DRAFT - Business Sensitive

Savannah River

BioEnergy Integration Center

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Savannah River Nuclear Solutions, LLC, Mission Development

Henry Ford really had a better idea.

A century ago, this iconic American farmer/industrialist foretold a future in which automobiles would be fueled with fruit, weeds, sawdust, or anything else that could be fermented. In 1908, his Model T became the world's first flexible-fuel vehicle, designed to run on gasoline, peanut oil, and ethanol.

Contents

The trunk of this 1941 Ford was made from soybeans.

Ford's penchant for integrating the farm with the factory extended beyond fuels. Select body parts on limited production runs of cars made during World War II, for example, were manufactured from soybeans.

Mr. Ford's vision took more than century to materialize at global scale largely because discoveries of huge petroleum reserves kept gasoline and diesel abundant and cheap. As a result, biofuels and "plastics" produced from agricultural products were largely forgotten throughout the latter decades of the 20th century. However, the realization that peak oil is upon us, high oil prices are here to stay, and carbon dioxide (CO2) emissions are causing climate change has rekindled interest in biofuels and bio-derived chemical feedstocks.

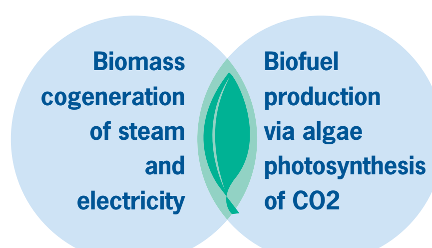
Advances in the technology and economics of biofuel production, along with statutory requirements in the Renewable Fuels Standard and other federal and state legislation, are also triggering significant growth in biofuel production. Between 2005 and 2008, for example, biofuel production in the U.S. increased from 4 billion to 9 billion gallons. The Renewable Fuels Standard will drive demand over 36 billion gallons by 2022.

At the Savannah River Site (SRS), the resurgence of interest in biofuel is evident in the research and development (R&D) portfolio of the Savannah River National Laboratory (SRNL), where biofuels via cellulolysis and bio-photosynthesis are the focus of several ongoing and planned initiatives. SRNL is poised to begin exploring the quantum breakthroughs in energy independence and stewardship of the environment potentially attendant to the integration of biofuel technologies with other clean energy platforms. To this end, SRNL has begun promoting the Savannah River BioEnergy Integration Center.

The BioEnergy Integration Center…

is a sustainable, carbon-neutral energy park platform that couples emerging biofuel technologies with other biomass energy sources to demonstrate, at industrial-scale, the reliability and economics of integrated biological renewables.

Although the BioEnergy Integration Center ultimately will demonstrate a wide range of bio-renewables, its initial focus will be integrating two technologies that are central to the immediate interests of SRNL and the balance of the SRS.

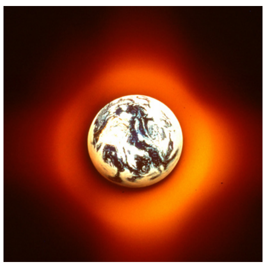


Mission Need for the BioEnergy Integration Center

Three primary drivers underpin the mission need for the Savannah River BioEnergy Integration Center.

Energy Independence

Dependence on foreign oil threatens the energy and economic security of the U.S. The Savannah River BioEnergy Integration Center will reduce this threat by demonstrating the technical readiness and commercial viability of a reliable, economical, and renewable system for the domestic production of electricity, steam, biodiesel and other liquid fuels.



Control of Climate Change

Congress is increasingly aware of the national need to provide impetus to the global effort to combat climate change. The Waxman-Markey and Kerry-Boxer energy bills, as well as President Obama's recent commitments at the United Nations Climate Change Conference in Copenhagen, are evidence of this awareness. The Savannah River BioEnergy Integration Center helps the U.S. exhibit such leadership by accelerating the development of carbon-neutral transportation fuels and other energy products. These technologies will be amenable to replication at hundreds of locations around the world, enabling quick and dramatic reductions in the global carbon footprint.

