UNIVERSITY of HOUSTON

Evolving the Role of "The Energy University" During the Energy Transition

UH Energy Strategic Plan

January 2020

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Executive Summary

Abundant, low-cost energy makes the modern world possible. Affordable and sustainable energy will be needed in ever increasing quantities throughout the 21st century as our planet's human population grows by an additional two to three billion people. Satisfying this need will be challenging. Adding to the challenge is the requirement that we must address energy-related climate-change risks.

The University of Houston is uniquely positioned to play a leading role in delivering the innovative solutions that will be required to address both of these global-scale imperatives. UH has committed to establishing itself as "The Energy University" – a university that will advance the science, technologies and policies that underpin the energy transition while providing low cost energy for our entire planet's inhabitants.

Earlier this year, UH Energy undertook a planning process to determine how to enhance the university's ability to deliver solutions for the energy needs of today and tomorrow.

Goals identified included:

- Prepare students and conduct research that helps meet the challenge of providing the energy needed for growing global demand while reducing emissions and other environmental impacts;
- Identify and communicate the potential technological, public, business, and regulatory policy solutions to meet future energy challenges recognizing the complex interaction of technical, societal and political factors;
- Be a recognized leader in helping to deliver energy solutions through innovation, entrepreneurship, technology and policy and ensure their applicability to Houston, Texas, the US and the world.

These goals align with strategic objectives of UH including Student Success, Research Excellence and Thought Leadership. Progress versus the goals will be tracked and re-evaluated on an ongoing basis to ensure continuous improvement.

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1. Objectives: Mission and Vision

The mission of UH Energy is to:

"Provide broad-based education, training, research, tech transfer and leadership skills to develop an educated workforce for the industry and betterment of society with an emphasis on Science – Technology – Engineering – Mathematics (STEM), Law, Policy, Architecture, and Business."

Specifically, UH Energy has focused our efforts on improving student success, advancing research and innovation developments and building a marketing and branding campaign to establish UH as the Energy University. Superimposed on this momentum, the energy field and more specifically the energy industry stands at the cusp of a transition that will usher in a more sustainable energy future.

Historically, global energy transitions take decades, and there is broad agreement that no single solution will likely be found. Therefore, it is critical that the University of Houston:

- Prepare students and conduct research that helps meet the challenge of providing the energy needed for growing global demand while reducing emissions and other environmental impacts;
- Identify and communicate the potential technological, public, business, and regulatory policy solutions to meet future energy challenges recognizing the complex interaction of technical, societal and political factors;
- Be a recognized leader in helping to deliver energy solutions through technology and policy and ensure their applicability to Houston, Texas, the US and the world.

UH Energy recognizes that many of the energy solutions are multi-disciplinary in nature and often require a systems approach. This multi-disciplinary systems approach is a significant guidepost for the strategic plan.

UH is well positioned to play a leadership role in the energy transition. UH is located in Houston, the focal point for the oil & natural gas industry, and maintains strong partnerships with the premier companies making up this industry. Further, Texas is the leading state in the U.S. for wind energy generation, the largest source of renewable energy in the U.S. and the world. Lastly, Texas' economy and population are amongst

the fastest growing in the U.S. making it the perfect place to test solutions that satisfy the dual challenges of affordable and sustainable energy at scale.

2. Background

The University of Houston has deep disciplinary strengths in multiple areas that are central to the energy industry of today and projected to be for the foreseeable future. These include leading-edge strengths in:

a. Energy Education

Education programs that span across ten colleges including Architecture, Business, Communications, Engineering, Honors, Law, Public Policy, Science, Social Science, Geosciences, and Technology at the undergraduate, graduate, professional continuing and executive education levels that cover disciplinary and interdisciplinary focal points

b. Oil and Gas Exploration and Production

(i) Exploration – Advances in seismic, micro-seismic, acoustic and numerical interpretation using geotechnical models and experimental techniques applied to conventional, unconventional and offshore

(ii) Drilling & Production – through environmentally friendly drilling, automated and remote operations, integrated reservoir management and enhanced oil recovery portfolios for brownfield and greenfield applications

