The Future of Nuclear Energy in a Carbon Constrained World

An MIT Study

Dr. David Petti
Executive Director

Professors Jacopo Buongiorno and Mike Corradini
Directors

MIT Energy Initiative

NSE
Nuclear Science and Engineering
science : systems : society

Acknowledgements

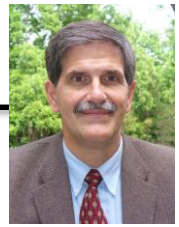
This study is supported by a generous grant from the Sloan Foundation

DISCLAIMER: MIT is committed to conducting research work that is unbiased and independent of any relationships with corporations, lobbying entities or special interest groups, as well as business arrangements, such as contracts with sponsors.

Study Team

Executive Director
Dr. David Petti (INL)

Co-Director
Prof. Jacopo Buongiorno
(MIT)



Co-Director
Prof. Emeritus Michael Corradini
(U-Wisconsin)

Team Members: Faculty, Students and Outside Experts

Prof. J. Lassiter
(Harvard)

Dr. J. Parsons
(MIT)

Prof. R. Lester
(MIT)

Dr. C. Forsberg
(MIT)

Prof. J. Trancik
(MIT)

Prof. D. Whyte
(MIT)

Prof. B. Yildiz
(MIT)

Prof. S. Ansolabehere
(Harvard)

Dr. R. Varrin
(Dominion Engineering)

Dr. J. Lovering
(Breakthrough Institute)

Ka-Yen Yau
(MIT student)

Amy Umaretiya
(MIT student)

Rasheed Auguste
(MIT student)

Lucas Rush
(MIT student)

Patrick Champlin
(MIT student)

Patrick White
(MIT student)

Karen Dawson
(MIT student)

Advisory Board

Name	Title	Background
Philip Sharp (Chair)	President, Resources for the Future; former US Congressman; Professor Emeritus, Harvard University	Government, energy policy
Kathryn McCarthy	Director, LWR Sustainability program, INL	Nuclear technology
Richard Meserve	President Emeritus, Carnegie Institution for Science; Head Emeritus, NRC	Nuclear regulations, science
William Magwood	Director, Nuclear Energy Agency; Commissioner Emeritus, NRC; Director Emeritus, DOE-NE	Nuclear technology, regulations, government, international dimension
Robert Budnitz	Project Scientist, Lawrence Berkeley National Laboratory	Nuclear waste and regulations
Zach Pate	CEO and Chairman Emeritus, INPO and WANO; former US Navy submarine commander	NPP operations, industry oversight, Navy experience
Susan Landhal	Chief Operating Officer of Fleet Operations, Exelon	NPP operations/industry
Jean-Pierre Benque	President Emeritus, EDF Development Inc. and EDF North America	International nuclear industry and energy markets
Edward Steinfeld	Professor of China Studies, Brown University	China energy markets
John Deutch	Institute Professor, MIT; Director Emeritus, CIA	Non-proliferation, government
Marvin Fertel	President and Chief Executive Officer, Nuclear Energy Institute	Nuclear industry, government
Michael Shellenberger	Co-founder and Senior Fellow, Breakthrough Institute	Environmental perspective
Akira Omoto	Professor, Tokyo Institute of Technology and Advisor to Nuclear Risk Research, ex-Director, Division of Nuclear Power, IAEA	Nuclear safety, Japan perspective
James Del Favero	Head, Cross-border M&A, Goldman Sachs	Finances

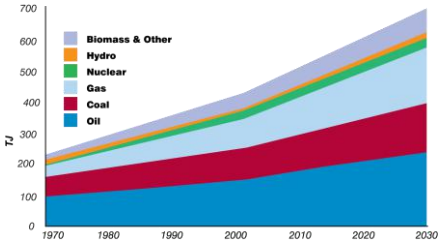
Main Goal and Key Questions

Main Goal: Identify the prospects for innovative nuclear technologies, policy and business models, and regulatory governance mechanisms to accelerate the transition to a lower-carbon global energy system in the United States and around the world. Identify the associated challenges and opportunities.

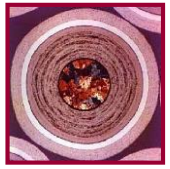
Key Questions: For each of these three time periods (present-2030, 2030-2050, beyond 2050):

- What are the energy markets whose de-carbonization nuclear can contribute to?
- What are the advanced nuclear technologies (reactors as well as cross-cutting technologies) that are likely to be ready for and cost-effective in those markets?
- What are the financial and regulatory approaches, as well as innovative policy and business models required to develop and commercialize these advanced nuclear technologies?
- Do advanced reactors systems offer the potential to accelerate the overall regulatory process because of their inherent safety characteristics?

