Long-Term Sustainable Energy and Environment

Leveraging science, technology, innovation and partnerships

Sustainable Energy Generation Decentralized - and potential new markets
São Paulo, Brazil - August 31, 2015

Mark Senti, CEO
AML Superconductivity and Magnetics (AML)
Palm Bay, Florida

AML Superconductivity and Magnetics

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Superconductivity “Promise”

Advanced materials such as superconductivity have the potential to be a transformational force for broad economic and social impact

“There is universal agreement between the United Nations and governments from the richest to the poorest nations that humanity faces unprecedented global challenges relating to sustainable energy, clean water, low-emission transportation, coping with climate change and natural disasters, and reclaiming use of land

***Clearly superconductivity is an ultimate energy-saving technology**, and its practical implementation will contribute to the reduction of CO2 emissions, improved water purification, reduction of waste and timely preparedness for natural disasters or significant events”*

Superconductivity and the environment: a roadmap,” iOP Publishing Ltd, (2013)

“Dialogue” Topics

Today’s Energy Landscape

- Global, Brazil

Opportunities

- Potential for significant impact to the Energy Landscape
- Brazil – Offhshore Wind, Hydropower, Transmission

Technology and Innovation

- Application of advanced materials such as superconductivity for transformative changes to the Energy Landscape

Leveraging technologies, investments and partnerships

- Addressing the broad energy landscape of generation, transmission and use

Decentralization and Micro-generation

- Distributed energy and micro-generation

Today's Energy Landscape

Global, US and Brazil

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Energy Landscape – Very Broad

Energy (Electrical)

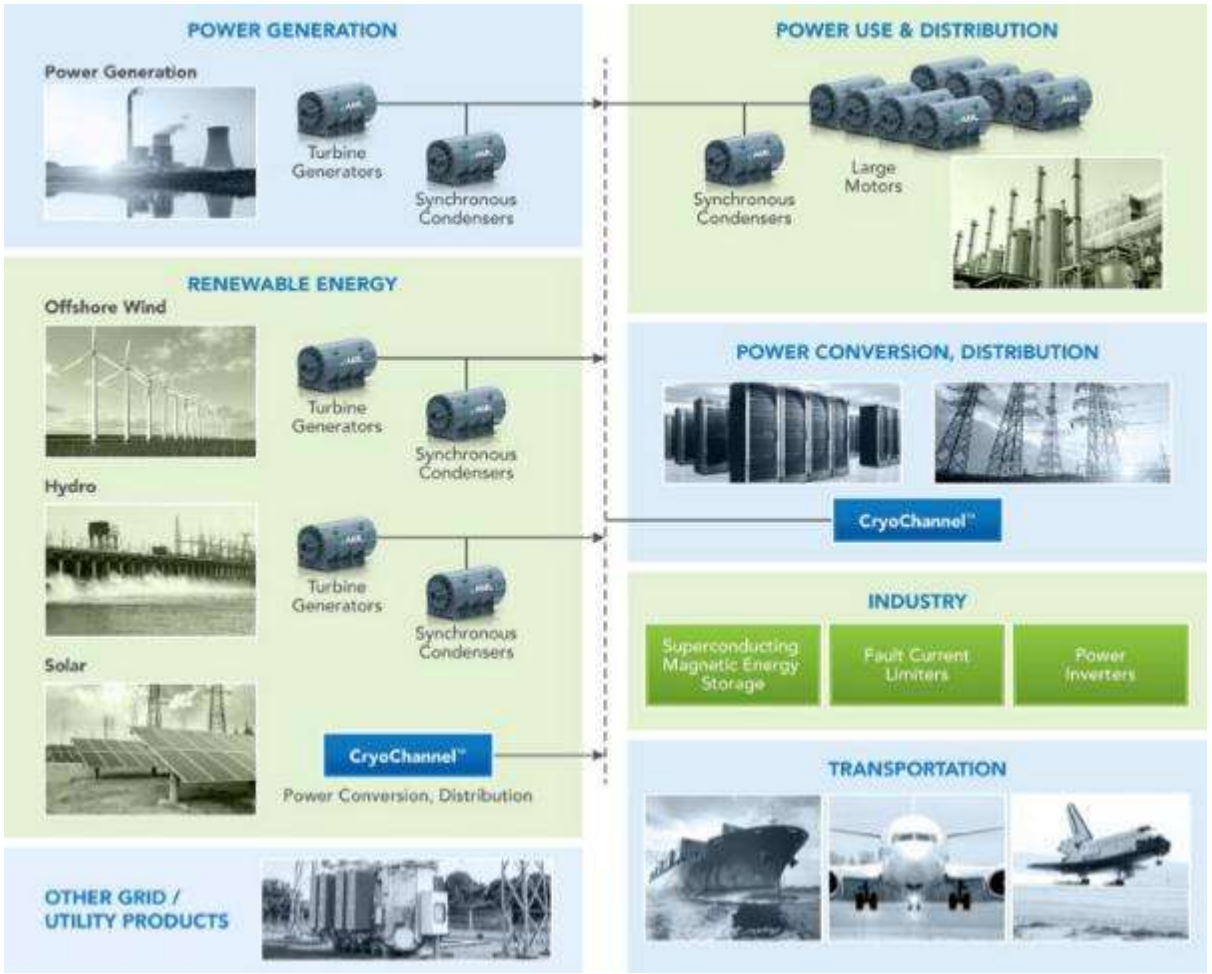
- Generation
- Distribution
- Stabilization
- Storage
- Use

Water & Environment

- Desalination
- Treatment

Transportation

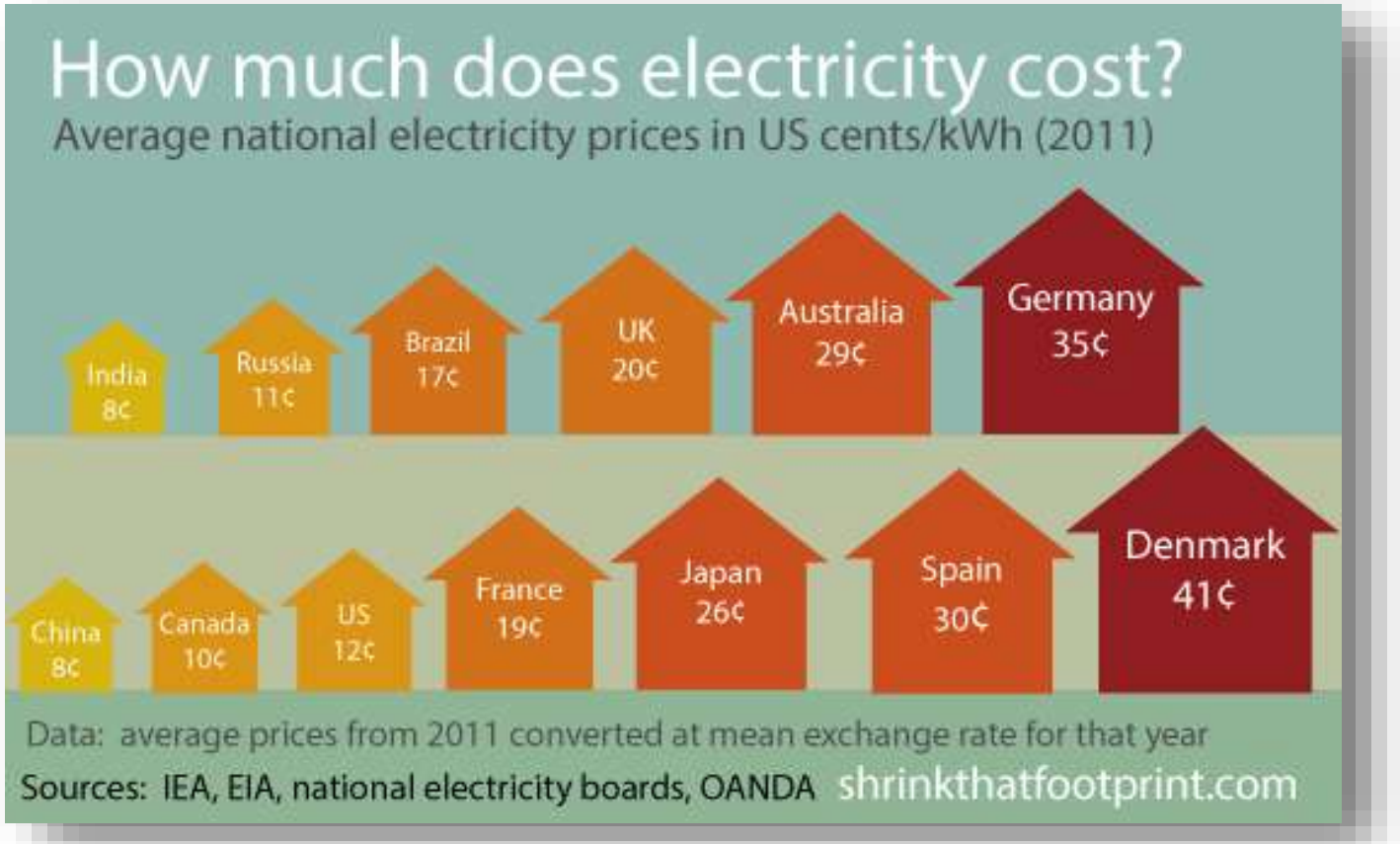
- Rail
- Cars, trucks
- Marine
- Aerospace



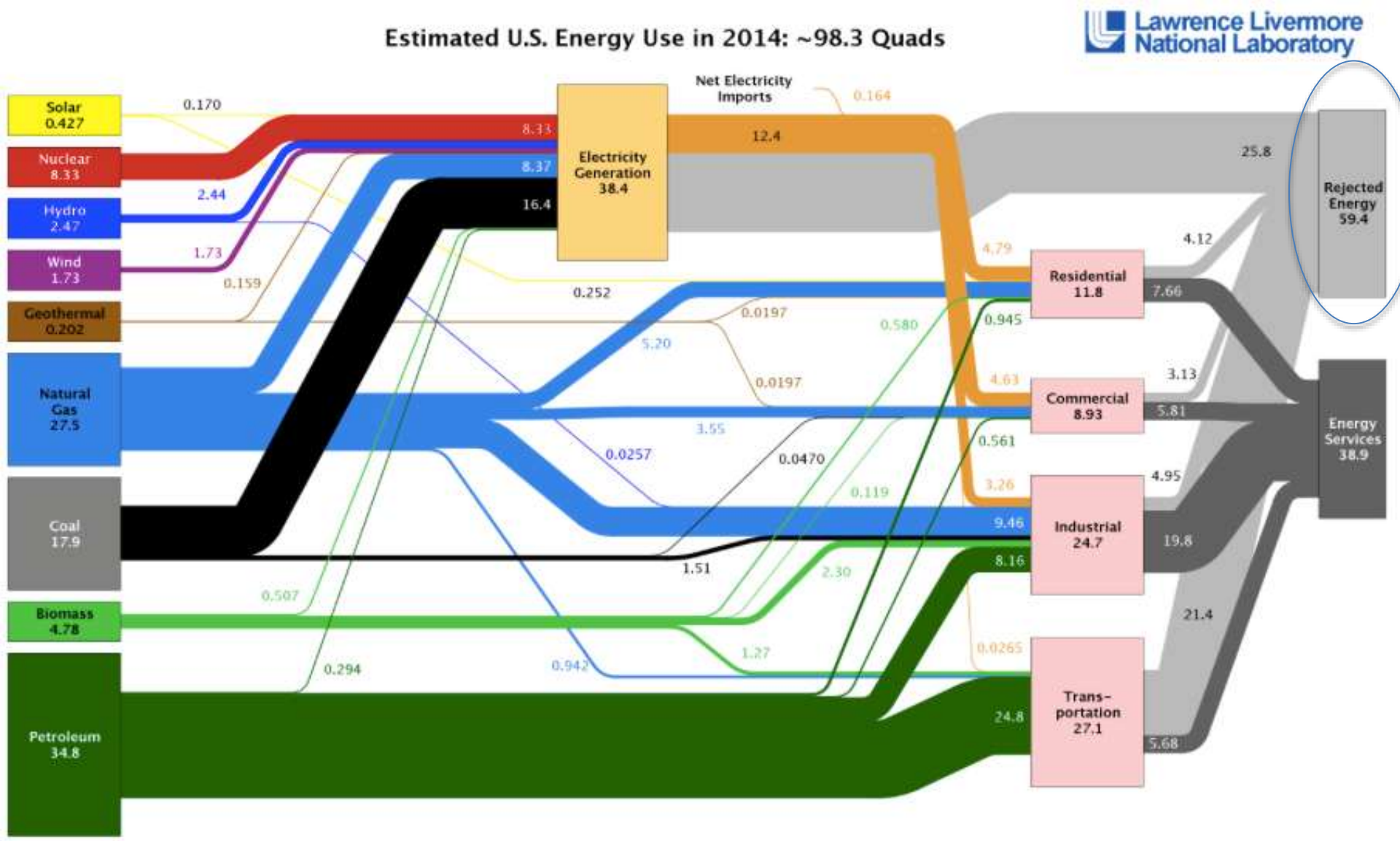
AML Energy - Superconductivity Market Opportunity

