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服务于基于消费的核算的投入产出模型和指标的新进展

作者: Arunima Malik, Darian McBain, Thomas O. Wiedmann, Manfred Lenzen, Joy Murray

关键字: 消费, 产业生态学, 投入产出分析, 社会足迹, 可持续性评估, 虚拟实验室

摘要:

在过去十年中, 运用全球性的、多区域的投入产出分析(MRIO)开展的基于消费的(足迹)核算显著增加。如果没有扩展的 MRIO 数据库的迅速发展, 那么针对消费相关的或蕴含在国际贸易中的环境和社会影响的全球性研究多数是无法完成的。本文概述了 MRIO 分析领域的发展, 尤其是在基于消费的环境和社会足迹核算方面的应用。我们首先讨论了已发表的基于各种全球 MRIO 数据库的研究成果及它们之间的差异, 然后重点讨论了虚拟实验室计算基础设施, 其为利用 MRIO 数据库开展协作研究提供可能, 并为处理更大的部门和区域层面细节性数据提供支持。本文进一步讨论了未来工作展望, 包括进一步扩展现有数据库, 尤其是需要将社会指标纳入基于消费的核算。最后, 本文讨论了制定详细的嵌套 MRIO 表的必要性, 用以调查不同国家、区域之间的联系。此外, 还指出全球 MRIO 分析这一迅速发展的领域可用于评估一个国家在联合国提出的可持续发展目标方面的表现。

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Advancements in Input-Output Models and Indicators for Consumption-Based Accounting

Arunima Malik, Darian McBain, Thomas O. Wiedmann, Manfred Lenzen, and Joy Murray

Keywords: consumption, industrial ecology, input-output analysis, social footprints, sustainability assessment, virtual laboratory

Summary:

The use of global, multiregional input-output (MRIO) analysis for consumption-based (footprint) accounting has expanded significantly over the last decade. Most of the global studies on environmental and social impacts associated with consumption or embodied in international trade would have been impossible without the rapid development of extended MRIO databases. We present an overview of the developments in the field of MRIO analysis, in particular as applied to consumption-based environmental and social footprints. We first provide a discussion of research published on various global MRIO databases and the differences between them, before focusing on the virtual laboratory computing infrastructure for potentially making MRIO databases more accessible for collaborative research, and also for supporting greater sectoral and regional detail. We discuss work that includes a broader range of extensions, in particular the inclusion of social indicators in consumption-based accounting. We conclude by discussing the need for the development of detailed nested MRIO tables for investigating linkages between regions of different countries, and the applications of the rapidly growing field of global MRIO analysis for assessing a country's performance toward the United Nations Sustainable Development Goals.

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尽管短期内磷并不短缺, 它的资源效率仍应该改进

作者: [Roland W. Scholz](#), [Friedrich-Wilhelm Wellmer](#)

关键字: 循环经济, 产业生态学, 材料效率, 预防原则, 回收, 废水

摘要:

德国政府通过了一项法律, 要求污水处理厂不仅要从废水中回收磷, 还要促进循环利用。我们认为全球没有短期或中期的磷稀缺。然而, 我们也认为德国政策有合理的理由, 包括: 预防措施, 以确保后代的长期供应安全, 在技术发展的有希望的阶段推广闭环经济技术, 并使用新的资源池减少当前的供应风险。

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Although there is no Physical Short-Term Scarcity of Phosphorus, its Resource Efficiency Should be Improved

[Roland W. Scholz](#) and [Friedrich-Wilhelm Wellmer](#)

Keywords: circular economy, industrial ecology, materials efficiency, precautionary principle, recycling, wastewater

Summary:

The German government has adopted a law that requires sewage plants to go beyond the recovery of phosphorus from wastewater and to promote recycling. We argue that there is no physical global short- or mid-term phosphorus scarcity. However, we also argue that there are legitimate reasons for policies such as those of Germany, including: precaution as a way to ensure future generations' long-term supply security, promotion of technologies for closed-loop economics in a promising stage of technology development, and decrease in the current supply risk with a new resource pool.

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对建筑组合体生命周期影响评价数据的结构化不充分赋值

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

关键字: 建筑物, 设计过程, 产业生态学, 简化的生命周期评估, 结构化不充分赋值, 不确定性分析**摘要:**

数据不确定性和数据偏差的存在是开展生命周期评价 (LCA) 尚存的挑战。此外, 进行完整的分析可能是复杂而且耗时的, 而且这种分析主要只能在产品设计完成之后进行。为支撑住宅建筑设计过程, 在无法获得被分析系统的特定相关信息时, 可以采用一种简化 LCA 的方法, 即结构化不充分赋值, 来量化环境影响。通过建筑材料和组件的结构化分类, 可在生命周期清单阶段使用替代数据, 从而获得环境影响以及伴随的不确定性。在设计过程中, 可以使用尽可能少的细节来列举建筑组件的材料清单。通过建筑材料的结构化分类, 并进行结构化不充分赋值, 可系统量化建筑组件的低精确度特征和与低精确度相关的不确定性。分析人员可使用这种分类方法来量化每个特异性水平下的结果的不确定性。对于建筑组件而言, 在数据结构内, 每个附加特异性水平上都能观察到平均 25% 的不确定性的降低。该方法被用于比较设计过程早期不同类型的外墙选择。即使是最低的特异性水平下, 几乎 50% 的差异在统计上也都是显著的。这一数据结构是简化方法的基础, 不仅适用于有完整的物料清单时, 在了解的细节较少时也同样适用。

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Structured Under-Specification of Life Cycle Impact Assessment Data for Building Assemblies

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

Keywords: buildings, design process, industrial ecology, streamlined life cycle assessment, structured under-specification, uncertainty analysis**Summary:**

The existence of uncertainties and variations in data represents a remaining challenge for life cycle assessment (LCA). Moreover, a full analysis may be complex, time-consuming, and implemented mainly when a product design is already defined. Structured under-specification, a method developed to streamline LCA, is here proposed to support the residential building design process, by quantifying environmental impact when specific information on the system under analysis cannot be available. By means of structured classifications of materials and building assemblies, it is possible to use surrogate data during the life cycle inventory phase and thus to obtain environmental impact and associated uncertainty. The bill of materials of a building assembly can be specified using minimal detail during the design process. The low-fidelity characterization of a building assembly and the uncertainty associated with these low levels of fidelity are systematically quantified through structured under-specification using a structured classification of materials. The analyst is able to use this classification to quantify uncertainty in results at each level of specificity. Concerning building assemblies, an average decrease of uncertainty of 25% is observed at each additional level of specificity within the data structure. This approach was used to compare different exterior wall options during the early design process. Almost 50% of the comparisons can be statistically differentiated at even the lowest level of specificity. This data structure is the foundation of a streamlined approach that can be applied not only when a complete bill of materials is available, but also when fewer details are known.

