IV. GREENHOUSES AND SOLAR COLD FRAMES

There is much to be said, in a northern climate, for the use of greenhouses in order to lengthen the growing season, both in the spring and in the fall. Any consideration of the utilization of rooftop wastelands for food production is bound to consider techniques for the intensification of plants growth, such techniques are hydroponics (see Chapter V) and the use of greenhouses.

The problems of constructing *large* greenhouses on rooftops has already been discussed in Chapter II, and we have restricted our activities to building small greenhouses (3) and Solar Cold Frames (10).

a) Windowframe Greenhouse

The most "primitive" of the small greenhouses is built out of used materials, in this case, discarded greenhouse frames. The design follows the traditional gable form and dimensions are determined by the glass frames available. The plan area is 1.8m x 2.7m, and the roof peak is 2.4m high. All glazing is simple pane glass except for the "left-over" triangular areas at each end which are filled by wooden frames with polyethylene film. A part of each triangular section is hinged to allow for ventilation.

This greenhouse is located adjacent to a plumbing vent, which, during the winter is a source of significant heat loss. This heat is chanelled into the greenhouse via an air duct and will provide some night-time protection against frost. Plants are grown in containers set on the floor.

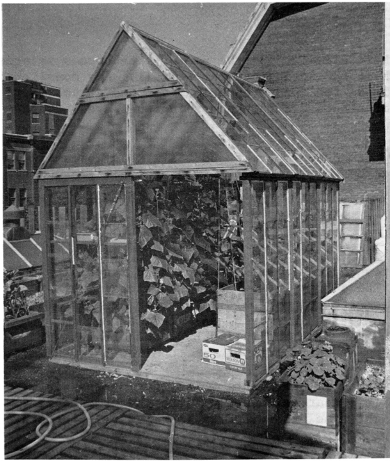
The cost of this greenhouse is extremely low, and covers only such items as hardware, plastic and paint.

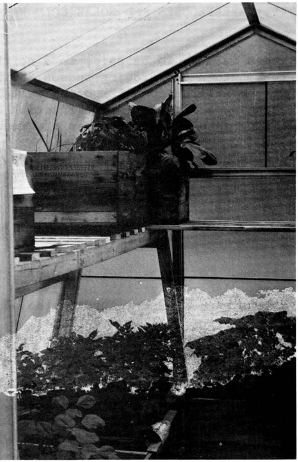
Early season minimum daily temperatures inside this structure were significantly above those inside the other two greenhouses, even though no supplemental heating was used in either structure at that time. The reasons for this are not obvious, though it is possible that a single layer of glass has better overall radiation transmission characteristics than the fibreglass and polyethylene used in the other two greenhouses.

b) Do-It-Yourself Dome

Domes have often been proposed for greenhouses structures, and in fact a number of companies do exist which market domestic dome-greenhouses. The advantage is the minimum structural materials required and high snow-carrying capacity, compared to traditional gable greenhouse forms. However the consensus of opinion, based on our experience, is that the *space* of a dome greenhouse is difficult to use effectively and *comfortably*. Compared to the rectangular plan, which allows for a narrow aisle and planting on either side, the circular plan of the dome is not easy to arrange, and finally does not lend itself, in our opinion, to convenient gardening.

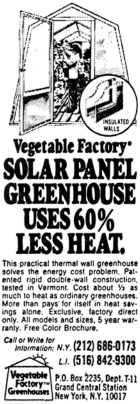
This particular dome is a 3-frequency geodesic. The triangles are prefabricated in the shop, from 2 x 3's, angle nipped on a table saw. These are connected by thin plywood gassats into trinagles and staple-covered with vinyl, more expensive but more durable than polyethylene. Vinyl is also advantageous in that it is transparent. The light triangular panels are easily and quickly erected on the roof by being bolted together through pre-drilled holes. The total material cost was sixty dollars.





