MISSION INNOVATION

Accelerating the Clean Energy Revolution

by

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U.S. Department of Energy

for

Experts Group on R&D Priority-Setting and Evaluation

International Energy Agency, Paris

17 May 2016

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Paris Climate Conference and Agreement – Key Features *

Well Below 2°C	Limit Warming to Well Below Target, and Try to Cap at 1.5°C
Achieve a Balance	Balance Anthropogenic GHG *Sources* and Removal by *Sinks* by Mid-Century
Every 5 years	Countries Will Review and Submit New, More Ambitious Plans Every Five Years
Technology Development	Advance Technology Innovation through Mission Innovation and Breakthrough Energy Coalition
Mobilize Climate Finance	Collectively Mobilize $100B per Year in Public and Private Funding for Developing Economies through 2025
Enhanced Transparency	Enhance Transparency for Reporting GHG Emissions, Subject to Expert Review

* Report on COP-21, “Inside the Paris Climate Deal”, *Science*, Warren Cornwall, Dec 2015: Vol. 350, Issue 6267, pp. 1451

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A Unique Moment in Time

- All on One Stage -- Leaders of 20 Countries Representing over 80% of Global Clean Energy R&D Investment Agreed to Support a *Joint Statement* on Innovation
- Each Country Supported a Doubling of Governmental Clean Energy R&D Investment over Next Five Years (www.mission-innovation.net)
- Gov't Investment was Complemented by a Private Sector Initiative led by Bill Gates, the Breakthrough Energy Coalition (www.breakthroughenergycoalition.com)

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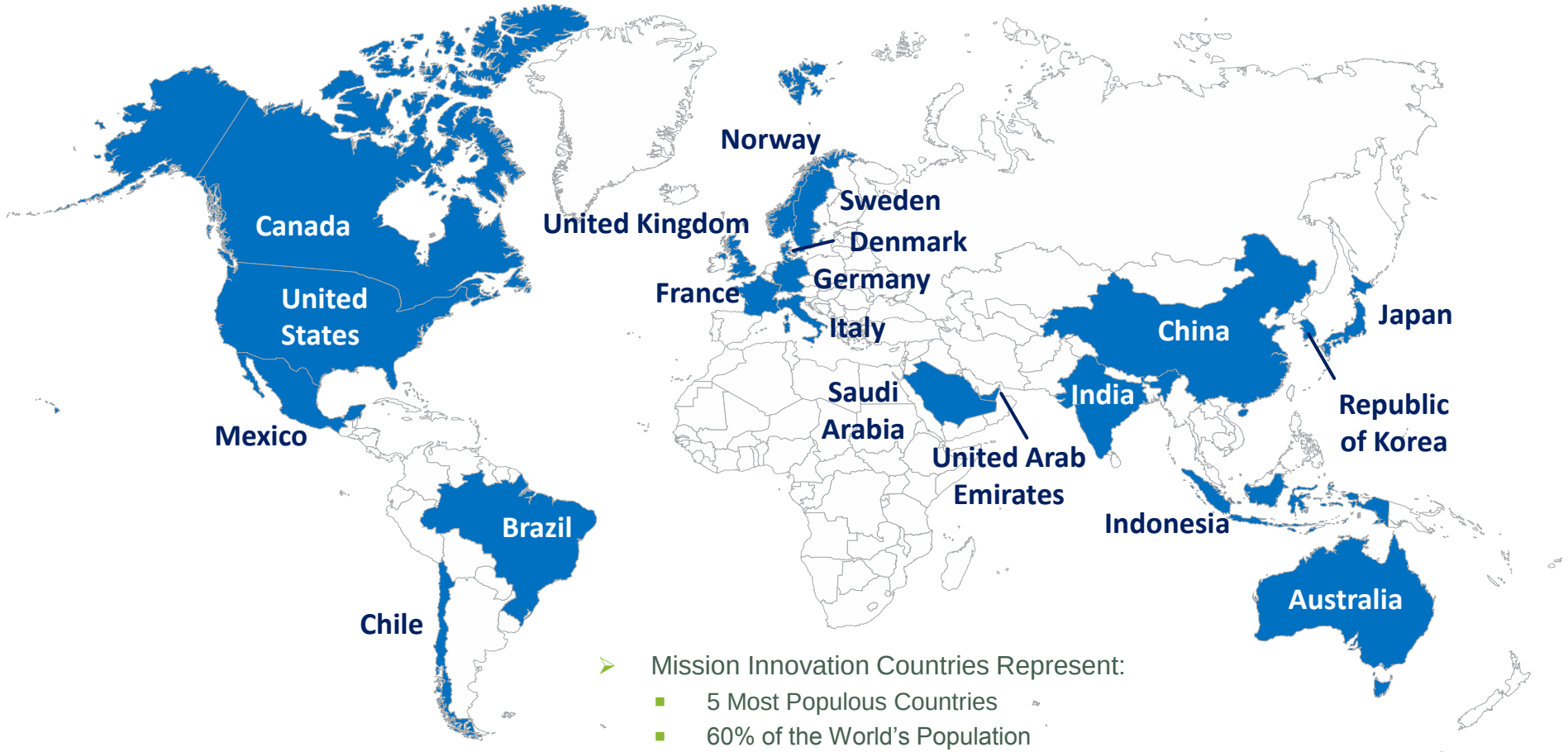
Global Scope



- Mission Innovation Countries Represent:
  - 5 Most Populous Countries
  - 60% of the World's Population
  - 67% of the Total Greenhouse Gas Emissions
  - 70% of Global GDP
  - 75% of the CO_2 Emissions from Electricity
  - 80% of Government Investment in Clean Energy R&D

