サスティナビリティに向けたイノベーション・システム

鎗目　雅
東京大学公共政策大学院
科学技術イノベーション・ガバナンス (STIG) 特任准教授
Honorary Reader, Department of Science, Technology, Engineering and Public Policy (STEaPP), University College London
yarimemasa@gmail.com

2016年10月27日
キヤノングローバル戦略研究所
エネルギー環境セミナー

Brief Self Introduction

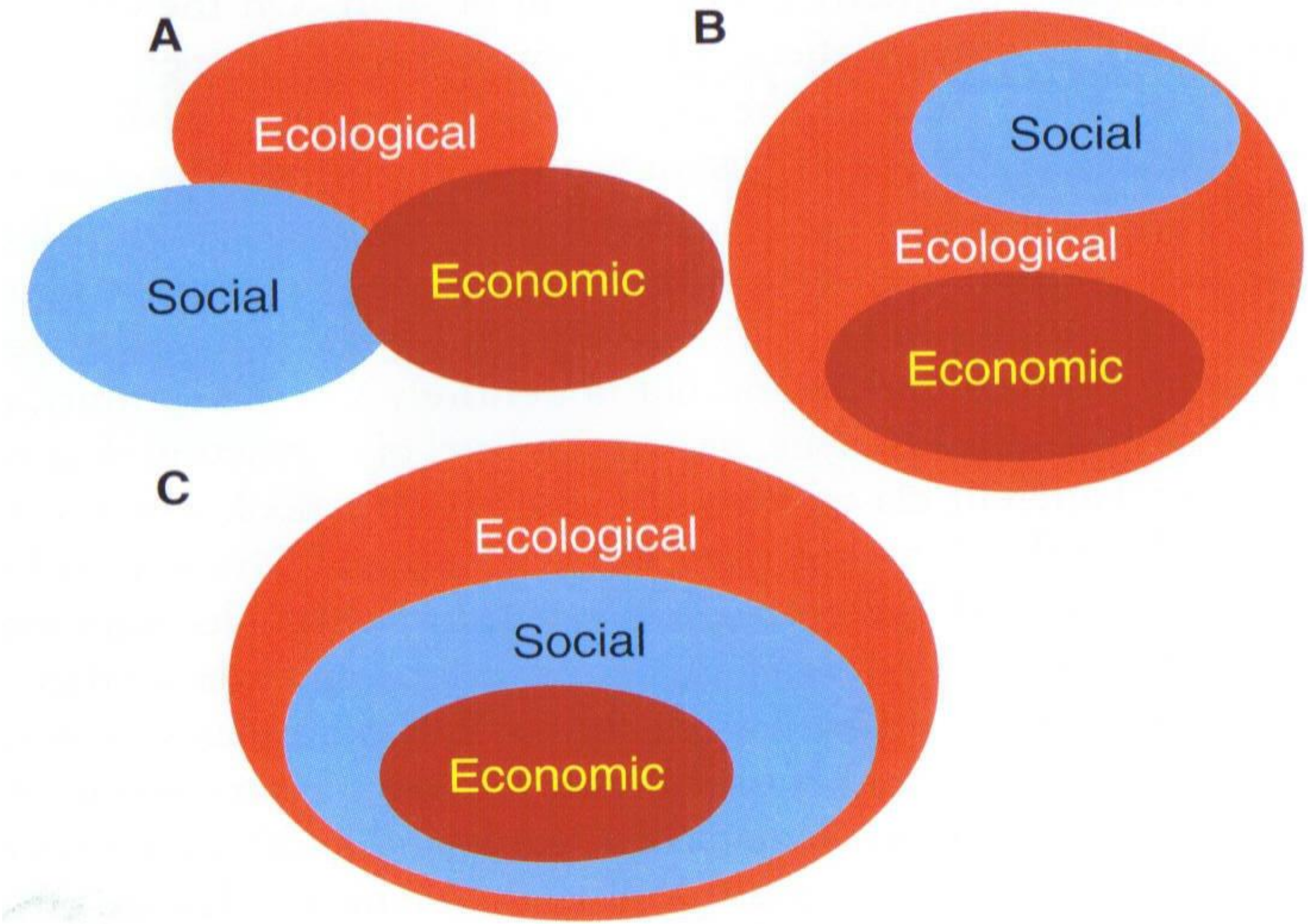
- B.Eng. in Chemical Engineering, University of Tokyo
  - Three-Phase Fluidized Beds
- M.S. in Chemical Engineering, California Institute of Technology
  - Physical and Chemical Processes of Air Pollution
- Ph.D. in Economics and Policy Studies of Technical Change, MERIT-UNU/INTECH Program, University of Maastricht, The Netherlands
  - Effects of Environmental Regulation on Innovation
- Research Center for Advanced Science and Technology, University of Tokyo
  - University-Industry-Government Collaboration for Innovation
- National Institute of Science and Technology Policy (NISTEP), Japanese Ministry of Education, Culture, Sports, Science and Technology
  - Science, Technology and Innovation Policy
- Graduate Program in Sustainability Science and Graduate School of Public Policy, University of Tokyo
  - Public Policy, Corporate Strategy and Institutional Design for Promoting Innovation for Global Sustainability
- Department of Science, Technology, Engineering and Public Policy (STEaPP), University College London (UCL)
  - Mobilization of Science, Technology, and Engineering Knowledge in Public Decision Making on International Environmental Issues, including Air Pollution in East Asia

サステイナビリティに向けた国際的な動向

- 生物多様性：愛知目標（2010年）、生物多様性及び生態系サービスに関する政府間科学・政策プラットフォームIPBES（2012年4月）、作業計画2014-2018
- 防災（災害リスク削減）：仙台枠組2015-2030（2015年3月）
- 開発に向けたファイナンス： アディス・アベバ行動目標（2015年7月）
- ポスト2015年開発アジェンダ：持続可能な開発目標(SDGs)（2015年9月、国連総会）
- 気候変動：COP21 パリ協定（2015年12月）
- 金融安定理事会 (FSB) Phase I Report of the Task Force on Climate-Related Financial Disclosures（2016年3月）
- 世界人道サミット（2016年5月、イスタンブール）


SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS

Sustainability: Integration of Ecological, Economic, and Social Dimensions

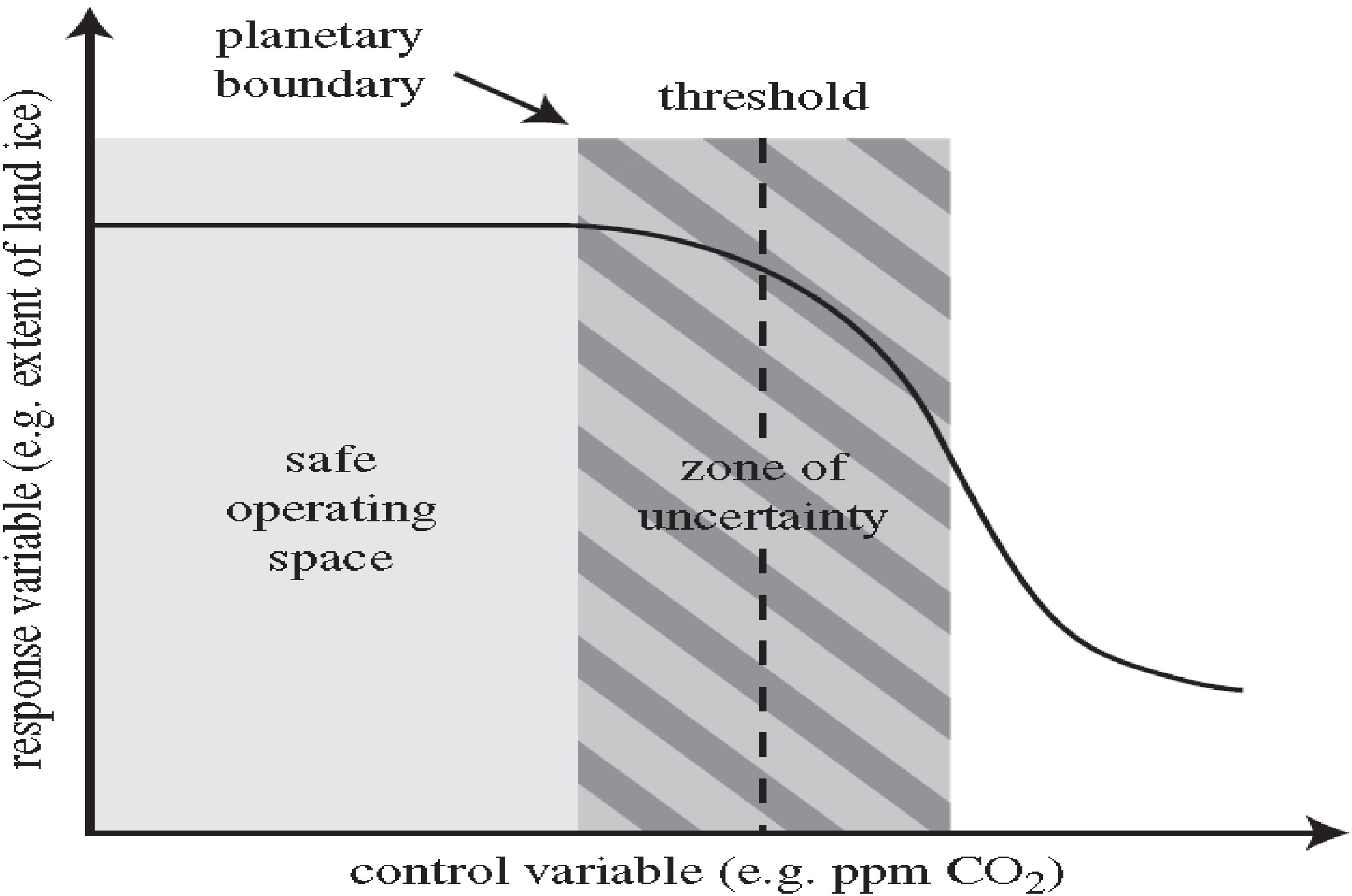


Voinov (2008)

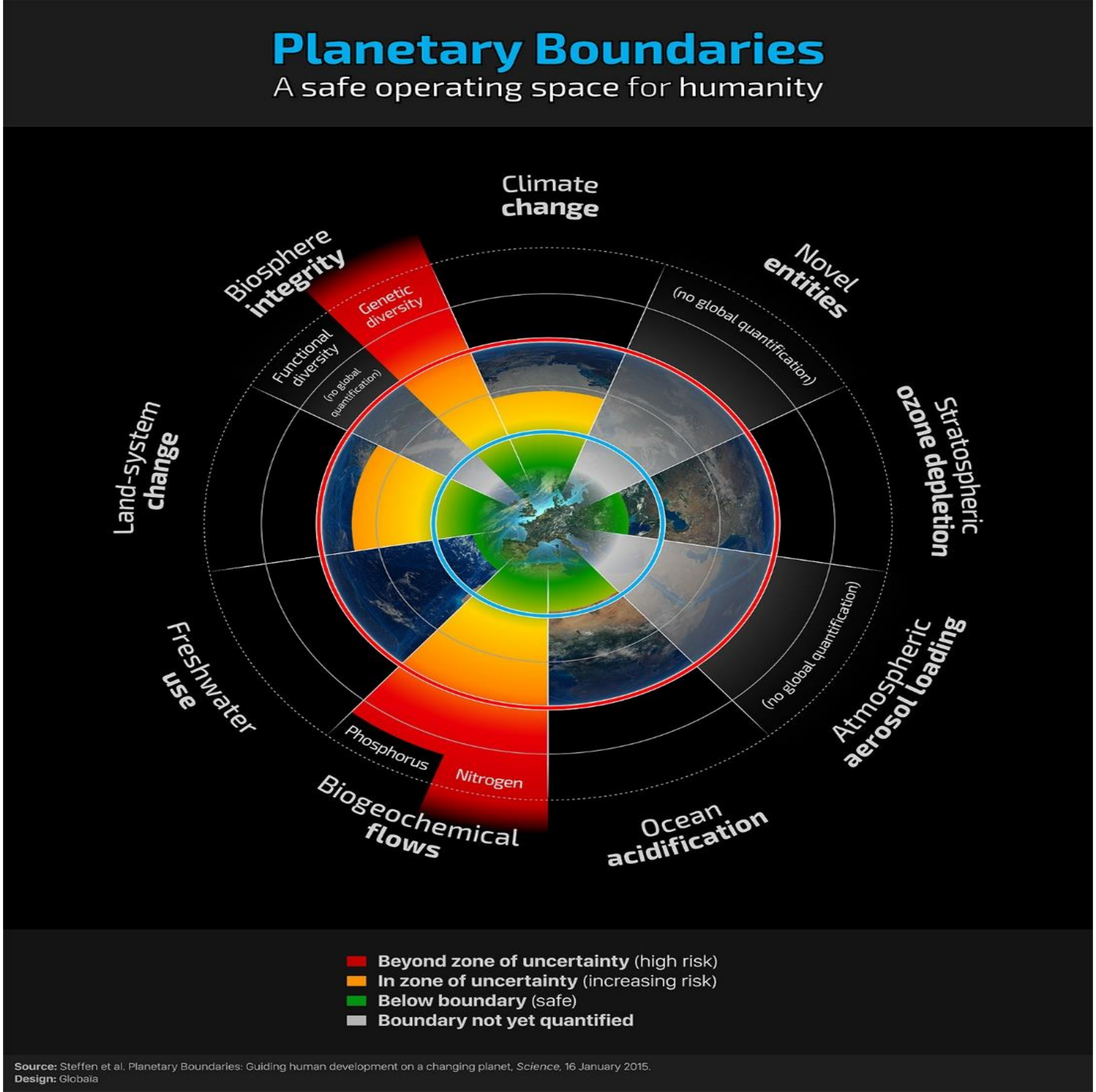
Earth’s Life Support System, Economy, and Society for Sustainability

Griggs, et al. (2013)

Planetary Boundaries: Non-linearity & Irreversibility



Steffen, Grinevald, Crutzen and McNeill (2011)



Planetary Boundaries
A safe operating space for humanity
Climate change
Novel entities
(no global quantification)
Stratospheric ozone depletion
Atmospheric aerosol loading
(no global quantification)
Ocean acidification
Biogeochemical flows
Nitrogen
Phosphorus
Freshwater use
Land-system change
Biosphere integrity
Genetic diversity
Functional diversity
(no global quantification)
Beyond zone of uncertainty (high risk)
In zone of uncertainty (increasing risk)
Below boundary (safe)
Boundary not yet quantified
Source: Steffen et al. Planetary Boundaries: Guiding human development on a changing planet, Science, 16 January 2015.
Design: Globaïa

ENVIRONMENT AND DEVELOPMENT

Earth System Science for Global Sustainability: Grand Challenges

Progress in understanding and addressing both global environmental change and sustainable development requires better integration of social science research.

W. V. Reid,[1*] D. Chen,[2] L. Goldfarb,[2] H. Hackmann,[3] Y. T. Lee,[2] K. Mokhele,[4] E. Ostrom,[5] K. Raivio,[2] J. Rockström,[6] H. J. Schellnhuber,[7] A. Whyte[8]

Tremendous progress has been made in understanding the functioning of the Earth system and, in particular, the impact of human actions (*1*). Although this knowledge can inform management of specific features of our world in transition, societies need knowledge that will allow them to simultaneously reduce global environmental risks while also meeting economic development goals. For example, how can we advance science and technology, change human behavior, and influence political will to enable societies to meet targets for reductions in greenhouse gas emissions to avoid dangerous climate change? At the same time, how can we meet needs for food, water, improved health and human security, and enhanced energy security? Can this be done while also meeting the United Nations Millennium Development Goals of eradicating extreme poverty and hunger and ensuring ecosystem integrity?

Answering these questions will require reorientation toward new research that better allows science and society to address the needs of decision-makers and citizens at global, regional, national, and local scales (*2*). We will have to meet a twofold challenge: (i) develop strategies to respond to ongoing global change while meeting development goals and (ii) deepen knowledge of the functioning of the Earth system and its critical thresholds (*3*). Promoting sustainable development requires research on a wide range of social, economic, cultural, institutional, and environmental issues (*4*). Given that sustainable development is no longer possible without addressing interactions with global change dynamics (*5*), we focus here on an important dimension of this larger sustainability agenda: the need to broaden and deepen Earth system research to encompass the intersection of global environmental change and sustainable development.

[1]David and Lucile Packard Foundation, Los Altos, CA 94022, USA. [2]International Council for Science (ICSU), 75116 Paris, France. [3]International Social Science Council (ISSC), 75732 Paris, France. [4]National Research Foundation of South Africa, Pretoria, 0001, South Africa. [5]Indiana University, Bloomington, IN 47408, USA. [6]Stockholm Environment Institute, SE-106 91 Stockholm, Sweden. [7]Potsdam Institute for Climate Impact Research, 14473 Potsdam, Germany. [8]Environment and Natural Resources, International Development Research Centre, Ottawa K1G 3H9, Canada.

