**Enoch, H.Z. 1977. A theory for optimalization of primary production in protected cultivation:
II. Primary plant production under different outdoor light conditions. Contr. No. 277-E, 1977 series, The Volcani Center, Bet-Dagan, Israel, 45-57.**

Net photosynthesis of a C_3 plant (spray carnation) grown in greenhouses with different light transmissivities was calculated for 4 locations representing 60, 50, 40 and 30° north latitude. The monthly and yearly primary production rates were influenced mainly by the outdoor global solar radiation, the greenhouse transmissivity and CO_2 concentration. Temperature influenced production to a minor degree.

In a greenhouse with 80% light transmission, at 330 ppm CO_2, there was a 17% increase in photosynthesis at 50°N lat. compared to 60°, whereas the rate was 40% higher at 40° compared to 50° with 30° (Jerusalem) almost double that at 40°N. Latitude. If the CO_2 concentration was increased twice 330 ppm, the benefit was greater the further south the location. However, the higher the solar radiation and the higher the outside temperature, the shorter the CO_2 enrichment time. If improvements in greenhouse transmissivity could be achieved above 80%, the primary production would increase about 1% for each percentage unit of additional transmissivity. The importance of clean roofs was emphasized by the fact that a greenhouse with 60% transmissivity at 40°N. latitude had the same productivity as one obtainable in a house with 80% at 50° N. latitude.

The purpose of energy minimization is to be able to deliver the plant product to the consumer with the smallest energy input per pound of plant yield. The author formulates 3 approaches:

Spatial solution: Transport:
First approach is to grow the greenhouse crop at a location where the productivity is higher and to transport the yield to the consumer. The calculated results indicate that it is good energy economy to transport the products by ship and rail northwards in all seasons of the year, however, air transport is uneconomical in the summer, although worthwhile in the winter.

Temporal solution: Storage:
The second approach is to store the products part of the year. Assuming as above that energy input per area is almost independent of yield, energy use per pound of yield is dependent upon yield. It does not appear economical to obtain a yield in mid-winter at 30° N. and market it during the summer months at 60° N. It is good energy economy to produce in the summer and store for winter use. With some product such as carnation cuttings, which can be produced as well in Jerusalem as in Bergen, Norway, one can question whether it is better energy economy to produce carnation cuttings in June in Jerusalem, or in Bergen in mid-July, assuming the cuttings are needed in Bergen by December 1. It may be economical to ship the carnations by ship but not by air, however, cooling may be required.

Technical solution: Climate control:
The third solution for decreasing energy input per pound of yield is to modify the greenhouse climate. Energy costs, however, increase the further one goes north. Such imputs follow the law of diminishing returns, and the energy input per pound yield eventually increases. The calculations showed that there was a considerable benefit from adding CO_2 at Bergen (60° N.), but only a minor advantage in adding light. At 30° N. (Jerusalem) the effect of environmental modification differs from that obtainable at 60° N. In Jerusalem, adding CO_2 increases energy efficiency, whereas additional units of light decrease energy efficiency. A small temperature increase at 30° N. is good energy economy, whereas the same increase during the summer is not useful. It would be an advantage to reduce the summer temperature in Mediterranean climates.