Levelized Cost of Energy (LCOE)

Motivation - Levelized cost of electricity (LCOE) is a measure of a power source which attempts to compare different methods of electricity generation on a comparable basis



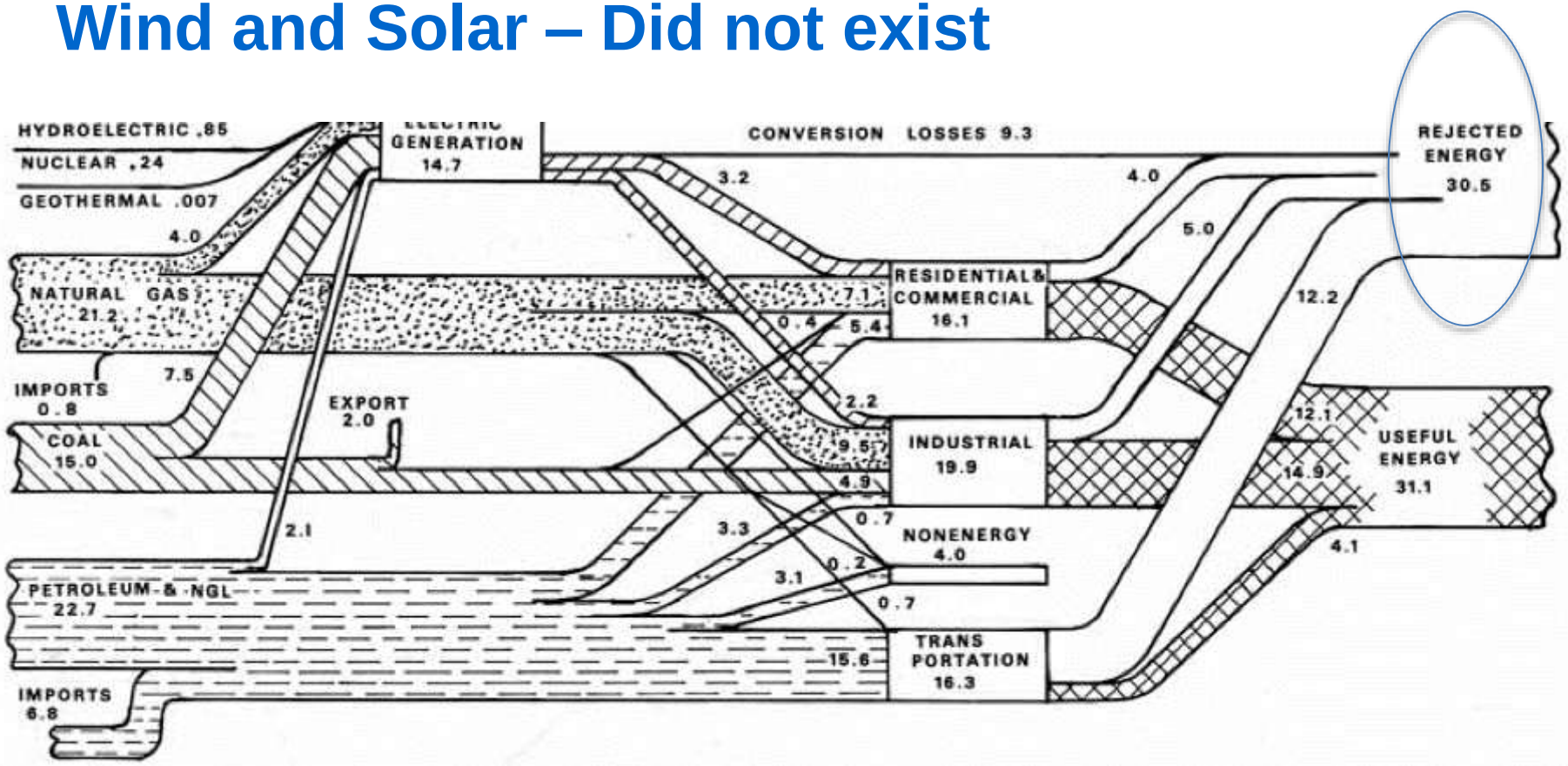
Complexity of Energy



Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

US Energy Flow - 1970

Wind and Solar – Did not exist



U.S. Energy Flow — 1970

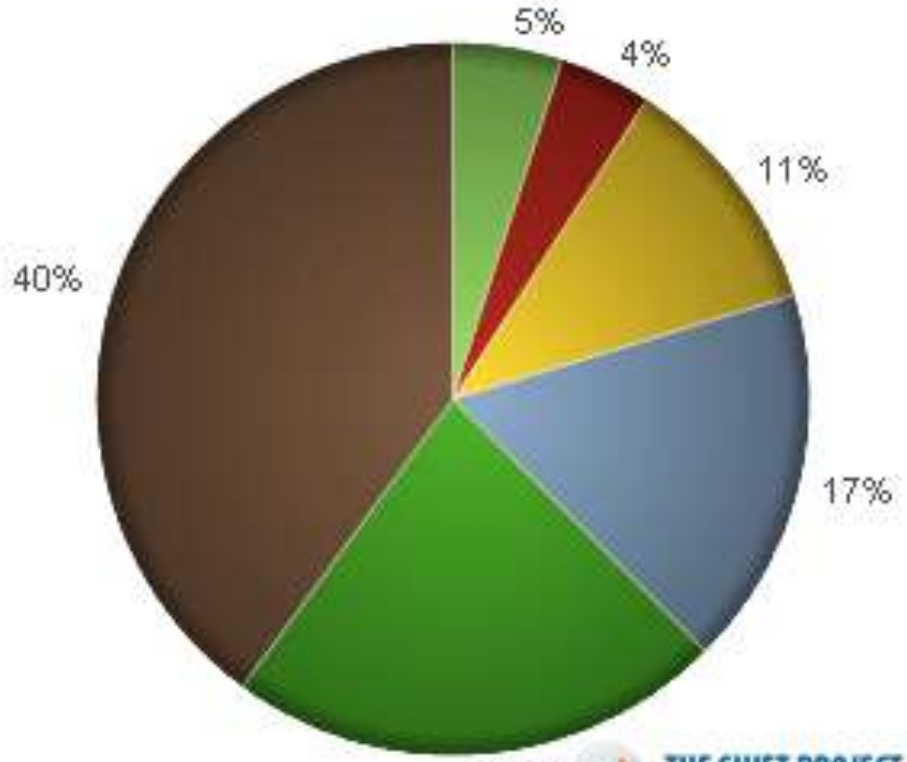
All values X 10^{15} Btu (2.12×10^{15} Btu = 10^{6} bbl/day oil)

Total energy consumption = 67.5×10^{15} Btu

Electrical Energy Generation - Global

World Electricity Production from All Energy Sources in 2012 (TWh)

Electricity Source	TWh
Others	1 042
Oil	879
Nuclear	2 344
Hydroelectric	3 619
Gas	4 744
Coal	8 390



Total = 21016 TWh

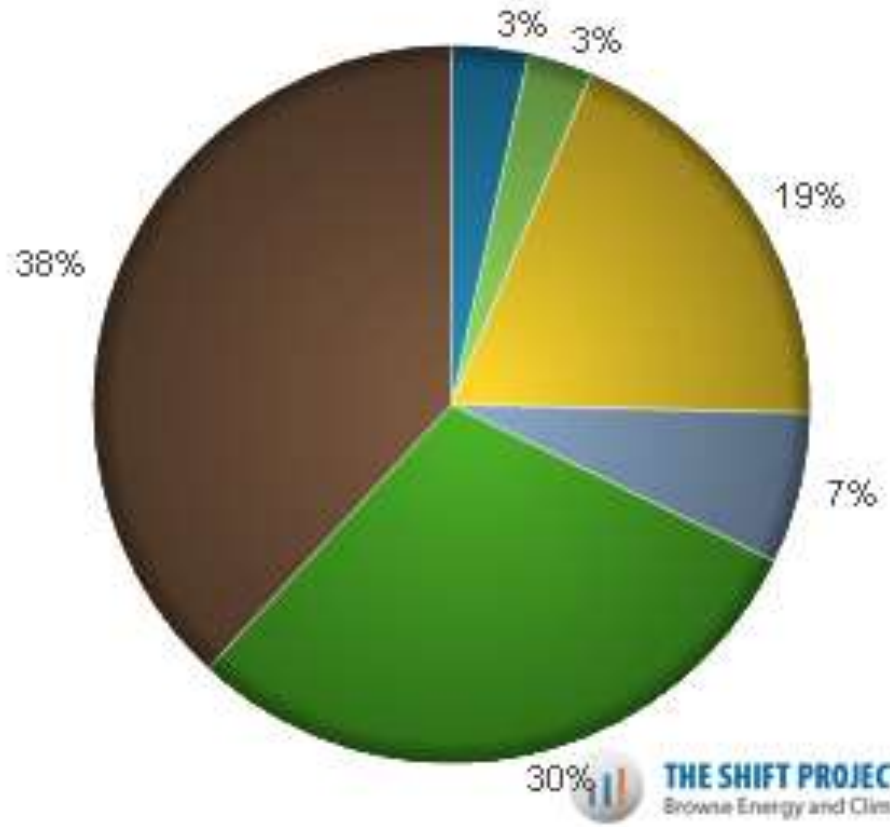
Source: http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart

Electrical Energy Generation - US

Electricity Production from All Energy Sources in 2012 (United States of America, TWh)

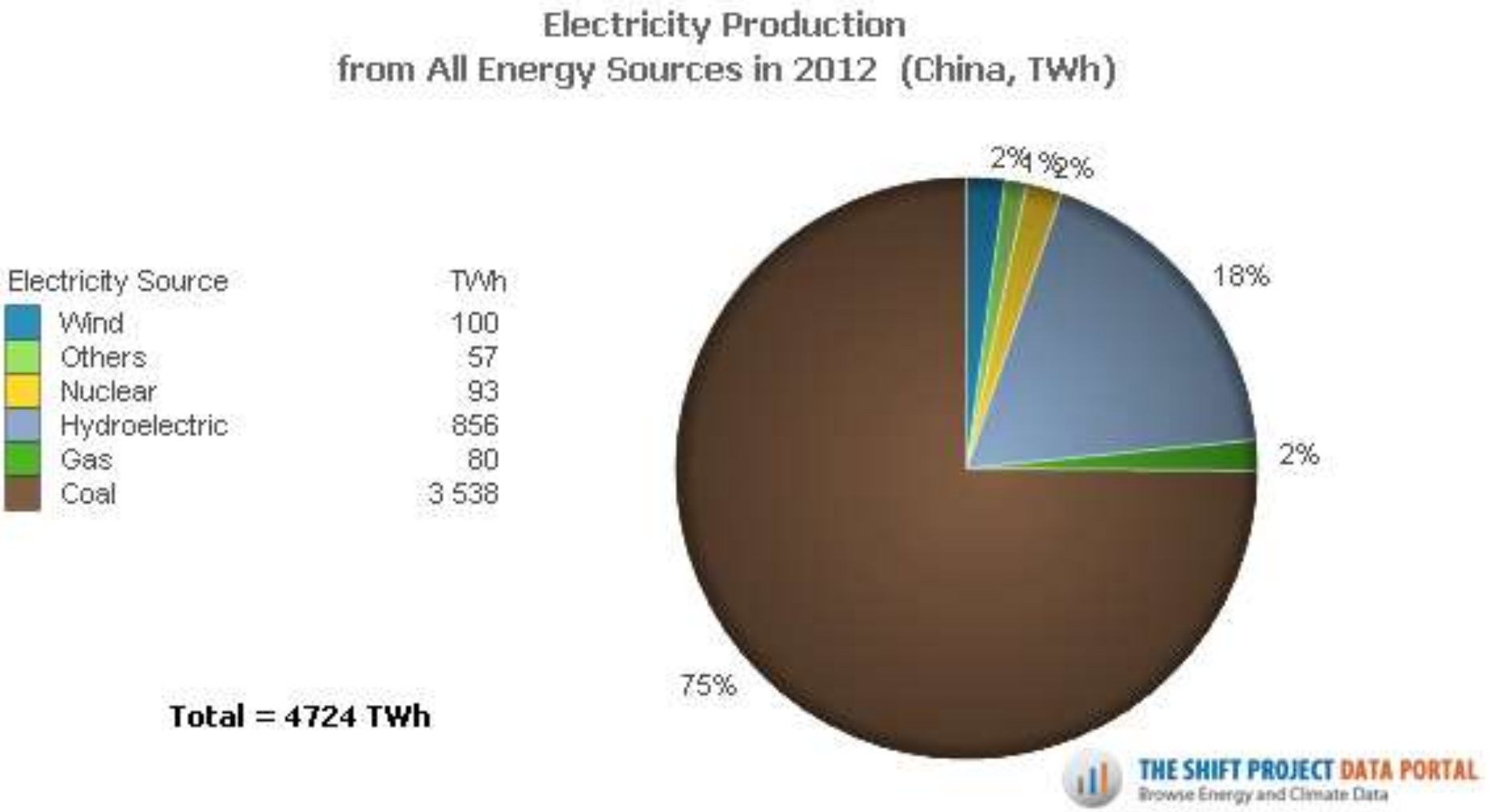
Electricity Source	TWh
Wind	140
Others	119
Nuclear	769
Hydroelectric	276
Gas	1 203
Coal	1 545