*Author for correspondence: wreid@packard.org

Grand Challenges

A great deal of collaborative international research on global environmental change is coordinated through four Global Environmental Change Research Programmes (*6*) and the Earth System Science Partnership. In light of the need for an overarching set of solution-focused and integrated research priorities for these institutions, the International Council for Science (ICSU) and the International Social Science Council (ISSC) carried out a consultative process to rethink the focus and framework of Earth system research (*7*, *8*). Efforts were made to obtain balanced input from developed and developing country experts, young and senior scientists, social and natural sciences, and both researchers and those using the findings of research. This process resulted in five "Grand Challenges" (listed below in italics), a consensus list of the highest priorities for Earth system science that would remove critical barriers impeding progress toward sustainable development (*9*). The challenges meet four criteria: (i) scientific importance, (ii) need for global coordination, (iii) relevance to decision-makers, and (iv) leverage (i.e., would help address multiple problems). For each grand challenge, several important research questions are identified as answerable within a decade.

Improve the usefulness of forecasts of future environmental conditions and their consequences for people. We need to develop what amounts to an enhanced Earth system simulator to improve our ability to anticipate impacts of a given set of human actions or conditions on global and regional climate and on biological, geochemical, and hydrological systems on seasonal to decadal time scales. Most current efforts to build state-of-the-art whole-Earth system models depart from sophisticated geophysical kernels (coupled atmosphere-ocean models based on exact dynamical equations like Navier-Stokes) that are to be complemented by equally powerful tools (once they become available) representing other parts of the planetary makeup. But, for instance, there is no marine-biosphere model available that will match the standards of the fluid-dynamics–based simulators of the atmosphere within the next 5 years, and the situation seems to be even worse when it comes to simulation of economic, social, and cultural processes. Thus, alternative approaches need to be explored, such as distributed simulators, where available models for all relevant Earth system compartments are virtually assembled from institutions around the world, even if those sectoral models differ heavily in predictive power, or an ensembles approach, where a given Earth system module would be represented by an entire set of credible realizations.

Research is also needed to assess the potential impact of environmental changes on regional economic conditions, food security, water supplies, health, biodiversity, and energy security. Furthermore, research is needed to understand how people are likely to respond to such changes in different sociogeographic and cultural contexts, in particular in poor and vulnerable communities.

Develop, enhance, and integrate observation systems to manage global and regional environmental change. Although investments are being made to build and coordinate more effective observation systems (e.g., the Global Earth Observation System of Systems), current systems fall short of addressing the grand challenges and meeting decision-makers' needs for forecasts and other research products. Economic and social science data, for example, are often gathered and reported at scales that are incompatible for analyzing interlinkages between social and natural systems. The paucity of empirical data on changes in social-environmental systems undermines the ability of decision-makers and the public to establish appropriate responses to emerging threats and address the needs of vulnerable groups. To design cost-effective systems that meet these needs, important scientific questions need to be addressed: What do we need to observe, at what scales, in coupled social environmental systems in order to respond to, adapt to, and influence global change?

Determine how to anticipate, avoid, and

Grand Challenges for Global Sustainability

- Improvement on forecasts
- Integration of observations
- Management of disruptive change
- Determination of institutional changes
- **Encouragement of innovation**

- Better integration of social science research required for progress in understanding and addressing global sustainability

Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report Synthesis Report

ipcc INTERGOVERNMENTAL PANEL ON climate change WMO UNEP

UNEP

Phase 1 Report

A New Angle on Sovereign Credit Risk

E-RISC: Environmental Risk Integration in Sovereign Credit Analysis

UNEP Finance Initiative
Innovative financing for sustainability

Global Footprint Network®
Advancing the Science of Sustainability

Journal of Sustainable Finance & Investment, 2013
http://dx.doi.org/10.1080/20430795.2013.837810

Taylor & Francis
Taylor & Francis Group

Towards a new framework to account for environmental risk in sovereign credit risk analysis

Margot Hill Clarvis[a,b*], Martin Halle[c], Ivo Mulder[b] and Masaru Yarime[d]

[a]*Institute of Environmental Sciences, University of Geneva, Geneva, Switzerland;* [b]*UNEP-FI, Geneva, Switzerland;* [c]*Global Footprint Network, Geneva, Switzerland;* [d]*Graduate School of Public Policy, University of Tokyo, Tokyo, Japan*

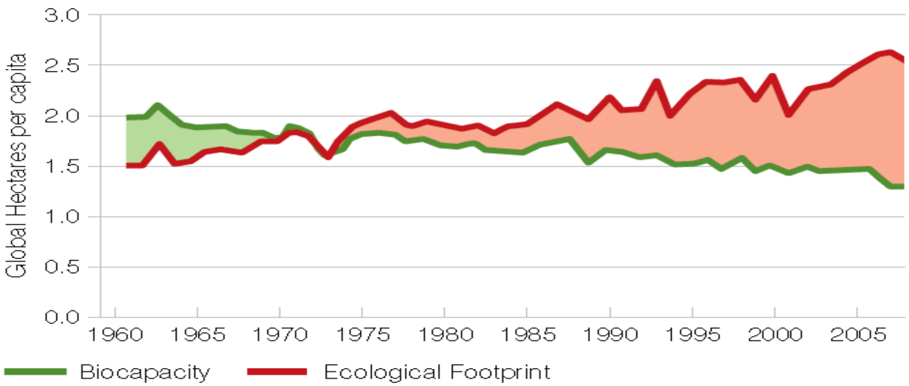
(*Received 14 August 2013; accepted 21 August 2013*)

Despite the growing body of evidence on ecosystem degradation and on-going development in measuring its economic implications, there remains a lack of understanding and integration of environmental risks into investment decision. There is, therefore, currently a weak financial rationale and a limited choice of tools to assess the materiality of environmental risk for the sovereign bond market. Improving investor understanding of the materiality of environmental risks is likely to be crucial to limiting risk exposure of important investments and to encouraging the transition to a greener more sustainable economy. This article presents the development and initial application of a framework that aims to improve the financial rationale for assessing the materiality of environmental risk in the sovereign bond market. It is the result of a collaborative and inter-disciplinary project of researchers and practitioners from a group of financial institutions, the United Nations Environment Programme Finance Initiative, and Global Footprint Network. Results not only show the long- and short-term implications of environmental risk for a wide variety of resource profiles, but also how these risks relate to macroeconomic factors that are already recognised as relevant to sovereign credit risk. This, therefore, presents a more accurate reflection of how these factors might influence the risk or return situation for an investor. More collaborative and innovative research between scientists and practitioners could improve both knowledge and methods to effectively account for the financial materiality of natural resource risks for a country's economy.

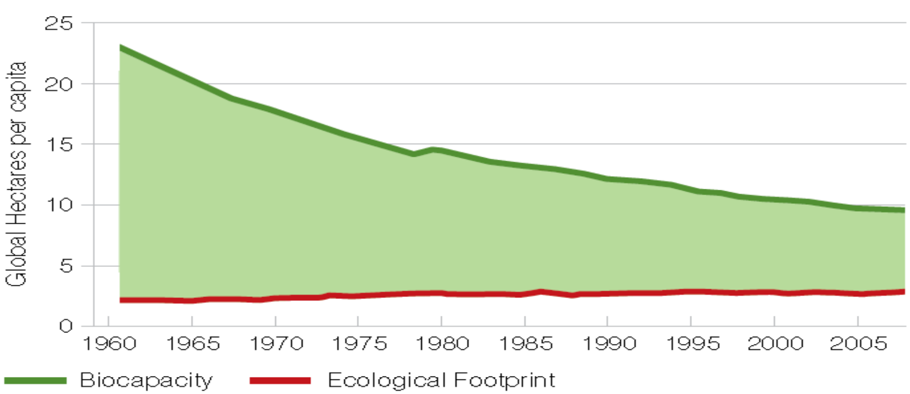
Keywords: sustainability; resource risks; sovereign credit worthiness analysis

FIGURE 7:
Ecological Footprint and biocapacity for five countries, 1961-2008. Green areas mean biocapacity exceeds Footprint and the country is therefore an ecological creditor. Red areas mean Footprint exceeds biocapacity and the country is therefore an ecological debtor. These trends are based on the National Footprint Accounts of Global Footprint Network, 2011 Edition.[30]

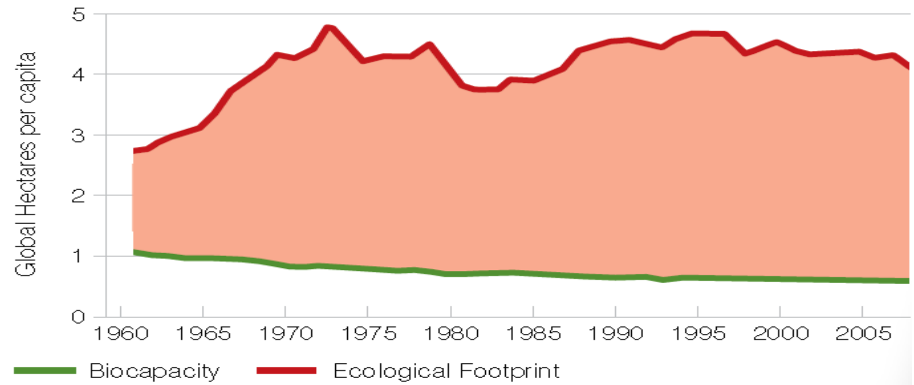
Turkey trends



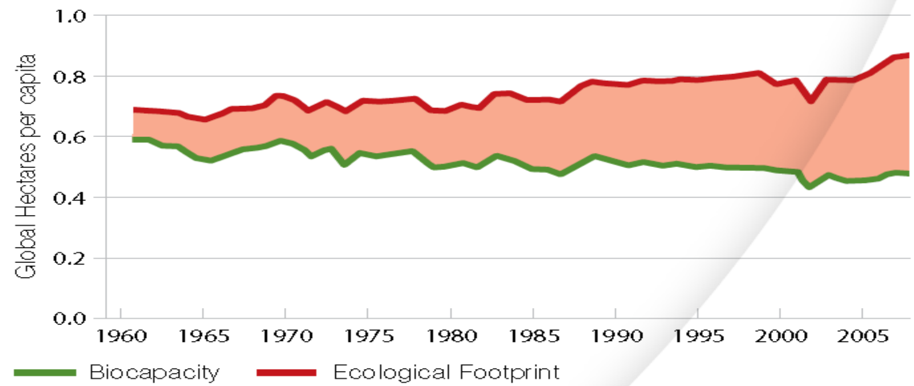
Brazil trends



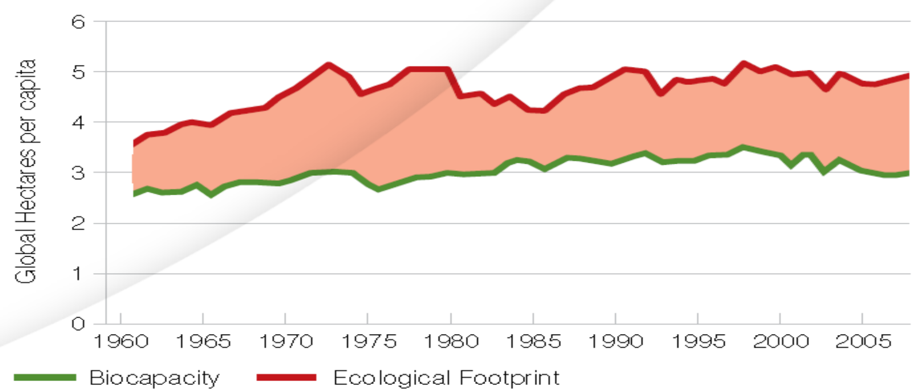
Japan trends



India trends



France trends

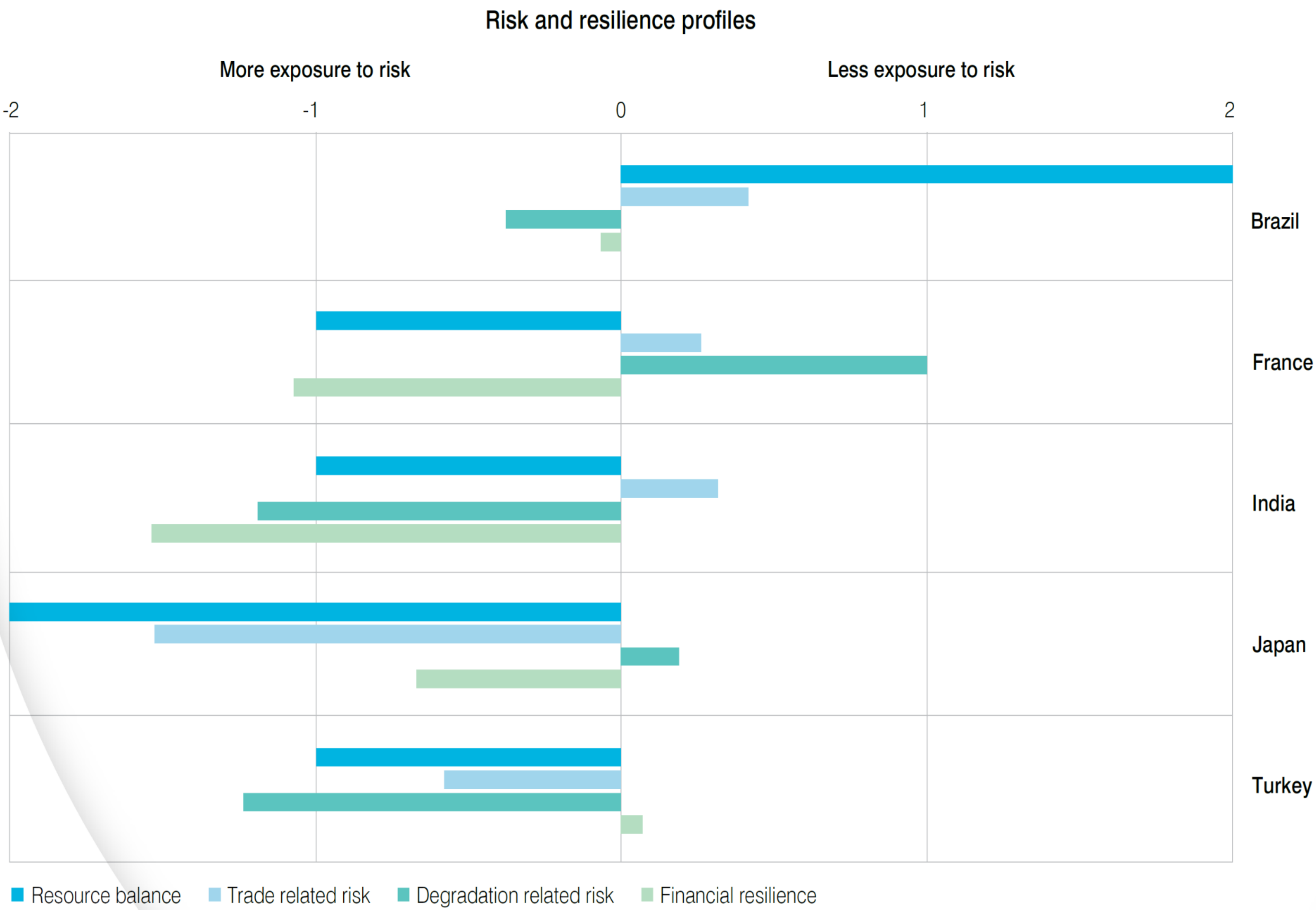


UNEP Financial Initiative (2012)

TABLE 1:
Typology of natural resource risks by timeline, nature, and effect.

Short-term risk	Medium-term risk	Long-term risk
Up to 5 years	5-10 years	10-25 years
Abrupt changes in international commodity trade markets	Cumulative environmental degradation from natural resource overuse	Emission of carbon dioxide (slower and potentially more long term)
Exposure to price volatility of commodities and supply disruption	Reduced productivity of natural resources (soil, crops, fish stocks, etc.) leading to reduced output of products derived from it.	Exposure to carbon pricing and climate change impacts

FIGURE 11:
Overview Results of the Comparative Assessment Tool



The Natural Capital Declaration

A commitment by the finance sector for Rio+20 and beyond

www.naturalcapitaldeclaration.org
info@naturalcapitaldeclaration.org
Twitter @NCDeclaration

Convened by

UNEP Finance Initiative
Innovative financing for sustainability

GCP
GLOBAL CANOPY PROGRAMME

FGV
GVces
Centro de Estudos em Sustentabilidade da EAESP

(2012)

Leading Financial Institutions Support the Launch and Implementation of the Natural Capital Declaration's Programme to Advance Environmental Risk Management in the Financial Sector

Banorte, National Australia Bank, Pax World, UniCredit and the World Bank Group (other Financial Institutions to join) and SECO are supporting NCD in its programme to develop approaches to monitor natural capital risks in portfolios

News Release: 24 November 2015 Bern, Edinburgh, Geneva, Oxford: The Natural Capital Declaration (NCD), the global finance-led initiative convened by the Global Canopy Programme (GCP) and the UN Environment Programme Finance Initiative (UNEP FI) announces today at the World Forum on Natural Capital the launch of its environmental risk management work programme to develop methodologies and tools to map natural capital risks across lending and investment portfolios and to help embed them in credit risk assessments.