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<http://dx.doi.org/10.1111/jieec.12742>**生命周期评估中的不确定性量化：探索分布选择和更大的数据粒度来表征产品使用**作者: [Stephen A. Ross](#), [Lynette Cheah](#)**关键字:** 空调, 大数据, 面向环境的设计 (DfE), 产业生态学, 概率分布, 随机建模**摘要:**

能耗产品的生命周期环境特征以产品的使用阶段为主。因此, 实际产品使用的变化可能导致生命周期评估 (LCA) 结果的巨大差异。输入参数的充分表征对于不确定性量化是至关重要的, 并且是对更广泛采用 LCA 方法的挑战。经过近几年对方法论发展的重视, 数据开发再次成为主要关注点。普遍的传感提供了收集丰富数据集和改进使用阶段参数分析的机会。以数据驱动方法为例, 我们研究了国内冷却系统中的能源使用, 重点关注气候变化作为影响类别。具体目标是探究: (1) 通过不同的概率分布表征使用阶段如何影响 LCA 建模结果和输出的不确定性 (2) 以连续更高的粒度聚合的特征数据如何影响 LCA 建模结果和输出的不确定性。从国内住宅采集了三年的电器尺度的电力数据。使用阶段变量在随机模型中传播, 并通过蒙特卡罗程序模拟分析。虽然分配选择不一定不会对估计产出产生重大影响, 但估计的不确定性存在差异。在连续更高的数据粒度下对模型中的使用阶段功耗的表征降低了输出不确定性, 并且收益递减。因此, 结果证明收集代表高能产品的生命周期使用阶段的高粒度数据集是合理的。通过普遍传感的扩散提供此类数据, 为更好地表征数据和增加对 LCA 结果的信心提供了更多机会。

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<http://dx.doi.org/10.1111/jieec.12742>**Uncertainty Quantification in Life Cycle Assessments: Exploring Distribution Choice and Greater Data Granularity to Characterize Product Use**

Stephen A. Ross and Lynette Cheah

Keywords: air conditioning, big data, design for environment (DfE), industrial ecology, probability distributions, stochastic modeling**Summary:**

The life cycle environmental profile of energy-consuming products is dominated by the products' use stage. Variation in real-world product use can therefore yield large differences in the results of life cycle assessment (LCA). Adequate characterization of input parameters is paramount for uncertainty quantification and has been a challenge to wider adoption of the LCA method. After emphasis in recent years on methodological development, data development has become the primary focus again. Pervasive sensing presents the opportunity to collect rich data sets and improve profiling of use-stage parameters. Illustrating a data-driven approach, we examine energy use in domestic cooling systems, focusing on climate change as the impact category. Specific objectives were to examine: (1) how characterization of the use stage by different probability distributions and (2) how characterizing data aggregated at successively higher granularity affects LCA modeling results and the uncertainty in output. Appliance-level electricity data were sourced from domestic residences for 3 years. Use-stage variables were propagated in a stochastic model and analyses simulated by Monte Carlo procedure. Although distribution choice did not necessarily significantly impact the estimated output, there were differences in the estimated uncertainty. Characterization of use-stage power consumption in the model at successively higher data granularity reduced the output uncertainty with diminishing returns. Results therefore justify the collection of high granularity data sets representing the life cycle use stage of high-energy products. The availability of such data through proliferation of pervasive sensing presents increasing opportunities to better characterize data and increase confidence in results of LCA.

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<http://dx.doi.org/10.1111/jiec.12755>**生命周期评价中的生态系统服务：关于技术生态协同分析的有效应用**

作者: Xinyu Liu, Bhavik R. Bakshi

关键字: 生物燃料, 生态系统服务, 环境指标, 产业生态学, 生命周期评价, 可持续性评价**摘要:**

生命周期评价(LCA)能够考虑传统工程方法边界之外的环境影响,但仍局限于LCA所设的边界。可持续性要求生态系统不受不利因素的影响,并且仍然能够提供用于支持人类活动的产品和服务。传统的LCA没有考虑自然生态系统的这种作用,它的指标适合于比较替代方案。这些相对指标没有提供关于绝对环境可持续性的信息,绝对环境可持续性的评价要求比较生态系统服务(ES)的需求和供应。技术生态协同(TES)是一种考虑生态系统服务的系统分析法,并已被应用于建筑和生产制造等边界有限的活动中。

本文在传统生命周期评价步骤上进一步拓展,在多个空间尺度上整合生态系统产品和服务的需求和供应,提出了技术-生态协同生命周期评价(TES-LCA)方法。这使方法使核算绝对环境的可持续性指标成为可能,并有助于更全面寻找改善生命周期可持续性的机会,即不仅可以通过减少环境影响,还可以通过恢复和保护生态系统来实现。应用TES-LCA方法,生物燃料的可持续性分析即识别出了碳封存、空气质量管理、供水的生态系统服务这些可提高可持续性的途径。结果表明,对于碳封存生态系统服务而言,农业在当地也许是可持续的,而在全球范围或服务层面却有可能是不可持续的。我们的研究表明,在美国东部,空气质量管理在所有尺度上都是不可持续的,而供水在所有尺度上都是可持续的。

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<http://dx.doi.org/10.1111/jiec.12755>**Ecosystem Services in Life Cycle Assessment while Encouraging Techno-Ecological Synergies**

Xinyu Liu and Bhavik R. Bakshi

Keywords: biofuel, ecosystem services, environmental metrics, industrial ecology, life cycle assessment (LCA), sustainability assessment**Summary:**

Life cycle assessment (LCA) has enabled consideration of environmental impacts beyond the narrow boundary of traditional engineering methods. This reduces the chance of shifting impacts outside the system boundary. However, sustainability also requires that supporting ecosystems are not adversely affected and remain capable of providing goods and services for supporting human activities. Conventional LCA does not account for this role of nature, and its metrics are best for comparing alternatives. These relative metrics do not provide information about absolute environmental sustainability, which requires comparison between the demand and supply of ecosystem services (ES). Technoecological synergy (TES) is a framework to account for ES, and has been demonstrated by application to systems such as buildings and manufacturing activities that have narrow system boundaries.

