JOURNAL OF INDUSTRIAL ECOLOGY

中文摘要
《产业生态学报》
第24 卷第1期

翻译

程蕾 黄莹 雷锦明 李霄 李智伟
刘致炜 蒲广颖 孙昊 辛文 杨薇
余颢凡 张安迎 张瑞瑞

Chinese Abstracts
Journal of Industrial Ecology
Volume 24, Issue 1

Translated by

Lei Cheng, Ying Huang, Jinming Lei, Xiao Li, Zhiwei Li,
Zhiwei Liu, Guangying Pu, Hao Sun, Wen Xin, Wei Yang,
Haofan Yu, Anying Zhang, Ruirui Zhang

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12954

新兴技术的生命周期评估：市场和技术成熟度不同阶段的评估技术

作者：Joule A. Bergerson, Adam Brandt, Joe Cresko, Michael Carbajales-Dale, Heather L. MacLean, H. Scott Matthews, Sean McCoy, Marcelle McManus, Shelie A. Miller, William R. Morrow III, I. Daniel Posen, Thomas Seager, Timothy Skone, Sylvia Sleep

关键字： 早期技术评估、环境影响、产业生态学、生命周期分析、技术研发、意外后果

摘要：
新兴技术的不断出现及其在实际中的应用，越来越需要生命周期分析（LCA）人员在技术开发的早期阶段进行系统分析。尽管早期阶段的分析能够有效指导技术的改进和减少该技术最终的环境影响，但分析结果的准确性容易受到质疑，例如，分析过程可用数据少，不确定性因素多，缺乏相应的的分析工具。虽然新兴技术的生命周期分析方法类似于已有的生命周期分析方法，但新兴技术的生命周期分析面临更多挑战。本文分析了能够影响新兴技术生命周期分析结果的市场和技术特征，并指出了哪些问题是研究人员在进行新兴技术生命周期分析过程必须要解决的。本文能够实现以下目的：（a）指导识别与具体技术相关的技术特征和动态市场环境；（b）综述了由于上述条件限制导致早期阶段分析面临的挑战；（c）总结了研究人员进行目标与边界设定过程存在的问题；（d）以交通运输为例说明新兴技术进行生命周期分析时，要考虑哪些重要因素。本文旨在用作组织平台，以综合现有的方法、程序和见解，并指导研究人员、分析人员和技术研发人员更好地认识技术开发过程的关键元素和管理研究成果。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12954

Life cycle assessment of emerging technologies: Evaluation techniques at different stages of market and technical maturity

Joule A. Bergerson, Adam Brandt, Joe Cresko, Michael Carbajales-Dale, Heather L. MacLean, H. Scott Matthews, Sean McCoy, Marcelle McManus, Shelie A. Miller, William R. Morrow III, I. Daniel Posen, Thomas Seager, Timothy Skone, Sylvia Sleep

Keywords: early stage technology assessment, environmental impacts, industrial ecology, life cycle assessment (LCA), research and development (R&D), unintended consequences

Summary:
Life cycle assessment (LCA) analysts are increasingly being asked to conduct life cycle-based systems level analysis at the earliest stages of technology development. While early assessments provide the greatest opportunity to influence design and ultimately environmental performance, it is the stage with the least available data, greatest uncertainty, and a paucity of analytic tools for addressing these challenges. While the fundamental approach to conducting an LCA of emerging technologies is akin to that of LCA of existing technologies, emerging technologies pose additional challenges. In this paper, we present a broad set of market and technology characteristics that typically influence an LCA of emerging technologies and identify questions that researchers must address to account for the most important aspects of the systems they are studying. The paper presents: (a) guidance to identify the specific technology characteristics and dynamic market context that are most relevant and unique to a particular study, (b) an overview of the challenges faced by early stage assessments that are unique because of these conditions, (c) questions that researchers should ask themselves for such a study to be conducted, and (d) illustrative examples from the transportation sector to demonstrate the factors to consider when conducting LCAs of emerging technologies. The paper is intended to be used as an organizing platform to synthesize existing methods, procedures and insights and guide researchers, analysts and technology developer to better recognize key study design elements and to manage expectations of study outcomes.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12807

LiSET：新兴技术早期生命周期筛选的框架

作 者： Christine Roxanne Hung, Linda Ager-Wick Ellingsen, Guillaume Majeau-Bettez

关键字： 新兴技术，环境筛选，新兴技术的生命周期筛选，LiSET，矩阵LCA，简化的LCA

摘要：
尽管生命周期评估（LCA）是经常用于评估产品和技术对环境影响的工具，但是执行此类研究所需的数据量给用常规 LCA 方法评估新兴技术带来挑战。由此存在一个开发悖论：全面环境评估的输入在开发阶段的早期就产生了最大的影响，但是通常缺少进行这种评估所需的数据，直到为时已晚。在 1990 年代末和 2000 年代初期，人们曾尝试寻找正规的策略以简化或筛选 LCA，主要是为了快速比较候选产品的环境性能。这些策略缺乏对大量早期开发候选产品进行环境筛选所需的透明性和一致性，而这类数据甚至很少。我们提出了新兴技术的生命周期筛选方法（LiSET）。LiSET 是一种适用于 LCA 的适应性筛选方法，它使用可用数据来系统、透明地评估处于低就绪水平的技术的环境绩效。迭代跟着技术发展，如果需要，可以逐步升级到完整的 LCA。在早期的迭代中，LiSET 可以将矩阵结构与“交通灯”颜色分级系统结合在一起。这种格式固有地传达了现阶段分析的高度不确定性，并提出了许多评估的环境因素。LiSET 利用分解分析和 LCA 中传统上不使用的数据来获得对生命周期影响的洞察力，并确保采用最具有环境可持续性的技术。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12807

LiSET: A framework for early-stage life cycle screening of emerging technologies

Christine Roxanne Hung, Linda Ager-Wick Ellingsen, Guillaume Majeau-Bettez

Keywords: emerging technology, environmental screening, Life Cycle Screening of Emerging Technologies, LiSET, matrix LCA, streamlined LCA

Summary:
While life cycle assessment (LCA) is a tool often used to evaluate the environmental impacts of products and technologies, the amount of data required to perform such studies make the evaluation of emerging technologies using the conventional LCA approach challenging. The development paradox is such that the inputs from a comprehensive environmental assessment has the greatest effect early in the development phase, and yet the data required to perform such an assessment are generally lacking until it is too late. Previous attempts to formalize strategies for performing streamlined or screening LCAs were made in the late 1990s and early 2000s, mostly to rapidly compare the environmental performance of product design candidates. These strategies lack the transparency and consistency required for the environmental screening of large numbers of early-development candidates, for which data are even sparser. We propose the Lifecycle Screening of Emerging Technologies method (LiSET). LiSET is an adaptable screening-to-LCA method that uses the available data to systematically and transparently evaluate the environmental performance of technologies at low readiness levels. Iterations follow technological development and allow a progression to a full LCA if desired. In early iterations, LiSET presents results in a matrix structure combined with a “traffic light” color grading system. This format inherently communicates the high uncertainty of analysis at this stage and presents numerous environmental aspects assessed. LiSET takes advantage of a decomposition analysis and data not traditionally used in LCAs to gain insight to the life cycle impacts and ensure that the most environmentally sustainable technologies are adopted.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12825

当背景成为重要问题时：在前瞻性生命周期评估中使用来自综合评估模型的情景

作者：Angelica Mendoza Beltran, Brian Cox, Chris Mutel, Detlef P. van Vuuren, David Font Vivanco, Sebastiaan Deetman, Oreane Y. Edelenbosch, Jeroen Guinée, Arnold Tukker