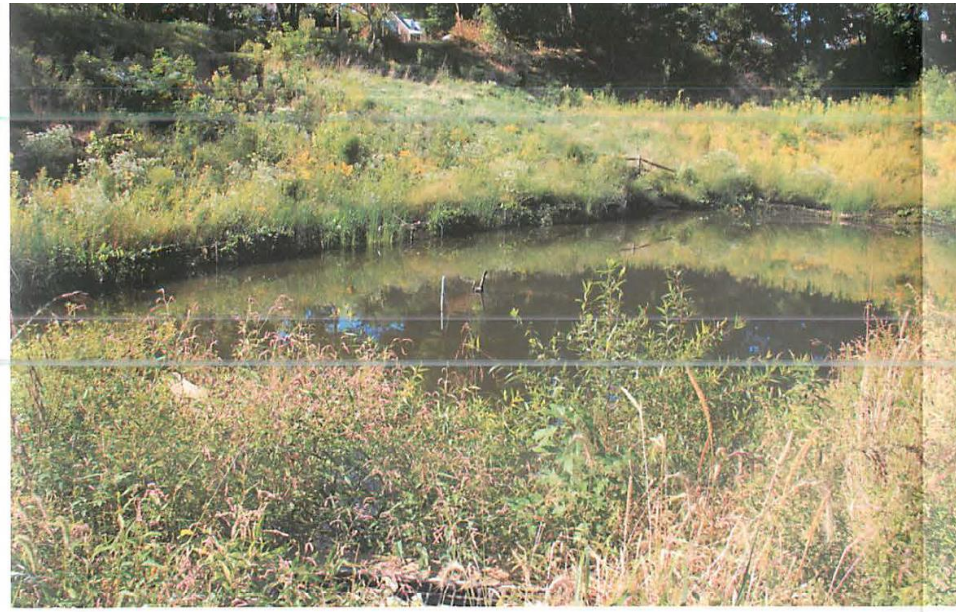
The NCD's 'Advancing Environmental Risk Management' project will commence from November 2015 and be completed over 2.5 years. The project aims to help catalyse sustainable investments and lending globally by reducing risks from environmental and natural resource pressures. The project will support the development of global methodologies to quantify risk and a have a focus on emerging markets such as South Africa, Indonesia, Colombia and Peru. In order to achieve these goals the project has received significant support from the Swiss State Secretariat for Economic Affairs (SECO) with a commitment of CHF 4.2 million (US$ 4.3 million). SECO is already supporting the Natural Capital Agenda at government level through WAVES and at the company level through the Natural Capital Accounting Project.

ISBN978-4-7571-2351-9
C0034 ¥2800E
9784757123519
NTT出版
定価（本体2,800円+税）
1920034028001

【自然資本研究会とは】

自然資本は、その価値や便益は十分認識されておらず、自然破壊や資源枯渇は危機的なレベルにまで達している。かかる状況に対し、欧米では自然資本を経済的に把握しGDPの補完手段としての国家会計への取り込みや、企業会計との統合などの取り組みがスタートしている。本研究会は、さまざまな研究成果などを取り込みながら、自然資本を経済に組み入れる方策を議論するとともに、対外的に広く発信し、「自然資本」が環境問題のキーワードの1つと認識される状況を作り出すことに貢献することを目的に、2013年に発足した。官公庁、シンクタンク、一般企業などのメンバーからなる。委員長は、鎗目雅東京大学公共政策大学院特任准教授。

自然資本入門
国、自治体、企業の挑戦
自然資本研究会［編著］
NTT出版



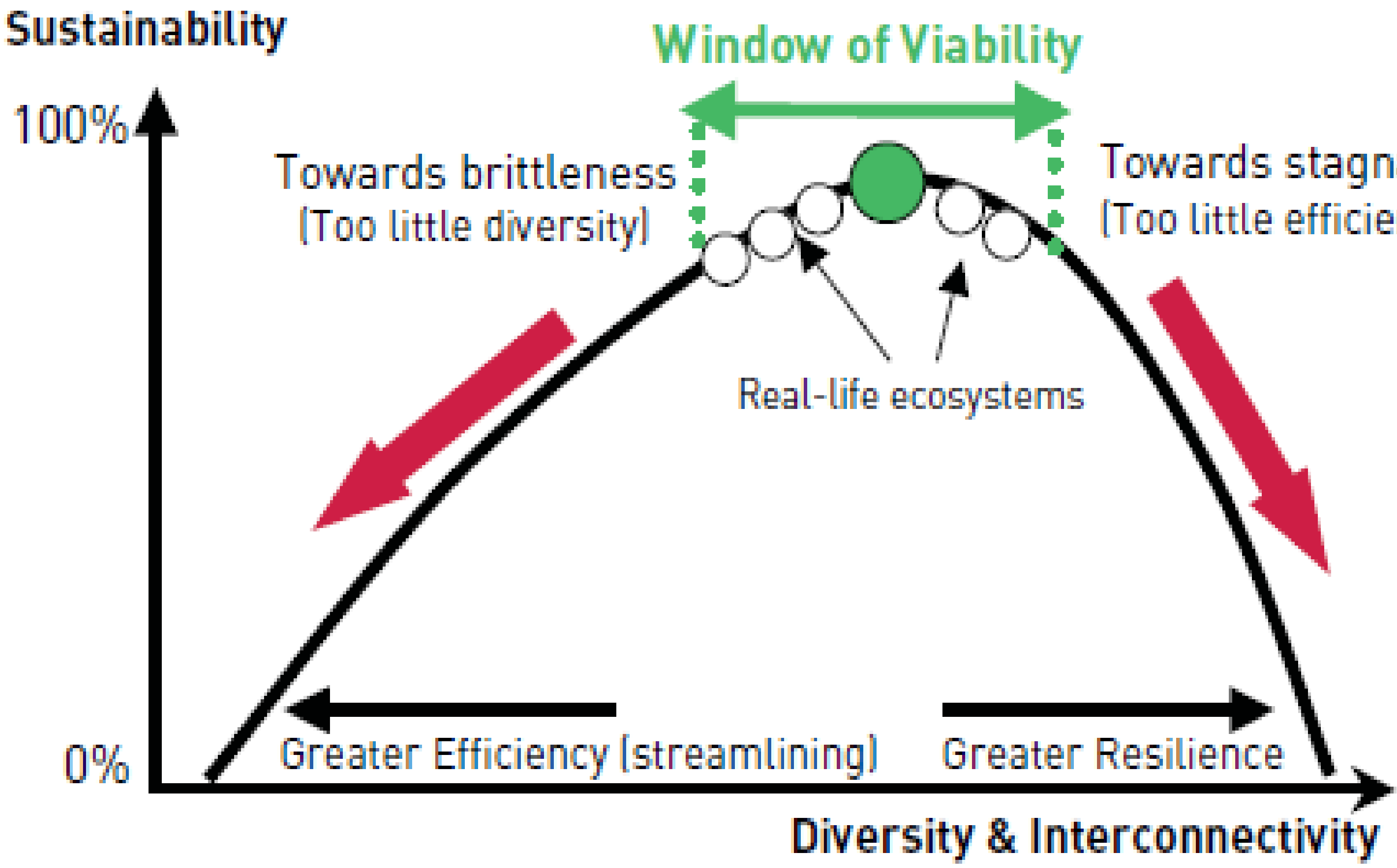
自然資本入門

国、自治体、企業の挑戦

自然資本研究会［編著］

NTT出版

Sustainability as a Balance between Efficiency and Resilience



- Diversity: Existence of different types of agents acting as nodes in network
- Interconnectivity: Number of pathways between agent

Lietaer, Ulanowicz, and Goerner (2009)

Energy Policy 87 (2015) 455–464

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Examining the resilience of national energy systems: Measurements of diversity in production-based and consumption-based electricity in the globalization of trade networks

Ali Kharrazi [a,g,*], Masahiro Sato [b,c], Masaru Yarime [a,d], Hirofumi Nakayama [c], Yadong Yu [e], Steven Kraines [f]

[a] Graduate School of Public Policy (GraSPP), University of Tokyo, Japan
[b] Economic and Social Research Institute, Government of Japan, Tokyo, Japan
[c] InterGreen Research Institute, Tokyo, Japan
[d] Department of Science, Technology, Engineering and Public Policy (STEaPP), University College London
[e] School of Business, East China University of Science and Technology, Shanghai, China
[f] Tokyo City University, Japan
[g] Advanced Systems Analysis Group, International Institute for Advanced Systems Analysis (IIASA), Austria

HIGHLIGHTS

- We examine the resilience of global embodied energy based on (MRIO) trade networks.
- We propose a secure and responsible mode of thinking for national energy consumption.
- Secure & responsible consumption requires diversity in energy generation and imports.

ARTICLE INFO

Article history:
Received 4 May 2015
Received in revised form
7 September 2015
Accepted 16 September 2015

Keywords:
Secure and responsible energy systems
Resilience
Production-based electricity
Consumption-based electricity
Embodied electricity import for consumption
Embodied electricity export for consumption

ABSTRACT

Energy is a critical component of achieving sustainable development. In addition to the three aspects of promoting access, renewables, and efficiency, the dimension of resilience in energy systems should also considered. The implementation of resilient energy systems requires a quantitative understanding of the socio-economic practices underlying such systems. Specifically, in line with the increasing globalization of trade, there remains a critical knowledge gap on the link between embodied energy in the production and consumption of traded goods. To bridge this knowledge gap, we investigate the resilience of global energy systems through an examination of a diversity measure of global embodied electricity trade based on multi-regional input-output (MRIO) networks. The significance of this research lies in its ability to utilize high resolution MRIO data sets in assessing the resilience of national energy systems. This research indicates that secure and responsible consumption requires the diversification of not only energy generation but also energy imports. This research will lay the ground for further research in the governance of resilience in global energy networks.

1. Introduction

A sustainable energy supply is critical for any social economic system. A recent proposal made by the Open Working Group of the United Nations General Assembly on Sustainable Development Goals (SDGs) has emphasized the three aspects of promoting access, renewables, and efficiency for energy systems (UN, 2014). However, it is also important to take into consideration the dimension of resilience in energy systems. Today we live in an environment that is continually faced with disruptions due to shocks, stresses, and extreme events. A disruption to the delivery of energy can lead to major socio-economic and environmental consequences. Many disruptions are associated with natural disasters,

* Corresponding author at: Graduate School of Public Policy (GraSPP), University of Tokyo, Japan and Advanced Systems Analysis Group, International Institute for Advanced Systems Analysis (IIASA), Austria.
E-mail addresses: ali@pp.u-tokyo.ac.jp (A. Kharrazi), masa@intergreen.jp (M. Sato), yarimemasa@gmail.com (M. Yarime), hirofumi.nakayama@intergreen.jp (H. Nakayama), artonry@gmail.com (Yu), steven@kraines.net (S. Kraines).

http://dx.doi.org/10.1016/j.enpol.2015.09.019
0301-4215/

A. Kharrazi et al. / Energy Policy 87 (2015) 455–464

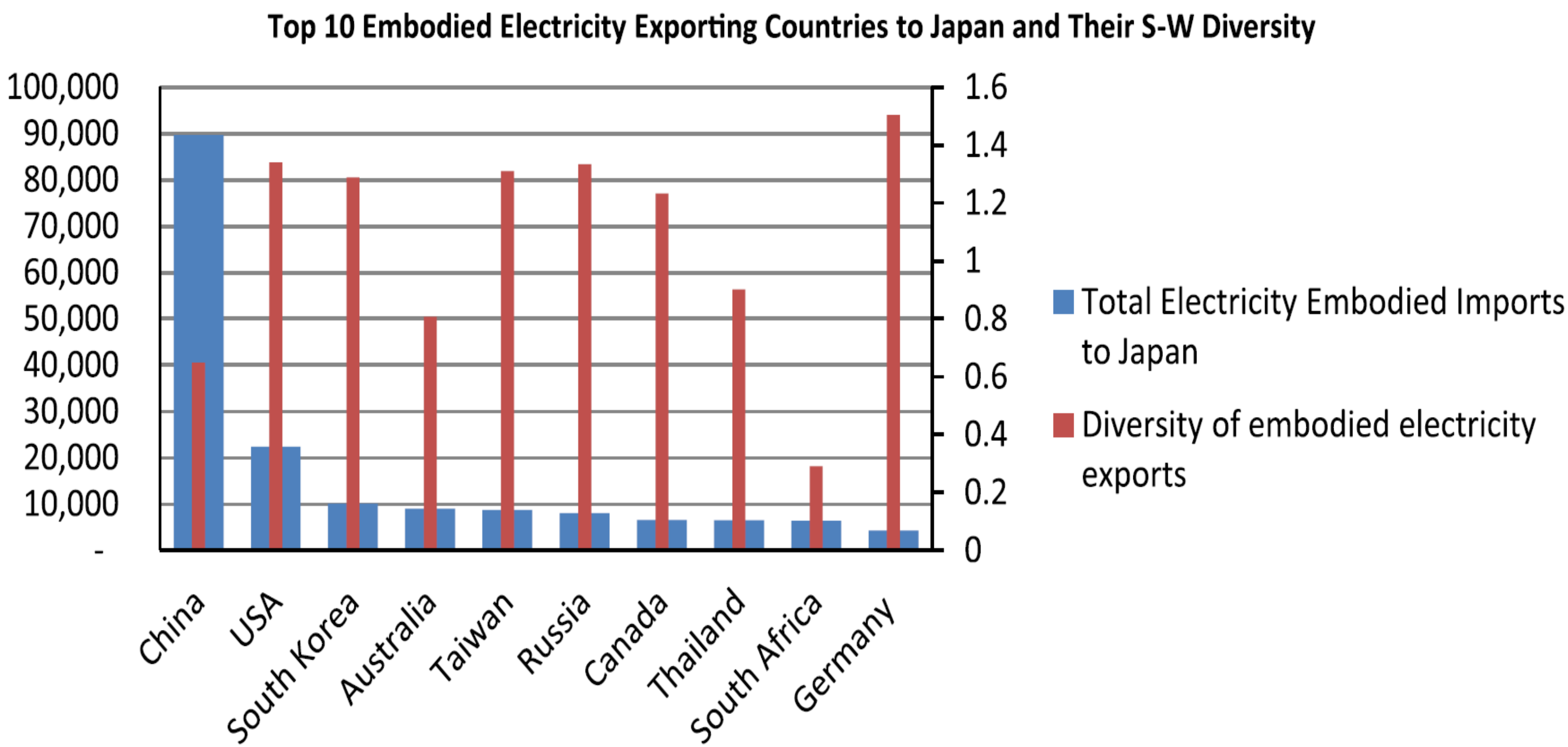
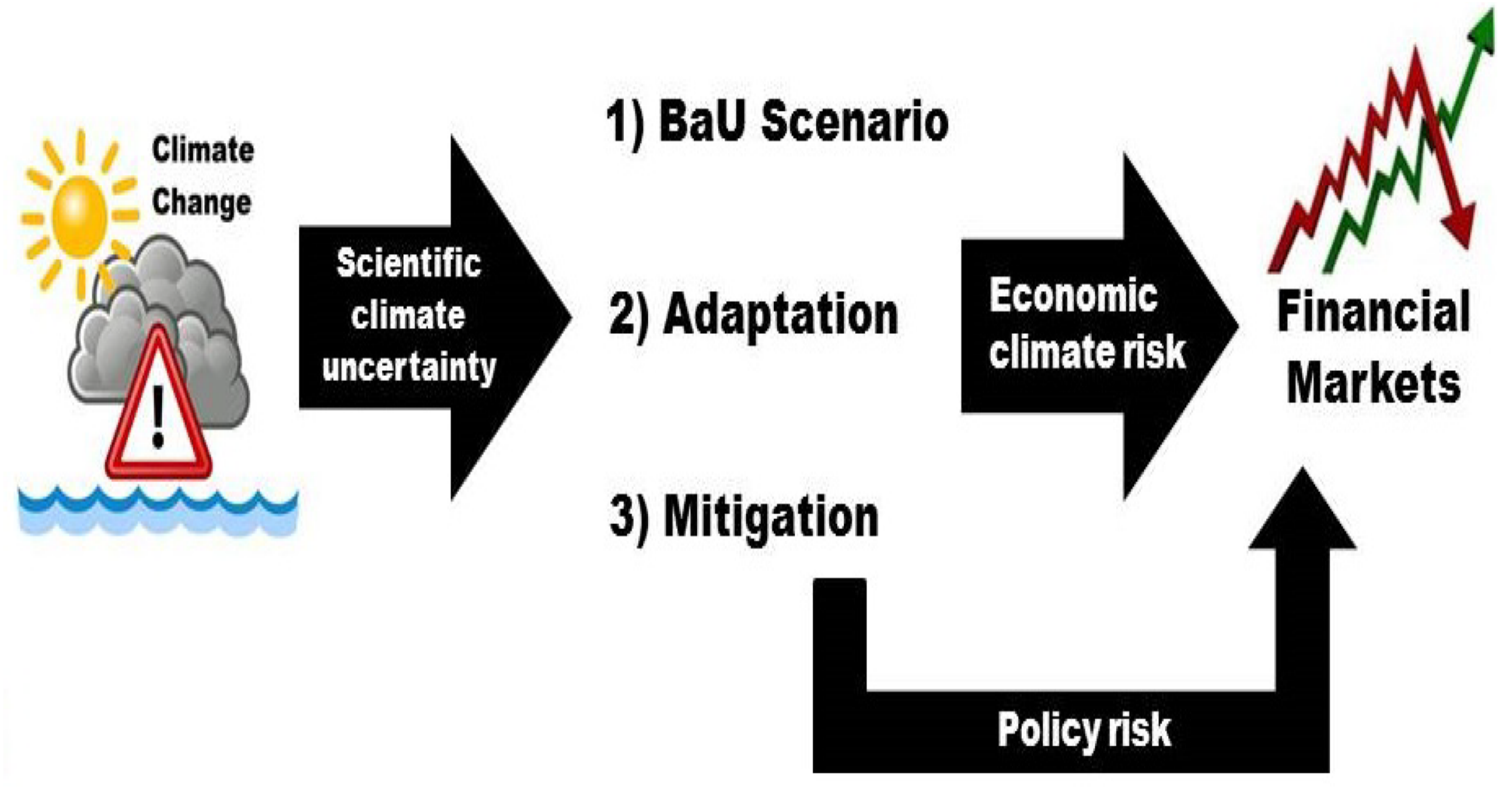


Fig. 3. Top 10 Embodied electricity exporting countries to Japan.

