USING LIGHT TO SOLVE SOCIETAL CHALLENGES

ASU LightWorks®

Arizona State University

ASULightWorks.com

#1 in the U.S. for innovation

#1 ASU #2 Stanford #3 MIT

–U.S. News & World Report

BEST COLLEGES
US News
MOST INNOVATIVE
2017

Since its inception, LightWorks® has provided solutions to the world's most pressing global energy challenges

through a simple idea: energy from sunlight. We discover and invent energy solutions to the world's fuel, electric and social challenges.

ASU LightWorks® envisions a resilient and equitable energy future supported by innovations in technology, policy, law, and markets. We pursue breakthroughs not just to power the world, but to empower it; to enrich people's lives everywhere; to enlighten communities across the globe; to achieve energy security; to secure energy justice, and to inspire future generations.

LightWorks® pulls light-inspired research at Arizona State University under one strategic framework. It is a multidisciplinary effort to leverage ASU's unique strengths, particularly in solar-electric energy, sustainable fuels and products, and energy and society.

LIGHTWORKS® FOCUS AREAS

"The world's energy system is at a crossroads. Current global trends in energy supply and consumption are **patently unsustainable** –environmentally, economically or socially."

IEA WORLD ENERGY OUTLOOK

ASU LightWorks®
Arizona State University

SOLAR ELECTRIC

To achieve sustained growth of solar electricity, the Solar Electric group will increase contribution of solar energy generation, enable systems that are scalable to market, and continue cost and performance improvements.

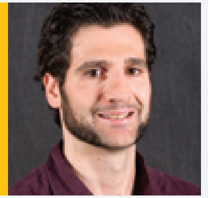
SUSTAINABLE FUELS AND PRODUCTS

Sustainable Fuels and Products is a coordinated, interdisciplinary network of researchers within LightWorks® that addresses high impact opportunities to enable and advance the production of sustainable fuels and products to meet society's grand energy challenges.

ENERGY AND SOCIETY

The Energy and Society group of LightWorks® aims to transition toward a sustainable energy future by employing social and humanistic sciences that address and promote policy and public engagement.

RESEARCH PROFILE



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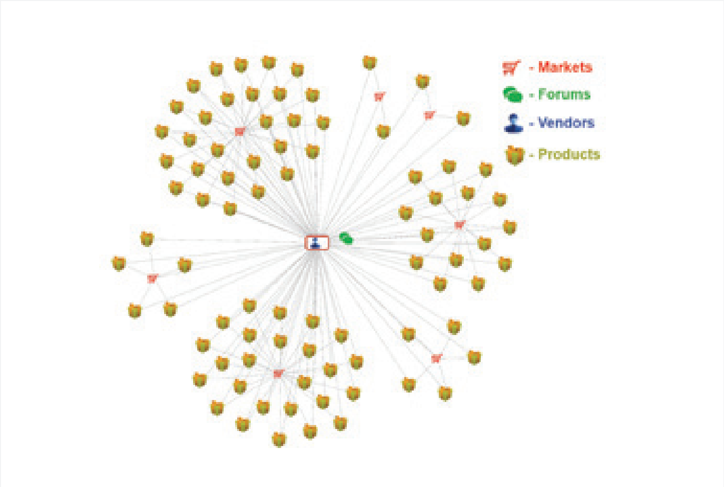
Pro-Active Cyber Threat Intelligence



Visualization of darkweb hacker communities

The increasing dependence of energy infrastructure upon information technology makes such systems susceptible to cyberattacks. In December 2015, such an attack became a reality as a regional electricity distribution point in Kyivoblenergo, Ukraine experienced outages caused by such an attack – that many have linked to the Russian government. We study how hackers can purchase components needed for such cyberattacks through darkweb marketplaces. We extract market information and modeled how such components can be used by an attacker. During the project, we also identified rich data can be gathered from hacker discussions as well. Hacking service advertisements, requests for help, and other conversations can be readily analyzed using a variety of machine learning techniques to understand the intention of these communities.

“During the project, we also identified rich data can be gathered from hacker discussions as well.”

