Stony Brook University College of Engineering and Applied Sciences

ENERGY SYSTEMS FOR SUSTAINABILITY

BACKGROUND

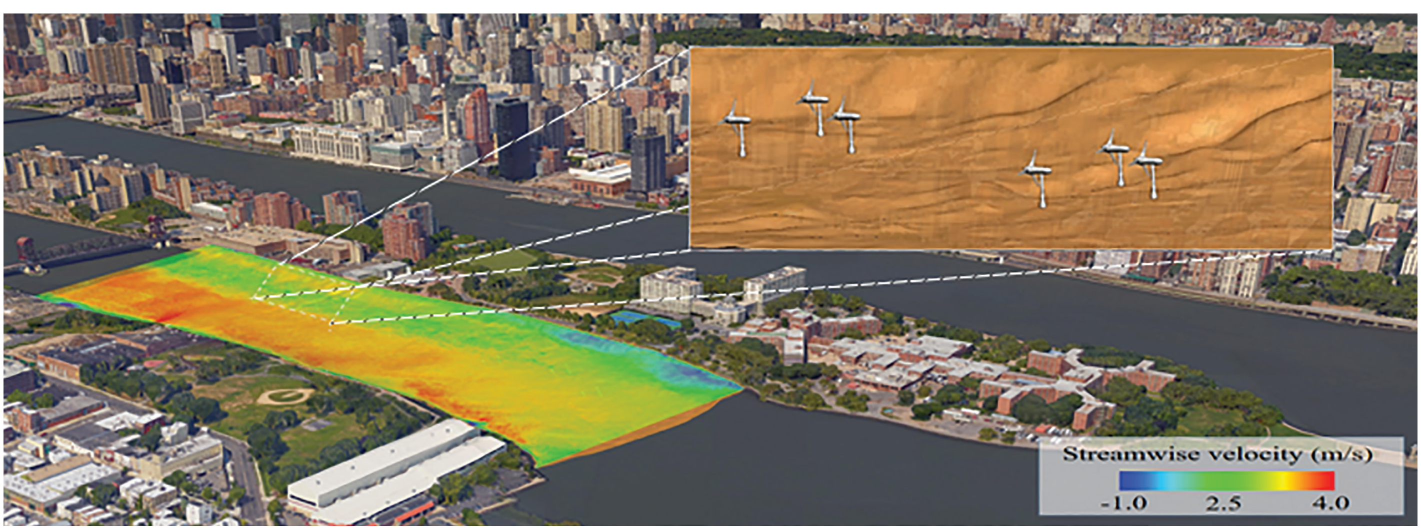
The projected population increase to almost 10 billion by 2050 is prompting a major effort in supporting basic necessities of food, energy and water (FEW). The United Nations recently adopted 17 sustainable development goals (SDGs) and energy is pervasive among all of them. Key energy-related areas include power and fuels production from renewable and low-carbon (natural gas) sources and efficient, reliable, and environmentally friendly energy delivery and consumption.

About 80% of all types of energy used in the United States is derived from fossil fuels. In 2015, the largest source of the country's energy came from petroleum (32%), followed by natural gas (28%), coal (21%), renewable sources (11%) and nuclear power (9%). The major directions of the US energy policy include: reducing our dependence on foreign oil, safe and responsible domestic oil and gas production, advancing clean energy and energy efficiency, developing clean fuels, and developing carbon capture and sequestration technologies.

With ambitious plans to reach 50 percent renewables by 2030, New York is one of the leading states in the development and implementation of clean energy technologies with Long Island playing a leading role. This includes the largest solar photovoltaic plant in the Eastern US at the Brookhaven National Laboratory and the plans to build the largest US offshore wind farm at the East End of Long Island.

Leveraging the excellence of our esteemed faculty, our Advanced Energy Research & Technology Center (AERTC), our partnership with Brookhaven National Laboratory (BNL), and strong ties with industry and stakeholders, The College of Engineering and Applied Sciences (CEAS) is uniquely positioned to develop a bold research agenda that can make a transformative impact on the energy landscape of the region and the nation, and lead the way in finding and implementing sustainable solutions for humanity's energy challenges.

Following an extensive, faculty-driven strategic planning effort, CEAS has identified four cross-cutting research topics of critical importance for advancing energy systems for sustainability. These efforts integrate science, engineering, and socio-economic approaches, to develop innovative energy solutions and pathways for sustainable implementation of these solutions.

