บรรณาธิการปริทัศน์/Editorial Corner

อุตสาหกรรมอาหารสีเขียวสู่การเป็นแหล่งกักเก็บคาร์บอน: การบูรณาการนวัตกรรมเชิงฟื้นฟูและกฎระเบียบเพื่อการปล่อยก๊าซเรือนกระจกสุทธิเป็นลบ

The Green Food Industry as a Carbon Sink: Integrating Regenerative Innovations and Regulations for Net-Negative Emissions

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The roadmap for achieving net-zero emissions in global food systems by 2050 indicates that net-zero emissions can be achieved by integrating cost-effective technologies to reduce emissions from land-use change, improving rice and livestock production, and accelerating renewable energy use in food processing by 2040–2050 [1]. To meet the 1.5°C warming limit established by the Paris Agreement, the international community must commit to swift and far-reaching cuts in global greenhouse gas emissions. Achieving this benchmark requires a radical shift away from historical emission patterns, necessitating immediate, large-scale decarbonization efforts across all sectors of the global economy. By prioritizing aggressive mitigation strategies now, nations can work toward stabilizing

การอ้างอิงบทความ: พัชนีย์ ยะสุรินทร์, สุวลักษณ์ อัศวสันติ, นรฤทธิ์ สุดสงวน และ Babu Dharmarlingam, "อุตสาหกรรมอาหารสีเขียวสู่การเป็นแหล่งกักเก็บคาร์บอน: การบูรณาการนวัตกรรมเชิงฟื้นฟูและกฎระเบียบเพื่อการปล่อยก๊าซเรือนกระจกสุทธิเป็นลบ," *วารสารวิชาการพระจอมเกล้าพระนครเหนือ*, ปีที่ 36, ฉบับที่ 3, หน้า 1–5, ก.ค.–ก.ย. 2569, เลขที่บทความ 263-8242, doi: 10.14416/j.kmutnb.2026.xx.xxx.

temperatures at pre-industrial levels and avoiding the most catastrophic impacts of climate change [2], [3].

The food industry value chain covers all steps from farm-to-table, including input supply, production, processing, distribution, marketing, and consumption [4]. Rapid and real decarbonization in sociotechnical food industry needs the integration of policy and regulations, market standardizing values and procedures, organizational strategies, changes to behavioral practices and innovations [5]. While Grubb *et. al.* [6] proposed that direct regulation combined with public investment and policy nudges, such as targeted carbon pricing, are key to enable the investment required for decarbonization pathways.

Greenhouse gas (GHG) emissions from the global food system can be mitigated through five key strategies targeting the entire value chain: adopting plant-rich diets worldwide; aligning per capita caloric intake with healthy consumption levels; increasing agricultural productivity by closing yield gaps and improving crop genetics and agronomic practices; reducing food loss and waste by 50%; and lowering the GHG intensity of food production through enhanced efficiency, including improved management systems and the implementation of innovative technologies [3].

Achieving net-negative emissions in the food industry, where the sector removes more greenhouse gases from the atmosphere than it requires a combination of enhancing natural carbon sinks, implementing advanced technologies, and managing waste effectively. Core mechanisms to achieve this by 2050 include scaling carbon sequestration, integrating biochar, implementing Bioenergy with Carbon Capture and Storage (BECCS) and adopting regenerative agriculture practices [1], [7], [8].

The core mechanisms for achieving net-negative emissions in the food industry encompass a combination of nature-based solutions, circular economy strategies, and improvements in supply chain and production efficiency. Soil and land-based sequestration approaches enhance the natural capacity of plants and soils to absorb CO_2 through sustainable land management practices. Soil Carbon Sequestration (SCS) focuses on transferring atmospheric carbon into stable soil organic matter, with key approaches including no-till or reduced tillage to preserve soil structure and prevent carbon loss, cover cropping to increase organic matter and reduce erosion, and rotational grazing to manage pasture in ways that enhance soil carbon storage [7]. In addition, agroforestry integrates trees into agricultural systems, offering significant technical potential for carbon sequestration [7], while afforestation and reforestation involve restoring forests on degraded or previously forested land to increase carbon storage in both biomass and soil [7].

Complementary strategies emphasize circular economy principles and improved waste management to mitigate greenhouse gas emissions. Manure and organic waste management involve the use of anaerobic digesters to convert manure and food waste into biogas, a form of renewable energy, and bio-fertilizer, thereby preventing methane emissions [1], [8]. Seaweed farming has also emerged as a promising approach, where cultivated seaweed can potentially be sequestered in the deep ocean

to function as a long-term carbon sink [1], [9]. Furthermore, reducing food loss and waste through the adoption of intelligent and active packaging, along with enhanced supply chain efficiency, can significantly decrease methane emissions generated from landfills [1], [10].

Mitigation efforts are further strengthened through the integration of clean energy and innovative technologies within agricultural systems. Renewable energy integration involves replacing fossil fuels with wind, solar, or biogas in agricultural machinery, irrigation systems, and processing facilities [9]. In parallel, green fertilizer production utilizes renewable hydrogen to synthesize nitrogen fertilizers, thereby eliminating upstream emissions associated with the Haber–Bosch process [1], [8]. Additionally, the use of livestock methane inhibitors, such as seaweed-based feed additives, has shown significant potential to reduce methane emissions from enteric fermentation in ruminants [1], [8].