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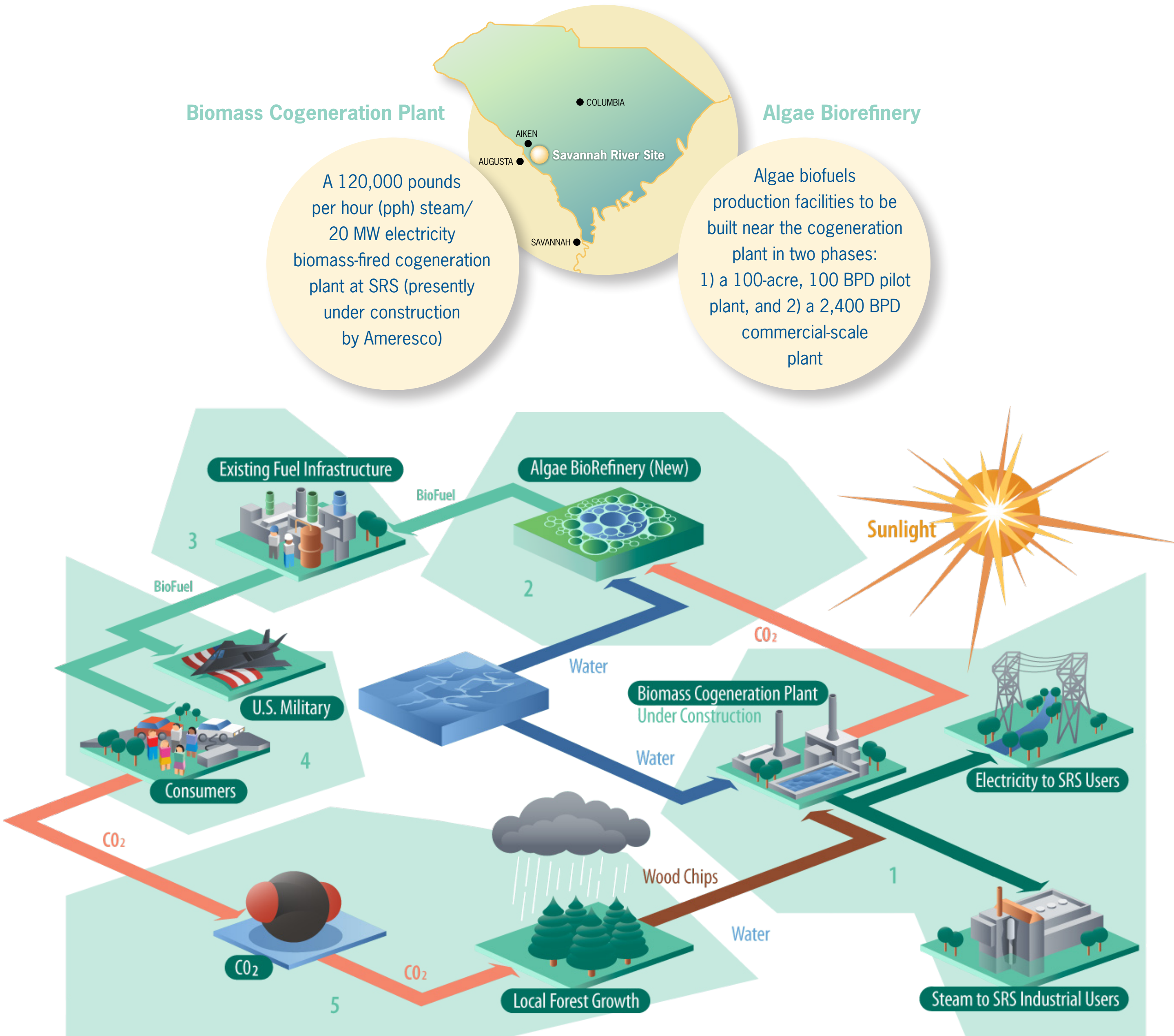
New Missions for SRNL