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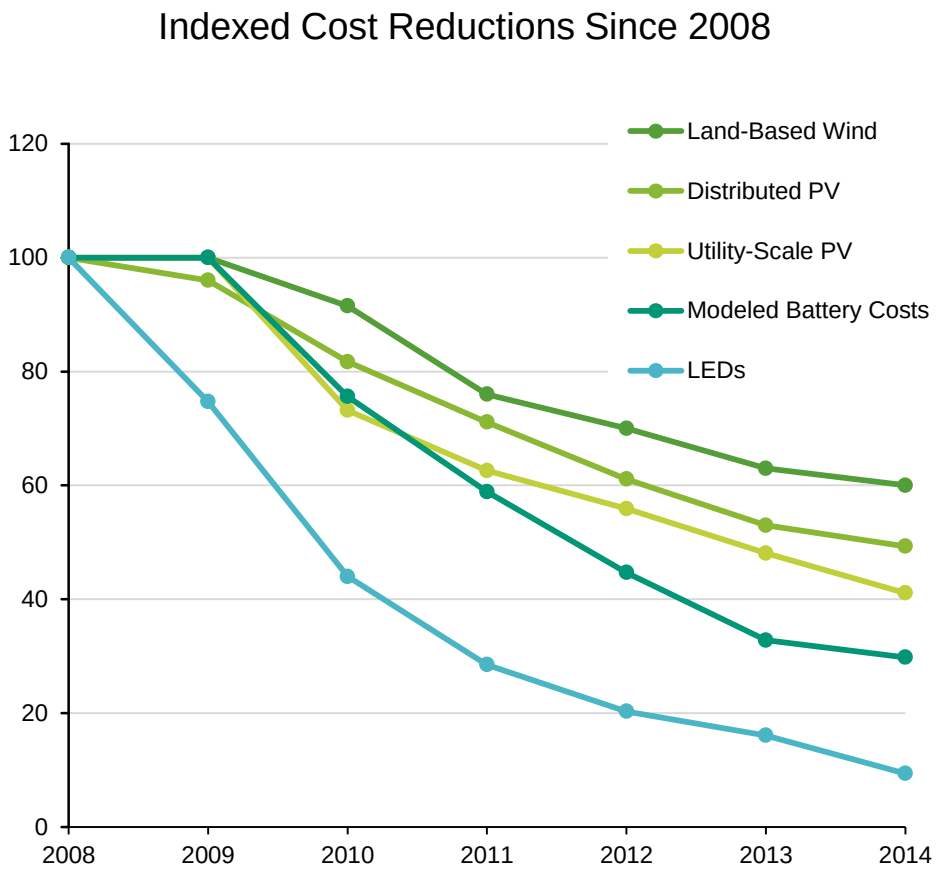
Motivating Factors

- On Climate Change, Time is Running Out:
  - Atmospheric Concentrations of GHGs are Rising, with Inexorable CC Effects
  - Changes in Climate are Manifest, Serious and Increasing
  - Business as Usual Approach is Unacceptable
  - Current Solutions are Ill-Suited or Too Costly for a World-Wide Acceptance
  - The Pace of Innovation is Too Slow
- Widely Affordable Solutions Can Be Found:
  - Costs of Wind, Solar PV, Battery Costs, and LEDs Have Dropped Dramatically
  - More Innovative Ideas Are on the Cusp of Realization, but Need a Boost to Market
  - Private Investment is Poised to Help
  - Global Mobilization of Innovative Talent Will Speed Solutions and Mitigate CC Effects



Source: Adapted from DOE, "Revolution…Now: The Future Arrives for Five Clean Energy Technologies – 2015 Update," http://www.energy.gov/eere/downloads/revolution-now-future-arrives-five-clean-energy-technologies-2015-update

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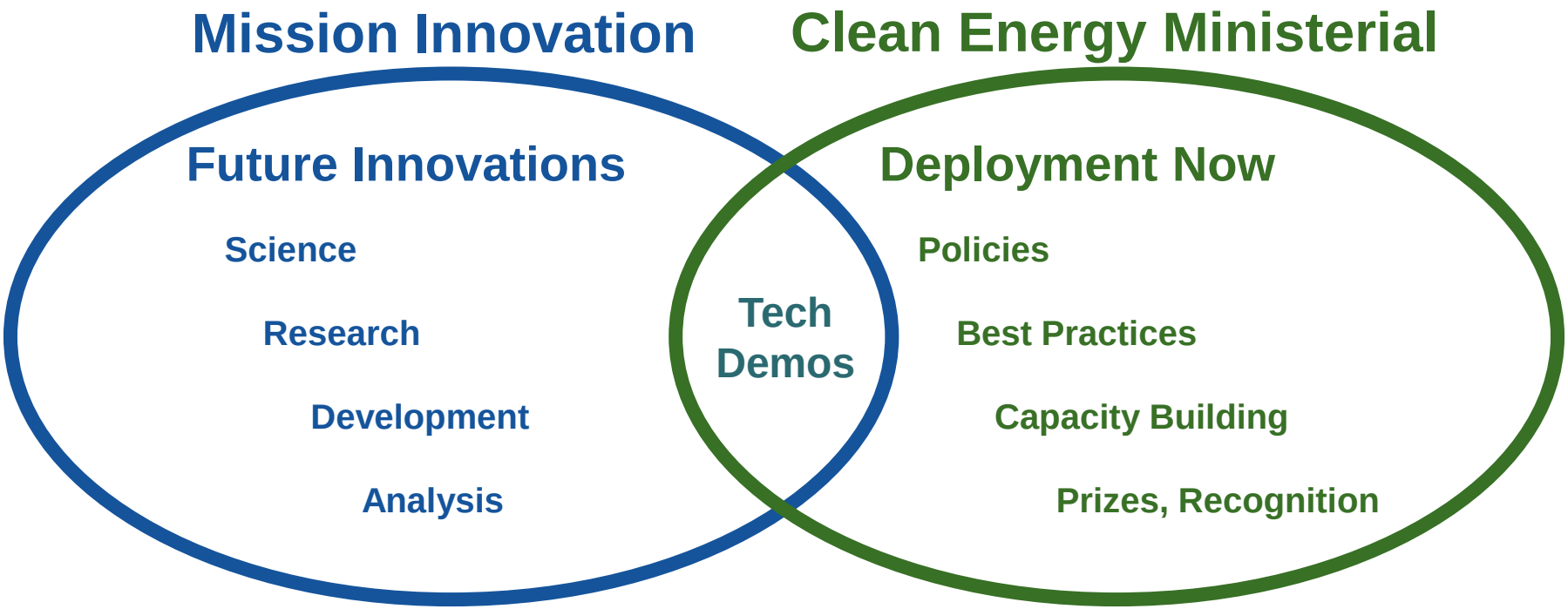
Clean Energy Solutions – For Today and Tomorrow