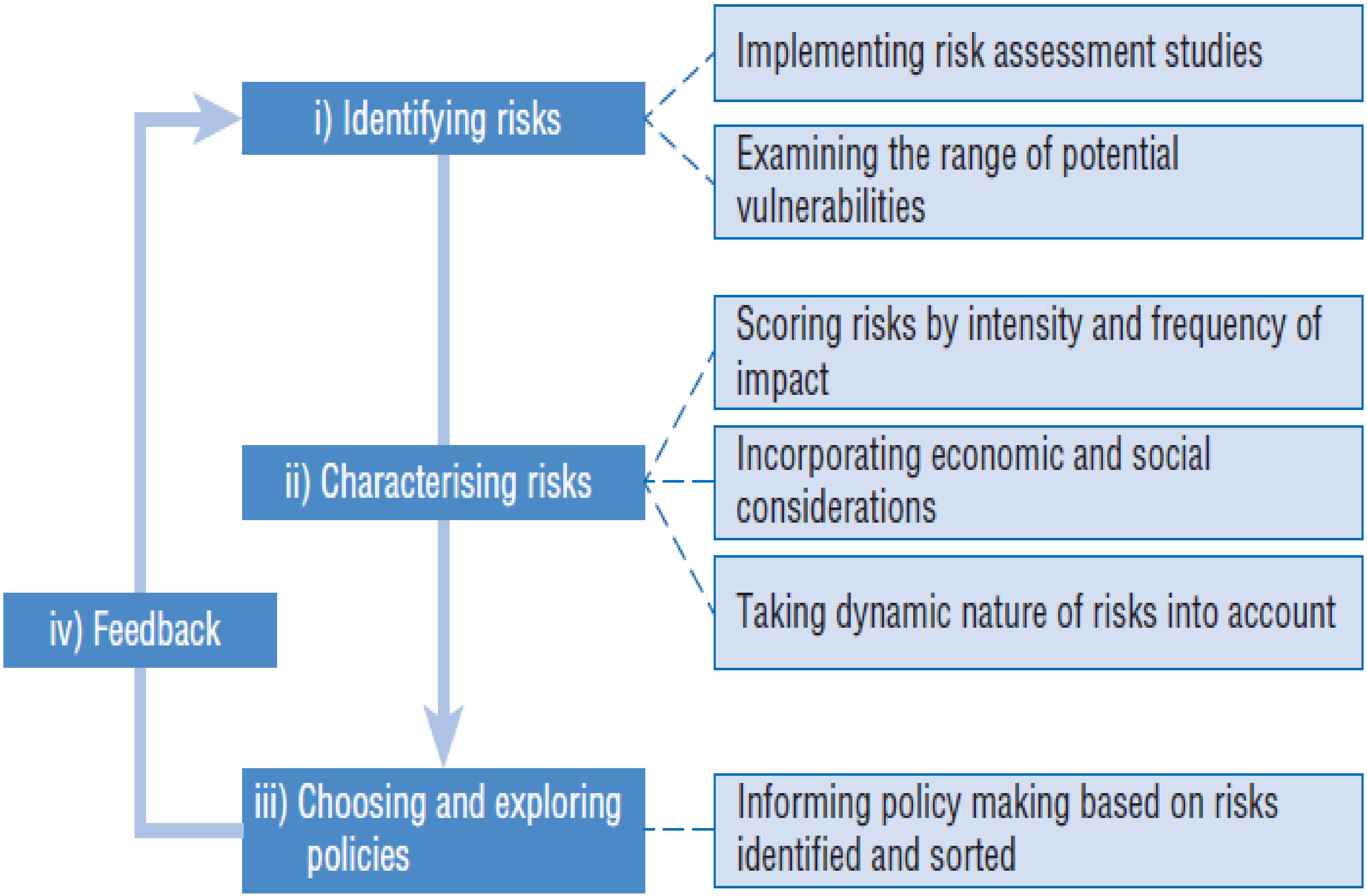
Kharrazi, Sato, Yarime, Nakayama, Yu, and Kraines (2015)

Climate Related Risks



Hjort (2016)

Figure 4.1. **Four steps in a risk-based approach**



OECD (2015)

TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

Phase I Report of the Task Force on Climate-Related Financial Disclosures

Presented to the Financial Stability Board

March 31, 2016

サステイナビリティに向けた課題

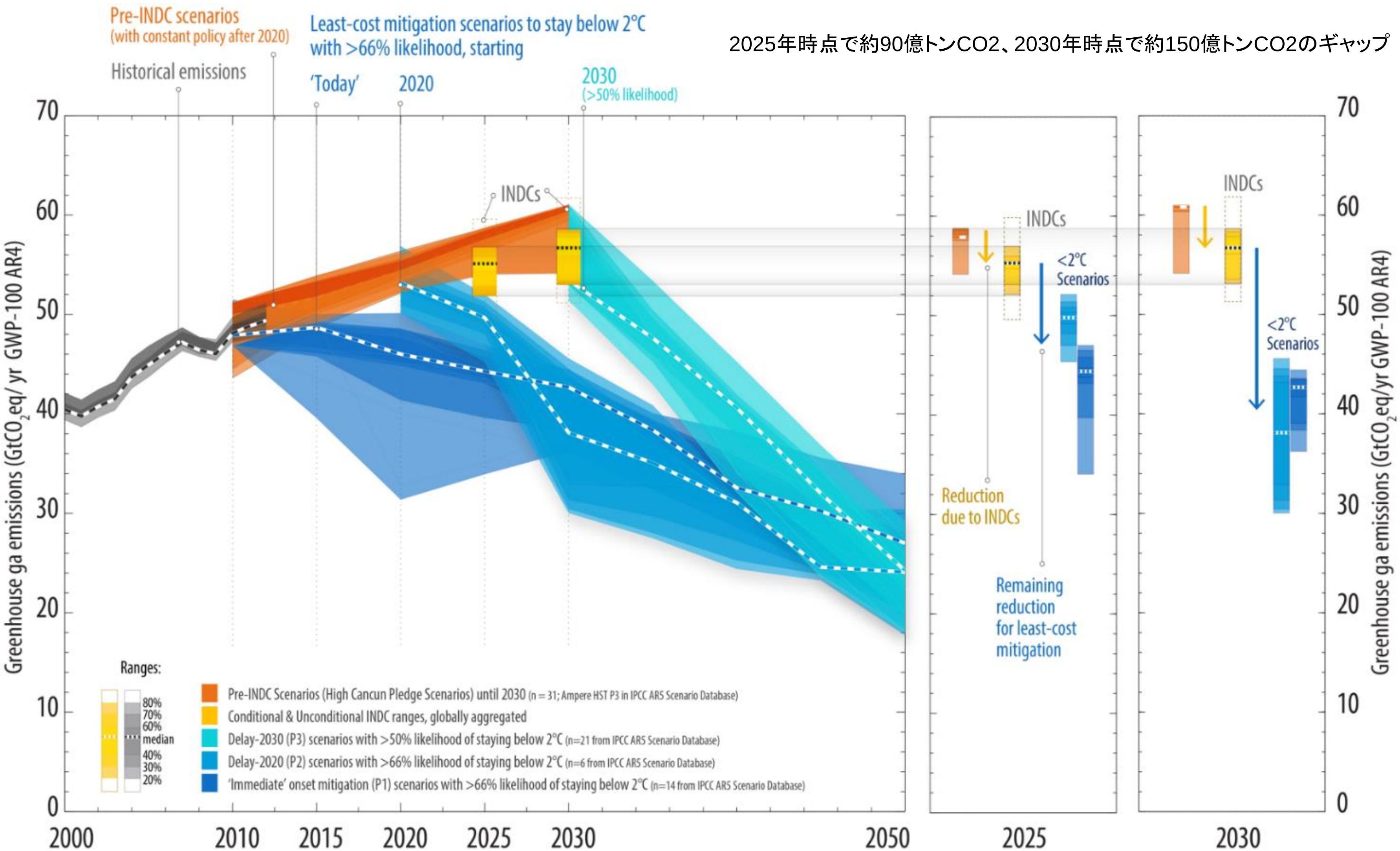
- 持続可能性に関わる多様な側面の複雑な相互依存性
- 環境影響の非線形性、不確実性、不可逆性、不均一性
- 気候変動、災害リスクの統合化
- 経済活動のグローバル化による貿易・投資関係の複雑化と潜在的な脆弱性
- サプライチェーン全体を通じたリスク・マネジメント
- レジリエンスに向けた投資
  - 事後的な対応・回復から、事前の準備・予防への投資
- 多様なステークホルダーとの対話と連携
  - コミュニティ、国、グローバル
  - セクター
- 長期的観点から多面的な情報の開示・評価

気候変動：COP21 パリ協定

- 世界共通の長期目標としての２℃目標、１．５℃への言及
- 全ての国が削減目標を５年ごとに提出・更新、実施状況の報告、レビュー
- JCMを含む市場メカニズムの活用
- 適応の長期目標の設定、各国の適応計画プロセスと行動の実施
- イノベーションの重要性

2025年及び2030年における各国約束草案 (INDC) に基づく世界排出量と気候変動2度以内抑制目標のギャップ

2025年時点で約90億トンCO2、2030年時点で約150億トンCO2のギャップ



UNFCCC Synthesis report on the aggregate effect of the intended nationally determined contributions (October 2015)

Critical Role of Innovation for Tackling Climate Change

- Paris Agreement Article 10-5
- **Accelerating, encouraging and enabling innovation is critical for an effective, long-term global response to climate change and promoting economic growth and sustainable development.** Such effort shall be, as appropriate, supported, including by the Technology Mechanism and, through financial means, by the Financial Mechanism of the Convention, for **collaborative approaches to research and development, and facilitating access to technology, in particular for early stages of the technology cycle, to developing country Parties.**

Innovation for Climate Change Mitigation

- *Stern Review on the Economics of Climate Change* (2007)
- Accelerating technological innovation as a key component of policies to deliver timely, effective and economically efficient climate change mitigation

Three Approaches to Accelerating Innovation

Theoretical Framing	Policy Area	Example Policy
Neo-classical economic approach	Carbon pricing	Taxes, Emissions Trading Scheme (ETS)
Innovation systems approach	Support for R&D, demonstration projects and early commercialization of clean technologies	Feed-in tariffs for renewable energy technologies (e.g., Germany, Spain, Japan)
Behavioral economics, Innovation management	Overcoming institutional and non-market barriers to deployment (Demand side)	Incentives to take up (cost effective) energy efficiency improvements

Experience of Emission Trading in Europe

- Oversupply of emissions permits in the first phase of the European ETS leading to a collapse in the trading price, reducing the incentive for emissions reductions
- Economic recession leading to a further drop in the carbon trading price in phase two of the ETS
- Incentives for the deployment of renewable energy technologies having only led to relatively modest increases in the take-up of these technologies (Stenzel and Frenzel, 2007)

Systems Approach to Encouraging Innovation

- Neo-classical Economic Approach
  - Market failures as the main obstacle
  - Getting the prices right (with taxes and subsidies) and public R&D subsidies to compensate for the private under investments in R&D as proposed solutions
- Systems Approaches to Innovation
  - Socio-technical configurations of actors, institutions, physical infrastructures and their relations
  - Many other system failures discouraging the prompt development and diffusion of innovations

Types of Innovation Systems

- System of importing, improving, developing and diffusing new technologies, products and processes
- National/regional innovation systems
  - U.S., Germany, U.K., Japan, China, Malaysia,
- Sectoral innovation systems
  - Industrial sectors
  - Chemical, materials, automobile,

The National Innovation System

- Central Role of R&D
- Government-University Axis
- University-Business Axis
- Government-Business Axis

Sectoral Systems of Innovation

- Knowledge Base
  - Specificities of scientific and technological knowledge domains
- Actors and Networks
  - Heterogeneity, linkages, and interactions
- Institutions
  - Norms, practices, rules, standards, laws, regulations, public policies

Innovation as a Co-Evolutionary Process of Technological and Institutional Developments

- Knowledge at the base of innovative activities changes over time and affects the boundaries and structure of sectoral innovation systems.
- Actors and networks are highly affected by the characteristics of and changes in the knowledge base with significant differences across sectoral systems.
- Changes in the knowledge base or in demand affect the characteristics of the actors, the organization of research and development (R&D) and of the innovative process, the type of networks and the structure of the market and the relevant institutions
- These variables in turn lead to further modifications in the technology, the knowledge base, and demand.

Promoting Green Innovation or Prolonging the Existing Technology

Regulation and Technological Change in the Chlor-Alkali Industry in Japan and Europe

Masaru Yarime

Keywords
diaphragm
industrial ecology
institution
ion-exchange membrane
mercury
research and development (R&D)

e-supplement available on the *JIE* Web site

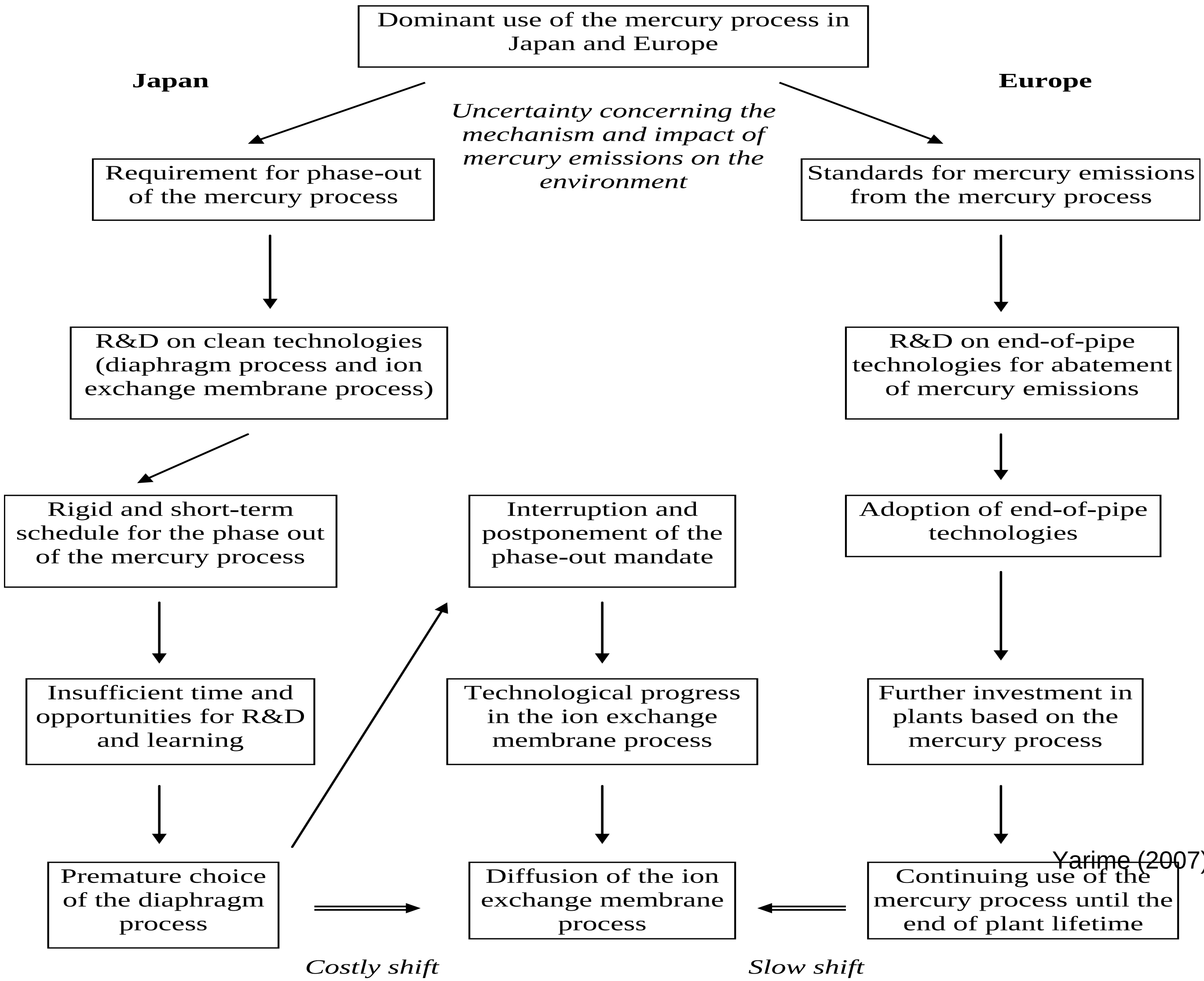
Address correspondence to:
Professor Masaru Yarime
Department of Human and Engineered Environmental Studies
Graduate School of Frontier Sciences
University of Tokyo
Environmental Building 227,
Kashiwanoha 5-1-5
Kashiwa-shi, Chiba 277-8563, Japan
<yarime@k.u-tokyo.ac.jp>
<http://ilab.k.u-tokyo.ac.jp/~yarime/Top-E.html>

