International Markets & Export Challenges for SMRs

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Roundtable Participants

American Nuclear Society

Duke Energy

Hyperion Power
New Clear Energy

AREVA

generation mPower

Savannah River NUCLEAR SOLUTIONS
FLUOR DANIEL • NORTHROP GRUMMAN • HONEYWELL

NEI
NUCLEAR ENERGY INSTITUTE

NUCLEARENERGY INSIDER

Shaw
a world of Solutions

Westinghouse

Department of Energy

GENERAL DYNAMICS
Information Technology

HOLTEC INTERNATIONAL

U.S.NRC

K&L|GATES

EXCEL SERVICES CORPORATION

GE | HITACHI

TVA

KAERI Korea Atomic Energy Research Institute

INVAP

CURTISS WRIGHT

Department of Commerce

U.S.ARMY

HIGH BRIDGE Associates, Inc.

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Purpose
Explore Major Issues

Roundtable Discussion:

- Explore international markets
- Major types of SMRs & why different
  - Light water reactors (LWRs)
  - Advanced reactors (high temperature, fast, metal-cooled, etc.)
- Certification challenges
- Export challenges
- Manufacturing challenges

Situation Analysis

- There is a Nuclear renaissance underway globally
  - Very slow in U.S. – implications for SMRs?
  - What does Fukushima portend?
- IAEA expects more reactors, widely dispersed
  - Now: 439 plants in 30 countries
  - IAEA says many emerging markets need small reactors
  - Forecasts up to: 500-1000 SMRs by 2040
- Potentially enormous export opportunity !
  - A global race and speed to market is important

"Everybody knows this is a global race to bring this very potent clean technology to the marketplace."

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SMR Macro Markets

- Commercial electricity production
  - New, incremental capacity additions
  - Replacement of coal (drop-in for old coal sites)
  - Isolated, hard to supply sites (Alaska)
  - Emerging country locations
- Military bases and other microgrids
  - Independence from commercial grids
  - Do U.S. military bases offer global potential?
- Industrial applications
  - Unconventional oil recovery – Canada, other locations
  - Other chemical and petrochemical applications (make hydrogen)
  - Water desalination

Country	*Population density*[a]	*CO_2 emissions*[b]	*Electricity imports*[c]	*Economic growth*[d]	*Energy consumption*[e]	*Nuclear capacity*[f]	*Total*
Latvia	4	4	1	4	4	1	18
Turkey	2	4	0	4	4	1	15
Jordan	3	2	1	4	4	1	15
Lithuania	4	4	0	3	2	1	14
India	1	4	1	4	3	0	13
Armenia	2	3	0	4	4	0	13
China	1	4	0	4	4	0	13
United Arab Emirates	3	4	0	1	4	1	13
Morocco	3	3	0	2	4	1	13
Estonia	4	2	0	3	3	1	13
Bulgaria	3	2	0	3	3	0	11
Brazil	4	3	1	1	2	0	11
Indonesia	1	4	0	2	3	1	11
Ghana	2	2	1	3	2	1	11
South Korea	1	3	0	3	3	0	10
Nigeria	1	2	0	3	3	1	10
Kenya	3	3	0	1	2	1	10
Mexico	3	3	0	1	2	0	9
South Africa	4	1	0	3	1	0	9
Slovak Republic	2	1	1	4	1	0	9
Ukraine	3	2	0	2	2	0	9
Poland	2	2	0	2	2	1	9
Egypt	2	1	0	2	3	1	9
Canada	4	1	0	1	1	0	7
Czech Republic	1	3	0	2	1	0	7
Slovenia	2	1	0	2	1	0	6
Netherlands	1	1	1	1	1	0	5

Key Questions

- What are the challenges for SMR certification by the U.S. NRC ?
  - Essentially slow process that could require 5-10 years for LWRs
  - Advanced reactors not being considered at present
- What are challenges for some other countries' regulators?
  - Regulations for local population safety
  - Coordinated with IAEA
  - Must prove in indigenous market before consideration of export?