关键字： 背景变化，认识论的不确定性，产业生态学，综合评估模型，生命周期评估，前瞻性LCA

摘要：

前瞻性生命周期评估(LCA)需要处理对未来的认识上的巨大不确定性，以支持对技术进行更有力的未来环境影响评估。本研究提出了一种新的方法，基于综合评估模型(IAM)，即 IMAGE 模型，系统地改变前瞻性 LCA 的背景过程，并使用 ecoinvent v3.3 在生命周期清单中评估来自 IMAGE 的一致的全球情景。为了测试这一方法，本文在对内燃机汽车(ICEV)和电动汽车(EV)进行的前瞻性 LCA 中，仅改变了电力部门，使用了截至 2050 年的 6 个基准和减缓气候变化情景。该案例研究表明，电力背景的变化对电动汽车的环境影响非常重要。此外，该方法表明电动汽车和 ICEV 的相对环境性能随时间的推移比以前假定的更加复杂和多面。由未来发展而产生的不确定性体现在产品(EV 或 ICEV)、影响类别以及所考虑的情景和年份的不同影响。通过将这种方法扩展到电力背景变化和交通应用之外的其他经济部门，以及通过将前景参数中的不确定性和变化纳入其中，可以实现对于新兴技术的更稳健的前瞻性 LCA。由 IAM 情景驱动的更系统和结构化的未来数据库有助于考虑认识论的不确定性，并增强新兴技术 LCA 中前景和背景系统的时间一致性。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12825

When the background matters: Using scenarios from integrated assessment models in prospective life cycle assessment

Angelica Mendoza Beltran, Brian Cox, Chris Mutel, Detlef P. van Vuuren, David Font Vivanco, Sebastiaan Deetman, Oreane Y. Edelenbosch, Jeroen Guinée, Arnold Tukker

Keywords: background changes, epistemological uncertainty, industrial ecology, integrated assessment models, life cycle assessment, prospective LCA

Summary:

Prospective life cycle assessment (LCA) needs to deal with the large epistemological uncertainty about the future to support more robust future environmental impact assessments of technologies. This study proposes a novel approach that systematically changes the background processes in a prospective LCA based on scenarios of an integrated assessment model (IAM), the IMAGE model. Consistent worldwide scenarios from IMAGE are evaluated in the life cycle inventory using ecoinvent v3.3. To test the approach, only the electricity sector was changed in a prospective LCA of an internal combustion engine vehicle (ICEV) and an electric vehicle (EV) using six baseline and mitigation climate scenarios until 2050. This case study shows that changes in the electricity background can be very important for the environmental impacts of EV. Also, the approach demonstrates that the relative environmental performance of EV and ICEV over time is more complex and multifaceted than previously assumed. Uncertainty due to future developments manifests in different impacts depending on the product (EV or ICEV), the impact category, and the scenario and year considered. More robust prospective LCAs can be achieved, particularly for emerging technologies, by expanding this approach to other economic sectors beyond electricity background changes and mobility applications as well as by including uncertainty and changes in foreground parameters. A more systematic and structured composition of future inventory databases driven by IAM scenarios helps to acknowledge epistemological uncertainty and to increase the temporal consistency of foreground and background systems in LCAs of emerging technologies.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12748

新兴技术的前瞻性环境分析：评论、方法论和对增量板材成形的案例研究

作者：Daniel R. Cooper, Timothy G. Gutowski

关键字： 预期环境分析、新兴技术、增量板材成形、产业生态学、前瞻性环境分析、可持续技术

摘要：
对新兴技术进行前瞻性的环境评估将有利于设计人员在技术开发的早期阶段就掌握有益的设计变化，也有利于政策制定者为项目提供资金并促使制造商朝着最可持续的技术应用方向发展。现有的分析通常存在一些缺陷，例如：没有考虑产品生命周期所有阶段的环境影响；隐含地假设新兴技术在技术上可行的地方将会是成本划算的；并假设足以中断人类行为长期趋势的乐观的技术应用情景。在本文中，我们提出了一种解决上述问题的新方法作为对 prospective LCA 和 anticipatory LCA 文献的补充，并试图通过使用分布对所有输入进行建模来理解此类分析中固有的巨大不确定性。本文重点介绍了新兴的制造技术，例如增量板材成形（ISF），但所研究的问题也适用于新的最终用途产品，例如自动驾驶汽车。本文利用的方法（例如 Bass 建模和产品同类化考虑）是习惯于对新技术的市场扩散及对现有技术销售影响进行预判的商业界人士所熟悉的。论文估算了截至 2030 年新兴的双面 ISF 流程对美国汽车行业的潜在环境影响，以此对所提出的方法进行了展示。ISF 和压模的能源和成本模型估计显示，到 2030 年每年可能节省大约 100 TJ 的能量和 6000 万美元的费用。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12748

Prospective environmental analyses of emerging technology: A critique, a proposed methodology, and a case study on incremental sheet forming

Daniel R. Cooper, Timothy G. Gutowski

Keywords: anticipatory environmental analysis, emerging technology, incremental sheet forming, industrial ecology, prospective environmental analysis, sustainable technology

Summary:
Prospective environmental assessment of emerging technology is necessary in order to inform designers of beneficial changes early in a technology's development, and policy makers looking to fund projects and nudge manufacturers toward the most sustainable application of a technology. Existing analyses often have shortcomings such as failing to consider the environmental impacts in all stages of a product's life cycle; implicitly assuming that the emerging technology will be cost-effective wherever it is technically viable; and assuming optimistic application scenarios that discontinue long-established trends in human behavior. In this article, we propose a new approach, complementary to the prospective and anticipatory life cycle assessment literature, addressing the above concerns and attempting to make sense of the large uncertainties inherent in such analyses by using distributions to model all the inputs. The paper focuses on emerging manufacturing technologies, such as incremental sheet forming (ISF), but the issues examined are also applicable to new end-use products, such as autonomous vehicles. This paper makes use of approaches (such as Bass modeling and product cannibalization considerations) familiar to those in the business community who anticipate market diffusion of a new technology and the effect on existing technology sales. The proposed methodology is demonstrated by estimating the potential environmental impacts in the U.S. car industry by 2030 of an emerging double-sided ISF process. Energy and cost models of ISF and drawing are used to estimate potential mean savings of around 100 TJprimary and 60 million U.S. dollars per year by 2030.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12965

新兴技术的生命周期评估综述

作者：Sheikh Moniruzzaman Moni, Roksana Mahmud, Karen High, Michael Carbajales-Dale

关键字： 新兴技术，事前LCA，产业生态学，生命周期评估（LCA），技术经济评估（TEA），技术成熟度（TRL）

摘要：
低技术成熟度（TRL）下生命周期评估（LCA）的应用前景在最近的文献中受到了极大的关注，因为它有潜力开发具有改善环境性能的新兴技术。然而，有限的数据、不确定的功能、规模扩大的问题和不确定性使标准生命周期评价导则在评价新兴技术方面面临很大的挑战，这需要在当前生命周期评价框架中取得方法上的进步。在本文中，我们回顾了已发表的文献，以确定解决这些问题的主要方法学挑战和关键的研究工作，重点关注五个主要领域的最新进展：交叉研究可比性、数据可用性和质量、规模扩大问题、不确定性和沟通不确定性以及评估时间。我们为未来的研究提供一些对低技术成熟度的新兴技术进行评估的建议：（a）制定新兴技术 LCA 的一致框架和报告方法；（b）将其他工具与生命周期评价相结合，如多准则决策分析，风险分析、技术经济分析；（c）开发用于新兴材料、工艺和技术的数据库。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12965

