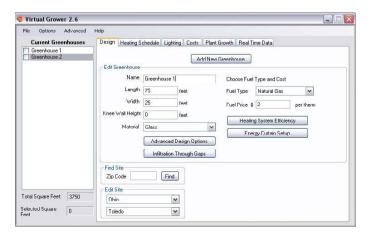# Virtual Grower: Software to Calculate Heating Costs of Greenhouse Production in the United States

Greenhouses are used in many climates for season extension or year-round production and can be expensive to heat. Greenhouse users and growers are often faced with management decisions that rely on an understanding of how temperature settings, heating systems, fuel types, and construction decisions influence overall heating costs. A computer program called Virtual Grower was created to easily calculate heating costs at many U.S. sites by taking into account these factors over full cropping seasons.

Users input design characteristics such as greenhouse building material and construction style, type of heating system, and heating schedule (Figure 1 and Figure 2). Virtual Grower compiles the user input with a database of typical hourly temperature, light, and wind information of 230 sites from the National Renewable Energy Laboratory to predict heating costs based on typical weather for the selected location.

The Virtual Grower model has been field-validated by comparing results of energy audits with model results at some locations in the United States. In general, these case studies illustrate that when full seasons or years are simulated, predictions have been found to be within 12% of actual costs with greenhouses maintained at fairly consistent temperatures and heating schedules. Greater variation in results have been found for case studies of shorter time frames (2 weeks to 1 month), indicating Virtual Grower is most useful for comparative analysis of efficiency improvements features over multiple seasons and to derive baseline operational characterizations.

Virtual Grower can serve as a platform from which many other features can be added, such as plant growth and scheduling. Continued development will improve the software and allow users to perform baseline analysis of their heating costs, identify areas in their production to improve efficiency, and take some of the guesswork out of energy analysis in unique greenhouses. Virtual Grower software can be downloaded for free from the internet at www.virtualgrower.net.
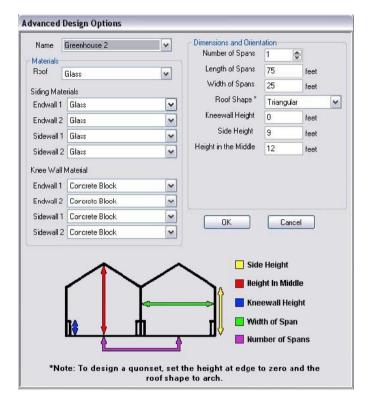

Figure 2. Advanced design options window in Virtual Grower, version 2.5. From this screen, a user can describe their greenhouse design and materials in detail, tailoring each wall to match their existing or planned structure. The diagram of the greenhouse at the bottom changes depending on the overall style of greenhouse that is selected.

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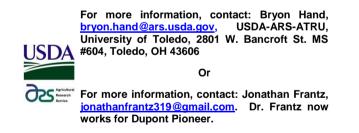
Figure 1. When a user begins using Virtual Grower software, this is the main design page and opening screen. The "Add New Greenhouse" button populates the middle of the window with values for greenhouse name, length, width, knee wall height, materials, fuel types, infiltration, and heating system efficiency. Additional areas of Virtual Grower are accessible through the tabs at the top of the screen.