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翻译

丛薇 马磊 黄莹 陈伟强
李顺 雷锦明 李霄 李杨
黄蓓佳 任亚楠 孙明星

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Translated by

Wei Cong, Lei Ma, Ying Huang, Weiqiang Chen,
Shun Li, Jinming Lei, Xiao Li, Yang Li,
Beijia Huang, Yanan Ren, and Mingxing Sun

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新兴技术的环境评估：对前瞻性 LCA 的建议

作者： Rickard Arvidsson, Anne-Marie Tillman, Björn A. Sandén, Matty Janssen, Anders Nordelöf, Duncan Kushnir, Sverker Molander

关键字： 案例研究, 新兴技术, 产业生态学, 生命周期评价（LCA）, 预期, 技术变革

摘要：
LCA 领域越来越多地讨论了利用生命周期评价（LCA）评估新兴技术的挑战。在本文中，我们提出了前瞻性 LCA 的定义：如果一项 LCA 所研究的（新兴）技术处于开发的早期阶段（例如，小规模生产），但对该技术的建模基于其未来更发达的阶段（例如，大规模生产），那么该 LCA 是前瞻性的。前瞻性 LCA 中的方法学选择必须经过调整以反映评估新兴技术的环境影响这一目标，这与传统 LCA 研究的典型目标背道而驰。本文的目的是为如何以相关方式进行此类前瞻性评估提出一些建议。这些建议基于对选定的前瞻性 LCA 案例研究的详细审查，这些案例主要来自于纳米材料、生物材料和能源技术领域。我们发现在前瞻性 LCA 研究中包含与未来相关的技术替代方案非常重要。预测方案和方案范围是前景和背景系统前瞻性清单建模的两种通用方法。许多不同的数据源可用于前景系统的前瞻性建模：科学文章、专利、专家访谈、未发表的实验数据和过程建模。但是，我们告诫不要使前景和背景系统在时间上不匹配，并建议单独报告前景和背景系统的影响，以增加评估结果在其他前瞻性研究中的适用性。

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Environmental Assessment of Emerging Technologies: Recommendations for Prospective LCA

Rickard Arvidsson, Anne-Marie Tillman, Björn A. Sandén, Matty Janssen, Anders Nordelöf, Duncan Kushnir, and Sverker Molander

Keywords: case study, emerging technology, industrial ecology, life cycle assessment (LCA), prospective, technological change

Summary:
The challenge of assessing emerging technologies with life cycle assessment (LCA) has been increasingly discussed in the LCA field. In this article, we propose a definition of prospective LCA: An LCA is prospective when the (emerging) technology studied is in an early phase of development (e.g., small-scale production), but the technology is modeled at a future, more-developed phase (e.g., large-scale production). Methodological choices in prospective LCA must be adapted to reflect this goal of assessing environmental impacts of emerging technologies, which deviates from the typical goals of conventional LCA studies. The aim of the article is to provide a number of recommendations for how to conduct such prospective assessments in a relevant manner. The recommendations are based on a detailed review of selected prospective LCA case studies, mainly from the areas of nanomaterials, biomaterials, and energy technologies. We find that it is important to include technology alternatives that are relevant for the future in prospective LCA studies. Predictive scenarios and scenario ranges are two general approaches to prospective inventory modeling of both foreground and background systems. Many different data sources are available for prospective modeling of the foreground system: scientific articles; patents; expert interviews; unpublished experimental data; and process modeling. However, we caution against temporal mismatches between foreground and background systems, and recommend that foreground and background system impacts be reported separately in order to increase the usefulness of the results in other prospective studies.

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因变型生命周期评价的启发性筛选辅助

作者： Deepak Rajagopal

关键字： 生物能源，气候变化，环境政策，生命周期评估（LCA），生命周期清单（LCI），市场中介效应

摘要：
因变型生命周期评价（CLCA）被认为是将归因生命周期评估（ALCA）的技术丰富性与基本经济直觉相结合框架，以评估创新对环境的潜在影响。然而，尽管文献越来越多，但 CLCA 仍缺乏系统边界定义的一般性指导原则。为了填补这一空白，本文提出了一个新的脆弱性指数，表明产品（或活动）大规模采用市场价格所产生的排放对其生命周期的影响。我们以玉米乙醇为例，说明了这样一个指数在多大程度上有助于选择一小部分受影响的活动供 CLCA 正式考虑。对玉米乙醇的应用表明，除了土地覆盖变化之外，还有其他脆弱性来源在生物燃料的情境下没有受到关注。我们还概述了利用脆弱性指数作为 CLCA 筛查辅助的一般程序。脆弱性指数的效用独立于可能用于正式 CLCA 的建模框架的类型（例如多市场部分均衡或可计算的一般均衡）。最后，这项工作说明了脆弱性指数方法如何连接 ALCA 和 CLCA。

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A Heuristic Screening Aid for Consequential Life Cycle Assessment

Deepak Rajagopal

Keywords: bioenergy, climate change, environmental policy, life cycle assessment (LCA), life cycle inventory (LCI), market-mediated effects

Summary:
Consequential life cycle assessment (CLCA) is envisioned as a framework that combines the technological richness of attributional life cycle assessment (ALCA) with basic economic intuition to assess the potential environmental impact of an innovation. However, despite a growing literature, CLCA still lacks general guidelines for system boundary definition.
Toward filling this gap, this article invents a new index of vulnerability of the life cycle impact of a product (or activity) to emissions arising from the impact of its large-scale adoption on market prices. Using corn ethanol as an example, it is illustrated how such an index might aid in the selection of a small set of affected activities for formal consideration in a CLCA. The
application to corn ethanol reveals that in addition to land-cover change, there exist other sources of vulnerability that have not received attention in the context of biofuels. A general procedure for utilizing the vulnerability index as a screening aid for CLCA is outlined. The utility of the vulnerability index is independent of the type of modeling framework (such as multimarket partial equilibrium or computable general equilibrium) that might be employed for a formal CLCA. Finally, this work illustrates how the vulnerability index approach bridges ALCA and CLCA.