(iii) Unconventional – integrated across reservoir characterization to reservoir management and abandonment and decommissioning strategies

(iv) Offshore – focused on digital transformation including data analytics, power systems and robotics / automation with a focus on asset integrity management, and late-life management

c. Oil and Gas Transportation, Conversion and Products

(i) Catalysis and reaction engineering – focused on oxide materials, catalyst development, natural gas upgrading

(ii) Process intensification & process optimization – shifting the chemicals and refining paradigm

(iii) Materials including polymers and soft materials – from fundamental chemistry, to characterization, processing and modeling

d. Electricity Generation, Transmission and Storage

(i) Renewable Generation: Offshore Wind Energy with a focus on development of energy systems; Development of roll-to-roll solar energy conversion systems; Advancing thermoelectric systems

(ii) Advancing Power Transmission: Superconductivity – from fundamental understanding of superconductivity to roll-to-roll manufacturing and deployment of superconductors; Power electronics – strengths in power electronics and data analytics applied to grid power

(iii) Storage: Energy storage through storage batteries including non-lithium based, flexible lithium based, superconductor based flywheels; chemical conversions including hydrogen and methanol and development of fuel cells

e. Sustainable Energy Development and Resilience

(i) Resilience – hurricane resilience and extreme weather resilience including human factors

(ii) Sustainable energy generation, transmission and storage including carbon capture, carbon utilization, safe storage, carbon management, bio-fuels and algae based fuels

(iii) Materials – Sustainable and Bio renewable: Plastics and materials recycling, incorporation of bio-based materials, development of circular economy fundamentals

f. Interdisciplinary crosscutting strengths at UH include:

(i) Global energy management especially the strengths associated with the Gutierrez Energy Management Institute (GEMI), Finance, Decision Information System and Supply Chain and Logistics

(ii) Innovation and entrepreneurship led by the Wolff Center for Entrepreneurship in the Bauer College of Business and extended across the UH with significant efforts in the College of Natural Science and Math, the Cullen College of Engineering and the College of Technology; The Office of Technology Transfer in the Division of Research and the Technology Bridge represent UH's crosscutting efforts to connect academia with the innovation ecosystem and the energy industry

(iii) Energy law especially the Center in the Law School focused on Energy, Environment and Natural Resources

(iv) Domestic, International and Economic policy focused on energy.

3. Feedback and Trends

Several trends regarding the various facets of the energy industry and higher education have emerged as we considered the advancement of a strategic plan for UH Energy.

With regards to student success, we observe a significant demographic shift that will affect all of higher education over the next decade and is related to declining enrollments nationally and a significantly altered mix of students entering higher education. There has also been a significant shift in international student attendance at major U.S. universities wherein fewer students from China and India are pursuing higher education options in the U.S. Lastly, the issue of increasing student debt and the importance of equity has never been more important in higher education and addressing proactive solutions will provide UH a leadership role.

Students at UH are also especially interested in experiential learning and this is the theme of the "Quality Enhancement Program" that UH has adopted as part of its accreditation with Southern Association of Colleges and Schools (SACS). Moreover, the student body and the potential employers of students from UH have emphasized the importance of global awareness and global connectivity. A crucial element for enhancing the uniqueness of the UH energy education would be a required experiential learning component that is developed to identify rising talent to the energy programs and establish a strong UH brand,

From an energy technology perspective, the energy field stands at the cusp of a transition that will usher in a more sustainable energy future. However, based on historical trends and the significant investment and technological challenges, such a global energy transition will take decades, there is broad agreement that no single solution will likely be found and that oil and gas will continue to play a significant role. Nevertheless, four macro-trends influence the strategic directions for UH Energy:

(1) Sustainable Development and Circular Economy
(2) Data Driven Decision Making and Integration of Cybersecurity
(3) Automation and Robotics
(4) Innovation and Entrepreneurship

Recognizing that oil and gas will continue to dominate the energy landscape for the next fifty years, it is critical for UH's existing education and research programs to integrate these important trends while ensuring that UH and the stakeholders its serves are leading the energy transition. With significant strengths in science and engineering, UH should identify mechanisms to develop sustainable energy at scale through chemistry and processes, with a focus on addressing hydrogen, methane and CO_2. Specifically, UH should leverage its strengths in materials to design and develop new materials, identify new supply chains for materials, and to connect these with advances in manufacturing, especially additive and high-throughput manufacturing. One specific challenge continues with the issue of energy storage, and development of disruptive breakthroughs are necessary here – UH is well positioned to lead this effort.