Windowframe greenhouse

Vegetable Factory Interior



Do-it-yourself dome

The Dome Greenhouse, if awkward to use, does have some redeeming qualities. It is an extremely lightweight structure that weighs less than 50 kg. This compares dramatically with the Windowframe Greenhouse which weight about 250 kg, or even the Vegetable Factory (see Chapter VI c) which weighs about 100 kg. This question of weight is not without importance on a roof, not only for roof load but also for the work required to bring materials up to the "site".

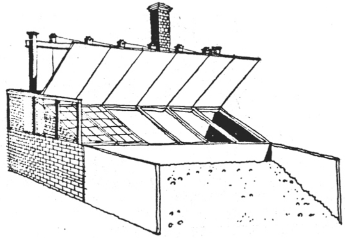
c) Vegetable Factory

This small (2.4 m X 2.4 m) commercially produced pre-frabricated greenhouse is especially marketted for the urban gardener, and hence its optimistic name. It is by far the most sophisticated of the three structures, uses the most durable materials (aluminum and fibreglass), and is the only one that could be used on a year-round basis, if desired. It can be provided with heaters and fans, both automated for the urban dweller. The cost of the structure alone is $799.00.

Although less attractive than glass, and more expensive than plastic, fibreglass is probably the ideal material for rooftop greenhouses due to its light weight and strength. The latter is an important point when one considers not only vandalism but also public safety (i.e. falling greenhouses). Rooftop greenhouses should be, firstly, built out of durable materials to maximize the effort required in moving materials up to a roof, and secondly, be portable and demountable, particularly for urban tenants who should be able to "take their greenhouse with them".

d) Solar Cold Frames

What is the alternative to small greenhouses for larger, more efficient growing areas if large greenhouses cannot be built? We felt that large glass-houses could be built if they were low enough, and this meant greenhouses scaled to plants and allowing minimal access to people. The answer is a modified hot-bed, or what we call the Solar Cold Frame.



"By the beginning of the 18th century, the Dutch had already developed forcing frames with sloped glass roofs, producing oranges, pineapples and grapes. The sloped-front forcing-frame was engineered to control the environment. The back wall was always masonry that would absorb the sun's rays and retain the warmth into the night....The front south wall was constructed entirely of glass set in wooden frames, with hinges on the sides or the top."

from "The Glass House"
by John Hix, Phaidon 1974

The underlying principles of the Solar Cold Frame are: south orientation, opaque and insulated north reflecting wall, removable glazing, and rear access for cultivation. In total, 10 of these structures were installed: six units containing approximately 3 square metres of growing area each were placed along the outer wall and four larger units, of approximately 7 square metres each were located above and interior beam.

During the cooler seasons, these beds are covered with roof frames designed around the concept of the north reflecting wall greenhouse, a traditional Dutch design dating from the eighteenth century, and adapted to the Montréal latitude. Since height considerations were limiting, the peak angle was maintained at 90^{o}. All the structures were aligned with their major axes east-west. The north sloping roof section of each was insulated with a sandwich panel containing two-inch thick polystyrene insulation. East and west end wall sections, as well as all sides and floors of the soil boxes are similarly insulated. All interior exposed surfaces are covered with a glossy white paint in order to reflect incident solar radiation onto the plant canopy and soil. The roof frames are removeable so that during late spring, summer and early fall months, the beds can be converted to open air gardens. This operation eliminates any need for cooling or ventilating interior spaces during these hotter months.

The south sloping transparent coveres are made of different materials in order to do comparative testing. Glazing on the four large frames is discarded greenhouse glass panels, single layer only, with staple-on plastic sheeting, an interior option for winter operation. Five the the smaller cold frames are covered with "Coroplast", a copolymer corrugated, fluted plastic sheet. This material is very lightweight, flexible and is almost as effective an insulator to longwave radiation as two layers of glass. Current research is underway both at the Rooftop Garden Project and elsewhere, to determine the longterm feasibility of utilizing this plastic material as a glazing for greenhouses. The sixth small cold frame is covered with three layers of "Solar Membrane", another copolymer plastic. Each layer of this plastic permits passage of more solar radiation than glass, yet reduces longwage re-radiation by 50% when compared with glass.

