpadau porastu, potražnja za energijom sve veća a raspoloživiprirodniresursi su ograničeni, korišćenjeotpadaje postala jednaodglavnihoblastiod interesazaistraživača. Predloženi konceptje predviđainput tokove u industrijskog kompleksakoristći ih za finalne proizvode, ili kao dodatne vrednostizadruge industrijeili procese. Koncept podrazumevaoptimizacijuintegrisanog sistemprocesaizahtevaindustrije sa redizajniranimprocesomproizvodnje uz korišćenja za resurse kako sirovinau procesu tako otpada u ciljuodrživosti. Ovo podrazumevakorišćenjeotpadakojimogu da budu dovedeni na nivo održivosti u zatvorenomkruguprocesima. Idealno, integrisaniprocesne proizvodiotpad. Otpadmože da bude resurs ako se stavina pravo mesto.

Ključne reči: *Nulta emisija, energija,industrija, otpad.*

Abstract

While proposed concepts to minimize, reuse and recycle wastes have generally, not solved the negative effects on environment, zero emissions concepts have arisen. The term Zero Emissions attracted special attention, as it is easily comprehensible and does not require translations. This concept is drawing mounting interest all around the world. In the recent years since the amount of waste generated is increasing, the demand of energy is pressed, and availability of natural resources is limited, the use of waste has become one of the main field of interest for researchers. This concept foreseen input streams to an industrial complex being used in the final products or converted into value added inputs for other industries or processes. It implies the optimization throughout an integrated system of processes and requires the industries to redesign manufacturing processes to resourcefully use both raw material within the process and waste towards the aim of sustainability. That implies exploitation of waste that can be brought to at sustainable levels in closed circle processes, ideally, the integrated process produces no wastes. Waste can be a resource if it is put in the right place.

Key words: *Zero emission, energy, industry, waste.*

1. INTRODUCTION

Historically control and reduction of emissions from industrial pollution sources have gone through three phases. The first was end-of-pipe pollution control technologies able to process wastes and emissions after they had been created i.e. use of pollution control technologies to treat process wastes. The second was the cleaner production concept aimed at redesign of processes and products in such way that fewer emissions are produced in the first place. The next third phase in the evolution in the control and reduction of emissions is the zero emissions concept that has aim to maximize resource productivity and to increase eco-efficiency simultaneously eliminating wastes or pollution linked with given products.

When applying the cleaner production concept the necessary modifications of process units must lead to a grouping and close networking of industries, as proposed by zero emissions. Both the cleaner production and zero emissions concepts will require industries to re-engineer their manufacturing systems so that they can fully utilise the resources within the industries and industry networks. Cleaner production can be understood as a transit phase towards zero emissions. The concept of zero emissions proposes to shift the industrial production away from the conventional linear model, in which raw materials end up as wastes in the end. Instead, zero emissions foreseen all industrial inputs being used in final products or converted into inputs for other industries or processes. Comparable to the functioning of natural ecological system, the industry as a whole is expected to dispose nothing to the environment [1].

On the other hand zero emissions concept requires a shift in society as a whole. It is widely acknowledged that production and consumption are tightly tangled activities. Thus, implementation of zero emissions concept requires consideration of the larger public systems within which industrial activities take place. Achieving zero emissions at a community level includes addressing urban and regional planning, consumption patterns, energy conservation, upstream industrial clustering, the reuse and recycling of products, and the interactions of these activities with the local industrial production base.

In 1997, a more holistic research meta-project was started by the Japanese universities, exploring areas where the ecological restructuring of entire communities might be achieved through changes in lifestyles, consumption and production patterns. Industrial process zero emissions, networking of different industries for the improved utilisation of resources, and community-based designing of complete material cycles were the three components of these research projects [2].

As of an environmental perspective, the elimination of waste represents the ultimate solution to pollution problems that threaten ecosystems at global, national and local levels, full use of raw materials, accompanied by a shift towards renewable sources, means that utilisation of the Earth's resources can be brought back to sustainable levels. From business point of view, zero emissions can mean greater competitiveness and represents a continuation of its inevitable drive towards efficiency, the productivity of raw materials producing more from less. Zero Emissions can therefore be understood as a new standard of efficiency and integration [3].