Lastly, solutions to current and future energy challenges must address the entire energy system and a university such as UH is located uniquely and with the ability to address simultaneously and holistically the technical, regulatory and public policy as well as business issues, including entrepreneurship and innovation. Such multi-disciplinary collaborations and solutions are crucial and supported as a strategic element at UH.

4. Strategic Objectives

a. Student Success

UH will continue to grow and expand its outstanding energy related fields to ensure that our students are well prepared for careers in the energy industry. Ensuring that our students are leaders in areas of energy need will require strategic and continuous engagement with the all stakeholders and a continuous adjustment of tactics. In addition to the pursuit of excellence through UH's energy focused disciplines, UH Energy plans to address the following key cross-disciplinary activities focused on student success:

(i) Growing Scholarships for interdisciplinary programs such as the Energy and Sustainability minor.
Currently, there are over 150 students enrolled in various stages of the minor program and represent students with diverse academic backgrounds. Over the last two years, UH Energy and the Honors College have established 15 scholarships funded by industry for students taking this minor. Over the next five years, we expect to raise enrollment to 300 students and with 50 competitive scholarships.

(ii) Expanding Experiential Learning

UH has identified experiential learning as a core value and UH Energy hopes to promote and expand this amongst the energy related students through:

(a) Increased internship opportunities
UH Energy anticipates growing internship opportunities across UH. As an exemplar, UH Energy working Bauer College of Business has established the Scholar – Intern program focused on Trading and Commercial training. Starting from an inaugural class of eight students in 2018, we anticipate that this program would expand to 25 students in each cohort.

(b) Cougars Initiative to Engage (CITE)
UH Energy has led programs in university wide CITE program through the Sustainable Community project in 2018 and the Geology of the Fra

Cristobal range, central New Mexico, in 2019. Maintaining at least one CITE related program each academic year is a goal for UH Energy.

Developing a robust experiential learning environment, especially in energy, will help brand the energy programs at UH as high quality opportunities for prospective students and a pursuit of excellence.

(iii) Expanding Innovation & Entrepreneurship Programs

UH Energy has noted some significant successes in advancing entrepreneurship and innovation across UH. Specifically, two student teams from the Wolff Center for Entrepreneurship, now representing start-up companies ReeCycle and SensyTec are notable successes in the energy space. Growing such energy related entrepreneurial activities is a significant goal for UH Energy. Specifically, working with the Subsea Systems Institute and potential Department of Energy (DOE) and Department of Interior (DOI) programs, UH Energy along with innovation and entrepreneurship initiatives in the Colleges of Business, Technology and Engineering will grow the efforts to increase energy related innovation and entrepreneurship activities and highlight them as unique UH Signature activities.

(iv) Advancing Multi-Disciplinary Graduate Education Programs

Masters, Doctoral and Professional education programs along with executive education programs must address complex energy related challenges and require new educational programs. Consistent with the research thrusts, UH Energy in collaboration with different colleges across plans to develop and offer various graduate educational programs. Previously, UH Energy has helped co-develop programs in Upstream Energy Safety and Global Energy, Development and Sustainability. Most recently, UH Energy has helped develop executive education on Sustainable Energy Development. Over the next five years, UH Energy plans to focus on developing multi-disciplinary graduate education programs in

(a) Sustainable Development and Circular Economy
(b) Data Driven Decision Making in Energy
(c) Energy Cybersecurity
(d) Automation and Robotics.

b. Research Excellence

UH Energy has advanced research excellence at UH through the establishment of National Centers as well as growth of University – wide centers and the growth of industry focused consortia.