The sunset of the SRS Environmental Management (EM) mission is on the horizon and SRNL is approaching a tipping point where it will transition from a primary focus on internal missions to external missions. SRNL must explore opportunities to keep its people and facilities engaged in new and enduring missions of national and global importance. The BioEnergy Integration Center is such an opportunity; its biomass focus aligned with the growing competency of SRNL in renewable energy and a natural follow-on to ongoing SRNL work with Clemson University, Renewed World Energies, the South Carolina Biomass Council, and others in the emerging biofuels arena.

"The day is not that far distant when, for every barrel of gasoline, a barrel of alcohol must be substituted."
— Henry Ford, 1916

Overview of the BioEnergy Integration Center

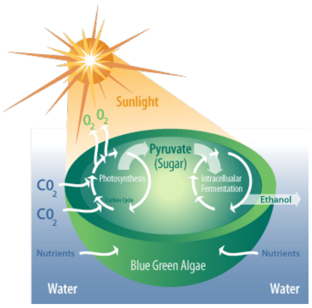
The BioEnergy Integration Center is a test bed for emerging biofuels technologies. Ultimately, it will provide pilot-to-industrial scale demonstration of each of the major processing steps, including feedstock growth and preparation, pre-treatment of raw materials, biomass processing and refining, and final product recovery. The major focus will be on cellulosic ethanol, biodiesel and alcohols from algae, and energy recovery from biomass combustion or gasification. Initially, the Center will demonstrate a carbon-neutral energy cycle using two major facilities to be collocated at SRS.

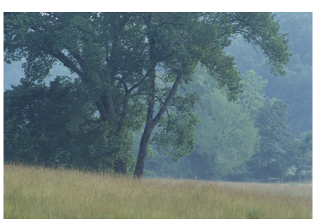


Savannah River BioEnergy Integration Center

Integrated production of carbon-neutral transportation fuel, electricity and steam from sunlight and water

The closed energy cycle involves five unit operations





Unit Operation 1: Biomass Cogeneration Locally-produced biomass is delivered to, and burned in, the cogeneration plant, producing steam and electricity for SRS. Primary fuel is forestry residues that are currently left to rot when timber is harvested.

Unit Operation 2: Biofuel Production Carbon dioxide and waste heat exhausted from the cogeneration plant are captured and recycled to banks of serpentine bioreactors, in which algae are cultivated under tightly-controlled conditions. The algae convert CO2 to sugars, lipids and alcohols via photosynthesis and intracellular fermentation. Mature algae populations are periodically harvested from the bioreactors and processed to recover the lipids and alcohols. These are further processed under controlled conditions to produce biodiesel and other liquid fuels.

Unit Operation 3: Biofuel Distribution The biofuels are delivered to consumers through existing commercial infrastructure (tanks, pipelines, fueling stations). In this respect the biofuels are “drop-in replacement fuels;” their heat of combustion, freeze point, flash point, stability, and other physical properties identical to their conventional counterparts and their use requiring no changes to existing fuel storage and distribution infrastructure.

Unit Operation 4: Biofuel Consumption Biofuels are purchased and consumed in automobiles, aircraft, and other transportation systems, releasing CO2 to the atmosphere

Unit Operation 5: Biomass Regeneration via Photosynthesis of CO2 Trees and other vegetation scavenge CO2 from the atmosphere and convert it through photosynthesis to biomass, which is harvested and fed to the cogeneration plant; thereby closing the carbon fuel cycle.

As noted above, this closed fuel cycle is carbon-neutral—zero net emissions of CO_2. Inputs to the cycle are renewable biomass, sunlight, and water; all of which are abundant at the SRS and many other places around the world. Outputs are sustainable supplies of greenhouse gas (GHG) free steam, electricity, and biofuels; all of which are in high demand locally and globally.

