

Sustainable Supply Chains As Catalysts For Global Environmental Responsibility: An Analysis Of United States Industrial Transformation

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Abstract

The operations of the supply chain in America have undergone a paradigm shift in recent years. Conventional models were focused on cost reduction and speed maximization. The current practice incorporates environmental responsibility as one of the main principles. Federal climate laws, corporate responsibility demands, and pressure from stakeholders have enhanced this change. As an example, the Inflation Reduction Act allocates \$369 billion for energy security and climate programs. Together with changing corporate policies, this law makes supply chains the key infrastructure for achieving environmental objectives without compromising the competitiveness of industries. The transportation and logistics sector accounts for approximately 29 percent of the total greenhouse gas emissions in America. The solution to this is the adoption of electric fleets, renewable fuels, and efficiency programs, such as the SmartWay Transport Partnership. Methods of Life Cycle Assessment and circular economy models give a structured methodology for measuring environmental impacts of value chains. These tools assist managers in balancing the ecological factor with operational demands. The goals of the National Recycling Strategy aim for a 50 percent recycling rate by 2030, which represents a systematic attempt to shift away from linear production trends. Instead, the emphasis is placed on regenerative systems that reuse materials and increase resource security, and reduce environmental burdens. The technologies of artificial intelligence, blockchain, and the Internet of Things provide continuous visibility throughout complex supply chains. Sustainability is not a periodic compliance reporting, but it becomes a daily reality of operations. By 2022, the clean energy and energy efficiency industries had employed 8.1 million Americans. The transformation of the environment yields physical economic benefits, including job creation, manufacturing expansion, and competitive advantages in new markets. Sustainable supply chain management is a twofold task, whereby an organization fulfills environmental requirements while contributing to economic growth. This raises questions about the premise of an inherent conflict between being ecologically responsible and financially successful. Industrial systems can operate within natural limits and provide prosperity.

Keywords: Sustainable Supply Chain Management, Circular Economy, Life Cycle Assessment, Clean Energy Manufacturing, Environmental Policy.

1. Introduction: The Paradigm Shift in American Supply Chain Management

The American supply chain management has undergone a radical transformation, with optimization focused on lowering costs and increasing the speed of operations. Modern strategies are based on the

integrability. This is more than a refinement of operations, an actual redesign of industrial networks that must operate under ecological and social constraints, climate laws, corporate responsibility frameworks, and stakeholder needs, placing supply chain experts at the heart of environmental care. Scholars have been able to trace this development by taking a comprehensive look at the adoption of sustainability in supply chain functions. Sustainable chain management is the strategic integration of normal business operations with environmental concerns in the product lifecycle. This process starts with the sourcing of raw materials and goes through the manufacturing process, distribution, consumption, and subsequent disposal [1]. The broad approach is not merely the isolated environmental programs but the systematic incorporation of the ecological principles. The principles run through relations, procurement, manufacturing, logistics, and the reverse supply chain process that deals with etuand and recycling [1].

Legal and regulatory circumstances across the board, particularly the Reduction Act and the National Climate Strategy, have created unparalleled convergence in economic incentives and climate goals. The Inflation Reduction Act became law through the presidential signature on August 16, 2022. This law is a landmark in the US environmental policy. Federal commitments total approximately \$369 billion in investments and tax benefits directed specifically toward energy security and climate change programs over the following decade [2]. Historic financial mechanisms accelerate transitions toward sustainable industrial practices. Production tax credits worth \$30 billion aim to expedite the manufacturing of solar panels, wind turbines, batteries, and critical facilities for critical minerals. Investment tax credits totaling \$10 billion are targeted at clean technology manufacturing sites. These provisions create direct economic incentives for companies that establish and expand production infrastructure on American soil [2]. Transportation and logistics sectors form essential components of supply chain operations. Special attention is drawn to these tax credits, offering up to \$ 7,500 for new clean vehicle purchases and up to \$40,000 for commercial clean vehicles. These directly subsidize shifts toward low-emission fleet operations underpinning modern supply chains [2].