Volume 11, Number 4

Summary

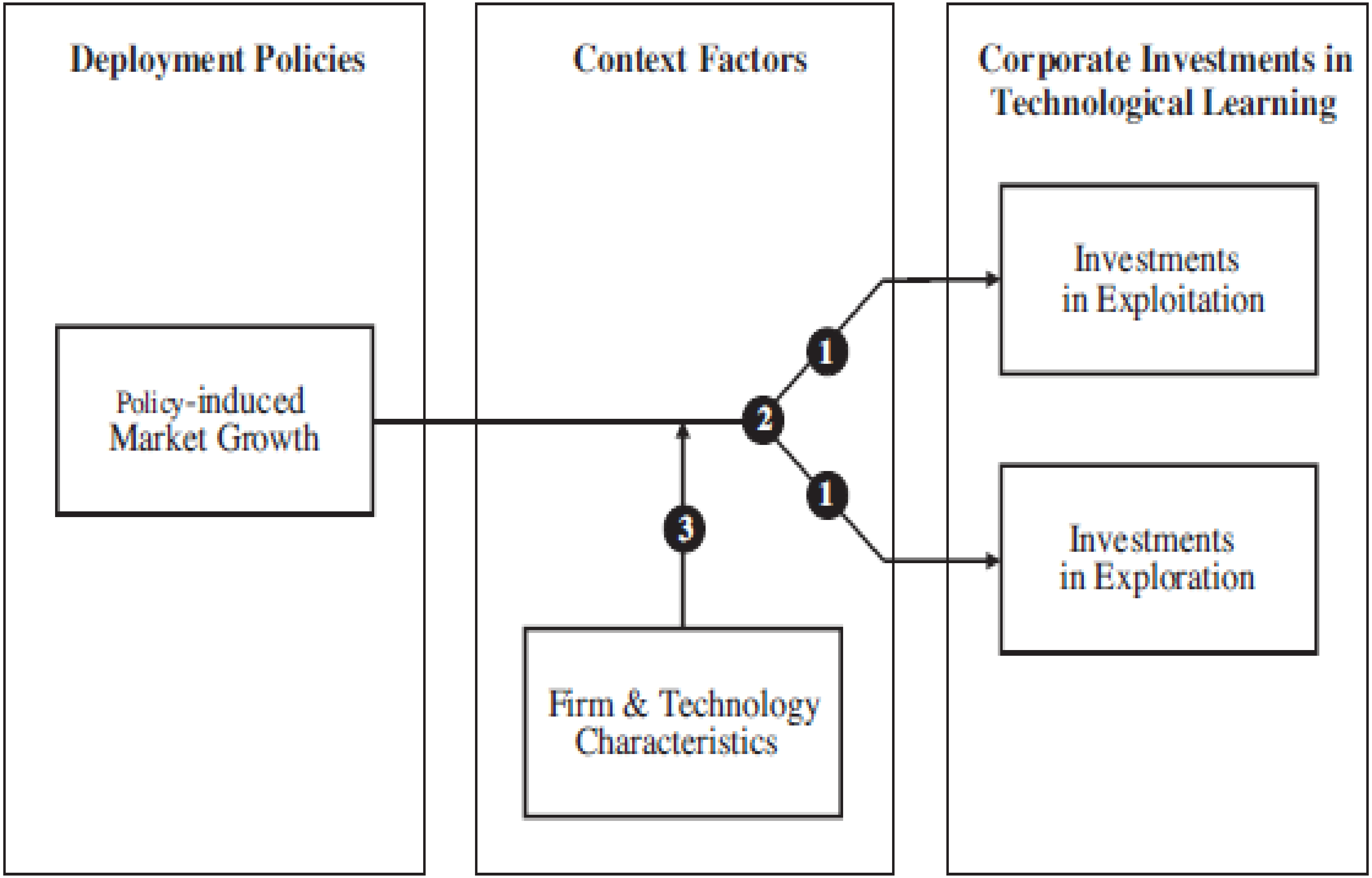
A case study of the chlor-alkali industry in Western Europe and Japan is presented examining the effects of environmental regulation on technological change. In Western Europe, standards were set for mercury emissions from chlor-alkali plants, which were gradually tightened subsequently. Research and development (R&D) efforts were directed to end-of-pipe technologies as well as process improvements for reducing mercury emissions, rather than to clean technologies, which eliminate mercury from within the production process. With a significant reduction in mercury emissions with end-of-pipe technologies, new plants continued to be built that relied on the mercury process. As long as these relatively new plants could be utilized, technological transition to the clean ion-exchange membrane process remained slow. The success in reducing mercury emissions with end-of-pipe technologies, in effect, helped to prolong the lifetime of the existing mercury process. In Japan, the government introduced policies to phase out the existing mercury process. The strict approach encouraged innovative companies to make R&D efforts on clean technologies, instead of end-of-pipe technologies for pollution abatement. Applied in a hasty and inflexible way, however, the stringent regulation initially induced most of the chlor-alkali producers to choose the diaphragm process, which later turned out to be inappropriate. After the regulatory schedule was modified to allow more time for process conversion, the remaining mercury-based plants were converted directly to the most efficient ion-exchange membrane process. The technological transition, however, was costly, as most of the diaphragm-based plants introduced following the regulatory mandate were operated only for a short period of time, with the large investment wasted.

Diverging Impacts of Environmental Regulations on Innovation in the Chlor-Alkali Industry in Japan and Europe



Yarime (2007)

Effects of Deployment Policies on Technological Exploration and Exploitation in Photovoltaics



(Hoppmann, Peters, Schneider & Hoffmann, 2013)

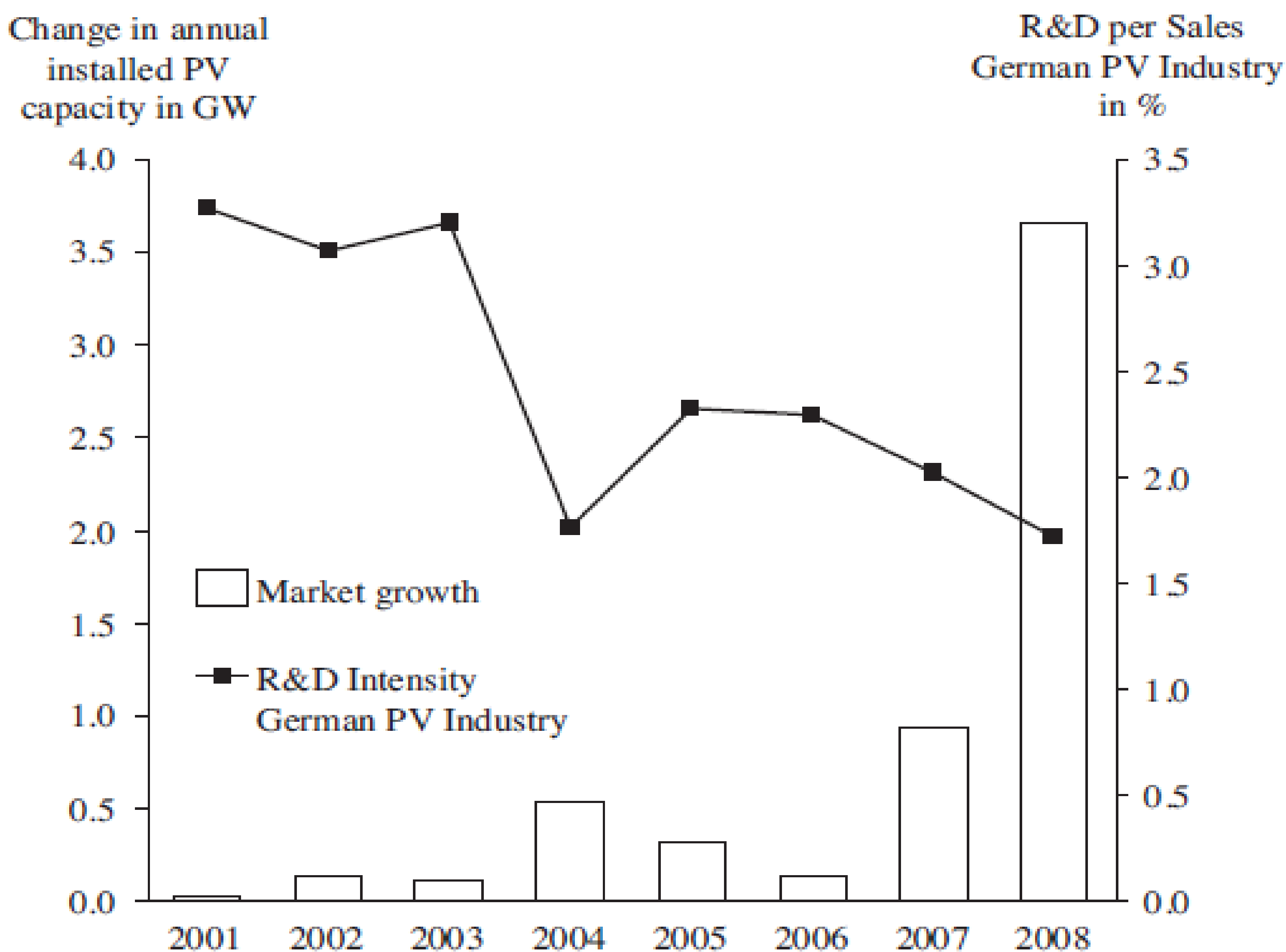


Fig. 3. Global market growth and R&D intensity of the German PV industry (data from BSW Solar, 2010; EPIA, 2011, no data available for 2009 and 2010).

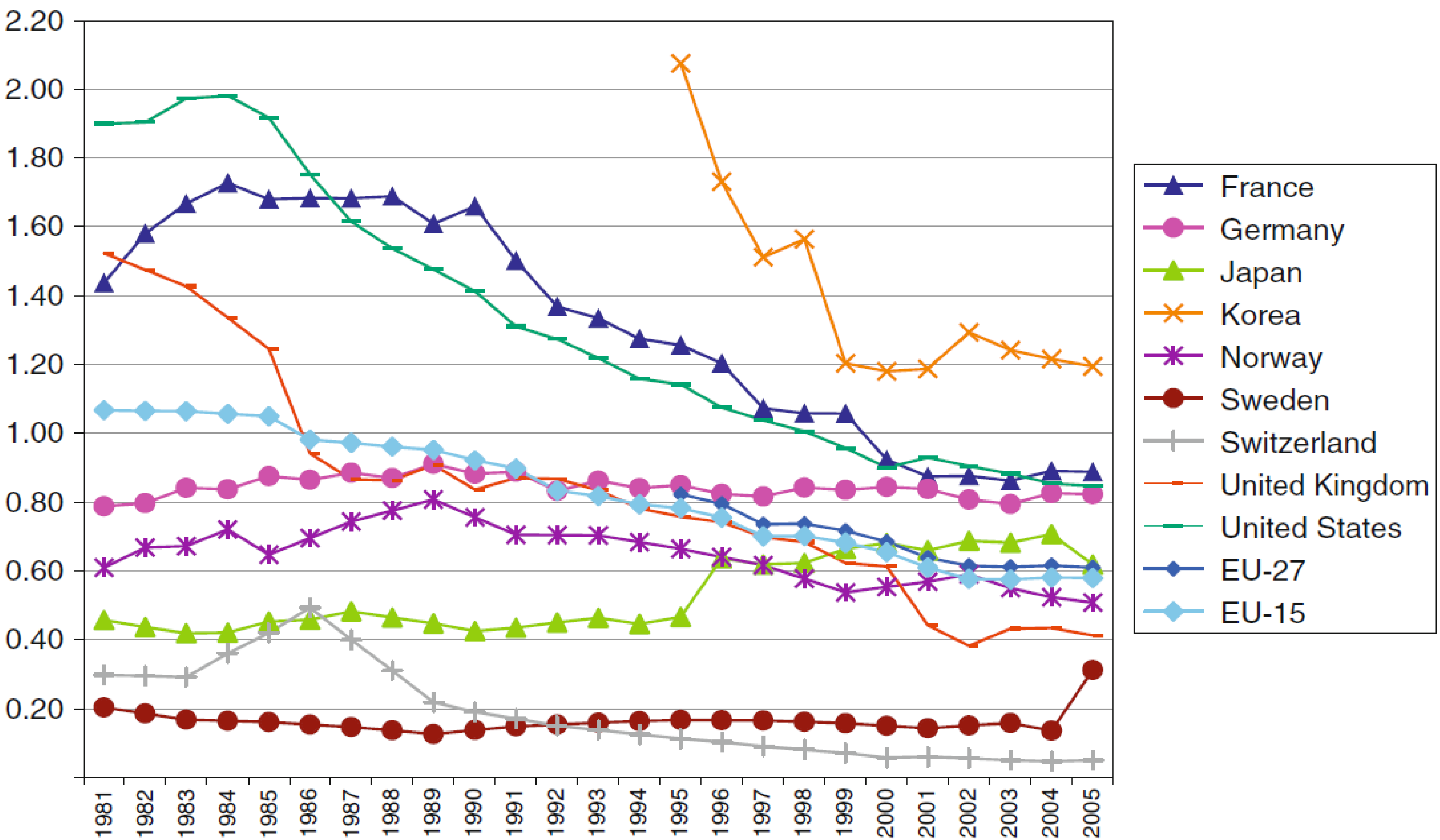
Recent Trends in Science, Technology & Innovation Policy 1

- Stagnation of Economic Growth
  - Since the oil crises in the 1970s, particularly industrialized countries
- Increasing Importance of Knowledge in Economic Growth
  - Endogenous Growth Models (Paul Romer)
  - Knowledge-Based Economies, OECD
- New Industrial Policy
  - Integration of Science, Technology, and Innovation Policy with Economic Policy
- Emphasis on Intellectual Property Rights
  - US Bayh-Dole Act (1980)
  - Allows universities to apply for patents based on the results of scientific research activities funded by the federal government, with similar legislation subsequently enacted in other industrialized countries
- Promotion of University-Industry-Government Collaboration

Recent Trends in Science, Technology & Innovation Policy 2

- Increasing Expectations to Address Societal/Grand Challenges
  - Environmental protection, energy security, public health, etc.
  - Global issues, requiring international coordination and harmonization
- Transformation of Society
  - Social innovation
  - Inclusive innovation
- European Union: Horizon 2020
- OECD Innovation Strategy (2010)
  - Applying innovation to address global and social challenges
  - Contemporary world's societies facing severe economic and social challenges
  - Many of challenges global in nature (climate change) or requiring global action (Health, food security, clean water)
  - Technological cooperation, predictable policy regime and long term incentives, new financing mechanism, flexible policy, effective policy mix
- OECD Green Growth Strategy (2010)
  - Remove barriers to green growth, support the transition, green job and skill development, strengthen international cooperation

Relative Weight of R&D Performed by Governments vs. Universities



Source: OECD (2007)

International Journal of Innovation Management
Vol. 14, No. 2 (April 2010) pp. 201–219

DOI: 10.1142/S1363919610002611

Imperial College Press
www.icpress.co.uk

SOURCES OF SUCCESS IN ADVANCED MATERIALS INNOVATION: THE ROLE OF "CORE RESEARCHERS" IN UNIVERSITY–INDUSTRY COLLABORATION IN JAPAN

YASUNORI BABA*

Research Center for Advanced Science and Technology, University of Tokyo, Komaba 4-6-1, Meguro-ku, Tokyo 153-8904, Japan
baba@zzz.rcast.u-tokyo.ac.jp

MASARU YARIME

Graduate School of Frontier Sciences, University of Tokyo, Kashiwanoha 5-1-5, Kashiwa-shi, Chiba 277-8563, Japan
yarime@k.u-tokyo.ac.jp