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家庭能源足迹的不确定性估计

作者：Jihoon Min, Narasimha D. Rao

关键字： 基于消费的核算，发展中国家，能源强度，家庭足迹，投入产出模型，不确定性

摘要：
我们开发了一种方法来表征和量化家庭能源足迹中将消费与生产相关联的不确定性。这种不确定性主要来自国民账户和住户调查之间的不一致，同时也有一小部分源于使用了多部门的汇总。在报告家庭足迹时，研究人员可能会忽略这些不一致性，从而导致较大的不准确性。我们将该方法应用于印度和巴西，我们发现这种不确定性的大小高于大多数收入水平家庭的足迹的 20%。我们认为由于这些不一致，以前可能高估了这些国家的家庭能源足迹。其他知识空白，例如多区域投入产出表和住户调查的不准确性，进一步增加了我们估计之外的不确定性。

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Estimating Uncertainty in Household Energy Footprints

Jihoon Min and Narasimha D. Rao

Keywords: consumption-based accounting, developing countries, energy intensity, household footprint, input-output model, uncertainty

Summary:
We develop a methodology to characterize and quantify uncertainty in relating consumption to production in household energy footprints. This uncertainty arises primarily from inconsistencies between national accounts and household surveys and, to a smaller extent, from using aggregated sectors. Researchers may introduce significant inaccuracies by ignoring these inconsistencies when reporting household footprints. We apply the methodology to India and Brazil, where we find the size of this uncertainty to be higher than 20% of footprints at most income levels. We expect that previous estimates for these countries may have been overestimated due to these inconsistencies. Other knowledge gaps, such as inaccuracies in multiregional input-output tables and household surveys, add further uncertainty beyond our estimates.

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用于评估美国发电二氧化碳排放的决策支持算法

作者： Nicole A. Ryan, Jeremiah X. Johnson, Gregory A. Keoleian, Geoffrey M. Lewis

关键字： 发电，电力设施，排放因子，温室气体（GHG）排放，产业生态边际排放

摘要：
本文介绍了一种帮助从业者确定估算电力负荷的二氧化碳排放量最合适方法的算法。其应用包括对产品、流程、能效改进、发电基础设施变化和电力需求变化的可持续性评估。目前，对计算特定电力负荷导致的温室气体排放的适当方法尚未达成共识。之前的研究表明，在使用不同方法时，排放存在显着差异，这种情况可能会导致有分歧的可持续性或政策建议。在本文中，我们基于区域大小、时间分辨率、平均或边际方法和时间尺度等方法特征来说明排放估算的分布。通过这些发现，我们提出了一种决策支持算法，该算法使用负载的关键特征和分析师的研究问题来提供关于适当方法类型的建议。我们定义了四种不同的案例来证明算法的实用性，并说明了以前研究中所用的方法的可变性。先前的研究通常采用简化假设，在某些情况下，可能导致电力被分配给不正确的发电资源和不正确的排放计算。该算法可以减少不适当的分配、假设的可变性，并增加电力排放估算的适当性。

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Decision Support Algorithm for Evaluating Carbon Dioxide Emissions from Electricity Generation in the United States

Nicole A. Ryan, Jeremiah X. Johnson, Gregory A. Keoleian, and Geoffrey M. Lewis

Keywords: electricity generation, electric utility, emissions factor, greenhouse gas (GHG) emissions, industrial ecology, marginal emissions

Summary:
This article presents an algorithm to aid practitioners in determining the most appropriate method to estimate carbon dioxide emissions from an electricity load. Applications include sustainability assessments of products, processes, energy efficiency improvements, changes in generation infrastructure, and changes in electricity demand. Currently, there is no consensus on appropriate methods for calculating greenhouse gas emissions resulting from specific electricity loads. Previous research revealed significant differences in emissions when different methods were used, a situation that could result in divergent sustainability or policy recommendations. In this article, we illustrate the distribution of emissions estimates based on method characteristics such as region size, temporal resolution, average or marginal approaches, and time scales. Informed by these findings, a decision support algorithm is presented that uses a load's key features and an analyst's research question to provide recommendations on appropriate method types. We defined four different cases to demonstrate the utility of the algorithm and to illustrate the variability of methods used in previous studies. Prior research often employed simplifying assumptions, which, in some cases, can result in electricity being allocated to the incorrect generating resources and improper calculation of emissions. This algorithm could reduce inappropriate allocation, variability in assumptions, and increase appropriateness of electricity emissions estimates.

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测算石油资源生产率：化学品网络及其应用

作者： Yanan Ren, Xiaojie Liu, Litao Liu, Lei Shi

关键字： 化学品网络, 中国, 石油, 层级结构, 产业生态学, 资源生产率

摘要：
石油资源生产率（RP）是衡量石油资源利用效率的重要指标。在本文中，我们提出了一种从复杂网络角度计算石油 RP 的方法。我们构建了一个由 578 种化学品组成的化学网络，并根据反应过程将所有化学品分为六个层级。我们提出了两个指标来表示两种计算方法：基于物质流分析的资源生产率（RPMF）和基于碳流分析的资源生产率（RPCF）。为了澄清这两个指标的含义差异，我们以该网络中的对二甲苯（PX）生产链为例进行说明，PX 链由原油、PX、纯对苯二甲酸和聚对苯二甲酸乙二醇酯组成。最终，我们采用了 RPCF 指标。我们计算出 1992-1999 年中国化学品网络六个层级的平均 RPCF 分别为 145、219,601、929、1474 和 4076 美元/吨碳。结果表明，石化产业存在产业链延伸增值效应。在石油衍生品中，化学品的 RPCF 明显高于油品的。国家、地区、工业园区和化学品公司可以通过扩展和选择化学品生产链及其组合来提高资源生产率。我们还可以使用该计算方法将生物质等其它碳源的资源生产率与石油的资源生产率进行比较，促进能源和化工生产中循环经济的发展。

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Measuring the Resource Productivity of Crude Oil: A Chemical Network and its Application

Yanan Ren, Xiaojie Liu, Litao Liu, and Lei Shi

Keywords: chemical network, China, crude oil, hierarchical levels, industrial ecology, resource productivity