This article develops an approach for techno-ecological synergy in life cycle assessment (TES-LCA) by expanding the steps in conventional LCA to incorporate the demand and supply of ecosystem goods and services at multiple spatial scales. This enables calculation of absolute environmental sustainability metrics, and helps identify opportunities for improving a life cycle not just by reducing impacts, but also by restoring and protecting ecosystems. TES-LCA of a biofuel life cycle demonstrates this approach by considering the ES of carbon sequestration, air quality regulation, and water provisioning. Results show that for the carbon sequestration ecosystem service, farming can be locally sustainable but unsustainable at the global or serviceshed scale. Air quality regulation is unsustainable at all scales, while water provisioning is sustainable at all scales for this study in the eastern part of the United States.

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<http://dx.doi.org/10.1111/jiec.12753>**生皮脱毛的生命周期评估: 化学处理与通过固态发酵回收酶法的比较**作者: [Eva Catalan](#), [Dimitrios Komilis](#), [Antoni Sanchez](#)**关键字:** 堆肥, 脱毛, 皮革工业, 生命周期评估 (LCA), 固态发酵, 固体废物管理**摘要:**

皮革工业需要从传统的化学法脱毛工艺转变为环保的脱毛工艺, 以减少环境的总体负担。因此, 本工作的主要目的是比较化学法皮革脱毛过程与酶法皮革脱毛过程, 后者使用了在脱毛过程中产生的毛发废物上进行固态发酵 (SSF) 后提取的酶。通过使用生命周期评估 (LCA) 方法比较了上述两种管理情景, 确定了脱毛阶段的环境负担。第一种情景是常用的技术, 通过化学过程去除毛发, 然后在开放的堆垛中堆肥。这种情景包括焚烧或填埋毛发废物这两种情景。在第二种情景中, 在残余毛发的 SSF 期间提取蛋白水解酶用于新的生皮的脱毛过程, 而非使用化学品。使用 SimaPro 8.0 LCA 软件, 将工业和实验室数据与国际数据库相结合, 对上述两种情景进行比较。酶法脱毛相关的环境影响显著低于常规化学法脱毛的环境影响。这种差异归因于与原始化学品生产相关的影响以及传统方法所消耗的电力。灵敏度分析表明, 结果受脱毛过程中所使用的化学品数量的影响。

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<http://dx.doi.org/10.1111/jiec.12753>**A Life Cycle Assessment on the Dehairing of Rawhides: Chemical Treatment versus Enzymatic Recovery through Solid State Fermentation**[Eva Catalan](#), [Dimitrios Komilis](#), and [Antoni Sanchez](#)**Keywords:** compost, dehairing, leather industry, life cycle assessment (LCA), solid state fermentation, solid waste management**Summary:**

The leather industry needs to switch from the traditional chemically based dehairing process to an environmentally friendly one so that the overall burdens to the environment are reduced. The primary goal of the work was thus to compare the chemical leather dehairing process to an enzymatically based one using the enzymes that are extracted after the application of solid state fermentation (SSF) on hair wastes generated after dehairing. The environmental burdens of the dehairing stage were determined using a life cycle assessment (LCA) approach by comparing the two aforementioned management scenarios. The first scenario was the commonly used technology in which hair is removed via a chemical process and then composted in open piles. This scenario included two subscenarios where hair waste is either incinerated or landfilled. In the second scenario, the proteolytic enzymes extracted during the SSF of the residual hair are used to dehair the new rawhides instead of chemicals. Industrial and laboratory data were combined with international databases using the SimaPro 8.0 LCA software to make comparisons. The environmental impacts associated with the enzymatic dehairing were significantly lower than the ones associated to the conventional chemical dehairing process. This difference is attributed to the impacts associated with the original production of the chemicals and to the electricity consumed in the conventional method. A sensitivity analysis revealed that the results are affected by the amounts of chemicals used during dehairing.

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<http://dx.doi.org/10.1111/jiec.12751>**船用燃料温室气体排放的生命周期评估 : 全球不同地区沙特原油与天然气比较案例研究**

作者: Hassan El-Houjeiri, Jean-Christophe Monfort, Jessey Bouchard, Steven Przesmitzki

关键字: 温室气体 (GHG) 排放, 重燃油 (HFO), 生命周期评价 (LCA), 液化天然气 (LNG), 船用燃料, 船用瓦斯油 (MGO)

摘要:

在讨论船用燃料的未来时, 需要从温室气体 (GHG) 排放维度进行理解, 在这种背景下推进当前生命周期评估 (LCA) 的实践变得非常重要。以前的船用燃料 LCA 研究依赖于一般的 LCA 模型, 如 GREET 和 JEC “从油井到车轮” 的研究。这些模型无法完全捕捉燃料供应链中的各种甲烷损失。本 LCA 研究的主要目标是比较沙特原油生产的重质燃料油和船用瓦斯油以及全球不同区域的液化天然气 (LNG) 的温室气体排放量。本研究进行了敏感性分析, 以显示非沙特原油的情况下结果如何变化。第二个目标是通过利用一系列自下而上的工程模型来推进船用燃料 LCA 研究, 这些模型能够对全球特定的石油和天然气项目进行详细的分析。结果表明, 与使用低碳强度原油生产的传统船用燃料相比, LNG 在海洋应用中被使用的特殊情况在气候变化方面具有显著的反作用。在根据 20 年与 100 年的甲烷全球变暖潜值计算的结果中, LNG 应用于海洋似乎与气候影响无竞争关系。

