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链接产业生态学和生态经济学：循环经济的理论与实证基础

作者: Aurélien Bruel, Jakub Kronenberg, Nadège Troussier, Bertrand Guillaume

关键字: 闭环经济系统, 产业生态学, 研究机会, 可持续发展, 理论基础, 跨学科研究

摘要:

循环经济 (CE) 是商品生产和消费的新模式, 作为一种可持续发展战略引起了广泛的政治关注。然而, 循环经济的理论基础仍然存在结构不合理、探索不足等缺陷。最近的研究表明, CE 模型借鉴了不同的思想流派, 其起源主要植根于产业生态学 (IE) 和生态经济学 (EE) 等领域。在本文中, 我们将研究 CE、IE 和 EE 之间的链接关系, 并概述这些领域之间的相似点和不同点。与此同时, 我们分析了 IE 和 EE 之间的链接可以在多大程度上为 CE 创建一个连贯的知识体系, 并用于确定进一步的研究机会。本文表明, 到目前为止, 对 CE 的研究似乎主要根植于 IE 领域, 并基于其他领域已经存在的概念和工具, 而不是发明新的领域。IE 和 EE 的协调可以提供一种超越这种狭隘焦点的机制, 增加对 CE 的理论和实践框架的了解, 从而有益于可持续性。

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Linking Industrial Ecology and Ecological Economics: A Theoretical and Empirical Foundation for the Circular Economy

Aurélien Bruel, Jakub Kronenberg, Nadège Troussier, and Bertrand Guillaume

Keywords: closed loop economic system, industrial ecology, research opportunity, sustainable development, theoretical foundation, transdisciplinary research

Summary:

The circular economy (CE) is a new model for the production and consumption of goods, which has attracted wide political attention as a strategy toward sustainability. However, the theoretical foundation of CE remains poorly structured and insufficiently explored. Recent studies have shown that the CE model draws on different schools of thought and that its origins are mainly rooted in fields such as industrial ecology (IE) and ecological economics (EE). In this article, we investigate the links between CE, IE, and EE and provide an overview of the similarities and differences between these fields. At the same time, we analyze to what extent the linkages between IE and EE can create a coherent body of knowledge for CE, and be used to identify further research opportunities. This paper shows that, until now, research on CE seems to be mainly rooted in the field of IE and based on concepts and tools that already exist in other fields, rather than inventing new ones. The reconciliation of IE and EE could provide a mechanism to extend beyond such a narrow focus, and increase knowledge of the theoretical and practical framework of CE to benefit sustainability.

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为了循环经济的产品/服务系统: 经济增长与资源消耗脱钩的途径?

作者: Louise Laumann Kjaer, Daniela C. A. Pigosso, Monia Niero, Nynne Marie Bech, Tim C. McAlloone

关键字: 循环经济, 脱钩, 产业生态学, 生命周期思维, 产品服务系统, 反弹效应

摘要:

专注于销售服务和性能而非产品的产品/服务系统 (PSS) 通常被视为实现循环经济 (CE) 的手段, 其中, 经济增长与资源消耗脱钩。然而, PSS 并不是 CE 的隐性保证, CE 战略也并不一定导致经济增长与资源消耗在绝对值上的脱钩。绝对资源脱钩只发生在资源使用下降时, 无论经济驱动因素的增长率如何。在本论坛论文中, 我们提出了一个两步框架, 旨在支持 PSS 及其导致绝对资源脱钩潜力的分析。在第一步中, 我们提出了四个可使 PSS 相对资源消耗减少的促成因素, 它们可以作为 CE 策略。在第二步中, 需要满足三个后续要求, 以便成功实现绝对资源脱钩。本文讨论了该框架的条件和限制。丹麦纺织品案例用于说明框架的要素及应用。我们期望该框架将挑战关于 CE 战略确保绝对资源脱钩的必要条件的辩论。

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<http://dx.doi.org/10.1111/jiec.12747>**Product/Service-Systems for a Circular Economy: The Route to Decoupling Economic Growth from Resource Consumption?**

Louise Laumann Kjaer, Daniela C. A. Pigosso, Monia Niero, Nynne Marie Bech, and Tim C. McAlloone

Keywords: circular economy, decoupling, industrial ecology, life cycle thinking, product-service system (PSS), rebound effect

Summary:

Product/service-systems (PSS) that focus on selling service and performance instead of products are often mentioned as means to realize a circular economy (CE), in which economic growth is decoupled from resource consumption. However, a PSS is no implicit guarantee for a CE, and CE strategies do not necessarily lead to decoupling economic growth from resource consumption in absolute terms. Absolute resource decoupling only occurs when the resource use declines, irrespective of the growth rate of the economic driver. In this forum paper, we propose a two-step framework that aims to support analyses of PSS and their potential to lead to absolute resource decoupling. In the first step, we present four PSS enablers of relative resource reduction that qualify as CE strategies. In the second step, three subsequent requirements need to be met, in order to successfully achieve absolute resource decoupling. Conditions and limitations for this accomplishment are discussed. Danish textile cases are used to exemplify the framework elements and its application. We expect that the framework will challenge the debate on the necessary conditions for CE strategies to ensure absolute resource decoupling.

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循环经济商业模式模式的综述与分类

作者: Florian Lüdeke-Freund, Stefan Gold, Nancy M. P. Bocken

关键字: 商业模式, 循环经济, 综述, 供应链, 类型学, 价值创造

摘要:

循环经济 (CE) 要求公司重新考虑其供应链和商业模型。基于学术研究和从业者发表的文献中提及的几个框架, 本文提出了循环经济商业模式 (CEBM), 从而重新定义了公司如何在遵守 CE 原则的同时创造价值。通过对这些框架的回顾梳理发现, 部分模型是研究者经常讨论的, 部分模型是基于特定框架的, 部分模型仅采用不同的措辞来提及类似的 CEBM, 因此, 研究者指出需要加强并统一当前的技术体系。我们对文献中涉及的 26 个当前的 CEBM 进行了形态分析, 定义了其商业模式主要维度并确定了这些维度的具体特征。根据分析, 我们确定了广泛的商业模式设计方案, 并提出了六种潜在支持资源闭合流动的主要 CEBM 模式, 包括: 维修和维护, 再利用和再分配, 翻新和再制造, 回收再循环, 层级利用和重新利用, 以及有机原材料商业模式模式。此外, 我们还讨论了支持这些 CEBM 发展的不同设计策略。

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A Review and Typology of Circular Economy Business Model Patterns

Florian Lüdeke-Freund, Stefan Gold, and Nancy M. P. Bocken

Keywords: business model, circular economy, review, supply chain, typology, value creation

Summary:

The circular economy (CE) requires companies to rethink their supply chains and business models. Several frameworks found in the academic and practitioner literature propose circular economy business models (CEBMs) to redefine how companies create value while adhering to CE principles. A review of these frameworks shows that some models are frequently discussed, some are framework specific, and some use a different wording to refer to similar CEBMs, pointing to the need to consolidate the current state of the art. We conduct a morphological analysis of 26 current CEBMs from the literature, which includes defining their major business model dimensions and identifying the specific characteristics of these dimensions. Based on this analysis, we identify a broad range of business model design options and propose six major CEBM patterns with the potential to support the closing of resource flows: repair and maintenance; reuse and redistribution; refurbishment and remanufacturing; recycling; cascading and repurposing; and organic feedstock business model patterns. We also discuss different design strategies to support the development of these CEBMs.