To create effective cyber-defenses, a priority requirement is generating fundamental knowledge about available malware and exploits that affect a given system or group of systems. Concurrently, we need to understand the environment in which malicious hackers interact, both on the darknet (via anonymizing protocols, e.g., TOR) and the open Internet (a.k.a., the “Clearnet”). These environments are a proliferation of forums and marketplaces supporting a wide range of malicious hacker activities.

They are also a critical resource for state and non-state actors to enhance their cyber capabilities. We currently scrape over 200 hacker sites that have significant access controls on a regular basis and provide the information through a web-based portal as well as an API. Significantly, we provide in-depth intelligence on threat actors, the malware and exploits they create, and general understanding of the cyber threat ecosystem.

Profitable Agriculture Through Recovered Energy, Nutrients, and Solids

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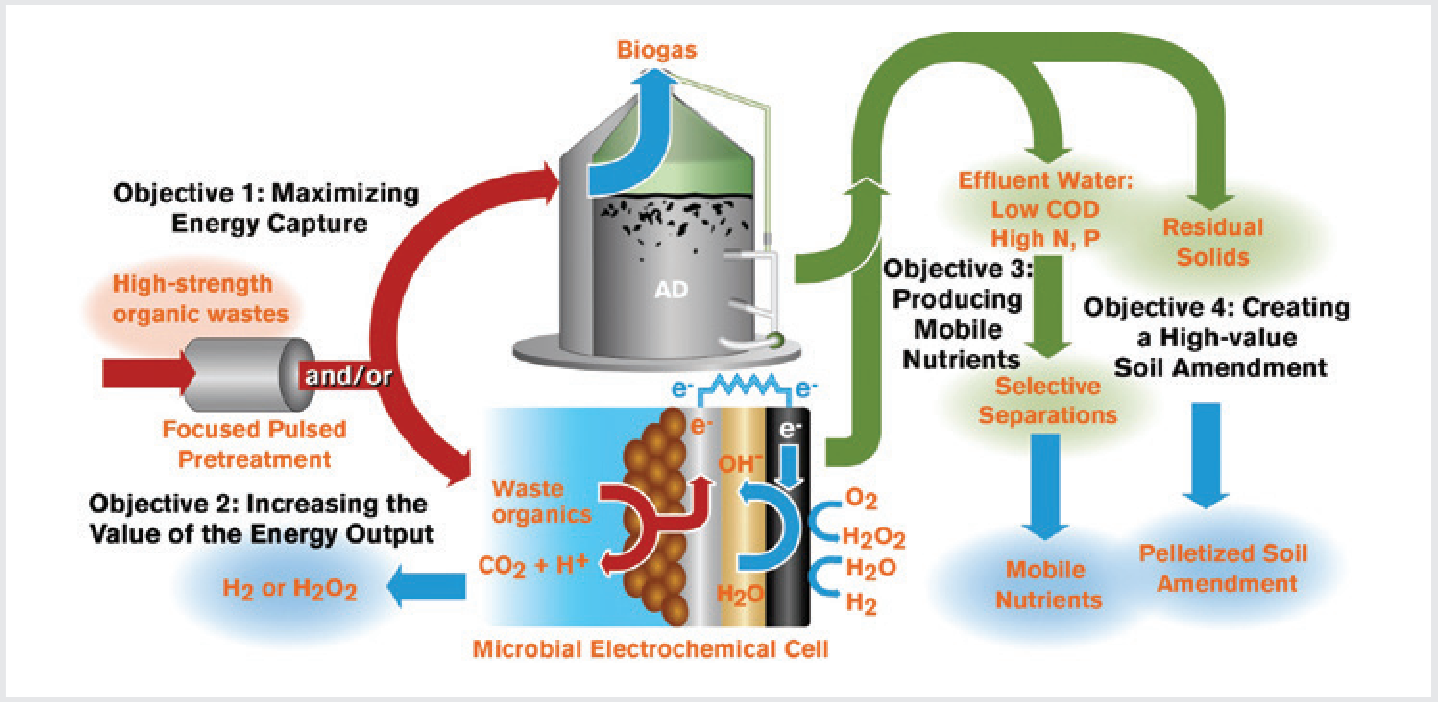
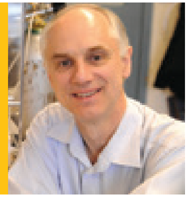
Current organic-waste management in agriculture is an economic and environmental liability. Regulatory risks are associated with handling animal wastes and the loss of nitrogen and phosphorus as water and air pollutants; the low cost of natural gas deters further investment in anaerobic digestion; and high transportation costs preclude using the bulky wastes to improve soil fertility. However, conversion of organic wastes into multiple high-value products can turn liability into profit, leading to improved employment and economic-development in rural areas.