Life cycle assessment of emerging technologies: A review

Sheikh Moniruzzaman Moni, Roksana Mahmud, Karen High, Michael Carbajales-Dale

Keywords: emerging technology, ex ante LCA, industrial ecology, life cycle assessment (LCA), technoeconomic analysis (TEA), technology readiness level (TRL)

Summary:
In recent literature, prospective application of life cycle assessment (LCA) at low technology readiness levels (TRL) has gained immense interest for its potential to enable development of emerging technologies with improved environmental performances. However, limited data, uncertain functionality, scale up issues and uncertainties make it very challenging for the standard LCA guidelines to evaluate emerging technologies and requires methodological advances in the current LCA framework. In this paper, we review published literature to identify major methodological challenges and key research efforts to resolve these issues with a focus on recent developments in five major areas: cross-study comparability, data availability and quality, scale-up issues, uncertainty and uncertainty communication, and assessment time. We also provide a number of recommendations for future research to support the evaluation of emerging technologies at low technology readiness levels: (a) the development of a consistent framework and reporting methods for LCA of emerging technologies; (b) the integration of other tools with LCA, such as multicriteria decision analysis, risk analysis, technoeconomic analysis; and (c) the development of a data repository for emerging materials, processes, and technologies.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12949

锂资源的未来（上）：资源模型

作者：Hanjiro Ambrose, Alissa Kendall

关键字： 关键材料、动态建模、产业生态学、生命周期评估、锂电池、资源耗竭

摘要：
近年来由于应用大规格锂离子电池的技术大量涌现（例如纯电动汽车等），锂被视作是一种重要的能源材料。近期锂资源需求的增长主要是由于持续增加的锂电池用量所造成的，这部分用途占了 2017 年锂资源总消耗量的 46%。这些新技术通常被应用在强化环境可持续性上，然而在其产品的生产过程中造成的的环境效应与对资源可持续性的影响却常常没有被人们很好地了解，尤其是在对这些技术的需求持续增长的背景下。

本文是本系列的上篇，在本系列中作者结合使用了资源生产模型和生命周期评估模型，估算出了锂资源的用量和使用锂资源对环境的长期影响。在本篇中，为了建立出未来的锂资源需求以及生产特征（例如时间、位置以及矿藏种类）的情境，作者建立了一个全新的资源生产模型。这些情境随后会在下篇中被用于进行生命周期研究，以观察生产系统在一段时期内的时空变化。

资源生产模型的运行结果表明，全球锂资源总储量在 2.93 到 5.27 亿吨碳酸锂当量（LCE）之间。到 2100 年，全球产量将会从 2018 年的年产 23.7 万吨增长到 440–750 万吨。即使需求量将急剧增长，从高等级卤水型锂矿中获取的锂资源产量还是可能满足 2035 年前的大部分需求缺口。尽管现存储量足以使用到 2100 年，到 2050 年后，发展从低等级矿藏中提取锂资源的技术仍可能需要被提上日程。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12949

Understanding the future of lithium: Part 1, resource model

Hanjiro Ambrose, Alissa Kendall

Keywords: critical materials, dynamic modeling, industrial ecology, life cycle assessment (LCA), lithium ion batteries, resource depletion

Summary:
Lithium is a critical energy material in part due to an array of emerging technologies from electric vehicles to renewable energy systems that rely on large-format lithium ion batteries. Recent growth in demand for lithium is primarily from increased use in batteries, which comprised 46% of total lithium by end use in 2017. These technologies are often deployed to improve environmental sustainability, yet the environmental effects and sustainability of the resources they rely on are often not well understood, especially as demand increases over time.

This is the first in a two part article series that together quantify the lithium resource use and its environmental effects over time by coupling a resource production model and life cycle assessment model. In this first part, a novel resource production model is developed to create scenarios of future lithium demand and production characteristics (e.g., timing, location, and ore type). These scenarios are then used to create a life cycle assessment in part two that captures temporal and spatial changes in production systems over time.

Results of the resource production model show global lithium resources range from 293 to 527 million metric tons (Mt) of lithium carbonate equivalent (LCE). Global production will likely increase from 237,000 metric tons LCE in 2018 to 4.4–7.5 Mt LCE/year by 2100. Even with rapidly increasing demand, production from high-grade brines may satisfy most lithium demand through 2035. Though resources can meet demand through 2100, development of lower grade and unfavorable deposits is likely required after 2050.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12942

锂资源的未来（下）：运用生命周期评估模型解析环境影响的时空特征

作者：Hanjiro Ambrose, Alissa Kendall

关键字： 电池，动态建模，电动汽车，生命周期评估（LCA），资源枯竭，技术与环境

摘要：
从电动汽车到可再生能源系统的一系列新兴技术都依赖于大尺寸锂离子电池（LIBs）。LIBs 是清洁能源技术的关键助推，这些技术通常与空气污染和温室气体减排策略有关。然而，LIBs 需要锂，而扩大锂的供应则需要新的锂生产能力，由于不同的资源类型和品位的矿石将被开采，这反过来又会改变与锂生产相关的环境影响。一个有趣的问题是，随着时间的推移，这是否会导致初级锂对环境的影响发生重大变化。这个由两部分组成的系列文章的第一部分描述了一种新型资源生产模型的开发，该模型可以预测未来的锂需求和生产特性（例如，时间、地点和矿石类型）。作为第二部分的本研究将与预测性生命周期评价（LCA）模型相结合，以预测估算在2018至2100年间每年生产电池级碳酸锂当量（LCE）的环境影响。

LCE 的标准化生命周期影响强度的结果反映了不断变化的资源类型、数量和生产区域。2100 年之前尤其是在 2050 年之后，锂需求的持续增长必然导致开采较低品位的资源和矿藏。尽管依赖于较低品位的资源，而且每个矿床 LCE 生产的影响强度不同，但 LCA 结果显示只有轻微至中等程度的影响增加，例如碳强度从 2020 年的 3.2 kg CO2 e/kg LCE 增加到 2100 年的 3.3 kg CO2 e/kg LCE。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12942

Understanding the future of lithium: Part 2, temporally and spatially resolved life-cycle assessment modeling

Hanjiro Ambrose, Alissa Kendall

Keywords: batteries, dynamic modeling, electric vehicles, life-cycle assessment (LCA), resource depletion, technology and environment

Summary:
An array of emerging technologies, from electric vehicles to renewable energy systems, relies on large-format lithium ion batteries (LIBs). LIBs are a critical enabler of clean energy technologies commonly associated with air pollution and greenhouse gas mitigation strategies. However, LIBs require lithium, and expanding the supply of lithium requires new lithium production capacity, which, in turn, changes the environmental impacts associated with lithium production since different resource types and ore qualities will be exploited. A question of interest is whether this will lead to significant changes in the environmental impacts of primary lithium over time. Part one of this two-part article series describes the development of a novel resource production model that predicts future lithium demand and production characteristics (e.g., timing, location, and ore type). In this article, part two, the forecast is coupled with anticipatory life-cycle assessment (LCA) modeling to estimate the environmental impacts of producing battery-grade lithium carbonate equivalent (LCE) each year between 2018 and 2100.