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循环经济进展的测度: 欧盟材料闭路循环的监测框架

作者: [Andreas Mayer](#), [Willi Haas](#), [Dominik Wiedenhofer](#), [Fridolin Krausmann](#), [Philip Nuss](#), [Gian Andrea Blengini](#)

关键字: 循环经济, 环境压力, 产业生态学, 再利用, 次级原料, 废弃物管理

摘要:

循环经济 (CE) 的概念日益受到政策制定者、工业界和学术界的关注。循环经济的定义、局限性、其对更广泛的可持续性议程的贡献、以及用于评估更大规模的循环经济措施有效性的指标, 有关这些方面的争论正在发生快速的发展变化。在此, 我们提出了一个框架, 以物质平衡方法为基础将资源开采、使用与废物流动的官方统计数据系统贯穿起来, 对循环经济进行物质层面的综合评估。该框架建立在应用广泛的经济范围物质流量核算框架的基础上, 并通过整合废物流、再回收和降级回收材料进行扩展。我们提出了一套全面的指标, 用于衡量总物质和废物流量的规模和循环度, 以及它们的社会经济和生态闭环情况。我们将此框架应用于监测欧盟 2014 年的循环经济状况。我们发现, 欧盟加工了 7.4 亿吨 (Gt) 材料, 其中只有 0.71 亿吨是再生原料。因此, 材料投入的社会经济循环率为 9.6%。此外, 在 4.8 亿吨的中间产出流量中, 14.8% 被再回收或降级回收。根据这些研究发现以及对框架进行敏感性评估的尝试, 我们认为有必要进行一系列改进: 改进废物的统计与报告, 对社会在用存量进行建模, 引入生态循环标准, 分解基于质量的指标以评估不同材料和循环计划的环境影响。

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<http://dx.doi.org/10.1111/jieec.12809>**Measuring Progress Towards a Circular Economy: A Monitoring Framework for Economy-wide Material Loop Closing in the EU28**

[Andreas Mayer](#), [Willi Haas](#), [Dominik Wiedenhofer](#), [Fridolin Krausmann](#), [Philip Nuss](#), and [Gian Andrea Blengini](#)

Keywords: circular economy, environmental pressures, industrial ecology, recycling, secondary materials, waste management

Summary:

The concept of a circular economy (CE) is gaining increasing attention from policy makers, industry, and academia. There is a rapidly evolving debate on definitions, limitations, the contribution to a wider sustainability agenda, and a need for indicators to assess the effectiveness of circular economy measures at larger scales. Herein, we present a framework for a comprehensive and economy-wide biophysical assessment of a CE, utilizing and systematically linking official statistics on resource extraction and use and waste flows in a mass-balanced approach. This framework builds on the widely applied framework of economy-wide material flow accounting and expands it by integrating waste flows, recycling, and downcycled materials. We propose a comprehensive set of indicators that measure the scale and circularity of total material and waste flows and their socioeconomic and ecological loop closing. We applied this framework in the context of monitoring efforts for a CE in the European Union (EU28) for the year 2014. We found that 7.4 gigatons (Gt) of materials were processed in the EU and only 0.71 Gt of them were secondary materials. The derived input socioeconomic cycling rate of materials was therefore 9.6%. Further, of the 4.8 Gt of interim output flows, 14.8% were recycled or downcycled. Based on these findings and our first efforts in assessing sensitivity of the framework, a number of improvements are deemed necessary: improved reporting of wastes, explicit modeling of societal in-use stocks, introduction of criteria for ecological cycling, and disaggregated mass-based indicators to evaluate environmental impacts of different materials and circularity initiatives.

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循环经济实践与可持续发展目标的相关性

作者: Patrick Schroeder, Kartika Anggraeni, Uwe Weber

关键字: 循环经济, 发展中国家, 产业生态学, 回收, SDG实施, 可持续发展目标

摘要:

本文确定了循环经济(CE)实践在多大程度上与实施可持续发展目标(SDG)相关。用于确定CE实践与SDG目标之间关系的文献综述和匹配练习的结果表明,CE实践可能直接有助于实现大量可持续发展目标。CE实践与SDG 6(清洁水和卫生)、SDG 7(可负担的清洁能源)、SDG 8(体面劳动和经济增长)、SDG 12(负责任的消费和生产)和SDG 15(陆上生活)之间存在最强的关系。本文还探讨了通过CE实践创造的若干可持续发展目标之间的协同作用。此外,本文还确定了体面劳动、安全工作环境和人类健康目标

和当前与城市垃圾、电子废物和废水回收相关的CE实践之间的若干潜在权衡,并提供了如何克服这些问题的建议。本文的结论是,CE实践可以作为“工具箱”和具体实施方法以实现相当数量的SDG目标。需要进一步的实证研究以确定在可持续发展目标背景下应用CE实践需要哪些具体类型的伙伴关系和实施手段。

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The Relevance of Circular Economy Practices to the Sustainable Development Goals

Patrick Schroeder, Kartika Anggraeni, and Uwe Weber

Keywords: circular economy, developing countries, industrial ecology, recycling, SDG implementation, sustainable development goals

Summary:

This paper identifies the extent to which circular economy (CE) practices are relevant for the implementation of the Sustainable Development Goals (SDGs). The results of a literature review and a matching exercise to determine the relationship between CE practices and SDG targets show that CE practices, potentially, can contribute directly to achieving a significant number of SDG targets. The strongest relationships exist between CE practices and the targets of SDG 6 (Clean Water and Sanitation), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 12 (Responsible Consumption and Production), and SDG 15 (Life on Land). The paper also explores synergies that can be created through CE practices among several of the SDG targets. Furthermore, it identifies several potential trade-offs between targets for decent work, safe working environments, human health and current CE practices relating to recycling of municipal waste, e-waste and wastewater, and provides suggestions how these can be overcome. The paper concludes that CE practices can be applied as a “toolbox” and specific implementation approaches for achieving a sizeable number of SDG targets. Further empirical research is necessary to determine which specific types of partnerships and means of implementation are required to apply CE practices in the SDG context.