The technologies to be deployed in the BioEnergy Integration Center have a high technology readiness level (TRL). Biomass-fired cogeneration, for example, dates back to the early years of the Industrial Revolution. CO_2 capture has been used for more than 60 years for natural gas purification and food-grade CO_2 production. It is beginning to be used commercially for post-combustion CO_2 capture at coal-fired power plants. Algae biofuels production has been extensively studied at laboratory and pilot-scale over the past few decades and is currently the subject of intensive research programs by both DOE and industry. Biodiesel fuel processing and delivery is commercially practiced using vegetable oils and soybean oil; extension to algae biodiesel is fairly straightforward. Consequently, the R&D SRNL expects to do in the BioEnergy Integration Center will be highly applied; concentrated toward process improvement and optimization. Identification of preferred algae strains and optimization of cultivation/harvesting are the least-developed areas. A highly-focused laboratory development program is planned to select the most suitable algae(s) for initial fuel production. In short, the algae biofuels project is based on well-known, proven technology for a vast majority of the processing steps and the technology for algae growth and harvesting is rapidly developing. The challenge now is to deploy, integrate, and demonstrate the reliability, economics, and environmental benefits of the technologies at a scale that can lead to rapid commercialization.

Expected Outcomes and Benefits

A principal expected outcome of the BioEnergy Integration Center is demonstrating the commercial viability of sustainable, carbon-neutral biofuels production using algae and recycled CO_2 emissions from stationary industrial sources. In doing so, it is expected that the BioEnergy Integration Center will prove the technical and economic feasibility of CO_2 recycling to a broad industrial audience, including operators of coal-fired power plants, cement kilns, and other large stationary sources of CO_2.

Another principal expected outcome is quantifying the Carbon Footprint Compounded Reduction Effect attendant to the industrial-scale integration of renewable energy sources. In this case, the biomass-fired cogeneration plant replaces the existing coal-fired D Area Powerhouse. This fuel substitution reduces the SRS carbon footprint by 100,000 tons of CO_2 annually. The Compounded Reduction Effect is subsequently realized by converting the CO_2 emissions from the cogeneration plant to renewable biofuels via algae photosynthesis, supplanting petroleum-based fuels and, when fully deployed at SRS, another 300,000 tons of net CO_2 emissions annually. The total expected carbon footprint reduction attributable to the fully-deployed algae biofuels component of the BioEnergy Integration Center is, thus, 400,000 tons of CO_2 per year.

The biomass-fired cogeneration plant will replace the existing coal-fired D Area Powerhouse.

Expected Outcomes and Benefits
Algae Biofuels Component at the Savannah River BioEnergy Integration Center

Commercial Viability

- Scalable pilot plant capacity of 100 BPD or 1.3 million GPY
- Plant reliability greater than 90%
- Low capital and O&M costs
- Compatibility with existing fuel storage and delivery systems
- Reliable and economic path to compliance with federal and state Renewable Fuel Standards

Sustainable Energy Independence

- Renewable biofuels from recycled CO_2
  - *1.3 million GPY from pilot plant*
  - *26 million GPY from industrial-scale plant*
- 120,000 pph steam and 20 MW of electricity from renewable biomass
- Stable and market competitive production costs for steam, electricity, and biofuels
- Carbon Footprint Compounded Reduction Effect—400,000 tons CO_2 per year

Local Jobs

- 300 short-term jobs in design and construction
- 125 long-term jobs in O&M
- 250 additional jobs in forestry, agricultural, and other associated local industries

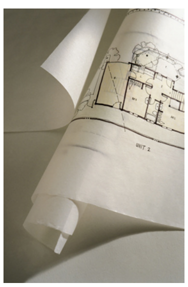
Leveraged SRS Assets

- Integrates with Biomass Cogeneration Facility being built by Ameresco at D Area
- Utilizes existing SRS infrastructure (roads, utilities, etc.)
- Follows on to SRNL algal biofuels research work with Clemson University, South Carolina State University, and Renewed World Energies