The result is a normalized life-cycle impact intensity for LCE that reflects the changing resource type, quantity, and region of production. Sustained growth in lithium demands through 2100 necessitates extraction of lower grade resources and mineral deposits, especially after 2050. Despite the reliance on lower grade resources and differences in impact intensity for LCE production from each deposit, the LCA results show only small to modest increases in impact, for example, carbon intensity increases from 3.2 kg CO2e/kg LCE in 2020 to 3.3 kg CO2e/kg LCE in 2100.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12959

在开发初期阶段对新兴环境技术进行生命周期评估——纳米结构材料的案例研究

作者：Irene Bartolozzi，Tiberio Daddi，Carlo Punta，Andrea Fiorati，Fabio Iraldo

关键字： 纤维素纳米海绵，生态设计，生命周期评估，纳米技术，前瞻LCA，规模化

摘要：
近年来，纳米材料在环境纳米修复领域得到了广泛的应用。这种方法不直接使用纳米材料，而是作为纳米多孔微尺度系统设计的构件，克服通常与纳米技术的使用相关的生态和健康毒理学风险。本文中，我们报告了生命周期评估（LCA）作为一种生态设计工具的使用来优化纤维素纳米海绵（CNS）——近来为水修复目的开发的纳米结构材料的生产。LCA 应用于原材料的获取到 CNS 的合成（从摇篮到大门），其中考虑了从实验室到模型规模化系统的三种生产系统。实验室规模的 LCA 确定了主要环境热点，即能量消耗步骤和材料的最终净化（清洗步骤）。在第二个实验室规模的生产中，可以实施改进措施，将洗涤溶剂从甲醇切换为水，并降低洗涤温度。第二个生命周期评价表明，材料对影响的贡献减少了，而全球影响保持在相同的数量级内。模拟的过程放大可以通过内部的循环来优化能耗步骤和用水量。第三个生命周期评价评估了由此产生的效益，并将全球影响降低了两个数量级。我们的研究有助于对生命周期评价社区的讨论，重点关注新兴技术（即纳米结构多孔材料）扩大规模的重要性，强调从产品设计（生态设计）一开始就采用基于生命周期评价的方法的益处。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12959

Life cycle assessment of emerging environmental technologies in the early stage of development: A case study on nanostructured materials

Irene Bartolozzi，Tiberio Daddi，Carlo Punta，Andrea Fiorati，Fabio Iraldo

Keywords: cellulose nanosponges, eco-design, life cycle assessment, nanotechnologies, prospective LCA, scale-up

Summary:
The use of nanostructured materials has been recently proposed in the field of environmental nanoremediation. This approach consists in using nanomaterials not directly, but as building blocks for the design of nano-porous micro-dimensional systems, overcoming the eco- and health-toxicology risks generally associated with the use of nano-sized technologies. Herein we report the use of life cycle assessment (LCA) as an eco-design tool for optimizing the production of cellulose nanosponges (CNS), nanostructured materials recently developed for water remediation purposes. LCA was applied from the acquisition of raw materials to the synthesis of CNS (from cradle-to-gate), considering three production systems, from the lab-level to a modeled scale-up system. The lab-scale LCA identified the main environmental hotspots, namely the energy-consuming steps and the final purification of the material (washing step). In a second lab-scale production, an improvement action could be implemented, switching the washing solvent from methanol to water and decreasing the washing temperature. A second LCA showed a reduced contribution to the impacts from the materials, while the global impacts remained within the same order of magnitude. A simulated scale-up of the process allowed to optimize the energy-consuming steps and the water consumption, through internal recycling. A third LCA assessed the resulting benefits and a decrease in the global impacts by two orders of magnitude. Our study contributes to the discussion of LCA community, providing a focus on the importance of scaling-up of emerging technologies, namely nanostructured porous materials, highlighting the benefits of a LCA based approach since the very beginning of product design (eco-design).

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12930

3D 打印地聚合物混凝土的生命周期评价

作者： Yue Yao, Mingming Hu, Francesco Di Maio, Stefano Cucurachi

关键字： 3D打印，混凝土，新兴技术，事前生命周期评价，地聚合物混凝土，产业生态学

摘要：

三维（3D）打印和地聚合物是混凝土制造中两项面向环境的创新。混凝土组件的 3D 打印旨在减少原材料消耗和废物的产生。目前正在开发的一种地聚合物，以取代普通硅酸盐水泥并减少混凝土中粘合剂的碳足迹。事前生命周期评估（LCA）对 3D 打印和地聚合物的结合使用进行评估得出环境绩效。首先，实施归类 LCA，使用从制造商处收集的数据来确定环境改善的热点。然后，与公司利益相关者合作，建立扩大规模的方案。将这些方案与现有生产系统进行了比较，以了解创新系统的潜在优势/劣势，并确定改进的潜在方向。

结果表明，3D 打印有可能减少浪费。然而，根据其配方，地聚合物可能比普通混凝土具有更大的环境影响。事前生命周期评价表明，经过原材料生产和运输的逐步改进，3D 打印地聚合物混凝土能够减少混凝土构件的碳足迹，而在非生物资源消耗和臭氧消耗等影响类别上，它的表现仍然较差。我们发现，降低 3D 混凝土环境影响的最有效方法是减少地聚合物配方中的硅酸盐。然而，由于之前的创新投资的锁定效应，该公司很难实现这种方法。案例研究表明，为了支持技术创新，必须在创新过程中尽早实施生命周期评价，以保持技术灵活性和改进已确定的环境热点。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12930

Life cycle assessment of 3D printing geo-polymer concrete: An ex-ante study

Yue Yao, Mingming Hu, Francesco Di Maio, Stefano Cucurachi

Keywords: 3D printing, concrete, emerging technologies, ex-ante, LCA, geo-polymer, industrial ecology

Summary:

Three-dimensional (3D) printing and geo-polymers are two environmentally oriented innovations in concrete manufacturing. The 3D printing of concrete components aims to reduce raw material consumption and waste generation. Geo-polymer is being developed to replace ordinary Portland cement and reduce the carbon footprint of the binder in the concrete. The environmental performance of the combined use of the two innovations is evaluated through an ex-ante life cycle assessment (LCA). First, an attributional LCA was implemented, using data collected from the manufacturer to identify the hotspots for environmental improvements. Then, scaled-up scenarios were built in collaboration with the company stakeholder. These scenarios were compared with the existing production system to understand the potential advantages/disadvantages of the innovative system and to identify the potential directions for improvement.

The results indicate that 3D printing can potentially lead to waste reduction. However, depending on its recipe, geo-polymer likely has higher environmental impacts than ordinary concrete. The ex-ante LCA suggests that after step-by-step improvements in the production and transportation of raw materials, 3D printing geo-polymer concrete is able to reduce the carbon footprint of concrete components, while it does still perform worse on impact categories, such as depletion of abiotic resources and stratospheric ozone depletion. We found that the most effective way to lower the environmental impacts of 3D concrete is to reduce silicate in the recipe of the geo-polymer. This approach is, however, challenging to realize by the company due to the locked-in effect of the previous innovation investment. The case study shows that to support technological innovation ex-ante LCA has to be implemented as early as possible in innovation to allow for maintaining technical flexibility and improving on the identified hotspots.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12943

从磁铁中回收稀土的经济评估和碳足迹：实验室规模的评估为工业化铺平道路

作者： Antoine Beylot, Nour-Eddine Ménad, Alain Seron, Michel Delain, Alice Bizouard, Yannick Ménard, Jacques Villeneuve