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挖掘公共采购潜力：循环经济的机遇

作者: [Katriina Alhola](#), [Sven-Olof Ryding](#), [Hanna Salmenperä](#), [Niels Juul Busch](#)

关键字: 循环经济, 清洁循环, 产业生态学, 公共采购, 可持续性, 价值保持

摘要:

循环经济 (CE) 的目标是通过物料闭路循环和最小化废物产生来维持经济活动中产品、材料和资源的价值。近年来, 公共采购被认为是城市和城镇向循环社会过渡的一个重要但尚未被充分利用的机会。本研究分析了公共采购中可促进 CE 的机会。通过案例研究确定了循环型公共采购的不同方法和实例。此外, 还确定了通过可持续和绿色公共采购政策促进 CE 的机会, 分析了预定义的可持续或绿色公共采购标准。本研究的结论是, 公共采购可以通过制定延长产品寿命、效率和/或使用强度, 生物或技术材料的有效循环以及确保清洁、无风险的循环等方面的标准和要求来促进 CE 和相关的商业模式。循环采购可以通过采购在循环方面质量更好的产品、采购新的循环产品、使用支持 CE 的业务概念以及对循环生态系统的投资来实现。确定了具有循环采购潜力的若干部门和产品组, 例如建筑、废物和废水管理、运输、食品和餐饮、家具和纺织品。本研究还表明, 使用某些工具可以促进循环采购, 如基于绩效的采购、生命周期方法和生命周期成本核算, 以及有关材料再利用和再循环的标准。供应链中的采购者和参与者之间的市场对话与合作对循环采购的未来发展非常重要

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Exploiting the Potential of Public Procurement: Opportunities for Circular Economy

[Katriina Alhola](#), [Sven-Olof Ryding](#), [Hanna Salmenperä](#), and [Niels Juul Busch](#)

Keywords: circular economy, clean cycles, industrial ecology, public procurement, sustainability, value retention

Summary:

The objective of a circular economy (CE) is to maintain the value of products, materials, and resources in the economy by closing material loops and minimizing waste generation. In recent years, the role of public procurement has been recognized as an important, but as yet not fully exploited, opportunity by cities and municipalities in their transition toward circular societies. This study analyzed public procurement opportunities to promote CE. Different approaches and examples of circular public procurement were identified using case studies. In addition, opportunities to promote CE through sustainable and green public procurement policy were identified analyzing predefined sustainable or green public procurement criteria. The study concludes that public procurement can promote CE and related business models by setting criteria and requirements for the extension of product life spans, efficiency and/or intensity of use, and efficient cycling of biological or technical materials, as well as for the securing of clean and nonrisky cycles. Circular procurement can occur through the procurement of better-quality products in circular terms, the procurement of new circular products, the use of business concepts that support the CE, and investments in circular ecosystems. Several sectors and product groups were identified as having potential for circular procurement, such as construction, waste, and wastewater management, transportation, food, and catering, furniture, and textiles. The study also suggests that the use of certain tools, such as performance-based procurement, life cycle approach, and life cycle costing, as well as criteria concerning reuse and recycling of materials, could promote circular procurement. Market dialogue and cooperation between procurers and actors in the supply chains are important for the future development of circular procurement.

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中国循环经济的探索和成: 就一次全面的政策综述

作者: Junming Zhu, Chengming Fan, Haijia Shi, Lei Shi

关键字: 循环经济, 清洁生产, 环境政策, 产业生态学, 再循环, 再利用

摘要:

作为追求可持续发展的重要途径, 循环经济的概念、实践和政策越来越受到关注。本文采用概念框架对中国循环经济的相关政策工作进行分类整理和深入探究。基于该框架, 确定了政策原型和具体示例, 可分为: 以资源为导向, 以生产为导向, 废物处理, 以使用为导向, 以及全生命周期政策。本文对 280 项相关政策进行了全面回顾, 结果表明, 中国在以资源为导向的政策方面有着悠久的历史, 而在 2000 年后很快实施了以生产为导向的政策。随着时间的推移, 中国发展循环经济的政策变得更加综合, 更多政府机构参与其中, 再循环的机会逐渐广阔, 生产政策涉及不同工业尺度, 使用的政策工具也更加多样。此外, 积极的国家行为者及其从国际社会中学到的经验推动了中国循环经济发展的持续进步。然而, 目前的政策框架更多地关注发展循环经济的手段而不是结果, 并且过分依赖直接补贴和其他财政激励措施。通过明确整个生产的生命周期并纳入考虑, 以及使用基于市场的政策设计, 可以改善政策制定。

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Efforts for a Circular Economy in China: A Comprehensive Review of Policies

Junming Zhu, Chengming Fan, Haijia Shi, and Lei Shi

Keywords: circular economy, cleaner production, environmental policy, industrial ecology, recycling, reuse

Summary:

Circular economy concepts, practices, and policies are increasingly drawing attention as important means for the pursuit of sustainable development. This article uses a conceptual framework to catalogue and investigate policy efforts for the circular economy in China. Based on the framework, policy prototypes and specific examples are identified: resource-oriented, production-oriented, waste, and use-oriented and life cycle policies. A comprehensive review of 280 related policies shows that China has a long history of resource-oriented policies and implemented production-oriented policies very quickly after the year 2000. China's policies toward the circular economy became more comprehensive through time, with a broad engagement of government agencies, an extensive and progressive coverage of recycling opportunities, production initiatives across multiple scales, and use of different policy instruments. The continuous progress has been driven by proactive state actors and their learning from the international society. The current policy framework, however, is concerned more with the means rather than the ends of the circular economy, and relies too much on direct subsidies and other financial incentives. Policy making can be improved by more explicit consideration of the whole production life cycle and use of market-based policy design.

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非物质化与循环经济: 减少电子产品生态系统物质影响的策略比较

作者: [Barbara V. Kasulaitis](#), [Callie W. Babbitt](#), [Andrew K. Krock](#)

关键字: 循环经济, 社区生态学, 非物质化, 电子产品, 物质流分析, 产品生态系统

摘要:

随着技术的快速发展和电子产品的普遍使用, 寻找到评价材料消耗的合适方法显得极为重要。虽然非物质化和循环经济(CE)都被倡导用于减少材料消耗, 但最近的研究表明这些方法在实现材料净使用减少方面可能无效: 当关注特定产品时, 这些方法会忽视复杂的相互作用, 也忽视了电子产品消耗量在不断增加的情况。此研究开发了一种基于评估整个“产品生态系统”的物质流分析, 从而能够在分析中综合考虑到消耗增长、产品交易和技术创新的影响。然后使用此结果来评估“自然的”非物质化(随着技术进步, 或小号的产品来替代大号, 在这个过程中自然降低物质消耗)和循环经济(关闭次级材料供应和主要材料需求之间的循环)的潜在效率。我们的分析结果表明, 美国家庭消耗电子产品所带来的材料消耗在 2000 年达到顶峰。这种消耗依赖于日益多样化的材料, 包括金、钴和钢, 这些材料的二次供应可以忽略不计, 因为其极低的小于 1% 的回收率。我们同时评估了材料潜在循环性指标如“稀释”, “分散”和“需求不匹配”。结果显示, 电子材料消耗的循环经济方法仍面临产品设计不合理、回收设备效率不高这些关键障碍。

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Dematerialization and the Circular Economy: Comparing Strategies to Reduce Material Impacts of the Consumer Electronic Product Ecosystem

Barbara V. Kasulaitis, Callie W. Babbitt, and Andrew K. Krock

Keywords: circular economy, community ecology, dematerialization, electronics, material flow analysis, product ecosystem

Summary:

The rapid technological evolution and adoption of consumer electronics highlights a growing need for adaptive methodologies to evaluate material consumption at the intersection of technological change and increasing consumption. While dematerialization and the circular economy (CE) have both been proposed to mitigate increasing material consumption, recent research has shown that these methods may be ineffective at achieving net material use reduction: When focused on specific products, these methods neglect the effects of complex interactions among and increasing consumption of consumer electronic products. The research presented here develops and applies a material flow analysis aimed at evaluating an entire “product ecosystem,” thereby including the effects of increasing consumption, product trade-offs, and technological innovations. Results are then used to evaluate the potential efficacy of “natural” dematerialization (occurring as technology advances or smaller products substitute for larger ones) and CE (closing the loop between secondary material supply and primary material demand). Results show that material consumption by the

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为了循环经济通过生态设计和资源回收来不断演进独立的可再生能源技术

作者: John Gallagher, Biswajit Basu, Maria Browne, Alan Kenna, Sarah McCormack, Francesco Pilla, David Styles

关键字: 循环经济, 生态设计, 生命周期评价, 再循环能力, 可再生能源, 资源损耗

摘要:

可再生能源 (RE) 技术有利于提供未来的能源需求和减少温室气体 (GHG) 排放。然而, 这些技术的推广应用需要大量有限的材料资源。我们将生命周期评估应用于 100 年三种独立的可再生能源技术 (太阳能光伏发电, 河流水电和风能) 的电力生产, 评估其环境负担与基础化石燃料发电差异。然后, 我们设计了方案, 将针对热点的循环经济 (CE) 改进纳入系统的生命周期, 特别是 (1) 提高原材料的回收率和 (2) 生态设计的应用。与其他可再生能源技术相比, 水力发电每千瓦时的发电环境负担最低, 因为它具有更高的效率和更长的主要部件寿命。基于对改进的回收率和生态设计的考虑, 我们观察到每个系统不同的环境表现。CE 措施在每种技术已经很低的温室气体排放负担中产生了类似的适度节约, 而生态设计特别有可能显著节省非生物资源的消耗。进一步研究探索可再生能源技术的 CE 措施的全部潜力将产生积极效应, 可以缓解气候变化所需的可再生能源技术的资源密集度。

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Adapting Stand-Alone Renewable Energy Technologies for the Circular Economy through Eco-design and Recycling

John Gallagher, Biswajit Basu, Maria Browne, Alan Kenna, Sarah McCormack, Francesco Pilla, and David Styles

Keywords: circular economy, eco-design, life cycle assessment (LCA), recyclability, renewable energy, resource depletion

Summary:

Renewable energy (RE) technologies are looked upon favorably to provide for future energy demands and reduce greenhouse gas (GHG) emissions. However, the installation of these technologies requires large quantities of finite material resources. We apply life cycle assessment to 100 years of electricity generation from three stand-alone RE technologies—solar photovoltaics, run-of-river hydro, and wind—to evaluate environmental burden profiles against baseline electricity generation from fossil fuels. We then devised scenarios to incorporate circular economy (CE) improvements targeting hotspots in systems' life cycle, specifically (1) improved recycling rates for raw materials and (ii) the application of ecodesign. Hydro presented the lowest environmental burdens per kilowatt-hour of electricity generation compared with other RE technologies, owing to its higher efficiency and longer life spans for main components. Distinct results were observed in the environmental performance of each system based on the consideration of improved recycling rates and eco-design. CE measures produced similar modest savings in already low GHG emissions burdens for each technology, while eco-design specifically had the potential to provide significant savings in abiotic resource depletion. Further research to explore the full potential of CE measures for RE technologies will curtail the resource intensity of RE technologies required to mitigate climate change.

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未来金属需求情境的环境启示：方法学和七种主要金属的应用案例

作者: Ester Van der Voet, Lauran Van Oers, Miranda Verboon, Koen Kuipers

关键字: 环境影响, 产业生态学, 生命周期可持续分析, 金属, 资源, 情境

摘要:

在本文中, 我们开发了一种评估金属需求情境对环境的影响的方法。该方法基于生命周期, 但能够实现前瞻性和升级。该方法旨在将金属需求情境转化为技术特定的供应情境, 这是实现环境影响转化所必需的。为了说明该方法的不同步骤, 我们将其应用于七种主要金属的情况。七种主要金属的需求情境来自文献。我们将这些转化为特定技术的供应情境, 并指定未来的环境影响时间序列, 包括回收率, 能源系统转型, 效率提升和矿石品位下降。我们证明该方法是适用的, 并且可能导致相关的, 尽管存在许多不确定性, 但结果相当可靠。预测显示, 与金属生产相关的环境影响预计会急剧增加。铁承担了相对一大部分影响, 而且排放相对不受生产和能源系统变化的影响。对于其他金属, 能量转换可能具有实质性的好处。到目前为止, 所有金属最有效的选择似乎是增加二次生产的份额。这将减少排放, 但预计只会在二十一世纪下半叶生效。因此, 金属循环经济议程是一个长期议程, 类似于气候变化: 必须尽快采取行动, 而好处只会在长期内才变得明显。

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Environmental Implications of Future Demand Scenarios for Metals: Methodology and Application to the Case of Seven Major Metals

Ester Van der Voet, Lauran Van Oers, Miranda Verboon, and Koen Kuipers

Keywords: environmental impacts, industrial ecology, life cycle sustainability analysis, metals, resources, scenarios

Summary:

In this paper, we develop a method to assess the environmental impacts of metal scenarios. The method is life cycle based, but enables forward looking and upscaling. The method aims at translating metal demand scenarios into technology-specific supply scenarios, necessary to make the translation into environmental impacts. To illustrate the different steps of the methodology, we apply it to the case of seven major metals. Demand scenarios for seven major metals are taken from literature. We translate those into technology-specific supply scenarios, and future time series of environmental impacts are specified including recycling rates, energy system transformation, efficiency improvement, and ore grade decline. We show that the method is applicable and may lead to relevant and, despite many uncertainties, fairly robust results. The projections show that the environmental impacts related to metal production are expected to increase steeply. Iron is responsible for the majority of impacts and emissions are relatively unaffected by changes in the production and energy system. For the other metals, the energy transition may have substantial benefits. By far, the most effective option for all metals appears to be to increase the share of secondary production. This would reduce emissions, but is expected to become effective only in the second half of the twenty-first century. The circular economy agenda for metals is therefore a long-term agenda, similar to climate change: Action must be taken soon while benefits will become apparent only at the long term.