ASU researchers are developing smart, interconnected systems that synergistically produce renewable and high-value energy, fertilizers, and soil amendments from organic wastes. A preliminary techno-economic analysis based on a dairy-farm setting indicates that waste management can be transformed into a significant profit center. The project's outputs will include integrated technologies, financial metrics, and agricultural partnerships.

> **"...conversion of organic wastes into multiple high-value products can turn liability into profit, leading to improved employment and economic-development in rural areas."**



Restoring the Carbon Balance



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Carbon dioxide piles up like garbage in the atmosphere. We will manage this waste by collecting, disposing of, and recycling excess carbon. We will establish in the minds of individuals and institutions the value of cleaning up excess carbon and creating the negative emissions necessary to hold warming below 2°C. We will test and demonstrate—with Arizona State University as the early adopter—small, nimble, affordable, and scalable technologies, market mechanisms, carbon accounting, and policies to balance the Earth's carbon budget. We then will replicate our success on ever-larger scales, with ever-larger institutions, thereby seeding the transition to a circular carbon economy that maintains a stable, safe climate.

An early, fully functional prototype of an air filter module for passive capture of carbon dioxide from air. Modules will be aggregated into large, sail-like structures to collect carbon dioxide from the wind, which could then be recycled or disposed.

Simulating Military Base Vulnerability and Resilience to Extreme Events

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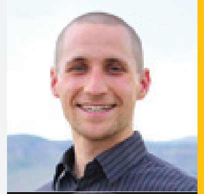

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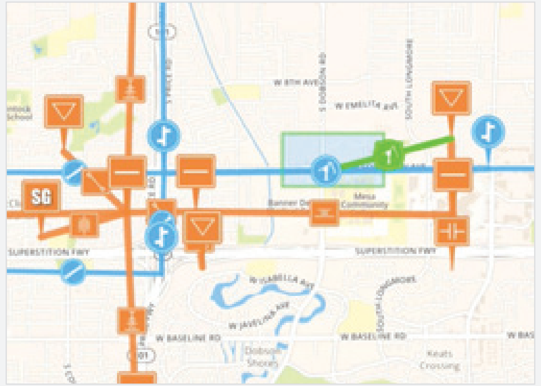

Simulating effects of severe storm on urban power grid.

The prevalence of extreme weather events and anthropogenic attacks are expected to exacerbate conflict and instability. The resilience of military bases to such threats will be critical to providing a source of stability around the globe. Vulnerability can take on many forms including immediate loss of critical resources, shortage of resources, and direct impact to human health. Understanding how such threats create short-term vulnerabilities (e.g., equipment failure) and long-term vulnerabilities (e.g., potable water shortage) can aid the US Navy to plan, deploy, and manage bases in both tactical and relief efforts.

Our work integrates power and water infrastructure modeling into an interactive simulation and training suite known as the Resilient Infrastructure Simulation Environment (RISE). That work supports the identification, adaptive response, and mitigation of cascading failures that result from complex interactions between interdependent infrastructures. RISE can be used for infrastructure planning or for real-time simulation. The proposed work will incorporate extreme events and characterize threats to military bases to permit the US Navy and other DoD branches to design and implement more resilient military bases and procedures. This project expands upon work completed under NSF #1441352 in conjunction with Dr. Thomas Seager, ASU.

