processes

Editorial

Special Issue on “Process Design and Sustainable Development”

Peter Glavič

Department of Chemistry and Chemical Engineering, University of Maribor, Smetanova 17, 2000 Maribor, Slovenia; peter.glavic@um.si; Tel.: +386-414-09611

Thirty years ago, at the United Nations' (UN) Earth Summit in Rio de Janeiro, Brazil, 178 countries adopted Agenda 21, a global partnership for sustainable development to improve human lives and protect the environment [1]. Twenty years ago, The Johannesburg Declaration on Sustainable Development was accepted to eradicate poverty and ensure sustainable development. Ten years ago, the UN Conference on Sustainable Development in Rio de Janeiro (Rio+20) adopted the outcome document “The Future We Want”, in which they decided to start a process to develop a set of Sustainable Development Goals (SDGs). The UN 2030 Agenda for Sustainable Development, with its 17 SDGs, was adopted in September 2015, and in December 2015 the Paris Agreement on Climate Change was accepted by the Parties to the United Nations Framework Convention on Climate Change, its goal being to limit global warming to well below 2 °C, preferably to 1.5 °C, compared to pre-industrial levels [2]. To achieve this long-term temperature goal, countries aim to reach a global peak of greenhouse gas emissions as soon as possible to achieve a climate-neutral world by mid-century.

Currently, the Earth is already about 1.1 °C warmer than it was in the late 1800s, and emissions continue to rise. Global GHG emissions have increased by 53%, from 32.52 Gt/a (billion tons per year) in 1990 to 49.76 Gt/a in 2019 [3]. To limit global warming to no more than 1.5 °C, emissions need to be reduced by 45% by 2030 and reach net zero by 2050 [4]. The European Union (EU) and its 27 member states, accepted the European Green Deal plan to transform the EU into a modern, resource-efficient, and competitive economy with no net GHG emissions by 2050 [5], and at least 55% less net greenhouse gas emissions by 2030, compared to 1990 levels. GHG emissions in the EU decreased by 32% between 1990 and 2020 [6]. Preliminary estimates indicate that emissions rebounded in 2022, exceeding the pre-COVID-19 levels [7]. At COP27 (Conference of the Parties, Egypt, 2022), the EU's climate policy chief, Frans Timmermans, even promised to exceed the EU's 2030 reduction target by 2%, to 57% [8].

In 2019, approximately 34% (20 Gt) of total net anthropogenic GHG emissions came from the energy supply sector; 24% (14 Gt) from industry; 22% (13 Gt) from agriculture, forestry and other land use; 15% (8.7 Gt) from transport; and 6% (3.3 Gt) from buildings [9]. Average annual GHG emissions growth between 2010 and 2019 slowed compared to the previous decade in energy supply (from 2.3% to 1.0%) and industry (from 3.4% to 1.4%) but remained roughly constant at about 2% in the transport sector.

Industry emitted 29.4% of all the GHGs: 24.2% originated from energy use, while industrial processes emitted an additional 5.2% of GHGs [10]. Global process industries are among the most intensive GHG emissions activities in industry, e.g., iron and steel—7.2%, chemical and petrochemical—3.6%, food and tobacco—1.0%, non-ferrous metals—0.7%, and paper and pulp—0.6%. Aside the emissions from energy production, process industries emit GHGs in their production processes, e.g., chemicals—2.2% and cement—3%. Further, transport, energy use in buildings, and fugitive emissions from energy production must also be added.

Process design and sustainable development are connected in their aim to reduce the negative effects of GHG emissions on human development. Process design is detrimental

check for updates

Citation: Glavič, P. Special Issue on “Process Design and Sustainable Development”. *Processes* **2023**, *11*, 117. https://doi.org/10.3390/pr11010117

Received: 28 December 2022
Revised: 29 December 2022
Accepted: 29 December 2022
Published: 31 December 2022

to energy and material usage during production and usage, as well as for GHG emissions. By designing for circular economy and efficiency improvements, and by applying process optimization, we can reduce GHG emissions and enlighten energy and material recycling. We can also extend the lifetime of products.

The number of papers dealing with the topic (keyword: process design and sustainable development, Web of Science) is increasing—from 821 to 3 586 per year in the period 2012–2021 (Figure 1). This follows the two most evident megatrends in the process industries: climate change and resource scarcity. This Special Issue on Process Design and Sustainable Development includes 16 papers, which can be grouped into process design, sustainable development, and other topics.