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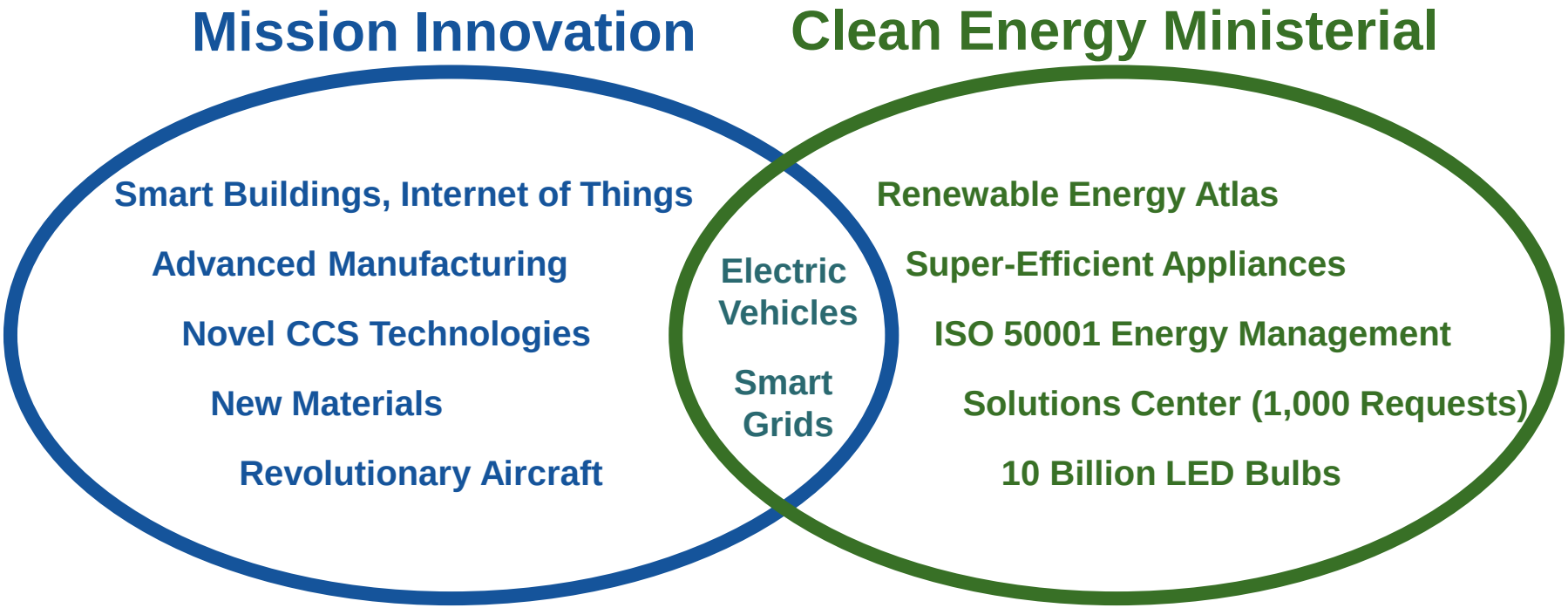
Clean Energy Solutions – Examples



Create New Ideas → Improve Performance → Reduce Cost → Raise Awareness → Facilitate Market Uptake

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MISSION INNOVATION -- EXAMPLES

Science

- New Materials
  - High Temperature
  - Tailored Mechanical Chemical Properties
  - Tailored Electrical Magnetic Properties
- Heat Transfer & Fluid Dynamics
- Combustion Materials
- Electro & Thermo Chemistry
- Photo & Radiation Chemistry
- Membranes & Separations
- Condensed Matter Physics
- Nanosciences
- Geosciences & Hydrology
- Chemical Catalysis
- Bio-Catalysis
- Plant and Microbial Genomics (Biotechnology)
- Bio-Based & Bio Inspired Processing
- Environmental Science
- Earth and Climate Science
- Atmospheric Science
- Advanced Scientific Computing Models and Simulations
- Fusion and Plasma Sciences
  - Plasma Confinement Systems
  - High Energy Density Physics
- 5 New Energy Frontier Research Centers (Total of 37)

Research

- Regional Clean Energy Innovation Partnerships
- Small Business Innovation Partnership Program
- Energy Technology Innovation Accelerators
- ARPA-E
- 2 New National Network for Manufacturing Innovation Institutes for Clean Energy
- Materials in Extreme Conditions Initiative
- Materials Manufacturing for Grid Applications Initiative
- New Desalination Hub
- Sensors & Instrumentation
- Basic Clean Energy Research
- Zero-Emission Fossil Energy
- Direct CO_2 Capture from Atmosphere
- Safe Long-Term Ocean Storage

Development

- Sustainable Transportation
  - SuperTrucks
  - Vehicle Lightweighting
  - Zero-Emission Vehicle Systems
  - Optimized Multi-Modal Intercity & Freight Transport
  - Very Low Aviation Emissions
- Renewable Power
  - Solar, SunShot Initiative
  - Wind
  - Water
  - Geothermal
  - Biomass
  - Fuel Cells
- Energy Efficiency
  - High Impact Technology (HIT) Catalysts
  - LEDs
  - Building Management and Information Systems
  - Shading Attachments and Awnings
  - Refrigeration Controls
  - Commercial Fans and Blowers
  - Smart Buildings
  - Smart Meters
  - Energy Managed Communities
  - Advanced Sensors and Controls
- Advanced Nuclear Energy
  - Pebble Bed
  - Molten Chloride Fast Reactor
  - Gen IV Energy Systems
  - Advanced Nuclear Fuels
  - Small Modular Reactors