Laws and regulations for net-negative emissions in the food industry are evolving from voluntary carbon-neutrality goals toward mandatory, science-based targets that require reducing emissions by over 90% and offsetting the remaining emissions through carbon removals. Key regulatory frameworks, particularly in the EU and UK, are beginning to mandate tracking of Scope 3 emissions and promoting regenerative practices to achieve negative emissions [1], [11], [12]. Policy frameworks play a crucial role in advancing net-zero targets within the global food industry. The EU Net-Zero Industry Act aims to achieve climate neutrality by 2050 by promoting the deployment of CO_2 storage technologies and strengthening the manufacturing ecosystem for net-zero solutions [12], while the EU Farm to Fork Strategy and its Code of Conduct encourage the transition to sustainable food systems through voluntary commitments aligned with the Paris Agreement [12].

In contrast, Thailand illustrates the challenges faced when national legal frameworks are not fully prepared to support 2050 net-zero greenhouse gas emission targets in the food sector [13]. Although the government has introduced the Bio-Circular-Green Economy as a key national strategy to promote sustainable production and emission reductions, its implementation remains limited due to insufficient systemic integration [13]. Consequently, the regulatory environment is still fragmented, with existing laws not adequately aligned with overarching net-zero objectives [13], highlighting the need for stronger coordination between current legal instruments and emerging frameworks to effectively support a circular economy and achieve long-term sustainability goals [13].

Achieving real impact from this transition requires coordinated policy frameworks, robust governance to prevent greenwashing, and sustained innovation across sociotechnical systems. As underscored by global assessments and scenario analyses, the convergence of science-based targets, industrial ecology, and circular economy principles will be critical in repositioning the food industry as a cornerstone of deep decarbonization and long-term climate stabilization.

References

[1] C. Costa, E. Wollenberg, M. Benítez, R. Newman, N. Gardner, and F. Bellone, “Roadmap for

achieving net-zero emissions in global food systems by 2050," *Scientific Reports*, vol. 12, no. 1, 2022, Art. no. 15064, doi: 10.1038/s41598-022-18601-1.

[2] M. A. Clark, N. G. G. Domingo, K. Colgan, S. K. Thakrar, D. Tilman, J. Lynch, I. L. Azevedo, and J. D. Hill, "Global food system emissions could preclude achieving the 1.5° and 2°C climate change targets," *Science*, vol. 370, no. 6517, pp. 705–708, 2020, doi: 10.1126/science.aba7357.

[3] F. W. Geels, B. K. Sovacool, T. Schwanen, and S. Sorrell, "Sociotechnical transitions for deep decarbonization," *Science*, vol. 357, no. 6357, pp. 1242–1244, 2017.

[4] M. Grubb, J.-C. Hourcade, and K. Neuhoff, "Planetary economics: Energy, climate change and the three domains of sustainable development," *Abingdon, UK and New York, USA, Routledge Earthscan*, 2014.

[5] H. Ishaq and C. Crawford, "Negative emission technologies: A way forward?" *RSC Sustainability*, vol. 3, no. 9, pp. 3652–3680, 2025, doi: 10.1039/d5su00162e.

[6] L. Rosa and P. Gabrielli, "Achieving net-zero emissions in agriculture: A review," *Environmental Research Letters*, vol. 18, no. 6, 2023, Art. no. 063002, doi: 10.1088/1748-9326/acd5e8.

[7] M. Almaraz, B. Z. Houlton, M. Clark, I. Holzer, Y. Zhou, L. Rasmussen, E. Moberg, E. Manaigo, B. S. Halpern, C. Scarborough, X. G. Lei, M. Ho, E. Allison, L. Sibanda, and A. Salter, "Model-based scenarios for achieving net negative emissions in the food system," *PLOS Climate*, vol. 2, no. 9, Sep. 2023, Art. no. e0000181, doi: 10.1371/journal.pclm.0000181.

[8] I. Shabir, K. K. Dash, A. H. Dar, V. K. Pandey, U. Fayaz, S. Srivastava, and N. R. Sharma, "Carbon footprints evaluation for sustainable food processing system development: A comprehensive review," *Future Foods*, vol. 7, Jun. 2023, Art. no. 100215, doi: 10.1016/j.fufo.2023.100215.

[9] M. Ilyas, U. Liaqat, M. Eqan, E. Boškailo, M. Safdar, T. Ajanovic, H. Yaqoob, J. Chovancová, and S. T. Onifade, "Policy frameworks and regulations for net zero," in *Net ZERO*, pp. 189–247, 2026, doi: 10.1016/B978-0-443-36426-6.00010-1.

[10] E. Tzoulia, "New EU legislation against greenwashing: Impacts on the food sector," *Proceedings*, vol. 134, no. 1, pp. 27, 2026, doi: 10.3390/proceedings2026134027.

[11] S. Vassanadumrongdee, "Legal Barriers to Promoting the Circular Economy in Thailand: The Case of the Plastics Industry," *Thai Environment*, vol. 29, no. 2, Aug. 2025, Art. no. 005, doi: 10.35762/TE.2568005.

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