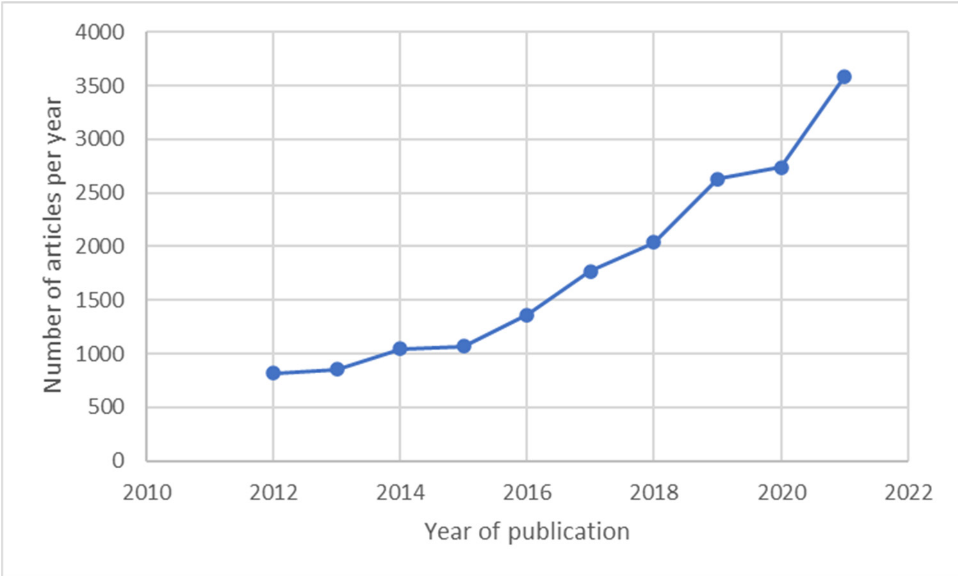

Figure 1. Number of papers on process design and sustainable development, Web of Science.

Design for sustainable development

The definitions of process design and sustainable development are described separately and together, as is the process design for sustainability, including environmental, economic, and social dimensions [11]. A case study of the EU27 chemical industry in the period 1990–2019, with a 47% increase in production and 54% reduction in GHG emissions, indicates that the decoupling of production and emissions is viable. The most urgent future development areas in process industries are (a) carbon capture with utilization or storage; (b) process analysis, simulation, synthesis, and optimization tools; and (c) zero waste, circular economy, and resource efficiency.

Design as a discipline has changed to address the complexity of the current problems [12]. Sustainable design, inclusive design, codesign, and social design have emerged as examples of such issues. Social, environmental, and cultural trends have affected design, but the design process itself remains almost unchanged. An alternative design process method and new criteria are needed to develop innovations in response to these trends. An extended design process includes distributed agencies, transparency, and pertinence, but it is also important to keep in mind the principle of proportionality.

The guiding principles of sustainability, sustainable design, green engineering, and sustainable engineering need to be updated to include the present state of human knowledge [13]. The updated principles include traditional and more recent items: a holistic approach, sustainability hierarchies, sustainable consumption, resource scarcity, equalities within and between generations, all stakeholders' engagement, and internalizing externalities. Equal importance is given to the principles of environmental, social, economic, and tridimensional systems' approach.

Project management is crucial for achieving business excellence in a new industrial paradigm [14]. Therefore, the impact of different levels of project management maturity on business excellence has been determined in the context of Industry 4.0. A sample of 124 organizations of different sizes from 27 countries, covering services, education, industry, and finance, was selected. A significant connection was found between project management maturity and business excellence. However, there was no evidence of a mediating effect of Industry 4.0 readiness on the relationship between project management maturity and business excellence.

Design for increased resource efficiency

Process industries are regular users of fossil fuels for energy production and processing. Energy usage relates to GHG emissions. In 2010, the European Commission proposed a 10-year strategy, Europe 2020, with five targets for sustainable development. One of them was the 20-20-20 target—to reduce greenhouse gas emissions by at least 20% compared to 1990 levels, increase the share of renewable energy in final energy consumption to 20%, and achieve a 20% increase in energy efficiency. The analysis of sustainability indicators, which were transformed into a synthetic measure for comparability of the resulting values, identified the best countries to fulfil the sustainable growth aims [15].

