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Article

Technologies for sustainable development to face climate crisis

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Abstract: Sustainable economies have demand for natural resources (i.e., ecological footprint) less than nature's renewable supply of resources (called biocapacity) to support clean production, development and equity in societies. The goal of this study is to identify new technologies that can support energy change from fossil fuels to renewable sources directed at zero-carbon and sustainable economies having lower environmental pollution and higher social well-being. Using data from scientific publications and patents until 2024 and a liner model for regression analyses, empirical results reveal that sustainable technologies having rapid growth and supporting the transformation of the energy sector, economic system and society are blue hydrogen, floating photovoltaic systems, carbon capture storage and utilization, green hydrogen and liquid metal batteries. The implications of findings here for sustainable policies oriented to new technologies are discussed to have, whenever possible, zero-carbon economies directed to long-run sustainable development. The purpose of this study here is basic to support sustainable economies with new technologies that provide the greatest level of general well-being of people with the least amount of resource use and with low environmental harm to support the "one health" of people, animals and natural ecosystems (i.e., optimal health results considering the interaction between population, zoologic, botanic and total environment ecosystems).

Keywords: sustainable economies; sustainable future; climate crisis; sustainable technologies; energy change; zero-carbon; carbon neutrality; renewable energy; sustainable development

1. Introduction

The evolution of modern societies with industrial acceleration, population growth, conflicts and other crises is generating changes in environment, climate, land and biodiversity with deterioration of many ecosystems [1]. Intensive industrialization of advanced and developing economies is also increasing carbon emissions associated with a rise in atmospheric greenhouse gases and emerging contaminants [2–6]. Human societies are inducing main alterations in Earth systems, such as atmosphere, lithosphere, hydrosphere, biosphere, etc. [7–11] that are driving the Anthropocene [12]. These changes are due to the intensity of human interactions with the total environment that have accelerated in recent decades [13–38]. Linstone [39] states that the future of socioeconomic systems depends on actions in the short run directed to lung-run sustainable development [40–43]. In this perspective, the goal of the investigation here is to explore sustainable technologies directed to support economies toward energy change based on zero-carbon emissions with low negative impact on environmental and human health.

2. Theoretical background and framework

Ayres [44] argues that technological transformations support socioeconomic progress [45]. Industrialization and several innovations from 1960s have generated economic and population growth [46–49]. However, industrial and technological change have also generated urbanization and environmental pollution [14,16]. In fact, high population growth increases the extraction of natural resources, the production and consumption of goods, and of solid, agricultural and special waste associated with high environmental pollution, emerging pollutants and health issues in population [8].

Ali et al. [15] show that resource depletion leads to environmental damage with consequential climate crisis [50–54]. Meadows et al. [55] argued that resources of the Earth may not sustain the food for World population beyond the 2110s, though new technologies. One of the solutions can be the circular economies to support a sustainable development and avoid severe damages in ecosystems for future generations [41,42,45,46,48,49,56–72]. Current economies endeavor to implement technological processes for renewable energy but they are not sufficient and also expensive investments to satisfy the high energy consumption of modern societies [48]. The study here uses the database of Scopus [73] to develop a statistical analysis based on a linear model of time series that detects and suggests promising technologies directed to sustainability [74]. Analyses of findings and an in-depth discussion provide main implications to support innovation policies for ecological change directed to sustainability in socio-economic systems.

3. Research methodology

3.1. Sources and data collection

Sources of scientific information are Scopus database [73]. **Table 1** shows main data about some critical sustainable technologies under study here for supporting energy change and sustainability [41,75–85]. As Coccia et al. [86] aptly point out, scientific publications (articles, conference papers, etc.) and patents serve as the bedrock for scientific and technological analyses of new technological directions. Technologies under study here are selected according to current literature in environmental and sustainability sciences [41,76–85]. The main goal is to identify technological pathways that not only combat environmental degradation but also foster ecological change directed to sustainability of socio-economic systems. To achieve this ambitious goal, the next sections describe the study design [74].

3.2. Measure of scientific and technological development

The scientific development of technologies directed to carbon neutrality in a perspective of sustainability is investigated considering articles and patents until June 2024 collected with the research strings described in **Table 1** [86–88].

Table 1. Queries for detecting directions of sustainable technologies.

Main research strings used to collect data of articles and patents of sustainable technologies	**Data analyzed until June 2024**		
	Articles	**Patents**	
Technologies and period under study	**Total number**	**Patent period**	**Total number**
Offshore wind turbine (1976–2024)	10,074	(1998–2024)	5541
Floating photovoltaic systems (2012–2024)	192	(2010–2024)	77
Grey hydrogen (2007–2024)	146	(2001–2024)	259
Green hydrogen (1997–2024)	5352	(1991–2024)	1033
Blue hydrogen (2016–2024)	265	(1979–2024)	358
Carbon capture utilization and storage (2010–2024)	1535	(2013–2024)	207
Smart grids of electricity networks (2006–2024)	480	(2010–2024)	313
Redox–flow batteries (1979–2024)	5932	(1983–2024)	7792
Liquid metal batteries (2009–2024)	259	(1981–2024)	226

Source: Scopus 2024 [73].

3.3. Modelling and statistical analysis

Log variables have normal distribution to perform appropriate statistical analysis. Data of **Table 1** are examined with a log-linear model:

$$\log F_{i,t} = a + b \text{ time} + u_{i,t} \quad (1)$$

- $F_{i,t}$ is scientific products of technology *i* at the time *t*
- a is a constant; b is the coefficient of regression; $u_{i,t}$ = error term
- log is logarithmic with base *e* = 2.71828.

Ordinary Least-Squares (OLS) method estimates parameters of Equation (1) with the software IBM SPSS Statistics 26®.

4. New technologies for energy change directed to next sustainable economies

Figure 1 shows trends of publications in some sustainable technologies for the change from fossil fuels to renewable energy sources in an effort to reduce CO_2 emissions for ecological transition and sustainable development. The growing trajectories are mainly given by technologies of offshore wind turbines, green hydrogen, carbon capture and utilization, blue hydrogen, and floating photovoltaic systems.

Figure 2 confirms that the amount of scientific publications and patents in sustainable technologies is higher in offshore wind turbines, redox flow batteries and green hydrogen (cf., **Table 1**).