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<http://dx.doi.org/10.1111/jiec.12751>**Life Cycle Assessment of Greenhouse Gas Emissions from Marine Fuels: A Case Study of Saudi Crude Oil versus Natural Gas in Different Global Regions**

Hassan El-Houjeiri, Jean-Christophe Monfort, Jessey Bouchard, and Steven Przesmitzki

Keywords: greenhouse gas (GHG) emissions, heavy fuel oil (HFO), life cycle assessment (LCA), liquefied natural gas (LNG), marine fuels, marine gas oil (MGO)

Summary:

The understanding of the greenhouse gas (GHG) emissions dimension in discussing the future of marine fuels makes it important to advance the current life cycle assessment (LCA) practice in this context. Previous LCA studies of marine fuels rely on general LCA models such as GREET and JEC well-to-wheels study. These models do not fully capture the various methane losses in the fuel supply chain. The primary goal of this LCA study is to compare the GHG emissions of heavy fuel oil and marine gas oil produced from Saudi crude oil to liquefied natural gas (LNG) in different global regions. A sensitivity analysis was performed to show how results may vary with non-Saudi crudes. A secondary goal was to advance LCA of marine fuels by utilizing, for the first time, a set of bottom-up engineering models that enable detailed analysis of specific oil and gas projects worldwide. The results show particular cases where LNG use in marine applications has a significant countereffect in terms of climate change compared to conventional marine fuels produced from a low-carbon-intensity crude oil. When the results are calculated based on a 20- versus 100-year methane global warming potential, LNG appears noncompetitive for climate impact in marine applications.

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<http://dx.doi.org/10.1111/jiec.12740>**污染税会提高中国火电行业的生态和经济联合效率吗? 基于数据包络分析的物料平衡方法**

作者: Ke Wang, Zhifu Mi, Yi-Ming Wei

关键字: 数据包络分析 (DEA), 经济和生态权衡, 减排, 环境效率, 物料平衡, 二氧化硫 (SO₂)**摘要:**

关于中国电力行业效率的已有研究在经济和环境结果内在权衡的政策启示方面见解有限。本研究提出了一种结合物料平衡原理的改进的数据包络分析方法, 用于估算中国电力行业的生态和成本效率。本文确定了能源投入再分配策略对提高效率的经济成本和生态影响, 并评估污染税对二氧化硫 (SO₂) 排放水平的可能影响。估算结果表明: (1) 通过提高技术效率可以降低能源投入成本和 SO₂ 排放。(2) 可以调整能量输入组合以达到生态效率, 相应地, SO₂ 将减少 15%。(3) 如果达到最佳生态效率, 中国电力行业将单位成本降低 9%, 如果达到最佳成本效率, 则将单位污染降低 13%, 这意味着具有能源成本节约的积极的生态协同效应具有积极作用以及减少二氧化硫污染的积极的经济协同效应。

(4) 二氧化硫减少的估计影子成本非常高, 这表明中国电力行业在短期内应追求成本效率而不是生态效率, 因为替代减排活动成本较低, 一些减排成本可能进一步被能源投入成本节省抵消。(5) 由于污染税率相对较低, 污染排放费和污染税对二氧化硫排放水平的影响不会有显著差异。

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<http://dx.doi.org/10.1111/jiec.12740>**Will Pollution Taxes Improve Joint Ecological and Economic Efficiency of Thermal Power Industry in China? A DEA-Based Materials Balance Approach**

Ke Wang, Zhifu Mi, and Yi-Ming Wei

Keywords: envelopment analysis (DEA), economic and ecological trade-offs, emission reduction, environmental efficiency, material balance, sulfur dioxide (SO₂)**Summary:**

Previous studies of the efficiency of Chinese electricity industry have been limited in providing insights regarding policy implications of inherent trade-offs of economic and environmental outcomes. This study proposes a modified data envelopment analysis method combined with materials balance principle to estimate ecological and cost efficiency in the Chinese electricity industry. The economic cost and ecological impact of energy input reallocation strategies for improving efficiency are identified. The possible impacts of pollution taxes upon the levels of sulfur dioxide (SO₂) emissions are assessed. Estimation results show that (1) both energy input costs and SO₂ could be reduced through increasing technical efficiency. (2) It is possible to adjust energy input mix to attain ecological efficiency, and, correspondingly, SO₂ would be reduced by 15%. (3) The Chinese electricity industry would reduce its unit cost by 9% if optimal ecological efficiency is attained and reduce its unit pollution by 13% if optimal cost efficiency is attained, implying that there are positive ecological synergy effects associated with energy cost savings and positive economic synergy effects associated with SO₂ pollution reductions. (4) Estimated shadow costs of SO₂ reduction are very high, suggesting that, in the short term, the Chinese electricity industry should pursue cost efficiency instead of ecological efficiency, since alternative abatement activities are less costly and some of the abatement cost could be further offset by energy input cost savings. (5) There would be no significant difference between the impacts of pollution discharge fees and pollution taxes on SO₂ emissions levels because of the relatively low pollution tax rate.