Analysis

- Demand Response and Dynamic Pricing
- Generation Flexibility
- Microgrids
- Distributed Generation
- Physical and Synthetic Inertia
- Electric Vehicles
- Power Electronics
- Resiliency
- Cybersecurity
- Polygeneration
- Hybrid Generation
- Combined Heat and Power
- Waste Heat Recovery
- CO_2 as a Working Fluid
- Carbon Management
- NGCC Carbon Capture Pilot Plant
- 3 Post Combustion CO_2 Capture Pilot Plants (10 MW Scale)
- 2 New FEED Studies for Advanced Combustion

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CLEAN ENERGY MINISTERIAL -- EXAMPLES

Energy Efficiency & Demand

- Super-Efficient Equipment and Appliance Deployment
  - Appliance Energy Efficiency Policy Exchange Forum
  - Efficiency Awards
  - Street Lighting Tool
  - Efficiency Standards and Labeling
- Global Lighting Challenge (10 Billion High Efficiency Bulbs)
- Electric Vehicles
  - EV City Casebooks
  - Global EV Outlook
- Energy Management Working Group
  - ISO 50001 Energy Management
  - Energy Management Toolbox and Case Studies
- Cool Roofs and Pavements Toolkit
- CHP/DHC Country Scorecards

Energy Supply

- Solar and Wind
  - Global Atlas for Renewable Energy
  - Renewable Energy Learning Partnership
  - Capacity Development Needs Diagnostics for Renewable Energy (CaDRE)
  - Renewable Energy Auctions and Policies Guides
- Carbon Sequestration Leadership Forum

Energy Systems & Integration

- 21st Century Power Partnership
  - Technical Assistance for Policy and Regulatory Implementation
  - 21CPP Fellowship Program
  - Distributed Generation Regulation Resource Library
  - Renewable Energy Roadmap for India
- Global Lighting and Energy Access Partnership
  - Global LEAP Awards
  - Off-grid Appliance Quality and Efficiency Testing
  - Global Lighting Quality Assurance Framework
  - Mini-Grids Quality Assurance Framework
- International Smart Grid Action Network
  - Smart Grids Best Practice Handbook
  - Smart Grids Training Academy
  - Smart Grids Integration Awards

Crosscutting

- Clean Energy Education and Empowerment
  - Awards for Mid-Career Leadership in Clean Energy
- Clean Energy Solutions Center
  - Ask-an-Expert Service
  - Online Training and Resources
  - Finance Solutions Center

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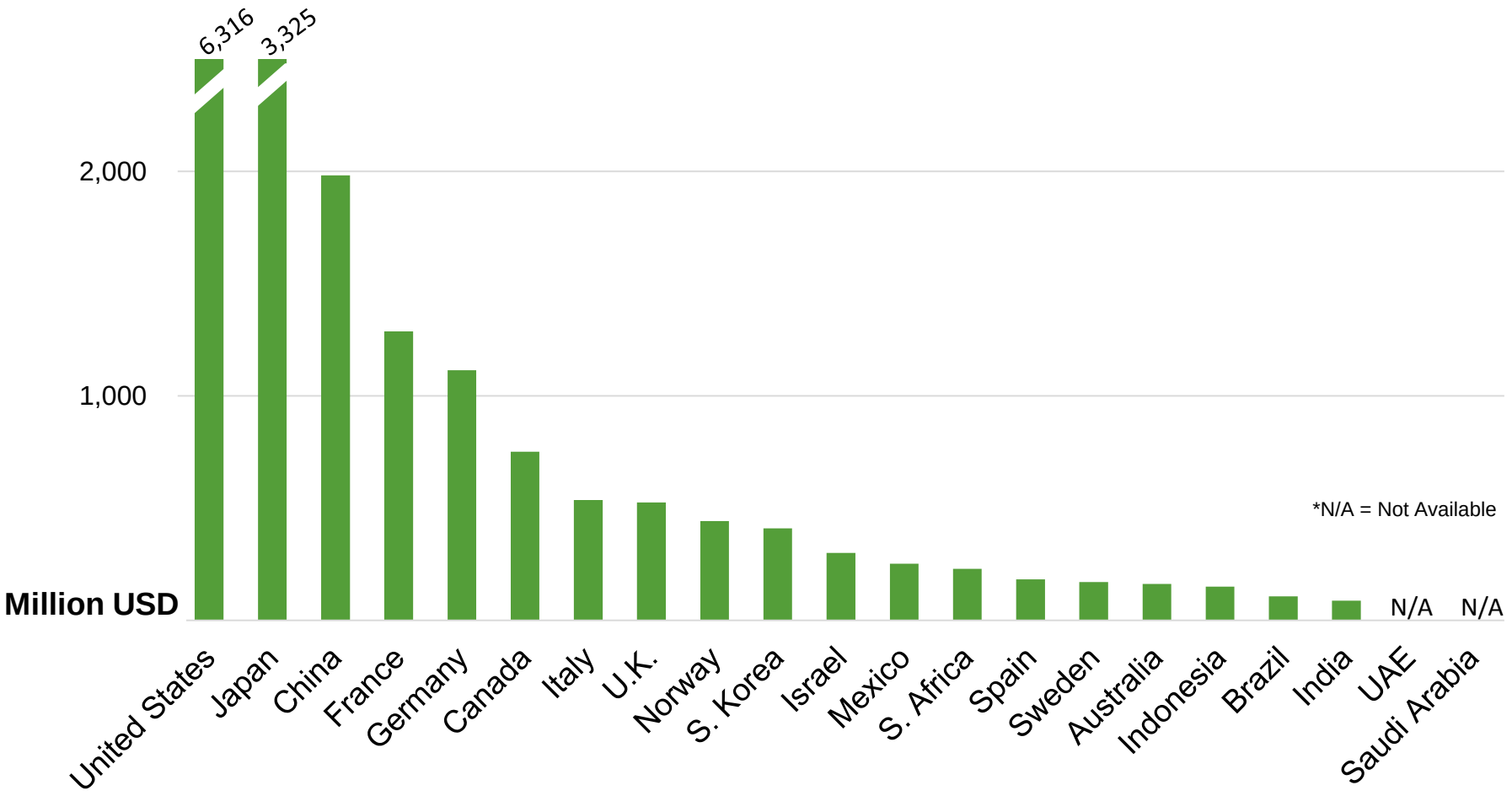
Interim Estimates on 2014 Clean Energy R&D Investments by Country



Source: International Energy Agency for most IEA countries, and Bloomberg New Energy Finance survey data for others. IEA data include all forms of energy R&D and demonstrations, but exclude deployment expenditures and costs for overhead and program direction. Note: the estimate for the United States is USG-based data, but reshaped to be compliant with IEA reporting guidelines.

