Title:	Cucumber: To determine the feasibility of establishing an up to date development and technology transfer facility for the cucumber industry.
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Keywords:	Cucumber, technology transfer, supplementary lighting, energy, thermal screens, hanging gutters, computerised environmental control system

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PROJECT SUMMARY

This study has examined the feasibility of establishing a "State of the Art Development and Technology Transfer Unit" for the cucumber industry and subsequently operating it over a four year period to evaluate new technologies that are becoming available to growers. The aim will be to grow year round cucumbers efficiently, thus maximising production per units of energy and labour used. This will help to provide the uninterrupted supplies of good quality produce that are increasingly being demanded by retail customers and thereby provide opportunities for import substitution.

A suitable modern glasshouse has been identified at Stockbridge Technology Centre Ltd, Cawood, North Yorkshire. Both the glasshouse and the site meet criteria specified by the CGA Main Committee. Ten private companies have agreed to become partners in the project and will contribute by providing equipment and expertise. This will enable the glasshouse to be fitted with a micro-turbine CHP unit, supplementary lighting units initially capable of providing 10,000lux and later 20,000 lux, retractable thermal screens, raised gutters, an advanced climate control system and all associated fittings and equipment. Provision has been made for the technical and logistical management of the installation of the equipment. The total set-up costs for the project will be £151,013, of which £79,247 will be contributed by partners, leaving a balance of £71,766 to be funded from additional sources. The cost of upgrading the lighting to 20,000 lux in year 3 will be £15,500, of which £6,000 will be contributed by partners, leaving a balance of £9,500.

The annual running costs of the unit have been calculated and adjusted to allow for income from the produce and for on-going contributions from suppliers/partners. The budgets include the cost of scientific assessments to collect and collate data relating to many important aspects of crop production and energy usage. The project will be overseen by a Project Steering Group of CGA members and managed on a day to day basis by a Project Administrator. The net annual running costs for the project in the first full year of cucumber production will be £57,089, of which £4,296 will be contributed by partners, leaving a balance of £52,793 to be funded from additional sources. If the additional lights are installed in year 3, the net running costs will increase to £64,554, of which £4,425 will be contributed by partners, leaving a balance of £60,129.

Funding for the main project will be sought through the Horticulture LINK programme, which aims to support the competitiveness and sustainability of the home horticultural industry, while integrating wider environmental and consumer interests. The topics addressed by this project are directly relevant to four of seven priority areas that have been identified by Horticulture LINK as appropriate for their support.

Horticulture LINK supports projects by providing cash funding to match the value of contributions made by industrial partners. It is therefore necessary for the project consortium to raise half of the overall cost of the project. This feasibility study has demonstrated that this could be achieved with cash contributions from the HDC of £15k in year 1 of the project and approximately £28-29k in each of years 2, 3 and 4. If additional lights are installed in year 3, cash contributions of approximately £6-7k will also be required from the CGA in years 3 and 4.

BACKGROUND

It is vital that the UK cucumber industry becomes more efficient if it is to survive. The Cucumber Growers' Association (CGA) has produced an R&D Strategy that includes medium to long-term goals of reducing energy and labour inputs relative to productivity. As a starting point, the CGA intend to evaluate new technologies and growing systems that are becoming available in various parts of northern Europe. Most of these new technologies have been developed for other crops, particularly tomatoes, peppers and ornamentals, and it is now important to determine how they may be modified and integrated to benefit cucumber production under UK environmental conditions. The CGA propose to establish a "State of the Art Development and Technology Transfer Unit", in which these studies will be done.

The CGA wish to maximise cucumber production per units of energy and labour used. Initially, it is anticipated that the approach will include:

- extending the growing season by using supplementary lights
- saving energy by using retractable screens
- optimising environmental control using state of the art computer programmes
- evaluating the benefits of hanging gutter systems

Other topics to be evaluated in the medium-term will include:

- closed irrigation systems
- developing novel growing and crop training systems
- matching cultivars to the new environment and growing systems

Prior to this study, a number of companies had already expressed an interest in becoming involved with the venture and had provisionally offered to supply and install equipment, and provide on-going expertise. The CGA had opened discussions with DEFRA regarding financial assistance to support scientific inputs to the project.

Assuming the main project goes ahead, it will be steered by a management group to be appointed by the CGA Committees. The CGA will operate a policy of continuous technology transfer, which will include regular updates in the CGA Newsletter, formal on-site study days and informal ad-hoc visits by members.