Total = 4052 TWh



Source: http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart

Electrical Energy Generation - China

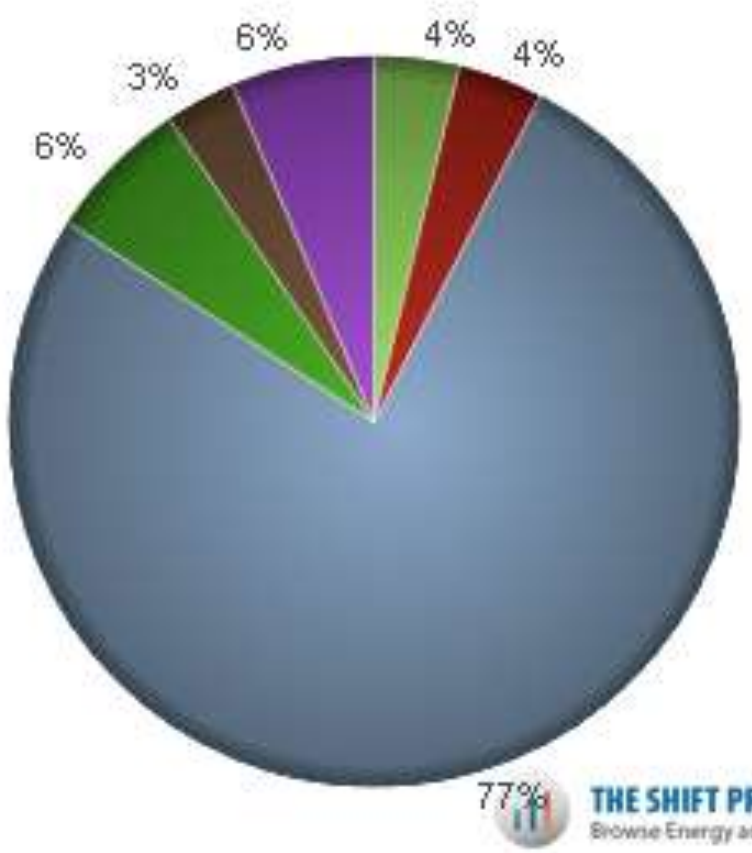


Source: http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart

Electrical Energy Generation - Brazil

Electricity Production from All Energy Sources in 2012 (Brazil, TWh)

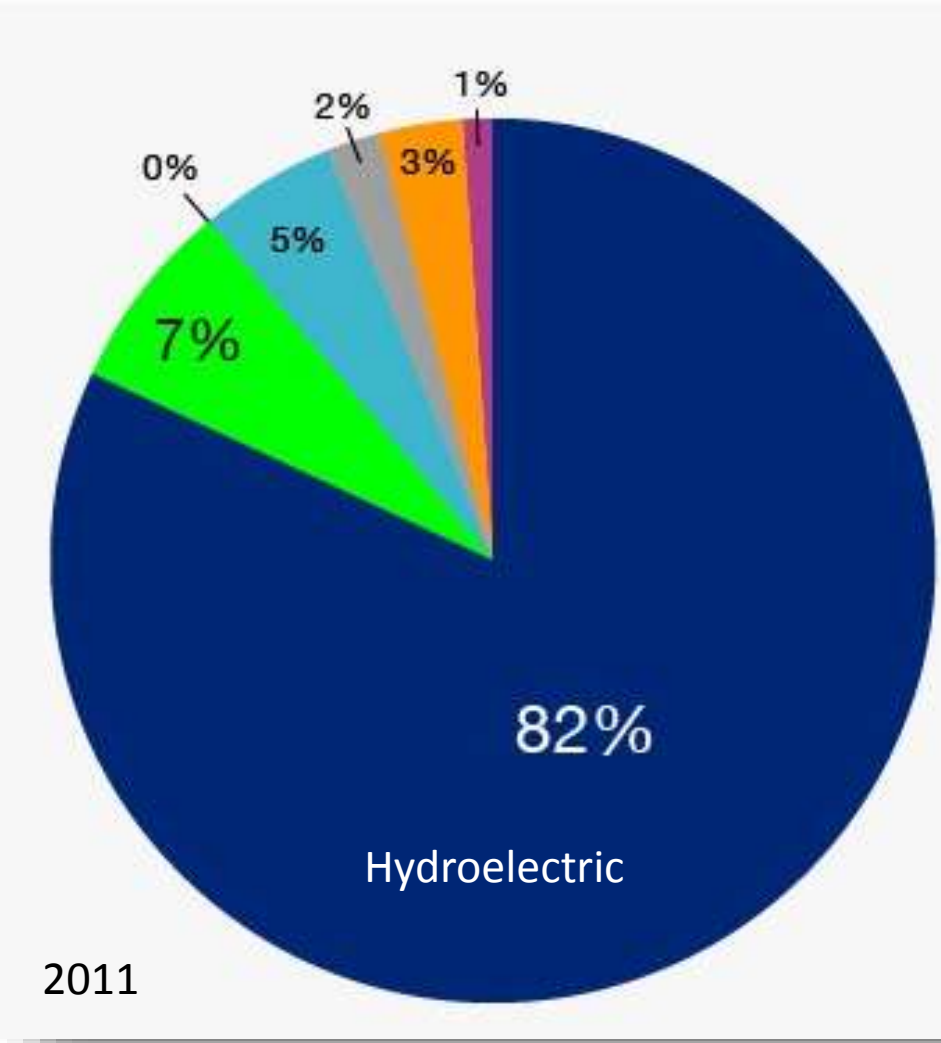
Electricity Source	TWh
Others	20
Oil	20
Hydroelectric	411
Gas	34
Coal	17
Biomass and Waste	34



Total = 536 TWh

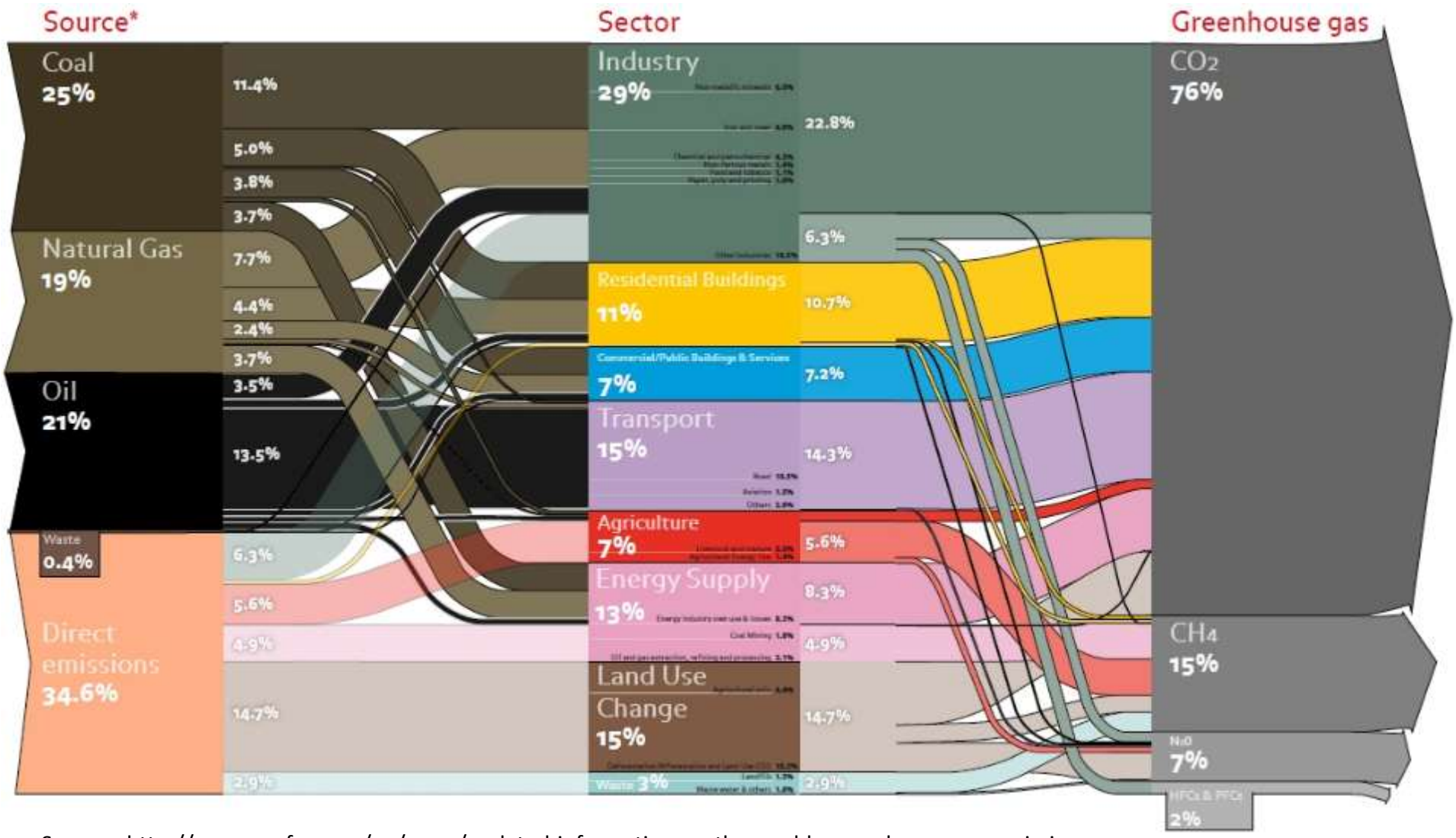
Source: http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart

Today's Brazil – "Hydropowered"



Source: http://riorenewables.com/why-renewables

Global Impact on Climate (2010)



Source: http://www.ecofys.com/en/news/updated-information-on-the-worlds-greenhouse-gas-emissions

Impact on Climate – Emissions (2012)