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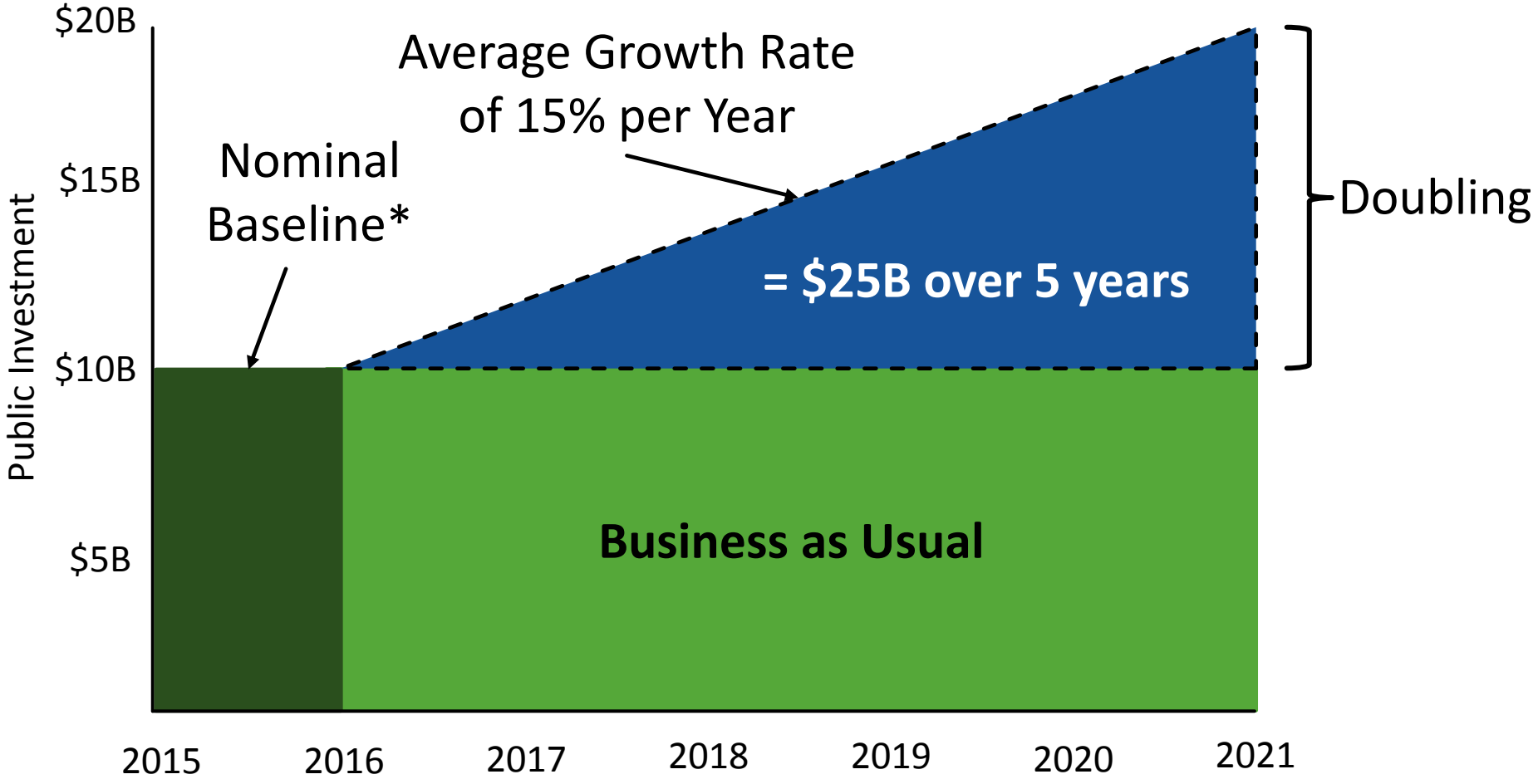
One Possible Global Funding Scenario for all MI Participating Countries



* Nominal baseline of $10 billion is a rough estimate, based on based on IEA Energy RD&D Expenditures and Survey Data from Bloomberg New Energy Finance for 20 MI countries. A better estimate will emerge, once MI countries report later in 2016.

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Next Steps

- Each Country Must Define Its Own Program Scope and Doubling Plan:
  - Establish a "Mission Innovation" R&D Baseline and Base-Year
  - Declare Amount of its Doubling Plan and by When
  - Provide a Country-Narrative Describing R&D Investment Priorities
- Additionally, to the Extent Practicable:
  - Evidence Commitment by Announcing a First-Year Plan
  - Provide Transparency by Disclosing Composition of Baseline and Growth
- Establish Information Sharing Mechanisms Among Countries
- Identify R&D Needs, Conduct Analyses, and Launch Road-Mapping
- Explore Joint Research & Capacity Building Opportunities
- Agree on an International Platform for Sustained MI Operation

First Ministerial Meeting Hosted by the U.S. on June 2, 2016 in San Francisco, CA

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Private Sector Actions

"We must…add the skills and resources of leading investors with experience in driving innovation from the lab to the marketplace."

"The private sector knows how to build companies, evaluate the potential for success and take the risks that lead to taking innovative ideas and bringing them to the world."

"Governments play an indispensable role in supporting energy research."