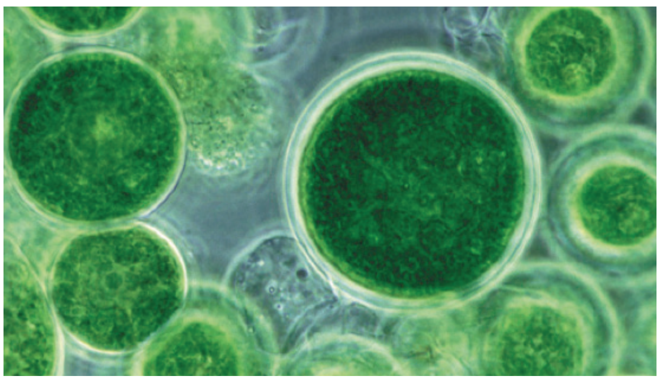


GREEN POWER AND FUELS PRODUCTION

Fuels are at the heart of the sustainability initiative. In 2015, the world consumed:

- 31 trillion barrels of petroleum, mostly for transportation
- 9 billion tons of coal and 120 trillion cubic feet of natural gas, mostly for power generation.

Under the best case scenario, petroleum consumption could decrease by over 60% by adopting electric cars but the fact remains that low-carbon fuels would be needed to produce additional electricity to satisfy the increased power demand for electric vehicles. All projections point to fossil fuels playing a major role (about 75% of the energy mix) through 2035 and beyond. Developing low-carbon fuels that would help reduce carbon footprint is the ideal solution.



Develop and understand hybrid renewables for low energy intensity
Harvest algae for biofuel feedstock production. Couple renewables with advanced combustion to balance loads. Understand behavior of intermittency regarding renewables through high-fidelity predictive models. Conduct energy analyses on potential sources and for optimal energy choices.

Develop materials for extreme environments
Advanced combustion and other developing systems require high-temperature materials for longevity and low-energy operation.

Manage and harvest leaks in methane producing systems
Systems include: Oil and gas operations, agriculture waste, wastewater and landfills. This pathway is also noted as managing wastes to reduce negative health and GHG effects. Natural gas a bridge fuel and scenarios to integrate carbon sequestration to reduce carbon intensity.

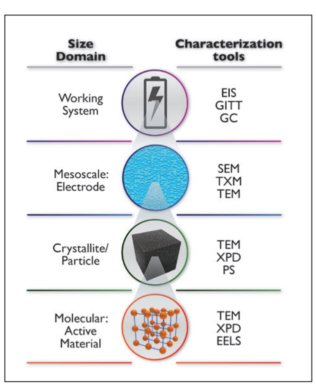
Create advanced systems for direct CO2 utilization
Capture from air and H2 from water and catalytic conversion. Produce on-site fuels for local consumption to eliminate fuel transport.

Identify test bed locations for large-scale low-carbon projects
Focus on resiliency against hurricanes and other natural disasters to identify demonstration sites in New York State.

ADVANCED ENERGY

Energy storage is foundational to the future energy vision. Widespread adoption of renewable forms of energy, such as wind and solar demand integration with high-density storage. Further commercial integration of high densities batteries on-road (for vehicles) and on-board (for airplanes) is needed.

Storage serves two roles:
1) stored energy for future use, and
2) leveling variable generation of power.
Outstanding issues include high-density, low-cost storage in large-scale systems by managing heat in confined spaces.



Storage materials by design
Molecular Architecture at both the molecular and meso scale are critical aspects. Control of structure and physiochemical material properties for storage technologies. Design and control the mesoscale environment of the active material and the electrode architecture. This demands participation of materials scientists and chemists.

Advanced characterization ex-situ, in-situ and operando methods are needed
Utilize and expand linkages with facilities and expertise at national laboratories such as BNL.

Heat Management in Confined Spaces
Controlled heat dissipation could resolve issues both at small and large scales. Envision a scientific solution to a practical problem.

Recycling by Regeneration
Effective methods to regenerate batteries after normal lifetime. Consider novel strategies to avoid batteries going into waste streams.