The automotive sector accounts for 16.2% of global energy consumption and 25% of CO_2 emissions from energy-related sectors [16]. If present trends persist, the worldwide transportation demand for energy, and CO_2 emissions from energy, are expected to double by 2050. Electric vehicles (EVs—hybrid, plug-in hybrid, and battery) emit only half of the conventional emissions [17]. Aside from the social preferences for environmental protection and energy policies, rising fuel prices are promoting EV adoption. Barriers to this adoption include the high purchase prices of EVs, limited driving distances, and long charging times. The multicriteria decision-making methods show that battery capacity and lifespan, and high costs are the most important barriers to EV transition, while government support promotes it.

A hybrid vehicle (HV) is one that draws its power from two or more different energy sources; the internal combustion engine (ICE) performs better at maintaining the high speed of the vehicle than a standard electric motor, while the electric motor is more effective at providing torque or turning power [18]. Integration of the ICE with the thermoelectric generator (TEG) takes advantage of ICE waste heat at the exhaust gate and predicts their reliability. Researchers seek to recycle wasted energy to produce electricity by integrating TEG with ICE, which rely on the electrical conductivity of the thermal conductor strips. The proposed metaheuristic verification improves the TEGs' efficiency by 32.21% and reduces fuel consumption by up to 19.63%.

Spent grains from microbreweries are mostly formed by malting barley. Transforming spent grains from waste to raw materials in the production of nontraditional flour requires a drying process [19]. A natural convection solar dryer (NCSD) was evaluated as an alternative to a conventional electric convective dryer (CECD) for the dehydration process of local microbrewers' spent grains. Suitable models (empirical, neural networks, and computational fluid dynamics, CFD) were used to simulate both types of drying processes under different conditions. NCSD produced a dried product with a comparatively better quality; overall operating costs were greatly reduced, and the NCSD was about 40–45% cheaper than the CECD.

The relationship among carbon dioxide emissions and linkage effects using the input–output data of the information and communications technology (ICT) industry between South Korea and the USA was examined [20]. The linkage effects were analyzed to determine the impact of the ICT industry on the national economy and CO_2 emissions. The results indicated that the ICT manufacturing industry in Korea has high backward and forward linkage effects, while the US has a small influence on both effects. The ICT service industries of the two countries have small backward linkage effects, so their influence on other industries is small. CO_2 emissions from ICT service are higher than from ICT manufacturing in both countries, South Korea and the US.

During watermelon fruit production, about half of the fruit—namely the rind—is usually discarded as waste. To transform such waste into a useful product such as flour, thermal treatment is needed. The drying temperature of the rind is most important to produce flour with the best characteristics. In [21], a multi-objective optimization (MOO, also known as multicriteria decision making) procedure was applied to define the optimum drying temperature for the rind flour fabrication to be used in bakery products. The group of process indicators comprised acidity, pH, water-holding capacity, oil-holding capacity, and batch time; they represented conflicting objectives that were balanced by the MOO procedure using the weighted distance method to find their optimal values.

Design for optimal operation

An efficient and flexible production system can contribute to production solutions. A detailed mathematical model of the system under investigation was presented in [22]. The evolutionary algorithm was the most efficient solution to the problem associated with the model. A computer application for this model was created, and it was run multiple times. The runtime results are also presented in this study. The sample task was taken from a real company, but it was simplified for reasons of transparency. Order-driven production can be mathematically described and assigned to a well-managed model. The problem was solved with a variation of the genetic algorithm.

The optimal cleaning scheduling of a heat exchanger unit undergoing fouling was analyzed and optimized for uncertain operating conditions in [23]. The fouling process, the flexibility assessment, and the optimization algorithm were presented. The fouling kinetic model was described, uncertain operating conditions were handled by the flexibility index, and the scheduling optimization and the corresponding decisional algorithm were discussed. The scheduling algorithm was applied to a case study, a sensitivity analysis with respect to two possible uncertain variables followed, and the results obtained with the process parameters accounted for the mechanical cleaning methodology, and for both, chemical and mechanical ones.