"Government research, however, is not enough. "

-Bill Gates

Bill Gates, "Energy Innovation: Why We Need It and How to Get It," http://www.breakthroughenergycoalition.com/assets/resources/Energy-Innovation-by-Bill-Gates-Nov-30-2015.pdf; Breakthrough Energy Coalition, "Introducing the Breakthrough Energy Coalition," http://www.breakthroughenergycoalition.com/en/index.html

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Breakthrough Energy Coalition

- **Different Kind** of Investor:
  - Long-term Commitment to New Technologies
  - Utilize Truly Patient, Flexible Risk-Tolerant Capital
- **Different Approach** to Investment:
  - Identify Investable Ideas Early
  - Speed Up Innovation Cycle
  - Focus on Ideas that Go to Scale
  - Adopt Different Types of Deal Structures

<Click on video to load>

Bill Gates, gatesnotes, "A Big Win for Cheap, Clean Energy," https://www.gatesnotes.com/Energy/Investing-in-Energy-Innovation

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Fund Principles

1. Invest Early	Provide Seed, Angel and Series A Investments. Once De-Risked, Traditional Investors may Follow.
2. Invest Broadly	Invest Across a Number of Sectors: ▪ Electricity Generation and Storage ▪ Transportation ▪ Industrial Use ▪ Agriculture ▪ Energy System Efficiency
3. Invest Boldly	Novel Technologies and Dramatic Improvements to Existing Technologies. Credible Path to Rapid Scale-Up without Burdening Essential Systems.
4. Invest Wisely	Tap Leading Experts to Guide Investment Decisions.
5. Invest Together	Invest in Mission Innovation Countries' Innovation Pipelines.

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Breakthrough Energy Coalition


Mukesh Ambani


John Arnold


Mark Benioff


Jeff Bezos


Alwaleed bin Ttalal


Richard Branson


Ray Delio


Aliko Dangote


John Doerr


Bill Gates


Reid Hoffman


Chris Hohn

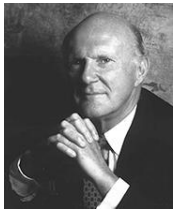

Vinod Khosla


Jack Ma


Patrice Motsepe


Xavier Niel


Hasso Plattner


Julian Robertson


Neil Shen


Simmons & Baxter-Simmons


Masayoshi Son


George Soros


Tom Steyer


Ratan Tata


Meg Whitman


Zhang Xin Pan Shiyi


Mark Zuckerberg, Priscilla Chan

- 27 investors & University of California; collective net worth: $300+ billion
- Commitment to invest in innovation emerging from Mission Innovation pipeline
- Long-term, patient, and risk-tolerant capital

Implementation

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MI Sub-Groups

- Six Thematic, Ad Hoc Sub-Groups: *
  1. Information Sharing
  2. Innovation Analysis and Road-Mapping
  3. Joint Research and Capacity Building
  4. Private Sector Engagement
  5. Statement of Mission
  6. Secretariat and Longer-Term Organization
- Sub-Groups “Staffed” by Int’l Volunteers from MI Countries
- Sub-Group Products to Flow into MI Framework Document

* Organized around themes of Joint Statement by MI Country Leaders

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Schedule

Mission Innovation Countries Flesh-out Key Elements of the Initiative's Implementation, Including Pledges	May 2016
Energy Ministers of MI Countries Meet in San Francisco, in Conjunction with Clean Energy Ministerial, Publicly State MI Baselines, Doubling Plans and Other Initiatives	1-2 June 2016
MI Countries Explore Joint R&D Opportunities	Fall 2016
Breakthrough Energy Coalition Launches Initial Investment Fund (Tentative)	December 2016

U.S. Government

Baseline and Doubling Plan

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Meeting the U.S. Pledge: Proposed U.S. FY 2017 Clean Energy R&D Budget

"Mission Innovation and the Breakthrough Energy Coalition constitute powerful complementary efforts to expand research and development for cutting-edge clean energy technologies and support a new generation of scientists, engineers, and entrepreneurs."

- White House Fact Sheet on the Proposed FY17 Budget for Mission Innovation

U.S. Pledged Action	Proposed U.S. Commitment
• Baseline (FY 2016)	$6.4 Billion
• Doubling Target (2021)	$12.8 Billion
• Needed Path to Doubling	15% per Year
• Proposed USG Increase, from FY 2016 to FY 2017	20% in 1st Year
• First-Year President's Budget (FY 2017)	$7.7 Billion (+ $1.3 Billion)
• Across 12 Agencies	DOE + 11 Other Agencies

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Proposed U.S. Government Budget, FY 2017

1. Department of Energy	Request
• Basic Clean Energy Research	$1,853M
• Sustainable Transportation Technologies	$880M
• Nuclear Energy Technologies	$804M
• Carbon Capture & Storage and Other Fossil Emissions Improvements	$564M
• Solar, Wind, Water, and Geothermal Energy	$500M
• Advanced Research Projects Agency – Energy	$350M
• Clean Energy Manufacturing, including 2 new National Network for Manufacturing Innovation Institutes	$261M
• Grid Modernization, Resiliency, and Clean Energy Integration	$177M
• New Regional Clean Energy Innovation Partnerships	$110M
• New Innovation Initiatives	$105M

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Proposed U.S. Government Budget, FY 2017 (continued)

2. National Science Foundation	
• Conversion, Storage, and Distribution of Power; Energy Materials	$512M
3. National Aeronautics and Space Administration	
• Low-Carbon Air Transportation	$348M
4. Department of Agriculture	
• Bio-Based Energy	$106M
5. Department of Housing and Urban Development	
• Enable Builders, Property Owners, and Tenants to Improve Efficiency	$10M
6. U.S. Agency for International Development	
• Clean Energy Innovation for Developing Countries through the Global Development Lab and the Global Climate Change Initiative	$25M
7. Other Agencies	$797M
TOTAL Clean Energy R&D Budget	$7.7 B

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DOE Budget Strategy (1 of 5)

- **Augment Existing Basic and Applied DOE Energy RD&D Programs**
  - BES (EFRCs and User Facilities) and BER (Bioenergy Research Centers)
  - OE and EERE (Additional NNMIs, New Hub, and Other Increases)
  - FE (Advanced Carbon Capture Technology) and NE (Advanced Reactor R&D)
- **Cross-cutting Innovation Initiatives**
  - National Laboratory "Small Business Partnership Program"
  - National Laboratory "Energy Technology Innovation Accelerators"
  - Regional Clean Energy Innovation Partnerships

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DOE Budget Strategy (2 of 5)