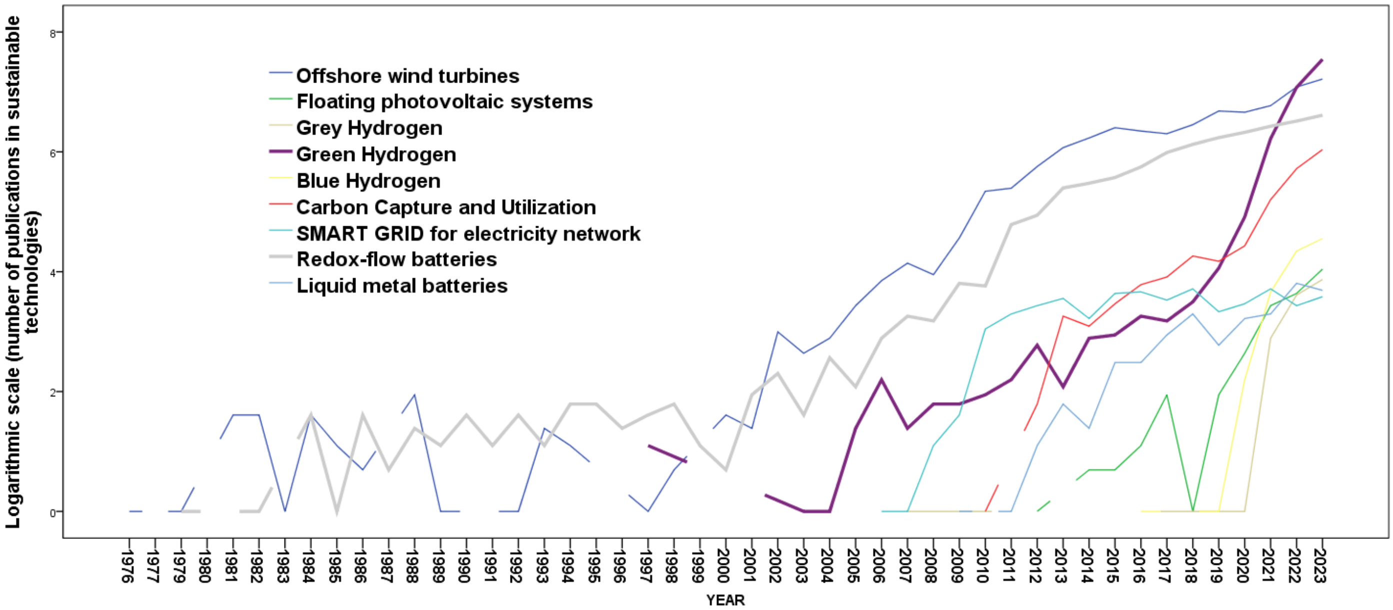

Figure 1. Trends of publications in sustainable technologies.

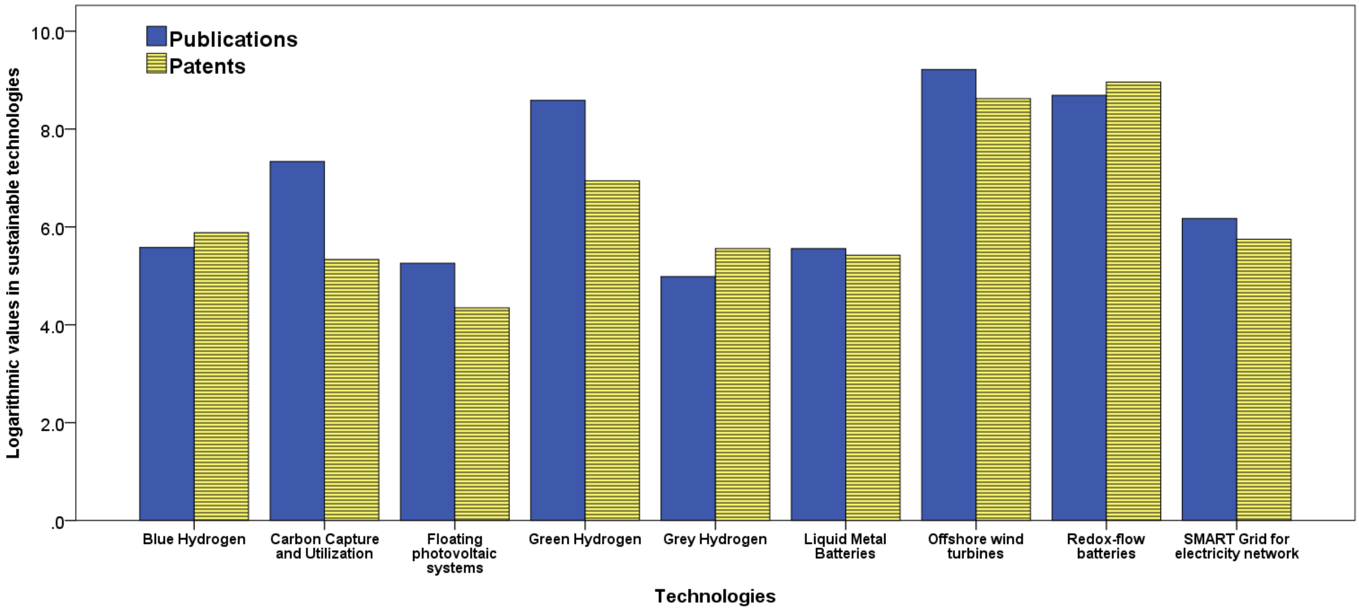

Figure 2. Comparison of patents and publications in sustainable technologies.

Table 2 shows the estimated relationships based on log-linear model (Eq. 1). The higher coefficient of regression is for the technologies of blue hydrogen $b = 0.64$ (p-value = 0.01); it indicates that 1-unit change in X (time) corresponds to an expected increase in Y of $e^{0.64} = 1.90$, i.e., 90%. Other emerging technologies having rapid temporal growth are floating photovoltaic systems and carbon capture and utilization $b = 0.35$ (p-value = 0.001), as a consequence $e^{0.35} = 1.42$: 1-unit change in X (time) corresponds to an expected increase in Y of 42%. Promising sustainable technologies having an acceleration of scientific knowledge and advances are also green hydrogen $b = 0.27$ (p-value = 0.001), every year this technology increases by 31% and finally liquid metal batteries $b = 0.25$ (p-value = 0.001), every year this sustainable technology increases by 28%.

Table 2. Results of regression analysis based on scientific production in sustainable technologies on time.

Technologies	**Coefficient *B***	**Constant**	***F*-test**	R^2
Offshore wind turbines	0.17***	–332.74***	218.32***	0.85
Floating photovoltaic systems	0.35***	–697.83***	38.94***	0.80
Grey Hydrogen	0.22	–443.71	5.16	0.56
Green Hydrogen	0.27***	–541.44***	89.76***	0.81
Blue Hydrogen	0.64**	–1292.24**	17.24**	0.78
Carbon Capture and Utilization	0.35***	–699.62***	88.60***	0.88
Smart Grid for Electricity Network	0.15**	–289.52**	13.62**	0.45
Redox-flow batteries	0.16***	–316.80***	307.08***	0.88
Liquid Metal Batteries	0.25***	–491.67***	62.74***	0.83

Note: Dependent variable: Log publications of technology *i*; Explanatory variable: time, year; *** significant at 1‰; ** significant at 1%; * significant at 5%. *F* is the ratio of the variance explained by the model to the unexplained variance. R^2 is the coefficient of determination.