关键字： 气候变化，经济评估，生命周期评估（LCA），稀土，回收利用，不确定性分析

摘要：
EXTRADE 项目开发了一种创新方法，可从用于小型应用的永磁体中回收稀土（RE）。为了评估从实验室规模到工业化的进一步研究的潜力，本研究进行了经济和环境评价。由于当前过程开发水平的数据不完整，因此本研究将不确定性传播到结果中。结果表明，EXTRADE 过程作为法国目前正在运行的硬盘驱动器（HDD）废物管理系统的补充，在气候变化方面可能既经济又有利。然而，尽管不确定性很强，在目前的发展阶段，产出产品的价格是经济盈利能力的关键决定因素。此外，由于用回收的可再生可再生氧化物代替了主要资源所产生的氧化物，EXTRADE 工艺可能会对气候变化产生积极影响（五年内有 80％的机会超过 990 吨二氧化碳当量）。回收废物的数量是与该过程所提供的环境和经济效益有关的另一个不确定的关键参数。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12943

Economic assessment and carbon footprint of recycling rare earths from magnets: Evaluation at lab scale paving the way toward industrialization

Antoine Beylot, Nour-Eddine Ménad, Alain Seron, Michel Delain, Alice Bizouard, Yannick Ménard, Jacques Villeneuve

Keywords: climate change, economic assessment, life cycle assessment (LCA), rare earths, recycling, uncertainty analysis

Summary:
Project EXTRADE developed an innovative process for recycling rare earths (RE) from permanent magnets used in small applications. To assess the potential of further research from lab scale toward industrialization, this study performs economic and environmental evaluations. Because data are incomplete at current levels of process development, this study propagates uncertainty into the results. Results show that the EXTRADE process, as a complement to the Hard Disk Drive (HDD) waste management system currently in operation in France, could be both economically profitable and beneficial in terms of climate change. However, at this stage of development the price of output products is a key determinant of the economic profitability while still particularly uncertain. Also, the EXTRADE process may offer a climate change benefit due to the substitution of recycled RE oxides for those produced from primary resources (80% chance to be superior to 990 tonnes CO2-eq over 5 years). The amount of the waste recycled is another key, uncertain parameter regarding both the environmental and economic benefits provided by the process.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12860

使用生命周期评估量化技术改进对共享自行车系统的影响

作者：Ricardo Javier Bonilla-Alicea, Bryan C. Watson, Ziheng Shen, Laura Tamayo, Cassandra Telenko

关键字： 电气和电子设备（EEE），生命周期评估（LCA），产品服务系统（PSS），智能自行车共享，运输，技术变革与创新

摘要：
同享单车系统（BSS）带来环境足迹的减少是其迅速普及的原因之一。随着技术发展，BSS 已经从智能停靠系统过渡到智能自行车系统，且尚不清楚增加 BSS 中电子设备的使用是否会带来净环境效益。本文提供了对将附加技术纳入 BSS 的影响评估，用以指导未来 BSS 的开发。这项工作使用生命周期评估（LCA）比较私人自行车、智能停靠 BSS 和智能自行车 BSS 的环境影响，揭示了技术之间的收支平衡点和折衷方案。这项研究也是作者所知首次发布的智能自行车 LCA 实证研究。按生命周期内骑行每单位公里测算，在生产阶段，智能自行车的排放量大约是智能停靠的三倍；如果考虑到人类健康、生态系统和资源影响，智能自行车对环境的影响约为 2.7 倍。该结果表明，为克服从智能停靠转变到智能自行车所增加的环境影响，需要将乘车率提高 1.8 倍。我们发现，智能停靠系统在人口密度介于 1030 人/ 平方公里（自行车友好城市）和 3100 人/平方公里（不太可能骑自行车的城市）之间的城市变得受欢迎。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12860

Life cycle assessment to quantify the impact of technology improvements in bike-sharing systems

Ricardo Javier Bonilla-Alicea, Bryan C. Watson, Ziheng Shen, Laura Tamayo, Cassandra Telenko

Keywords: electrical and electronic equipment (EEE), life cycle assessment (LCA), product service systems (PSS), smart bike sharing, transportation, technological change and innovation

Summary:
The reduced environmental footprint of bicycle sharing systems (BSS) is one of the reasons for their rapid growth in popularity. BSS have evolved technologically, transitioning from smart dock systems to smart bicycle systems, and it is not clear if the increased use of electronics in BSS results in a net environmental benefit. This article provides an evaluation of the impact of incorporating additional technology into BSS and uses that analysis as guidance for future BSS development. By comparing the impacts of a private bicycle, a smart dock BSS, and smart bike BSS using a life cycle assessment (LCA), this work reveals breakeven points and tradeoffs between the technologies. This study is also the first published empirical LCA of a smart bike known to the authors. In the production phase, smart bikes generate approximately three times the amount of greenhouse gas (GHG) emissions compared to the smart dock bikes per kilometer ridden over the lifetime, and when considering the endpoint categories of human health, ecosystem, and resources, smart bikes have approximately 2.7 times the environmental impact. The results suggest that shifting from smart dock to smart bike requires an increase in ridership by a factor of 1.8 to overcome the increased environmental impact based on the GHG emissions. We find that smart docks become preferable at a population density between 1,030 residents/km2 (in a bike friendly city) and 3,100 residents/km2 (in a city that is less likely to bike).

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12964

自动化重型卡车的全生命周期可持续性评估

作者：Burak Sen, Murat Kucukvar, Nuri C. Onat, Omer Tatari

关键字： 混合投入产出分析，产业生态学，全生命周期可持续评估，可持续货运，互联自动载货汽车

摘要：
互联自动化运输（CAV） 作为一种新兴技术，有望能提高运输系统的环境、社会和经济指标。运输工具的选择对空气质量、运输行业可持续性发展、和运输过程安全有着重要的影响。重型卡车（HDTs）由于承运了美国大部分货物，被认为是互联自动化运输技术应用最理想的领域。Eora 数据库主要由国家的投入产出表组成，由于其几乎覆盖了全球经济数据，因而被认为是一个详细的投入产出数据库。本研究开发了基于 Eora 数据库的投入产出模型，并利用该模型分析了采用自动化技术的柴油重卡和电动重卡的环境、经济和社会影响。然后，将其生命周期可持续性指标与传统的柴油重卡的指标进行比较。研究发现，采用自动化技术的柴油重型卡车导致的死亡人数比电动重型卡车多 18%，柴油重型卡车的全球变暖潜力（GWP）比电动重型卡车高 4700 吨二氧化碳当量。关于对健康的影响，柴油重型卡车是电动重型卡车的两倍。总体而言，自动化有利于提升重型卡车的可持续性指标，例如，全球变暖潜力、生命周期成本、国内生产总值、减少进口和增加收入等。研究结果还表明，在矿物、化石资源耗竭和环境收益之间，是否对重型卡车采用互联自动化运输技术需要权衡才行。考虑到互联自动化技术的未来发展和商业化，这可能使决策进程更加复杂

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12964

Life cycle sustainability assessment of autonomous heavy-duty trucks

Burak Sen, Murat Kucukvar, Nuri C. Onat, Omer Tatari

Keywords: hybrid input–output analysis, industrial ecology, life cycle sustainability assessment (LCSA), sustainable freight transportation, connected automated trucks

Summary:
Connected and automated vehicles (CAVs) are emerging technologies expected to bring important environmental, social, and economic improvements in transportation systems. Given their implications in terms of air quality and sustainable and safer movement of goods, heavy-duty trucks (HDTs), carrying the majority of U.S. freight, are considered an ideal domain for the application of CAV technology. An input–output (IO) model is developed based on the Eora database—a detailed IO database that consists of national IO tables, covering almost the entire global economy. Using the Eora-based IO model, this study quantifies and assesses the environmental, economic, and social impacts of automated diesel and battery electric HDTs based on 20 macro-level indicators. The life cycle sustainability performances of these HDTs are then compared to that of a conventional diesel HDT. The study finds an automated diesel HDT to cause 18% more fatalities than an automated electric HDT. The global warming potential (GWP) of automated diesel HDTs is estimated to be 4.7 thousand metric tons CO2-eq. higher than that of automated electric HDTs. The health impact costs resulting from an automated diesel HDT are two times higher than that of an automated electric HDT. Overall, the results also show that automation brings important improvements to the selected sustainability indicators of HDTs such as global warming potential, life cycle cost, GDP, decrease in import, and increase in income. The findings also show that there are significant trade-offs particularly between mineral and fossil resource losses and environmental gains, which are likely to complicate decision-making processes regarding the further development and commercialization of the technology.