Figure 1. CO_2 emissions by sector

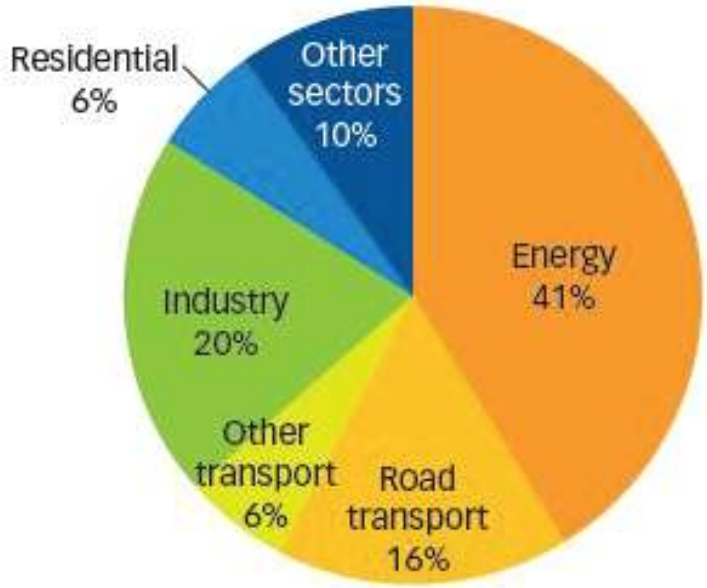
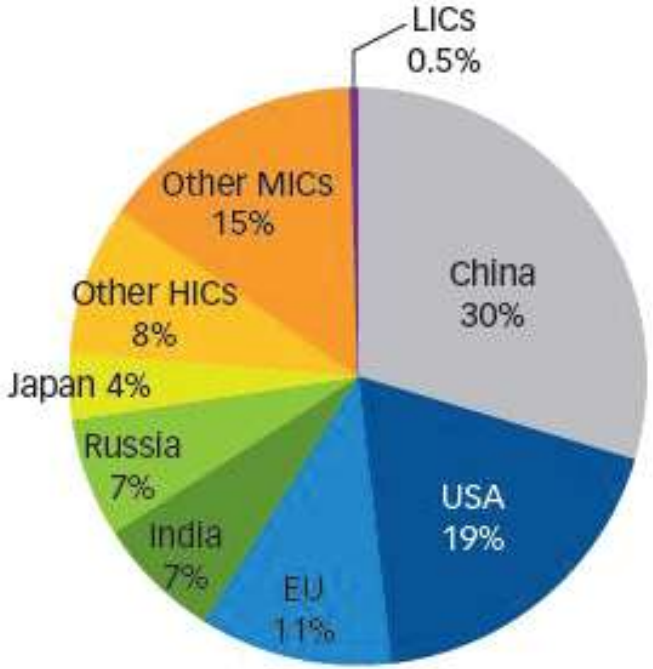


Figure 2. Energy-related CO_2 emissions by country

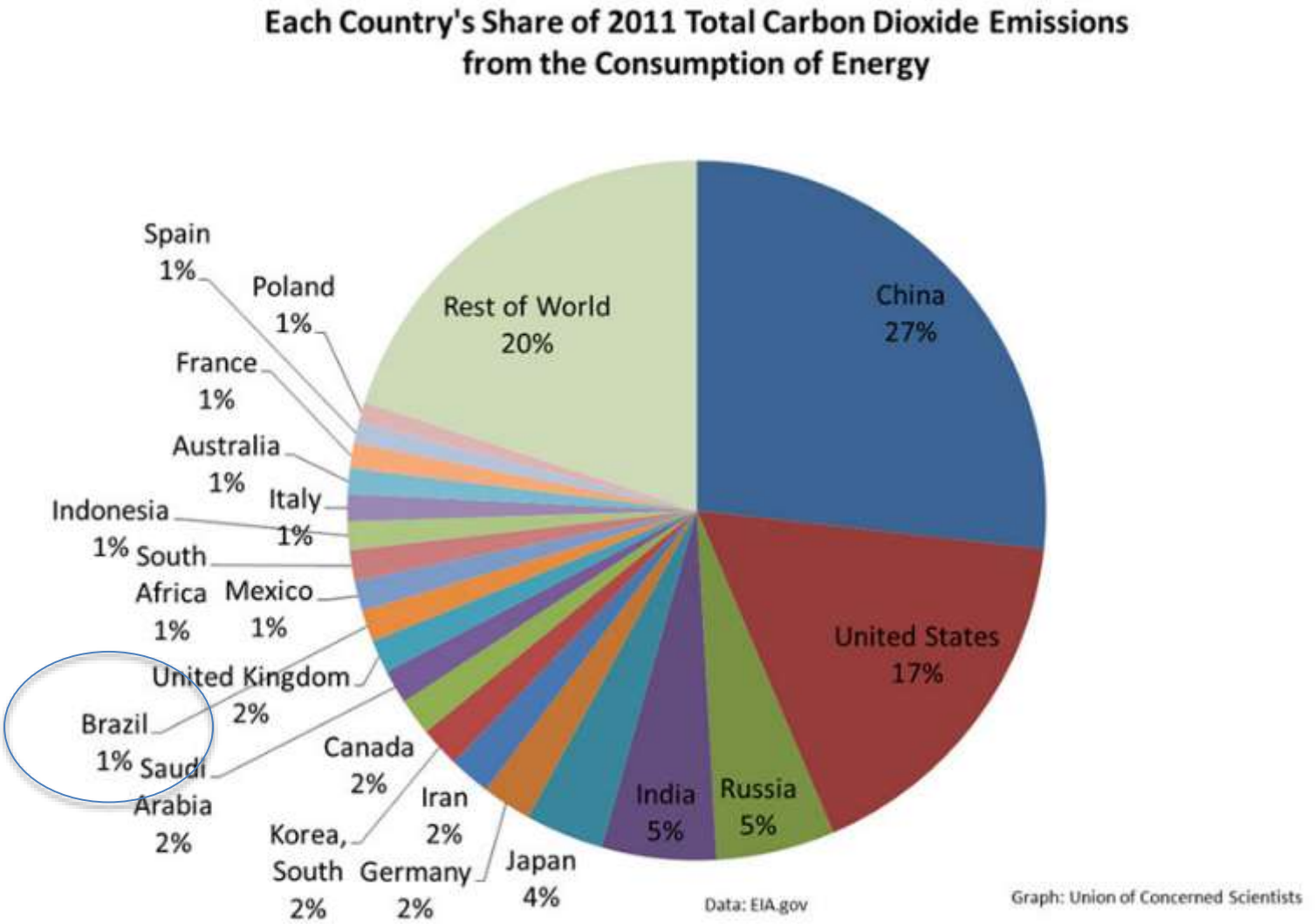


Notes: Energy-related CO2 emissions are CO2 emissions from the energy sector at the point of combustion. Other Transport includes international marine and aviation bunkers, domestic aviation and navigation, rail and pipeline transport; Other Sectors include commercial/public services, agriculture/forestry, fishing, energy industries other than electricity and heat generation, and other emissions not specified elsewhere; Energy = fuels consumed for electricity and heat generation, as defined in the opening paragraph. HIC, MIC, and LIC refer to high-, middle-, and low-income countries.

Source: IEA 2012a.

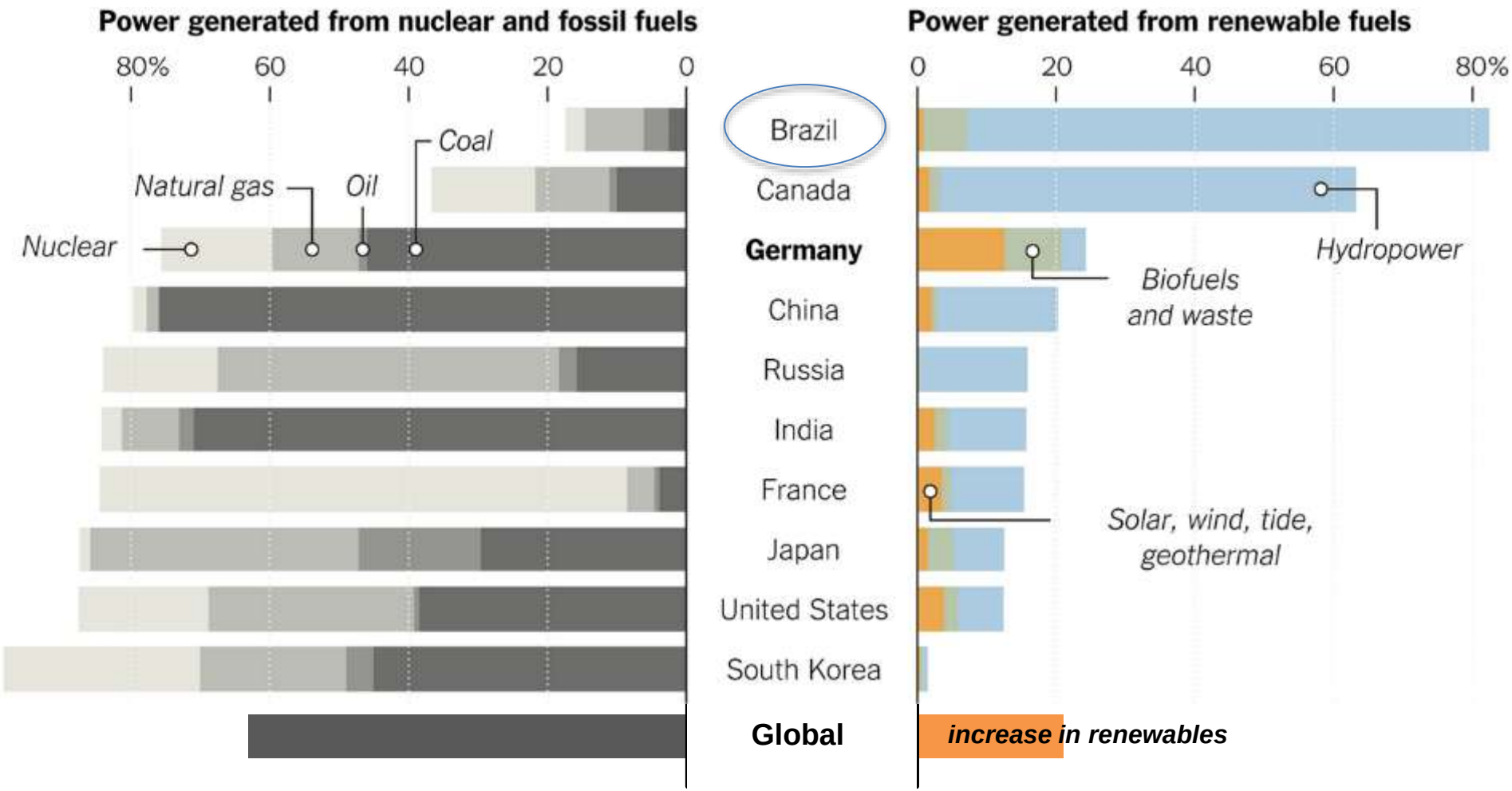
Source: http://www.itekenergy.com/wp-content/uploads/2015/04/gobalco2e.jpg

Impact on Climate – Emissions



Source: http://www.ucsusa.org/global_warming/science_and_impacts/science/each-countrys-share-of-co2.html#.VeMRQGAeCCs

From fossil to renewables…



Source: International Energy Agency

Opportunities

Potential for significant impact to the Energy Landscape

What is the value proposition?