5. Analysis of results and discussions

Results, using the estimated coefficients of regression in **Table 2**, reveal, unlike **Figure 1** that sustainable technologies having a rapid growth are:

- blue hydrogen process;
- floating photovoltaic technological systems [89];
- carbon capture storage and utilization [90,91];
- green hydrogen technology;
- liquid metal batteries.

Other new sustainable technologies having the potential of growth and that are in the emerging phase of evolutionary growth are:

- redox-flow batteries;
- smart grids for electricity delivery [85,92].

As the future is coming fast, societies will be dealing with a vastly different climate and energy landscape soon. The study here shows that new technologies directed to carbon neutrality that can reduce environmental damages are mainly based on CO_2 capture and utilization, blue hydrogen, photovoltaic solar plants, etc. Moreover, these technologies are more and more basic for clean production [93–95]. Results show that energy transition for sustainable economies is associated with scientific advances directed in specific sustainable technologies, just mentioned, that can improve the total environment. However, the negative side of renewable energy sources is that they are intermittent, such as a limited number of hours of sunlight per day, variability of wind speed over time and space, such that supply and demand can generate continuous disequilibrium. Sustainable technologies discussed here can improve some aspects for decarbonization in critical industrial sectors and a systemic strategy for sustainable economies and development is based on:

- energy policy directed to cost-effective renewable energy sources and clean technologies that reduce environmental pollution and factors associated with climate crisis to maintain, whenever possible, natural ecosystems.

- technological policies directed to innovations for reducing CO_2 emission, improving natural resource efficiency and expanding sustainability in industrial sectors to support employment, income, environment, health and wellbeing of people.

However, a long-term strategy for sustainable economies also needs good governance, efficient institutions and a national leadership, involving all social communities to reduce environmental pollution and running out of natural resources [55,96] directed to the long-run goal of 'one health' of people, animals and natural ecosystems [97–99].

6. Concluding remarks

Main findings here reveal that some sustainable technologies have rapid technological evolution, such as blue hydrogen processes, floating photovoltaic technologies and carbon capture storage and use and are promising for carbon neutrality in economics. In order to advance sustainability and reduce environmental issues related to the shortage or exhaustion of normal assets, these new technological directions must be progressively taken after [96,100]. Subsequently, in order to guarantee that human society may proceed for a future ecological transition, financial frameworks ought to back the sustainable innovations that are the subject of this investigation to minimize natural debasement and ensure the biosphere [97,99,101]. The progression of some technologies in sustainable directions, as well as commercialization of related innovations, can be quickened by public and private funding and appropriate inventive to R&D investments in different industrial sectors [102–104]; in short the policymakers should design R&D strategies toward promising innovations (described here) related to ecological transition and energy change from fossil fuels to renewable energy sources to support sustainable economies [105,106]. These R&D strategies can be connected to energy and financial arrangements that foster positive interactions between human society inside cities, the environment and common assets in large urban agglomerations for circular and sustainable economies. In other words, institutional and economic change should be directed to financial sustainability in technologies protecting the total environment [107,108].

In common, countries ought to create and actualize long-term sustainable strategies that reduce more and more coal and petroleum-based economies. Hence, new innovation avenues should foster large circular economic systems, which improve the ecosystem for current and future generations' well-being, and support sustainability in economic and social development [109,110].

6.1. Limitations

Conclusions here are, of course, tentative. This study shows some interesting but preliminary results in forecasting new directions in sustainable technologies. Although this paper yields a few captivating insights, some limitations are that: 1) scientific outputs and research topics can only detect certain aspects of the ongoing dynamics of sustainable technologies; 2) statistical analyses consider results and implications based on specific technologies directed to sustainability; 3) proposed framework analyzes some technologies, but discarding interesting insights from other technological fields for ecological transition; 4) finally, other social, institutional and economic factors can influence the adoption and implementation of sustainable technologies that deserve to be investigated in future researches. However, although these limitations, the results here clearly illustrate the dynamics of some technologies that can drive ecological transition and sustainability in future socioeconomic systems.

6.2. Ideas for future research

There is a need for much more detailed research into the investigation of scientific and technological directions for ecological transition and sustainability. The precise areas for further investigations have to focus on:

1) complementary analyses based on a lot of patents that provide a more comprehensive view of evolutionary pathways in different technologies and related scientific and innovative ecosystems directed to sustainability in society.
2) confounding factors, such as the level of public and private R&D investments, international collaboration in specific sustainable technologies, etc. These factors can explain other aspects of emerging research fields and technologies for ecological transition.
3) A higher variety of scientific and technological fields that clarify the overall ecological transition.

However, difficulties in the analyses of technological fields directed to future sustainability can be synthetized by Wright [109] that properly claims: “In the world of technological change, bounded rationality is the rule”. To conclude, these findings here extend the scientific and technological information directed to clarify sustainable technologies that support ecological transition [111–152]. However, future studies should be directed to intensive and progressing investigations that are required to upgrade the sustainable expectations about new technology that nations must design and implement in next industrial systems to moderate environmental degradation and foster sustainability of the total environment and well-being in society [153–184].

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References

1. Foley SF, Gronenborn D, Andreae MO, et al. The Palaeoanthropocene–The beginnings of anthropogenic environmental change. Anthropocene. 2013; 3: 83–88.
2. Marsh GP. Man and Nature. Harvard University Press; 1864.
3. Fowler D, Brimblecombe P, Burrows J, et al. A chronology of global air quality. Philosophical Transactions of the Royal Society A. 2020; 378. doi: 10.1098/rsta.2019.0314
4. Núñez-Delgado A, Zhang Z, Bontempi E, et al. Topic Reprint, New Research on Detection and Removal of Emerging Pollutants. MDPI; 2024. Volume I and II.
5. Akan AP; Coccia M. Changes of Air Pollution between Countries Because of Lockdowns to Face COVID-19 Pandemic. Applied Sciences. 2022; 12(24): 12806. doi: 10.3390/app122412806.
6. Núñez-Delgado A, Zhang Z, Bontempi E, et al. Editorial on the Topic “New Research on Detection and Removal of Emerging Pollutants”. Materials. 2023; 16(2): 725. doi: 10.3390/ma16020725
7. Global Change. Population growth. Available online: https://ugc.berkeley.edu/background-content/population-growth/ (accessed on 24 March 2024).
8. La Scalia G, La Fata CM, Certa A, et al. A multifunctional plant for a sustainable reuse of marble waste toward circular economy. Waste Management & Research. 2022; 40(6): 806–813. doi: 10.1177/0734242X211029161