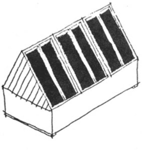
All the glazings used have proven quite satisfactory to date. The test period has not been long enough to enable quantitative evaluation of the different transparent covers. Such tests are being pursued both at the Brace Research Institute and the Department of Phytologie, Université Laval. All of the cover systems have withstood one complete growing season with no apparent deterioration in radiation transmission characteristics and no noticeable structural failures.

Ventilation of all hot/cold frames is either by opening the sloping window surfaces, which are hinged for this purpose, or by opening the rear access port, in the case of the larger structures.

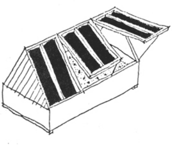
Irrigation is manual, either by using an external hose or watering can, and drainage is through drainholes pierced in the bottom of the soil container at regular intervals. Heat losses through the transparent covers have been inhibited in one unit only by the use of moveable insulation panels.

Three of the larger units have been fitted with a heating system which uses waste heat, normally escaping up the chimney. In this system, a heat exchanger is placed at the point where the hot gases first enter the vertical chimney section. A circulating glycol solution is heated by the rising gases and pumped up to the roof whence it is fed in parallel into the three hot beds. In each structure the glycol solution passes in succession through a finned air heat exchanger, a heating coil embeded 25 cm deep in the soil, and a second finned air heat exchanger. No storage of hot glycol solution is used, however, considerable heat sorage is inherent in the system in the form of the heated soil, The glycol is used as a working fluid instead of water in order to eliminate the danger of freezing in the transfer pipes. The circuit diagram for the heating system is shown, and the photos illustrate various features of the installation.

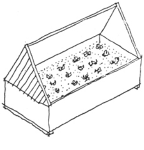
This heating system has been installed in conjunction with S.Albert and Sons, a



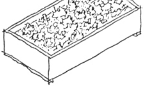
Winter



Fall & Spring



Early Summer



Summer

Montréal based heating fuel distributor. Their input has been to design the heat exchanger for the chimney as well as much of the heating system for the hot bed interiors. In addition, they have underwritten part of the costs of installation of this experimental heating system.

A number of unfortunate circumstances delayed the installation of this waste heat extraction system. Nevertheless, this system has now been installed and experimental evaluation of its effectiveness will be undertaken during the fall months of 1976. A report on the conclusions and experiences with this heating system will be submitted to the Scientific Authority on termination of the experimental program.

The six smaller cold frames have roof sections which, instead of being completely removed for summer operation, can be slid back two feet to the north of their winter positions and temporarily fixed in place. This operation serves two purposes in addition to eliminating the need to cool interior spaces. First it allows a greater exposure of the plants in the box section to solar and sky radiation during the summer months, and second the roof sections, in their summer positions, serve as security fence for this area of the roof.

During the colder seasons, entry into the larger hot beds, in order to tend plants, is through the rear insulated roof section. The opening can be closed behind the gardener to eliminate excessive heat losses. Depressed areas have been left inside each of these hot beds in order to allow the gardener sufficient head room to work, albeit in a kneeling position.

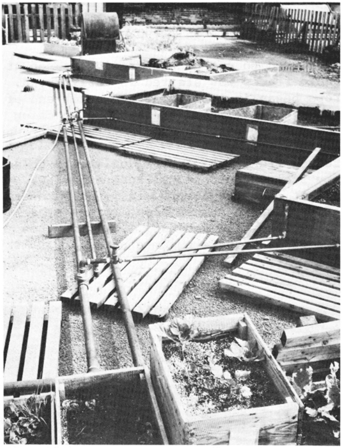
The material costs for these cold frames and hot beds range from $90.00 to $170.00 not including heating systems, nor moveable insulation panels. Various aspects of the cold frames and hot beds are illustrated in the accompanying photographs.