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Opportunities – Large Scale Energy

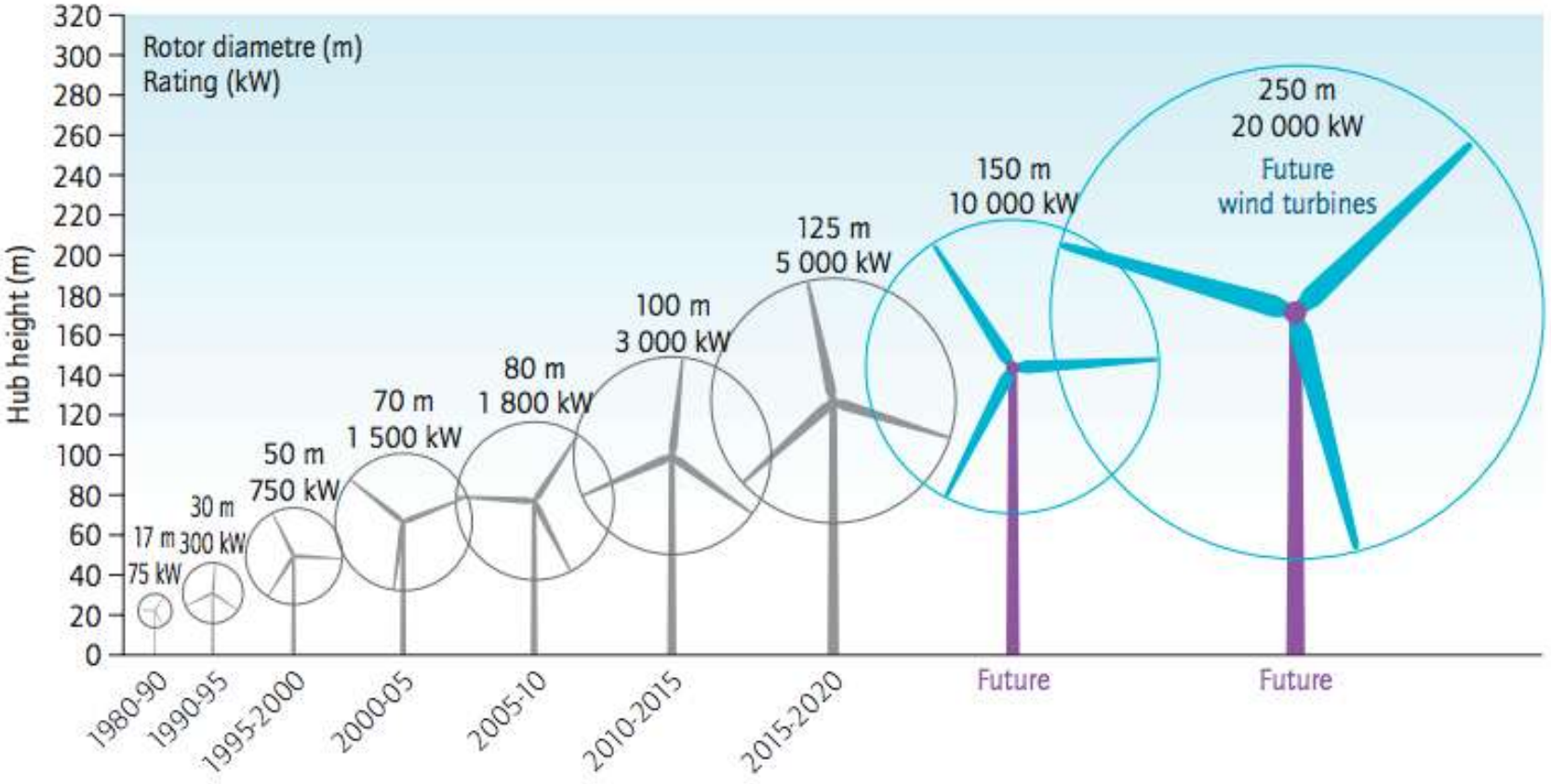
Opportunities exist to leverage common technologies and global partnerships to address the broader energy landscape

1. **Lower cost energy production**
   - ✧ $ per kWh / MWh
2. **Lower loss energy transmission**
   - ✧ Generate energy closer to load centers (population)
3. **Higher efficiency of energy use**
   - ✧ High efficiency transmission and use
   - ✧ Reduced heat loss and/or waste heat recovery
4. **Reduced impact to the environment**
   - ✧ Reducing CO2 emissions

Lower Cost Energy Production

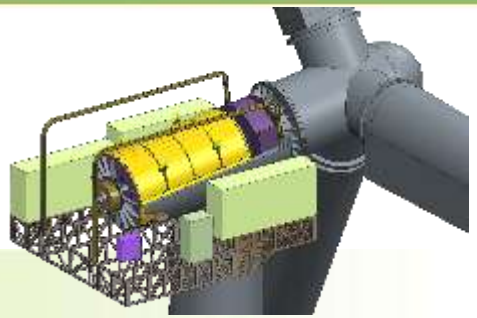
Renewable Energy - *Wind*

- Trend for larger and *Offshore Wind Turbines* strives to lower the cost of energy generation and transmission

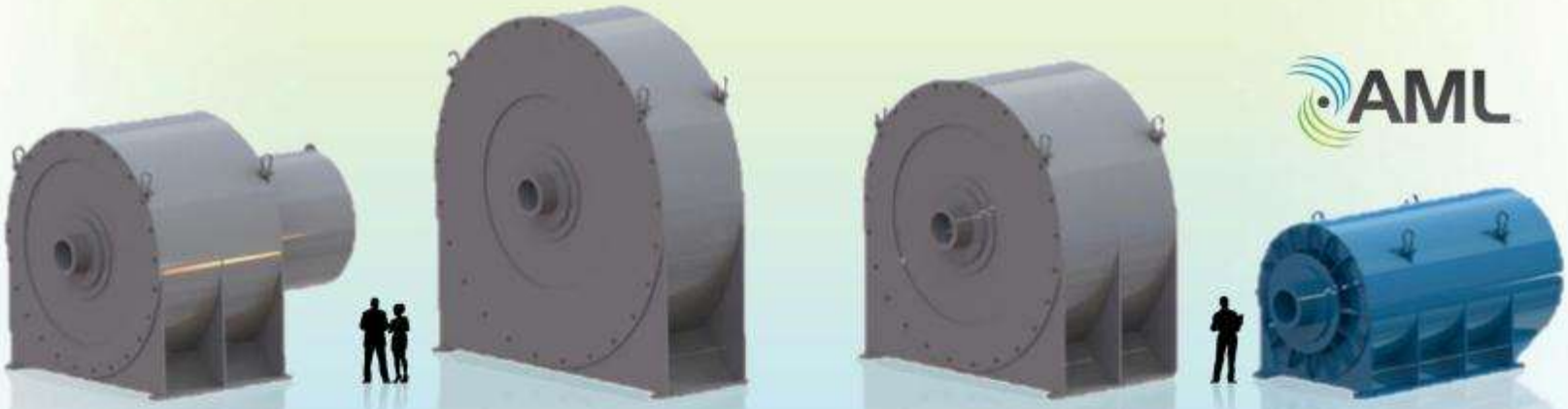


Lower Cost Energy Production

Significant reduction in size and weight enables very large and more cost effective wind turbines



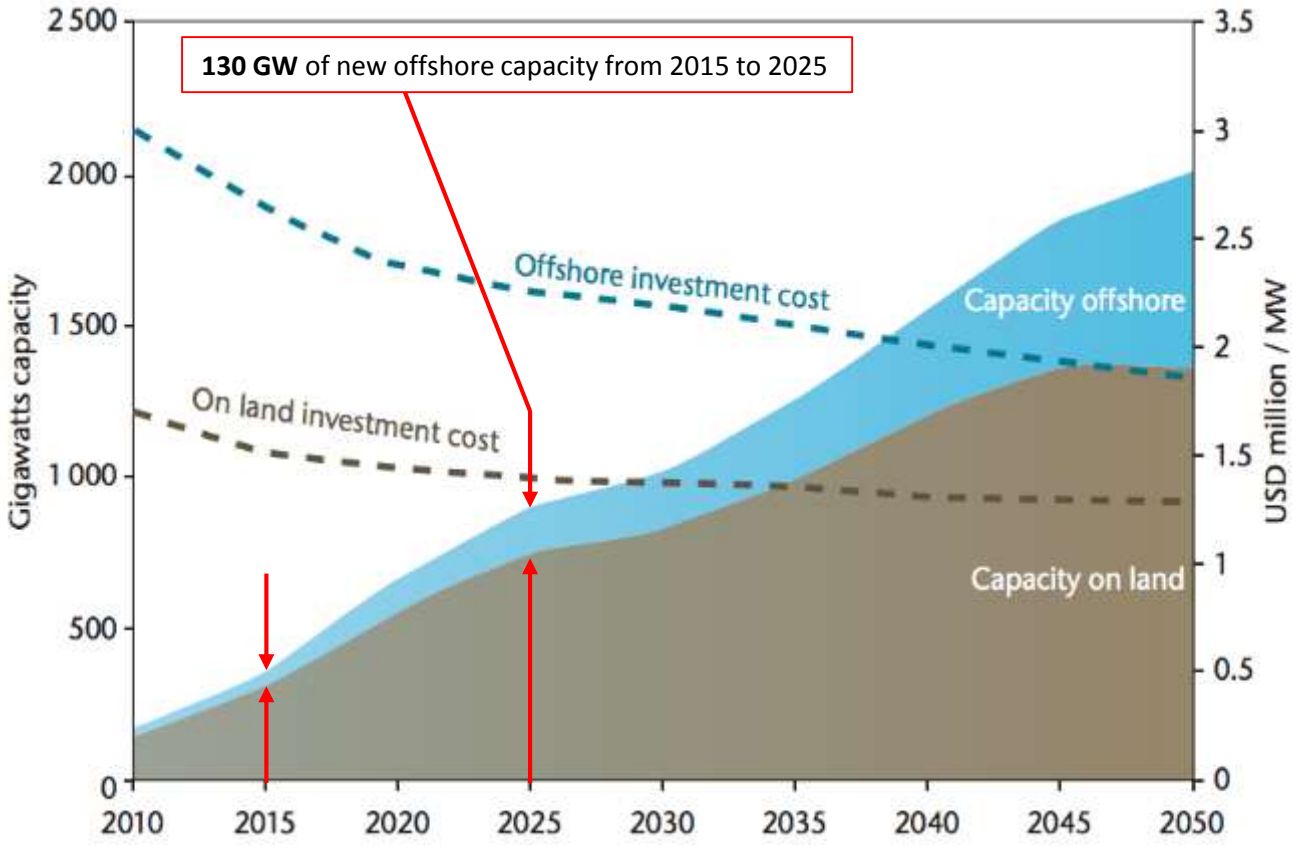
10 MW GENERATORS



Lower Cost Energy Production

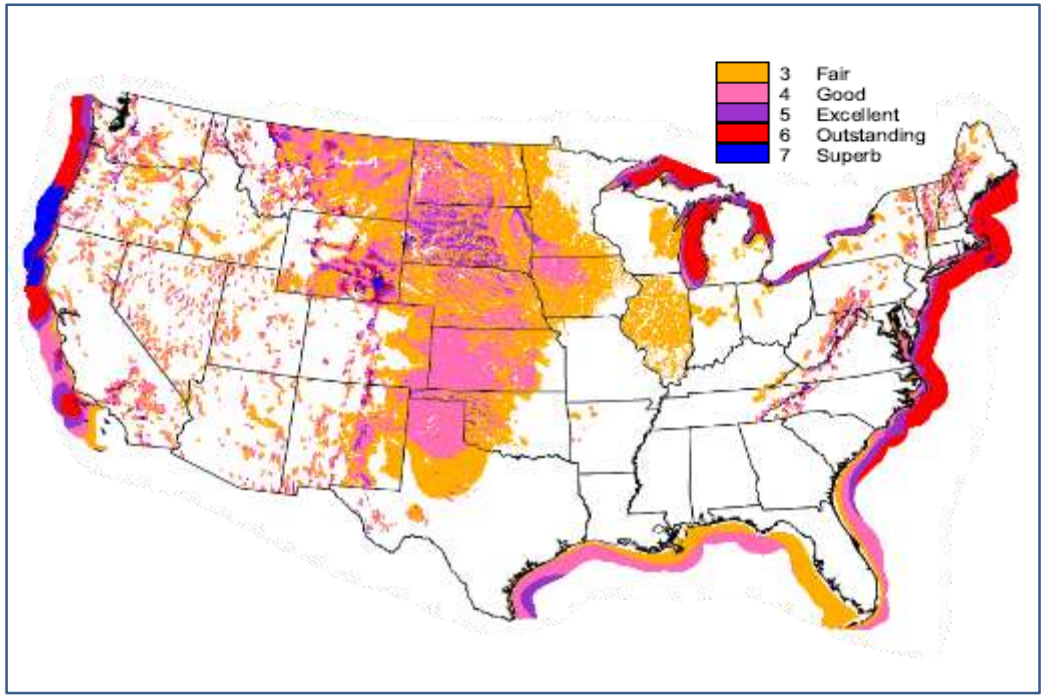
By 2050, 32% of wind capacity will be offshore, up from 19% in 2030

In the next 10 years, 130 GW of new offshore capacity is forecasted (>13,000 new 10 MW turbines)



Lower Loss Energy Transmission

Offshore wind allows energy production to be located close to the load centers reducing the cost of power transmission