Specifically, the Subsea Systems Institute, a Restore – Act Center of Excellence, has grown UH's leadership role in offshore energy technologies and has spawned three industry-based consortia on

Power electronics and energy storage,
Pipeline asset integrity management, and
Robotics and automation for Offshore Platforms,

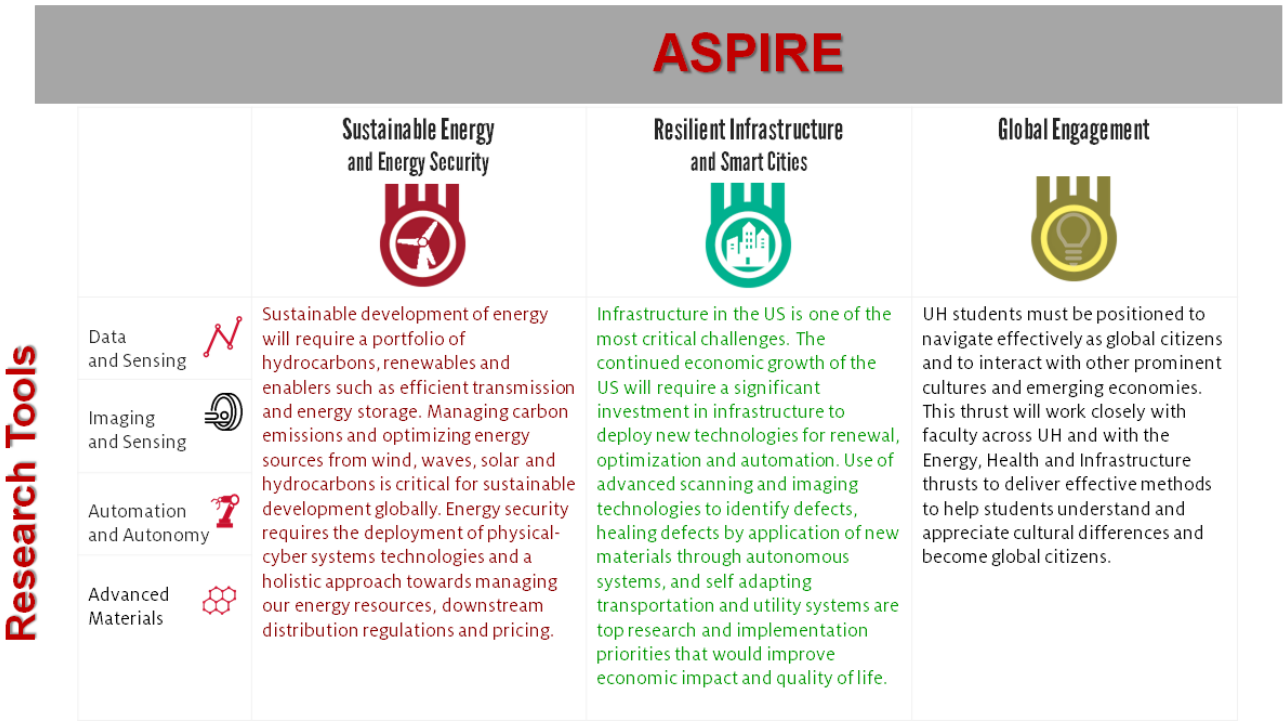
that have engaged over 20 companies.

Similarly, the Center for Carbon Management in Energy and the Consortium for Energy Corporate Social Responsibility, have engaged with the industry and are poised for significant growth and advancement (Appendix 1). Growing these centers and consortia, as strategic partners for the energy industry is a key objective for UH Energy.

UH has developed strong research and educational programs focused on energy cybersecurity and these complement the growing strengths of UH's HPE - Data Science Institute to advance the data analytics efforts across the energy related disciplines (Appendix 2).

Similarly, UH is developing a strong Sustainable Polymer and Soft Matter center through the Welch Center for Polymer Chemistry. These areas for growth and advancement must be translated into strategic partnerships with industry and gain national recognition. These materials related efforts complement significant expertise in oxide and superconductor materials as well as advanced manufacturing areas.