"To think we will manufacture in the U.S. and export without a local market is a pipe dream"

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Key Questions

- Challenges for global regulations coordinated by IAEA
  - Unified internationally accepted set of regulations?
  - Depends on maturity of country nuclear program
  - Example of complexity: Transportation of fuelled reactors

Key Questions

- Organizations in U.S. Russia, China, Japan, Korea, France, others have SMR designs and eyeing export market
  - Not limited to LWRs
  - Not a level playing field for competition
- Examples: selected vendors by country
  - U.S. – G.A. EM^2, GE Prism, Holtec Hi-SMUR, Hyperion, mPower, NuScale, TerraPower TW, Westinghouse
  - France – AREVA underwater SMR
  - Russia – Rosatom aggressively developing multiple units for export including “floating” reactors
  - Japan – Toshiba 4 S
  - Korea – SMART developing for export
  - South Africa - PBMR

Key Questions

- What are the export issues involving nuclear patents, designs and products?
  - U.S. & others have strict export controls on nuclear devices, components and materials
  - State Department, IAEA
  - Bilateral agreements; 123 agreement
  - Complex considerations doing business with U.S.
    - U.S. vendors sell technology/patents/designs outside U.S.
    - Foreign vendors bring technology into U.S.
    - U.S. vendors sell nuclear components outside U.S.
    - Foreign vendors sell nuclear components inside U.S.
    - U.S. vendors manufacture nuclear components outside U.S.
    - Foreign vendors manufacture nuclear components inside U.S.
    - Same complexity for each country?

Factors Affecting Export of SMRs / Technical Data to Countries with Nuclear Power Whose Grid or Geography May be Conducive to SMRs

Country	§123 Agreements with U.S.	IAEA CSA	Ratified AP	DOE "Restricted" Country	Modern Nuclear Liability Regimes
Argentina 	Yes	Yes	No	No	1963 VC Party
Brazil 	Yes	Yes	No	No	1963 VC Party
China 	Yes	Yes	Yes	Yes	No (Declaration but no law)
India 	Yes	Yes	Signed, but not ratified	Yes	No (bill pending in Parliament)
Mexico 	No	Yes	Signed, but not ratified	No	1963 VC Party
South Africa 	Yes	Yes	Yes	No	Nuclear liability law based on VC principles
Taiwan 	Yes (but expires in 2014)	Yes, Trilateral Safeguards Agreement	No	No	Nuclear liability law based on VC principles

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Factors Affecting Export of SMRs/SMR Technical Data to Certain Countries with Emerging Nuclear Power Programs

Country	§123 Agreements with U.S.	IAEA CSA	Ratified AP	DOE "Restricted" Country	Modern Nuclear Liability Regimes
Chile 	No	Yes	Yes	No	No
Jordan 	No	Yes	Yes	No	No
Malaysia 	No	Yes	Signed, but not ratified	No	No
Namibia 	No	Yes	Signed, but not ratified	No	No
Thailand 	Yes (but expires in 2014)	Yes	Signed, but not ratified	No	No
Turkey 	Yes	Yes	Yes	No	Yes (Paris Convention)
Vietnam 	No	Yes	Signed, but not ratified	No	No
UAE 	Yes	Yes	Signed, but not ratified	Yes	Stated intent to join Vienna Convention

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Status of NPP Introduction in New-comer Countries

Type	Status and Category of Nuclear Energy Program	Countries	Current Installed Capacity (GWe)
A	New NPP under construction	Iran	44.2
B	New NPP being ordered	United Arab Emirates	15.7
		Turkey	38.8
C	Invitation to Bid submitted	-	
D	Decided to introduce NPP and started preparing infrastructure	Egypt	23.4
		Indonesia	24.6
		Jordan	2.1
		Lithuania	4.7
		Malaysia	23.3
		Vietnam	11.3
E	Active Preparation for possible NPP programme	Morocco	5
		Thailand	29.9
F	Considering NPP Programme	Kazakhstan	18.7
		Kuwait	10.9
G	Not planning, but may consider in the future	Saudi Arabia	33.5
		Singapore	10.1

Key Questions

- What are the manufacturing issues?
  - SMRs offer economies of manufacturing and construction scale, not necessarily lower cost per KWh
  - Practical “experience”
    - Prototype and pilot units must be built and operated to prove technology
    - R&D and deployment will improve efficiencies over time
  - Where should SMRs be manufactured?
    - Cost considerations: labor and materials
    - Quality considerations: must meet strict standards / specifications
    - Proximity to markets
  - What are the transportation issues?
    - Delivery and return
    - Safety
  - What about ongoing service, decommissioning and returns?