Summary:
The resource productivity (RP) of crude oil is an important indicator to measure the utilization efficiency of a petroleum resource. In this article, we proposed a methodology to calculate the RP of crude oil from a complex network perspective. We constructed a chemical network comprising 578 chemicals and divided all chemicals into six hierarchical levels according to their processing steps. We put forward two indicators to represent two calculation methods: resource productivity based on material flow analysis and resource productivity based on carbon flow analysis (RPCF). To clarify the differences in the meanings of these two indicators, we extracted the paraxylene (PX) production chain, which is composed of crude oil, PX, pure terephthalic acid, and polyethylene terephthalate, from the network as an example. Finally, we adopted the RPCF indicator. We calculated that the average RPCFs of the six hierarchical levels of crude oil in China from 1992 to 1999 are 145, 219, 601, 929, 1,474, and 4,076 US$/(tonnes carbon). The results show that there is a value-added effect in the extension of petrochemical industrial chains. Among the derivatives of crude oil, the RPCFs of chemicals are obviously higher than those of oils. Countries, regions, industrial parks, and chemical companies can improve RP by extending and choosing chemical production chains and combinations thereof. We can also use the calculation methodology to compare RP of other sources of carbon like carbon dioxide and biomass with that of crude oil, and promote the development of circular economy in energy and chemical production.

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快速发展的城市中隐含的温室气体：用结构元素分解和政策情景看住宅库存的演变

作 者： Verena Göswein, Jonathan Krones, Giulia Celentano, John E. Fernández, Guillaume Habert

关键字： 非洲，建筑材料，温室气体（GHG）排放，产业生态学，存量动态，城市代谢

摘要：
非洲目前正在经历人口迅速增长和加速城市化进程。这种人口变化将需要大量的新建筑材料，从而产生严重的环境影响。对于非洲大陆的许多城市而言，数据差距使得具体量化和对这种影响的可靠预测非常困难。本文介绍了一种使用自下而上的类型学方法评估快速增长的城市建筑存量动态和隐含排放的方法。这种方法允许通过重新回顾的 Sankey 图来定位不同构造元素中的隐含温室气体（GHG）排放，从而确定适当的脱碳工程。我们比较了不同种类的房屋类型和建筑技术。我们采用约翰内斯堡市作为案例研究，以说明建筑类型、技术和住宅建筑存量隐含温室气体之间的关系。这种新的可视化揭示了材料和 GHG 最密集的住宅类型和建筑元素。改进的 Sankey 图以简单的方式展示了建筑物存量及其驱动因素，可以清楚地了解潜在替代方案的结果。 基准情景显示，2011 年至 2040 年期间，新建筑的二氧化碳当量（Mt CO2-eq）为 100.5 百万吨。动态模型的结果表明，随着时间的推移，在为所有人提供足够可持续住房的情况下，只有密集的建筑物与多层建筑物的组合和使用替代建筑材料和技术显示出减少温室气体排放的真正潜力（到 2040 年为 3,300 万吨二氧化碳当量）。

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Embodied GHGs in a Fast Growing City: Looking at the Evolution of a Dwelling Stock using Structural Element Breakdown and Policy Scenarios

Verena Göswein, Jonathan Krones , Giulia Celentano, John E. Fernández, and Guillaume Habert

Keywords: Africa, building materials, greenhouse gas (GHG) emissions, industrial ecology, stock dynamic, urban metabolism

Summary:
Africa is currently experiencing rapid population growth and accelerated urbanization. This demographic shift will require a large amount of new construction material resulting in substantial environmental impact. For many cities on the continent, data gaps make specific quantification and robust prediction of this impact highly difficult. This article presents a method to assess the stock dynamics and embodied emissions of a rapidly growing urban built environment using a bottom-up, typological approach. This approach allows for the identification of appropriate engineering solutions for decarbonization by localizing embodied greenhouse gas (GHG) emissions in the different constructive elements with a revisited Sankey diagram. Different alternatives regarding housing type and construction techniques are compared. The city of Johannesburg is used as a case study to illustrate the relation between building types, technologies, and embodied GHG of its residential building stock. This new visualization uncovers the most material- and GHG-intense dwelling types and building elements. The adapted Sankey represents the building stock and its drivers in a simple way, allowing clear understanding of the consequences of potential alternatives. The business-as-usual scenario indicates 100.5 megatons carbon dioxide equivalent (Mt CO2- eq) for new construction between 2011 and 2040. The results of the dynamic model over time show that only a combination of a densified building stock with multistory buildings and the use of alternative construction materials and techniques show real potential to decelerate GHG emissions (33.0 Mt CO2-eq until 2040) while aiming to provide adequate and sustainable housing for all.

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利用贝叶斯推断的增量物料流分析

作者： Richard C. Lupton, Julian M. Allwood

关键字： 贝叶斯推断，产业生态学，马尔科夫链蒙特卡洛方法，物料流分析，钢铁，不确定性

摘要：
物料流分析（MFA）被广泛用于研究材料从生产、使用、再利用、到再循环或处置的全生命周期过程，以识别环境影响并寻求潜在解决方案。然而，这种类型的分析的发展往往受到数据的制约，这些数据可能是不确定的，矛盾的，缺失的或过度聚合的。

本文提出了一种贝叶斯方法，运用概率分布刻画对于物料流的不确定的认识。如果初始可用的数据很少，则模型预测将相当模糊。随着新数据的获取，不断进行相应的系统性整合将降低不确定性水平。

在回顾了前人应对 MFA 不确定性的方法后，本文引入了贝叶斯方法，并开发了将其应用于物料流分析的一般方法。本文运用马尔可夫链蒙特卡罗模拟，将该方法用于绘制全球钢铁产量。该方法除了可以帮助分析师应对不完整数据带来的困难，还增强了解决整个过程中的不确定性的透明度，从而改善了不同研究结果之间的交流。

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Incremental Material Flow Analysis with Bayesian Inference

Richard C. Lupton and Julian M. Allwood

Keywords: Bayesian inference, industrial ecology, Markov Chain Monte Carlo, material flow analysis, steel, uncertainty

Summary:
Material flow analysis (MFA) is widely used to study the life cycles of materials from production, through use, to reuse, recycling, or disposal, in order to identify environmental impacts and opportunities to address them. However, development of this type of analysis is often constrained by limited data, which may be uncertain, contradictory, missing, or over-aggregated.