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<http://dx.doi.org/10.1111/jiec.12734>

贸易和消费中能源和排放核算的部门聚合误差

作者: Da Zhang, Justin Caron, Niven Winchester

关键字: 边境碳调整, 气候政策, 隐含排放, 隐含能源, 环境会计, 产业生态学**摘要:**

正确核算消费和贸易中隐含的能源和排放对有效的气候政策设计至关重要。政策制定和研究都需要强有力的方法, 例如, 边界碳调整 (BCAs) 和温室气体减排责任的分配皆依赖于此类估算的一致性和准确性。该分析研究了贸易和消费隐含的能源和排放估算中误差的潜在程度和后果。为了量化隐含排放核算的误差, 我们比较了来自分解的全球贸易分析项目 (GTAP 8) 数据集的结果, 该数据集包含 57 个部门, 可产生不同聚合级别的结果 (3、7、16 和 26 个部门), 使用了 5000 个随机生成的部门聚合方案以及几个常用决策规则生成的聚合。我们发现一些常用的部门聚合决策规则会产生很大的误差。我们进一步表明, 根据能源、排放和贸易强度 (净出口比产出) 对行业进行聚类的聚合方案可以最大限度地减少不同汇总水平下的隐含能源和排放核算的误差。这种部门聚合方案可以很容易地用于任何投入产出分析, 并为可计算的一般均衡建模应用提供有用的信息 (在此类建模中部门聚合是必要的), 尽管我们的研究表明, 在可能的情况下应该使用最多的分解数据。

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Sectoral Aggregation Error in the Accounting of Energy and Emissions Embodied in Trade and Consumption

Da Zhang, Justin Caron, and Niven Winchester

Keywords: border carbon adjustments, climate policy, embodied emissions, embodied energy, environmental accounting, industrial ecology**Summary:**

Correctly accounting for the energy and emissions embodied in consumption and trade is essential to effective climate policy design. Robust methods are needed for both policy making and research—for example, the assignment of border carbon adjustments (BCAs) and greenhouse gas emission reduction responsibilities rely on the consistency and accuracy of such estimates. This analysis investigates the potential magnitude and consequences of the error present in estimates of energy and emissions embodied in trade and consumption. To quantify the error of embodied emissions accounting, we compare the results from the disaggregated Global Trade Analysis Project (GTAP 8) data set, which contains 57 sectors to results from different levels of aggregation of this data set (3, 7, 16, and 26 sectors), using 5,000 randomly generated sectoral aggregation schemes as well as aggregations generated using several commonly applied decisions rules. We find that some commonly applied decision rules for sectoral aggregation can produce a large error. We further show that an aggregation scheme that clusters sectors according to their energy, emissions, and trade intensities (net exports over output) can minimize error in embodied energy and emissions accounting at different levels of aggregation. This sectoral aggregation scheme can be readily used in any input-output analysis and provide useful information for computable general equilibrium modeling exercises in which sector aggregation is necessary, although our findings suggest that, when possible, the most disaggregated data available should be used.

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<http://dx.doi.org/10.1111/jiec.12760>**从历史数据模型看农业中的能源, 氮和剩余农产品转移
法国, 1882–2013**

作者: Souhil Harchaoui, Petros Chatzimpiros

关键字: 农业转型, 能源投资收益率 (EROI), 外部能源依赖, 农业自给自足, 产业生态, 氮利用效率 (NUE)**摘要:**

本文根据 19 世纪以来的历史资料, 论述了农业中能量、氮、农业生产、自给自足、农产品剩余的新陈代谢和转移情况。它基于法国连续 130 年 (1882–2013) 农业生产和生产资料的经验数据。我们的结果显示, 法国农业转型使农业净产量和农业盈余增加了 4 倍, 实现了自给自足。自 1882 年以来, 能源消耗保持了基本稳定, 但农业能源和氮素结构发生了根本变化。在 1950 年之前的 EROI (能源投资回报率) 是 2, 工业化前的农业消耗了与可出口盈余相同的能量, 用以支持非农业人口。在过去 60 年中, EROI 翻了两番, 一方面是通过用马达替代牵引动物提高了牵引效率, 另一方面作物产量和氮利用效率也同时增加了。农业能源和氮转移效率的提高, 使法国从自给自足的农业国转向了化石能源的粮食出口国家。本文对长期资源转换机制的研究突显出农业新陈代谢变化对系统供给能力的影响。农场自给自足是应对化石燃料缩紧、价格波动、温室气体排放的有利因素, 但它同样意味着降低了城市化下的农产品盈余。

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<http://dx.doi.org/10.1111/jiec.12760>**Energy, Nitrogen, and Farm Surplus Transitions in
Agriculture from Historical Data Modeling. France, 1882–
2013.**

Souhil Harchaoui and Petros Chatzimpiros

Keywords: agricultural transitions, energy return on invested energy (EROI), external energy dependence, farm self-sufficiency, industrial ecology, nitrogen use efficiency (NUE)**Summary:**

This article addresses agricultural metabolism and transitions for energy, nitrogen, farm production, self-sufficiency, and surplus from historical data since the nineteenth century. It builds on an empirical data set on agricultural production and production means in France covering 130 consecutive years (1882–2013). Agricultural transitions have increased the net production and surplus of farms by a factor of 4 and have zeroed self-sufficiency. The energy consumption remained quasi-stable since 1882, but the energy and nitrogen structure of agriculture fully changed. With an EROI (energy return to energy invested) of 2 until 1950, preindustrial agriculture consumed as much energy to function as it provided in exportable surplus to sustain the nonagricultural population. The EROI doubled to 4 over the last 60 years, driven, on the one hand, by efficiency improvements in traction through the replacement of draft animals by motors and, on the other hand, by the joint increase in crop yields and efficiency in nitrogen use. Agricultural energy and nitrogen transitions shifted France from a self-sufficiency agri-food-energy regime to a fossil-dependent food export regime. Knowledge of resource conversion mechanisms over the long duration highlights the effects of changing agricultural metabolism on the system's feeding capacity. Farm self-sufficiency is an asset against fossil fuel constraints, price volatility, and greenhouse gas emissions, but it equates to lower farm surplus in support of urbanization.