Economic Benefit*

- 100 MW SMR
  - $500 million to manufacture and install on-site
  - Would create 7,000 jobs
  - Generate $1.3 billion in sales
  - $404 million in payroll
  - $35 million in business taxes
- 100 MW SMR – Annually
  - 375 jobs
  - $107 million in sales
  - $27 million in payroll
  - $9 million in business taxes

*Source: Solan & Peterson, Dept of Business, U of Idaho
Presentation to CSIS 9/29/10

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Appendix

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Small, Modular Reactors

- DOE defines as < 300 Mwe; NEI - 350
  - Allows favorable insurance treatment
  - Linking for larger output (6-pack; 12-pack)
- Avoid huge capital investments; quicker ROI
- May be higher cost/KWh
  - Some skepticism over *economies of scale*
  - *Economies of mass production* expected
    - Factory fabrication
    - Faster, efficient construction
- "Drop-in" at existing coal sites?
- Long refueling cycles in some

"Develop these technologies today or import them tomorrow"
– Sec. of Energy, Steven Chu

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Situation Analysis

- Still in "pre-license application discussion stage"
  - Interested potential customers
    - Electric utilities
    - Remote municipalities (Galena, Alaska)
    - Industrial energy users
    - Military bases

"We see SMRs as possibly an opportunity for our next generation of plant development" – Utility EVP

- A number of SMR designs and potential niches
  - Light water reactors, mostly electric applications
    - B&W mPower, NuScale, Westinghouse IRIS
  - Mini, distributed & fuel cycle applications
    - Hyperion, Toshiba 4S, GE Hitachi PRISM
  - High temperature gas reactors for process heat and hydrogen
    - General Atomics, AREVA, PBMR

Expected SMR Advantages

- Lower capital cost (but higher per KWh cost)
- Shorter construction duration
- Scalability / incremental capacity additions
- Cost benefits resulting from factory/modular construction of components
- Potentially longer refueling cycle
- Improved security from underground placement
- Microgrids and distributed generation

SMR Categories

Company	Design	Description	Niche Benefit
Light Water Reactors			
Babcock & Wilcox	mPower	125 - 140 MW PWR	Below ground containment; expected to license quicker and offer versatility to utilities.
Nuscale Power Inc.	Nuscale	45 MWe PWR	
Toshiba-Westinghouse	SMR + IRIS	100-350 MWe PWR	
High Temperature Gas Reactors			
Pebble Bed MR Ltd.	PBMR	80 Mwe, helium gas cooled; steam turbine for power conversion.	Developed in South Africa.
General Atomics	EM2	240 MW Gas Turbine Modular	Recycles use LWR fuel. Helium gas-cooled.
Liquid Metal Cooled and Fast Reactors			
GE Hitachi	PRISM	300 MW Liquid sodium cooled	Went partially through licensing, part of advanced recycling center concept.
Hyperion Power	HPM	25 MW	Favorable for military mini grids and oil shale applications. Back end disposal of weapons Pu & HEU.
Toshiba	4S	10 MWe Liquid sodium cooled	
TerraPower	TWR	~200 - 1,000 MW Traveling wave reactor	Breed-burn reactor with a long refueling cycle.

Small, Modular Reactors

- Open questions
  - One control room or two?
  - Emergency planning issues
  - Timing of certification
  - Economies of scale
  - Is security being downplayed?
  - Value of testing on DOE site
    - NRC role

"SMRs have a long road ahead of them. There are about 20 issues unresolved.."

- Most believe siting multiple technologies at a single "test bed" location is no problem
- Several designs offer opportunities for disposition of surplus nuclear materials and used LWR fuel

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Small, Modular Reactors

- Other Issues
  - Industry task forces
    - ANS & NEI collaboration
  - Commercial market timing
  - Costs & investments
- Management/operational concerns
  - Designing safety & security in
  - Proliferation-resistance and physical protection challenges in remote, widely dispersed locations
  - Operations, training, maintenance and planning
  - Who operates? Who regulates?
  - Nuclear liability

"SMRs have a long road ahead of them. There are about 20 issues unresolved.."

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NRC Licensing & Policy Issues

- Licensing process
- Design requirements
- Source term, dose & siting
- Component & system design
- Operational
- Financial
  - Fee assessment (SMRs vs. large reactors)
  - Decommissioning funding
- Emergency planning
- Modularity
- Application format & content
- Price Anderson, insurance
- Design certification & COL
- Early site permits

Key Questions

- Why are SMRs under serious consideration, when until recently, we have been moving to larger and larger units?
- What are the applications and niches for SMR designs?
- Will they be a disruptive technology?
- Where will SMRs be sited?
- What will be the all-in costs of electric power from a typical SMR?
- What is the anticipated timeline for licensing and commercialization?
- What are the key challenges?
- How can we impact the future of SMRs?

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Insights for Industry and Government

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Who is Linton Consulting?