This article proposes a Bayesian approach, in which uncertain knowledge about material flows is described by probability distributions. If little data is initially available, the model predictions will be rather vague. As new data is acquired, it is systematically incorporated to reduce the level of uncertainty.

After reviewing previous approaches to uncertainty in MFA, the Bayesian approach is introduced, and a general recipe for its application to material flow analysis is developed. This is applied to map the global production of steel using Markov Chain Monte Carlo simulations. As well as aiding the analyst, who can get started in the face of incomplete data, this incremental approach to MFA also supports efforts to improve communication of results by transparently accounting for uncertainty throughout.

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大小尺度气凝胶制造的生命周期评价：石油泄漏修复中使用先进材料的权衡

作者：Osman Karatum, Md Mainul H. Bhuiya, Mary K. Carroll, Ann M. Anderson, Desiree L. Plata

关键字： 气凝胶,产业生态学,生命周期评价（LCA）,溢油,快速超临界萃取,垃圾焚烧发电（WTE）

摘要：
近年来的研究表明，先进的气凝胶复合材料(Aspen Aerog.Spaceloft[SL])具有通过高吸油能力和选择性、优异的可重复使用性和高机械强度来转化油修复的潜力。了解先进气凝胶的生命周期环境影响，可以在考虑溢油后的采油技术的使用时实现更全面的决策。在此研究中，我们按照国际标准化组织的标准（ISO）14040 2006 对 SL 与传统吸油材料——聚氨酯泡沫进行从摇篮到坟墓的生命周期评价（LCA）。该模型包括多种处置方案，例如一次及多次利用、垃圾填埋、焚烧和焚烧发电方法，用于清洁 1 立方米（m3）的轻质原油。结果表明，SL 应用的理想情况是多次使用和焚烧发电(材料使用减少 68%，WTE 能量回收约 7×103 兆焦耳[MJ])，但 SL 即使使用一次并通过传统处理方式（如垃圾填埋）也能够提供能量和节省材料。除了评估这些已经规模化的过程，我们还为实验室规模化的气凝胶制造过程进行了 LCA 预测，从而为下一代气凝胶的可持续设计提供信息。该模型特别比较了快速超临界萃取（RSCE）和两种常规超临界萃取方法——乙醇和二氧化碳超临界萃取（分别是 ASCE 和 CSE）对硅气凝胶整体的影响。我们的研究结果表明，与 ASCE 和 CSCE 相比，RSCE 对 1 m3 单片二氧化硅气凝胶制造的累计节省能量分别超过 76×103 和 100×103 MJ。

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Life Cycle Assessment of Aerogel Manufacture on Small and Large Scales: Weighing the Use of Advanced Materials in Oil Spill Remediation

Osman Karatum, Md Mainul H. Bhuiya, Mary K. Carroll, Ann M. Anderson, and Desiree L. Plata

Keywords: aerogel, industrial ecology, life cycle assessment (LCA), oil spill, rapid supercritical extraction, waste-to-energy (WTE)

Summary:
Recent studies demonstrated that advanced aerogel composites (Aspen Aerogels ® Spaceloft ® [SL]) have the potential to transform oil remediation via high oil uptake capacity and selectivity, excellent reusability, and high mechanical strength. Understanding the life cycle environmental impacts of advanced aerogels can enable a more holistic decision-making process when considering oil recovery technologies following a spill. Here, we perform a cradle-to-grave streamlined life cycle assessment (LCA) following International Organization for Standardization (ISO) 14040 2006 for SL weighed against the conventional oil sorbent material, polyurethane foam. The model included alternative use and disposal scenarios, such as single or multiple uses, and landfill, incinerator, and waste-to energy (WTE) approaches for cleaning 1 cubic meter (m^3) of light crude oil. Results showed that the ideal case for SL application was comprised of multiple use and WTE incineration (68% reduction in material use, approximately 7×10^3 megajoules [MJ] of energy recovery from WTE), but SL offered energy and materials savings even when used once and disposed of via traditional means (i.e., landfill). In addition to evaluating these already-scaled processes, we performed an anticipatory LCA for the laboratory-scaled aerogel fabrication process that might inform the sustainable design of next-generation aerogels. In particular, the model compared rapid supercritical extraction (RSCE) with two conventional supercritical extraction methods—alcohol and carbon dioxide supercritical extraction (ASCE and CSCE, respectively)—for silica aerogel monoliths. Our results showed that RSCE yielded a cumulative energy savings of more than 76×10^3 and 100×10^3 MJ for 1 m^3 of monolithic silica aerogel manufacturing compared to ASCE and CSCE, respectively.

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普通多年生作物农场的生命周期评估结果的时空差异：秘鲁可可的种植进展和森林采伐问题的案例研究

作者：Giancarlo Raschio, Sergiy Smetana, Christian Contreras, Volker Heinz, Alexander Mathys

关键字： 生命周期的时空差异，产业生态学，土地利用变化，生命周期评估，多年生作物影响评价，森林采伐的相对风险

摘要：
在生命周期评估（LCA）研究中，应用空间和时间显性信息来提高结果精度的势头正不断扩大。评估与遮荫作物一起种植的多年生作物与非生产年份的环境影响至关重要。现有研究依赖于 LCA 输入的差异化生命周期清单数据或适用的影响评估方法的应用。本研究使用从平均 LCA 结果估算的温室气体排放（GHG）热点（具有高或低温室气体排放值的统计上显著的农场集群）的识别，并评估此类热点中的相对毁林风险。在 2008 年至 2010 年期间，秘鲁圣马丁地区托卡切省共有 1892 个农场进行了评估。平均 LCA 结果与农场规模、年龄和森林采伐程度相结合，可以确定在环境影响和潜在森林砍伐上具有高相对风险的地区和农场。据估计，属于高温室气体排放热点的农场比低温室气体排放热点的农场扩大其农业边界和造成森林采伐的可能性高两倍。将 LCA 与地理信息系统和地质统计学相结合是探索评估结果差异的可行途径，这可能导致更快、更准确和资源有效的方法来解决环境影响，同时还可以解决诸如毁林等重要环境影响。未来研究需要进一步将本文建议的方法应用于其他多年生作物和其他地理区域。