Implementation Approach and Timeline

The preferred location for the BioEnergy Integration Center's algae biorefinery is in close proximity to the new cogeneration plant being constructed by Ameresco in D Area at SRS. Given the maturity and commercial potential of the underlying technologies, the BioEnergy Integration Center need not be an exclusively Government endeavor. SRNL leadership, in fact, is pursuing the formation of a public-private partnership, perhaps one led by the SRS Community Reuse Organization, to promote, capitalize, construct, and operate the BioEnergy Integration Center. SRNL recently secured its first industrial partners in the Center—Honeywell and its wholly-owned subsidiary UOP, LLC.

The first major facility in the Center is already in progress. U.S. Secretary of Energy Steven Chu and a Congressional delegation from South Carolina and Georgia broke ground on the new Biomass Cogeneration Facility at SRS on December 1, 2009. The plant is scheduled to begin operations in December 2011. An aggressive approach to capturing and implementing the new mission opportunity afforded by the remainder of the BioEnergy Integration Center is recommended, as follows:



FY 2010

- Initiate R&D aimed at rapidly selecting and characterizing promising algae species for commercial production
- Establish a public-private partnership to promote, capitalize, construct, and operate the BioEnergy Integration Center venture
- Develop NEPA/permitting strategy
- Notify DOE of the partnership's intent to acquire through the transfer process of 10 CFR Part 770 the necessary land to site new facilities
- Pursue seed money for the venture through federal funding, grant, or similar source
- Start engineering design of the algae biofuels pilot plant

FY 2011

- Complete selection of first-generation algae and testing in a photobioreactor
- Complete capitalization of the BioEnergy Integration Center venture with additional Government, private equity, and venture capital
- Complete engineering design of the CO2 capture and algae biofuels pilot plant and start procurement of major equipment

FY 2012

- Complete algae development and identify improved strains
- Construct the CO2 capture and purification system.
- Construct new algae biofuels pilot plant

