Future-Proofing Fuel Cells

Critical Raw Material Governance in Sustainable Energy

Martin David · Stephen M. Lyth
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Foreword

The concept for this book project grew out of a mutual recognition for the need of stronger interdisciplinary collaboration in sustainable energy studies. It is the result of in-depth discussions about early stage fuel cell technology governance between scientists from very different disciplinary backgrounds, broadly including materials science, engineering, sociology, and political science (although it should be noted that disciplinary labels are becoming less relevant in modern academia).

In particular, an interdisciplinary "back casting" exercise crystalized some of the concepts that are followed through in this book. During these exchanges the need to "translate" disciplinary language and jargon for a non-specialist audience was quickly realized, as well as the need to develop a common analytical framework to enable a fruitful interdisciplinary collaboration. This is reflected in the structure of the book, which introduces the reader to relevant aspects of fuel cells, critical raw materials (CRMs), and governance in short, dedicated chapters in a way that is hopefully understandable to different portions of the disciplinary spectrum.

This approach of course has limitations, since the scope is rendered by only four individuals and does not allow for active participation from other actors. While we acknowledge these shortcomings, we hope this text provokes a more profound discussion on anticipative governance strategies to address CRM issues in future sociotechnical pathways related to fuel cells.

Fukuoka, Japan — Stephen M. Lyth

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Abbreviations

(Ca-, Sr-)$LaCrO_3$	Lanthanum Chromite Doped with Either Calcium or Strontium
BEV	Battery Electric Vehicle
CAPEX	Capital Expenditure
CCS	Carbon Capture and Sequestration
CGO	Gadolinium-Doped Cerium Oxide
CH_4	Methane
CHP	Combined Heat and Power
CO	Carbon Monoxide
Co	Cobalt
CO_2	Carbon Dioxide
CRM	Critical Raw Material
DOI	U.S. Department of Interior
DWSB	Bismuth Oxide Doped with Tungsten and Dysprosium
Dy	Dysprosium
ECS	Electrochemical Society
ESB	Bismuth Oxide Doped With Erbium
EU	European Union
FCEV	Fuel Cell Electric Vehicle
FCH JU	Fuel Cells and Hydrogen Joint Undertaking
FCV	Fuel Cell Vehicle
FP7	Seventh Framework Programme for Research and Technological Development
Ge	Germanium
H_2	Hydrogen
H_2O	Water
IEA	International Energy Agency

JSPS	Japanese Society for the Promotion of Science
LCA	Life-Cycle Analysis
Li	Lithium
Li-ion	Lithium-Ion
LSCF	Strontium-Doped Lanthanum Iron Cobaltite
LSGM	Lanthanum Gallium Oxide Doped with Strontium and Magnesium
LSM	Strontium-Doped Lanthanum Manganite
LST	Lanthanum-Doped Strontium Titanate
METI	Ministry of Economy, Trade and Industry
MHPS	Mitsubishi Hitachi Power Systems Ltd.
MIECs	Mixed-Ionic Electronic Conductors
MITEI	Massachusetts Institute of Technology Energy Initiative
MRS	Materials Research Society
MRV	Measurement, Reporting and Verification Tools
NASA	National Aeronautics and Space Administration
Nd	Neodymium
NGO	Non-governmental Organization
Ni	Nickel
O_2	Oxygen
OECD	Organisation for Economic Co-operation and Development
OPEX	Operational Expenses
PEFC	Polymer Electrolyte Fuel Cell
PGM	Platinum Group Metal
Q-PIT	Platform for Inter- and Transdisciplinary Energy Research
RSC	Royal Society of Chemistry
rSOC	Reversible Solid Oxide Cell
SDGs	Sustainable Development Goals
Si	Silicon
SOEC	Solid Oxide Electrolyser Cell
SOFC	Solid Oxide Fuel Cell
TKK	Tanaka Kikinzoku Kogyo
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US DOE	United States Department of Energy
WTO	World Trade Organization
YSZ	Yttria-Stabilized Zirconia
μSOFC	Micro-SOFC

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CHAPTER 1

Introduction

1.1 Climate Change and Decarbonization

The burning of fossil fuels releases carbon dioxide into the atmosphere. This greenhouse gas causes climate change, which is the biggest threat to the survival of our species. In 1997, the urgency of this issue was recognized at the United Nations Framework Convention on Climate Change (UNFCCC), in the form of the Kyoto Protocol. This formed the cornerstone of international climate policy. In 2015, the international community negotiated the landmark Paris Agreement, which entered into force in 2016 and committed the signatory UN member states to hold "the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels" (UNFCCC, 2015, S. 3). Around the same time, the Agenda for Sustainable Development, with its 17 Sustainable Development Goals (SDGs), was agreed upon. SDG 7 was specifically formulated to ensure access to affordable, reliable, sustainable, and modern energy for all people in the world by 2030 (UN, 2015). These agreements have framed current efforts to deploy renewable energy technologies for decarbonization in the ongoing global energy transition.

However, progress on decarbonization of the world's energy systems has been slow, and global energy demand is set to increase even further. The International Energy Agency (IEA) recently stated that "the pace and scale of the global clean energy transition is not in line with climate

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