The first step is to determine the feasibility of the whole venture and this was the basis of this preliminary study, which has been done by sub-contractors under the guidance of the CGA Committees.

OBJECTIVES

The overall aim of this preliminary study was to determine whether it is economically and technically feasible to establish a “State of the Art Development and Technology Transfer Unit” for the cucumber industry that will subsequently be used to evaluate new technologies to maximise cucumber production per units of energy and labour used.

The brief given to the sub-contractors was to:

- Find a suitable location for the main project.
- Establish partnerships with suppliers of the equipment required.
- Calculate cost of installation of equipment.
- Identify additional services etc (including costs) that may be required to run the unit at the chosen location.
- Design the layout of the unit taking into account both practical and financial efficiencies, and experimental design.
- Prepare a schedule for the installation of equipment.
- Prepare an outline of scientific/technical input
- Estimate the cost per annum of running the unit over the next three years.
- Prepare a technical/financial plan to form the basis of proposals for future funding.

PRINCIPAL FINDINGS OF STUDY

1. LOCATION FOR THE MAIN PROJECT:

The CGA set three important requirements for the glasshouse unit:

- It must be modern and completely separate from other glasshouse blocks.
- It must have, or be possible to install, an individual environmental control system.
- The chosen site must be readily accessible to CGA members and have facilities to host grower open days and seminars. The owners must be prepared to accept visitors on a frequent basis.

The chosen glasshouse unit is located at Stockbridge Technology Centre Ltd, Cawood, Selby, North Yorkshire. The STC site is located in the centre of the UK, close to major north –south (A1) and east-west (M62) trunk roads, and railway stations at York and Selby. Both Leeds/Bradford and Humberside international airports are close by, while Manchester airport is less than an hours drive away.

STC is based on the former Stockbridge House site, which has been an important centre for the development of horticultural crop production for over 50 years and has a long history of close liaison with the UK protected crop industry. STC was launched in April 2001 as a grower-led initiative to encourage continued technological developments for the industry. It is supported by both the production and supply sectors of the industry, who are represented on a customer-based liaison group. STC has become the adopted home of the CGA. By selecting this site, the CGA are able to draw on the expertise of a multi-disciplinary team with an excellent reputation for the timely delivery of high quality research, development and technology transfer. Apart from the chosen glasshouse unit, STC offers laboratories, culture rooms, a Plant Clinic, meeting/seminar rooms and a conference facility.

The chosen unit (coded M18) is a Wilco High Light Double Venlo glasshouse. Specifications include:

- 896m^2 floor area (909m^2 over dwarf walls)
- 25.6m wide by 35m long
- 4 double Venlo bays with 6.4m trellis orientated east-west
- Central 3m wide concrete road running north- south.
- Usable growing area - 820m^2
- The height to gutter is 4.0m and to the top of ridge is 4.7m.
- Boal narrow profile box section aluminium gutters.
- Roof glazing in 1.0m wide glass
- Twin rubber glass seals
- 64 half pane ventilators, fitted for independent control on both sides of the ridge in staggered formation, giving 23.4% ventilation over floor area. All ventilators fitted with rubber seals.

2. EXPECTED START DATE:

1 November 2002

3. SUMMARY OF TECHNOLOGIES TO INCLUDE AT OUTSET

i) Supplementary lighting at a single intensity throughout the unit.

A supplementary lighting system uses electrically powered lamps to increase the amount of photosynthetic energy available inside the greenhouse. The number of UK growers using such systems is very small, which contrasts to other northern European countries with similar climatic conditions. The heat produced by the lighting units makes a considerable contribution to the temperature of the glasshouse and some of the operating costs can be offset against reductions in heating fuel consumption. The principal potential benefit of supplementary lighting will be the ability to produce good quality cucumbers all year round and provide the uninterrupted supplies that are increasingly demanded by retail customers.

ii) Energy screens of a single design throughout the unit.

A good quality retractable energy screen can reduce heat loss by over 40% when closed on cold days and nights. They can also reduce plant stress in very bright days, particularly during the summer replanting phase. Modern materials allow high light transmission (*e.g.* 88% of direct light and 81% of diffuse light) and transmit water vapour to prevent the formation of condensation.

iii) An advanced environmental control system.