This alignment signals a departure from the historical tension between profitability and sustainability. Contemporary frameworks present these as mutually reinforcing dimensions of competitive advantage. Recognition of supply chains as strategic instruments for innovation and responsible growth reflects maturation in academic understanding and practical application. Conceptual structures developed through extensive literature synthesis identify four distinct components that define the supply chain management. Environmental thinking integrates into standard supply chain management practices. Cooperation with suppliers and customers accomplishes ecological goals. Closed-loop systems minimize waste. Environmental management systems develop throughout supply networks [1].

Table 1: Federal Policy Framework for Sustainable Supply Chain Transformation [1, 2]

Policy Component	Strategic Objective	Implementation Mechanism
Inflation Reduction Act	Accelerate clean energy transition and domestic manufacturing	\$369 billion in federal investments and tax incentives over ten years
Production Tax Credits	Expedite renewable energy component manufacturing	\$30 billion allocated for solar panels, wind turbines, batteries, and critical minerals processing
Investment Tax Credits	Establish sustainable production infrastructure	\$10 billion targeting clean technology manufacturing facilities
Commercial Vehicle Incentives	Decarbonize logistics and freight operations	Tax credits up to \$40,000 for commercial clean vehicles
Sustainable Supply Chain Framework	Integrate environmental thinking throughout the product lifecycle	Coordination of procurement, manufacturing, distribution, and reverse logistics
Environmental Management Systems	Establish governance structures for sustainability	Systematic integration across supplier relationships and operational processes

2. Environmental Burden and Industrial Response in United States Supply Networks

American supply chains leave substantial environmental footprints. This presents both challenges and opportunities for systematic transformation. America ranks among the world's largest and most significant contributors of emissions. The transportation sector accounts for approximately 29% of national greenhouse gas emissions, according to Environmental Protection Agency evaluations. The environmental impact within supply chain operations highlights key areas for improvement. Logistics, manufacturing, and sourcing decisions carry significant weight in national efforts to decarbonize. An examination of greenhouse gas emission sources reveals that transportation activities are the fastest-growing contributor to climate change in America. Growth reached approximately 20% between 1990 and 2005. This trajectory significantly exceeded most other emission sectors during this period [3].

Freight transportation forms the operational backbone of supply chain logistics and accounts for considerable shares of these emissions—medium and heavy-duty trucks alone shoulder approximately 20% of all transportation-related greenhouse gas output [emissions]. The carbon intensity of freight operations extends beyond direct fuel combustion. Infrastructure impacts matter too. Roadway construction, maintenance, and associated land use contribute to additional environmental burdens throughout the lifecycle of the transportation network. The ecological consequences of freight transportation extend beyond greenhouse gas emissions. Considerable additions to air pollution in the area arise. The emissions of heavy-duty vehicles, which include particulate matter and nitrogen oxides, have been proven to pose public health challenges that are well-documented. Bordering major freight corridors and distribution centers, these areas face these difficulties [3].

The reaction of industries to environmental forces has evolved into numerous dimensions. Large companies in the automotive, technology, and energy industries set ambitious net-zero goals between 2040 and 2050. The fundamentals of the production systems and logistics are needed. If toward electric vehicle fleets, the use of renewable fuels, and the creation of energy-efficient warehousing facilities are significant capital investments in environmental goals. An example of these collaborative approaches facilitated by the government is the SmartWay Transport Partnership program and the Better Plants Program. The actions of public policy and the private sector set up established channels for emission cutdown reduction, leading to an increase in industrial competitiveness in terms of technological enhancements and operational efficiency. The Environmental Protection Agency started the Way Transport Partnership. This is a voluntary joint system of collaboration among shippers, carriers, and logistics service providers, operating in a coordinated effort.

Goals include improved fuel efficiency and reduced greenhouse gas emissions across transportation networks [4]. Participating organizations receive comprehensive tools and standardized methodologies. These measures, measures are, and verify freight transportation environmental performance. Evidence-based decision-making in logistics operations becomes possible [4]. Systematic tracking and reporting mechanisms enable sensible partners to quantify their carbon footprint reductions accurately. Environmental efficiency evaluation covers different transportation modes and carrier options. Strategic opportunities for operational improvements emerge—enhancements that simultaneously improve environmental outcomes and reduce operating costs [4]. The partnership framework facilitates transparent communication of environmental performance data throughout supply chains. Shippers make informed carrier decisions about selection based on verified efficiency metrics. Transportation providers gain incentives to continuously improve operational practices through competitive benchmarking and recognition programs [4].