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家庭塑料垃圾回收系统质量评估与可循环潜力

作者: Marie Kampmann Eriksen, Anders Damgaard, Alessio Boldrin, Thomas Fruergaard Astrup

关键字: 循环经济, 环境污染, 产业生态学, 生命周期评价, 消费后废弃物, 替代

摘要:

在向着循环经济和实现塑料闭环的转变过程中, 塑料回收得到大力提倡, 回收目标通常基于质量设定。从家庭垃圾 (HHW) 中回收的塑料往往受到污染且种类多样, 由于其质量差, 从 HHW 回收的塑料通常应用范围有限。为正确评估通过回收实现塑料闭环循环的能力, 需要同时考量塑料的数量和质量。本研究定义了可循环潜力, 用来表示在假定市场条件稳定的情况下, 回收系统实现物料闭环循环的能力。根据包括杂质在内的塑料废物平均组成, 本研究评估了 84 种回收情景, 情景设置考虑了多种分类方案、源分离效率和物料回收设施 (MRF) 的配置和性能。回收成分的质量是在欧洲范围内根据污染程度和每种情景下计算的可循环性潜力来评估的。在所有情景中, 产生的塑料中 17%–100% 可以回收利用, 提升源分离效率和 MRF 效率可以提升回收率。然而, 如果综合考虑质量因素, 由于污染, 产生的塑料中至多有 55% 适合回收利用。研究发现, 源分离、高目标组分数量和有效的 MRF 回收是关键因素。可循环潜力的计算表明, 不足 42% 的塑料闭环循环率与现有技术和原材料要求相关。因此, 欧洲还远没有能力实现塑料闭环循环。在向循环经济过渡的过程中, 重点应为通过产品设计、技术改进及更有针对性的塑料废物管理来管控杂质和损失。

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Quality Assessment and Circularity Potential of Recovery Systems for Household Plastic Waste

Marie Kampmann Eriksen, Anders Damgaard, Alessio Boldrin, and Thomas Fruergaard Astrup

Keywords: circular economy, contamination, industrial ecology, life cycle assessment, postconsumer waste, substitution

Summary:

Plastic recycling is promoted in the transition toward a circular economy and a closed plastic loop, typically using mass-based recycling targets. Plastic from household waste (HHW) is contaminated and heterogeneous, and recycled plastic from HHW often has a limited application range, due to reduced quality. To correctly assess the ability to close plastic loops via recycling, both plastic quantities and qualities need to be evaluated. This study defines a circularity potential representing the ability of a recovery system to close material loops assuming steady-state market conditions. Based on an average plastic waste composition including impurities, 84 recovery scenarios representing a wide range of sorting schemes, source-separation efficiencies, and material recovery facility (MRF) configurations and performances were assessed. The qualities of the recovered fractions were assessed based on contamination and the circularity potential calculated for each scenario in a European context. Across all scenarios, 17% to 100% of the generated plastic mass could be recovered, with higher source-separation and MRF efficiencies leading to higher recovery. Including quality, however, at best 55% of the generated plastic was suitable for recycling due to contamination. Source-separation, a high number of target fractions, and efficient MRF recovery were found to be critical. The circularity potential illustrated that less than 42% of the plastic loop can be closed with current technology and raw material demands. Hence, Europe is still far from able to close the plastic loop. When transitioning toward a circular economy, the focus should be on limiting impurities and losses through product design, technology improvement, and more targeted plastic waste management.

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实现电子废弃物的闭环：一种跨学科的视角

作者: Ben Bridgens, Kersty Hobson, Debra Lilley, Jacquetta Lee, Janet L. Scott, Garrath T. Wilson

关键字: 循环经济, 产业生态学, 淘汰, 产品寿命, 产品服务系统 (PSS), 资源回收

摘要:

本文提出了由多学科小组开发的一种新型闭环系统来回收贵金属并减少电子废物, 并以手机为案例, 描述了电子废弃物闭环循环所面临的挑战以及其中的机遇。这种多学科方法与现行的自上而下的向循环经济 (CE) 过渡的方法形成对比。本研究目的在于开发一种产品服务系统 (PSS), 以促进从手机电路板中回收有价值的功能组件和金属。为了创建整体性的解决方案并尽可能减少意想不到的后果, 除技术解决方案外, 本文还考虑了适当的组件寿命, 在循环经济中往往被忽视的公民的角色, 消费者与 PSS 的互动, 环境生命周期评估, 以及所提出的 PSS 的社会影响。研究还描述了开发使能技术和材料, 以促进组件和金属的回收, 并提供从个人情感的角度而言耐用的外壳。该研究还强调了从多角度和跨学科角度理解循环经济价值的重要性。

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Closing the Loop on E-waste: A Multidisciplinary Perspective

Ben Bridgens, Kersty Hobson, Debra Lilley, Jacquetta Lee, Janet L. Scott, and Garrath T. Wilson

Keywords: circular economy, industrial ecology, obsolescence, product lifetime, product service system (PSS), resource recovery

Summary:

This paper describes the challenges faced, and opportunities identified, by a multidisciplinary team of researchers developing a novel closed loop system to recover valuable metals and reduce e-waste, focusing on mobile phones as a case study. This multidisciplinary approach is contrasted with current top-down approaches to making the transition to the circular economy (CE). The aim of the research presented here is to develop a product service system (PSS) that facilitates the recovery of valuable functional components and metals from mobile phone circuit boards. To create a holistic solution and limit unintended consequences, in addition to technological solutions, this paper considers appropriate component lifetimes; the (often ignored) role of the citizen in the circular economy; customer interaction with the PSS; environmental life cycle assessment; and social impacts of the proposed PSS. Development of enabling technologies and materials to facilitate recovery of components and metals and to provide an emotionally durable external enclosure is described. This research also highlights the importance of understanding value in the CE from a multifaceted and interdisciplinary perspective.

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追求关键材料的闭环供应链：绿色能源部门的探索性研究

作者: Yulia Lapko, Andrea Trianni, Cali Nuur, Donato Masi

关键字: 循环经济, 闭环供应链 (CLSC), 关键材料, 绿色能源技术, 产业生态学, 回收**摘要:**

闭环供应链 (CLSC) 被认为是确保材料可持续利用的重要解决方案, 也是确保材料长期可用性的有效战略。后者在讨论稀缺材料时显得尤其重要。面临供应中断的关键原料 (CRM) 给许多行业造成了不确定的运营环境, 特别是对于采用多种 CRM 的绿色能源技术。然而关键原材料的回收率非常低, 而且从事关键原料的闭环供应链的公司也非常有限。本研究探讨了光伏电池板和风力涡轮机技术中实施关键原料闭环供应链的影响因素。研究目的是分析这些因素在供应链上不同公司中的表现, 并确定实施关键原材料闭环供应链的促成因素和瓶颈条件。这项研究的新颖性有两个方面: 关注材料而不是产品流, 以及从多方面角度审视影响因素。我们的研究表明, 参与该研究的制造公司和供应链运营商对关键原料的闭环供应链的发展关注角度不同 (前者关注产品, 而后者重视材料)。这些发现强调了供应链参与者之间相互作用的必要性, 以及需要为回收过程提供良好的竞争环境, 并对技术和基础设施的开发进行投资。本文为从业者和政策制定者实施关键原料的闭环供应链提供了建议, 并为进一步研究指明了方向。

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In Pursuit of Closed-Loop Supply Chains for Critical Materials: An Exploratory Study in the Green Energy Sector

Yulia Lapko, Andrea Trianni, Cali Nuur, and Donato Masi

Keywords: circular economy, closed-loop supply chains (CLSC), critical materials, green energy technologies, industrial ecology, recycling**Summary:**

A closed-loop supply chain (CLSC) is considered not only an important solution for ensuring sustainable exploitation of materials, but also a promising strategy for securing long-term availability of materials. The latter is especially highlighted in the materials criticality discourse. Critical raw materials (CRMs), being exposed to supply disruptions, create an uncertain operational environment for many industries, particularly for green energy technologies that employ multiple CRMs. However, recycling rates of CRMs are very low and engagement of companies in CLSC for CRM is limited. This study examines factors influencing CLSC for CRM development in photovoltaic panels and wind turbine technologies. The aim is to analyze how the factors manifest themselves in different companies along the supply chain and to identify enabling and bottleneck conditions for implementation of CLSC for CRM. The novelty of the study is twofold: the focus on material rather than product flows, and examination of factors from a multiactor perspective. The evidence obtained suggests that the manufacturing companies and reverse supply-chain operators engaged in the study take different perspectives (product vs. material) regarding development of CLSC for CRM and thus emphasize different factors. The findings underline the need for interactions between supply-chain actors, a sound competitive environment for recycling processes, and investment in technologies and infrastructure development if CLSC for CRM is to be developed. The paper provides implications for practitioners and policy makers for implementation of CLSC for CRM, and suggests prospects for further research.