9. NASA Global climate change. The Effects of Climate Change. Available online: https://climate.nasa.gov/effects/ (accessed on 5 March 2024).
10. Steingraber S. Living Downstream: An Ecologist Looks at Cancer and the Environment. Addison-Wesley; 1997.
11. Thomson MC, Stanberry LR. Climate Change and Vector borne Diseases. The New England Journal of Medicine. 2022; 387: 1969–1978. doi: 10.1056/NEJMra2200092
12. Crutzen PJ, Stoermer EF. The Anthropocene. Global IGBP Change Newsletter. 2000; 41: 17–18.
13. Coccia M. Theories of Development. A. Farazmand (ed.), Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer; 2019.
14. Adam D. How far will global population rise? Researchers can't agree. Nature. 2021; 597(7877): 462–465. doi: 10.1038/d41586-021-02522-6
15. Ali A, Audi M, Roussel Y. Natural Resources Depletion, Renewable Energy Consumption and Environmental Degradation: A Comparative Analysis of Developed and Developing World. International Journal of Energy Economics and Policy. 2021; 11(3): 251–260.
16. Belpomme D, Irigaray P, Hardell L, et al. The multitude and diversity of environmental carcinogens. Environmental Research. 2007; 105(3): 414–429.
17. Coccia M. Disruptive firms and industrial change. Journal of Economic and Social Thought. 2017; 4(4): 437–450. doi: 10.1453/jest.v4i4.1511
18. Coccia M. Sources of disruptive technologies for industrial change. L'industria–Rivista di Economia e Politica Industriale. 2017; 38: 97–120. doi: 10.1430/87140
19. Coccia M. The source and nature of general purpose technologies for supporting next K-waves: Global leadership and the case study of the U.S. Navy's Mobile User Objective System. Technological Forecasting and Social Change. 2017; 116: 331–339. doi: 10.1016/j.techfore.2016.05.019
20. Coccia M. An introduction to the theories of national and regional economic development. Turkish Economic Review. 2018; 5(4): 350–358. doi: 10.1453/ter.v5i4.1794
21. Coccia M. What are the characteristics of revolution and evolution? Journal of Economic and Social Thought. 2018; 5(4): 288–294. doi: 10.1453/jest.v5i4.1789
22. Coccia M. Disruptive firms and technological change. Quaderni IRCrES-CNR. 2018; 3(1): 3–18. doi: 10.23760/2499-6661.2018.001
23. Coccia M. Classification of innovation considering technological interaction. Journal of Economics Bibliography. 2018; 5(2): 76–93. doi: 10.1453/jeb.v5i2.1650
24. Coccia M. The theory of technological parasitism for the measurement of the evolution of technology and technological forecasting. Technological Forecasting and Social Change. 2019; 141: 289–304. doi: 10.1016/j.techfore.2018.12.012
25. Coccia M. What is Technology and Technology Change? A New Conception with Systemic-Purposeful Perspective for Technology Analysis. Journal of Social and Administrative Sciences. 2019; 6: 145–169.
26. Coccia M. Comparative Institutional Changes. In: Farazmand A (editors). Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer, Cham; 2019.
27. Coccia M. Intrinsic and extrinsic incentives to support motivation and performance of public organizations. Journal of Economics Bibliography. 2019; 6(1): 20–29. doi: 10.1453/jeb.v6i1.1795
28. Coccia M. Theories of the evolution of technology based on processes of competitive substitution and multi-mode interaction between technologies. Journal of Economics Bibliography. 2019; 6(2): 99–109. doi: 10.1453/jeb.v6i2.1889
29. Coccia M. Why do nations produce science advances and new technology? Technology in society. 2019; 59(101124): 1–9.
30. Coccia M. Factors determining the diffusion of COVID-19 and suggested strategy to prevent future accelerated viral infectivity similar to COVID. Science of the Total Environment. 2020; 729.
31. Coccia M. How does science advance? Theories of the evolution of science. Journal of Economic and Social Thought. 2020; 7(3): 153–180. doi: 10.1453/jest.v7i3.2111
32. Coccia M. Destructive Technologies for Industrial and Corporate Change. In: Farazmand A (editors). Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer, Cham; 2020.
33. Coccia M. Fishbone diagram for technological analysis and foresight. International Journal of Foresight and Innovation Policy. 2020; 14(2–4): 225. doi: 10.1504/ijfip.2020.111221

34. Coccia M. Asymmetry of the technological cycle of disruptive innovations. Technology Analysis & Strategic Management. 2020; 32(12): 1462–1477. doi: 10.1080/09537325.2020.1785415
35. Coccia M. The evolution of scientific disciplines in applied sciences: Dynamics and empirical properties of experimental physics. Scientometrics. 2020; 124: 451–487.
36. Constant K, Nourry C, Seegmuller T. Population growth in polluting industrialization. Resource and Energy Economics. 2014; 36(1): 229–247.
37. IPCC. Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2007. p. 17.
38. IPCC. Summary for Policymakers. In: Stocker TF, Qin D, Plattner G-K, et al. (editors). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press; 2013.
39. Linstone HA. Historians and complexity: Trends vs. collapses? Technological Forecasting and Social Change. 2010; 77(8): 1415–1428.
40. Sanni M, Verdolini E. Eco-innovation and openness: Mapping the growth trajectories and the knowledge structure of open eco-innovation. Sustainable Futures. 2022; 4(100067). doi: 10.1016/j.sftr.2022.100067
41. Chapman A, Ertekin E, Kubota M, et al. Achieving a Carbon Neutral Future through Advanced Functional Materials and Technologies. Bulletin of the Chemical Society of Japan. 2022; 95(1): 73–103.
42. National Academies of Sciences, Engineering, and Medicine. Carbon Dioxide Utilization Markets and Infrastructure: Status and Opportunities: A First Report. The National Academies Press; 2022.
43. NIST. Reference Fluid Thermodynamic and Transport Properties Database (REFPROP): Version 10. Available online: https://www.nist.gov/srd/refprop (accessed on 12 June 2024).
44. Ayres RU. Towards a Disequilibrium Theory of Endogenous Economic Growth. Environmental and Resource Economics. 1998; 11(3–4): 289–300.
45. Sterner T, Jeroen CJ, Van Den Bergh M. Frontiers of Environmental and Resource Economics. Environmental and Resource Economics. 1998; 11(3–4): 243–260.
46. Ayres RU. Technological transformations and long waves. Part. Technological Forecasting and Social Change. 1990; 37(1): 1–37.
47. Ayres RU. Technological transformations and long waves. Part II. Technological Forecasting and Social Change. 1990; 37(2): 111–137.
48. Campbell CJ. Petroleum and People. Population and Environment. 2002; 24(2): 193–207.
49. Coccia M. Measuring the impact of sustainable technological innovation. International Journal of Technology Intelligence and Planning. 2009.5(3): 276-288. doi: 10.1504/IJTIP.2009.026749
50. Coccia M. Bolstering effect in the interaction between artificial intelligence and quantum science for scientific and technological development. Advance. 2024. doi: 10.31124/advance.25140980.v1
51. Coccia M. Digital Pathology Ecosystem: Basic Elements to Revolutionize the Diagnosis and Monitoring of Diseases in Health Sector. In: Faghih N (editors). Digital Entrepreneurship. Contributions to Management Science. Springer, Cham; 2024. pp. 111–134.
52. Coccia M. New Technological Directions for a Sustainable Development and Sustainability. In: Núñez-Delgado A (editors). Planet Earth: Scientific Proposals to Solve Urgent Issues. Springer, Cham; 2024.
53. Coccia M. The General Theory of Scientific Variability for Technological Evolution. Sci. 2024; 6(2): 31. doi: 10.3390/sci6020031
54. Coccia M. Converging Artificial Intelligence and Quantum Technologies: Accelerated Growth Effects in Technological Evolution. Technologies. 2024; 12(5): 66. doi: 10.3390/technologies12050066
55. Meadows DH, Meadows DL. Randers J, Behrens III WW. The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind. Universe Books; 1972.
56. Coccia M. A Theory of the General Causes of Long Waves: War, General Purpose Technologies, and Economic Change. Technological Forecasting & Social Change. 2018; 128(March): 287-295.
57. Bowman DMJS, Balch J, Artaxo P, et al. The human dimension of fire regimes on Earth. Journal of Biogeography. 2011; 38(12): 2223–2236.