State of the art environmental control systems are able to use weather forecasting data to help predict the optimum settings and control the greenhouse environment to attain optimum crop development. The principal benefits are overall energy savings, smoothing out of energy consumption peaks, improved light/temperature balance and improved utilisation of CO_2.

iv) Raised gutter system

Hanging or raised gutter systems have several potential advantages:

- Better drainage and water collection, allowing potential for recirculation.
- Warmer slabs at the start of the season without using insulation or under slab heating.
- Better air circulation around the base of the plants, which could reduce diseases such as *Mycosphaerella*, *Botrytis* and *Penicillium*.

v) Mini combined heat and power (CHP) generator

CHP is the generation of electricity and useful heat from the same item of plant. This provides efficiency of fuel use and savings on total energy costs. There are additional benefits for glasshouse installations because the exhaust gases can be used to provide low cost CO_2 enrichment. The UK government is committed to increasing the country's total CHP capacity as a means of reducing greenhouse gas emissions and such systems are currently exempt from the Climate Change Levy for energy costs. It is possible that there will be additional legislation and incentives to further encourage use of CHP.

4. POTENTIAL CONTRIBUTORS:

- Bowman Power Ltd.
- CMW horticulture UK Ltd
- Defra
- Derek Hargreaves (Horticultural Consultant)
- Ecotech (UK) Ltd
- FEC Services
- Green Meteor
- Grodan (UK) Ltd
- Horticultural Development Council
- Hortilux Schreder b.v.
- HortLINK
- Hoogendoorn Automation
- Leen Huisman b.v.
- Ludvig Svensson b.v.
- Low Carbon Innovations Programme of Carbon Trust
- Rijk Zwaan UK Ltd
- Stockbridge Technology Centre Ltd

5. SUPPLY & INSTALLATION OF EQUIPMENT:

5.1. Supplementary lights:

Target Lighting Levels

Based on the light intensities being used for supplementary lighting cucumber crops on commercial nurseries in northern Europe and recommendations resulting from recent research (Spaargaren, 2001), the lighting equipment in the facility should have the capability of operating at minimum irradiance of $24W/m^2$ PAR. It is felt however that, in order to maximise the effects of supplementary lighting, the ability to investigate the use of lighting at an intensity of $48W/m^2$ PAR would also be desirable. With high-pressure sodium lamps these irradiances are equivalent to 10,000 lux and 20,000 lux respectively.

Using historical light data for the STC site, and assuming that the supplementary lights will be turned off at global radiation intensities above 250 W/m^2, the additional amounts of PAR provided at the two intensities detailed above are calculated to be as follows:

Supplementary Lighting Level W/m^2 (PAR)	Additional amount of PAR supplied per annum (%)
24	39.5
48	79.0

In both of the above cases it has been calculated that the lighting will operate for 4150 hours per annum.

As yield of a cucumber crop is directly related to the total amount of PAR received, the above figures give an indication of the likely yield response of the crop at the two target lighting levels.

Because of the nature of the facility, it is important that these lighting levels are achieved under typical operating conditions, having taken into account such factors as voltage drop, depreciation of lamp output, degradation of reflector surface etc. Therefore, it will not be sufficient to meet the target levels at the date of commissioning of the installation. A more appropriate specification is to meet the required irradiance after 3,000 hours of operation. This is particularly important at $24W/m^2$ as, at this level, lighting is only being applied at the minimum recommended level.

Equipment Requirements

Based on the use of 600watt lamp and luminaire units, the approximate calculated equipment requirements are:

1. To meet $48W/m^2$ – Assuming that both sides of the path are identical, the use of 272 luminaires is recommended. These should be arranged in 17 rows of 16 luminaires per row (*i.e.* 8 luminaires each side of the central road). This recommendation takes into consideration the depreciating performance of the installation with hours of operation as discussed above. It is suggested that the unit should use the latest Hortilux equipment (or equivalent) which is based on the use of remotely located ballast / operating gear units. It is also suggested that the use of the recently launched 400 volt units would be desirable.
2. To meet $24W/m^2$ – The requirements will be half of that detailed above.

Equipment Control

The operation of the lights should be via the climate control computer. Ideally this should be based on a measured PAR irradiance inside the greenhouse structure. However, due to the fact that it is currently common practice to only measure global radiation levels outside the greenhouse, it is recommended that in the first instance external global radiation is used as the control variable.