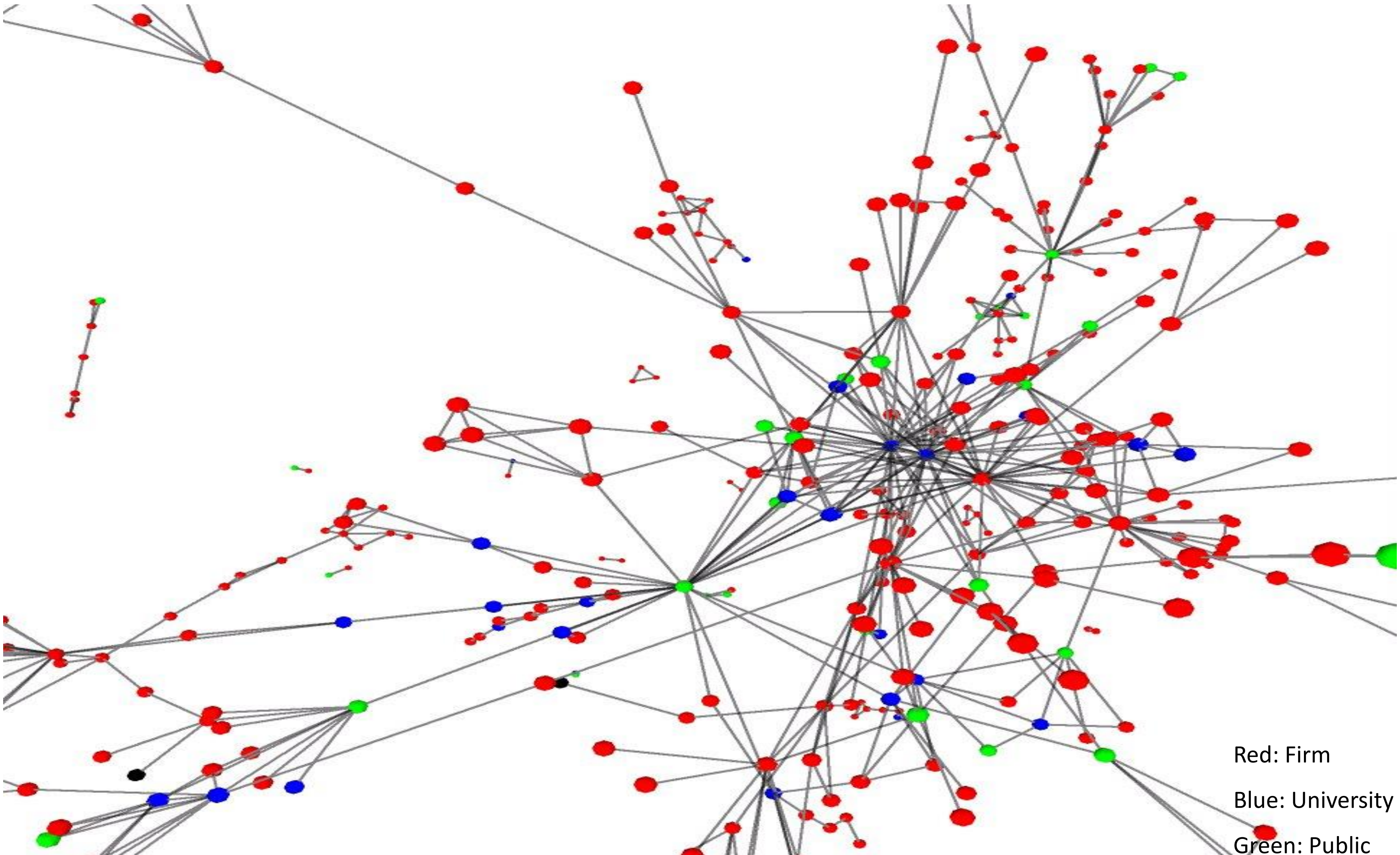
NAOHIRO SHICHIJO

Interfaculty Initiative in Information Studies, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku Tokyo 113-0033, Japan
shichi@iii.u-tokyo.ac.jp

This article aimed to identify the effect of university-industry collaborations on the innovative performance of firms operating in the advanced materials field, and it proposed an original classification of the research organization partners. The main contribution resides in the estimation of the role played by collaborations with differently experienced corporate researchers. In the advanced materials industry the most effective collaborations are driven by "core researchers," who have been involved in authoring scientific papers, in addition to applying sizeable patents. The results of the case study focusing on partner firms collaborating with "Pasteur scientists" such as Fujishima and Hashimoto of the University of Tokyo confirm the idea that core researchers have the quality to work as boundary spanners between science and technology, and that their becoming heavy-weighted project leaders pushed the firms' R&D towards commercialization.

Keywords: University–industry collaborations; core researchers; advanced materials; innovation; Japan.

Collaboration Network between Core Researchers, Industry, and Public Institutes on Photocatalyst (2002)



Red: Firm

Blue: University

Green: Public Institute

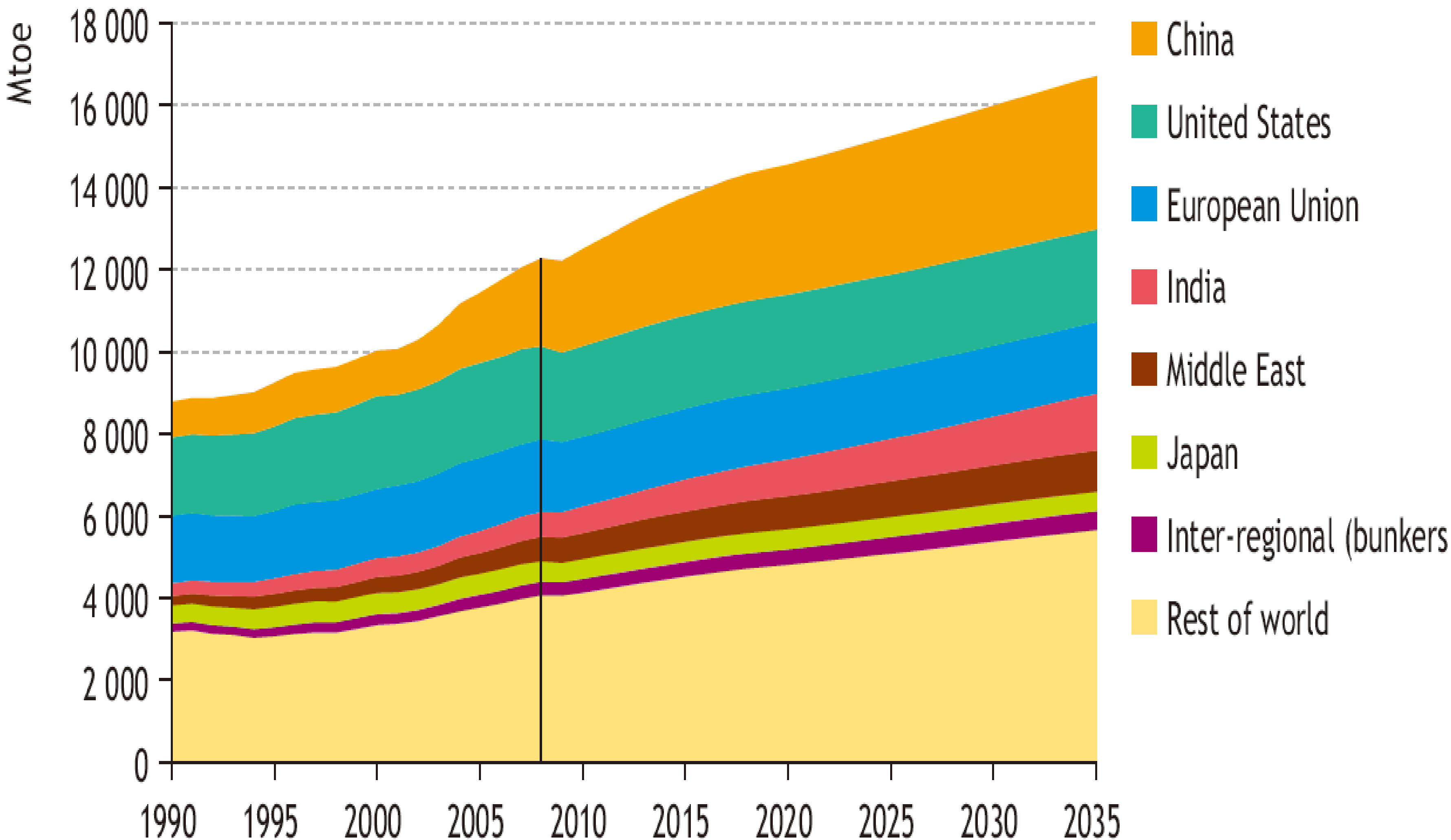
Innovation System of New Materials with Implications for Environmental Applications

- University scientists functioning as a hub of networks of the science and technology community and promoting growth in the number and variety of participants in the community (open university/public institute <-> private company)
- Importance of maintaining solid scientific capability at university
- Institutional flexibility and mobility of researchers for changing research agenda
- Neutral position of university researchers for establishing impartial technical assessments and standards

Innovation System of New Materials with Implications for Environmental Applications

- Firms working closely with university successful in developing and commercializing products
- Successful cases of applying new materials in fields where collaborating firms have prior knowledge on user needs
- Firms with previous experiences of commercializing products move into applications for social objectives, including environmental protection
- Public sector working as a bridge in developing technologies for environmental protection

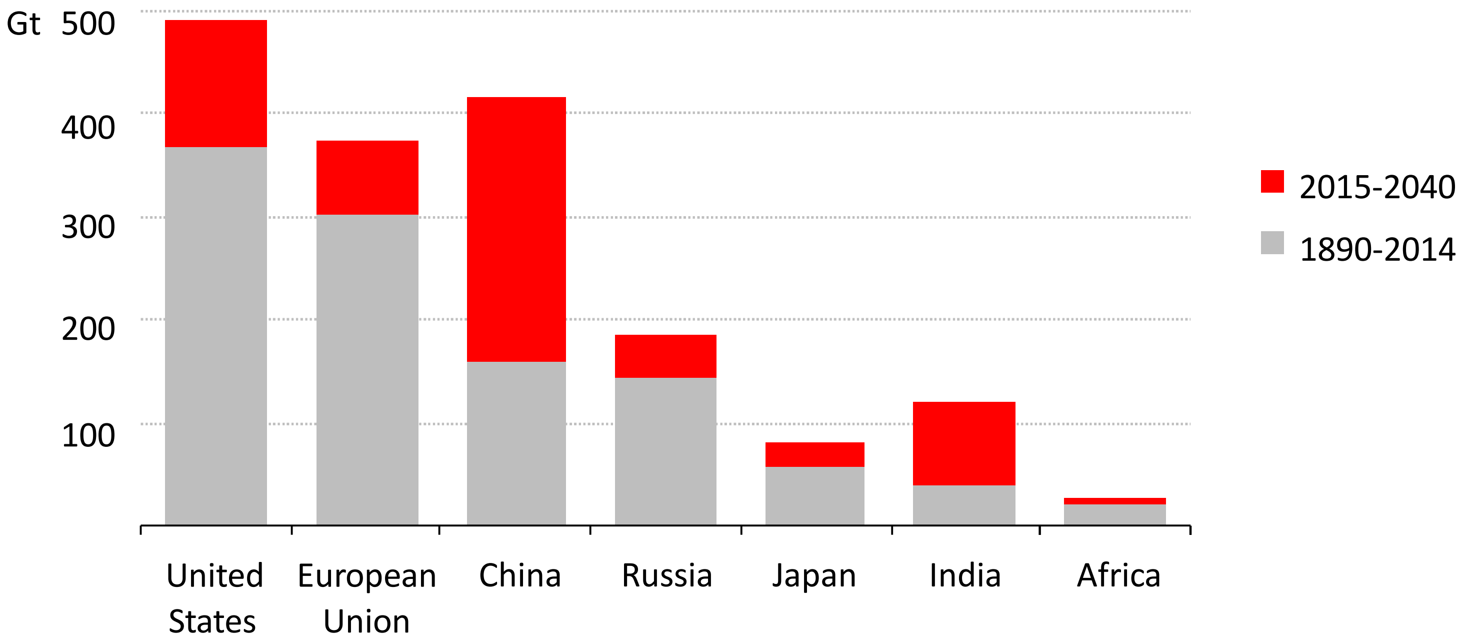
World Primary Energy Demand by Region



OECD/IEA (2010)

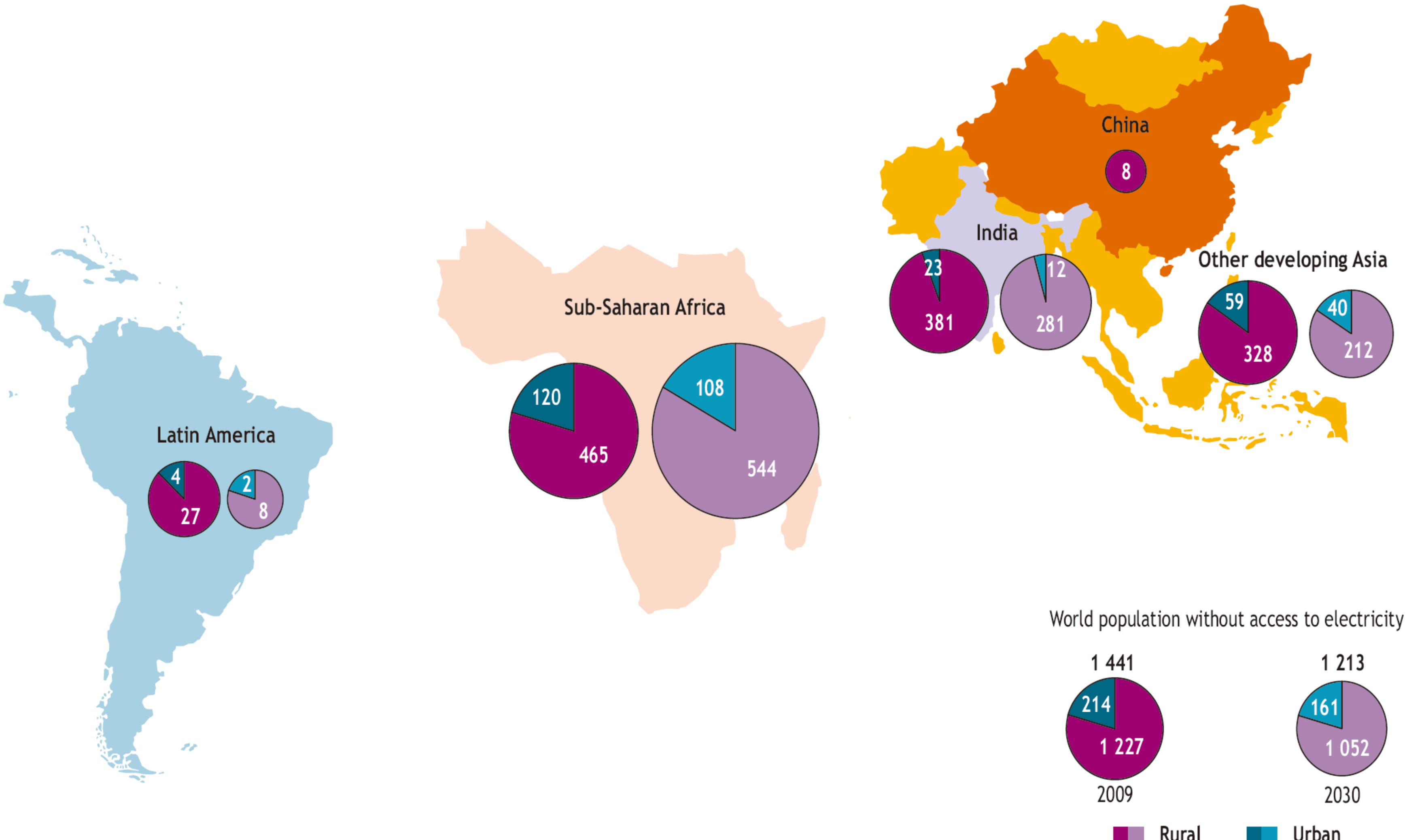
Emissions burden moves over time

Cumulative energy-related CO_2 emissions by region



Past emissions are important, although the source of emissions shifts with changes in the global economy

Population without Access to Electricity in Rural and Urban Areas (in million)



OECD/IEA (2010)