Table 2: Transportation Sector Environmental Impact and Mitigation Strategies [3, 4]

Environmental Dimension	Impact Characterization	Mitigation Approach
Greenhouse Gas Emissions	Transportation represents 29% of national emissions; increased d 20%	SmartWay Transport Partnership for efficiency improvement and emission

	between 1990-2005	reduction
Freight Transportation	Medium and heavy-duty trucks account for 20% of transportation emissions	Systematic tracking, benchmarking, and verification of carrier environmental performance
Infrastructure Burden	Roadway construction and maintenance contribute to lifecycle carbon intensity	Integration of environmental considerations into logistics network design
Air Quality Effects	Diesel particulate matter and nitrogen oxides impact communities near freight corridors	Transition toward electric fleets and renewable fuel adoption
Performance Measurement	Lack of standardized environmental metrics across carriers	Comprehensive tools for measuring, comparing, and verifying transportation efficiency
Collaborative Framework	Fragmented efforts between shippers and carriers	Voluntary partnership connecting freight stakeholders in coordinated improvement initiatives

3. Life Cycle Assessment and Circular Economy Principles in Supply Chain Design

Life Cycle Assessment methodologies have become foundational elements in data-driven sustainability strategies across the American industry. LCA frameworks are increasingly relied on by federal agencies, research institutions, and corporate organizations. These measures environmental performance through entire value chains, which encompass the extraction of raw materials up to the top of the supply chain. Sustainability, methodological rigor, and consistency have been promoted by the work of the Environmental Protection Agency through its Sustainable Materials Management Program and by the National Institute of Standards and Technology through the standardization process. It becomes possible to conduct a comparative analysis and make informed choices.

Life Cycle Assessment constitutes a comprehensive analytical framework for evaluating environmental burdens associated with products, processes, and services throughout their entire life cycle. This spans initial resource extraction through manufacturing, distribution, utilization, and final disposition [5]. The methodology addresses fundamental challenges in environmental management. Systematic documentation and quantification of material flows, energy consumption patterns, and emissions releases occur across all life cycle stages. Identification of environmental and optimization opportunities becomes possible, with details that remain hidden in more limited analytical approaches [5]. LCA frameworks have undergone substantial evolution since their emergence in the 1960s. Progression moved from rudimentary energy accounting exercises to sophisticated multi-impact assessments. Simultaneous evaluation encompasses change contributions, ecosystem quality, human health effects, and structural resource depletion. Standardized characterization models and impact indicators enable this [5]. Contemporary LCA practice addresses approximately ten to fifteen distinct environmental impact categories. Scientifically validated methodologies quantify each category. Inventory data on emissions and resource consumption translates into potential ecological consequences. Decision-makers comprehend the differences between various impact types, and shifting from one environmental domain to another becomes avoidable [5]. Standardization of LCA procedures through International Organization for Standardization guidelines has enhanced methodological consistency. Significant variations persist in impact assessment approaches, system boundary definitions, allocation procedures for multi-functional processes, and data quality standards across different applications and geographic contexts [5].

Alongside the adoption of Life Cycle Assessment in American industrial policy, circular economy ideas have gained significant traction. While resource security issues take center stage, environmental goals are addressed. By promoting design-for-reuse integration and reverse implementation logistics in industrial sectors, the National Recycling Strategy of the Environmental Protection Agency formalizes these ideas.

Concepts between governments, state governments, industry players, and non-governmental organizations led to the development of the National Recycling Strategy. By 2030, the goal is to reach a 50% national recycling rate. This represents a substantial advancement from current performance levels [6]. Effective recycling systems generate multiple societal benefits beyond waste diversion. Greenhouse gas emission reductions occur. Energy gets conserved. Natural resources receive preservation. Economic development occurs through domestic manufacturing that utilizes readily available materials. Employment creation spans collection, sorting, processing, and manufacturing sectors [6]. There are significant constraints facing recycling. Recycling activities are economically delicate to unstable commodity markets. There is a poor infrastructure investment.

Contamination problems reduce material quality. Insufficient coordination exists across the fragmented collection and processing landscape [6]. The strategic framework emphasizes developing robust end markets for recycled materials; government procurement preferences help, as do manufacturing incentives for utilizing recycled content. Standardized labeling systems communicate recyclability and recycled content information to consumers and procurement professionals [6].