58. Glikson A. Fire and human evolution: The deep-time blueprints of the Anthropocene. Anthropocene. 2013; 3: 89–92.
59. Chin A, Fu R, Harbor J, et al. Anthropocene: Human interactions with earth systems. Anthropocene. 2013; 1: 1–2.
60. Coccia M. Energy metrics for driving competitiveness of countries: Energy weakness magnitude, GDP per barrel and barrels per capita. Energy Policy. 2010. 38(3): 1330-1339.
61. Coccia M. Effects of human progress driven by technological change on physical and mental health. STUDI DI SOCIOLOGIA. 2021; (2): 113–132. doi: 10.26350/000309_000116
62. Coccia M. Technological Innovation. In: Ritzer G, Rojek C (editors). The Blackwell Encyclopedia of Sociology. John Wiley & Sons, Ltd; 2021.
63. Kaza S, Yao LC, Bhada-Tata P, Van Woerden F. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. In: Urban Development. World Bank; 2018.
64. Ruddiman WF. The anthropogenic greenhouse era began thousands of years ago. Climate Change. 2003; 61: 261–293.
65. Steffen W, Crutzen PJ, McNeill JR. The Anthropocene: Are humans now overwhelming the great forces of nature? AMBIO. 2007; 36(8): 614–621.
66. Zalasiewicz J, Williams M, Haywood A, Ellis M. The Anthropocene: A new epoch of geological time? Philosophical Transactions of the Royal Society A. 2011; 369: 835–841.
67. United Nations. Sustainable development. 2024. Available online: https://sdgs.un.org/goals (accessed on 3 September 2024)
68. van Dijk M, Morley T, Rau ML, Saghai Y. A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. Nat Food. 2021; 2: 494–501. doi: 10.1038/s43016-021-00322-9
69. Hausfather Z, Peters GP. Emissions-the ‘business as usual’ story is misleading. Nature. 2020; 577(7792): 618–620. doi: 10.1038/d41586-020-00177-3
70. Moss R, Edmonds J, Hibbard K. et al. The next generation of scenarios for climate change research and assessment. Nature. 2010; 463: 747–756. doi: 10.1038/nature08823
71. Tollefson J. How hot will Earth get by 2100? Nature. 2020; 580(7804): 443–445. doi: 10.1038/d41586-020-01125-x
72. Wang F, Harindintwali JD, Yuan Z, et al. Technologies and perspectives for achieving carbon neutrality. The Innovation. 2021; 2(4). doi: 10.1016/j.xinn.2021.100180
73. Scopus. Start exploring, search documents. Patents. Available online: https://www.scopus.com/search/form.uri?display=basic#basic (accessed on 5 March 2024).
74. Coccia M, Benati I. Comparative Models of Inquiry, A. Farazmand (ed.), Global Encyclopedia of Public Administration, Public Policy, and Governance. 2018; Springer Nature, doi: 10.1007/978-3-319-31816-5_1199-1.
75. EPO. Technologies to enable a sustainable energy transition. Available online: https://www.epo.org/en/news-events/in-focus/green-tech/energy-transition-technologies (accessed on 25 June 2024).
76. Gonzalo Peinado A, Benmessaoud T, Entezami M, García Márquez FP. Optimal maintenance management of offshore wind turbines by minimizing the costs. Sustainable Energy Technologies and Assessments. 2022; 52(102230).
77. Li M, Cao S, Zhu X, et al. Techno-economic analysis of the transition towards the large-scale hybrid wind-tidal supported coastal zero-energy communities. Applied Energy. 2022; 316(119118).
78. Wang L, Kolios A, Liu X, et al. Reliability of offshore wind turbine support structures: A state-of-the-art review. Renewable and Sustainable Energy Reviews. 2022; 161(112250).
79. Balaji K, Rabiei M. Carbon dioxide pipeline route optimization for carbon capture, utilization, and storage: A case study for North-Central USA. Sustainable Energy Technologies and Assessments. 2022; 51(101900).
80. Elavarasan RM, Pugazhendhi R, Irfan M, et al. State-of-the-art sustainable approaches for deeper decarbonization in Europe–An endowment to climate neutral vision. Renewable and Sustainable Energy Reviews. 2022; 159(112204). doi: 10.1016/j.rser.2022.112204
81. Gadikota G. Carbon mineralization pathways for carbon capture, storage and utilization. Communications Chemistry. 2021; 4(1): 23.
82. Bapat S, Koranne V, Shakelly N, et al. Cellular agriculture: An outlook on smart and resilient food agriculture manufacturing. Smart and Sustainable Manufacturing Systems. 2022; 6(1): 1–11.
83. Moritz J, Tuomisto HL, Ryynänen T. The transformative innovation potential of cellular agriculture: Political and policy stakeholders’ perceptions of cultured meat in Germany. Journal of Rural Studies. 2022; 89: 54–65.
84. Esmaeilzadeh P. Benefits and concerns associated with blockchain-based health information exchange (HIE): A qualitative study from physicians’ perspectives. BMC Medical Informatics and Decision Making. 2022; 22(1): 80.