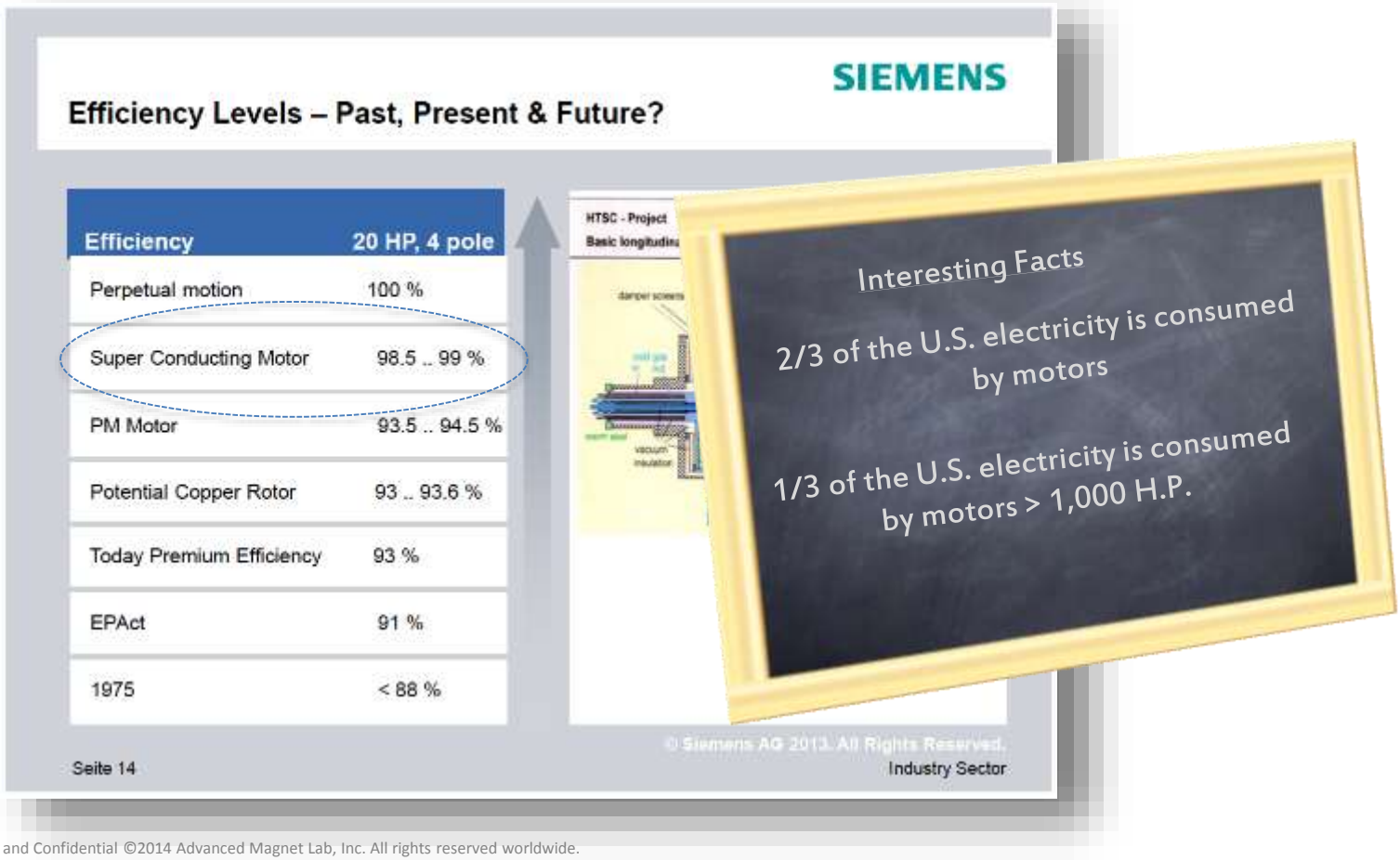


- Two-thirds (2/3) of the US population lives along the coasts where there is the most consistent and abundance of wind energy

Higher Efficiency of Energy Use

Industrial Motors and Generators

- Superconducting versions of these systems that operate at greater than 95% efficiency will significantly to reduce energy consumption



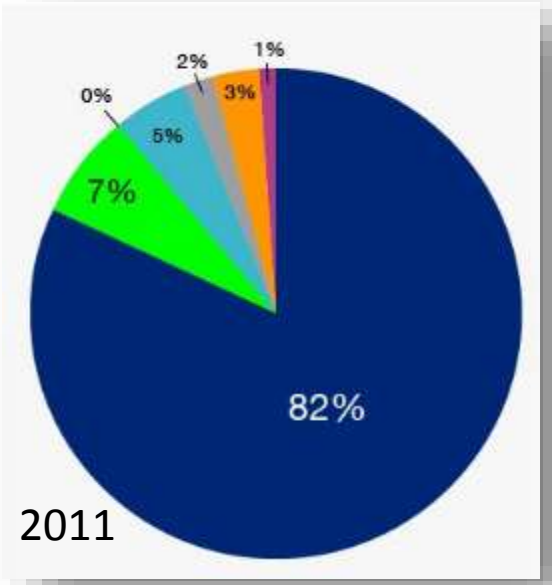
Higher Efficiency of Energy Use

Industrial Motors and Generators

- Hydropower is a fixed energy resource based on the maximum flow/storage of water
- Increased energy output and lower energy costs is limited to improvements in efficiency
- ***Potential exists to replace conventional power generators with superconducting generators to achieve the maximum efficiency possible (approaching 99%)***

75 Gigawatts Output

- **Example efficiency increase by 2%-5% = 1.5GW – 3.75 GW per year**



Higher Efficiency of Energy Use

Electrical Grid Components

- Superconductors allow for higher reliability, stability and efficiency of power grids
- *Fault Current Limiters* - instantaneously limit unanticipated electrical surges
- *Synchronous Condensers* - serve as grid voltage regulators and "shock absorbers", dynamically generating or absorbing reactive power

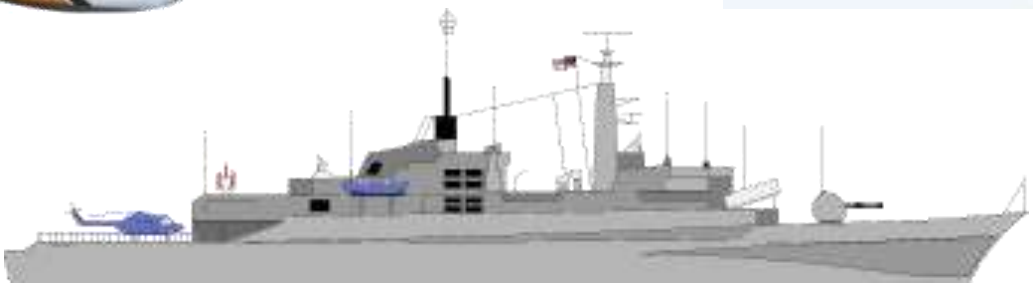
Power Distribution

- The use of modular, scalable and high efficiency systems to distribute or aggregate multiple megawatts of power within facilities such as *Data Centers* and *Solar Farms* respectively

Reduced Impact to the Environment

Transportation

- All-electric propulsion systems are highly desirable for many types of transportation including aviation and ship propulsion
  - More efficient
  - Very low emissions
  - Less noise
- Superconducting *Motors* and *Generators* are smaller and lighter than their counterparts will be a key enabler for next generation transportation



Technology and Innovation

Application of advanced materials such as superconductivity for transformative changes to the Energy Landscape

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Technology Revolutions

Historically, technology revolutions are the result of a discovery and applications of "new" materials and/or processes

Industrial Revolution

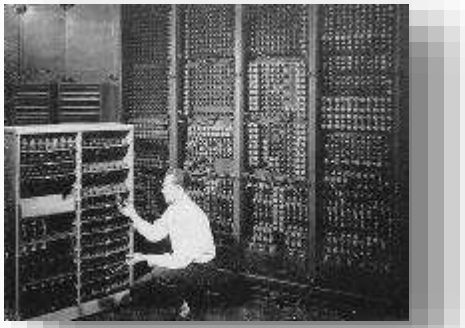
- Coal, fueled steam driven power - Replacing "horses and cattle
- Oil, fueled combustion engines - Enabling the modernization of mining, manufacturing and society

Information / Digital Age

- In 1947, AT&T invented the transistor which replaced the vacuum tube as a competitive advantage for long distance communication
- Based on fundamental material technology – Silicon
- This new, emerging technology - semiconductors - gave birth to the Information Age and the Silicon Valley

Technology Revolutions

Where would we be without “silicon”?



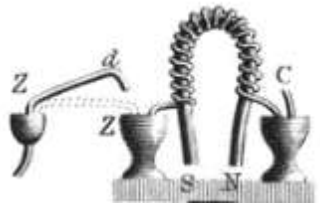
Electricity – "Greatest Discovery?"

Electricity grids today are based on 19th Century technology for generation, stabilization transmission and use

- Copper based electrical conductors
- Conventional magnets – Core to electromechanical systems

The primary products which drive the generation and use of electricity – large *motors* and *generators* - have fundamentally not changed since the 1800s

- 1820
  - Hans Oersted discovered electric current affects compass needle
  - Ampere finds that wires carrying current produce forces on each other.
  - Michael Faraday proves effect of currents on magnets
- 1821 – 1831
  - William Sturgeon invented the electromagnet
  - Motor & Generator Invented (Faraday)
- 1883
  - Nikola Tesla demonstrated the first induction motor



1st Electromagnet - 1823


Tesla Motor - 1883


Motor - 2015

Next Industrial Revolution??

Like the past, the next technology revolution will be based on new (advanced) materials such as superconductors and nanomaterials

Copper vs. Superconductor

***Superconductivity* - long been pursued as a potentially transformational force that could forever change broad economic and social impact**

- A phenomena that allows the flow of electrical current with ***zero resistance and without energy losses***…when operating in a very low [cryogenic] temperature
- Superconducting is both an *enabling* [MRI] and *transformational* [energy] technology
- Superconductor-based systems for energy can provide higher efficiency, lower cost, lighter and smaller systems, higher reliability and performance, highly scalable and is environmentally friendly

Magnetic Resonance Imaging (MRI)

Large Generators, Motors

Commercialization of Superconductivity

To date, practical commercial successes have been limited to medical MRI, research and scientific applications

The recurring challenges of *cost*, *reliability* and *performance* are key factors that have inhibited mainstream commercialization

The primary and inter-related *obstacles* driving these challenges are:

1. Conductor materials
2. Cryogenic Technology
3. Magnet technology
4. Superconducting systems design and integration experience

Magnetic Resonance Imaging (MRI)

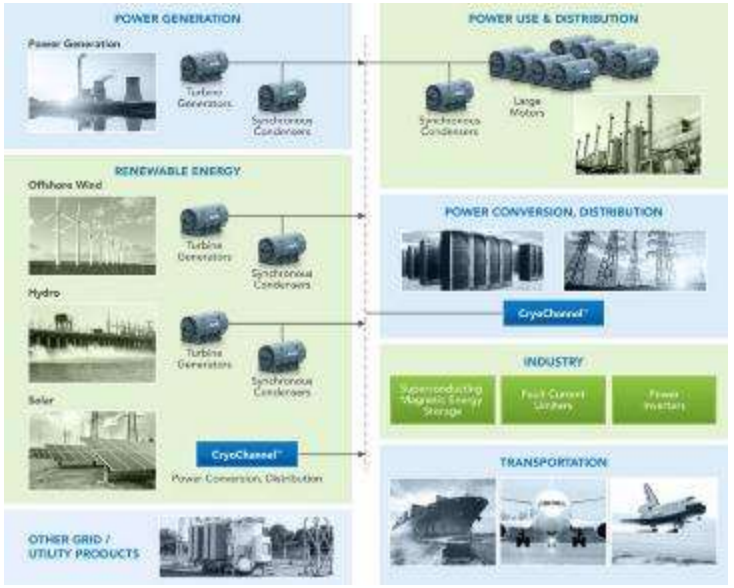
Large Hadron Collider at CERN

Addressing the Obstacles

Beginning in 1995, fundamentally unchanged since the 1800s, AML set out to rethink the principles of magnets and how taking a different approach could enable transformational applications in the vast space of magnetic based products and solutions

AML "'Perfect-Field™ Application Development Process"