Table 3: Life Cycle Assessment and Circular Economy Implementation [5, 6]

Strategic Element	Functional Characteristics	Systemic Challenge
Life Cycle Assessment Methodology	Comprehensive evaluation from resource extraction through end-of-life disposal	Variations in system boundaries, allocation procedures, and data quality standards
Environmental Impact Categories	Ten to fifteen distinct categories, including climate change, ecosystem quality, and resource depletion	Trade-off identification between different environmental impact domains
LCA Evolution	Progression from energy accounting to multi-impact assessment frameworks	Maintaining methodological consistency across diverse applications
National Recycling Strategy	Target of 50% recycling rate by 2030	Economic fragility of recycling operations and volatile commodity markets
Circular Economy Transition	Shift from linear to regenerative systems, emphasizing reuse and remanufacturing	Inadequate infrastructure investment and contamination are reducing material quality
End Market Development	Government procurement preferences and recycled content incentives	Insufficient coordination across fragmented collection and processing systems

4. Sustainable Procurement, Ethical Sourcing, and Digital Transformation

Sustainable procurement is no longer a peripheral concern; it has become a pillar of corporate environmental strategy in America. It is now not just leading organizations that require disclosive sustainability disclosures from suppliers in accordance with the codified frameworks, such as the Sustainability Accounting Standards Board and Global Reporting Initiative standards. The requirements are not only limited to environmental compliance but also include labor equity, resilience in domestic sourcing, and adherence to federal climate risk regulations of major government suppliers. The various conceptual bases of sustainable supply chain management were the result of decades of scholarly research and field testing. The initiative started in the 1990s. Progression continued through increasingly sophisticated frameworks that integrated the mental, social, and economic dimensions of organizational performance [7]. Scholarly analysis reveals that sustainable supply chain management represents more

than incremental operational improvements. Instead, fundamental reconceptualization of value creation extends organizational boundaries to encompass entire networks of upstream suppliers and downstream distribution channels [7]. Evolution demonstrates a clear trajectory from reactive compliance with environmental regulations toward proactive strategic positioning. Sustainability capabilities become sources of competitive differentiation, risk mitigation, and enhanced stakeholder relationships. Examining organizational practices across diverse industries reveals that effective and sustainable supply chain management necessitates simultaneous attention to multiple dimensions. Green purchasing practices evaluate suppliers based on environmental criteria. Supply chain partners encourage companies to create environmental collaboration. Eco-design principles involve the environmental in product development.

Investment recovery programs monetize waste streams and obsolete materials. Intern, generating revenue from previously unusable resources, establishing organizational structures and processes for sustainability governance [7]. These dimensions function interdependently rather than in isolation. Organizations that achieve superior environmental performance utilize integrated approaches. The procurement decisions, supplier relations, product design, manufacturing process, and reverse logistics become consistent with consistent sustainability strategies [7]. Continuous improvement and scalable accountability become possible. The Clean Energy Manufacturing Initiative represents a comprehensive federal strategy designed to strengthen American industrial competitiveness while simultang environmental objectives through the transformation of the energy sector. It is recognized that achieving national clean energy deployment targets requires not only technological innovation but also robust domestic manufacturing capacity. The production of panels, wind turbines, batteries, electric vehicles, and other clean energy technologies at scale and competitive cost becomes necessary [8]. The program coordinates investments across the entire innovation pipeline. Fundamental materials science research receives support. Pilot-scale demonstration projects get funded. Full commercial production facilities obtain backing. This addresses the systemic challenge that promising laboratory discoveries often fail to achieve commercial viability. Insufficient support during the challenging transition from research to manufacturing is a contributing factor to the problem [8]. Federal funding through this initiative supports multiple strategic objectives. Reduction of manufacturing energy intensity happens through process optimization and waste heat recovery. The development of advanced manufacturing techniques reduces material consumption and production costs. The establishment of domestic supply chains for critical materials, currently sourced predominantly from international suppliers, is occurring under development programs that equip American workers with the technical skills required for advanced manufacturing operations in the clean energy sector.