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照亮欧洲的铟回收潜力

作者: Luca Ciacchi, Tim Werner, Ivano Vassura, Fabrizio Passarini

关键字: 产业生态学, 工业代谢, 生命周期评估 (LCA), 物质流分析 (MFA), 回收, 废弃电气和电子设备 (WEEE)

摘要:

随着对人类活动对环境影响的不断了解以及对自然资源日益增长的社会价值的认识, 研究人员开始关注元素周期的描述。由于供应短缺和在使用寿命结束时不存在回收的可能性, 铟已经引起了人们的极大关注。对于依赖铟进口的国家, 特别是许多欧洲国家, 这种潜在关键特征的组合被放大了。为了分析物质流动的动态和估计可用于再循环的二次铟源的大小, 欧洲的人为铟循环已经通过物质流分析进行了研究。结果表明, 该地区是含铟成品的主要消费国, 城市矿山累计添加铟估计约为 500 吨。我们从完善该地区金属循环的角度讨论这些结果。虽然确保获取关键原材料是欧洲的一个优先事项, 但是趋向于对铟城市金属矿山的开车仍然只具有理论风险, 除非废物收集和加工方面的创新可以使所发展的技术变得经济上可行和环境可持续。

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Backlighting the European Indium Recycling Potentials

Luca Ciacchi, Tim Werner, Ivano Vassura, and Fabrizio Passarini

Keywords: industrial ecology, industrial metabolism, life cycle assessment (LCA), material flow analysis (MFA), recycling, waste electrical and electronic equipment (WEEE)

Summary:

With increased understanding of the effects of human activities on the environment and added awareness of the increasing societal value of natural resources, researchers have begun to focus on the characterization of elemental cycles. Indium has captured significant attention due to the potential for supply shortages and nonexistent recycling at end of life. Such a combination of potentially critical features is magnified for countries that depend on imports of indium, notably many European countries. With the aims of analyzing the dynamics of material flows and of estimating the magnitude of secondary indium sources available for recycling, the anthropogenic indium cycle in Europe has been investigated by material flow analysis. The results showed that the region is a major consumer of finished goods containing indium, and the cumulative addition of indium in urban mines was estimated at about 500 tonnes of indium. We discuss these results from the perspective of closing the metal cycle in the region. Securing access to critical raw materials is a priority for Europe, but the preference for recycling metal urban mines risks to remain only theoretical for indium unless innovations in waste collection and processing unlock the development of technologies that are economically feasible and environmentally sustainable.

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利益相关者对生产者责任延伸和产品管理的认知差异: 国际问卷调查和统计分析

作者: Tomohiro Tasaki, Naoko Tojo, Thomas Lindhqvist

关键字: 生产者责任延伸 (EPR), 产业生态学, 产品设计变更, 回收, 利益相关者认知, 废物管理

摘要:

对生产者责任延伸和产品管理 (EPR/PS) 概念的不同认知往往会导致长期的政策争议, 并可能影响 EPR/PS 政策设计。因此, 本研究调查了利益相关者对 EPR/PS 概念的认知, 包括其目标、应用和基本原理, 并通过回归和聚类方法分析了 376 份问卷结果。结果清晰地表明了利益相关者认知的多样性, 并确定/确认了利益相关者的认知和属性之间的几种模式。对于“目标”, 本研究分析表明, 来自中/低收入国家的利益相关者更加看重 EPR/PS 政策中适当处理和减少废物这一目标, 而来自欧洲、北美、日本和亚洲其他国家的利益相关者对 EPR/PS 的 7 个目标有不同的认知, 特别是对增加收集和将责任转移给生产者, 及上游和下游改进 (例如, 分别进行更好的产品设计和进行回收) 给予不同的关注。本研究还证实, 受访者认为地方政府在废物管理方面缺乏能力主张更多的 EPR/PS, 而对信息获取有积极意义的受访者则更加重视物理责任。对 EPR/PS 认知的最大贡献变量是 14 个特定的 EPR/PS 机制/问题, 这表明如果要发展对 EPR/PS 概念的共同的和更好的理解, 关于 EPR/PS 政策的具体机制的讨论是关键。受访者赞同 EPR/PS 的主要理论基础是生产者的能力, 但是, 58% 的受访者支持受益人的概念, 特别是各国政府和北美人士。最后, 讨论了本研究结果对 EPR/PS 政策发展的影响。

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Differences in Perception of Extended Producer Responsibility and Product Stewardship among Stakeholders: An International Questionnaire Survey and Statistical Analysis

Tomohiro Tasaki, Naoko Tojo, and Thomas Lindhqvist

Keywords: extended producer responsibility (EPR), industrial ecology, product design change, recycling, stakeholder perception, waste management

Summary:

Different perceptions of the concept of extended producer responsibility and product stewardship (EPR/PS) have tended to lead to prolonged policy disputes and have likely affected the design of EPR/PS policies. We therefore surveyed stakeholders' perceptions of the concept of EPR/PS, including its aims, application, and rationales, and analyzed 376 responses with regression analysis and cluster analysis. The results clearly demonstrated the diversity in stakeholders' perceptions and identified/confirmed several patterns between stakeholders' perceptions and attributes. Concerning aims, our analysis showed that stakeholders from middle-/low-income countries placed more importance on proper treatment and waste reduction in EPR/PS policy, while those from Europe, North America, Japan, and the rest of Asia had different perceptions on seven aims of EPR/PS, especially for increasing collection and shifting responsibility to producers, and paid varying attention to upstream and downstream improvement (e.g., better product design and recycling, respectively). Our analysis also confirmed that respondents perceiving lack of capability of local governments regarding waste management advocated EPR/PS more and respondents positive about information acquisition put more importance on physical responsibility. The largest contributing variables to the perception of EPR/PS were 14 specific EPR/PS mechanisms/issues, suggesting that discussion about specific mechanisms of EPR/PS policy is a key if common and better understandings of the EPR/PS concept are to develop. The dominant rationale of EPR/PS agreed upon by the respondents was producers' capability, but the concept of beneficiary bears was also supported by 58% of respondents, especially by national governments and North Americans. Finally, implications of the results for EPR/PS policy development were discussed.