Recommendation

Having considered all aspects of the project including installation and running costs, the energy supply infrastructure of the site and the likely crop response, it is recommended that the demonstration facility should initially install lighting equipment to achieve $24W/m^2$ PAR. It should however consider the use of the higher irradiance in the longer term, as this will provide the opportunity to investigate and demonstrate the full potential of supplementary lighting in the UK. With this in mind it is considered prudent to install electrical cabling, control panels and connection equipment such that the installation can be upgraded at later date with ease.

<u>Costs</u>

Ecotech (UK) Ltd has quoted £33,540 to supply and install 136 luminaires plus cabling and sockets for 238. The supplier of the light units, Hortilux Schreder b.v., will contribute £6179, leaving a balance of £27,361. The cost of upgrading the lighting system in year 3 will be a further £15,500, with £6000 contributed by the supplier and a balance of £9,500.

5.2. Energy screens:

<u>Products:</u>

Lugvig Svensson b.v. SLS 10 Ultra Plus energy screen materials have been chosen for the project because they have the following features:

- potential to reduce heating cost by 43% when closed, which probably equates to18-20% saving over the whole year
- minimal light loss when closed and also when folded open
- allows transfer of humid air
- the structure prevents condensation and dripping
- high resistance to growth of algae

<u>Costs:</u>

C.M.W. Horticulture Ltd and Leen Huisman, in conjunction with Ludvig Svensson b.v. will provide the manufactured screening sheets and fittings at a total cost of £2676. Leen Huisman and Ludvig Svensson will contribute £1238, leaving a balance of £1438.

The suppliers estimate that installation in the empty glasshouse will take 130 hours, which at £20/hr will cost £2600.

5.3. Environmental control:

In order that the demonstration unit can operate in an energy efficient manner it is essential that a ‘state of the art’ climate control computer be used. One key feature of the installed equipment is that it should have the ability to apply temperature integration strategies. This strategy has been shown to achieve energy savings of around 15% when growing a commercial cucumber crop (van den Berg *et al.*, 2001). A number of modern designs have this facility, but key discussions have taken place with Hoogendoorn Automation with regard to commercial sponsorship of this project. The basic outline specification for the climate control computer should be as follows:

Environmental parameters measured:

- Internal temperature
- Pipe temperature
- Humidity
- CO_2
- Internal light levels
- External weather data including global solar radiation (via Kipp Solarimeter), windspeed and direction, ambient temperature and the presence of rainfall.

Equipment control requirements:

- Heating valve/s
- Thermal screens – top and side screens
- Air circulation fans
- Ventilation - lee-side and wind-side vents
- CO_2 valve
- Supplementary lighting
- Irrigation

Control Strategies:

To include temperature integration complete with predictive weather forecasting facilities. Also to include strategies for the prediction of the onset of crop condensation in order that the use of appropriate minimum pipe settings can be achieved.

Additional requirements:

Input from heat metering equipment and the ability for data export to remote files etc to be included in order that full energy management & monitoring functionality can be achieved.

Costs:

The Hoogendoorn Econaut CTI meets the above specification. Ecotech (UK) Ltd has quoted £20,681 to supply and install the complete system. The suppliers of the equipment, Hoogendoorn Automation, will contribute £8,900, leaving a balance of £11,781. In addition, new CO_2 distribution ducting for inside the glasshouse will cost approximately £500 and heat metering equipment will cost approx £1,500.

5.4. Gutters:

The approach:

There will be a comparison of rockwool slabs placed on the floor following conventional practice (northern half of glasshouse) and on raised gutters (southern half of glasshouse).

Products:

The leading supplier of raised gutter systems is Green Meteor (based in Holland) and their UK agents are Ecotech (UK) Ltd. The most suitable system for the CGA glasshouse is considered to be the GM-05, which is manufactured from galvanised steel with the upper side coated with a PVC coating (Plastisol). The gutter is an inverted design with the plants grown on top and drain water running into isolated channels on each side. A major advantage of this system is that drain water does not come into contact with other plants and thus reduces the risk of disease spread. Irrigation pipes clip underneath the gutter.

Costs:

Ecotech (UK) Ltd have quoted £2260 and £1056 to supply and install the gutter and irrigation system respectively. Green Meteor will contribute £1430 to the costs, leaving an overall balance of £1886.

5.5. Power source:

The equipment:

One of the major considerations regarding the suitability of the STC site is the ability of the site energy supply infrastructure to accommodate the demands brought about by operation of the unit. This is particularly the case when considering the electricity demands of the supplementary lighting equipment.