- **Science/BES**
  - 5 New EFRCs (Total of 37) (Possible New Focus Area on Subsurface R&D)
  - Increase BES User Facility Operating Rates to 100% of Optimal Hours to Accommodate Increased Mission Innovation-Related Work
  - Increase Focus of Nanoscale Science Research Centers on Mission Innovation Objectives
- **Science/BER**
  - Increase Funding for Final Year of 10-year program at 3 Existing Bioenergy Research Centers (BRCs), Focused on Technology Demonstration and Transfer; Plan to Conduct FOA for New BRCs to be Funded in FY 2018
- **EERE/Crosscutting**
  - Next Generation Innovation: Support the On-Ramping of High-Impact Technologies through RD&D Projects Across EERE's Sustainable Transportation, Renewable Power, and Energy Efficiency Sectors

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DOE Budget Strategy (3 of 5)

- **Energy Efficiency/Advanced Manufacturing**
  - Support 3 Existing National Network of Manufacturing Innovation Institutes; Establish 2 Additional Institutes in FY 2016
  - Propose 2 New Initiatives in FY 2017 - - Materials in Extreme Conditions and Materials Manufacturing for Grid Applications (Grid Institute)
  - Propose New Hub (Desalination)
- **Fossil Energy/Carbon Management**
  - Support 3 Pilot Plant Projects (10 Mw Scale) to Test Advanced Concepts for Post Combustion Carbon Capture
  - Support 4 FEED Studies of Advanced Combustion Technologies
  - Initiate Construction of a NGCC Carbon Capture Pilot Plant
  - New Research Initiative to Address Materials in Extreme Environments

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DOE Budget Strategy (4 of 5)

- **Nuclear Energy/Reactors**
  - Fulfill DOE's Funding Commitment to Design Certificate Document for NuScale SMR
  - Fund 2 Advanced Reactor R&D Concepts - Pebble Bed and Molten Chloride Fast Reactor
  - Implement New Integrated Waste Strategy - Consent Based Siting, Consolidated Storage, Separate Defense Repository, Deep Borehole R&D, Transportation Systems
- **Office of Electricity**
  - Increased Energy Storage R&D Program
- **Increase Annual Appropriations for ARPA-E**
- **Discretionary Appropriations will Support Expansion of Current ARPA-E Activities**
  - Fund 7-8 New Solicitations
  - Supplement Highly Successful Existing Projects to Achieve Investment Readiness Support

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DOE Budget Strategy (5 of 5)

- **National Laboratory Small Business Partnerships**
  - Provide Competitively Awarded Clean Energy R&D Funding at National Laboratories to Partner with Small Businesses to Address their Critical Clean Energy R&D Challenges and Opportunities
- **National Laboratory Energy Technology Innovation Accelerators**
  - Couple the Talent and Commitment of Early-Stage Clean Energy Technology Entrepreneurs with the World-Class Tools and Expertise of the National Labs through RD&D Projects that Encourage Mentorship and Network Support Leading to New Company Creation and the Development of Successful Commercialization Strategies
- **Regional Clean Energy Innovation Partnerships**
  - Competitively Awarded, Cost-Shared Support for the Creation of Up to 10 Regional Clean Energy Innovation Partnerships
  - Partnerships will Support Targeted Regionally-Focused Technology-Neutral Clean Energy RD&D Initiatives to Address Regionally Relevant Energy Challenges and Opportunities in Energy Innovation

Cooling Technologies in MI Countries

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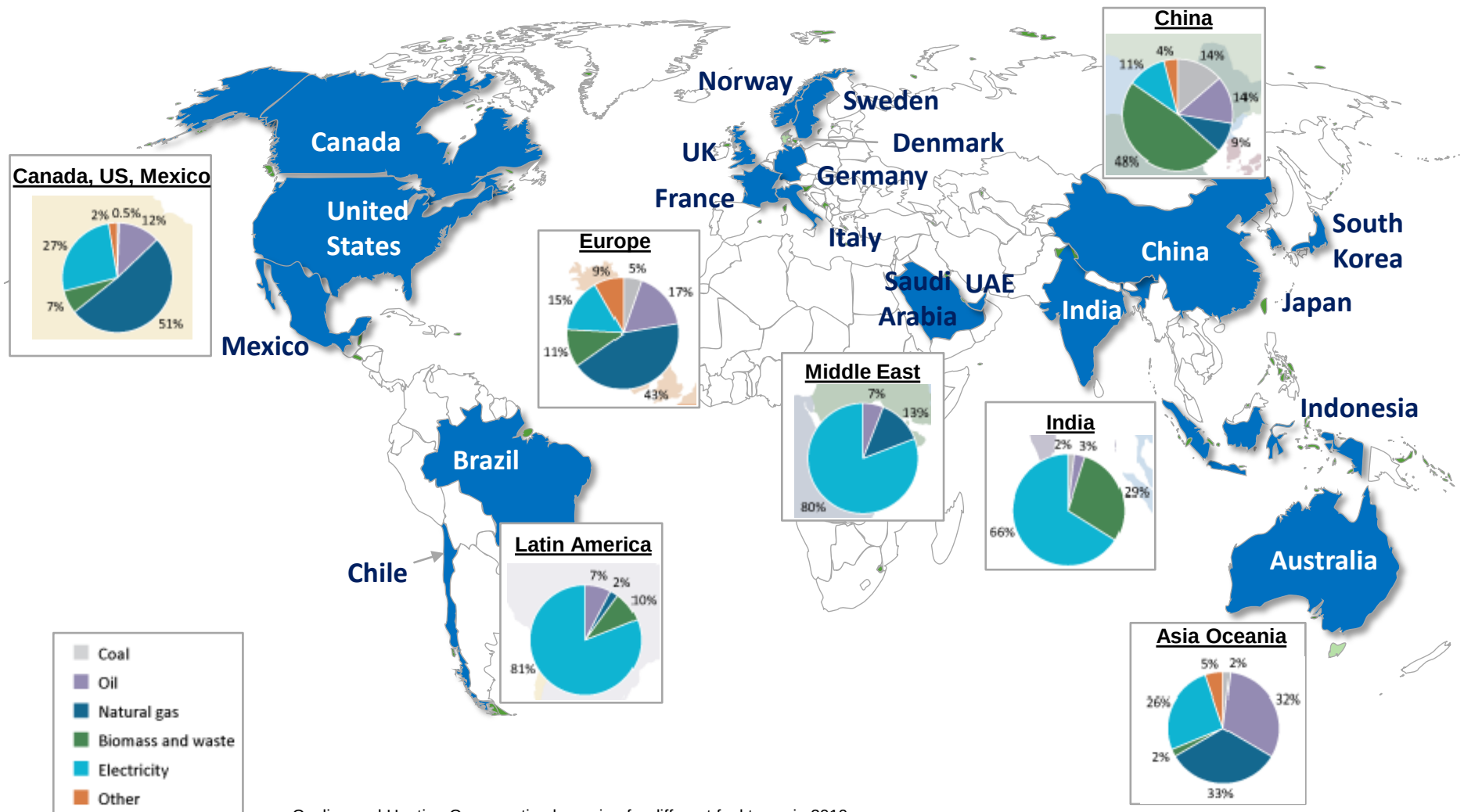
Cooling & Heating Consumption in MI Countries