Unconstrained design flexibility, dramatically redefines what is possible

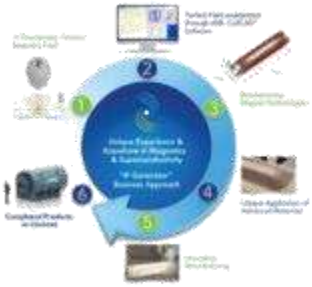


Core Value Proposition – “Secret Sauce”

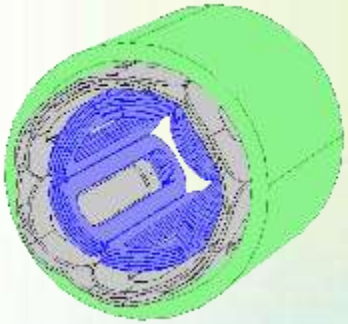
Unique system design, manufacturing and integration experience

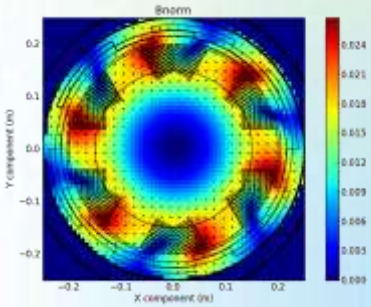
Leveraging experience, technologies and partners

- Innovative new conductor and magnet technologies, composites, manufacturing, design software, cryogenic systems, systems integration and testing capabilities



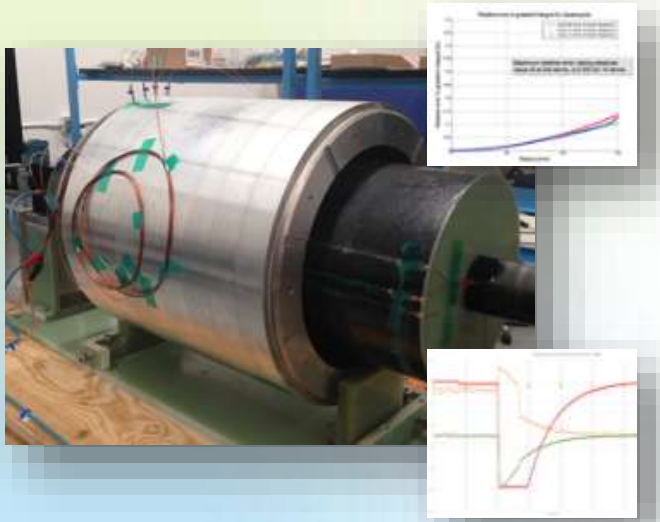
Perfect-Field™ Process





Design

Highly Automated and Precise Manufacturing



Test & Qualification

Leveraging technologies, investments and partnerships

Addressing the broad energy landscape of generation, transmission and use

AML Superconductivity and Magnetics™

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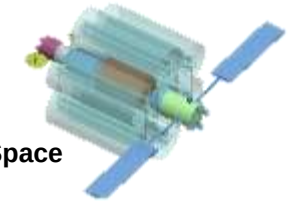
Leveraging Technologies for Multiple Applications

Medical

Power Generation

Renewable Energy

Industrial Processes

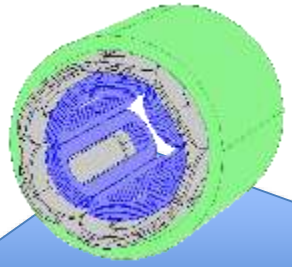


Space

Utility Grid

Water & Environment

Research



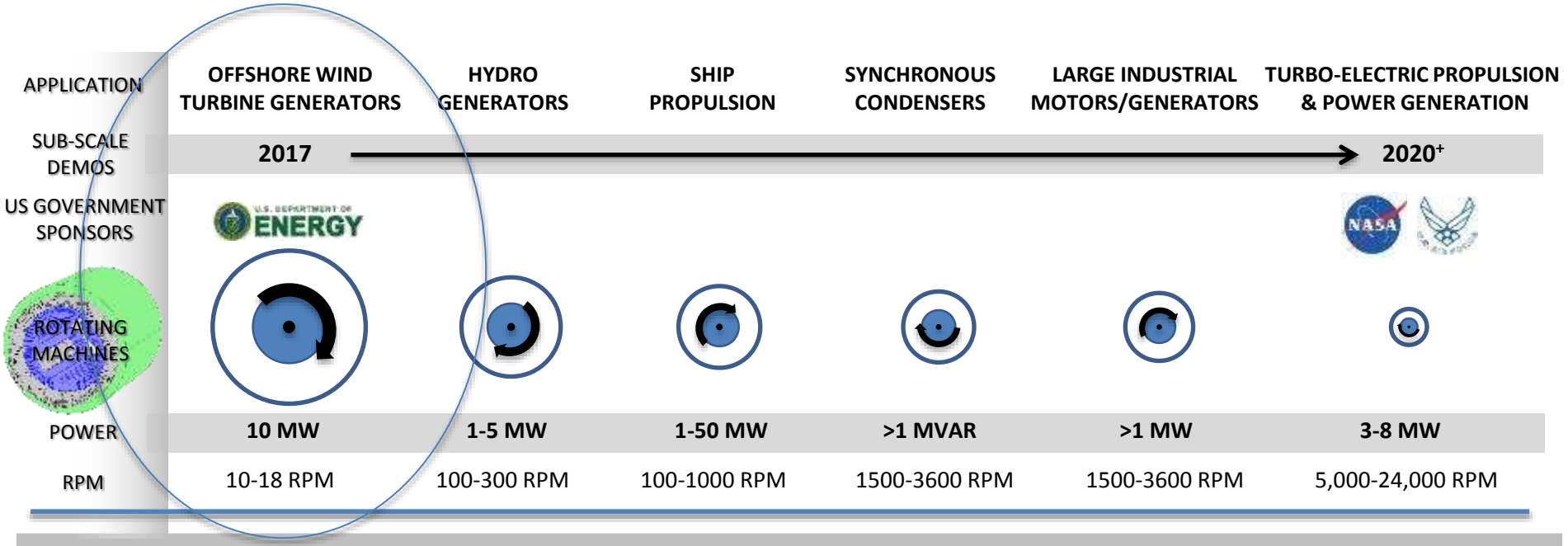
Superconducting technology core to broad array of sectors and applications

Transportation

KEY DEVELOPMENT AREAS – OFFERING A BROAD PLATFORM OF SUPPORTING INDUSTRYS			
MAGNET TECHNOLOGY	CONDUCTORS	CRYOGENIC COOLING	SYSTEMS DESIGN & INTEGRATION
COMPOSITES	MANUFACTURING & TEST	POWER CONVERSION/DISTRIBUTION	DESIGN & MODELING SOFTWARE

Superconducting Rotating Machines

Leveraging investments, common technologies and a world-class development team for rotating machine developments



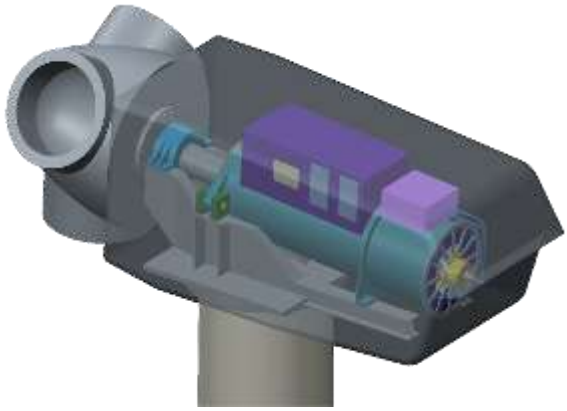
KEY DEVELOPMENT ELEMENTS			
MAGNET TECHNOLOGY	CONDUCTORS	CRYOGENIC COOLING	SYSTEMS DESIGN & INTEGRATION
COMPOSITES	MANUFACTURING & TEST	POWER CONVERSION/DISTRIBUTION	DESIGN & MODELING SOFTWARE

AML's WORLD CLASS DEVELOPMENT TEAM					
U.S. DoE	NASA / U.S. AIR FORCE	ARGONNE NATIONAL LABORATORY	NATIONAL RENEWABLE ENERGY LABORATORY	CENTER FOR ADVANCED POWER SYSTEMS (FSU)	UNIVERSITY OF HOUSTON
EMERSON ELECTRIC	CREARE	COLUMBUS SUPERCONDUCTORS	HYPERTECH RESEARCH	AERODYN	WINONA STATE UNIVERSITY