The current electricity supply to the STC site will only just be adequate to accommodate the installation of lighting at the proposed initial level of 24W/m^2 PAR. Therefore should the unit go ahead, their will be no opportunity for increased electricity demand on the site. This is a particularly important point if the lighting level is to be increased to 48W/m2 in the future.

Because of this limitation, and the opportunities for energy efficiency improvements, the integration of CHP has been investigated. This is based on the use of a new generation of micro-turbine machines that have the ability to supply heat, electricity and CO_2 to the greenhouse. Machines of this type are particularly attractive because flue gas treatment is not required to allow the exhaust gasses to be used for CO_2 enrichment. This is in direct contrast to the capabilities of CHP based on reciprocating engines where expensive flue gas scrubbing equipment is a necessity.

As natural gas is not available at the STC site, so the CHP unit must have the ability to operate on alternative fuels such as LPG or fuel oil. Operation of micro-turbines on both of these optional fuels is still in its infancy plus oil fuels do not provide the opportunity to use the flue gases for CO_2 enrichment (due to the high level of pollutants). However, discussions with a CHP unit manufacturer (Bowman Power Ltd) have revealed that they have technology that would be suitable for incorporation into the project. This is based on a unit with an output of 80kW (electrical) that runs on LPG. This unit produces 140kW of heat plus 64kg/hr of CO_2.

Although this unit will match well with the electrical demands of the demonstration facility, the amount of heat and CO_2 produced will be in excess of the demands of the greenhouse used for the demonstration facility. For example initial estimates indicate that the heat produced will be sufficient to heat a greenhouse space of at least $2000m^2$ and the CO_2 produced would be sufficient to enrich 1 ha to traditional levels. Usable surplus heat and CO_2 will be purchased by STC Ltd.

A 12 tonne LPG storage tank (ie 7.5m long x 2.3m dia.) will be required. Although this will be hired, there will be an in initial installation cost and an annual rental of £800.

<u>Costs:</u>

The CHP unit is valued at approximately £50,000. Bowman Power Ltd will provide this item on loan to the CGA for use under their guidance for the duration of the project. The installation costs, are estimated to be £15,000 for the micro turbine, which will include the provision of cabling to the lighting control panels, and installation of the LPG tank.

5.6. Growing medium and associated equipment:

<u>Products:</u>

The plants will be propagated in rockwool cubes and grown on rockwool slabs, either on the floor or on raised gutters (section 5.4). Grodan have offered to supply the cubes and slabs required for up to four crops per year on a condition of exclusivity (*i.e.* no other rockwool brand used in the project) and that, after use, they are transported at GGA expense to the Grodan recycling facility near Hull. These costs are included in the annual costs (Section 7).

Grodan will also provide an automatic water content meter (WCM-A) to be continuously connected to the computer and, if necessary, a hand held WCM. Both will be supplied on loan for the duration of the project on condition the CGA cover installation costs.

<u>Costs:</u>

The cost of supply and installation of the moisture content meters is £1850. Grodan will contribute £1500, leaving a balance of £350 to be charged to project.

5.7.Management of installation and set-up phase of project:

The installation of the equipment in the glasshouse will require careful management both from technical and logistical standpoints. The technical input will be overseen by a suitably qualified consultant in close liaison with representatives of the supply companies. It is anticipated that the consultant will make 4-5 full day site visits during the set-up phase of the project and devote a further 4-5 days of office-based time, at a total cost of £3,600. The in-kind contributions from the various supply companies, including site visits and other guidance, are valued at approximately £10,000. The STC Maintenance Manager will be available on an ad-hoc basis to provide assistance at an estimated cost of £3,000. The logistics of the installation work will be managed by the Project Administrator, at an estimated cost of £2750.

5.8. Total cost of installed equipment (exclusive of VAT):

Item	Cost (£)		
	Total	Contribution by supplier	Net cost to project
Lighting equipment (supply and install)	33540	6179	27361
Screen - supply - install	2676 2600	1238	1438 2600
Environmental control - supply and install - CO_2 ducting - Heat metering equipment	 20681 500 1500	 8900	 11781 500 1500
Gutters and irrigation (supply and install)	3316	1430	1886
CHP (supply and install)	65000	50000	15000
Project management consultation and labour	19350	10000	9350
Moisture content meters (supply and install)	1850	1500	350
TOTAL	151,013	79,247	71,766

6. INSTALLATION SCHEDULE:

The project will begin in November 2002. There will an initial period of two months for detailed planning and organisation, followed by a further two months to complete the practical installation work. The first crop will be planted in March 2003. If the start date is delayed, the whole schedule will be moved back accordingly.