- Independent practice providing insights to industry and government for business strategy, policy and market development in Energy and Manufacturing
  - Over 30 years experience with large consulting / E&C firms
  - Over a decade of consulting experience
  - Extensive industry contacts & ongoing interviews

Strategic View Industry Studies

- 2010 Energy Challenges/ Energy Parks
- 2008 Nuclear Renaissance
- 2007 Oil, Gas, Chemicals
- 2006 Energy
- 2005 Mfg./Industrial
- 2004 Food & Beverage
- 2003 Pharmaceutical
- 2002 Power
- 2001 Infrastructure Life Cycle, Others

Past *Linton* Industry Studies

- Oil & Gas
- Electric Power
- Engineering and Construction
- Water/Wastewater
- Environmental
- Asia/Pacific
- *Market Reports* - Series

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2010 Research Conducted – For SRNS Energy Park Study

115 Interviews, Discussions, and Meetings*

- Ameresco
- American Nuclear Society
- Arizona Clean Fuels
- B&W
- BetterPlace
- BP
- Building Construction Trades Dept. (AFL-CIO)
- Canup & Associates
- Carolinas' Nuclear Cluster
- CH2M Hill
- ConocoPhillips
- CSIS
- Duke Energy
- DOE
- DOE- EM
- Dow Chemical
- Eastman Chemical
- Economic Development Partnership
- EIA
- EPRI
- Exelon Corporation
- Fluor
- Gasification Technologies Council
- General Atomics
- General Electric
- GE- Hitachi
- George Mason University
- Honeywell
- Hyperion Power
- Marathon
- Marston Consulting
- MIT
- NEI
- New Carolina
- NNSA
- NRC
- Peabody Coal
- PJM Interconnection
- Progress Energy
- Rentech
- S-4 Energy Solutions
- SCANA
- SC Regional Development
- Senator Graham's Office
- Senator DeMint's Office
- Shaw Group
- Siemens-America
- Southern Company
- SRNL
- SRNS
- SRNS- Honeywell
- SRNS- Northrup Grumman
- SRS-CRO
- TerraPower
- Technology Ventures
- Three Rivers Solid Waste Authority
- University of South Carolina
- UOP - Honeywell
- USEA
- Westinghouse

*Some organizations had multiple interviews

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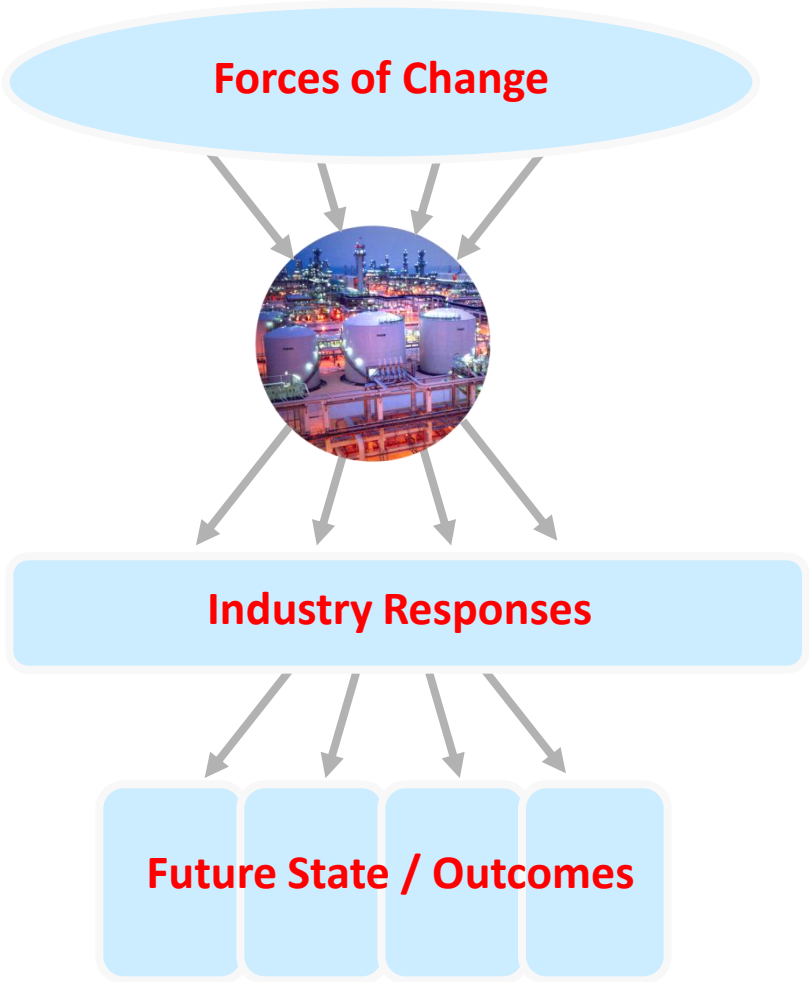
What is *Strategic View*?