UH Energy is well positioned to lead the efforts to develop and grow the ASPIRE fund related activities over the next five years. Specifically, UH Energy is helping define the ASPIRE Institute for Sustainable Energy and Energy Security, as an interdisciplinary research and education institute.



The vision statement and strategic planning for the ASPIRE institute is ongoing and will complement the efforts more broadly within UH Energy.

c. Thought Leadership:

UH Energy is tasked with growing the reputation of UH as the Energy University. This requires identification of: (i) Message; (ii) Audience; and (iii) Dissemination tools.
UH Energy has identified three key mechanisms to promote and grow the reputation of UH:

(i) Symposium Series: The Critical Issues in Energy series is in the seventh year. Audience numbers, online attendance and media coverage have grown. Mechanisms to engage broadly across the wide range of stakeholders continue to be fine-tuned.

(ii) Energy Fellows Opinions and Blog: The opinions and blogs posted by UH subject matter experts have been featured in print media and online media including Forbes.com that features the UH Energy Fellows blogs. Growing the number, the breadth, readership and potential re-distribution is a key strategic goal.

(iii) UH Energy White Papers: Based on Chatham House rules-based discussions with stakeholders these white papers have become a powerful mechanism to demonstrate thought leadership. The number of white papers, improving and quantifying dissemination, as well as translation of

these to research projects and industry collaborations are leading metrics to follow.

UH Energy will continue to strive to develop methods to engage the diverse student and unique student body along with the connectivity to the broader community to enhance and grow engagement and awareness of energy related issues. In addition, we will develop knowledge-driven collateral to help advice policy on the local, state and national levels for energy related issues. Most importantly UH Energy will target its marketing of thought-leadership with national and international media to ensure the highest-level exposure for the resident expertise.

5. Management of Strategic Objectives

UH Energy will be accountable for the management of the strategic objectives and will follow a well-established continuous improvement plan. Each strategic objective has been assigned a budgetary resource and performance goals and time-period for evaluation established. With continuous monitoring and corrective methods developed in consultation with stakeholders, UH Energy will monitor and continuously improve the implementation of Strategic Objectives.

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Appendix 1: Center for Carbon Management in Energy (CCME)

The Center for Carbon Management in Energy (CCME) at UH has the capability and capacity develop solutions to meet the lower carbon future energy transition challenges. Multi-disciplined, collaborative research from the required fields of engineering and science, business, law, regulatory and policy, as well as education for the marketplace, are strategically aligned with our industry partners to address the needs of oil and gas, petrochemicals, and electric power markets.

1) Safe and Reliable CO_2 storage – In saline aquifers, depleted oil and gas reservoirs amongst others. Identification of safe storage sites, estimating realistic and maximum storage potential, monitoring of storage, estimating and monitoring of impact of fluid storage on reservoirs, quantification of short-term and long-term risks, detecting CO_2 plume migration and leakage, and connecting these to the varying regulatory bodies and business climates globally.
2) Business Case for CO_2 Use and 45Q – Business, legal, science and technology, engineering principles that build on the capability and capacity for to provide the fundamentals of a business case for 45Q/CCUS , in the U.S. and in anticipation of global deployment of CCUS and a global price on carbon. NPC study and OGCI white space research requirements and needs.
3) Enhanced Oil Recovery – EOR of onshore conventional oil reservoirs, offshore fields, residual oil zones (ROZ), unconventional resources, and CO_2 use maximization by EOR considering technical, business, legal and policy.
4) Life cycle analysis for “low carbon hydrocarbons” in the implementation of E&P to end use in transportation, power generation and petrochemicals. Scenarios and fuel options, technology insertions, business case and legal/policy frameworks to catalyze and grow supply and consumer demand
5) CO_2 conversion options in conventional and unconventional settings – considering conversions of CO_2 to fuels including methanol, chemicals, high value additives including particles and plastics
6) Regulatory and Public Policy and Legal frameworks for CCUS and new business models for implementation. Use, re-use, disposal, and long-term liability and risk management scenarios and assessments.
7) CO_2 as a Global Commodity: Matching sources and sinks, transportation modalities, trade policy, tax and use credits, credit trading, development of regulatory frameworks and convergence of public policy and global policy.
8) Zero Emissions Refinery – technology, economics, project implementation including financing, timing, integration of renewable resources and new grid technologies.
9) Modular CO_2 capture including those for point sources and distributed air capture. Technology development including process intensification methods,

integration with renewables and stranded resources, techno-economic analysis tools, regulatory and public policy development.