The first year of the project will therefore include eight months of crops grown with supplementary lighting to a maximum of 10,000 lux. This will continue through the whole of the second year before the decision is made regarding upgrading the supplementary lighting to 20,000 lux. This will allow a further two years to collect crop production data at the higher light intensity.

7. **ANNUAL RUNNING COSTS**:

Costs to project:

- Heat, CO_2 and lights – Based on CHP, the annual energy costs (providing 24W/m^2 supplementary lighting) for the facility are predicted to be £21,500. If the supplementary lighting is increased to 48W/m^2 from year 3, the annual energy costs will then increase to £39,200.
- LPG tank - Annual rental cost = £800.
- Grower Consultant – 20 days/yr =£7,000.
- Labour for crop work - 2700hrs/yr, which takes into account the long season, slower work rate due to short rows, overheads, etc = £36,720/yr.
- Ad-hoc maintenance – estimated to be 140 hrs/yr = £2,800/yr.
- Water - 2190m^3 @ £0.762/ m^3 = £1669/annum
- Fertiliser - £1.73/m^2 = £1420/yr.
- Plants - At 1.5 plants/m^2, this is 1300/crop = 52004920/annum (allows 5% wastage). The equivalent to commercially raised plants (ie £0.85 each), less seed and rockwool cubes = £2548
- Biocontrol – Estimated to be £0.72/m^2 for 4 crops = c£590/annum
- Glasshouse Rental - £4.5/m^2/yr = £4090/yr.
- Transport and marketing costs – Based on fixed charge of £1.10/box (5.6kg) at 17.58 boxes/ m^2 = £15,857
- Miscellaneous – (canes, string, plastic, pesticides, contingencies etc) - £4500
- TOTAL AT OUTSET - £99,494
- TOTAL FROM YEAR 3 - £120,749

Costs covered by suppliers:

- Rockwool cubes and slabs – slabs at £1.2 each (2 plants per slab and new slabs each crop) = £2460/yr. Cubes at £0.13 each = £640. Total = £3100
- Seeds – 5835 seeds ata average cost of £0.205 each + £1196
- TOTAL - £4,296
- TOTAL FROM YEAR 3 - £4,425

Income from produce to be deducted from running cost:

At 10,000 lux
Conservative estimated yield = 225 cucumbers per m^2.

£0.40 for first 35	= £14.00
£0.255 for next 90	= £22.95
£0.20 for remainder	= £20.00
Total	= £56.95 x 820 m^2 = £46,699

At 20,000 lux
Conservative estimated yield = 285 cucumbers per m^2.

£0.40 for first 55	= £22.00
£0.255 for next 105	= £26.77
£0.20 for remainder	= £25.00
Total	= £73.77 x 820 m^2 = £60,491

Summary of annual cost of growing crops (years 1 and 2):

Item	Cost (£)		
	Total	Contribution by supplier	Net cost to project
Heat, CO_2, lighting	21500		21500
LPG tank rental	800		800
Grower Consultant	7000		7000
Labour – crop work	36720		36720
Labour – ad hoc maintenance	2800		2800
Water	1669		1669
Fertiliser	1420		1420
Plants	2548		2548
Biocontrol	590		590
Transport and marketing costs	16912		16912
Glasshouse rental	4090		4090
Miscellaneous	4500		4500
Rockwool cubes and slabs	3100	3100	
Seeds	1196	1196	
Total Expenditure	103,788	4,296	99,492
Total income from produce	46,699	-	46,699
Balance	57,089	4,296	52,793

Summary of annual cost of growing crops (year 3):

Item	Cost (£)		
	Total	Contribution by supplier	Net cost to project
Heat, CO_2, lighting	39200		39200
LPG tank rental	824		824
Grower Consultant	7210		7210
Labour – crop work	37822		37822
Labour – ad hoc maintenance	2884		2884
Water	1719		1719
Fertiliser	1462		1462
Plants	2624		2624
Biocontrol	608		608
Transport and marketing costs	17419		17419
Glasshouse rental	4213		4213
Miscellaneous	4635		4635
Rockwool cubes and slabs	3193	3193	
Seeds	1232	1232	
Total Expenditure	125,045	4,425	120,749
Total income from produce	60491	-	60491
Balance	64,554	4,425	60,129

Summary of annual cost of growing crops (year 4):

The running cost for year 4 are calculated as year 3 costs / income plus 3% inflation. The adjusted figures are shown in section 11.