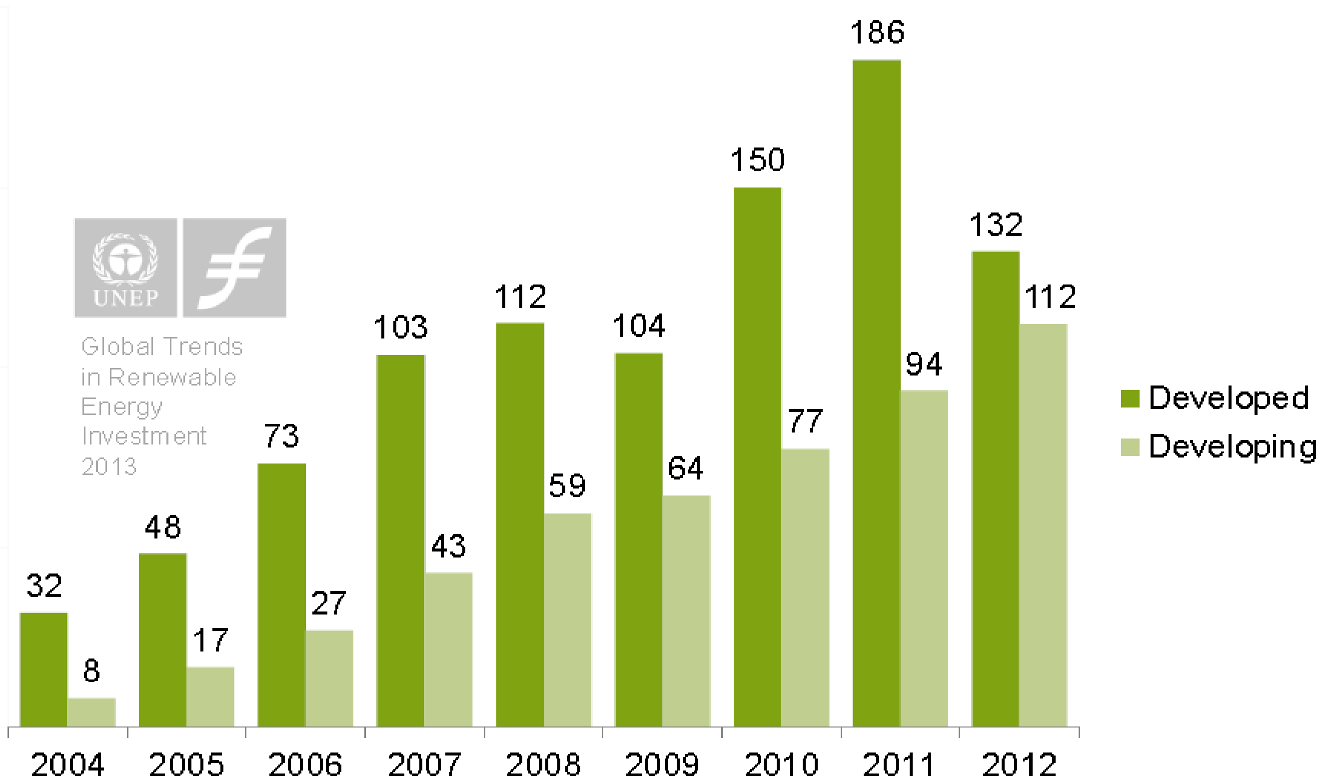
Sustainable Development Goal 7: Energy

- 7.1 By 2030, ensure universal access to affordable, reliable and modern energy services
- 7.2 By 2030, increase substantially the share of renewable energy in the global energy mix
- 7.3 By 2030, double the global rate of improvement in energy efficiency
- 7.a By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- 7.b By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programmes of support

Increasing Developing Countries' Share in Global Investment

GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY: DEVELOPED VS. DEVELOPING, 2004–12($BN)

Frankfurt School
UNEP Collaborating Centre
for Climate & Sustainable Energy Finance



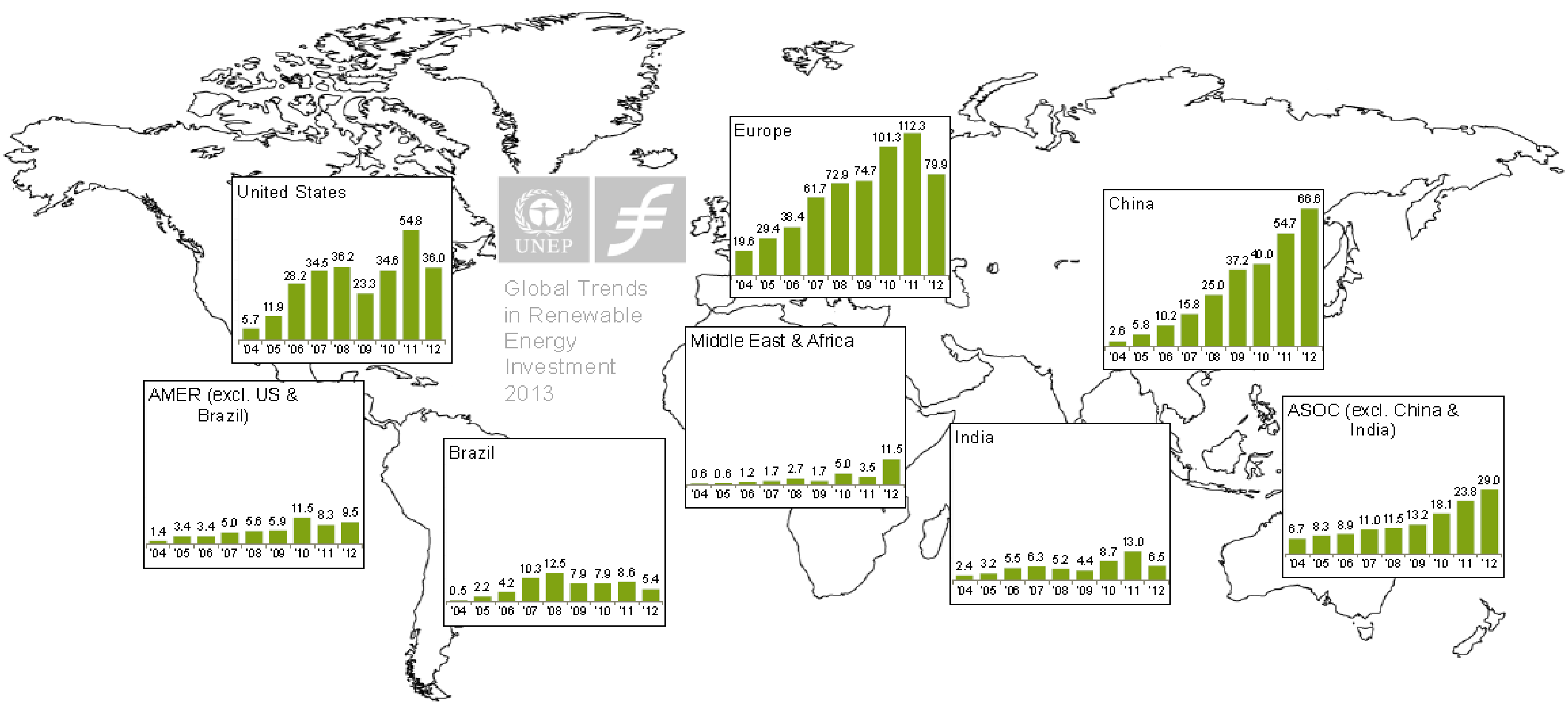
Note: New investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals. Developed volumes are based on OECD countries excluding Mexico, Chile, and Turkey.

Source: Bloomberg New Energy Finance; UNEP

Growing Investment in China, Slow in India, Middle East & Africa

GLOBAL NEW INVESTMENT IN RENEWABLE ENERGY
BY REGION, 2004–12 ($BN)

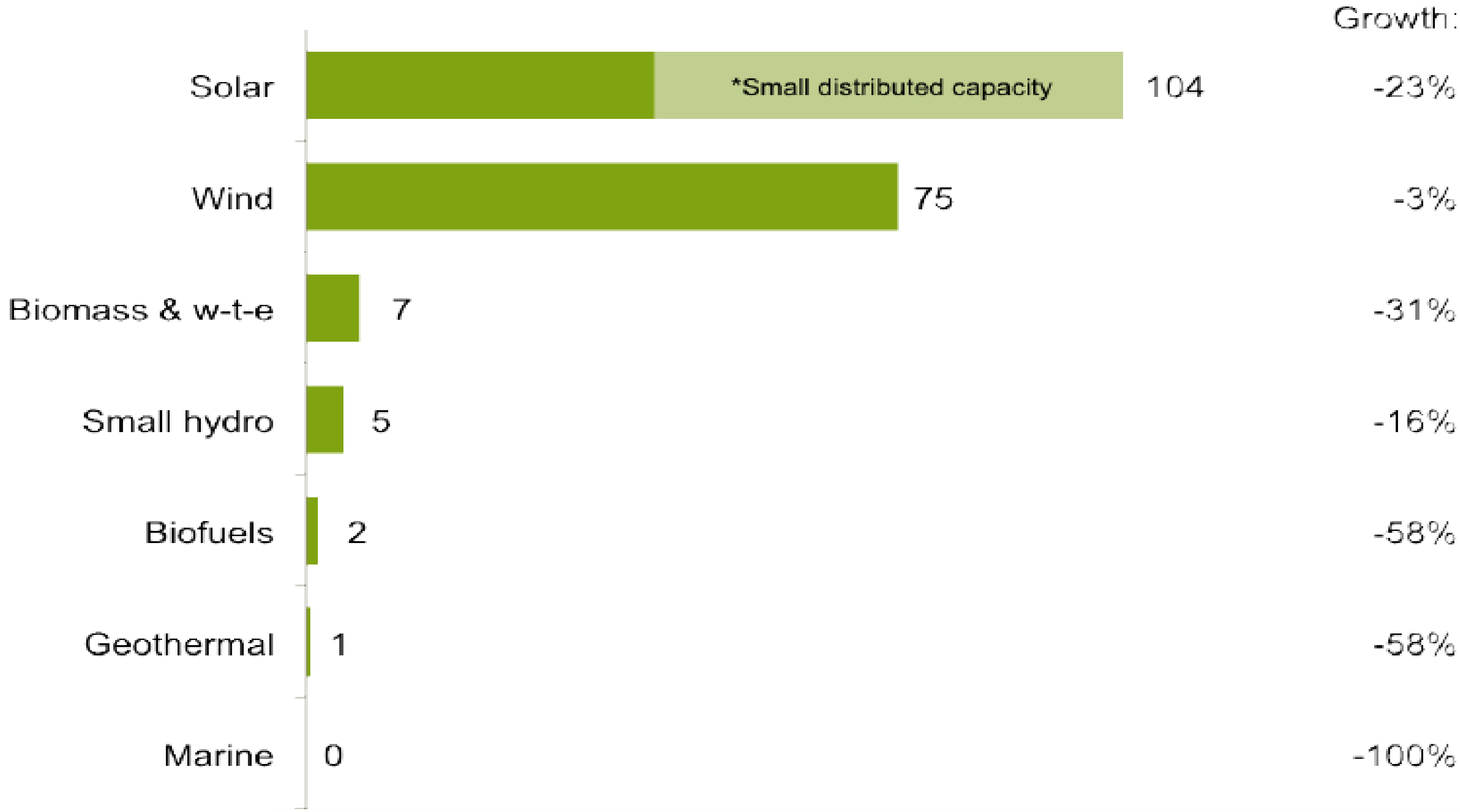
Frankfurt School
UNEP Collaborating Centre
for Climate & Sustainable Energy Finance



Note: New investment volume adjusts for re-invested equity. Total values include estimates for undisclosed deals. This comparison does not include small-scale projects.

Source: Bloomberg New Energy Finance; UNEP

Asset Finance of Renewable Energy Assets and Small Distributed Capacity (2013)



Total values include estimates for undisclosed deals.
Source: UNEP, Bloomberg New Energy Finance

Inventor Countries for Climate Change Mitigation (2000-2005)

Country	Rank	Average % of world inventions	Average % of world's high-value inventions	Country's top three technology fields (decreasing order)
Japan	1	37.1	17.4 (2)	All technologies
United States	2	11.8	13.1 (3)	Biomass, insulation, solar
Germany†	3	10.0	22.2 (1)	Wind, solar, geothermal
China	4	8.1	2.3 (10)	Cement, geothermal, solar
South Korea	5	6.4	4.4 (6)	Lighting, heating, waste
Russia	6	2.8	0.3 (26)	Cement, hydro, wind
Australia	7	2.5	0.9 (19)	Marine, insulation, hydro
France†	8	2.5	5.8 (4)	Cement, electric and hybrid, insulation
United Kingdom†	9	2.0	5.2 (5)	Marine, hydro, wind
Canada	10	1.7	3.3 (8)	Hydro, biomass, wind
Brazil	11	1.2	0.2 (31)	Biomass, hydro, marine
The Netherlands†	12	1.1	2.1 (12)	Lighting, geothermal, marine
Total	—	87.2	77.2	

Source: Authors' calculations, based on PATSTAT data.

[a]Together, the twenty-seven countries of the European Union (EU27) represent 24% of the world's inventions.

[b]High-value inventions are defined as inventions that have been patented in at least two countries.

Dechezleprêtre, Glachant, Hascic, Johnstone, Ménière (2011)

Rate of Export of Inventions by Inventor Country (2000-2005)

Inventor country	Rate of export of inventions (%)
The Netherlands	89.9
United Kingdom	60.3
France	46.1
Germany	56.1
Canada	56.9
United States	42.3
Korea	24.5
Japan	21.7
Australia	15.8
China	6.8
Brazil	6.9

Source: Authors' calculations, based on PATSTAT data.

Dechezleprêtre, Glachant, Hascic, Johnstone, Ménière (2011)

Development in the city of Jiangyin, which lies close to the Yangtze River near China's east coast.

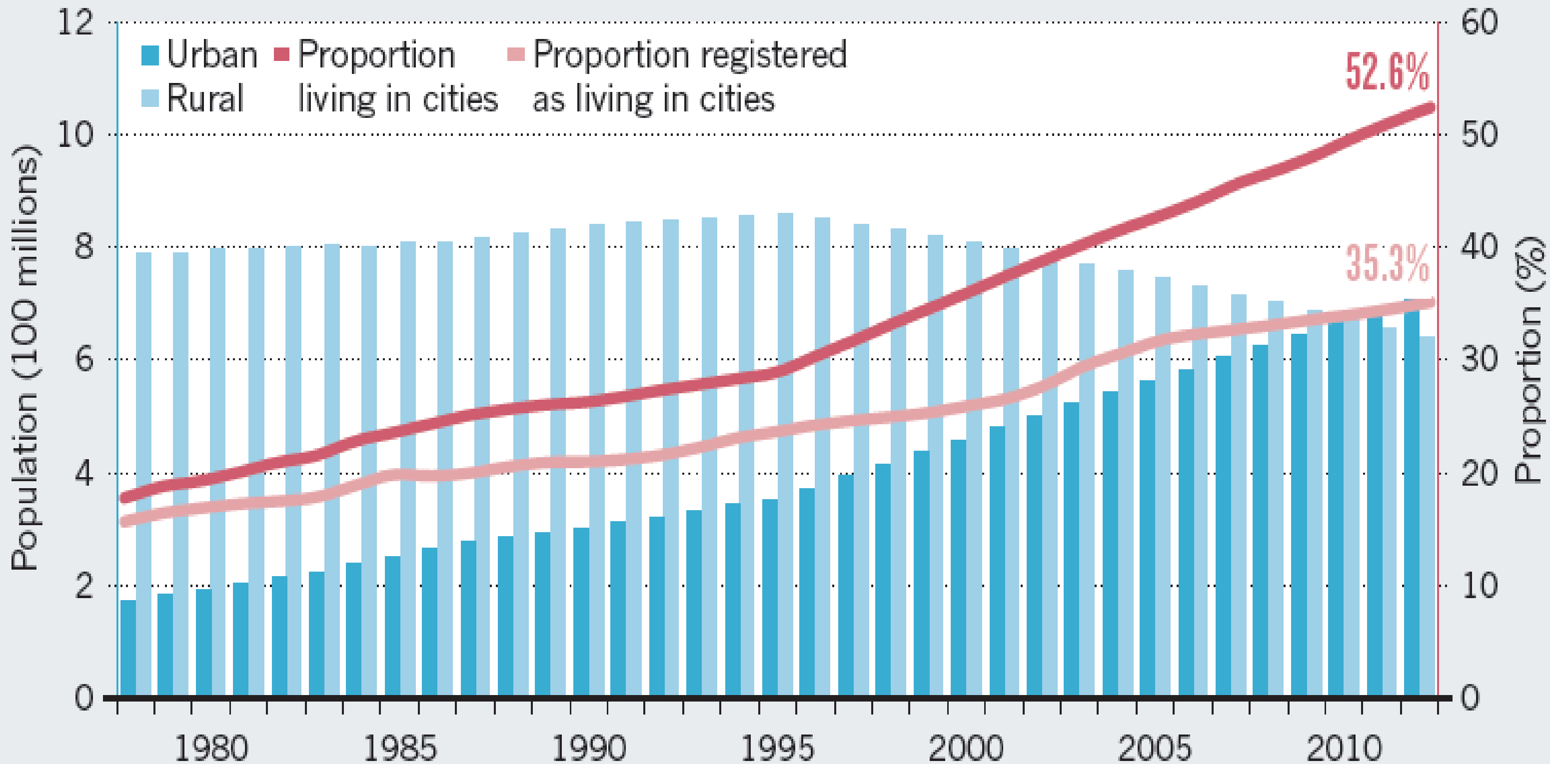
Realizing China's urban dream

Local implementation and public scrutiny will make or break the government's urbanization strategy, say **Xuemei Bai**, **Peijun Shi** and **Yansui Liu**.