85. Strepparava D, Nespoli L, Kapassa E, et al. Deployment and analysis of a blockchain-based local energy market. Energy Reports. 2022; 8: 99–113.
86. Coccia M, Roshani S, Mosleh M. Evolution of Sensor Research for Clarifying the Dynamics and Properties of Future Directions. Sensors. 2022; 22: 9419. doi: 10.3390/s22239419
87. Coccia M. Technological trajectories in quantum computing to design a quantum ecosystem for industrial change. Technology Analysis & Strategic Management. 2022; 36(8): 1733–1748. doi: 10.1080/09537325.2022.2110056
88. Coccia M. Probability of discoveries between research fields to explain scientific and technological change. Technology in Society. 2022; 68: 101874. doi: 10.1016/j.techsoc.2022.101874
89. Iberdrola. Floating photovoltaic solar energy. Available online: https://www.iberdrola.com/innovation/floating-photovoltaic (accessed 24 June 2024).
90. Coccia M. General sources of general purpose technologies in complex societies: Theory of global leadership-driven innovation, warfare and human development. Technology in Society. 2015; 42: 199-226.
91. Coccia M. The Fishbone diagram to identify, systematize and analyze the sources of general purpose technologies. Journal of Social and Administrative Sciences. 2017; 4(4): 291–303. doi: 10.1453/jsas.v4i4.1518
92. Centobelli P, Cerchione R, Del Vecchio P, et al. Blockchain technology for bridging trust, traceability and transparency in circular supply chain. Information & Management. 2021; 59(7): 103508.
93. Coccia M. Sources of technological innovation: Radical and incremental innovation problem-driven to support competitive advantage of firms. Technology Analysis & Strategic Management. 2017; 29(9): 1048–1061. doi: 10.1080/09537325.2016.1268682
94. Coccia M. Optimization in R&D intensity and tax on corporate profits for supporting labor productivity of nations. The Journal of Technology Transfer. 2018; 43(3):792-814. doi: 10.1007/s10961-017-9572-1
95. Coccia M. A Theory of classification and evolution of technologies within a Generalized Darwinism. Technology Analysis & Strategic Management. 2019; 31(5): 517–531.
96. Sulston J. People and the Planet. The Royal Society (Britain). 2012.
97. Magdoff F. Global Resource Depletion: Is Population the Problem? Monthly Review. 2013. doi: 10.14452/MR-064-08-2013-01_2
98. Magdoff F, Bellamy Foster J. What Every Environmentalist Needs to Know About Capitalism. Monthly Review Press; 2011. pp. 124–131.
99. Saeli M, Capela MN, Campisi T, et al. Architectural technologies for life environment: Spent coffee ground reuse in lime-based mortars. A preliminary assessment for innovative green thermo-plasters. Construction and Building Materials. 2022; 319(126079). doi: 10.1016/j.conbuildmat.2021.126079
100. Roshani S, Bagherylooieh M-R, Mosleh M, et al. What is the Relationship between Research Funding and Citation-Based Performance? A Comparative Analysis between Critical Disciplines. Scientometrics. 2021; 126: 7859–7874. doi: 10.1007/s11192-021-04077-9
101. Roshani S, Coccia M, Mosleh M. Sensor Technology for Opening New Pathways in Diagnosis and Therapeutics of Breast, Lung, Colorectal and Prostate Cancer. HighTech and Innovation Journal. 2022; 3(3): 356–375. doi: 10.28991/hij-2022-03-03-010
102. Mosleh M, Roshani S, Coccia M. Scientific Laws of Research Funding to Support Citations and Diffusion of Knowledge in Life Science. Scientometrics. 2022; 127(4): 1931–1951. doi:10.1007/s11192-022-04300-1
103. Coccia M. Comparative Critical Decisions in Management. In: Farazmand A. (eds), Global Encyclopedia of Public Administration, Public Policy, and Governance. Springer, Cham. doi: 10.1007/978-3-319-31816-5_3969-1, 2021
104. Kargi B, Coccia M. Emerging innovative technologies for environmental revolution: a technological forecasting perspective. International Journal of Innovation.2024. 12(3), e27000. doi: 10.5585/2024.27000
105. Aidnik M. Envisioning a Utopian Ecosocialism in the Darkness of the Covid-19 Pandemic. Capitalism Nature Socialism. 2022; 33(2): 44–59. doi: 10.1080/10455752.2021.2016878
106. Adaman F, Devine P. Revisiting the Calculation Debate: A Call for a Multiscale Approach. Rethinking Marxism. 2022; 34(2): 162–192. doi: 10.1080/08935696.2022.2051374
107. Aresta M, Dibenedetto A. Carbon Recycling Through CO_2-Conversion for Stepping Toward a Cyclic-C Economy. A Perspective. Frontiers in Energy Research. 2020; 8: 159. doi: 10.3389/fenrg.2020.00159

108. Pronti A, Coccia M. Agroecological and conventional agricultural systems: Comparative analysis of coffee farms in Brazil for sustainable development. International Journal of Sustainable Development. 2021; 23(3–4): 223–248. doi: 10.1504/IJSD.2020.115223
109. Wright G. Towards a More Historical Approach to Technological Change. The Economic Journal.1997. 107 (444): 1560–1566.
110. Coccia M. 2020. How (Un)sustainable Environments are Related to the Diffusion of COVID-19: The Relation between Coronavirus Disease 2019, Air Pollution, Wind Resource and Energy. Sustainability 12(22), 9709; doi: 10.3390/su12229709
111. Ali S, Yan Q, Hu J. et al. Can bioenergy act as an entrepreneurial opportunity for the sustainable economic development of an emerging economy? A socio-technical approach. Environmental Science and Pollution Research. 2023; 30: 98106–98126. doi: 10.1007/s11356-023-29211-3
112. Ampelli C. Electrode design for ammonia synthesis. Nature Catalysis. 2020; 3: 420–421. doi: 10.1038/s41929-020-0461-x
113. Anastopoulos I, Bontempi E, Coccia M, et al. Sustainable strategic materials recovery, what’s next? Next Sustainability. 2023; 100006. doi: 10.1016/j.nxsust.2023.100006
114. ArcelorMittal. Clean power steelmaking. Available online: https://automotive.arcelormittal.com/sustainability/clean_power_steelmaking (accessed on 12 June 2024).
115. Ardito L, Coccia M, Messeni Petruzzelli A. Technological exaptation and crisis management: Evidence from COVID-19 outbreaks. R&D Manag. 2021; 51: 381–392. doi: 10.1111/radm.12455
116. Balkan green energy news. China building world’s biggest green hydrogen factory. Renewables, 15 August 2022.
117. Batrancea LM, Nichita A, Balcı MA, et al. Empirical investigation on how wellbeing-related infrastructure shapes economic growth: Evidence from the European Union regions. PLoS ONE. 2023; 18(4): e0283277. doi: 10.1371/journal.pone.0283277
118. Batrancea L. The Nexus between Financial Performance and Equilibrium: Empirical Evidence on Publicly Traded Companies from the Global Financial Crisis Up to the COVID-19 Pandemic. Journal of Risk and Financial Management. 2021; 14(5): 218. doi: 10.3390/jrfm14050218
119. Batrancea L. Empirical Evidence Regarding the Impact of Economic Growth and Inflation on Economic Sentiment and Household Consumption. Journal of Risk and Financial Management. 2021; 14(7): 336. doi: 10.3390/jrfm14070336
120. Batrancea LM. The Hard Worker, the Hard Earner, the Young and the Educated: Empirical Study on Economic Growth across 11 CEE Countries. Sustainability. 2023; 15(22): 15996. doi: 10.3390/su152215996
121. Batrancea LM, Rathnaswamy MM, Rus MI, Tulai H. Determinants of Economic Growth for the Last Half of Century: A Panel Data Analysis on 50 Countries. Journal of the Knowledge Economy. 2022; 14: 2578–2602. doi: 10.1007/s13132-022-00944-9
122. Calza F, Parmentola A, Tutore I. Big data and natural environment. How does different data support different green strategies? Sustainable Futures. 2020; 2(100029). doi: 10.1016/j.sftr.2020.100029
123. Cavallo E, Ferrari E, Bollani L, Coccia M. Attitudes and behaviour of adopters of technological innovations in agricultural tractors: A case study in Italian agricultural system. Agricultural Systems. 2014; 130: 44–54. doi: 10.1016/j.agsy.2014.05.012
124. Chen J, Mao B, Wu Y, et al. Green development strategy of offshore wind farm in China guided by life cycle assessment. Resources, Conservation and Recycling. 2023; 188(106652).
125. Cho R. What is Decarbonization, and How do we make it happen? News from the Columbia Climate School, 22 April 2022.
126. CNBC. Sustainable energy. Available online: https://www.cnbc.com/2022/09/15/green-hydrogen-siemens-commissions-german-production-plant.html (accessed on 12 June 2024).
127. Coccia M. Steel market and global trends of leading geo-economic players. International Journal of trade and global markets. 2014; 7(1): 36–52. doi: 10.1504/IJTGM.2014.058714
128. Coccia M. New directions of technologies pointing the way to a sustainable global society. Sustainable Futures. 2023; 5(100114). doi: 10.1016/j.sftr.2023.100114
129. Coccia M. New Perspectives in Innovation Failure Analysis: A taxonomy of general errors and strategic management for reducing risks. Technology in Society. 2023; 75(102384). doi: 10.1016/j.techsoc.2023.102384
130. Coccia M. Promising technologies for fostering simultaneous environmental and socioeconomic sustainability. Journal of Economic and Social Thought. 2023; 10(1–2): 28–47. doi: 10.1453/jest.v10i1-2.2452
131. Coccia M, Bellitto M. A critique of human progress: A new definition and inconsistencies in society. Quaderni IRCrES-CNR. 2018; 4(3): 51–67. doi: 10.23760/2499-6661.2018.017