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Spatio-Temporal Differentiation of Life Cycle Assessment Results for Average Perennial Crop Farm: A Case Study of Peruvian Cocoa Progression and Deforestation Issues

Giancarlo Raschio, Sergiy Smetana, Christian Contreras, Volker Heinz, and Alexander Mathys

Keywords: geo-spatial differentiation in LCA, industrial ecology, land-use change, life cycle assessment, perennial crops impact assessment, relative risk of deforestation

Summary:
The application of spatially and temporally explicit information to increase result precision is gaining momentum in Life Cycle Assessment (LCA) studies. It is vital for the assessment of environmental impact of perennial crops with non-productive years, grown in combination with shade crops. Available studies rely on differentiated life cycle inventory data for the inputs in LCA or application of adapted impact assessment methodologies. This study uses the identification of greenhouse gas emissions (GHG) hotspots (statistically significant clusters of farms with either high or low GHG emission values) estimated from average LCA results and assesses a relative deforestation risk in such hotspots. A total of 1892 farms in the Tocache province of San Martin region of Peru were evaluated between the year 2008 and 2010. Combination of average LCA results with farm size, age and deforestation progression allowed for the identification of areas and farms with a high relative risk of environmental impacts and potential deforestation. It was estimated that farms belonging to high-GHG emission hotspots were twice more likely to expand their agricultural frontier and cause deforestation than farms in low-GHG emission hotspots. Combining LCA with geo-information systems and geostatistics is a viable path to explore the differentiation of assessment results, which might lead to faster, more accurate, and resource-efficient ways to tackle environmental impacts while also accounting for important environmental impacts such as deforestation. Further research on the application of suggested approaches with other perennial crops and other geographical areas is needed.

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马尼拉的脏衣服： 个人和共享式洗衣方式的资源消耗比较

作者： Monique Retamal, Heinz Schandl

关键字： ：发展中国家，家庭，产业生态学，产品-服务系统，社会实践，可持续消费

摘要：

改变发展中国家和新兴经济体的生活方式伴随着技术使用、日常实践和资源消耗的转变。重要的是要了解这些变化带来的的可持续性方面的后果，以及通过可能的政策指导实践向更可持续的生活方式转变。在本研究中，我们调查了菲律宾马尼拉市的洗衣方式，包括：（1）传统手工洗涤、（2）家用机器洗涤、以及（3）使用洗衣服务，并比较了三种不同方式的资源消耗情况。除了水、能源和洗涤剂的消耗的对比外，我们还从社会实践理论的视角探讨了洗衣的社会影响。通过访谈洗衣服务运营商和家庭洗衣人员，我们获取了经验数据，定性和定量地分析了洗衣实践及资源消耗情况。结果显示手洗的水耗和能耗最低，但洗涤剂用量很大。机洗和洗衣服务水耗相当，但使用干洗的洗衣服务能耗显著较高。社会变革，如：女性工作机会增多、未来住房的性质等，可能会影响采用共享或个人洗衣方式的占比。这些发现表明了向产品-服务系统过渡的社会复杂性以及社会和环境影响之间的相互依赖关系。

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Dirty Laundry in Manila: Comparing Resource Consumption Practices for Individual and Shared Laundering

Monique Retamal and Heinz Schandl

Keywords: developing countries, households, industrial ecology, product-service system (PSS), social practices, sustainable consumption

Summary:

Changing lifestyles in developing and emerging economies entail a shift in technology use, everyday practices, and resource consumption. It is important to understand the sustainability consequences of these changes and the potential for policy to guide practices toward more sustainable lifestyles. In this study, we investigate laundry practices in the City of Manila, the Philippines, and compare the resources consumed in three different modes of laundering. We examine (1) traditional washing by hand, (2) washing by machine at home, and (3) using a laundry service. In addition to comparing the consumption of water, energy, and detergents, we also examine the social aspects of laundering using the lens of social practice theory. We use empirical data gathered in interviews with laundry service operators and people laundering at home to undertake qualitative and quantitative analyses of laundry practices and resource consumption. We find that hand washing uses the least water and energy, but large quantities of detergents. Machine washing and laundry services are comparable for water consumption, but energy use is much higher for services as they use dryers. Social changes, such as an increase in work available for women and the nature of future housing, are likely to influence the dominance of either shared or individual laundering methods. These findings illustrate the social complexity of transitions to product-service systems and the interdependencies between their social and environmental impacts.

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工业园区发展的环境绩效评价 ： 以沈阳为例

作者： Huijuan Dong, Zuoxi Liu, Yong Geng, Tsuyoshi Fujita, Minoru Fujii, Lu Sun, Liming Zhang

关键字： 分解分析，能值，环境表现，产业生态学，产业共生，可持续性

摘要：
为提升工业园区的整体可持续性，需要了解工业园区的发展特点，从而提出相应的管理措施。在此背景下，本研究通过能值指标分析沈阳经济技术开发区（SETDZ）环境绩效的变化，并运用分解分析方法探讨其内在驱动力。结果表明，在招商阶段（2001-2006），随着产业规模的扩大，当地资源的开发利用使总能值迅速上升，可持续性水平显著下降。进入产业集群和升级阶段（2007-2010），总能值加速增长，但由于资源效率提高和技术进步，环境绩效没有下降太多。落实产业共生（IS）（2011-2013）能够进一步有效降低总能值消耗，改善环境绩效，但目前构建产业共生的投入尚显不足，需要进一步加以推动。在各发展阶段总能值消耗的影响因素中，区域生产总值和工业园区面积是最重要的驱动因素。在能值可持续性方面，可再生能源占比（R1/U）是一个关键的影响因素。因此，如何提升可再生资源比重，扩大产业共生规模，将是实现园区可持续发展的关键战略部署。