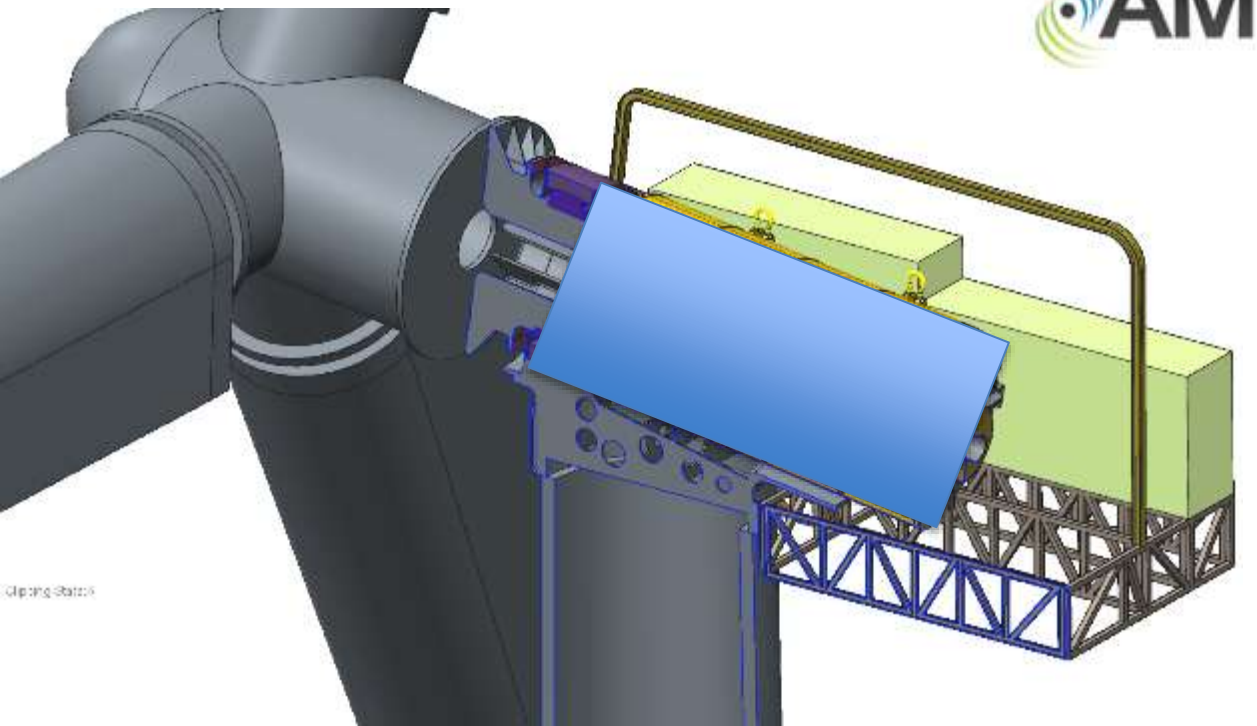
Leveraging Partnerships

Wind Turbine Drivetrain

- 1.5 MW Retrofit Generators
- 10+ MW Offshore Generators



World-Class Development Team

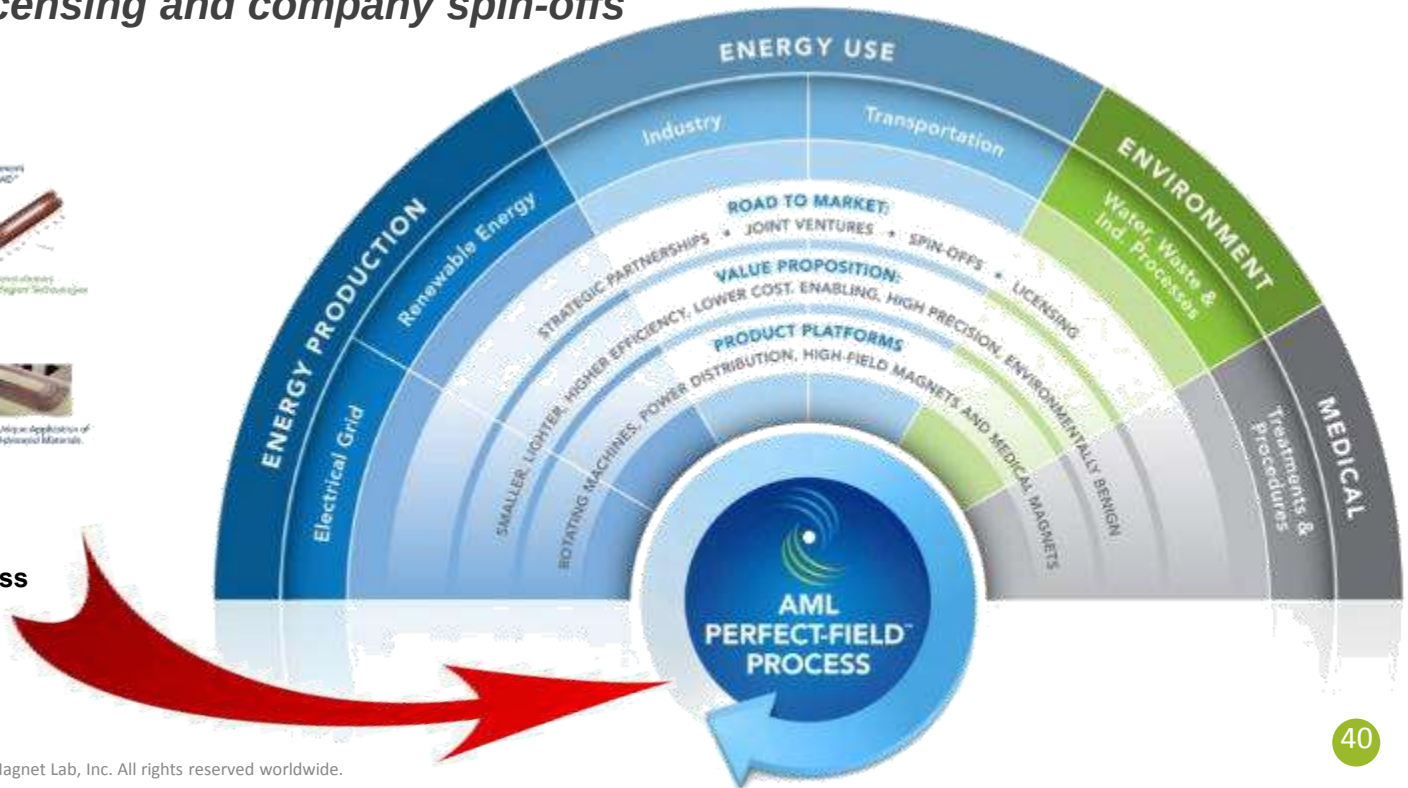


Business Model and Marketplace

Global impact applications representing multiple, multi-billion dollar markets

- A combination of revolutionary capabilities, a deep IP portfolio enables the rapid creation of new applications across a spectrum of industries and markets
- ***Road-to-market channels include a combination of manufacturing, joint ventures, licensing and company spin-offs***

Perfect-Field™ Process



AML Global Partnerships

Chile - Impact Innovation Alliance (Joint Venture)

- Focused on applying superconductivity for environment – Magnetic Separation for the Mining Industry

United Arab Emirates (UAE)

- Focused on addressing “Grid Stabilization”
- Masdar, Masdar Institue, Abut Dhabi Water and Electricity Authority

Decentralization

Distributed energy and microgeneration (small scale energy)

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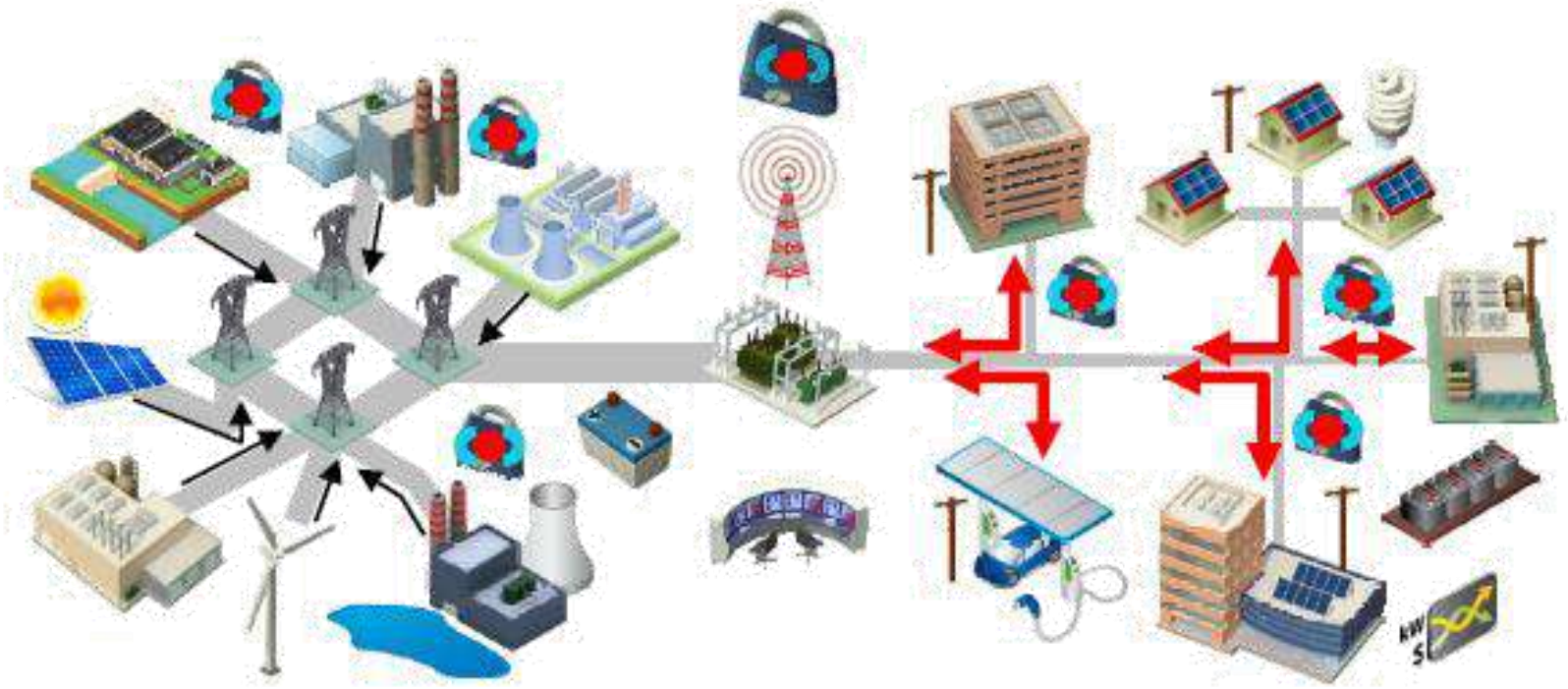
Evolving Utility Grid

Distributed Energy – Decentralize

- Point of service energy solutions such as solar, wind, waste energy (micro-turbines)…
- Smart Grid and Grid Stability are essential elements



Evolving Utility Grid

Decentralized Energy – Microgeneration

- Similar to large scale(megawatt) energy solutions – Achieving competitive “Cost of Energy” (COE) is a challenge
- Unlike large scale energy, opportunity exists for innovative and more flexible business model innovation and possibly less governmental regulation

Example products are vertical wind turbines, integrated solar, heat recovery micro-turbines, fuel cells, biofuels etc…

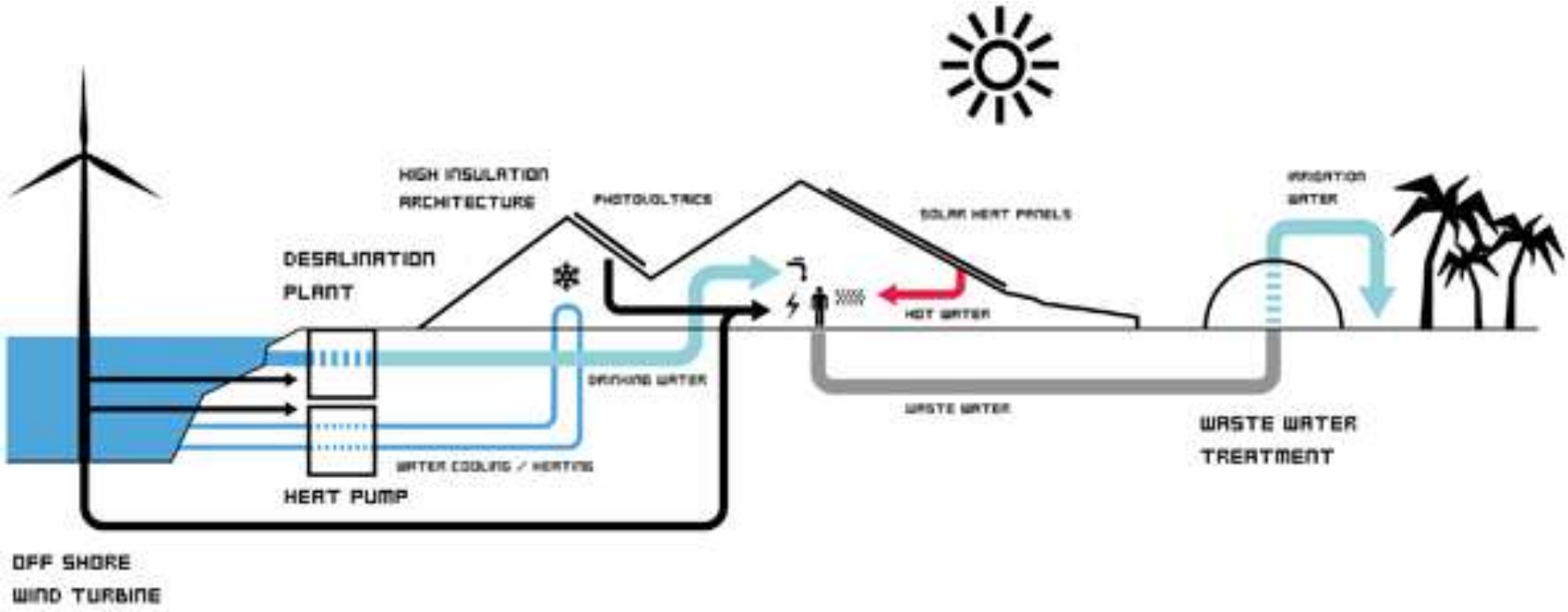
Value Proposition does not have to compete with utility electricity prices

- Product/solution is likely integrated into the energy consuming device such as a street lighting, pumping water, treating water….

Evolving Utility Grid

Decentralized Energy – Large Scale

- Large scale energy consumers such as Data Centers, Desalination, water treatment can be **directly connected** (off Grid)



http://www.magazmagazine.com/magaz2012/index.php?option=com_content&task=view&id=478:304-56&Itemid=112

Conclusion

Why the pursuit of transformational energy solutions?

What are the "final" obstacles?

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High-Value and Impact - Global

Innovative and transformative technology have the potential to:

- ✧ Lower renewable energy costs
- ✧ Lower power transmission losses
- ✧ Increase energy use efficiencies
- ✧ Decrease in wasted power
- ✧ Increase efficiency of existing power generation
- ✧ Increase deployment of “point of use” energy
- ✧ Utility scale energy storage – “Holy Grail” of RE

Social and Environmental Impact

- ✧ Application of superconducting based products will result in lower cost energy, food, water and consumer goods….

  ….without compromising our environment and sustainability

Obstacles

Development of innovative technologies and business models which are sustainable

- Profitable
- Scalable
- Environmentally Friendly

Changing the way “we” approach innovation

- Investment Mindset
  - Long term, strategic and leveragable
- Technology and Product Development
  - Transformational as opposed to incremental
  - Leveragable across multiple products, applications and sectors
- Politics
  - Strengthen business value proposition to minimize government subsidies
  - Decentralized / Directly coupled (energy to application) solutions

Brazil points the way…..

August 2015

Thank You!

*"**The stage is now set for superconductivity to make more general contributions**. Humanity uses practically unthinkable amounts of energy to drive our modern way of life. Overall, global power usage has been predicted to almost double from 16.5 to 30 Terawatt in the next four decades."*

2011 Equinox Summit: Energy 2030