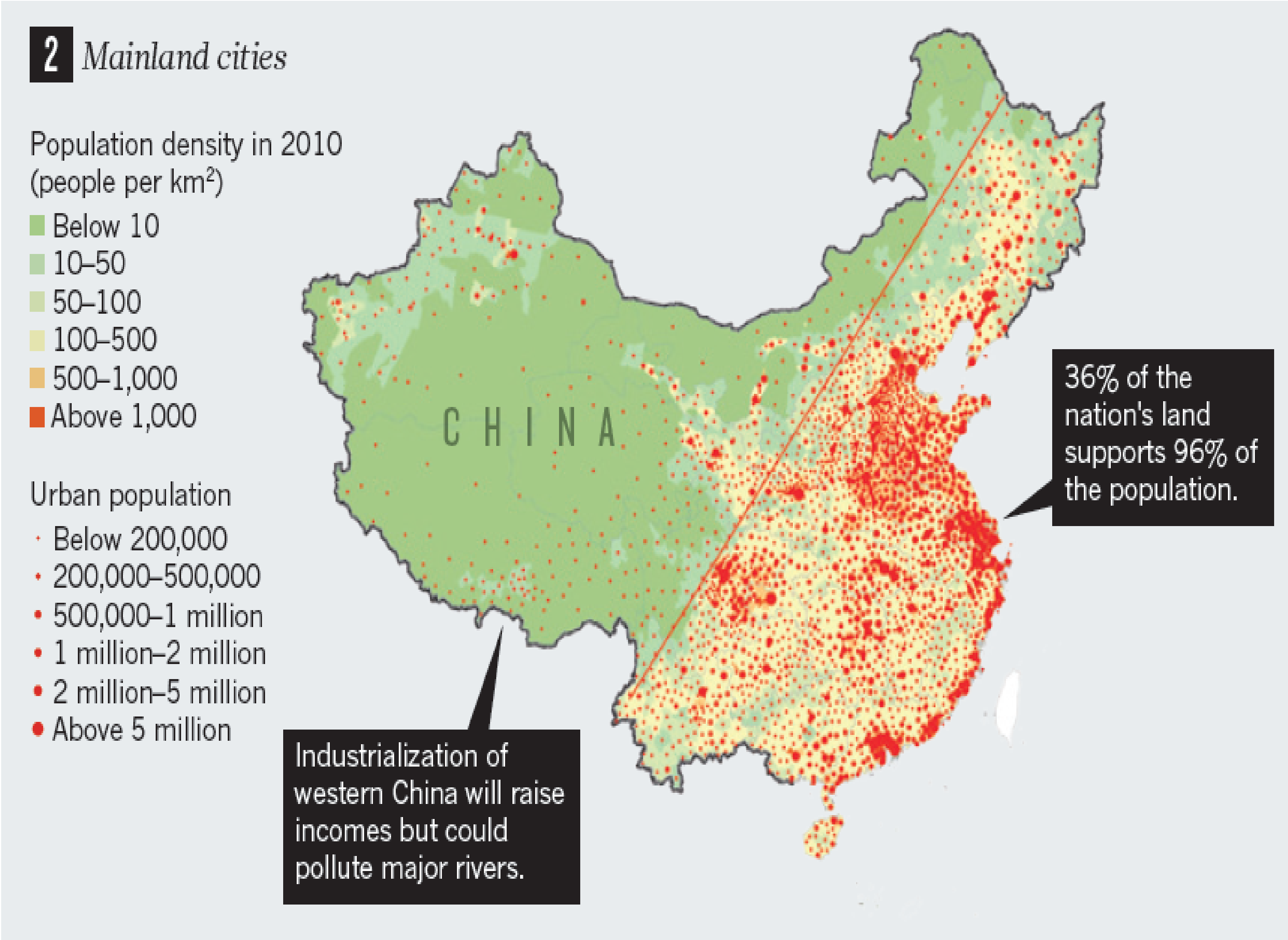
URBAN EXPANSION

The proportion of China's population living in cities has risen steadily since the 1970s (**1**). Workers moving from rural areas to cities are prevented from integrating, however, by a household registration system that restricts them from officially changing their permanent residence. Urban populations concentrate in the eastern part of the mainland (**2**).

1 *Relocation trends*



Bai, Shi & Liu (2014)



Bai, Shi & Liu (2014)

Sustain Sci (2012) 7 (Supplement 1):101–113
DOI 10.1007/s11625-012-0157-5

SPECIAL FEATURE: ORIGINAL ARTICLE

Sustainability science: bridging the gap between science and society

Establishing sustainability science in higher education institutions: towards an integration of academic development, institutionalization, and stakeholder collaborations

Masaru Yarime · Gregory Trencher · Takashi Mino · Roland W. Scholz · Lennart Olsson · Barry Ness · Niki Frantzeskaki · Jan Rotmans

Received: 17 October 2011 / Accepted: 3 January 2012 / Published online: 3 February 2012

Abstract The field of sustainability science aims to understand the complex and dynamic interactions between natural and human systems in order to transform and develop these in a sustainable manner. As sustainability problems cut across diverse academic disciplines, ranging from the natural sciences to the social sciences and humanities, interdisciplinarity has become a central idea to the realm of sustainability science. Yet, for addressing complicated, real-world sustainability problems, interdisciplinarity per se does not suffice. Active collaboration with various stakeholders throughout society—transdisciplinarity—must form another critical component of sustainability science. In addition to implementing interdisciplinarity and transdisciplinarity in practice, higher education institutions also need to deal with the challenges of institutionalization. In this article, drawing on the experiences of selected higher education academic programs on sustainability, we discuss academic, institutional, and societal challenges in sustainability science and explore the potential of uniting education, research and societal contributions to form a systematic and integrated response to the sustainability crisis.

Keywords Higher education institutions · Interdisciplinarity · Transdisciplinarity · Institutionalization · Stakeholder collaboration · Social experimentation

Handled by Arnim Wiek, Arizona State University, USA.

M. Yarime (✉) · G. Trencher · T. Mino
Graduate Program in Sustainability Science (GPSS),
Graduate School of Frontier Science, University of Tokyo,
Kashiwanoha 5-1-5, Kashiwa, Chiba, Japan
e-mail: yarime@k.u-tokyo.ac.jp

R. W. Scholz
Institute for Environmental Decisions (IED), Natural and Social Science Interface (NSSI), ETH Zurich, Zurich, Switzerland

L. Olsson · B. Ness
Lund University Centre for Sustainability Studies (LUCSUS), Lund, Sweden

N. Frantzeskaki · J. Rotmans
Dutch Research Institute For Transitions,
Faculty of Social Sciences, Erasmus University Rotterdam, Rotterdam, The Netherlands

Academic, institutional, and societal challenges in sustainability science

Global sustainability concerns long-term constraints on resources, including, among others, food, water, and energy. The challenge of sustainability is the reconciliation of society's development goals with the planet's environmental limits over the long term (Clark and Dickson 2003). The field of sustainability science aims to use the understanding of complex and dynamic interactions between natural and human systems for transforming and developing these sustainably (Clark and Dickson 2003; Jerneck et al. 2011; Kates et al. 2001; Komiyama and Takeuchi 2006; Komiyama et al. 2011; Spangenberg 2011; Wiek et al. 2012a).

Sustainability science faces the critical challenge of establishing itself as an academic field (Clark 2007; Komiyama and Takeuchi 2006; Lang et al. 2012; Talwar et al. 2011; Wiek et al. 2011a; Yarime 2011c). Major hurdles include the development and use of concepts and methodologies, the transforming of institutional structures (e.g., incentives and reward systems), the initiation of collaboration with stakeholders outside of academia (Yarime 2011c), as well as the development of a coherent set of sustainability competencies and effective pedagogical

Science and Public Policy **41** (2014) pp. 151–179
Advance Access published on 11 August 2013
doi:10.1093/scipol/sct044

Beyond the third mission: Exploring the emerging university function of co-creation for sustainability

Gregory Trencher[1,*], Masaru Yarime[2], Kes B. McCormick[3], Christopher N. H. Doll[4] and Steven B. Kraines[5]

[1]*Graduate Program in Sustainability Science, Graduate School of Frontier Sciences, University of Tokyo, Kashiwanoha 5-1-5, Kashiwa, Chiba 277-8581, Japan*
[2]*Graduate School of Public Policy (GraSPP), University of Tokyo, Faculty of Medicine Building 1 Room S207, Hongo 7-3-1 Bunkyo-ku, Tokyo 113-0033, Japan; Email: yarimemasa@gmail.com.*
[3]*International Institute for Industrial Environmental Economics (IIIEE), Lund University, P.O. Box 196, 22100 Lund, Sweden; Email: kes.mccormick@iiiee.lu.se.*
[4]*United Nations University Institute of Advanced Studies, 6F International Organizations Center, Pacifico-Yokohama 1-1-1 Minato Mirai, Nishi-ku Yokohama 220-8502 Japan; Email: doll@ias.unu.edu.*
[5]*Future Centre Initiative, Graduate School of Frontier Sciences, University of Tokyo, Tokyo, Japan; Email: sk@fc.u-tokyo.ac.jp.*
**Corresponding author. Email: trencher@sustainability.k.u-tokyo.ac.jp.*

This paper explores a global trend where universities are collaborating with government, industry and civil society to advance the sustainable transformation of a specific geographical area or societal sub-system. With empirical evidence, we argue that this function of ‘co-creation for sustainability’ could be interpreted as the seeds of an emerging, new mission for the university. We demonstrate that this still evolving mission differs significantly from the economic focus of the third mission and conventional technology transfer practices, which we argue, should be critically examined. After defining five channels through which a university can fulfil the emerging mission, we analyse two frontrunner ‘transformative institutions’ engaged in co-creating social, technical and environmental transformations in pursuit of materialising sustainable development in a specific city. This study seeks to add to the debate on the third mission and triple-helix partnerships. It does so by incorporating sustainable development and place-based co-creation with government, industry and civil society.

Keyword: sustainability; co-creation; university; mission; transformation; collaboration.

1. Introduction

> If you want to go fast, go alone. If you want to go far, go together. (African proverb)

Approximately 15 years ago Etzkowitz (1998) and Clarke (1998) alerted the world to the emergence of an ‘entrepreneurial university’. In this establishment, a ‘third mission’ of contributing to economic development had emerged alongside the ‘first mission’ of teaching and the ‘second mission’ of conducting basic research. Epitomised by institutions such as MIT and Stanford (Etzkowitz et al. 2000), for the entrepreneurial academy:

> . . . identifying, creating and commercialising intellectual property have become institutional objectives.

Such activities may be undertaken with the aim of:

> . . . improving regional or national economic performance as well as the university’s financial vantage and that of its faculty. (Etzkowitz et al. 2000: 313)

Global Environmental Change 28 (2014) 153–165

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

University partnerships for co-designing and co-producing urban sustainability

Gregory Trencher[a,*], Xuemei Bai[b], James Evans[c], Kes McCormick[d], Masaru Yarime[e,f]

[a] University of Tokyo, Graduate School of Frontier Sciences, Japan
[b] Australian National University, Fenner School of Environment and Society, Australia
[c] University of Manchester, School of Environment, Education and Development, United Kingdom
[d] Lund University, International Institute for Industrial Environmental Economics, Sweden
[e] University of Tokyo, Graduate School of Public Policy, Japan
[f] University College London, Department of Science, Technology, Engineering and Public Policy, United Kingdom

ARTICLE INFO

Article history:
Received 7 March 2014
Received in revised form 21 June 2014
Accepted 23 June 2014
Available online

Keywords:
University partnerships
Sustainability
Urban
Co-design
Co-production
Stakeholder collaborations

ABSTRACT

Universities are playing an increasingly central role in advancing sustainability at the local, regional and national scale through cross-sector collaborations. Accompanying the launch of Future Earth, interest is mounting in the co-design and co-production of knowledge and solutions for advancing global sustainability, particularly in urban areas. Place-based university partnerships appear as particularly significant vehicles for enacting co-design and co-production in the context of urban sustainability. However, the nature and role of these partnerships are not well understood, in part due to the absence of systematic analyses across multiple cases. To fill this gap, the objectives of this paper were to conduct a large-scale international survey focusing on university partnerships for urban sustainability in industrialised Europe, Asia and North America to (1) determine defining features such as focus areas, geographical scales, mechanisms, actors and motivations, and (2) identify commonly encountered drivers, barriers and potential impacts.

Results indicate that partnerships most typically target energy, buildings, governance and social systems, unfold at local or city-scales, and involve collaborations with local or regional government. Our analysis shows that potential outcomes of university initiatives to co-design and co-produce urban sustainability are not limited to knowledge and policy. They also encompass the creation of new technological prototypes, businesses and new socio-technical systems, in addition to transformations of the built and natural environment. Findings also suggest that individual partnerships are making strong social, environmental and sustainability impacts, with less evidence of economic contributions. Strategies are required to enhance project management and ensure that projects address contrasting priorities and time horizons in academia and local government. Implications for policy include findings that targeted funding programmes can play a key role in fostering partnerships. Measures are also required to challenge academic norms and incentive structures that, in some cases, hinder university efforts to engage in place-based initiatives to co-design and co-produce urban sustainability.

1. Introduction

The grand sustainability challenges of our time such as climate change, food, water and resource security, pollution, environmental degradation and other socio-economic concerns are symptomatic of systematic failures (Rotmans and Loorbach, 2008). Tackling such problems requires fundamental re-configuration of inter-connected technological, environmental, social, economic and political systems and processes (McCormick et al., 2013; O'Brian et al., 2012). Cities are loci where many of these problems coexist and such systems and processes intertwine (Grimm et al., 2008). With the majority of humanity concentrated in urban areas, cities are widely regarded as central arenas in the pursuit of global sustainability (Clark, 2003; Kamal-Chaoui and Robert, 2009; Nevens et al., 2013). However, creating societal transformations towards greater sustainability surpasses the resources or expertise of any single player or organisation (Kania and Kramer, 2011). The

* Corresponding author. Tel.: +81 471364877; fax: +81 471364878.
E-mail addresses: trencher@sustainability.k.u-tokyo.ac.jp, gregtrencher@hotmail.com (G. Trencher).

http://dx.doi.org/10.1016/j.gloenvcha.2014.06.009

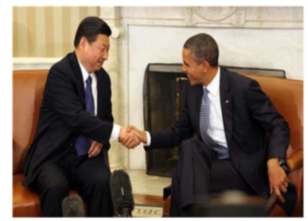
U.S.-China Clean Energy Research Center (CERC)

Vision

CERC accelerates development and rapid deployment of critical technologies for clean energy in the United States and China. CERC's mission is to generate a diversified energy supply and accelerate the transition to an efficient and low-carbon economy while mitigating the long-term threat of climate change.

About CERC

In November 2009, President Barack Obama and President Hu Jintao announced the establishment of the $150 million U.S.-China Clean Energy Research Center (CERC). The Protocol formally establishing the Center was signed by the leaders of the US Department of Energy, the Chinese Ministry of Science and Technology, and the Chinese National Energy Administration. CERC is also supported by the Chinese Ministry of Housing, Rural and Urban Development. CERC continues to enjoy high-level support in the new administrations of both countries. In November 2014, President Barack Obama and President Xi Jinping announced the extension and expansion of CERC, to add a new technical track on energy and water research. http://www.whitehouse.gov/the-press-office/2014/11/11/us-china-joint-announcement-climate-change



CERC facilitates joint research and development on clean energy technology by teams of scientists and engineers from the United States and China. It is a flagship initiative funded in equal parts by the United States and China. It has broad participation from universities, research institutions and industry, supporting more than 1,100 researchers, with more than 100 US and Chinese partnering entities.

CERC Consortia

The work of CERC is carried out in three (which will expand to four) areas of strategic importance to both countries:

	Joint Work Plan Research Areas: Public Private Partnership
Advanced Coal Technology Consortium	Advanced power generation; clean coal conversion technology; pre-combustion capture; post-combustion capture; oxy-combustion capture; CO_2 sequestration; CO_2 utilization (including EOR, algae); simulation and assessment; and communication and integration.
Clean Vehicles Consortium	Advanced batteries and energy conversion; advanced biofuels and clean combustion; vehicle electrification; advanced lightweight materials and structures; vehicle-grid integration; and energy systems analysis, technology roadmaps and policy.
Building Energy Efficiency Consortium	Integrated design; building envelope; building equipment; integration of distributed and renewable energy; lighting systems and controls; whole building technology integration; monitoring and simulation activities; and policy and market promotion research.
NEW: Energy-Water	This technical track will begin in calendar year 2015, with the United States and China mutually agreeing to Joint Work Plan Research Areas.

CERC Intellectual Property Protection

CERC is empowered by the Protocol's Intellectual Property Annex that strengthens protection of IP and provides precedent-setting terms that enable joint creation and exchange of IP. All CERC research projects comport with the mutually agreed-upon IP "Technology Management Plans," endorsed by both governments.

Joining CERC

Procedures, criteria and guidelines for joining CERC may be found at the CERC website, noted below. All members of CERC benefit from the opportunity to interact with leading organizations in the field, build relationships with partners and other-country participants, and provide strategic direction to leading edge research with paths to commercialization. CERC members support the mission and add value to the work program by providing contributions of an intellectual, technical, financial or other in-kind nature.

For more about the U.S.-China Clean Energy Research Center, see: http://www.us-china-cerc.org/