Breakout Session
Report Out
Systems Integration

Len Malczynski, Jake Jacobson, and John Hogan

December 9, 2008

Systems integration definition

- A system is an aggregation of subsystems cooperating so that the system is able to deliver the over-arching functionality.
- Systems integration is bringing together of the component subsystems into one system and ensuring that the subsystems function together as a system.
- System integration involves integrating existing (often disparate) subsystems.
- Integration involves joining the subsystems together by "gluing" their interfaces together.
- System integration is about determining the required "glue".

http://en.wikipedia.org/wiki/System_integration accessed 12/04/08

Barriers to systems integration

- Knowledge and understanding of:
  - – Complexity: number and diversity of subsystems, number of possible paths to fuel production
  - – Uncertainty: state of readiness for each algal biofuel subsystem and interface
  - – System of systems: the algal biofuel system fit into distribution, refining, investment, etc.

Systems Integration summary

Analyzing systems integration as it relates to developing algal biofuels is challenging.

There is uncertainty about producing algal biofuels, including viability in different environments, bringing these types of fuels into commercialization, and the complexity of defining associated processes and systems.

Substantial efforts must be put into understanding the algal biofuel production process and its role in the larger transportation and co-product economy.

Barriers & Goals

Defining systems integration as it relates to algal biofuels

Challenges

- Difficulty aggregating the sub-systems involved with algal biofuels
- Working cooperatively toward the goal of over-arching functionality
- Considering issues of scale and impending difficulties
- Making distinction between systems integration and systems engineering

Strategies

- Determine the cohesive factor among subsystems
- View algal biofuels as a subsystem, which is part of other systems
- Determine the probability with achieving subsystem goals/processes
- Apply future outlook of technology to systems and subsystems
- Develop a database of systems and interfaces
- Monitor progress and establish ways to update systems to reflect dynamic nature of algal biofuels

Barriers & Goals

Essential conditions of success

Challenges

- Determining the critical requirements for algal biofuels production (biological/nutrient requirements, rate of limitations, etc.)
- Mapping the process/systems involved
- Choosing the information needed to establish critical path

Strategies

- Make production plans with respect to co-products, boundaries, and scope
- Standardize production (a successful system will lead to successful plants)
- Map the process/systems based on specific options/choices and by simulating risk

Barriers & Goals

Sustainability of algal biofuel production

Challenges

- Economic feasibility and investment
- Achieving energy security
- Unknowns regarding ability of algae to be produced successfully and thrive, challenges with genetically modified organisms (GMOs)

Strategies

- Conduct life cycle assessments
- Close the loop on inputs and outputs, endogenize the system
- Make use of resources and establish requirements for how resources are used and to what extent
- Establish nutrient balances/requirements
- Develop flexible processes, which allow for regional solutions to produce algal biofuels in different environments, while still maintaining benefits of scale up

Barriers & Goals

Costs/markets for biofuel and co-products

Challenges

- Differentiating products from co-products
- Displacing markets (impacts on other biofuels, food versus fuel issue)
- Effects on competitive fuel producers (petroleum-based fuels)

Strategies

- Integrate use of products and co-products in hopes of creating self-supporting biofuels
- Use economic modeling and relative price analyses to address challenges
- Establish fuel price floors for transportation fuels
- Utilize R&D to reduce production costs and toquantify and manage risk
- Participate in carbon credits/trading

Barriers & Goals

Scale compatibility of algal biofuel production

Challenges

- Newness of algal biofuel production, inability to predict learning
- Geographic and time constraints related to scalability

Strategies

- Implement system changes and make them adaptable to dynamic nature of algal biofuels
- Synchronize sub-systems (sub-systems that should be in place over a specific period of time)

Barriers & Goals

Geographic, temporal, and regulatory constraints

Challenges

- Conceptual and policy barriers
- Regulatory issues tied to sustainable production
- Need for innovation, making algal biofuels a viable alternative
- Time issues associated with production and scale up

Strategies

- Map a systems approach to follow as opposed to challenging barriers individually
- Create a focused and integrated approach
- Take steps toward defining timelines around algal biofuels production

Contentious/Controversial Topics

What is the scope of systems integration for algal biofuel production?

Differing views on this topic included:

- High level view versus focus on the components of an algal biofuel production system
  - Since there is much uncertainty (and therefore need for research) about producing algal biofuel it was felt that systems integration should deal with the role of algal biofuel in the larger transportation and co-products systems. This was preferred instead of integrating the various components of algal biofuel production, i.e. cultivation, harvesting, extraction, etc.
- Linear and static approach versus a systematic approach
  - Time and feedback dependencies and the consequences of algal biofuel production are important to overall systems integration. Static calculations and simple linear production sequences are insufficient for understanding algal biofuel's role in the larger transportation fuels system.