2. ZERO EMISSIONS CONCEPT

A method towards a zero emissions industrial ecosystem is established having three basic steps. The methodology starts with analyzing the material and energy flows that run through the industrial systems and partly end up in wastes, followed by analyzing various possibilities to prevent the generation of wastes in the second step. The third step concentrates on identifying, analyzing and designing potential offsite recovery and reuse options. It also entails the identification of remaining wastes in this step to treat follow a reasonable method toward zero emissions [4].

Analyzing material and energy flows*:* is important for an identification of sources of by products/waste, excessive materials, and energy consumption in the production. This analysis concentrates to determine the type as well as amount of by products, waste, materials, and energy used in the production units. It is started by going through the whole production process to obtain an overview on where inputs are processed and where by products or waste are generated. Materials and energy balances for input-output is also done in this step. Material and energy balance contributes to the understanding of the relative importance of different causes of waste generation, energy consumption as well as the costs used in the production.

The possibilities to prevent waste: this step is based on the step of analyzing material and energy flow. It implies that data analyzed can be used for appropriate possibilities to prevent and minimize waste generation. Waste prevention concentrated at preventing wastes from being generated. Waste minimization aims at dealing with minimizing waste that have been generated by a producer based on the information of the quantity, characteristics, waste handling methods, etc. Depending on the specific process circumstances and the socio-economic conditions several alternatives for prevention and minimization of waste generation are usually combined to come to an optimum set of option for waste prevention. The assessment of individual and combinations of options should result in an integration of various alternatives into a practical and feasible model. The feasible options are often selected based on criteria of environmental regulations and issues, available technology, product quality, economic efficiency, etc.

Identifying, analyzing and designing potential offsite recovery and reuse options*:* reusing, recycling, and recovery by products are considered in this step. By products will be reused as process inputs for the other processes to reach the aim of ‘zero waste’. Waste treatment will also be done in this step of course. The treatment certainly depends on characteristics and the amount of waste, environmental standards or pollution reduction requirements, available treatment technologies, etc.

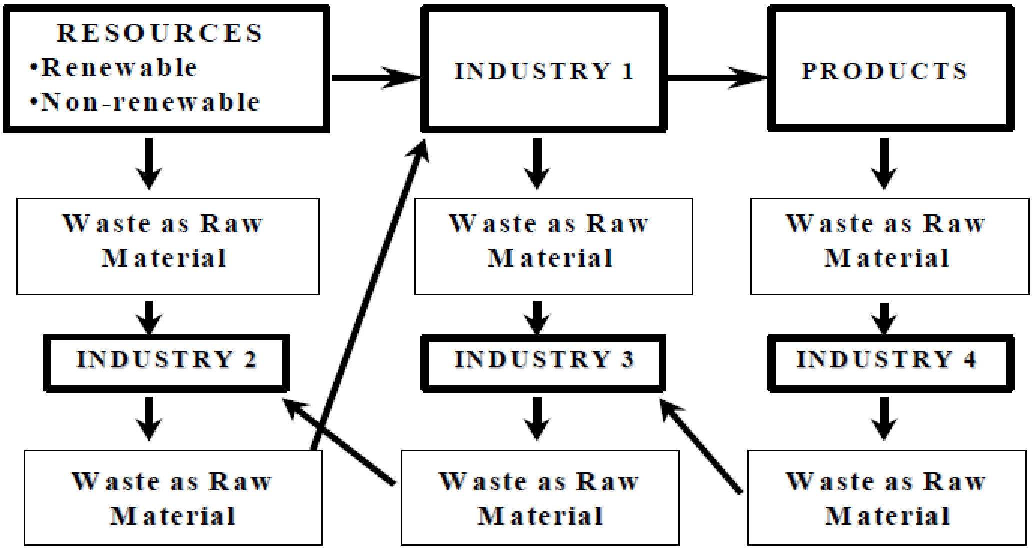

Figure 1. Zero Emissions industrial cluster

The target "no waste" and eco-efficiency demand to use integrate industrial cluster approach. In this cluster waste output from one industry becomes an input for another (Fig.1). Zero emissions industrial cluster imitates the Nature, and in principle eliminates waste targeting near zero emissions. According to this simplest sequential connection example of different industries this would complete the clustering of N industries, at least temporarily. However, the representation could be much complicated and we should operate with a large net of industries. Analysis of technologies connection in cluster reveals interesting ‘‘lock-in’’ phenomena. The next and unsolved question relates to the size of industrial cluster, technological flexibility and possible technological ‘‘lockin’’, which could act as a barrier for technological change. In large scale cluster with many components the interconnection among various processes and technologies would increase, while technological flexibility in technologies dynamics would be diminished. So, clustering will decrease possibility of technological change. May be this limiting factor determines the cluster size. In any case we will start with relatively small and simple clusters. In some cases only one separate technique could act as a limiting bottleneck. Such situation could allow improving technology with minimal costs [4].