8. PROJECT STEERING GROUP (PSG)

The PSG will be appointed by the CGA Committees to oversee all aspects of the project. The Group will meet once per month to receive updates from the Project Administrator, Grower Consultant and Energy Specialist. Following discussions with members of the CGA Main Committee, it is anticipated that the PSG will involve 10 days per annum for each of the following individuals. The costs are calculated at the rate of £350 per individual per day, including expenses and overheads.

- CGA Chairman
- Project Administrator
- Grower Consultant
- Energy Specialist
- Irrigation Specialist
- CHP Representative
- Seed Company Representative

Costs to project:

The Project Administrator, Grower Consultant and Energy Specialist will be funded by the project = £10,500.

Costs covered by partners:

The remaining four group members, and any ad-hoc participants, will attend at their own cost = £14,000.

9. SCIENTIFIC RECORDS

The scientific programme has been discussed by members of the project consortium and agreed in outline. It will involve monitoring many aspects of crop production and energy use, compiling and collating data, and drawing comparisons with conventionally grown commercial crops. The collated data will also be made available to individual growers for comparison with their own crop production records. The full details of the programme are beyond the scope of this report but will be included in any subsequent project proposals. In summary:

<u>Agronomic assessments</u>

The measurements of plant performance will focus on the overall quantity (*i.e.* number and weight per m^2) of cucumbers harvested within the specification demanded by retail customers. Other fruit will be graded and recorded to determine why they failed to meet the correct specification. Additional records will determine the number of marketable fruit that may be carried on the main stem.

Irrigation will be monitored continuously, and adjusted as necessary, using water content meters linked to “GrowNow” computer software and the Hoogendoorn Econaut CTI. The volume of water applied and the percentage running to waste will be recorded. The ec of the water/feed solution will be continuously monitored at the point of application and within the rockwool slab. The records will allow the volume and quantity of water and feed used to be examined in relation to light availability (natural and supplementary), as well as yield.

The labour used for key activities (*e.g.* picking fruit, crop work, pest and disease control, etc.) will be recorded.

Experienced entomologists and plant pathologists will monitor the incidence of pests and diseases in the crop, document all actions taken and calculate the cost of control programmes. Particular attention will be paid to the rate of establishment of pests and pathogens, and the effectiveness of control measures, during periods of maximum supplementary lighting.

<u>Energy / environment assessments</u>

The following information relating to energy use and the internal environment within the glasshouse will be collected:

- Quantity of heating energy used and determination of heating profile (using heat meter in the glasshouse).
- Quantity of electrical energy supplied for lighting.
- Data describing the internal environmental conditions in the greenhouse, including temperature, humidity and internal & external light levels.
- Prevailing weather conditions including ambient temperature, wind-speed and direction, solar radiation levels and rainfall.

The climate control computer will log the above information and data will be regularly transmitted by modem link for monitoring and review by the specialist energy consultants, thus minimising the amount of time needed on-site. The data will enable the relationships between energy use, internal and external environment, and weather conditions to be determined. Regular review meetings will be held at the trial site throughout the course of the project. This will enable performance to be assessed against targets and strategies to be modified where necessary.

<u>Reports</u>

The data will be collated regularly and made available to CGA members for comparison with production and energy use data in their own glasshouses.
Annual reports will be prepared in a format to be agreed with all partners.

The total cost of the scientific recording and consultancy will be:

Cost to project:	
Agronomic assessments	- £15,013
Energy assessments	- <u>£ 4,200</u>
TOTAL	- £19,213
Costs covered by partners:	
Environmental control system	- £3,500

10. FURTHER FUNDING

A cash contribution to the main project will be sought from the HDC based on the findings of this feasibility study (see section 11). It is anticipated that the combined value of the supplier/partner and HDC contributions will be matched by a cash contribution through either Horticulture LINK (HortLINK) or the Low Carbon Innovations Programme of the Carbon Trust.