Electrostatic desalting is one of the most popular methods to remove saline water from crude oil by applying an external electrostatic field. Complex phenomena, such as the frequency of collisions and coalescence, were included in a CFD model for better understanding and optimization of the desalting process from the perspectives of both process safety and improvement [24]. The main process parameters are electric field strength, water content, temperature (through oil viscosity), and droplet size on the collision time or frequency of collision between a pair of droplets. First, a simplified collision model between two droplets in water-in-oil emulsions was developed. Then, this model was employed to perform a complete process analysis determining the effect of the main process variables on the collision frequency.

In [25], the cooperative optimization of two-stage desulfurization processes in the slime-fluidized bed boiler (FBB) was studied, and a model-based optimization strategy was proposed to minimize the operational cost of the desulfurization system. First, a mathematical model for the FBB with a two-stage desulfurization process was established. Then, several parameters affecting the SO_2 concentration at the outlet of the slime-fluidized bed boiler were simulated and deeply analyzed. Finally, the optimization operation problems under different sulfur contents were studied with the goal of minimizing the total desulfurization cost. The optimized operation reduced the total desulfurization cost by 9%.

In Fischer–Tropsch (FT) synthesis, synthesis gas (or syngas, i.e., a mixture of H_2 and CO) is converted into a variety of hydrocarbon products, including paraffin, olefins, and value-added chemicals [26]. A two-dimensional CFD scale-up model of the FT reactor was developed to thermally compare the Microfibrous-Entrapped-Cobalt-Catalyst (MFECC) and the conventional Packed Bed Reactor (PBR). The model implemented an advanced predictive detailed kinetic model to study the effect of a thermal runaway on C5+ hydrocarbon product selectivity. The results demonstrated the superior capability of the MFECC bed in mitigating hotspot formation due to its ultra-high thermal conductivity. A significant improvement in C5+ hydrocarbon selectivity was observed in the MFECC bed in contrast to a significantly low number for the PBR.

Rheology studies the stress and deformation of matter that may flow; not only does it include liquids, but also soft solids and substances such as sludge, suspensions, and human body fluids [27]. The rheological characterization of fluids using a rheometer is an essential task in food processing, materials, healthcare, or even industrial engineering; in some cases, the high cost of a rheometer and the issues related to the possibility of developing both electrorheological and magnetorheological tests in the same instrument must be overcome.

Conclusions

The Special Issue on Process Design and Sustainable Development covers a highly important and rapidly expanding area of research and development. The articles included in the Special Issue cover a selection of important topics from the area. These topics will be interesting for many scientists, researchers, and engineers. As of December 2022, the articles have received approximately 20,000 views and 50 citations.

Conflicts of Interest: The author declares no conflict of interest.