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<http://dx.doi.org/10.1111/jiec.12749>**韩国国家生态工业园区项目产业共生的扩大: 审视 2005-2014 年间十年的演变: 审视 2005-2014 年间十年的演变**作者: [Jooyoung Park](#), [Jun-Mo Park](#), [Hung-Suck Park](#)**关键字:** 生态工业园 (EIP), 推动, 产业生态学, 产业共生, 扩大规模, 韩国**摘要:**

2005 年, 韩国分三个阶段启动了为期 15 年的国家生态工业园发展计划, 通过促进产业共生 (IS) 逐步将老龄工业园区转变为生态工业园区 (EIPs)。在前 5 年的试点经验的基础上, 该方案的第二阶段侧重于在更广泛的区域上扩大 IS。关键的扩大战略包括通过连接多个工业园区来扩大目标区域, 过程标准化和学习传播以及开发有助于区域发展的大型项目。在本研究中, 我们研究了 2005 年至 2014 年间过去 10 年 IS 的演变, 主要是为了了解这些扩大规模战略的特征和影响。我们的研究结果表明, 与第一阶段相比, 第二阶段的 IS 规模在各个方面都有所增加。经营项目的数量从 52 个增加到 159 个, 参与公司的数量从 90 个增加到 596 个, IS 的平均距离从 40 公里增加到 48 公里。随着私人投资和政府研究经费的增加, 经济和环境效益的规模也在增加。我们进一步分析了区域的 EIP 作为推动者的作用, 他们的活动如何影响 IS 的扩大, 并讨论了韩国 IS 的方法的特点。

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<http://dx.doi.org/10.1111/jiec.12749>**Scaling-up of Industrial Symbiosis in the Korean National Eco-Industrial Park Program: Examining Its Evolution over the 10 Years between 2005-2014**[Jooyoung Park](#), [Jun-Mo Park](#), and [Hung-Suck Park](#)**Keywords:** eco-industrial park (EIP), facilitation, industrial ecology, industrial symbiosis, scaling-up, South Korea**Summary:**

In 2005, South Korea initiated the 15-year National Eco-Industrial Park Development Program in three stages to gradually transform aged industrial complexes into eco-industrial parks (EIPs) by promoting industrial symbiosis (IS). Building upon the pilot experiences from the first 5 years, the second phase of the program focused on the scaling-up of IS at a broader regional level. Key scaling-up strategies included the expansion of target areas by connecting multiple industrial complexes, the standardization of processes and dissemination of learning, and the development of large-scale projects that could contribute to the regional development. In this study, we examined the evolution of IS over the last 10 years between 2005 and 2014, primarily to understand the characteristics and impact of these scaling-up strategies. Our findings showed that the scale of IS in the second phase had increased in various aspects in comparison to that in the first phase. The number of operating projects had increased from 52 to 159, the number of participating firms increased from 90 to 596, and the average distance of IS increased from 40 to 48 kilometers. The size of economic and environmental benefits also increased along with an increase in the private investment and government research funding. We further analyzed the role of the regional EIP centers as facilitators, how their activities influenced the scaling-up of IS, and discussed the characteristics of the Korea's approach to IS.

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基于市场的生产者责任延伸案例讨论: 明尼苏达电子回收法案

作者: Isil Alev, Ximin (Natalie) Huang, Atalay Atasu, L. Beril Toktay

关键字: 电子和电气设备, 环境政策, 生产者责任延伸 (EPR), 电子废物, 明尼苏达州, 产业生态学**摘要:**

在本文中, 我们分析了明尼苏达电子回收法案, 以探索基于市场的生产者责任延伸 (EPR) 立法实施的益处和潜在缺点, 并为制造商提供操作灵活性。根据公开报告和利益相关方访谈, 我们发现明尼苏达州法案实现了基于市场的 EPR 的两个关键目标 (即更高的成本效率和大量的垃圾填埋转移); 然而, 这可能是以选择性收集和再循环、地方政府负担加重和利益相关者之间的合同权力的失衡为代价的。我们观察到这些问题的产生是因为制造商提供了特定的灵活性条款, 使他们能够以成本效益为重点实施 EPR 合规性。因此, 我们得出结论, 必须将 EPR 目标小心地转化为运营规则, 以实现目标, 同时避免意外后果。

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A Case Discussion on Market-Based Extended Producer Responsibility: The Minnesota Electronics Recycling Act

Isil Alev, Ximin (Natalie) Huang, Atalay Atasu, and L. Beril Toktay

Keywords: electrical and electronic equipment, environmental policy, extended producer responsibility (EPR), e-waste, State of Minnesota, industrial ecology**Summary:**

In this article, we analyze the Minnesota Electronics Recycling Act to explore the benefits and potential drawbacks of a market-based extended producer responsibility (EPR) legislation implementation with operational flexibility for manufacturers. Based on publicly available reports and stakeholder interviews, we find that the Minnesota Act attains two key goals of market-based EPR (i.e., higher cost efficiencies and substantial landfill diversion); however, this may come at the expense of selective collection and recycling, an increased burden on local governments, and a loss of balance in contractual power between stakeholders. We observe that these concerns arise because of specific flexibility provisions afforded to manufacturers that allow them to operationalize their EPR compliance with a cost-efficiency focus. Thus, we conclude that EPR goals must be carefully translated into operating rules in order to achieve goals while avoiding unintended consequences.