The project appears to be particularly suitable for the HortLINK programme, which aims to support the competitiveness and sustainability of the home horticultural industry, while integrating wider environmental and consumer interests. HortLINK have publicised seven priority subject areas to receive funding. The following four are directly relevant to this project:

- Technologies to ensure the availability of quality UK produce at times required by the market
- Efficient use of resources (especially energy, water and growing media)
- Novel and more efficient production systems
- Efficient, environmentally acceptable and sustainable pest and disease control, contributing to integrated crop protection management (ICMS)

If successful, a LINK project will be governed by a LINK Project Management Committee (PMC), which will meet at six monthly intervals. Wherever possible these meetings will coincide with PSG meetings to minimize traveling time and costs incurred by partners. It is anticipated that the LINK PMC will consist of the PSG, plus representatives from Hoogendoorn Automation, Ecotech (UK) Ltd and CMW Horticulture Ltd, plus representatives from HortLINK, Defra and HDC. The requirements of administering a LINK project incur additional costs that must be built into the budgets:

Cost to project of administering the LINK project:

The Project Administrator, Grower Consultant and Energy Specialist will prepare the documentation for the LINK meetings and attend with project funding. The total cost is estimated to be £4,200/yr.

Costs covered by partners:

The remaining LINK PMC participants will attend meetings at their own cost. This will involve a total of 17 days per annum (nb - excluding HortLINK, Defra and HDC staff) at an estimated cost of £5,950/yr.

11. TOTAL COSTS OVER FOUR YEARS:

Year 1.

Item	Cost (£)		
	Total	**Contribution by supplier**	**Net cost to project**
Set-up costs (section 5.8)	151013	79247	71766
8 months net growing season	38059	2864	35195
8 months science input	15142	2334	12808
Project Steering Group costs	24500	14000	10500
LINK PMC costs	10150	5950	4200
TOTAL	238,864	104,395	134,469

Cash funding from sought from HDC = £ 15,037
Supplier/partner contributions = £104,395
Total non-Defra money = £119,432

Contribution sought from Defra = £119,432

Year 2.

Item	Cost (£)		
	Total	**Contribution by supplier**	**Net cost to project**
12 months net growing season	57089	4296	52793
12 months science input	22713	3500	19213
Project Steering Group costs	24500	14000	10500
LINK PMC costs	10150	5950	4200
TOTAL	114,452	27,746	86,706

Cash funding from sought from HDC = £29,480
Supplier/partner contributions = £27,746
Total non-Defra money = £57,226

Contribution sought from Defra = £57,226

Year 3.

Item	Cost (£)		
	Total	Contribution by supplier	Net cost to project
Installation of second phase lights	15500	6000	9500
12 months net growing season	64554	4425	60129
12 months science input	23394	3605	19789
Project Steering Group costs	25235	14420	10815
LINK PMC costs	10454	6128	4326
TOTAL	139,137	34,578	104,559

Cash funding from CGA = £ 7,000
Cash funding from sought from HDC = £27,990
Supplier/partner contributions = £34,578
Total non-Defra money = £69,568

Contribution sought from Defra = £69,568

Year 4.

Item	Cost (£)		
	Total	Contribution by supplier	Net cost to project
12 months net growing season	66490	4558	61933
12 months science input	24096	3713	20383
Project Steering Group costs	25992	144852	11140
LINK PMC costs	10768	6311	4457
TOTAL	127,346	29,433	97,913

Cash funding from CGA = £ 6,000
Cash funding from sought from HDC = £28,240
Supplier/partner contributions = £29,433
Total non-Defra money = £63,673

Contribution sought from Defra = £63,673

12. ADDITIONAL BENEFITS FROM THIS STUDY

Although this study has been commissioned by the Cucumber Growers' Association and the main project has been designed specifically for the benefit of U.K. cucumber growers, many aspects of the work will be relevant to growers of other glasshouse crops. For example, new knowledge will be gained about the following equipment that will be under test:

- Efficiency, reliability and running costs of the micro-turbine CHP machine.
- Reliability and durability of energy screens, and the financial savings attributable to their use.
- Ease of use of the climate control system and the financial savings attributable its use.
- Actual running costs and maintenance costs of supplementary lighting systems.
- Potential benefits of the water and nutrient management system.

It is possible that the data collected from the experimental cucumber crops could form the basis of theoretical predictions of potential yield responses to supplementary lighting in other similar crops (*e.g.* tomato, pepper, aubergine, melon, courgette, etc) and to estimate the productivity of those crops per units of energy used.

In addition, the "Development and Technology Transfer Facility" will provide a model for the establishment of similar units for other crops.