Table 4: Sustainable Procurement and Manufacturing Innovation [7, 8]

Management Dimension	Operational Integration	Capability Development
Sustainable Procurement Evolution	Transition from peripheral consideration to central strategic pillar	Green purchasing practices evaluators on environmental criteria
Supply Chain Reconceptualization	Extension of organizational boundaries to encompass entire value networks	Environmental collaboration initiatives fostering joint problem-solving
Sustainability Governance	Internal management systems establish processes	Investment recovery programs monetizing waste streams and obsolete materials
Strategic Positioning	Shift from regulatory compliance toward competitive differentiation	Eco-design principles incorporate environmental considerations into product development
Clean Energy Manufacturing Initiative	Coordination across the innovation pipeline from research to	Reduction of manufacturing energy intensity through process optimization

	commercial production	
Domestic Capacity Building	Establishment of supply chains for critical materials	Workforce development programs for advanced manufacturing technical skills

5. Socioeconomic Implications and National Competitiveness

Sustainable supply chain practices have social and economic impacts that can be measured, extending beyond environmental metrics. Workforce development initiatives are implemented in accordance with ethical sourcing requirements and fair labor standards. Green manufacturing infrastructures provide excellent employment opportunities in the country. Policies such as the Good Jobs Initiative and the Build America, Buy America Act specifically relate to sustainable procurement and the approach to inclusive economic growth. The integration of social, environmental, and financial goals becomes evident. The United States energy sector employed approximately 8.1 million workers as of 2022. This represents a substantial and diverse workforce spanning traditional energy production, emerging clean energy technologies, energy efficiency services, and supporting supply chain activities [9]. In this broader employment context, the clean energy industries have revealed relatively stable growth patterns.

The workforce in solar energy numbered approximately 263,000 people. Wind energy employs approximately 126,000 people. The battery storage and electric vehicle manufacturing sectors experienced rapid expansion as transportation electrification accelerated [9]. The energy efficiency sector constitutes the largest and most significant of clean energy employment. Approximately 2.3 million workers are engaged in activities, including building retrofitting, heating and cooling system upgrades, lighting improvements, and industrial efficiency enhancements. This reflects the labor-intensive nature of efficiency implementation and the distributed character of efficiency opportunities across the built environment [9]. Energy sector employment growth significantly outpaced overall national employment trends during the 2021-2022 period. Energy jobs increased by approximately 3.8% compared to 2.7% growth in total United States employment. This demonstrates the economic dynamism of energy sector transformation and employment generation potential associated with clean energy transition [9]. The occupation of energy employment encompasses a diverse range of skills and wage levels. Substantial representation exists in the construction trades, manufacturing production, engineering and technical professions, as well as installation and maintenance occupations. Employment pathways are created that are accessible to workers with varying educational backgrounds and training levels [9].

From a competitive standpoint, sustainable practices enhance long-term market positioning and financial performance. Organizations integrating circular economy principles and clean technology benefit from reduced exposure to resource price volatility. Better access to capital comes with the increased investor confidence in climate-aligned businesses. The strategic transition to renewable energy makes the United States a global leader in climate-congruent industrial innovation.

Supply chain transformation serves as both an environmental imperative and a catalyst for national advancement. Theoretical relationships between corporate sustainability initiatives and economic finance reveal that environmental innovation frequently generates competitive advantages rather than imposing net costs on implementing organizations [10]. Research examining sustainable entrepreneurship reveals that companies integrating sustainability principles into their core business strategies and operational practices develop distinctive capabilities. Resource efficiency improves. Process innovation advances. Stakeholder relationship management translates into measurable financial benefits [10]. Benefits manifest through multiple value creation mechanisms. Operational cost reductions are achieved through material improvements and energy efficiency enhancements. These enhancements occur through the development of environmentally differentiated products and services that command premium pricing or access in market segments. Risk mitigation happens through reduced regulatory exposure and enhanced supply chain resilience. Greater access to capital is also achieved as investors incorporate more fundamental performance into valuation models and portfolio allocation processes [10]. The level of correlation

between sustainability performance and traditional sustainability seems high in cases where ecological programs align with core competencies and strategic positioning. Instead of using sustainability investments as a tool of compliance or a peripheral corporate social responsibility connection to the valuation processes, organizations utilize them as a source of differentiation [10].