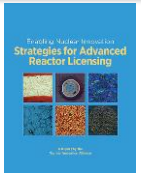
Five Major Themes

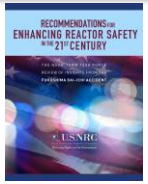


1. Opportunities



2. Technology Evaluation





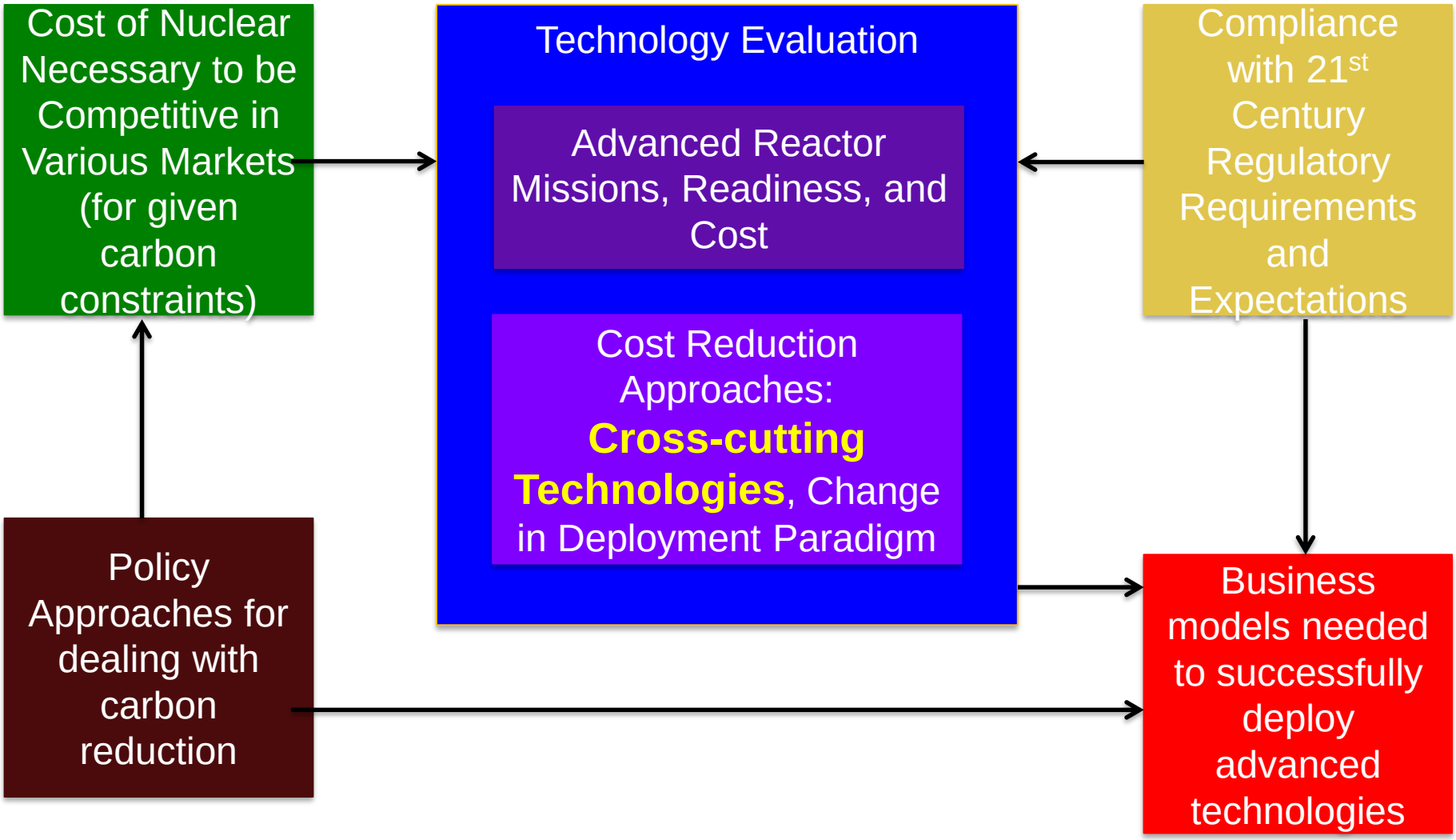
3. Regulatory Assessment

=

4. Policy Options

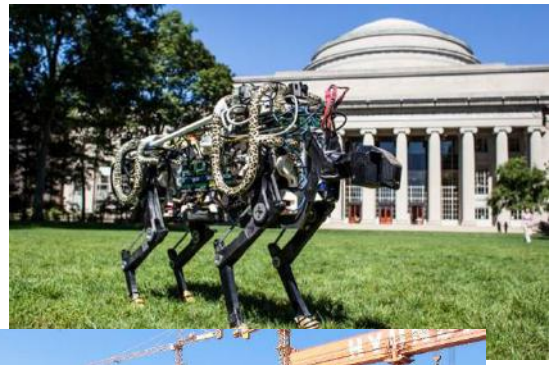
5. Business Models

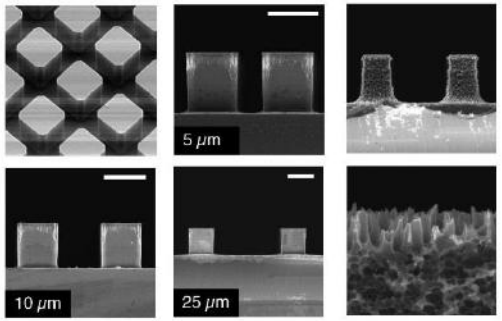
Interaction Between Major Themes of the Study