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<http://dx.doi.org/10.1111/jieec.12757>**对于材料关键性的高分辨率洞察: 量化初级生产中副产品金属的风险**作者: [Xinkai Fu](#), [Adriano Polli](#), [Elsa Olivetti](#)**关键字:** 副产品金属, 计量经济模型, 产业生态学, 非弹性供给, 材料关键性, 供应潜力**摘要:**

许多先进的能源和环境相关技术依赖已被确定为关键或可用性有限的金属。这些元素中一些主要是开采其他基础金属(载体)产生的副产物。材料关键性相关研究者提出将副产品依赖性作为重要的供应风险指标。本文提供了新的定量证据表明, 在一些情况下, 副产品金属的可用性可能不会直接受到载体供应的限制。基于副产品金属的必需特性, 我们进行了评估, 涉及的特性包括物理浓度、金属市场价值和提取技术效率。我们分析了 40 个载体/副产品对, 并确定了 5 个“高副产品”对, 评估了这些金属的供应响应性。分析表明, 并非是限制载体的初级生产, 而是缺乏提高回收效率的动力, 可能会限制副产品的可用性。这种现象存在于锌-镉和铜-硒系统中。另一方面, 锗的情况有所不同, 我们认为副产品市场本身的影响导致供应的价格缺乏弹性。作为对材料系统的其他定量方法(如物料流分析)的补充, 我们采用聚类分析和计量经济学建模, 对副产品金属问题提供必要的技术经济分析。该方法提供了与提取效率和供应链结构相关的供应风险缓解策略的洞察。

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<http://dx.doi.org/10.1111/jieec.12757>**High-Resolution Insight into Materials Criticality
Quantifying Risk for By-Product Metals from Primary Production**[Xinkai Fu](#), [Adriano Polli](#), and [Elsa Olivetti](#)**Keywords:** by-product metals, econometric modeling, industrial ecology, inelastic supply, material criticality, supply potential**Summary:**

Many advanced energy and environmentally relevant technologies rely on metals that have been identified as critical, or whose availability may be limited. Several of these elements are produced mostly as by-products of mining other base metals (carriers). This by-product dependence has been proposed as a significant supply-risk indicator by the materials criticality community. This article provides new quantitative evidence that, in several cases, by-product metals' availability may not be directly limited by carrier supply. We perform an assessment based on characteristics essential to by-product metals, including physical concentration, market value of metals, and extraction technology efficiency. We analyze 40 carrier/by-product pairs and identify five 'high-by-product' pairs. We assess the supply responsiveness of these metals. Our analysis suggests that rather than limited primary production of carrier, lack of incentive for improving recovery efficiency may limit availability of the by-product. This behavior is found in the zinc-indium and copper-selenium systems. For germanium, on the other hand, we instead propose influence from the by-product market itself leading to price inelasticity of supply. As a complement to other quantitative methods developed for material systems, such as material flow analysis, we provide an essential technoeconomic analysis of the by-product metals problem by employing cluster analysis and econometric modeling. This approach provides insight into supply-risk mitigation strategies related to extraction efficiency and supply-chain structure.

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在美国填埋的废物的数量, 组成和价值

作者: Jon T. Powell, Marian R. Chertow

关键字: 循环经济, 产业生态学, 填埋场, 城市固体废物 (MSW), 循环, 废物成分

摘要:

目前的生产和消费系统需要依据功能做最终处置, 但上游生产-消费与下游垃圾填埋作为终点之间的联系充其量只是一种脆弱的单向关系, 这表明部分系统失效。修复这个环节的一个出发点就是系统地面对混乱垃圾填埋的“黑箱”, 查询其当地情况, 并确定可用于扩大结果的基线。在这里, 我们开发了一个详细的模型, 描述了美国填埋的城市固体废物 (MSW) 在材料数量、质量、位置和时间方面的信息。该模型对 1,161 个垃圾填埋场 (占垃圾填埋量的 95%) 进行了三角测量并对在美国 222 个点取的 15,169 个固体废物样本进行了收集和分析。我们确认填埋量的纸张 (6300 万兆克 [Mg]), 食物垃圾 (3500 Mg), 塑料 (3200 Mg), 纺织品 (1000 万 Mg) 和电子废物 (350 万 Mg) 远远大于美国政府以前自上而下方法的计算估计。我们估计了 2015 年垃圾填埋处置的成本 (107 亿美元) 和可回收材料的商品总损失 (14 亿美元)。此外, 我们估计垃圾填埋场的甲烷排放 (依据质量) 到比 2015 年美国清单高出 14%。通过主要依靠每年记录的废物数量和类型的测量, 该模型可以提供更有效、有针对性的干预措施, 从减少垃圾填埋量, 改善当地、区域和国家排放估算, 增强物流分析中的耗散损失估算, 并阐明将材料、能源和经济维度与生产、消费和处置周期联系起来的动态关联。

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Quantity, Components, and Value of Waste Materials Landfilled in the United States

Jon T. Powell and Marian R. Chertow

Keywords: circular economy, industrial ecology, landfill, municipal solid waste (MSW), recycling, waste composition

Summary:

The current system of production and consumption needs end-of-life disposal to function, but the linkage between upstream production-consumption with the downstream landfill as terminus is, at best, a tenuous, one-way relationship, suggesting a partial system failure. A starting point to fix this link is to confront, systematically, the messy “black box” that is mixed waste landfilling, interrogate its contents locally, and determine a baseline that can be used to scale up results. Here, we develop a detailed model characterizing landfilled municipal solid waste (MSW) in the United States across the dimensions of material quantity, quality, location, and time. The model triangulates measurements spanning 1,161 landfills (representing up to 95% of landfilled MSW) and 15,169 solid waste samples collected and analyzed at 222 sites across the United States. We confirm that landfilled quantities of paper (63 million megagrams [Mg]), food waste (35 million Mg), plastic (32 million Mg), textiles (10 million Mg), and electronic waste (3.5 million Mg) are far larger than computed by previous top-down U.S. government estimates. We estimate the cost of MSW landfill disposal in 2015 (10.7 billion U.S. dollars [USD]) and gross lost commodity value of recyclable material (1.4 billion USD). Further, we estimate landfill methane emissions to be up to 14% greater (mass basis) than the 2015 U.S. inventory. By principally relying on measurements of waste quantity and type that are recorded annually, the model can inform more effective, targeted interventions to divert waste materials from landfill disposal, improve local, regional, and national emission estimates, enhance dissipative loss estimates in material flow analyses, and illuminate the dynamics linking material, energy, and economic dimensions to production, consumption, and disposal cycles.