Training for Microgrid Developers and Operators

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Microgrid training programs are needed to grow global capacity to address the human resource gap to meet both on-grid and off-grid investments in microgrids that are expected to exceed $40 billion/year by 2024. Our program at Arizona State University is answering this challenge through a global hub-and-spoke model to train 100–200 people in each partner country. A Center of Microgrid Excellence exists at ASU and with each local partner including electric utilities and vocational schools. In our current program, we host an intensive one-week micro-grid boot camp that provides student Veterans, reservists, and active military with experience in designing, modeling, integrating, operating, and maintaining micro-grids. That program is currently being expanded to 200-hours of training. Simulation-based design is coupled with hands-on integration to provide an "all inclusive" approach to micro-grid education. Knowledge gained through simulation is then applied through hands-on training within ASU's micro-grid testbed. Topics include safety, integration, standards, and testing are also included to permit students to evaluate new technologies in the rapidly evolving microgrid market. Original training program developed with support from the Office of Naval Research under the NEPTUNE Program.

Our training program educates students to design, integrate, test, maintain, and safely operate on-grid and off-grid microgrids.

Enhanced Yields of High Energy-Density Liquid Fuels and Co-Products from Waste Carbon

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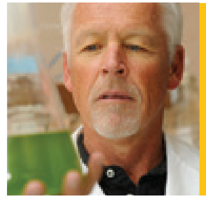
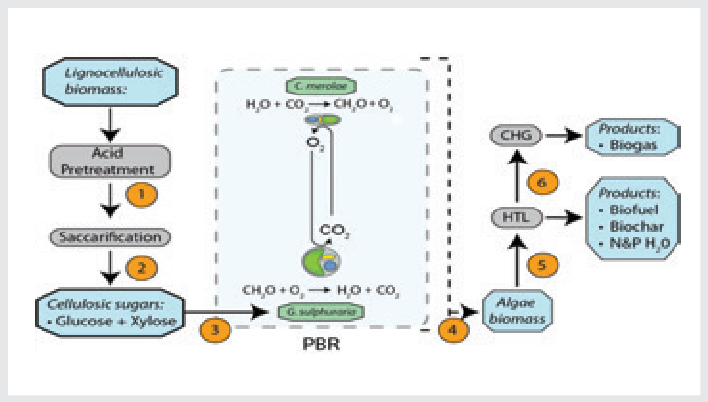


Systems for generating renewable fuels from agricultural waste products will increase U.S. energy independence and create new rural economic development opportunities. Our project goal is to double fuel yields derived from lignocellulosic biomass. The process begins with the conversion of cellulose into sugars (see diagram steps 1 and 2). The sugars are fed into a photobioreactor (PBR, step 3) where two extremophilic microalgae generate and exchange the key metabolic gases, CO_2 and O_2. The xoverall process yields *G. sulphuraria* biomass from cellulosic (bottom equation) to CO_2 plus an equal amount of *C. merolae* biomass from photosynthesis (top equation). The algae biomass is then converted into liquid bio-crude oil and methane gas via hydrothermal liquefaction HTL and catalytic gasification (steps 5 and 6). We plan to genetically enhance *C. merolae* to produce the enzymes required for cellulose breakdown into sugars (step 2) and also to produce high-value biochemical feedstocks to improve overall process economics.



Cellulose-dependent mixotrophic co-culture system for biomass, bio-fuels and bio-products. Our synthetic biology objectives include: a) increases in photosynthetic efficiency, b) synthesis of saccarification enzymes to move step 2 into the PBR and c) transgene-dependent co-product synthesis for higher economic returns.

ENERGY EDUCATION AND ENGAGEMENT

ASU's goal is to prepare society for a transition to a more sustainable future, one that relies more on renewable energy. We are leading the way in this educational transformation by developing new frameworks for understanding energy and its broader societal and environmental contexts.

Through comprehensive education efforts and partnerships in energy change, we are reaching across K-12, high school, special groups, and university settings to meet the future energy challenges. We are preparing tomorrow's leaders for a sustainable future.

Students can pursue a focus in energy policy, human and social dimensions of energy, and energy technology at ASU. Additional course offerings and degree programs are available for undergraduates and graduate students alike. Visit www.asu.edu/programs for more information on what course and degree offerings are available.

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