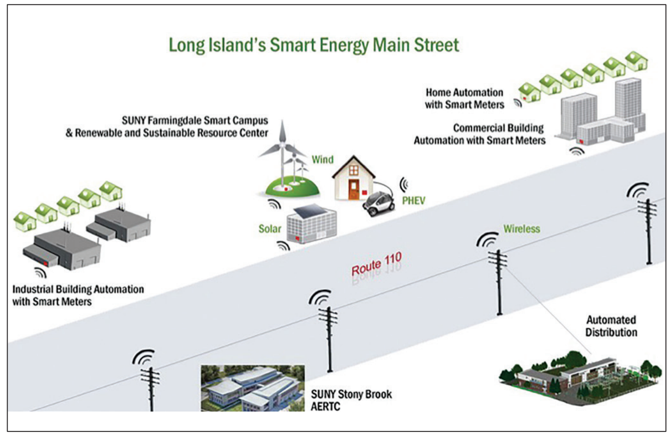
Modeling to Understand Storage Needs
for integration opportunities with renewables at large scales and with multiple sources of power. Smooth switching among renewables.

SMART GRID TECHNOLOGIES

Smart Grid technologies utilize computer-based remote control, automation, two-way communication technologies, and time-resolved information processing to increase system reliability and efficiency. They also provide seamless integration of large volumes of intermittent renewable generation and large percentages of electric vehicles to the grid.

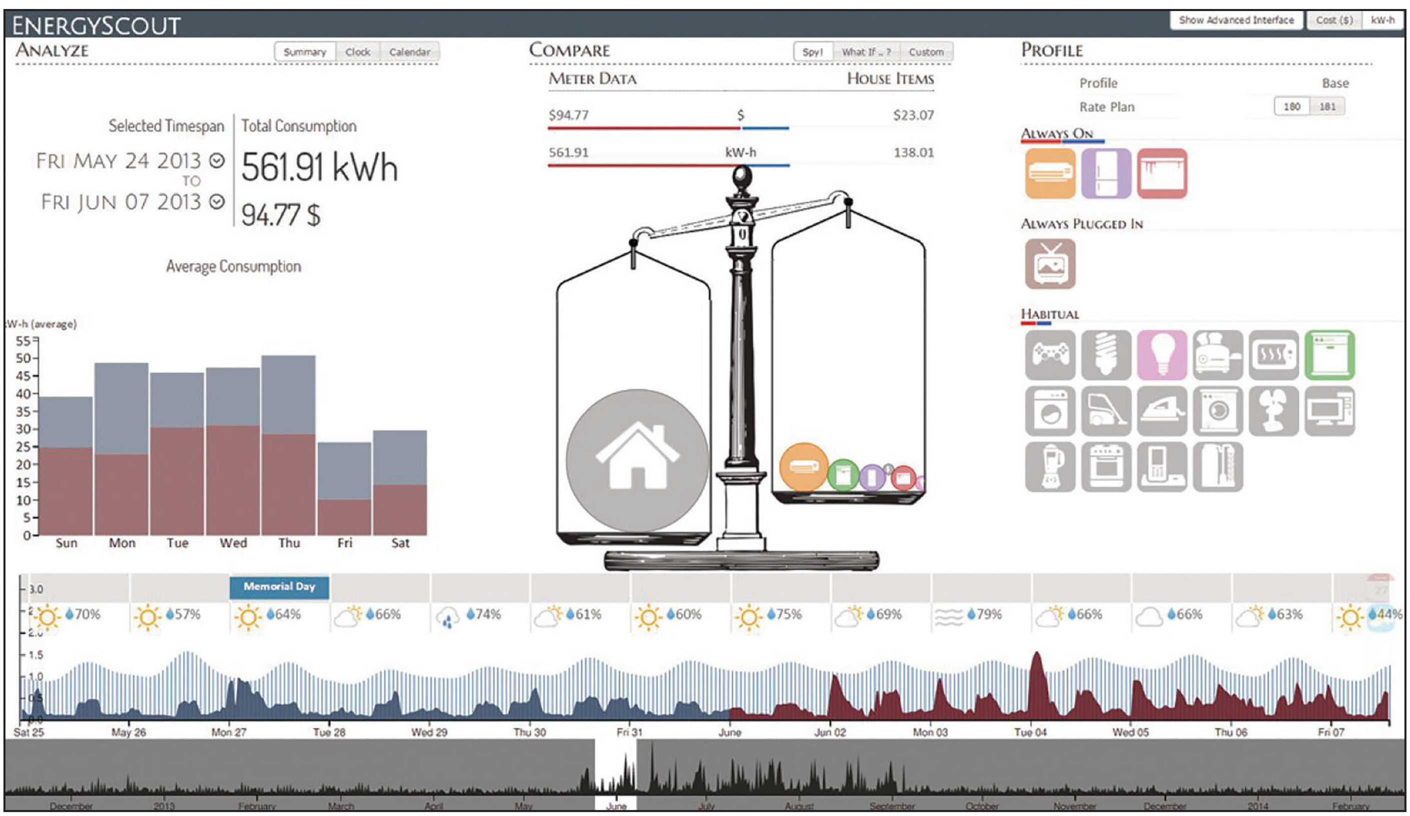
Stony Brook has two Centers for Advanced Technology, the SENSOR CAT and Center for Integrated Electric Energy Systems (CIEES) funded by New York State Division of Science, Technology and Innovation (NYSTAR). Stony Brook University is a founding member of the New York State Smart Grid Consortium