References

1. United Nations, Sustainable Development Goals. Available online: https://sdgs.un.org/goals (accessed on 27 December 2022).
2. United Nations Climate Change, The Paris Agreement. Available online: https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement (accessed on 27 December 2022).
3. Our World in Data, Greenhouse Gas Emissions. Available online: https://ourworldindata.org/greenhouse-gas-emissions (accessed on 27 December 2022).
4. United Nations Climate Action, Net Zero Coalition. Available online: https://www.un.org/en/climatechange/net-zero-coalition (accessed on 27 December 2022).
5. European Commission, A European Green Deal. Available online: https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en (accessed on 27 December 2022).
6. European Environment Agency, Total Greenhouse Gas Emission Trends and Projections in Europe. Available online: https://www.eea.europa.eu/ims/total-greenhouse-gas-emission-trends (accessed on 27 December 2022).
7. Eurostat, Quarterly Greenhouse Gas Emissions in the EU. Available online: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Quarterly_greenhouse_gas_emissions_in_the_EU (accessed on 27 December 2022).
8. Euronews, EU Climate Chief Announces Updated Emissions Goal at COP27. Available online: https://www.euronews.com/green/2022/11/15/not-backtracking-eu-climate-chief-announces-updated-emissions-goal-at-cop27 (accessed on 27 December 2022).
9. Intergovernmental Panel on Climate Change (IPCC), Climate Change 2022, Mitigation of Climate Change. Available online: https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SPM.pdf (accessed on 27 December 2022).
10. Our World in Data, Emissions by Sector. Available online: https://ourworldindata.org/emissions-by-sector (accessed on 27 December 2022).
11. Glavič, P.; Novak Pintarič, Z.; Bogataj, M. Process Design and Sustainable Development—A European Perspective. *Processes* **2021**, *9*, 148. [CrossRef]
12. Hernandez, R.J.; Goñi, J. Responsible Design for Sustainable Innovation: Towards an Extended Design Process. *Processes* **2020**, *8*, 1574. [CrossRef]
13. Glavič, P. Updated Principles of Sustainable Engineering. *Processes* **2022**, *10*, 870. [CrossRef]
14. Fajsi, A.; Morača, S.; Milosavljević, M.; Medić, N. Project Management Maturity and Business Excellence in the Context of Industry 4.0. *Processes* **2022**, *10*, 1155. [CrossRef]
15. Širá, E.; Kotulič, R.; Kravčáková Vozárová, I.; Daňová, M. Sustainable Development in EU Countries in the Framework of the Europe 2020 Strategy. *Processes* **2021**, *9*, 443. [CrossRef]
16. Ritchie, H.; Roser, M. CO2 and Greenhouse Gas Emissions. Available online: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions (accessed on 24 March 2021).
17. Kuo, T.-C.; Shen, Y.-S.; Sriwattana, N.; Yeh, R.-H. Toward Net-Zero: The Barrier Analysis of Electric Vehicle Adoption and Transition Using ANP and DEMATEL. *Processes* **2022**, *10*, 2334. [CrossRef]
18. Abed, A.M.; Seddek, L.F.; Elattar, S. Building a Digital Twin Simulator Checking the Effectiveness of TEG-ICE Integration in Reducing Fuel Consumption Using Spatiotemporal Thermal Filming Handled by Neural Network Technique. *Processes* **2022**, *10*, 2701. [CrossRef]
19. Capossio, J.P.; Fabani, M.P.; Reyes-Urrutia, A.; Torres-Sciancalepore, R.; Deng, Y.; Baeyens, J.; Rodriguez, R.; Mazza, G. Sustainable Solar Drying of Brewer's Spent Grains: A Comparison with Conventional Electric Convective Drying. *Processes* **2022**, *10*, 339. [CrossRef]

20. Mun, J.; Yun, E.; Choi, H. A Study of Linkage Effects and Environmental Impacts on Information and Communications Technology Industry between South Korea and USA: 2006–2015. *Processes* **2021**, *9*, 1043. [CrossRef]
21. Capossio, J.P.; Fabani, M.P.; Román, M.C.; Zhang, X.; Baeyens, J.; Rodriguez, R.; Mazza, G. Zero-Waste Watermelon Production through Nontraditional Rind Flour: Multiobjective Optimization of the Fabrication Process. *Processes* **2022**, *10*, 1984. [CrossRef]
22. Fülöp, M.T.; Gubán, M.; Gubán, A.; Avornicului, M. Application Research of Soft Computing Based on Machine Learning Production Scheduling. *Processes* **2022**, *10*, 520. [CrossRef]
23. Di Pretoro, A.; D'Iglio, F.; Manenti, F. Optimal Cleaning Cycle Scheduling under Uncertain Conditions: A Flexibility Analysis on Heat Exchanger Fouling. *Processes* **2021**, *9*, 93. [CrossRef]
24. Ramirez-Argaez, M.A.; Abreú-López, D.; Gracia-Fadrique, J.; Dutta, A. Numerical Study of Electrostatic Desalting Process Based on Droplet Collision Time. *Processes* **2021**, *9*, 1226. [CrossRef]
25. Xiao, Y.; Xia, Y.; Jiang, A.; Lv, X.; Lin, Y.; Zhang, H. Research on Optimization of Coal Slime Fluidized Bed Boiler Desulfurization Cooperative Operation. *Processes* **2021**, *9*, 75. [CrossRef]
26. Abusrafa, A.E.; Challiwala, M.S.; Wilhite, B.A.; Elbashir, N.O. Thermal Assessment of a Micro Fibrous Fischer Tropsch Fixed Bed Reactor Using Computational Fluid Dynamics. *Processes* **2020**, *8*, 1213. [CrossRef]
27. Hernández-Rangel, F.J.; Saavedra-Leos, M.Z.; Morales-Morales, J.; Bautista-Santos, H.; Reyes-Herrera, V.A.; Rodríguez-Lelis, J.M.; Cruz-Alcantar, P. Continuous Improvement Process in the Development of a Low-Cost Rotational Rheometer. *Processes* **2020**, *8*, 935. [CrossRef]