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Evaluating Environmental Performance of Industrial Park Development: The Case of Shenyang

Huijuan Dong, Zuoxi Liu, Yong Geng, Tsuyoshi Fujita, Minoru Fujii, Lu Sun, and Liming Zhang

Keywords: decomposition analysis, emergy, environmental performance, industrial ecology, industrial symbiosis, sustainability

Summary:
In order to improve the overall sustainability of industrial parks, it is necessary to understand the development characteristics of industrial parks so that appropriate management measures can be raised. Under such a circumstance, this study analyzes the changes in the environmental performance of Shenyang Economic and Technology Development Zone (SETDZ) in terms of emergy-based indicators and explores underlying driving forces using decomposition analysis methods. The results show that in the industrial recruitment stage (2001–2006), the total emergy increased rapidly and the sustainability level decreased significantly because of the exploitation of local resources with the expansion of industrial scale. After entering the industrial cluster and upgrading stage (2007–2010), the total emergy increased even faster, while the environmental performance did not decrease too much because of the improved resource efficiency and improved technological progress. The implementation of industrial symbiosis (IS) (2011–2013) could have further effectively reduced the total emergy consumption and improved the environmental performance, but current symbiosis efforts were not sufficient and need to be further promoted. Gross regional product and area of the industrial park were the most important driving factors to the total emergy for all the development stages. In terms of emergy sustainability, renewable emergy ratio (R1/U) was one key impact factor. Therefore, how to improve the ratio of renewable resources and enhance IS scopes will be the key strategies for its sustainable development.

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班加罗尔市的城市代谢：水量平衡分析

作者： Reba Paul, Steven Kenway, Brian McIntosh, Pierre Mukheibir

关键字： 替代水资源，系统边界，水性能指标，水回用，城市水核算，城市水规划

摘要：
城市为满足自身用水需求越来越依赖能源密集型水源，例如遥远的河流和海洋。然而，如果另辟蹊径，使用一些当地水源（例如废水、雨水和暴雨水），则可以避免依赖那些昂贵的水源。由于估算本地化水资源需要在复杂的城市水系统中进行全面核算，因此许多城市都缺少对它们的有力记录。本文研究建立在城市水量平衡基础上的城市代谢评估框架是否有助于分析这些资源，尤其是对于快速发展中的城市。我们首先完善了 Kenway 及其同事在 2011 年针对发展中国家开发的水量平衡方程，并使其涵盖一些重要组成部分，如系统损失。而后，我们首次将完善后的方程应用于一个真实案例——2013 至 2014 年的印度班加罗尔市，这是一类较为少见的水量平衡分析。该公式帮助分析了班加罗尔的城市供水系统。可用的废水、暴雨水和雨水总量为 656 千兆升（GL）。如果利用 54%的回用潜力，可以满足水需求和供水之间的差距。废水具有足够的潜力（362 GL）来取代来自 Cauvery 的整个集中供水。情景分析表明，如果利用 60%的回用潜力，可以满足 2021 年水资源供需之间的差距。本方法可用于帮助其它城市识别替代水源的潜力，并支持综合水资源规划和监测水代谢表现。

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Urban Metabolism in Bangalore City: A Water Mass Balance Analysis

Reba Paul, Steven Kenway, Brian McIntosh, and Pierre Mukheibir

Keywords: alternative water resources, system boundary, water performance indicator, water reuse, urban water accounting, urban water planning

Summary:
Cities are increasingly depending on energy-intensive water sources, such as distant rivers and the ocean, to meet their water demand. However, such expensive sources could be avoided using alternative local sources of water such as wastewater, rainwater, and stormwater. Many cities do not have robust accounts of those localized water resources, as estimating those resources requires comprehensive accounting in complex urban water systems. In this article, we investigate whether an urban metabolism evaluation framework built on the urban watermass balance can help analyze these resources, especially in a rapidly growing developing city. We first refined the water mass balance equation developed by Kenway and his colleagues in 2011 for a developing country context with the inclusion of some significant components such as system loss. Then, we applied the refined equation for the first time to Bangalore city in India, a developing country, for the year 2013–2014 as a real case example, which is a rare water mass balance analysis of its kind. The refined equation helped analyze Bangalore's urban water system. The total available wastewater, stormwater, and rainwater were 656 gigaliters (GL). The gap between water demand and supply could be met if 54% of this recycled potential were harnessed. Wastewater had enough potential (362 GL) to replace the whole centralized water supply from the Cauvery. A scenario analysis showed that the gap between water demand and supply in 2021 can be met if 60% of total recycled potential is utilized. This approach can be used to help other cities identify the potential of alternative water sources and support integrated water planning and monitoring water metabolic performance.

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美国产品尺度的铝在用存量动态分析

作者：Wei-Qiang Chen

关键字： 产业生态，在用存量，铝的使用模式，存量与流量分析，物质流分析，资源可持续使用

摘要：

本研究估算了美国 1960–2009 年（部分产品的时间段更长）铝的在用存量，并对产品尺度和部门尺度铝在用存量的历史演变趋势进行了分析。主要结论如下：（1）在除了机械设备之外的 5 个部门中，产品尺度与部门尺度的估算结果匹配的很好，从而验证了两种估算方法的稳健性和可靠性；（2）铝的在用存量（无论从绝对量、人均量还是户均量计算），在用铝产品进入市场后会经历一个阶段的持续增加，但在此后基本遵循四种不同的模式（增加、减少、趋于饱和以及震荡波动）；（3）对比产品尺度与部门尺度的铝在用存量，可以揭示和解释少数产品主导或强烈影响某一个部门铝在用存量历史演变趋势的现象。相较以往仅限于部门尺度的核算结果，本研究中在产品尺度上核算的铝在用存量结果可以使制造商、金属供应商、回收商和政府决策者更加准确地寻求与材料可持续利用相关的政策举措。