《产业生态学报》

2020 年，第24卷 第1期
http://dx.doi.org/10.1111/jiec.12937

长途运输中能源载体的技术生态分析

作者：Sebastian Wolff, Michael Fries, Markus Lienkamp

关键字： 温室气体排放，产业生态学，基础设施，长途运输，汽车模拟，井到轮

摘要：
在未来，长途运输需求预计将增加，这将会导致更高的二氧化碳排放。不同的动力传动系统技术可能提供解决这个问题的方案，如混合动力或纯电动汽车、电气化道路、液化天然气和氢燃料。为了评估其生态和经济影响，本文对这些概念进行了模拟，包括一个权重和成本模型，以估计总拥有成本。利用一种进化算法对每一辆车进行优化，以找到一个特定概念的最优解。使用同一个模型，计算满足每种概念所需能源和基础设施的投资最小值。从井到轮的分析考虑了源头和途中的二氧化碳排放，以比较全电动汽车和传统的内燃机汽车。尽管电气化道路提供低二氧化碳排放，但对新基础设施的投资是其最大缺陷。柴油混合动力是减少碳排放和降低成本之间的最佳平衡。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12937

Technoecological analysis of energy carriers for long-haul transportation

Sebastian Wolff, Michael Fries, Markus Lienkamp

Keywords: GHG Emissions, industrial ecology, infrastructure, long-haul transportation, vehicle simulation, well to wheel

Summary:
Long-haul transportation demand is predicted to increase in the future, resulting in higher carbon dioxide emissions. Different drivetrain technologies, such as hybrid or battery electric vehicles, electrified roads, liquefied natural gas and hydrogen, might offer solutions to this problem. To assess their ecological and economic impact, these concepts were simulated including a weight and cost model to estimate the total cost of ownership. An evolutionary algorithm optimizes each vehicle to find a concept specific optimal solution. A model calculates the minimum investment in infrastructure required to meet the energy demand for each concept. A well-to-wheel analysis takes into account upstream and on-road carbon dioxide emissions, to compare fully electric vehicles with conventional combustion engines. Investment in new infrastructure is the biggest drawback of electrified road concepts, although they offer low CO2 emissions. The diesel hybrid is the best compromise between carbon reduction and costs.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12916

利用预期生命周期评价助力未来可持续建设

作者：Verena Göswein，Carla Rodrigues，José D. Silvestre，Fausto Freire，Guillaume Habert，Jakob König

关键字： 预期生命周期评估（a-LCA），生态设计，环境评估，外墙，预见性，产业生态学

摘要：
建筑环境是最大的二氧化碳排放源，也是重要的能源消耗源。许多研究都致力于提高建筑运营和建筑产品的效率。生命周期评价（LCA）通常用于评价现有建筑物或建筑物产品。然而，传统的生命周期评价并不适合于评价开发技术的环境绩效。一种新的方法，预期生命周期评价（a-LCA），承诺了各种各样的优势，可以作为产品开发阶段的设计约束。它有助于克服四个挑战：（1）数据可用性，（2）利益相关者纳入，（3）风险评估，和（4）多标准问题。本文对这条研究路线的贡献有两个方面：第一，它采用了 a-LCA 方法，从理论上解决了建筑业面临的四大挑战。其次，将该方法应用于一个创新的预制模块化围护系统 CleanTechBlock（CTB），重点是挑战 1。对 36 种 CTB 设计进行了测试，并与传统墙体进行了比较。通过结构化场景分析实现技术预见的包含。此外，挑战 4 是通过分析不同的环境影响类别、与运输有关的影响和 CTB 墙组件的厚度来解决的。实例研究结果表明，要使环境影响降到最低，需要优化材料选择和产品设计。方法学研究结果强调了针对具体情况的解决方案的重要性以及对新产品进行基准测试的必要性。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12916

Using anticipatory life cycle assessment to enable future sustainable construction

Verena Göswein，Carla Rodrigues，José D. Silvestre，Fausto Freire，Guillaume Habert，Jakob König

Keywords: anticipatory life cycle assessment (a-LCA), ecodesign, environmental assessment, external wall, foresight, industrial ecology

Summary:
The built environment is the largest single emitter of CO2 and an important consumer of energy. Much research has gone into the improved efficiency of building operation and construction products. Life Cycle Assessment (LCA) is commonly used to assess existing buildings or building products. Classic LCA, however, is not suited for evaluating the environmental performance of developing technologies. A new approach, anticipatory LCA (a-LCA), promises various advantages and can be used as a design constraint during the product development stage. It helps overcome four challenges: (i) data availability, (ii) stakeholder inclusion, (iii) risk assessment, and (iv) multi-criteria problems. This article's contribution to the line of research is twofold: first, it adapts the a-LCA approach for construction-specific purposes in theoretical terms for the four challenges. Second, it applies the method to an innovative prefabricated modular envelope system, the CleanTechBlock (CTB), focusing on challenge (i). Thirty-six CTB designs are tested and compared to conventional walls. Inclusion of technology foresight is achieved through structured scenario analysis. Moreover, challenge (iv) is tackled through the analysis of different environmental impact categories, transport-related impacts, and thickness of the wall assemblies of the CTB. The case study results show that optimized material choice and product design is needed to reach the lowest environmental impact. Methodological findings highlight the importance of context-specific solutions and the need for benchmarking new products.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12855

实验室规模新兴技术的生命周期评估：以纳米线太阳能电池为例

作者：Georgios Pallas, Martina G. Vijver， Willie J. G. M. Peijnenburg，Jeroen Guinée

关键字： 产业生态学、生命周期评估（LCA）、生命周期清单（LCI）、纳米技术、光伏、可持续性

摘要：
纳米材料有望在可持续产品开发中发挥重要作用。在太阳能电池中使用纳米材料有可能提高其转换效率。在这项研究中，我们对一种新兴的基于纳米线的太阳能技术进行了生命周期评估（LCA）。比较了两种制备纳米线太阳能电池的实验室层面的制造路线：在硅衬底上直接生长 GaInP 纳米线和在自然衬底上生长 InP 纳米线后，通过剥离和转移到硅衬底上。此分析揭示了目前实验室层面上涉及制造路线的关键原材料使用并废弃的有三氟甲烷（CHF3）、黄金、InP 晶片和印章。对两条生产线在不同情景下的环境绩效进行了评估。这些方案包括使用替代工艺来降低对金的要求，例如电镀而不是金属化、回收金以及 InP 晶圆和印章的再利用。基于生命周期评价的结果，一些建议已经传达给研究人员，包括尽量减少金的使用，进一步探索电镀工艺的升级，增加晶圆和印章的使用寿命，以及使用无氟蚀刻材料，以改善环境技术性能。最后，讨论了实验室级生命周期评价作为指导新兴技术可持续发展的工具的有用性和局限性。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12855

