

How to Modify the BSM for New Analyses

This document compiles tips from doctoral candidates who have modified the BSM for their own analyses.

Part 1. Getting started

1. **Develop a mental model:** Experience in system dynamic modeling is not required to learn about the BSM. However, it is helpful to have a mental model of the biomass-to-biofuels system that includes interconnections within the biofuels supply chain stages, system boundaries (identifying exogenous vs. endogenous factors), and distinctions between cause and effect.
2. **Understand the general context of the BSM:** This paper is recommended reading: “An Overview of the Biomass Scenario Model” (<http://www.nrel.gov/docs/fy15osti/60172.pdf>, Peterson et al. 2013). Other NREL papers on more specific topics explain additional details in the BSM.
3. **Be familiar with STELLA software:**
 - The fundamental concepts of the systems dynamics are introduced in the screencast (<http://github.com/NREL/bsm-public/guidance/screencasts>).
 - It is necessary to become familiar with the STELLA platform, including icons, functions, etc.
 - Detailed explanations and tutorials are documented on the isee systems website (<https://www.iseesystems.com/resources/help/v1-4/default.htm>).
 - ➔ E.g. The definition and behavior of the basic STELLA model components such as stock/conveyor/ flow/array are searchable through the search box in STELLA website.
4. **Explore the BSM hands-on:** The complexity of the model can be overwhelming at first sight. An initial approach to enable users to better understand the model logic and data sources could be:
 - a. Read the BSM publications related to your topic. Please see https://openei.org/wiki/File:BSM_Analysis_Questions.pdf (recent publications with key) or https://www.zotero.org/groups/209264/bsm_publications/items (all)
 - b. Understand the interconnections of the main modules.
 - c. Select and focus on the modules of your interest.
 - d. Navigate through the modules, using the documentation tab in STELLA to view details about items (converter, flow, stock) as necessary.
 - i. Identify the sub-modules.
 - ii. Understand the input and output variables.
 - iii. Follow flows and stocks.
 - iv. Find the main interconnections.
 - e. Reference the “Searchable Definitions” Excel file as a searchable source of the documentation data that also groups inputs for scenario design.

Part 2. Learning from previous work

1. **Replicate previous work:** As with any new model, an important early exercise is to replicate BSM results. One can then make modifications to get a better understanding of key drivers in the model.
 - BSM GitHub (<https://github.com/NREL/bsm-public/tests/studies>) provides an example: Potential Avenues for Significant Biofuels Penetration in the U.S. Aviation Market (Emily et al 2017)
2. **Review scenario designs:** The list of previously explored analysis questions and the groups of variables for scenario design in the searchable definitions document provide a starting point for

replicating other scenarios. Please see https://openei.org/wiki/File:BSM_Analysis_Questions.pdf and <http://github.com/NREL/bsm-public/guidance>.

Part 3. Developing your own model

1. **Identify your own research questions** that can be evaluated by using the BSM.
2. **Develop a hypothetical mechanism** or mental model of system behavior. Use this to generate hypotheses about system behavior and results that would address your research question. (e.g. Module to focus, Input changes -> price changes -> Maturity change -> NPV change -> Investment attractiveness change -> Plant allocation change -> Total production level change)
3. **Trace the mechanism in the BSM**
 - a. Identify the parts of the BSM that are involved
 - i. Submodules and variables (What needs to be modified or added?)
 - ii. Data (Does the input format need to be revised?)
 - b. Identify logic in other submodules that might be replicated to help meet your goal
 - c. Note questions as they arise (e.g. parts of the hypothetical mechanism that are missing, linkages that are unclear, data and assumptions to revisit)
4. **Propose a method to answer the question**
 - a. While exploring the BSM, one can identify whether the question can be answered by changing input data or would require structural modification of the BSM.
 - b. For structural modifications, write a document that follows a logical sequence to achieve the goal. Consider including screenshots to show the model, key equations, array dimensions, and units. This document will be useful to clarify ideas and understand the module logic before making modifications to the model.
5. **Refine the method**
 - a. Ask for a second opinion of your plan
 - b. Consider making a toy model and examining if its behavior is useful. If the toy model seems to work reasonably, then it can be implemented in the BSM.
6. **Implement the method**
 - a. In making changes, document all changes and the rationale for the changes.
 - b. Create a separate version of the BSM.
 - c. Do the modifications needed, check arrays, check units, check equations.
 - d. Create input sheets. Avoid continuous data changes inside the model, as these can be harder to track.
 - e. Run the model.
 - f. Validate the model.
 - i. Iteratively examine the result of the modified model.
 - ii. Check the behavior and results against the hypothesis.
 - g. Check the main variables, conveyor, and stocks; verify whether the results make sense. You can do this using Stella (view results, graphics and tables) or you can create tables and copy the results to Excel or other visualization for graphics and comparisons.
 - h. Make sure that you can explain the system behavior and its causes and effects in a logical way.

Part 4. Presenting results

As you review, analyze, and present final results, document limitations, caveats, and uncertainties, possibly by including sensitivity analyses. See <http://www.nrel.gov/docs/fy17osti/68438.pdf>.