10) CH_4 monitoring technologies and implementation approaches including convergence of policy challenges with multiple federal agencies (EPA, FAA and FERC)

11) Stranded CH_4 conversion options in conventional and unconventional settings – to impact CH_4 emissions, flaring and create new business models including conversion to fuels (including methanol) and chemicals. Development of modular technologies to supplement scaled-up units and combining with renewable and intermittent resources.

Next Steps:

- CCME 6-12 month aspirations and a view of our future state
- Integration with Consortium of Energy Corporate Social Responsibility with education, equivalence of approaches and business case development
- Executive Education of Sustainable Energy Development
- ASPIRE - Institute for Sustainable Energy and Energy Security
- Develop a National Carbon Innovation Hub

Appendix 2: Cyber-Security for the Energy Industry

The digital transformation of the energy industry has been accelerating and is seen as the key to increasing reliability and efficiency and therefore making energy more affordable. The emergence of smart grids, digital oil field, data analytics driven sustainability enterprises and data driven supply chain and optimization across the energy sector are critical to the growth of a modern global economy. Moreover, with a focus on safety, reliability and reducing risk, the energy industry is rapidly implementing robotics and automation in many aspects of the technology and operations. Cyber threats, especially ones that can result in significant loss of physical assets, financial loss and data theft, remain a persistent challenge that will grow with the expanding digital transformation and automation of the industry.

The adoption of digital and automation is at varying levels of maturity in the subsets of the energy industry (including exploration and production of oil and gas (upstream), the transportation and refining of oil and gas (midstream), petrochemicals (downstream) and electricity generation (from multiple energy sources), distribution and storage) and present distinctly different challenges, opportunities and operational risk.

The University of Houston, working through its significant strengths in the HPE DSI, Computer Science and Math departments along with deep application strengths in Engineering, Technology and Business will help develop hardware and software to secure the increased deployment of automation and the supply chain network contributing to the upstream, midstream and downstream and electric energy industry. We propose to address the issue of securing the increasing digitalization and automation of operations in each of the three oil and gas sectors and further propose to collaborate with hardware developers and operators to extend conditioned-based monitoring, decision making at the edge and ensuring the security of the supply chain of raw material, product, equipment and manufacturing processes.