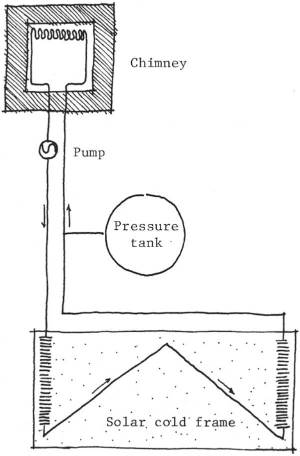
To date these structures have been used as cold frames in the traditional sense of obtaining an early start on the growing season. They have also served to extend this growing season well into the fall months. In addition, with their roof sections removed, they become open growing boxes in mid-season. The adapted roof and transparent covering systems tend to act somewhat as heat traps, allowing a significant amount of solar and sky radiation to enter, but reducing thermal radiation losses. As well, the insulated soil sections tend to store much of the heat they acquire and to release it slowly so that a thermal intertia effect reduces extreme temperature fluctuations in the soil. Because of the improved heat retention characterictics of these cold frames, when compared with the traditional cold frame structure, they have, at least in a partial sense, been acting as hot beds. In addition, due to the mechanism of supporting these structures on the roof membrame, the heat that normally escapes through the main building roof tends to pass into the soil first. Although this is not a significant source of heat for the soil, it does tend to cut down on bottom heat losses.

e) Some Operational Aspects

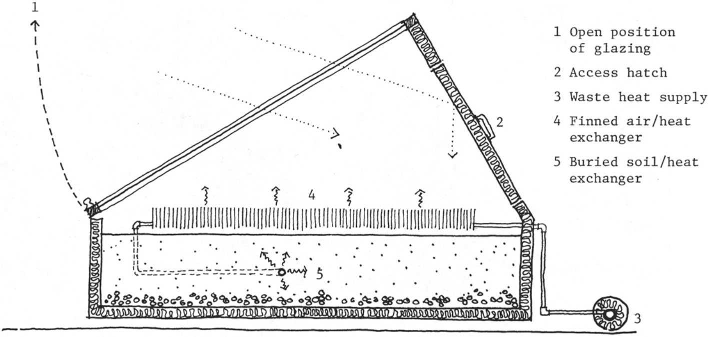
The growing areas provided in each cold frame offer a large enough surface for fairly intensive, individualized gardens. A number of traditional gardening techniques, such as companion planting and intercropping can be used to advantage in these larger growing containers because there is not the competition for space so evident in the smaller boxes.

The soil depth is approximately 30 cm, adequate for growing most vegetable crops. During the season when the roof structures are not in place, there is no limitation to the height of plants that can be grown in these containers. However, when the roof





SCHEMATIC OF WASTE HEAT RECOVERY AND SOLAR COLD FRAME HEATING SYSTEM



SOLAR COLD FRAME SECTION SHOWING HEATING SYSTEMS is installed there is very limited headroom along the south edge due to the low angle of the transparent cover section. A narrower strip along the north inclined insulated wall also has restricted room above it for plant growth. It is important to bear these limitations in mind when planning crop layout.

These Solar Cold Frames have been effectively used to extend the growing season at both ends. Growth in one of the unheated cold frames was started in early March. Harvesting of radishes and some lettuce crops began in April. At the other end of the season, during the first year of operation, very limited vegetable production was still underway in early December in a cold frame with no supplemental heat supply.

The use of moveable insulation panels to reduce front heat losses during the colder months has not proven to be too satisfactory from an operational point of view. Although the idea is technically sound the fact that the covers are manually operated requires someone to be available as soon after sunrise and as close to sunset as possible, particularly between the months of October and February. Only in this way can the plants inside be assured of receiving adequate amounts of solar and sky radiation during the season of low solar intensity.