Cooling and Heating Consumption by region for different fuel types in 2010.
http://www.iea.org/etp/buildings/dataandfigures/heatingandcoolingtechnologies/

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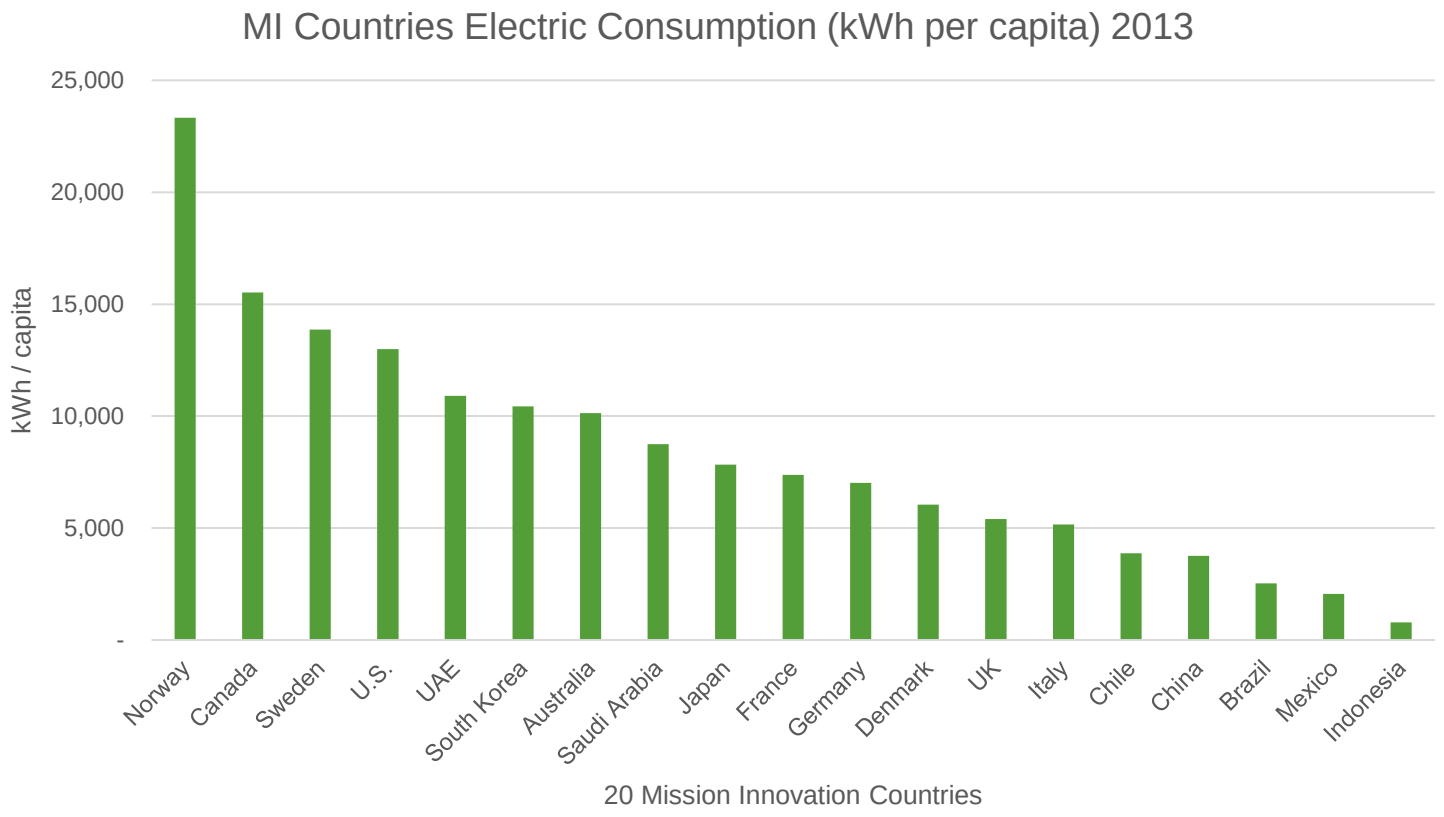
Electric Consumption in MI Countries



http://data.worldbank.org/indicator/EG.USE.ELEC.KH.PC/countries?order=wbapi_data_value_2013%20wbapi_data_value%20wbapi_data_value-last&sort=asc&display=map

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R&D and Emerging Building Cooling Technologies in MI Countries

Northern Europe (Denmark, Germany, Norway, Sweden, United Kingdom)

- Robust Insulation and Glazing Technologies
- District Cooling (Instead of De-centralized Systems)
- Natural Ventilation
- Radiant Cooling
- Geothermal
- Air-Cooled Chillers

Southern Europe (France, Italy)

- District Cooling
- Geothermal

Australia

- Solar Cooling

Emerging countries (Brazil, Chile, China, India, Saudi Arabia)

- Phase-down of HFCs, particularly in Mini-Split Air Conditioning Units

Japan

- Heat Pump Systems for Energy Efficiency

United States

- Non-Vapor and Advanced Vapor Compression Systems with Low-GWP Refrigerants