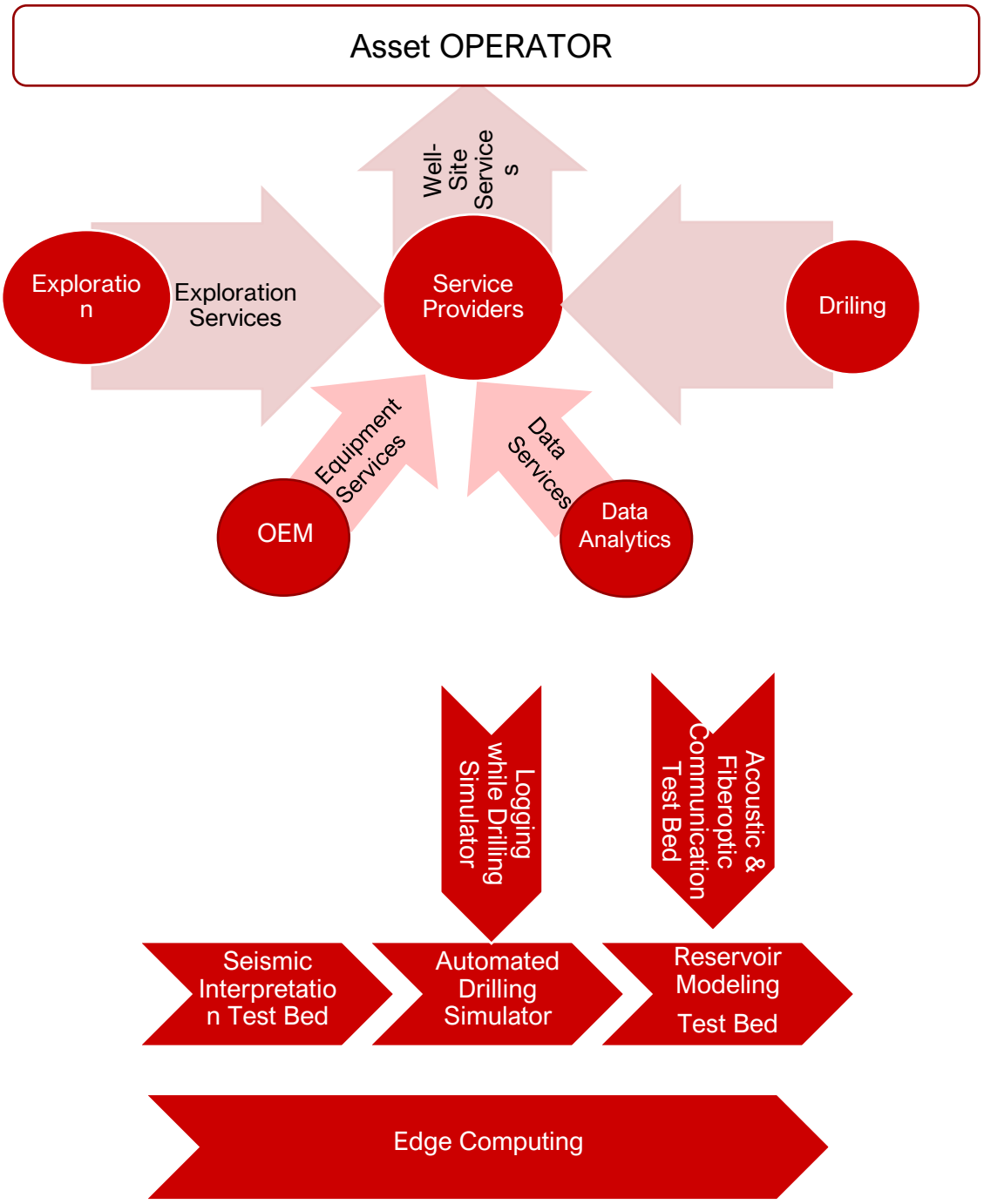
Some examples of specific topics to advance through the manufacturing institute include:

a. Securing automated drilling and increasing efficiency of drilling operations by securing the supply chain
b. Improved reservoir management through secured and digitally transformed production operations
c. Increasing efficiency and improving asset integrity for midstream operations
d. Improved process intensification through secured process optimization and adjustment of processes in response to changes in raw material feed
e. Securing the electric grid and enhancing digital management of transmission and distribution network to improve efficiency
f. Development of common standards to implement along the Energy Vertical to secure entire network
g. Provide test bed for advanced manufacturing facilities for evaluation of advanced sensors for manufacturing process monitoring and control

h. Education and Workforce development for best practices in cybersecurity tailored for Energy industries.

Upstream Exploration and Production: Network & Operation

Exploration and drilling operations are complex multi-stakeholder driven operations, and the extensive seismic, acoustic, electro-magnetic logging, and other downhole sensors provide multi-modal data that needs immediate processing for decision-making and archiving and retrieval for analysis during production.



Midstream Transportation and Processing: Network & Operation

Midstream oil and gas operations are also complex and engage multiple stakeholders as part of their supply chain. The main focus is transportation of oil and gas, with compression and pumping being the main energy consumers. Key issues include monitoring, metering, and inventory control, especially at points where custody control changes.

All stages in the supply chain are heavily dependent on automation in many aspects of their technology and operations, and they are potentially vulnerable to cyber threats. Working with our industry partners, we anticipate that the institute will utilize and develop both “digital twins” and scaled physical models of the supply chain to identify vulnerabilities and to help develop hardware and software to secure the network.