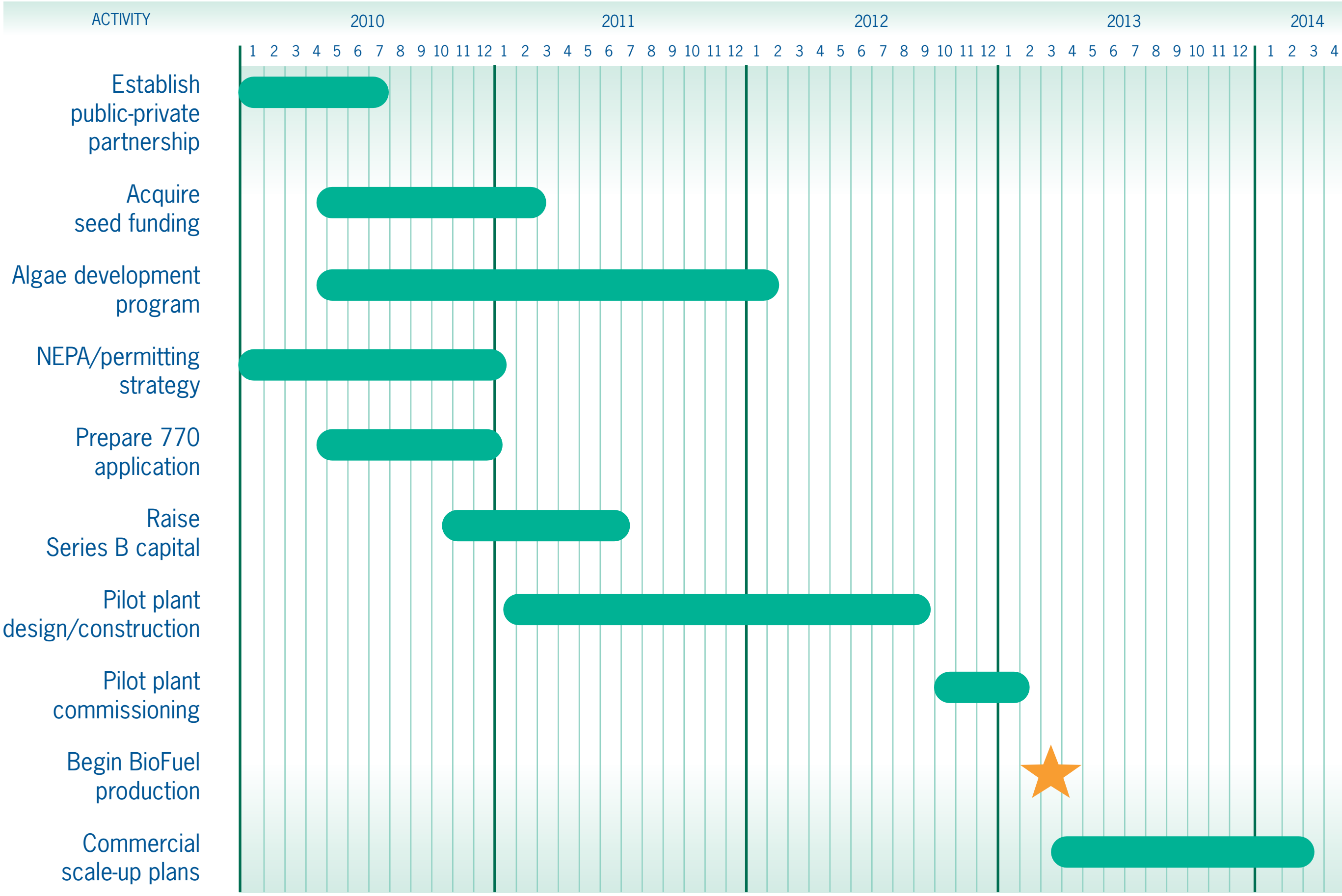
FY 2013

- Commission the CO2 capture system and algae biofuels facilities
- Begin producing biofuels in pilot plant (100 BPD)
- Finalize program of design and construction for commercial scale algae biofuels plant

FY 2014

- Initiate scale-up to commercial capacity (26 million GPY)