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统一材料信息系统 (UMIS): 整合的材料存量和流量数据结构

作者: Rupert J. Myers, Tomer Fishman, Barbara K. Reck, T. E. Graedel

关键字: 数据结构, 产业生态学, 投入产出分析 (IOA), 生命周期评估 (LCA), 物料流分析 (MFA), 系统建模**摘要:**

现代社会依赖于许多不同材料的使用。从供应链分析到量化其环境影响, 了解未来的资源可用性, 有效管理这些材料变得越来越重要和复杂。材料存量和流量数据可以进行此类分析, 但目前主要以散乱的形式存在, 具有高度变化的类型、范围和结构。这些因素构成了整体整合以及对现有的和尚未公布的材料存量和流量数据进行具有普遍性的分析的一大障碍。我们提出了统一材料信息系统 (UMIS), 通过全面整合材料存量和流量数据来克服这一障碍, 跨空间、时间、材料和数据类型进行集成, 能够不受数据分解程度影响, 不丢失信息, 且避免重复计算。因此, UMIS 可用于构建不同的材料存量和流量数据及其元数据, 应用于不同材料系统分析方法, 如物料流分析 (MFA)、投入产出分析和生命周期评估。UMIS 独特地标记和可视化 UMIS 图中的过程和流量; 因此, 在 UMIS 图中可视化的材料存量和流量数据可以在数据库和计算模型中单独引用。文章举例展示了使用 UMIS 重构现有的材料存量和流量数据, 即使用经济系统物料流分析分类系统得出的块流程图、系统动力学图、桑基图、矩阵所表示的数据。UMIS 提高了对材料系统进行复杂定量分析、存档以及材料存量和流量数据计算的能力。

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Unified Materials Information System (UMIS): An Integrated Material Stocks and Flows Data Structure

Rupert J. Myers, Tomer Fishman, Barbara K. Reck, and T. E. Graedel

Keywords: data structure, industrial ecology, input-output analysis (IOA), life cycle assessment (LCA), material flow analysis (MFA), systems modeling**Summary:**

Modern society depends on the use of many diverse materials. Effectively managing these materials is becoming increasingly important and complex, from the analysis of supply chains, to quantifying their environmental impacts, to understanding future resource availability. Material stocks and flows data enable such analyses, but currently exist mainly as discrete packages, with highly varied type, scope, and structure. These factors constitute a powerful barrier to holistic integration and thus universal analysis of existing and yet to be published material stocks and flows data. We present the Unified Materials Information System (UMIS) to overcome this barrier by enabling material stocks and flows data to be comprehensively integrated across space, time, materials, and data type independent of their disaggregation, without loss of information, and avoiding double counting. UMIS can therefore be applied to structure diverse material stocks and flows data and their metadata across material systems analysis methods such as material flow analysis (MFA), input-output analysis, and life cycle assessment. UMIS uniquely labels and visualizes processes and flows in UMIS diagrams; therefore, material stocks and flows data visualized in UMIS diagrams can be individually referenced in databases and computational models. Applications of UMIS to restructure existing material stocks and flows data represented by block flow diagrams, system dynamics diagrams, Sankey diagrams, matrices, and derived using the economy-wide MFA classification system are presented to exemplify use. UMIS advances the capabilities with which complex quantitative material systems analysis, archiving, and computation of material stocks and flows data can be performed.

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解开耦合: 探索资源综合利用的路径

作者: David Font Vivanco, Ranran Wang, Sebastiaan Deetman, Edgar Hertwich

关键字: 反馈回路, 产业生态学, 投入产出分析 (IOA), 资源管理, 结构路径分析, 水-能耦合

摘要:

为应对全球自然资源禀赋的空前下降, 在资源管理实践中, 所谓耦合框架的影响越来越大。在本研究中, 我们通过“耦合路径”(nexus pathways)的概念来实现资源耦合。耦合路径是资源沿供应链流动的配置, 从而实现两种或更多种资源的组合使用。研究中确定了三类一般途径: 直接(现场使用), 依赖(单向供应链)和相互依赖(供应链反馈)。我们通过多区域投入产出分析和结构路径分析来量化和比较了每种路径, 并将此方法应用于美国和中国的水-能关系(WEN)比较的案例研究。相互依赖性或反馈通常被认为与WEN相关, 尤其是在水和能源部门之间。然而, 通过对这两个国家的整体经济分析, 我们发现, 反馈在WEN或水和能源部门之间均未发挥重要作用。最重要的反馈对总资源使用的贡献不到1%, 而这些反馈主要发生在制造业部门之间。总体而言, 研究案例中的WEN主要由依赖途径驱动, 在较小程度上由直接资源使用驱动。中美两国之间的差异主要是源于经济结构, 技术和资源禀赋的差异。我们的研究结果对当前的研究和政策重点提出了质疑, 并建议更多地关注复杂性不强但更具决定性的实现资源完全利用的途径。

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Unraveling the Nexus: Exploring the Pathways to Combined Resource Use

David Font Vivanco, Ranran Wang, Sebastiaan Deetman, and Edgar Hertwich

Keywords: feedback loops, industrial ecology, input-output analysis (IOA), resource management, structural path analysis, water-energy nexus

Summary:

In response to the unprecedented decline in global natural resource endowments, the so-called nexus framework is gaining increasing influence on resource management practices. In this research, we approach the resource nexus through the concept of nexus pathways. Nexus pathways are configurations that resource flows follow along supply chains leading to the combined use of two or more resources. Three general types of pathways are identified: direct (on-site use), dependent (one-way supply chains), and interdependent (supply-chain feedbacks). We quantify and compare each pathway by means of multiregional input-output analysis and structural path analysis, and apply this approach to a comparative case study on the water-energy nexus (WEN) in the United States and China. Interdependencies or feedbacks are generally thought to be relevant for the WEN, especially between water and energy sectors. Our economy-wide analysis for both countries indicates, however, that feedbacks neither play an important role in the WEN nor substantially take place between water and energy sectors. The most important feedbacks contribute to less than 1% of total resource use, and these take place mostly between manufacturing sectors. Overall, the studied WEN is mostly driven by dependent pathways and, to a lesser degree, direct resource use. Comparative differences between the two countries are largely explained by differences in economic structure, technology, and resource endowments. Our findings call into question current research and policy focus and suggest greater attention to less complex, but more determining, pathways leading to absolute resource use.

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<http://dx.doi.org/10.1111/jiec.12739>**建筑材料的空间和时间尺度分析: 基于地理信息的建筑存量和流量模拟与预测**作者: [Niko Heeren](#), [Stefanie Hellweg](#)**关键字:** 建筑材料, 建筑垃圾地理信息系统 (GIS), 工业生态学, 生命周期评估 (LCA), 物质流分析 (MFA)**摘要:**

建筑材料在建筑物引发的环境影响中占有越来越重要的比重。为了从单一建筑层面研究材料对建筑的影响, 我们提出了一种自下而上的建筑物存量核算模型, 该模型使用三维地理信息来核算瑞士住宅建筑中建筑材料的存量。我们使用概率模型法来计算未来每单一建筑的物质流动。我们假设了人均建筑面积、建筑库存周转率和建筑材料组成等模型因子, 从而分析了 6 种情景。我们的结果显示, 到 2035 年瑞士住宅建筑的材料将经历重要的结构变化, 并将导致新建建筑量的减少, 材料流动量的增加。总的物质流入将减少一半, 而流出量将增加一倍。2055 年材料进出总量几乎相等, 标志着关闭建筑材料循环的重要机会来临。随着时间的推移, 生产和处理建筑材料造成的总环境影响保持相对稳定。木材情景的累积影响相比其他影响相对较少。而具有更多绝缘材料的情景将导致与材料相关的排放提高。人均建筑面积或材料流通量的增加将导致环境影响大幅增加。新的建模方法克服了以前自下而上建筑模型的局限性, 并允许在空间和时间上观察建筑材料流量和存量。这有利于制定减少建筑物材料环境影响的对应措施。