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Dynamic Product-Level Analysis of In-Use Aluminum Stocks in the United States

Wei-Qiang Chen

Keywords: industrial ecology, in-use stock, patterns of aluminum use, stocks and flow analysis, substance flow analysis (SFA), sustainable resource use

Summary:

This study estimates product-level in-use stocks of aluminum in the United States for the period 1960–2009 (or longer in some cases) and explores patterns of the historical evolution of in-use aluminum stocks at both product and sector levels. The principal findings are the following: (1) results estimated by the product-level methods in this study match reasonably well with those estimated by the sector-level method for five sectors (except the Machinery and Equipment sector), meaning that the methods verify the robustness and reliability of each other; (2) after early period(s) of increase since aluminum-containing products were introduced into the market, in-use aluminum stocks at the product level, based on either absolute, per capita, or per household terms, follow one of four different patterns (Increase, Decrease, Saturation, and Fluctuation), determined by the historical evolution of product stocks and flows and aluminum contents in products; and (3) when aggregated, in-use aluminum stocks at the product level can be used to compare with and explain the historical evolution of the in-use aluminum stocks at the sector level that are estimated by the top-down method, with only a few products dominating or significantly influencing the historical evolution pattern for a whole sector. These results may enable manufacturers, metal suppliers, recyclers, and governments to plan their material-related policies and actions with increased precision compared to previous top-down results that are only available at the sector level.

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贸易中的工业集约化和隐含能源： 捷克斯洛伐克计划经济下的能源远景

作者：Hana Nielsen

关键字： 中央计划，捷克斯洛伐克，经济史，隐含能源，对外贸易，产业生态学

摘要：
本文通过自下而上的方法计算了制造品贸易过程中的隐含能源，以探究捷克斯洛伐克的对外贸易在其能源消费中的作用。研究从独特的视角展示了一个政体不断变化的国家贸易中隐含能源的年际变化。整体而言，捷克斯洛伐克在整个二十世纪一直是能源的净出口国，国内能源消费平均 12%体现在出口上。研究发现，中央计划对贸易中隐含能源的绝对水平有显著影响，1972 年贸易中隐含能源达到峰值，当时捷克斯洛伐克人均实际能源净出口为 29 千兆焦耳，远高于 1970 年的瑞典和 2013 年的中国。产品专业化程度的提升和向重工业产品的转移，对出口中隐含能源的构成也造成了明显影响。尽管如此，在调整对外贸易后，捷克斯洛伐克的能源强度曲线并没有随之发生显著变化。

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Industrial Intensification and Energy Embodied in Trade: Long-Run Energy Perspective of the Planned Economy of Czechoslovakia

Hana Nielsen

Keywords: central planning, Czechoslovakia, economic history, embodied energy, foreign trade, industrial ecology

Summary:
This paper examines the role of foreign trade in the consumption of energy in Czechoslovakia through a bottom-up approach in accounting for energy embodied in trade with manufactured goods. It provides a unique analysis of annual changes in energy embodied in trade in a country characterized by changing political regimes. On the whole, Czechoslovakia has been a net exporter of energy throughout the twentieth century with an average 12% of domestic energy consumption embodied in exports. The role of central planning was found to have a significant effect on the absolute levels of energy embodied in trade, which reached its peak in 1972, when Czechoslovakia had net exports of embodied energy of 29 gigajoules per capita, well above those of Sweden in 1970 or China in 2013. Increased product specialization with a shift toward heavy industrial goods also had a clear impact on the composition of energy embodied in exports. Despite this development, the energy intensity curve of Czechoslovakia does not change substantially when adjusted for foreign trade.

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国家社会-代谢概况的解释变量和全球化经济中国家物质流预测的问题

作者：James West, Heinz Schandl

关键字： 预测，物质流分析（MFA），面板分析，社会代谢，社会代谢转型，STIRPAT

摘要：
确定哪些社会经济因素可以解释国家社会代谢概况的差异，并量化它们的表现，与国家层面的物质流量是否能够准确预测到足以为政策提供信息的程度的问题相关。在这项研究中，我们采用面板分析来测试各种社会经济变量，以分析他们对不同国家之间物质流动轨迹变化的解释能力。我们发现，除了长期存在的人口和富裕（人均国内生产总值[GDP]）的解释变量之外，其他变量几乎无法解释各国之间的剩余差异。对此提出的主要解释是，随着产品供应链日益全球化，期望国家层面的物质流动能够密切反映国家层面的发展是不合适的。全球化贸易对国家物质流动的影响是深远的，并且通过文中讨论的许多不同的机制影响。这意味着，尝试长期预测国家对初级材料的需求不大可能是一项富有成效的活动，而进一步改进现有模型的努力可能不会大大改善结果。相反，在全球范围内预测物质流量可能是合理的，但其取决于对人口和 GDP 的准确预测。国家物质流和全球经济的联系对于试图通过在国家一级孤立采取政策措施以实质性地影响全球可持续性的效力具有重要意义。

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Explanatory Variables for National Socio-Metabolic Profiles and the Question of Forecasting National Material Flows in a Globalized Economy

James West and Heinz Schandl

Keywords: forecasting, material flow analysis (MFA), panel analysis, societal metabolism, sociometabolic transitions, STIRPAT

Summary:
Identifying which socioeconomic factors can explain differences in national sociometabolic profiles, and quantifying how well they do it, is relevant to the question of whether national-level material flows can be forecast accurately enough to inform policy. In this study, we employed panel analyses to test a wide range of socioeconomic variables with respect to their ability to explain variations in the material flows trajectories between different nations. We found that, apart from the long-established explanatory variables of population and affluence (gross domestic product [GDP] per capita), additional variables do little to explain the remaining variation between countries. The main explanation proposed for this is that, as product supply chains are increasingly globalized, expecting national-level material flows to closely reflect national-level development is not appropriate. The effects of globalized trade on national material flows are profound, and come via a number of different mechanisms, discussed in the study. This implies that attempting long-term prediction of national demand for primary materials is unlikely to be a fruitful activity, and that further efforts to refine existing models will probably not greatly improve results. Conversely, forecasting material flows at the global scale may not be unreasonable, but would be contingent on having accurate forecasts of population and GDP. The linkage of national material flows to the global economy has important implications for the efficacy of attempting to materially affect global sustainability via policy measures taken in isolation, at the national level.