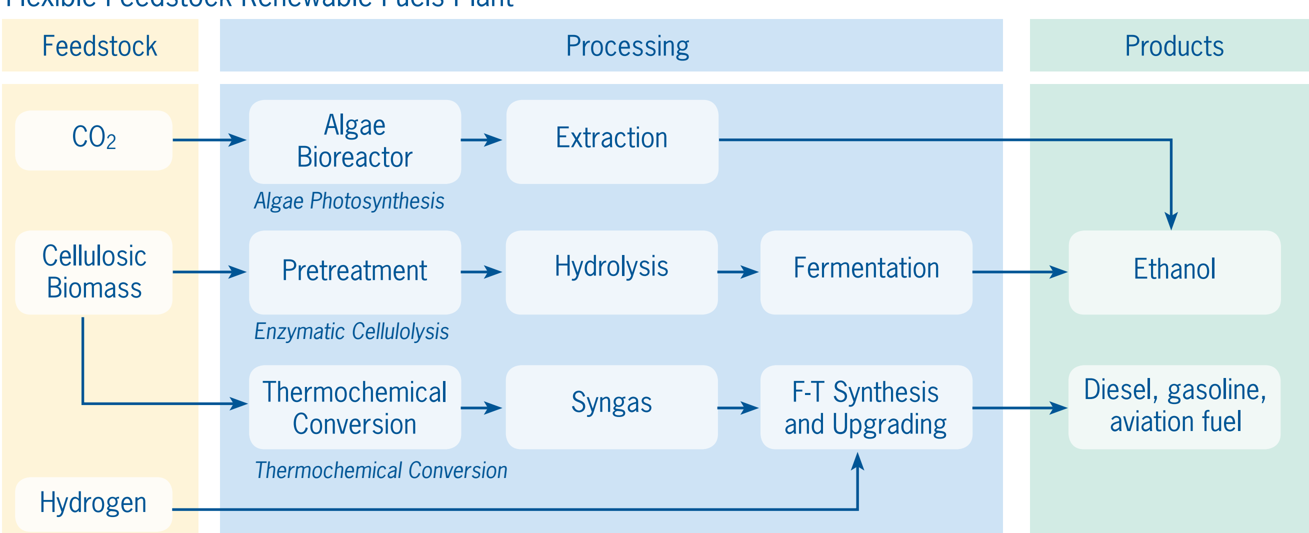
Timeline for capture and implementation



Future Expansion

After completing the start-up of the algae biofuels pilot plant and the design and construction plans for scale-up to commercial operations, SRNL expects to begin diversifying the biofuels production flowsheet. Alternative production processes to be explored include biofuels via enzymatic cellulolysis and thermochemical conversion of switchgrass, sorghum and other locally grown biomass. Ultimately, SRNL envisions the BioEnergy Integration Center maturing into an integrated flexible feedstock renewable fuels plant.

Flexible Feedstock Renewable Fuels Plant



Financial Considerations

The biomass cogeneration facility is already being constructed by Ameresco using third-party financing. No additional funding is required to complete the cogeneration facility. Estimated funding needs for the algae biofuels pilot plant are shown in the table below.

BioEnergy Integration Center Funding Requirements	FY 2010	FY 2011	FY 2012	FY 2013	Total
Establish Public-Private Partnership	0.25				0.25
Algae Development Program	1	3	2		6
Engineering Design	0.75	8			8.75
Procurement, Construction, and Commissioning		5	40	15	60
Total	2	16	42	15	75

Funding needs for future expansion and diversification of the plant will be identified in a separate concept paper(s).

The recommended funding strategy for the algae biofuels pilot plant is to seek a Congressional earmark or other Government funding (DOE, DARPA, USDA, etc.) in an amount of approximately $18 million to establish the public-private partnership and sustain the project through FY 2011. Upon its establishment, the partnership will prepare a prospectus for the BioEnergy Integration Center to facilitate capitalization of the remaining $57 million from private sources.

SRNL has identified a promising opportunity to expand the SRS mission portfolio while helping the U.S. make giant steps toward sustainable energy independence and control of climate change.

This opportunity, the Savannah River BioEnergy Integration Center, is a sustainable, carbon-neutral energy park that couples emerging algae biofuel production technology with biomass cogeneration of steam and electricity to demonstrate, at industrial-scale, the reliability, economics, and carbon footprint compounded reduction effect of integrated biological renewables.

As contemplated by SRNL, the BioEnergy Integration Center can rapidly be expanded to a commercial-scale production facility with outputs of 26 million gallons per year of biofuels, 120,000 pounds per hour of steam, and 20 MW of electricity from recycled CO2 and renewable biomass. Its construction and operation will reduce the carbon footprint by 400,000 tons of CO2 annually.

More importantly, the BioEnergy Integration Center will demonstrate the commercial viability (high reliability and low cost) of integrated biomass renewables. Its design and operation will set the stage for replication throughout the U.S., blazing a path to sustainable national energy independence.

The estimated cost of the BioEnergy Integration Center is $75 million over the first four years. SRNL intends to establish a public-private partnership to fund, design, build, and operate the BioEnergy Integration Center. This partnership will be seeking $18 million in Government seed funding, perhaps through a Congressional earmark. The partnership will fund the balance of the project with private equity.

Algal biofuels…

- Provide a sustainable and affordable alternative source of transportation fuels and chemical feedstocks
- Consume CO2 and slow down climate change
- Do not impact food prices
- Can be sited on non-arable lands
- Require no food-based feedstocks like corn or sugarcane

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A Fluor Daniel Partnership

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