Interfaces

Systems integration topics that should be shared with other breakout groups include:

- Sustainability
- Costs/markets
- Geographic, time, and regulatory constraints
- Product Intermediates (biomass format: liquid – solid)
- Storage options throughout the supply system

Recommendations

Recommendations and priorities discussed in the session:

Establish demonstration-scale plants for algal biofuels production.

- To validate technology and costs
- To provide guidance on future research, decision-making, and areas for improvement
- To help establish an industry trajectory to a commercialization tipping point
- To enable Integrated/modular testing

Create an “Apollo” project for alternative fuels; an organized effort and funding for creating viable production.

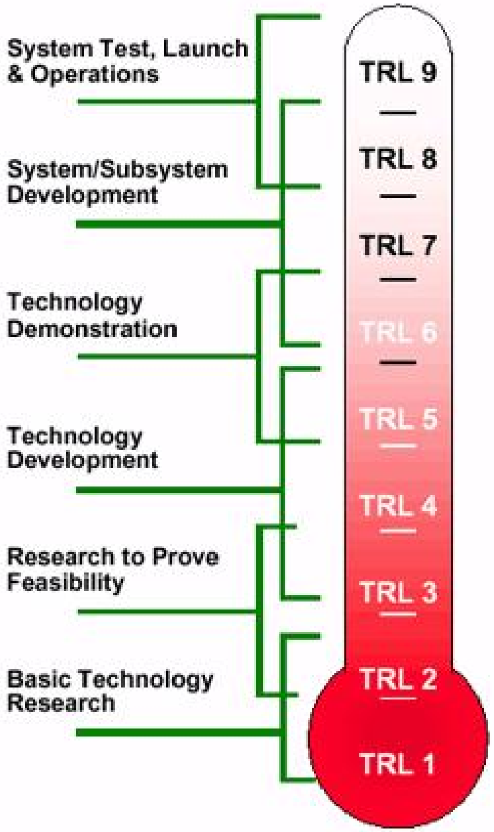
Expand funding and proportional support for basic science.

Gain political support of alternative fuels in pursuit of energy security.

Use recommendations to create a platform to address issues of sustainability, costs/markets, constraints, and externalities.

Systems integration tools: Technology Rediness Level

- Technology Readiness Level (TRL) is a measure used to assess the maturity of evolving technologies (materials, components, devices, etc.) prior to incorporating that technology into a system or subsystem.
- Generally speaking, when a new technology is first invented or conceptualized, it is not suitable for immediate application. Instead, new technologies are usually subjected to experimentation, refinement, and increasingly realistic testing.
- Once the technology is sufficiently proven, it can be incorporated into a system/subsystem.



http://en.wikipedia.org/wiki/Technology_Readiness_Level accessed 12/04/08

Systems integration tools: Learning or Experience curves

- The **learning curve effect** and the closely related **experience curve effect** express the relationship between experience and efficiency. As individuals and/or organizations get more experienced at a task, they usually become more efficient at it. These effects are often expressed graphically. The curve is plotted with cumulative units produced on the horizontal axis and unit cost on the vertical axis. A curve that depicts a 15% cost reduction for every doubling of output is called an “85% experience curve”, indicating that unit costs drop to 85% of their original level.
- Mathematically the experience curve is described by a power law function sometimes referred to as **Henderson's Law**:

$$C_n = C_1 n^{-a}$$

where

C_1 is the cost of the first unit of production

C_n is the cost of the *n*th unit of production

n is the cumulative volume of production

a is the elasticity of cost with regard to output

http://en.wikipedia.org/wiki/Experience_curve_effects accessed 12-04-08

Systems integration tools: System dynamics modeling

- A system dynamics model should have the following characteristics[1]:
  - Be able to describe any statement of cause-effect relationships that we may wish to include.
  - Be simple in mathematical nature.
  - Be closely synonymous in nomenclature to industrial, economic and social terminology.
  - Be extendable to large numbers of variables (thousands) without exceeding the practical limits of desktop computers, and
  - Be able to handle "continuous" interactions in the sense that any artificial discontinuities introduced by solution-time intervals will not affect the results. It should, however, be able to generate discontinuous changes in decisions when these are needed.

[1] From Jay W. Forrester, Industrial Dynamics, 1961