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食品废弃物对食品包装环境绩效评估的影响

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关键字: 食品包装, 食物浪费, 温室气体排放, 产业生态, 生命周期评估, 生命周期能源分析**摘要:**

对食品包装的环境影响审查催生了一系列食品行业可持续政策, 但是其主要关注的还是材料对环境的直接影响。人们越发意识到食品包装会影响食品的浪费程度, 从而会影响食品包装的环境评估。在这项研究中, 我们通过构建一个生命周期评估框架对 13 种食品及其典型的包装形式进行分析, 从而讨论食物浪费对整个系统中温室气体 (GHG) 排放和能源需求 (CED) 的影响。基于美国农业部预估出的食物浪费率, 我们的计算显示食物浪费率的降低有可能减少 10% 的温室气体排放和能源需求。该计算结果提示我们, 创新包装会增加环境影响这样的观点有明显的局限性。食品浪费与食品包装环境影响的紧密关系为预测食品废物对整体环境影响提供了方向。基于对某食品全生命周期 (LCA) 文献的查阅, GHG 排放的比率范围为 0.06 (葡萄酒) 到 780 (牛肉)。谷类、乳制品、海鲜和肉类等食品的比率较高, 说明这些食品通过基于创新包装减少食品废物, 从而减少影响的潜力更大。虽然本研究的目的并非精确模拟核算产品/包装系统的全生命周期环境影响, 但它确实说明了在比较包装替代品时考虑食物浪费的重要性, 以及通过使用包装来减少食物浪费从而降低食品链整体环境影响的潜力。

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Mapping the Influence of Food Waste in Food Packaging Environmental Performance Assessments

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Keywords: food packaging, food waste, greenhouse gas (GHG) emissions, industrial ecology, life cycle assessment (LCA), life cycle energy analysis**Summary:**

Scrutiny of food packaging environmental impacts has led to a variety of sustainability directives, but has largely focused on the direct impacts of materials. A growing awareness of the impacts of food wastes a recalibration of packaging environmental assessment to include the indirect effects due to influences on food waste. In this study, we model 13 food products and their typical packaging formats through a consistent life cycle assessment framework in order to demonstrate the effect of food waste on overall system greenhouse gas (GHG) emissions and cumulative energy demand (CED). Starting with food waste rate estimates from the U.S. Department of Agriculture, we calculate the effect on GHG emissions and CED of a hypothetical 10% decrease in food waste rate. This defines a limit for increases in packaging impacts from innovative packaging solutions that will still lead to net system environmental benefits. The ratio of food production to packaging production environmental impact provides a guide to predicting food waste effects on system performance. Based on a survey of the food LCA literature, this ratio for GHG emissions ranges from 0.06 (wine example) to 780 (beef example). High ratios with foods such as cereals, dairy, seafood, and meats suggest greater opportunity for net impact reductions through packaging-based food waste reduction innovations. While this study is not intended to provide definitive LCAs for the product/package systems modeled, it does illustrate both the importance of considering food waste when comparing packaging alternatives, and the potential for using packaging to reduce overall system impacts by reducing food waste.

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<http://dx.doi.org/10.1111/jiec.12759>**综合混合分析下的企业和产品碳足迹：在西班牙木材公司的应用**

作者: Sergio Alvarez, Maria-Angeles Tobarra, Jorge-Enrique Zafrilla

关键字: 碳排放, 企业环境报告, 环境投入产出分析, 混合生命周期评价, 投入产出生命周期评价 (IO-LCA), 木材公司

摘要:

欧盟 (EU) 正在向着实现大气中温室气体浓度稳定的目标稳步推进。如今各部门均有义务进行温室气体削减, 同时鼓励基于碳足迹制定并实施新政策。然而, 所谓范畴 3 排放的自愿报告制度阻碍了这些政策的成功实施。在本研究中, 我们提出了分层混合分析的方法, 依据 ISO / TR 14069 标准报告温室气体排放情况, 并完整测算基于范畴 3 的排放量。针对上游范畴 3 排放, 对范畴 1 和范畴 2 排放的过程分析补充了多区域投入产出分析。这种新方法被用于西班牙木材公司的案例研究。经过测算, 2011 年其碳足迹总量为 783,660 千克二氧化碳当量, 其中 88% 对应范畴 3 排放量。这些排放分布在全球; 71% 来自欧洲国家, 其次是 8% 来自新兴经济体 (巴西, 俄罗斯, 印度, 印度尼西亚, 澳大利亚和土耳其), 5% 来自中国, 16% 来自世界其他地区。在欧洲实施这种新的计算方法可以极为有效地减少全球碳排放, 我们也讨论并明确了这种新方法的优缺点。

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<http://dx.doi.org/10.1111/jiec.12759>**Corporate and Product Carbon Footprint under Compound Hybrid Analysis: Application to a Spanish Timber Company**

Sergio Alvarez, Maria-Angeles Tobarra, and Jorge-Enrique Zafrilla

Keywords: carbon emissions, corporate environmental reporting, environmental input-output analysis, hybrid life-cycle assessment, input-output life cycle assessment (IO-LCA), timber company

Summary:

The European Union (EU) is advancing steadily toward the stabilization of atmospheric greenhouse gas concentrations. Various sectors are now obliged to make reductions, and new policies based on the carbon footprint are being encouraged. However, voluntary reporting of so-called scope 3 emissions is hindering successful implementation of these policies. In this study, we present a tiered hybrid analysis to report emissions according to the ISO/TR 14069 standards and to obtain complete measures of scope 3 emissions. A process analysis for scope 1 and scope 2 emissions is complemented with a multiregional input-output analysis for upstream scope 3 emissions. This novel approach is applied to the case study of a Spanish timber company. Its total carbon footprint in 2011 was 783,660 kilograms of carbon-dioxide equivalent, of which 88% correspond to scope 3 emissions. These emissions are globally distributed; 71% are from European countries, followed by 8% from emerging economies (Brazil, Russia, India, Indonesia, Australia, and Turkey), 5% from China, and, finally, 16% from the rest of the world. We identify and discuss the advantages and disadvantages of this novel approach, the European implementation of which could be highly effective in reducing global carbon emissions.