The agro-container concept of the 21st century

CEET 2005

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Research Work Plan
of the consortium consisting of:
NDX intermodal B.V.
P&O Nedlloyd B.V.
The Greenery International
Shell Solar Energy B.V.
Carrier Transicold Company
Ecofys Energy and Environment
Agrotechnological Research Institute ATO-DLO

The consortium wishes to conduct research on the grounds of the Resolution on subsidies for Economy, Ecology and Technology from the Ministries of Economic Affairs and of Education, Culture and Science.

Appendix 1: Research Work Plan

3.0 Title of the project

The agro-container concept of the 21st century (CEET 2005)

Summary of the project

Integration of innovative technology within the transport sector, leading to sustainable economic growth, is needed to let transport be the important economic factor for The Netherlands it has been for centuries. Within the Dutch transport chain, the main products are agro-products (6.5% of the agro trade world-wide). Quality preservation is essential and only possible by means of a adequate control of the experienced climate during the entire chain. The energy required to achieve this is substantial and, at present, gives rise to high pressure on the environment.

The **goal** of this project is to reduce the environmental pressure of climate controlled agro-transport, by means of both energy savings (80% reduction is foreseen) and integration of sustainable energy sources in stand-alone containers. The specifications are determined by the energy needs of high-quality agro-products, the technological feasibility of climate conditioning and the logistic chain. The outcome will be an innovative concept for the transport of agro-products in the next decades.

Substantial amounts of energy are required to maintain the quality of agro-products during transport. Until now, attention is paid to the long lasting storage of a product under "energy-unlimited" circumstances. The amount of required energy is supplied by fossil fuels, which are becoming limited in the near future (see e.g. Jennings, 1995). With this in mind, it is opportune (and more convenient) to switch to durable energy sources, such as solar systems. Consequently, the environmental pressure will substantially be reduced.

The availability of "unlimited" energy has led to (1) substantial air transport, and (2) over-dimensioning of the sea/land transport container. The latter is reflected by too stringent climate settings, such as very low temperatures and high ventilation rates. From the point of view of energy saving these settings must and can be optimized. The first question to be answered during the project relates to the actual energy need of the agro-product, given a specific quality level and logistic chain (**task 1: product quality**). Based on this, acceptable climatic conditions will be defined and technologically realized (**task 2: energy efficient climate conditioning**). Thereby, attention is paid to the integration of a robust sustainable energy-supply system (**task 3: sustainable energy provision**), the use of Green Chemicals to slow-down the action of post-harvest pathogens (**task 4: Green chemicals**), the implementation of quality monitoring techniques (**task 5: quality monitoring**), the optimization of the logistic and marketing chains (**task 6: multi-modal logistics**), and the development of optimal-model-based control algorithms into a stand-alone container to address the complex behavior of product quality, climate and chain performances (**task 7: system control**), see figure 1.

Economical and ecological benefits cover reduction of actual energy use (80%), switch from fossil fuels to sustainable energy (up to 100%) and, consequently, negligible CO_2 emission (100%), an important impulse for multi-modal transport, improved product quality, less transhipment loss (5% for The Netherlands and up to 40% worldwide) and less waste processing (5%), 100% use of Green Chemicals instead of synthetic compounds, reduction of noise (75%), improved logistic efficiency (25%) and new market possibilities (switch from air transport to

waterways yielding at least a factor five reduction of transport costs), to mention the most important.

Technological innovation includes an integrated concept for stand-alone multi-modal agro-containers, hybrid sustainable energy systems, switch from static to dynamic product-regulated energy efficient climate conditioning systems, product quality monitoring techniques, improved container isolation and ventilation heat recovery and development of integrated logistic and marketing concepts for multi-modal transport.