- Research model
  - Used 14 years; 5 in energy
  - Forces affecting the future of the energy industry
  - Industry responses
  - Where it is leading – the future state/outcomes
- Process
  - Interviews with executives and thought leaders
  - Research & analysis
  - Executive Roundtable
  - Follow up & plan integration



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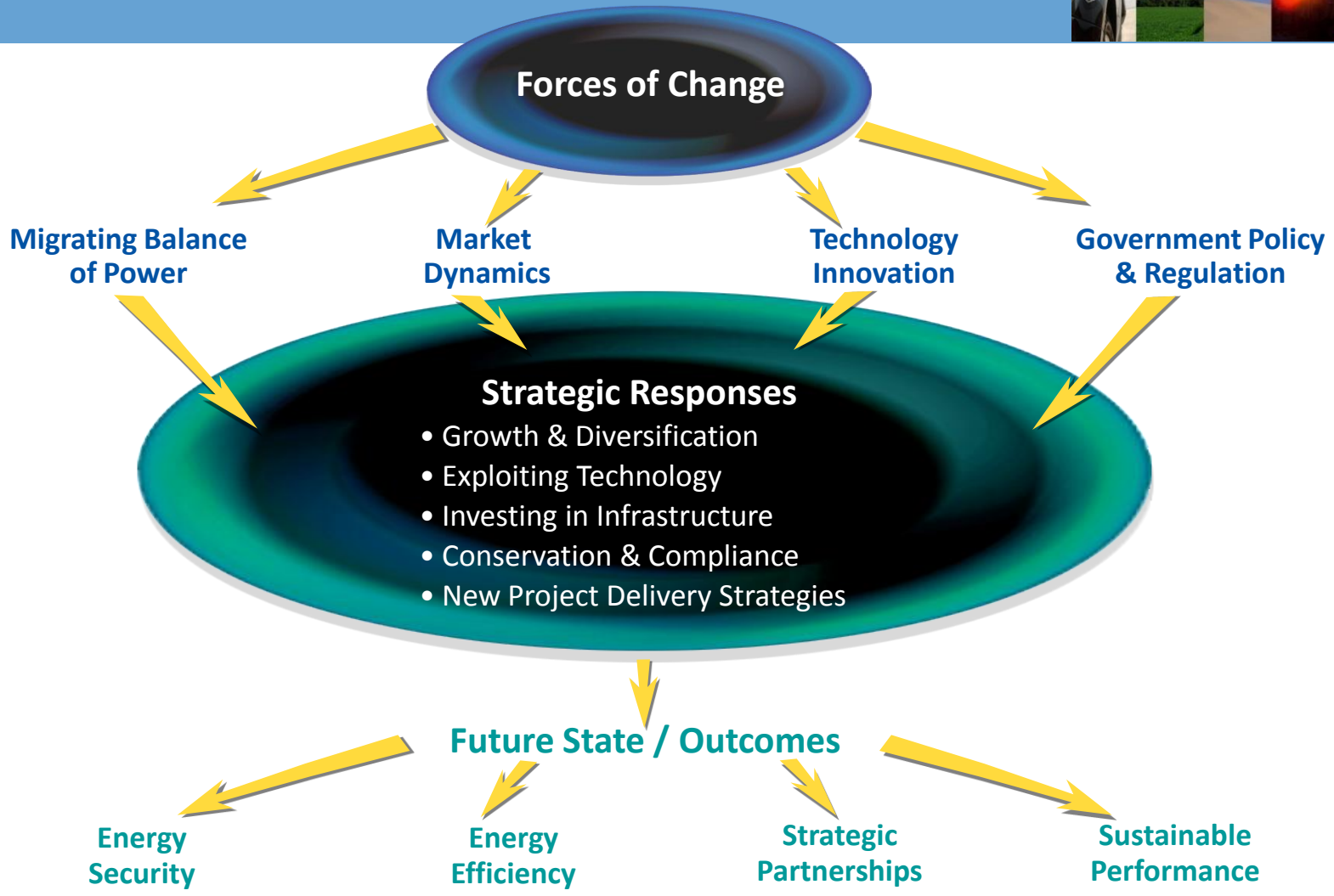
Strategic View – Energy (Example)



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Executive Roundtables

- Common purpose
  - Convene executives and thought leaders for knowledge exchange
  - Expand understanding
  - Share perspectives
  - Confirm/challenge paradigms
  - Advise leadership
  - Uncover ideas and opportunities for your organization
  - Explore Future – trends and challenges
  - Establish practical, realistic path forward

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