Mathematical modeling of distribution and transmission systems and developing computational and forecasting methods
Statistical methods for forecasting of electric load and system reliability, and developing control algorithms for transmission and distribution networks and for demand response. Computer modeling of energy generation and integration, methods of fluid dynamics for simulating and forecasting wind energy production



Microgrid technologies and their integration
Reliability improvements of distribution systems to avoid catastrophic events during weather extremes such as what happened during hurricane Sandy.

Computer science applications to Smart Grid
Technologies to improve visualization capabilities and cyber security.



GREEN COMPUTING

Data Center energy consumption has increased rapidly over the last decade. In the U.S. alone, data centers consumed about 91 Billion kWh in 2013, at a staggering estimated cost of $6.4 Billion. The projected increase in population and rising demand for data centers will only increase these costs further in the years ahead.

The Response: A Smart Energy Technology (SET) cluster to initiate inter-disciplinary research activities at Stony Brook University (SBU) in collaboration with BNL to reduce data center energy consumption. **1)** Cloud Computing workloads, including those hosted by Google, Microsoft, and Amazon, **2)** High Performance Computing (HPC) workloads, such as those deployed by National Labs, including BNL, LBNL, and ORNL.

Analyze the workload profile of HPC Data Centers
Investigate key resource contributors to power consumption and deterrents to performance; leverage existing Power PC-based HPC clusters at BNL as a starting point.

Develop Mathematical Models and Simulation Frameworks
Base on the above analysis to quickly evaluate and optimize various scheduling, placement, and resource management policies aimed at lowering data center energy usage.

Research System Design Solutions
Realize full potential energy savings by leveraging server-level power management solutions, including dynamic voltage and frequency scaling (DVFS), low-power sleep states, and hardware accelerators.

Analyze the aggregate resource demand in and across cloud data centers
Assess the potential for aggressively consolidating dynamically varying workloads without significantly impacting user performance needs.

Develop dynamic capacity management solutions
Base on control theory models to further leverage the short- and long-term variations in demand, resulting in lower server, and subsequent cooling, energy consumption.

Investigate hybrid HPC-Cloud architectures
Cloud computing resources can be used to absorb excess demand from local data hosting and computing environments, including HPC and dedicated application clusters.

SUMMARY AND RECOMMENDATIONS

"Energy Systems for Sustainability" encompasses four topics for engagement to adopt potential solutions and tools and resources needed to implement them.

- Green Power and Fuels Production
- Advanced Energy Storage
- Smart Grid Technologies
- Green Computing

Develop hybrid renewable systems
Traditionally, renewables are single-application focused. Advanced concepts that combine multiple renewable sources could open multiple applications.

Address high-density storage at low cost in large-scale systems
A multi-disciplinary approach to managing heat in confined spaces should be developed.

Boost power management through smart grid
Prioritize solutions to load variability during integration with renewables

Adopt green computing
Pervasive and necessary in energy management. Develop application-specific computing methods with a focus on big data.

Work with local, state and federal agencies to solve specific challenges
New York State is a hot bed for technology development and at the forefront of climate change strategies. Integrate state developed roadmaps to facilitate initiatives.

Think global, act local
Planetary boundaries are strained to a point that global action is needed. New York State could serve as a test bed for advanced technologies scale-up..

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