3. ZERO EMISSIONS SYSTEMS IN FOOD PROCESSING INDUSTRY

The food processing industry is part of an interlinked group of sectors. It plays an important role in the economic development of every country. However, a strongly growing food processing industry greatly magnifies the problems of waste management, pushing the management of waste as well as pollution to the forefront of environmental challenges.

The food processing industry requires agricultural raw materials; derived primarily from crops, plants, and fresh fruits; as process input materials. Output for those processes are food products and huge amounts of waste (solid, gas and liquid). Unfortunately the amount of waste could be a serious environmental pollution sources regarding sanitary environmental issues.

If waste treatment and waste management methods have not been applied thoroughly, the negative effects on the environment and human will be very serious, especially the negative effects of odors, leachate, and spreading of pathogens at open-landfill sites. This waste amount, however, has a great potential for the generation of gaseous energy carriers. It can serve as input material for fermentation in anaerobic digestion. Moreover fermentation technology which can be applied in zero emissions concept is not difficult to conduct. Digesters are already widely established. This means that the application of zero emissions techniques in the food industry will be possible; it is a promising path to adapt to issues environmentally friendly through alternative usage of fossil fuels, the use of chemical fertilizers, reduction of greenhouse effect gases, and minimize waste.

The plantation in food industry core business utilizes maximum 10% of biomass and only few its components (for example, sugar cane juice, oil from oil palm, fibers from sisal, pineapple fruits, coffee, etc.). The loss of materials and biochemicals is the loss of value and diversity. A total conversion of plantation and agricultural waste materials into value added biochemicals like sugars, vitamins, citric acid, furfural, lipids, waxes, xylitol, medicals and many other products means applying a strategy of replacing petroleum products with biochemicals from biomass and it should facilitate an indirect biodiversity conservation. It has been shown that the substitution of petroleum refinery with biorefinery modifies 3R approach (reduce, reuse, recycle) to 4R approach (replace, reduce, reuse, recycle). Biorefinery separates the plant biomass, so called lignocellulosic materials, into building blocks - phenols and sugars. Biorefinery technologies produce value-added products that might range from basic food ingredients to complex pharmaceuticals and from simple building materials to complex industrial composites. Strategies of replacing petroleum products with chemicals from biomass need an integration of industries in the clusters with zero emissions. Besides environmental benefits there are economical benefits from biorefinery. Biorefinery creates new economy - lignocellulosics (in the narrow sense "carbohydrate") economy similar to petrochemical economy. The progress of new and conventional biorefinery technologies such as steam explosion, solid state extrusion, pyrolysis, etc. together with biotechnologies has been demonstrated [5].

Application of zero emissions techniques in food industry can eliminate both the cost of treating waste, disposing of waste, and even the cost of the raw materials or services that would be wasted. Some of these benefits are considered as the major advantages of a zero emissions system including more efficient use of human and physical resources and increased recovery and recycling of materials. Some other advantages compared with the different waste management methods in environmental protection progress will be:

- Using by-products as inputs for new processes;
- Support fertilizer for agriculture;
- Support water for irrigation in agriculture;

- Producing biogas renewable energy;
- Reduce the negative effects on the environment and human on landfill waste; and
- To reduce Greenhouse effect gas.

The food industry is an important industry in the economic development of every country. However, the amount of by-products from food production is not low, if waste can be managed and used as input material for the process this can offer beneficial environmental and economic efficiencies; it does not only reduce the costs for waste treatment as well as the negative effects but also protect the environment. Principally zero emissions techniques can apply to small-, medium-, and large-sized companies, but there are in practice several key differences as the technological options vary widely different scales of operation. Actually small firms or small companies obviously have very limited financial and human resources available for environmental improvements. In addition, government institutions pay limited attention to the environmental performance of smaller industries and are more closely observing large-scale enterprises. Because of this, bringing the food processing industrial sectors together in industrial bigger zones will offer bigger advantages at two sides. Firstly we can collect more by-products for reusing and recycling in environmentally friendly new production processes. Secondly waste management will be more concentrated, the costs for waste management and services will get less through economies of scale [5].