Life cycle assessment of emerging technologies at the lab scale: The case of nanowire-based solar cells

Georgios Pallas, Martina G. Vijver， Willie J. G. M. Peijnenburg， Jeroen Guinée

Keywords: industrial ecology, life cycle assessment (LCA), life cycle inventory (LCI), nanotechnology, photovoltaic, sustainability

Summary:
Nanomaterials are expected to play an important role in the development of sustainable products. The use of nanomaterials in solar cells has the potential to increase their conversion efficiency. In this study, we performed a life cycle assessment (LCA) for an emerging nanowire-based solar technology. Two lab-scale manufacturing routes for the production of nanowire-based solar cells have been compared—the direct growth of GaInP nanowires on silicon substrate and the growth of InP nanowires on native substrate, peel off, and transfer to silicon substrate. The analysis revealed critical raw materials and processes of the current lab-scale manufacturing routes such as the use of trifluoromethane (CHF3), gold, and an InP wafer and a stamp, which are used and discarded. The environmental performance of the two production routes under different scenarios has been assessed. The scenarios include the use of an alternative process to reduce the gold requirements—electroplating instead of metallization, recovery of gold, and reuse of the InP wafer and the stamp. A number of suggestions, based on the LCA results—including minimization of the use of gold and further exploration for upscaling of the electroplating process, the increase in the lifetimes of the wafer and the stamp, and the use of fluorine-free etching materials—have been communicated to the researchers in order to improve the environmental performance of the technology. Finally, the usefulness and limitations of lab-scale LCA as a tool to guide the sustainable development of emerging technologies are discussed.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12843

第三代生物丁醇的环境影响及局限性：利用基因工程蓝藻生产正丁醇的生命周期评估

作者：Astrid Nilsson, Kiyan Shabestary, Miguel Brandão, Elton P. Hudson

关键字： 生物燃料、丁醇、蓝藻、产业生态学、生命周期评价、代谢工程

摘要：
作为第三代生物燃料的生产生物，光合蓝藻引起了人们的兴趣，其中微生物直接利用阳光和 CO2 来合成燃料分子。正丁醇是一种十分适宜的生物燃料，已经有一些实验室报告表明转基因光合蓝藻能够合成和分泌正丁醇。本研究通过“从摇篮到坟墓”的因变型生命周期评估（LCA）来评估蓝藻产生正丁醇的环境影响和累积能量需求（CED）。文章假设了一个位于瑞典北部的生产工厂（面积 1 公顷，每年生产 5-85 m3 正丁醇），并评估了各种培养方式和细胞生产率方案。根据具体情况，温室气体排放量（GHGe）在 16.9 至 58.6 g CO2eq/MJBuOH 之间，而 CED 在 3.8—13 MJ/MJBuOH 之间。尽管在瑞典北部的工厂减少了反应器冷却所需的能源，但与附近的化石燃料相比，假设附近有一家造纸厂为热和二氧化碳提供废物源，其可持续性要求至少要节省 60%的 GHGe。在所有情况下，较高的 CED 都表明必须进行大量的代谢工程，例如正丁醇的碳分配因子大于 90%，以及改善光利用率，才能开始替代化石燃料甚至第一代和第二代生物乙醇。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12843

Environmental impacts and limitations of third-generation biobutanol: Life cycle assessment of n-butanol produced by genetically engineered cyanobacteria

Astrid Nilsson, Kiyan Shabestary, Miguel Brandão, Elton P. Hudson

Keywords: biofuel, butanol, cyanobacteria, industrial ecology, LCA, metabolic engineering

Summary:
Photosynthetic cyanobacteria have attracted interest as production organisms for third-generation biofuels, where sunlight and CO2 are used by microbes directly to synthesize fuel molecules. A particularly suitable biofuel is n-butanol, and there have been several laboratory reports of genetically engineered photosynthetic cyanobacteria capable of synthesizing and secreting n-butanol. This work evaluates the environmental impacts and cumulative energy demand (CED) of cyanobacteria-produced n-butanol through a cradle-to-grave consequential life cycle assessment (LCA). A hypothetical production plant in northern Sweden (area 1 ha, producing 5–85 m3 n-butanol per year) was considered, and a range of cultivation formats and cellular productivity scenarios assessed. Depending on the scenario, greenhouse gas emissions (GHGe) ranged from 16.9 to 58.6 gCO2eq/MJBuOH and the CED from 3.8 to 13 MJ/MJBuOH. Only with the assumption of a nearby paper mill to supply waste sources for heat and CO2 was the sustainability requirement of at least 60% GHGe savings compared to fossil fuels reached, though placement in northern Sweden reduced energy needed for reactor cooling. A high CED in all scenarios shows that significant metabolic engineering is necessary, such as a carbon partitioning of >90% to n-butanol, as well as improved light utilization, to begin to displace fossil fuels or even first- and second-generation bioethanol.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12973

基于生命周期评估的日本氢能技术实施的区域特定环境分析

作者：Teruyuki Shimizu, Kei Hasegawa, Manabu Ihara, Yasunori Kikuchi

关键字： 燃料电池汽车，氢能系统，产业生态学，基于端点建模（LIME）的生命周期影响评估方法，区域特征，城市就业区

摘要：
实现可持续性需要能量载体充足的可再生能源系统。在加快技术实施以过渡到新能源系统之前，应从系统视角仔细审查特定区域的实施效果。本研究通过结合生命周期评价和区域能源仿真模型的方法，分析以氢为载体的能源系统。该模型计算排放量，例如 CO2，氮氧化物（NOx），硫氧化物（SOx）和挥发性有机化合物的排放量，以及它们对人体健康、社会资产、初级生产和综合指数的影响。该分析按区域、生命周期阶段和影响类别定量介绍了各种环境影响。气候变化在综合指数中占主导地位，而其他影响类别也很重要。燃料电池汽车在减轻当地空气污染方面是有效的，尤其是在受到不利影响的多人口地区。尽管技术实施有助于减轻能源使用者造成的环境影响，但它也有可能在设备制造和原材料加工场所产生负面影响。如何划分区域也是能源系统设计中的重要因素，这是因为生命周期评价的最终结果对特定区域特征高度敏感。针对特定区域的分析将支持地方政府和技术开发商设计适合区域的能源系统，并针对特定目标制定营销计划。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12973

A region-specific environmental analysis of technology implementation of hydrogen energy in Japan based on life cycle assessment

Teruyuki Shimizu, Kei Hasegawa, Manabu Ihara, Yasunori Kikuchi

Keywords: fuel cell vehicle, hydrogen energy system, industrial ecolog,y life cycle impact assessment method based on endpoint modeling (LIME), region-specific characteristics, urban employment area