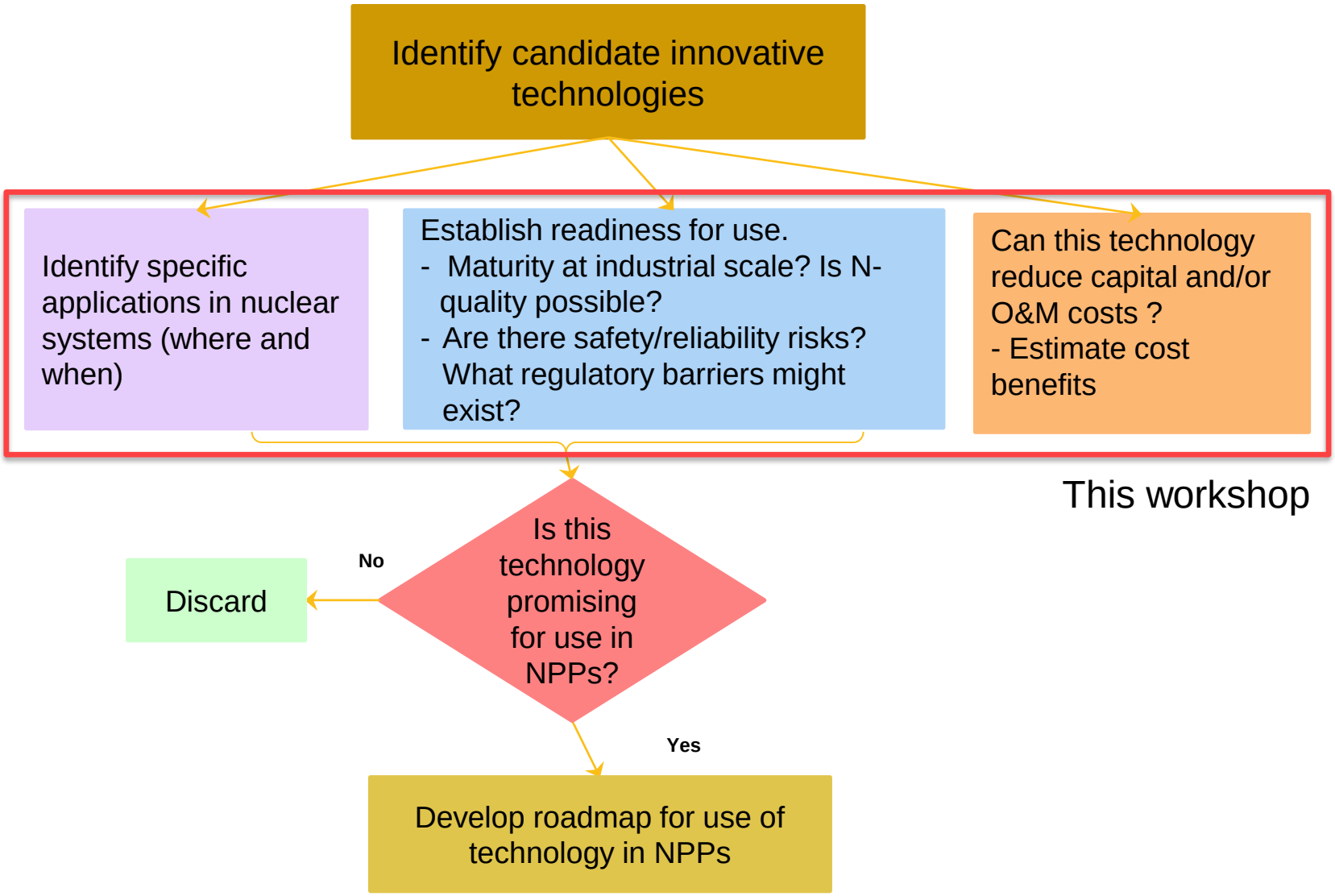
Advanced nuclear systems can benefit greatly from cross-cutting technology innovations in other fields

- **ROBOTICS and INFORMATICS:** automate operations, maintenance and emergency response in nuclear plants (increase reliability, predict failures, reduce costs)
- **SHIPYARD CONSTRUCTION:** build large nuclear plants in short time leveraging infrastructure of offshore oil/gas industry
- **3D PRINTING:** fabricate nuclear components with complex geometries (e.g. fuel assemblies, core internals) without welding (nuclear QA available from weapons program)
- **NANOTECHNOLOGY:** nano-engineer cladding, fuel or coolant to improve core thermal and irradiation performance





Cross cutting enabling technologies



Proposed Schedule