4. ZERO EMISSION FOSSIL FUEL POWER PLANTS TECHNOLOGY

The world continues to face a major challenge in meeting the often-conflicting needs of the environment, human health and economic development, whilst at the same time ensuring security of energy supply. Fossil fuels may be critical in ensuring today's economic and energy security, but their use also has a major impact on the environment, due to the emission of greenhouse gases. The zero emissions concept can be applied to each of the fossil energy industries. This concept applies, for example, when carbon dioxide from energy conversion processes is used for enhanced recovery of oil and gas. It also applies to power generation from any fossil fuel by using new energy conversion cycles that are closed loop for pollutants rather than the open loop cycles used in traditional combustion-based systems. The zero emissions concept covers all potential pollutants. While carbon dioxide is recognized as the principal pollutant related to global warming, improvement strategies must also deal with emissions of sulphur oxides, nitrogen oxides, other greenhouse gases, particulates and ash. Zero emission technologies for fossil fuels are in various stages of development. It requires further progress on components, innovative system integration, and commercial application. Sustained and collaborative effort to fulfil this aims will be required.

Expectations of growing world energy demand and the experience from the relatively moderate introduction of new energy resources to date in global supply emphasizes the question of how the world will be able to meet its increasing energy needs. In light of future population growth and the aspirations of the less developed countries to enjoy the same life styles as the developed countries, the world faces a huge, unmet need for energy. According to UN forecasts the world population in 2050 will be in the region of 9 billion people and reach more than 11 billion by the turn of the century. One-third of the world's population does not have access to reliable electricity today. The role of fossil fuels and hydrocarbons in particular to support future growth in energy demand will be a key issue in securing world energy needs in the 21st century. Coal, oil and gas currently provide 85% of the world's energy supply. The hydrocarbon proportion of global energy supply is more than 50%. Despite massive government financially support for research on alternative fuels, today only nuclear has increased its market share in relation to fossil fuels. Renewable energy (wind, solar, etc.) represent only about 1% of global energy supply, showing little or no increase in its role in global supply since the beginning of the 70's.