Conclusion

The evolution of sustainable supply chain management in America reflects comprehensive alignment between federal policy instruments, industrial innovation, and environmental responsibility imperatives. Together, these establish operational models reconciling ecological stewardship with economic competitiveness. The integration of Life Cycle Assessment methodologies quantifies environmental impacts across entire value chains. Circular economy design principles transform waste into resource streams. Digital transparency tools enable real-time performance monitoring. American supply networks demonstrate that sustainability and profitability function as mutually reinforcing rather than opposing strategic objectives. The \$369 billion commitment to clean energy and manufacturing that the Inflation Reduction Act will make is more than the federal government has ever invested in transforming the industrial sector. Economic incentives will accelerate the adoption of renewable energy systems, electric transport fleets, and new production lines. Considerable employment opportunities are created at various skill levels and geographical locations. The shift in transportation and logistics to be dependent on substitutes for fossil fuels, such as electricity, and the optimization of efficiency will address the most significant of national greenhouse gas emissions. At the same time, the operational expenses are reduced, and the supply chain becomes resilient to fluctuations in the cost of resources. The fact that employment rates in clean energy industries are expanding faster than the economy, supported by empirical data on the progress of sustainability initiatives with documented financial returns, lends validity to the suggestion.

Environmental management constitutes an investment in competitive advantage rather than compliance costs. The role of supply chain professionals has expanded from operational management focused on cost and price toward strategic leadership in environmental transition. These practitioners become architects of industrial systems that function within planetary boundaries, delivering economic prosperity. Frameworks, technologies, and practices being developed across U.S. industries provide replicable models for global application. American supply chain management establishes itself as a source of both domestic economic resilience and international environmental leadership. Policy support continues through legislative instruments and regulatory frameworks. Technological capabilities advance through digital innovation and the development of clean energy manufacturing. Supply chains remain central infrastructure for achieving national climate objectives while maintaining industrial competitiveness in an increasingly resource-constrained and climate-conscious global economy. Environmental responsibility and economic advancement represent convergent rather than divergent pathways for industrial development.

References

- [1] Stefan Seuring, Martin Müller, "From a literature review to a conceptual framework for sustainable supply chain management," ScienceDirect, 2008. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S095965260800111X>
- [2] The White House, "Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action," 2023. [Online]. Available: <https://bidenwhitehouse.archives.gov/wp-content/uploads/2022/12/Inflation-Reduction-Act-Guidebook.pdf>
- [3] EPA, "Environmental Defense Fund, Inventory of U.S. Greenhouse Gas Emissions and Sinks," [Online]. Available: <https://library.edf.org/AssetLink/145ky510ew61fk1tq5c2klp5kq5yp33j.pdf>
- [4] University of Illinois Facilities & Services, "SmartWay Transport Partnership," [Online]. Available: <https://fs.illinois.edu/smartway-transport-partnership/>

- [5] G. Rebitzerl et al., "Life cycle assessment: Part 1: Framework, goal and scope definition, inventory analysis, and applications," ScienceDirect, 2004. [Online]. Available: <https://www.sciencedirect.com/science/article/abs/pii/S0160412003002459>
- [6] U.S. Environmental Protection Agency, "National Recycling Strategy: Part One of a Series on Building a Circular Economy for All," EPA. [Online]. Available: <https://www.epa.gov/system/files/documents/2021-11/national-recycling-strategy-executive-summary.pdf>
- [7] Craig Carter, P. Liane Easton, "Sustainable Supply Chain Management: Evolution and Future Directions", ResearchGate, 2011. [Online]. Available: https://www.researchgate.net/publication/241674710_Sustainable_Supply_Chain_Management_Evolution_and_Future_Directions
- [8] U.S. Department of Energy, "Clean Energy Manufacturing Initiative, ". [Online]. Available: <https://www.energy.gov/clean-energy-manufacturing-initiative>
- [9] U.S. Department of Energy, "UNITED STATES ENERGY & EMPLOYMENT REPORT 2023," 2023. [Online]. Available: <https://www.eesi.org/files/DOE-2023-USEER-FULL-REPORT.pdf>
- [10] Stefan Schaltegger, Marcus Wagne, "Sustainable entrepreneurship and sustainability innovation: categories and interactions," *Business Strategy and the Environment*, 2011. [Online]. Available: <https://onlinelibrary.wiley.com/doi/abs/10.1002/bse.682>