Summary:
Energy systems using renewables with adequate energy carriers are needed for sustainability. Before accelerating technology implementation for the transition to the new energy system, region-specific implementation effects should be carefully examined as a system. In this study, we aim to analyze an energy system using hydrogen as an energy carrier with the approach of combining life cycle assessment and a regional energy simulation model. The model calculates the emissions, such as CO2, nitrogen oxides (NOx), sulfur oxides (SOx), and volatile organic compounds, and their impacts on human health, social assets, primary production, and an integrated index. The analysis quantitatively presented various environmental impacts by region, life cycle stage, and impact category. Climate change was dominant on the integrated index while the other impact categories were also important. Fuel cell vehicles were effective in mitigating local air pollution, especially in high-population regions where many people are adversely affected. Although technology implementation contributes to mitigating environmental impacts at locations of energy users, it also has possibilities to have negative impacts at locations of device manufacturing and raw material processing. The definition of the regional division was also an important factor in energy system design because the final results of life cycle assessments are highly sensitive to region-specific characteristics. The proposed region-specific analysis is expected to support local governments and technology developers in designing appropriate energy systems for regions and building marketing plans for specific targets.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12934

温室的温室气体排放——对光伏集成温室的环境和经济影响评估

作者：Joseph A. Hollingsworth, Eshwar Ravishankar, Brendan O'Connor, Jeremiah X. Johnson, Joseph F. DeCarolis

关键字： 食品系统、温室、产业生态学、生命周期评估（LCA）、有机太阳能电池、可持续农业

摘要：
温室蔬菜生产在向全球市场全年提供新鲜蔬菜方面起着至关重要的作用，它比露天种植产量更高、用水量更少，但是对能源的需求更大。本文研究了将半透明有机光伏（OPV）集成到温室设计中带来的生命周期环境和经济影响。我们使用生命周期评估来分析和比较了在三个地区利用 Solar PoweRed INtegrated Greenhouse (SPRING)光伏温室、不毗邻光伏阵列的传统温室和毗邻光伏阵列的传统温室种植西红柿的六种环境影响。SPRING 设计可显著减少对环境的影响，尤其是在日光直射和电力密集型能源需求较高的地区。例如，研究发现，在亚利桑那州，对于传统温室、毗邻光伏阵列的温室和和 SPRING 温室，种植 1 kg 西红柿的全球变暖潜值分别为 3.71、2.38 和 2.36 kg CO2 当量。与传统温室相比，由于 OPV 的遮阳效果会增加供暖需求，SPRING 设计可能会增加较冷地区的生命周期环境负担。我们的分析表明，SPRING 设计必须将农作物产量保持在与传统温室相似的水平上，以便具有经济竞争力。假设作物单产相同，不确定性分析表明，亚利桑那州传统温室、毗邻光伏阵列的温室和和 SPRING 温室的生产 1 kg 西红柿的成本的平均净现值分别为 3.43 美元、3.38 美元和 3.64 美元。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12934

Environmental and economic impacts of solar-powered integrated greenhouses

Joseph A. Hollingsworth, Eshwar Ravishankar, Brendan O'Connor, Jeremiah X. Johnson, Joseph F. DeCarolis

Keywords: food systems, greenhouse, industrial ecology, life cycle assessment (LCA), organic solar cells, sustainable agriculture

Summary:
Greenhouse vegetable production plays a vital role in providing year-round fresh vegetables to global markets, achieving higher yields, and using less water than open-field systems, but at the expense of increased energy demand. This study examines the life cycle environmental and economic impacts of integrating semitransparent organic photovoltaics (OPVs) into greenhouse designs. We employ life cycle assessment to analyze six environmental impacts associated with producing greenhouse-grown tomatoes in a Solar PoweRed INtegrated Greenhouse (SPRING) compared to conventional greenhouses with and without an adjacent solar photovoltaic array, across three distinct locations. The SPRING design produces significant reductions in environmental impacts, particularly in regions with high solar insolation and electricity-intensive energy demands. For example, in Arizona, global warming potential values for a conventional, adjacent PV and SPRING greenhouse are found to be 3.71, 2.38, and 2.36 kg CO2 eq/kg tomato, respectively. Compared to a conventional greenhouse, the SPRING design may increase life cycle environmental burdens in colder regions because the shading effect of OPV increases heating demands. Our analysis shows that SPRING designs must maintain crop yields at levels similar to conventional greenhouses in order to be economically competitive. Assuming consistent crop yields, uncertainty analysis shows average net present cost of production across Arizona to be $3.43, $3.38, and $3.64 per kg of tomato for the conventional, adjacent PV and SPRING system, respectively.

《产业生态学报》

2020 年, 第24卷 第1期
http://dx.doi.org/10.1111/jiec.12989

根据供应商和风力数据对浮动海上风电场进行生命周期评估

作者：Baptiste Poujol, Anne Prieur-Vernat, Jean Dubranna, Romain Besseau, Isabelle Blanc, Paula Pérez-López

关键字： 浮动海上风电场，地理位置模式，产业生态学，生命周期评估，可再生能源，风能

摘要：
可再生能源系统对于未来确保有效的能源供应和环境保护至关重要。尽管其在运行过程中对环境的影响很小，但仍需要考虑生命周期的其他阶段。本研究对浮动海上风电场这一新兴技术进行了具有地理定位的生命周期评估，并在地中海的一个试点项目上进行开发与应用。材料清单基于来自供应商的真实数据，并耦合至参数化模型，发电情况由该模型利用地理信息系统风力数据库来估算。这项多标准评估得出：由于浮子的制造这一环节，材料的开采和转化是造成环境影响的主要因素，例如气候变化（占 22.3 g CO2-eq/kWh 的 70%）、用水（占 6.7 L/kWh 的 73%）和空气质量（占 25.2 mg PM2.5/ kWh 中的 76%）。研究结果证实了该新兴技术与其他能源相比对环境的影响较小。根据地理位置风力数据得出的发电量估计值是影响环境表现的模型的重要组成部分。灵敏度分析强调了项目运行寿命的重要性，因为它是导致所分析类别变化的主要参数。研究应分析背景不确定性，并可以通过将数据收集集中在环境影响的重要贡献方上来减少背景不确定性。地理位置建模被证明是解决可再生能源技术地理变异性的有效技术，将为可再生能源开发的决策过程提供帮助。

Journal of Industrial Ecology

2020, Vol. 24, Issue 1
http://dx.doi.org/10.1111/jiec.12989

Site-specific life cycle assessment of a pilot floating offshore wind farm based on suppliers' data and geo-located wind data

Baptiste Poujol, Anne Prieur-Vernat, Jean Dubranna, Romain Besseau, Isabelle Blanc, Paula Pérez-López

Keywords: floating offshore wind farm, geo-located mode, industrial ecology, life cycle assessment, renewable energy, wind energy

Summary:
Renewable energy systems are essential in coming years to ensure an efficient energy supply while maintaining environmental protection. Despite having low environmental impacts during operation, other phases of the life cycle need to be accounted for. This study presents a geo-located life cycle assessment of an emerging technology, namely, floating offshore wind farms. It is developed and applied to a pilot project in the Mediterranean Sea. The materials inventory is based on real data from suppliers and coupled to a parameterized model which exploits a geographic information system wind database to estimate electricity production. This multi-criteria assessment identified the extraction and transformation of materials as the main contributor to environmental impacts such as climate change (70% of the total 22.3 g CO2 eq/kWh), water use (73% of 6.7 L/kWh), and air quality (76% of 25.2 mg PM2.5/kWh), mainly because of the floater's manufacture. The results corroborate the low environmental impact of this emerging technology compared to other energy sources. The electricity production estimates, based on geo-located wind data, were found to be a critical component of the model that affects environmental performance. Sensitivity analyses highlighted the importance of the project's lifetime, which was the main parameter responsible for variations in the analyzed categories. Background uncertainties should be analyzed but may be reduced by focusing data collection on significant contributors. Geo-located modeling proved to be an effective technique to account for geographical variability of renewable energy technologies and contribute to decision-making processes leading to their development.