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<http://dx.doi.org/10.1111/jiec.12739>**Tracking Construction Material over Space and Time: Prospective and Geo-referenced Modeling of Building Stocks and Construction Material Flows**

Niko Heeren and Stefanie Hellweg

Keywords: building material, construction and demolition waste, geographic information systems (GIS), industrial ecology, life cycle assessment (LCA), material flow analysis (MFA)**Summary:**

Construction material plays an increasingly important role in the environmental impacts of buildings. In order to investigate impacts of materials on a building level, we present a bottom-up building stock model that uses three-dimensional and geo-referenced building data to determine volumetric information of material stocks in Swiss residential buildings. We used a probabilistic modeling approach to calculate future material flows for the individual buildings. We investigated six scenarios with different assumptions concerning per-capita floor area, building stock turnover, and construction material. The Swiss building stock will undergo important structural changes by 2035. While this will lead to a reduced number in new constructions, material flows will increase. Total material inflow decreases by almost half while outflows double. In 2055, the total amount of material in- and outflows are almost equal, which represents an important opportunity to close construction material cycles. Total environmental impacts due to production and disposal of construction material remain relatively stable over time. The cumulated impact is slightly reduced for the woodbased scenario. The scenario with more insulation material leads to slightly higher material related emissions. An increase in per-capita floor area or material turnover will lead to a considerable increase in impacts. The new modeling approach overcomes the limitations of previous bottom-up building models and allows for investigating building material flows and stocks in space and time. This supports the development of tailored strategies to reduce the material footprint and environmental impacts of buildings and settlements.

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通过结构化不完整性和概率选择法简化建筑物的生命周期评：探索资源综合利用的路径

作者: Paolo Tecchio, Jeremy Gregory, Elsa Olivetti, Randa Ghattas, Randolph Kirchain

关键字: 建筑, 混合模型, 产业生态学, 概率分类法, 简化生命周期评估, 不确定性

摘要:

生命周期思想在建筑行业的可持续发展中发挥着重要作用。然而, 数据收集和范围定义的复杂性限制了生命周期评价 (LCA) 的应用。即便已有收集好的, 列表整理的索引库存数据, 该方法仍耗时较大, 对于研究者而言, 可能是令人气馁的。该研究阐释了如何通过结构化环境影响数据的不完整性以及实际高效的数据收集分类, 有效地简化建筑物的 LCA, 并保证稳健性。基于从摇篮到门的研究边界, 本研究通过一系列建筑类型进行了方法测试。研究中对概率分类方法进行了测试, 以选定需要详细说明的活动, 因其对总影响贡献最大, 以此减少数据收集工作。研究评估了全球变暖, 酸化, 富营养化和烟雾产生等环境影响, 结果显示, 物料清单中 40%-46% 的物料成分贡献了单户住宅和多户住宅建筑总环境影响的 75%。仅通过将物料清单的优先级子集指定到最高特异性水平, 就能够得到相当准确的结果, 同时这一过程也是相对省时省力的。

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Streamlining the Life Cycle Assessment of Buildings by Structured Under-Specification and Probabilistic Triage

Paolo Tecchio, Jeremy Gregory, Elsa Olivetti, Randa Ghattas, and Randolph Kirchain

Keywords: Buildings, hybrid models, industrial ecology, probabilistic triage, streamlined life cycle assessment, uncertainty

Summary:

Life cycle thinking plays an important role in sustainable development in the building sector. However, the complexity of data collection and scope definition limits life cycle assessment (LCA) applications. Even if the inventory data have already been collected, tabulated, and indexed, the method is still time-consuming, which may be discouraging for designers. This study demonstrates how the LCA of buildings can be robustly streamlined using structured underspecification of impact data combined with an effective and efficient triage of the data collection. Tests were conducted with a series of building typologies that were analyzed with a cradle-to-gate approach. The probabilistic triage approach was tested to identify selected activities requiring detailed specification because they contribute most to total impact, thereby reducing data gathering effort. Impacts such as global warming, acidification, eutrophication, and smog creation were assessed, and results showed that 40% to 46% of the bill of materials components represent 75% of total impacts of single-family houses and multifamily buildings. By specifying only a prioritized subset of the bill of materials to the highest level of specificity, results proved to be reasonably accurate and obtainable with less effort.

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拉丁美洲城市住宅区物资存量的地理空间特征

作者: Carlos Mesta, Ramzy Kahhat, Sandra Santa-Cruz

关键字: 地理信息系统, 产业生态学, 物质强度, 资源回收, 城市环境, 城市存量

摘要:

建筑物库存构成了城市中建筑材料的巨大储存库, 也是未来替代主要资源的潜在来源。本文介绍了应用方法学方法分析建筑物中的材料存量 (MS) 及其在城市范围内的空间分布。通过结合地理信息系统 (GIS) 数据, 人口普查信息和从不同来源收集的数据, 我们对一个年轻的拉丁美洲城市——秘鲁奇克拉约市进行分析。应用该方法可产生建筑物实际尺寸 (即建筑面积和楼层数) 及其材料成分的具体指标。2007 年, 建筑物的总体 MS 估计为 2440 万吨 (Mt), 即人均 47 吨。存量主要由矿物材料 (97.7%), 主要是混凝土 (14.1 百万吨) 组成, 而有机材料 (例如 0.15 万吨木材) 和金属 (例如 0.40 万吨钢) 构成剩余份额 (2.3%)。此外, 历史人口普查数据和预测用于评估 1981 年至 2017 年 MS 的变化, 结果显示过去 36 年来 MS 增长了 360%。该研究为城市规划者提供了必要的支持信息, 有助于更好地了解城市资源的可用性及其未来潜在的回收供应, 以及制定施工和拆除废弃物管理的策略。

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Geospatial Characterization of Material Stock in the Residential Sector of a Latin-American City

Carlos Mesta, Ramzy Kahhat, and Sandra Santa-Cruz

Keywords: geographical information systems, industrial ecology, material intensity, resource recovery, urban environment, urban stocks

Summary:

Building stock constitutes a huge repository of construction materials in a city and a potential source for replacing primary resources in the future. This article describes the application of a methodological approach for analyzing the material stock (MS) in buildings and its spatial distribution at a city-wide scale. A young Latin-American city, the city of Chiclayo in Peru, was analyzed by combining geographical information systems (GIS) data, census information, and data collected from different sources. Application of the methodology yielded specific indicators for the physical size of buildings (i.e., gross floor area and number of stories) and their material composition. The overall MS in buildings, in 2007, was estimated at 24.4 million tonnes (Mt), or 47 tonnes per capita. This mass is primarily composed of mineral materials (97.7%), mainly concrete (14.1 Mt), while organic materials (e.g., 0.15 Mt of wood) and metals (e.g., 0.40 Mt of steel) constitute the remaining share (2.3%). Moreover, historical census data and projections were used to evaluate the changes in the MS from 1981 to 2017; showing a 360% increase of the MS in the last 36 years. This study provides essential supporting information for urban planners, helping to provide a better understanding of the availability of resources in the city and its future potential supply for recycling as well as to develop strategies for the management of construction and demolition waste.