132. Coccia M, Bellitto M. Human progress and its socioeconomic effects in society. Journal of Economic and Social Thought. 2018; 5(2): 160–178. doi: 10.1453/jest.v5i2.1649
133. Coccia M, Roshani S. Evolutionary Phases in Emerging Technologies: Theoretical and Managerial Implications from Quantum Technologies. IEEE Transactions on Engineering Management. 2024. doi: 10.1109/TEM.2024.3385116
134. Coccia M, Roshani S. General laws of funding for scientific citations: How citations change in funded and unfunded research between basic and applied sciences. Journal of Data and Information Science. 2024; 9(4): 1–18. doi: 10.2478/jdis-2024-0005
135. Coccia M. Converging scientific fields and new technological paradigms as main drivers of the division of scientific labour in drug discovery process: The effects on strategic management of the R&D corporate change. Technology Analysis & Strategic Management. 2013; 26(7): 733–749. doi: 10.1080/09537325.2014.882501
136. Coccia M. Radical innovations as drivers of breakthroughs: Characteristics and properties of the management of technology leading to superior organisational performance in the discovery process of R&D labs. Technology Analysis & Strategic Management. 2015; 28(4): 381–395. doi: 10.1080/09537325.2015.1095287
137. Coccia M, Roshani S. Research funding and citations in papers of Nobel Laureates in Physics, Chemistry and Medicine, 2019–2020. Journal of Data and Information Science. 2024; 9(2): 1–25. doi: 10.2478/jdis-2024-0006
138. Coccia M, Bontempi E. New trajectories of technologies for the removal of pollutants and emerging contaminants in the environment. Environmental Research. 2023; 229(115938). doi: 10.1016/j.envres.2023.115938
139. Coccia M, Ghazinoori S, Roshani S. Evolutionary Pathways of Ecosystem Literature in Organization and Management Studies. Research Square. 2023. doi: 10.21203/rs.3.rs-2499460/v1
140. Coccia M, Roshani S, Mosleh M. Evolution of Quantum Computing: Theoretical and Innovation Management Implications for Emerging Quantum Industry. IEEE Transactions on Engineering Management. 2024; 71: 2270–2280. doi: 10.1109/tem.2022.3175633
141. Coccia M, Roshani S, Mosleh M. Scientific Developments and New Technological Trajectories in Sensor Research. Sensors. 2021; 21(23): 7803. doi: 10.3390/s21237803
142. Coccia M, Wang L. Evolution and convergence of the patterns of international scientific collaboration. Proceedings of the National Academy of Sciences of the United States of America. 2016; 113(8): 2057–2061. doi: 10.1073/pnas.1510820113
143. Coccia M. Watts J. A theory of the evolution of technology: Technological parasitism and the implications for innovation management. Journal of Engineering and Technology Management. 2019; 55(101552). doi: 10.1016/j.jengtecman.2019.11.003
144. CTCN. CO_2 storage technologies. Available online: https://www.ctc-n.org/technologies/co2-storage-technologies (accessed on 12 June 2024).
145. Cui X, Tang C, Zhang Q. A Review of Electrocatalytic Reduction of Dinitrogen to Ammonia under Ambient Conditions. Advanced Energy materials. 2018; 8(22): 1800369. doi: 10.1002/aenm.201800369
146. Edeme RK, Nkalu NC, Idenyi JC, Arazu WO. Infrastructural Development, Sustainable Agricultural Output and Employment in ECOWAS Countries, Sustainable Futures. 2020; 2(100010). doi: 10.1016/j.sftr.2020.100010
147. Elia A, Taylor M, Ó Gallachóir B, Rogan F. Wind turbine cost reduction: A detailed bottom-up analysis of innovation drivers. Energy Policy. 2020; 147(111912). doi: 10.1016/j.enpol.2020.111912
148. Equinor. Carbon capture, utilisation and storage (CCS). Available online: https://www.equinor.com/energy/carbon-capture-utilisation-and-storage (accessed on 12 June 2024).
149. Feng Y, Hu J, Afshan S, et al. Bridging resource disparities for sustainable development: A comparative analysis of resource-rich and resource-scarce countries. Resources Policy. 2023; 85(Part A): 103981. doi: 10.1016/j.resourpol.2023.103981
150. Fortunato S, Bergstrom CT, Börner K, et al. Science of science. Science. 2018; 359(6379): eaao0185. doi: 10.1126/science.aao0185
151. Ghiat I, Al-Ansari T. A review of carbon capture and utilisation as a CO_2 abatement opportunity within the EWF nexus. Journal of CO_2 Utilization. 2021; 45(101432). doi: 10.1016/j.jcou.2020.101432
152. Howson P. Tackling climate change with blockchain. Nature Climate Change. 2019; 9: 644–645. doi: 10.1038/s41558-019-0567-9
153. Hughes A, Park A, Kietzmann J, Archer-Brown C. Beyond Bitcoin: What blockchain and distributed ledger technologies mean for firms. Business Horizons. 2019; 62(3): 273–281.