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物质强度的统计预测 ： 来自全球经济和 107 个国家的证据

作者： George C. Efthimiou, Panos Kalimeris, Spyros Andronopoulos, John G. Bartzis

关键字： Beta分布，经济增长，极值，物质强度，物质流核算，概率密度函数

摘要：
经济的物质强度（MI）仍然是国际统计和报告中引用最广泛的指标之一，它评估了经济过程中自然资源的有效利用和生产力。在当代经济范围物质流核算框架下，通过估计国内物质消耗（DMC）与国内生产总值（GDP）指数的比率（DMC/GDP）来评估一个国家的物质强度。实际上，自然资源对经济过程的重要贡献需要建立对未来这种错综复杂关系的可靠预测。这些预测可以为决策者和从业者提供关键信息，以评估在生产过程中有效利用自然资源的未来动态。为实现这一目标，本研究基于 β 分布，通过使用确定性模型预测最大期望值，评估并提出 MI 统计预测的替代新方法。我们根据全球经济估计的 MI 计算确定性模型的参数，然后通过使用来自 107 个国家估计的 MI 来进行模型的评估。模型与估算之间的一致性非常好。所提出的方法的优点是其简单性，因为通过使用物质强度的两个统计量（均值和方差）和完整的时间尺度，可以计算具有高置信度的任何国家的 MI 的概率。

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Statistical Projection of Material Intensity: Evidence from the Global Economy and 107 Countries

George C. Efthimiou, Panos Kalimeris, Spyros Andronopoulos, and John G. Bartzis

Keywords: beta distribution, economic growth, extreme value, material intensity, material flow accounting, probability density function

Summary:
The material intensity (MI) of the economy remains among the most widely cited indicators in international statistics and reports, evaluating the efficient use and productivity of natural resources in the economic process. In the context of the contemporary economy-wide material flow accounting framework, the material intensity of a country is evaluated through the estimation of the ratio of the domestic material consumption (DMC) to the gross domestic product (GDP) index (DMC/GDP). Indeed, the essential contribution of natural resources to the economic process requires the establishment of reliable projections of this intricate relationship to the future. These projections may provide critical information to policy makers and practitioners in order to evaluate the future dynamics of the efficient use of natural resources in the production process. Toward this objective, the present study evaluates and proposes an alternative novel methodology for MI statistical projections, based on the beta distribution, by using a deterministic model for predicting the maximum expected values. The parameters of the deterministic model are calculated from the estimated MI of the global economy. The evaluation of the model is then performed by using MI estimates from 107 individual countries. The agreement between the model and the estimates is very good. The proposed method's merit is its simplicity, as by using two statistics of the material intensity (mean and variance) and an integral time scale, it is feasible to calculate the probabilities of the MI of any country with a high degree of confidence.

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耦合强度：一种评估全球资源耦合的新指标

作者：David Font Vivanco, Ranran Wang, Edgar Hertwich

关键字： 足迹, 产业生态学, 投入产出分析（IOA）, 线性目标规划, 资源管理, 资源耦合

摘要：

获取自然资源的机会有限是各种空间尺度可持续性的主要制约因素。这一挑战引发了学术界对资源之间的联系或耦合的兴趣，以期帮助预测不可预见的后果，确定权衡和共同利益，并找到最佳解决方案。然而，尽管进行了数十年的研究，研究的范围和重点仍然存在局限性。最近建立的多区域投入产出（MRIO）数据库以前所未有的细节覆盖了全球经济及其资源使用，可以系统地调查各级生产和消费过程的资源使用情况，并获得对全球资源耦合（GRN）问题的新见解。本文讨论了如何确定此类问题的优先级。使用 MRIO 数据库 EXIOBASE，我们考虑了五种关键资源来解决 GRN 问题：蓝水、一次能源、土地、金属矿石和矿物。我们提出了耦合强度这一度量指标，它依赖于线性目标规划，根据其相关组合资源使用和各种加权方案对行业和产品进行排名。我们的结果验证了当前研究将水、能源和土地确定为全球及各尺度的最强联系是正确的，同时，也有对 GRN 的新发现，其中：（1）从消费的角度来看，它似乎更强大、更复杂；（2）金属和矿物是关键但被低估的组成部分；以及（3）由于经济结构、国内政策、技术和资源禀赋的差异，它在各国之间表现出相当大的多样性。

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Nexus Strength: A Novel Metric for Assessing the Global Resource Nexus

David Font Vivanco , Ranran Wang, and Edgar Hertwich

Keywords: footprints, industrial ecology, input-output analysis (IOA), linear goal programming, resource management, resource nexus

Summary:

The limited access to natural resources is a major constraint for sustainability at various spatial scales. This challenge has sparked scholarly interest in the linkages or nexus between resources, with a view to helping anticipate unforeseen consequences, identify trade-offs and co-benefits, and find optimal solutions. Yet, despite decades of research, limitations in the scope and focus of studies remain. Recently constructed multiregional input-output (MRIO) databases, which cover the global economy and its use of resources in unprecedented detail, allow systematically investigation of resource use by production as well as consumption processes at various levels and garner new insights into global resource nexus (GRN) issues. This article addresses the question of how to prioritize such issues. Using the MRIO database, EXIOBASE, we address the GRN considering five key resources: blue water, primary energy, land, metal ores, and minerals. We propose a metric of nexus strength, which relies on linear goal programming to rank industries and products based on its associated combined resource use and various weighting schemes. Our results validate current research efforts by identifying water, energy, and land as the strongest linkages globally and at all scales and, at the same time, lead to novel findings into the GRN, in that (1) it appears stronger and more complex from the consumption perspective, (2) metals and minerals emerge as critical, yet undervalued, components, and (3) it manifests with a considerable diversity across countries owing to differences in the economic structure, domestic policy, technology, and resource endowments.