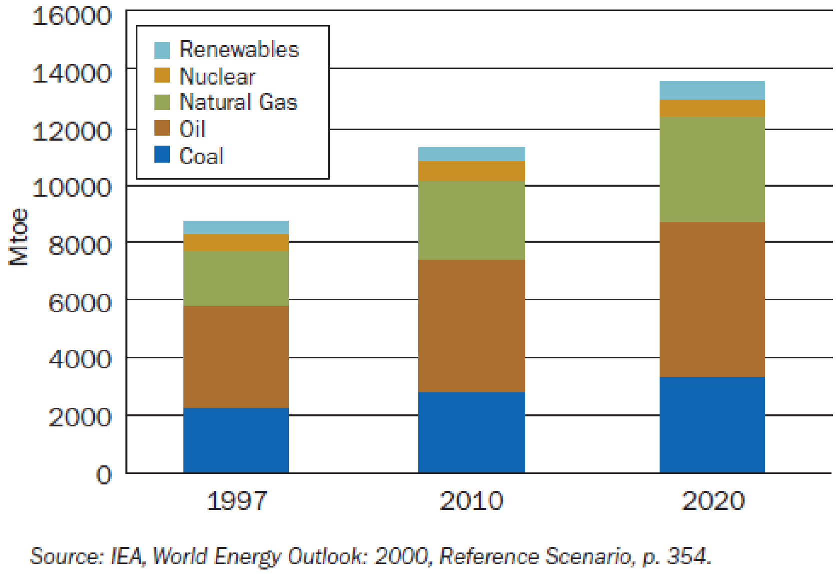

Figure 2. World total primary energy supply 1997-2020

In most cases, fossil fuels are inexpensive, widely available, and flexible than any other type of energy source, and their economic advantages are not likely to change in the first half of this century. Although estimates vary, world total primary energy consumption is projected to increase by 57 percent between 1997 and 2020. As seen in Figure 2, under the Reference scenario of the World Energy Outlook 2000, fossil fuels will account for around 90 percent of the world primary energy supply by 2020. In the developed world, energy market reform will continue to favour the use of fossil fuels. Private markets respond to fuel costs when making generation decision, and fossil fuels will remain the low-cost option. The demand for energy will grow especially quickly in the developing world. These countries will account for 68 percent of the increase in world energy demand between 1997 and 2020. Developing countries are already heavily reliant on fossil fuel. China and India alone will account for 70 percent of the incremental world coal demand from 1997–2020. Across the developing world, fossil fuels will maintain their leading position [7].

Development of zero emissions technologies for fossil fuels may be the most important technology issue related to fossil fuel use in the twenty-first century. The zero emissions concept may potentially be applied to a broad range of applications for each fossil fuel, spanning production, conversion and utilization. The concept has been proposed for applications involving enhanced oil recovery, power generation and even the utilization in transportation applications. Other applications may also emerge. Clean, advanced fossil fuel technologies that are zero-emission, fuel flexible and highly efficient are required if countries are to resolve conflicting needs. When developed, these technologies would have a transforming impact on world energy use, and are vitally needed to simultaneously:

- Provide affordable, clean energy to meet expanding energy demand;
- Solve critical environmental problems (reduce carbon dioxide and other pollutant emissions);
- Address energy safety and security issues by supporting the use of diverse fossil fuels; and
- Ease the economic costs of sustainable development.

The bulk of this investment into zero-emission fossil fuels technologies will be in developing countries as they will account for a growing share of global emissions from all fossil fuels types, but the scale of investment will require major capital inflows from developed countries. The European Commission has addressed these matters in its Energy Green Paper [6], and has specifically highlighted the environmental challenges, security of energy supply and industrial competitiveness as central issues for the development of energy policy priorities [7]. Reducing CO_2 emissions in the energy sector has become a top priority for national governments within the European Union. The main approaches that will be used to reduce CO_2 emissions are:

- Reducing end consumption of energy through demand side management;
- Increasing the efficiency of energy conversion and utilisation;
- Switching to lower carbon content fuels, e.g. natural gas instead of coal;
- Enhancing the sinks for CO_2, e.g. forests and soils which draw-down CO_2 from the atmosphere, and reduce forest burning;
- Using energy sources such as nuclear energy, solar, wind or hydro-power which have zero or very low CO_2 emissions;
- Using CO_2-neutral fuels such as biomass;
- Capturing and storing CO_2 from fossil fuel combustion.

Measures to reduce energy consumption and switch to low carbon fuels are immediately cost-effective and will deliver useful reductions in emissions. Enhancing natural sinks such as forests could contribute in the short term, but the capacity of the sinks is limited and carbon stored in them is not always secure. In the longer term, large reductions in emissions could, in theory, be achieved through a widespread switch to non-fossil fuel energy sources, providing these are safe and affordable. However, adopting such fuel-switching to non-fossil sources and introducing efficiency measures at a realistic pace will not be enough to meet the currently required CO_2 reduction requirements. Emissions must be cut rapidly in order to avoid further adverse climate change.In the long term, safe, carbon-neutral energy sources will dominate, but such a transition will take time. Fossil fuels will continue to play a vital role during this period, although the undesirable environmental impact must be eliminated. The global climate challenge requires the stabilisation of atmospheric CO_2 levels as a matter of urgency. Given the rising energy demand, this implies the need for a massive reduction in CO_2 emissions from fossil fuels. Carbon Dioxide Capture and Storage (CCS) is a technology with the potential to reduce the greenhouse gas problem and facilitate the continued use of fossil fuels. For CCS to be introduced on a commercially viable basis, early action must be taken to overcome the remaining technical issues and ensure the framework and market conditions needed to stimulate demand.