154. Iberdrola. Puertollano Green Hydrogen Plant. Available online: https://www.iberdrola.com/about-us/what-we-do/green-hydrogen/puertollano-green-hydrogen-plant (accessed on 12 June 2024).
155. IEA. Carbon capture, utilisation and storage. Available online: https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage (accessed on 12 June 2024).
156. Javid I, Chauhan A, Thappa S, et al. Futuristic decentralised clean energy networks in view of inclusive-economic growth and sustainable society. Journal of Cleaner Production. 2021; 309(127304).
157. Kaldellis JK, Chrysikos T. Wave energy exploitation in the Ionian Sea Hellenic coasts: spatial planning of potential wave power stations. International Journal of Sustainable Energy. 2019; 38(4): 312–332.
158. Khan MN, Huang J, shah A, et al. Mitigation of greenhouse gas emissions from a red acidic soil by using magnesium-modified wheat straw biochar. Environmental Research. 2022; 203(111879).
159. Lv X-W, Weng C-C, Yuan Z-Y. Ambient Ammonia Electrosynthesis: Current Status, Challenges, and Perspectives. ChemSusChem. 2020; 13(12): 3061–3078. doi: 10.1002/cssc.202000670
160. Nemet GF. How Well Does Learning-by-Doing Explain Cost Reductions in a Carbon-Free Energy Technology? FEEM Working Paper. 2006. doi: 10.2139/ssrn.946173
161. Nti KE, Cobbina SJ, Attafuah EF, et al. Environmental sustainability technologies in biodiversity, energy, transportation and water management using artificial intelligence: A systematic review. Sustainable Futures. 2022; 4(100068). doi: 10.1016/j.sftr.2022.100068
162. Oh HS. Unit commitment considering the impact of deep cycling. Sustainable Futures. 2020; 2(100031). doi: 10.1016/j.sftr.2020.100031
163. Peplow M. The race to upcycle CO_2 into fuels, concrete and more. Nature. 2022; 603: 780–783. doi: 10.1038/d41586-022-00807-y
164. Pérez CJ, Ponce CJ. Disruption costs, learning by doing, and technology adoption. International Journal of Industrial Organization. 2015; 41: 64–75. doi: 10.1016/j.ijindorg.2015.03.010
165. Price D. Little Science, Big Science. Columbia University Press; 1986.
166. Pronti A, Coccia M. Multicriteria analysis of the sustainability performance between agroecological and conventional coffee farms in the East Region of Minas Gerais (Brazil). Renewable Agriculture and Food Systems. 2020; 36(3): 299–306. doi: 10.1017/S1742170520000332
167. Resources magazine. Carbon Capture and Storage 101. Available online: https://www.rff.org/publications/explainers/carbon-capture-and-storage-101/ (accessed on 12 June 2024).
168. Roco M, Bainbridge W. Converging Technologies for Improving Human Performance: Integrating from the Nanoscale. Journal of Nanoparticle Research. 2002; 4: 281–295. doi: 10.1023/A:1021152023349
169. Roger M, Brown F, Gabrielli W, Sargent F. Efficient hydrogen dependent carbon dioxide reduction by Escherichia coli. Current Biology. 2018; 28(1): 140–145.
170. Sahal D. Patterns of Technological Innovation. Addison-Wesley Publishing Company; 1981.
171. Scharnhorst A, Borner K, Besselaar P. Models of Science Dynamics: Encounters Between Complexity Theory and Information Sciences. Springer; 2012.
172. Soloveichik G. Electrochemical synthesis of ammonia as a potential alternative to the Haber–Bosch process. Nature Catalysis. 2019; 2: 377–380. doi: 10.1038/s41929-019-0280-0
173. Sterner T, Coria J. Policy instruments for environmental and natural resource management, 2nd ed. RFF Press and Routledge; 2012.
174. Sun X, Kaur J, Milojević S, et al. Social Dynamics of Science. scientific reports. 2013; 3(1069). doi: 10.1038/srep01069
175. Tan L, Yang Z, Irfan M, et al. Toward low-carbon sustainable development: Exploring the impact of digital economy development and industrial restructuring. Business Strategy and the Environment. 2024; 33(3): 2159–2172.
176. Tavella F, Giusi G, Ampelli C. Nitrogen reduction reaction to ammonia at ambient conditions: A short review analysis of the critical factors limiting electrocatalytic performance. Current Opinion in Green and Sustainable Chemistry. 2020; 35: 100604. doi: 10.1016/j.cogsc.2022.100604
177. Tracxn. Top Thermal Energy Storage System Startups. Available online: https://tracxn.com/d/trending-business-models/startups-in-thermal-energy-storage-system/__SbdP7ocu1tKeQaRpbGrORT4jhy3O06dTKrztYQpA-gg/companies (accessed on 12 June 2024).

178. Uçkaç BC, Coccia M, Kargi B. Diffusion COVID-19 in polluted regions: Main role of wind energy for sustainable and health. International Journal of Membrane Science and Technology. 2023; 10(3): 2755–2767. doi: 10.15379/ijmst.v10i3.2286
179. Uçkaç BC, Coccia M, Kargı B. Simultaneous Encouraging Effects of New Technologies for Socioeconomic and Environmental Sustainability. Bulletin Social-Economic and Humanitarian Research. 2023; 19(21): 100–120. doi: 10.52270/26585561_2023_19_21_100
180. Willett W, Rockström J, Loken B, et al. Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet. 2019; 393(10170): 447–492. doi: 10.1016/S0140-6736(18)31788-4
181. Zhu H, Chen S, Irfan M, et al. Exploring the role of the belt and road initiative in promoting sustainable and inclusive development. Sustainable Development. 2024; 32(1): 712–723.
182. Zhu Q, 2019. Developments on CO_2-utilization technologies. Clean Energy. 2019; 3(2): 85–100. doi: 10.1093/ce/zkz008
183. Coccia M. Comparative Incentive Systems. A. Farazmand (ed.), Global Encyclopedia of Public Administration, Public Policy, and Governance. 2019; Springer, doi: 10.1007/978-3-319-31816-5_3706-1
184. Coccia M, Roshani S. Evolution of topics and trends in emerging research fields: multiple analyses with entity linking, Mann–Kendall test and burst methods in cloud computing. Scientometrics. 2024. 129:347–5371.