CCS activities are being driven forward by EU industry, which recognises that large-scale demonstrations are needed to prove the commercial viability of technologies and to inspire public confidence. Most of the power generation equipment commercially available today was designed for fuels and working fluids considerably different from those that are likely to be used in a future zero emission power plants. CO_2 capture involves the separation of CO_2 from combustion gases and compressing it so that it is suitable for safe transport and storage. The main technologies currently being studied for CO_2 capture are:

- ***Post-combustion separation***, in this process, the CO_2 is separated from the flue gases after combustion has taken place. Instead of being discharged directly to the atmosphere, the flue gas is passed through an absorbent or a selective membrane, which separates most of the CO_2. Previously compressed CO_2, is fed to a storage reservoir and the remaining flue gas is discharged into the atmosphere.
- ***Pre-combustion separation***, it involves reaction of fuel with oxygen or air, and possibly also with steam, to produce a 'synthesis gas (syngas)' or 'fuel gas', composed mainly of carbon monoxide and hydrogen. The carbon monoxide is then reacted with steam in a catalytic reactor, called a shift converter, to give CO_2 and more hydrogen. Then the CO_2 is separated, usually by a physical or chemical absorption process, resulting in a hydrogen-rich fuel which can be used in many applications, such as boilers, furnaces, gas turbines, engines and fuel cells.
- ***Oxy-fuel combustion***, in oxy-fuel combustion, nearly pure oxygen is used for combustion instead of air, resulting in a flue gas that is mainly CO_2 and H_2O. This simplifies the separation process as the water vapour can readily be condensed to liquid, leaving the CO_2 for subsequent treatment.

While post-combustion separation has thrown up its own challenges, the other two technologies involve substantial modifications to the combustion process and to major components of a power plant, whether it is natural gas or coal fired. This means that, in addition to considerable research, extensive product development will be needed prior to the introduction of validated technologies into efficient and reliable power plants [8].

Once captured and transported, most CO_2 will be stored in geological reservoirs. The EU is interested in a number of such reservoirs, including depleted and disused oil and gas fields, deep saline aquifers and deep un-mined coal seams. Detailed knowledge and understanding are needed as to where and how CO_2 can be stored. **Depleted Oil and Gas Fields** present a significant possibility for CO_2 storage, with European capacities estimated at 14.5 billion tonnes offshore and 13.1 billion tonnes onshore. **Enhanced Oil and Gas Recovery** as an intermediate step, there is scope for injecting CO_2 into mature fields to improve the recovery of oil (and gas) through Enhanced Oil Recovery (EOR), increasing production by 4-20%. The European Commission has estimated that the EOR storage capacity of the North Sea in major economically viable projects will range between 200 and 1800 million tonnes of CO_2 over the next 25-year period, depending on the oil and CO_2 credit prices and the actual oil recovery rates. **Saline aquifers** have by far the greatest potential for storing CO_2, globally as well as in Europe. Such aquifers are sedimentary rocks (usually sandstone and less frequently limestone or other rocks), which are porous enough to store great volumes of CO_2 and permeable enough to allow the flow of fluids. Storage of CO_2 will take place at depths below some 7-800 meters where CO_2 behaves as a fluid, and where the pores of the sediments are filled with salt water. The European storage potential for CO_2 in saline aquifers is huge, with the possibility for 80 - 100 billion tonnes of CO_2 in structural traps of 8 EU countries alone, and much more in the unconfined aquifers. **Un-mineable coal seams** offer another opportunity to store CO_2 at a low net cost. In Enhanced Coal Bed Methane (ECBM) projects if a production well is opened, the coal adsorbs CO_2 and N_2 and methane is displaced, enhancing its production. While this approach is still in its early stages and needs more research, it is considered a promising concept due to the added value of the produced methane [8].

5. CONCLUSION

When the idea of a zero emissions system emerged in 1991, there are some ideas regarding 'zero emissions' to argue that it is simply unrealistic because it can be found that no matter how good we get at recycling and reducing our waste, there will always be something left over for which there is no reasonable way of dealing with except disposal. Also, critics argue that a zero emissions industrial system is impossible. The multitude of zero emissions projects in industrialising and developing countries illustrates the problems in its implementation, but nevertheless its mid-term and long-term feasibility. There is still a long way to go to realise Zero Emissions. In addition one should keep in mind that zero emissions is not a protected term and is thus applied under rather different circumstances and for different purposes The experiences of the first 20 years of zero emissions work have proved the feasibility and attractiveness of the concept. But future incentives will be necessary to further sharpen he concept, to diffuse the findings and to initiate a discourse with all relevant actors.

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