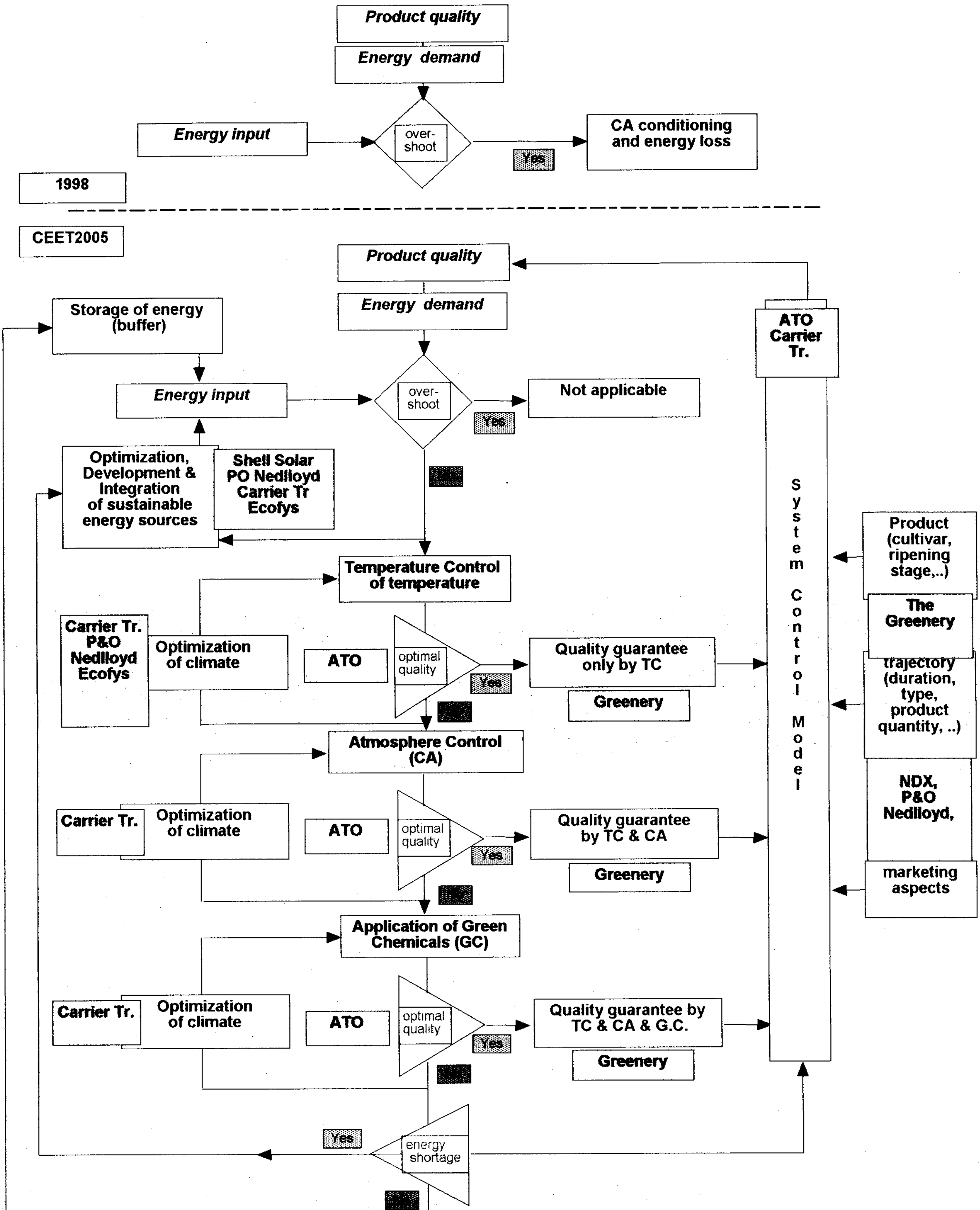

Figure 1a (above the dotted line) The situation in 1998.
Figure 1b.(below the dotted line) The CEET2005 concept, i.e. the system control model (task 7), is focused on minimal energy input and avoidance of energy loss. The model optimizes climate settings based on the energy demand of a high quality product, being monitored, and the delivered sustainable energy; the sequence in which climate settings are changed is related to the amount of energy required to achieve the setting. Boundary conditions are product trajectory characteristics (right hand side).

3.1 Background of the project

Transport of perishable products is of great economic importance in the Netherlands. The Dutch transport sector covers 6.5% (600 billion$; FAO, 1995) of the entire world trade of agro-produce. In case of fresh salads the percentage even amounts to 20%; The Netherlands are for example the fifth largest apple exporter.

This indicates that improvement of the infrastructure within The Netherlands as well as improvement of the connections to foreign countries remains essential for the leading Dutch role in the agro-trade sector[1]. Extension of the transhipment capacity of the Rotterdam Port and the Multimodal Transport Centre (MTC) in Valburg near the German border, as well as the construction of the Betuwelijn (indication of 3-5% of transported products) and the North-East rail connection are some of the Dutch initiatives to make container transport more efficient, flexible and competitive than by road transport alone[2]. Especially, the development of multi-modal transport is encouraged, not only from an infrastructure point of view, but also through innovative transport facilities (source: Ministry of Transport).

The transport of fresh agro-produces implies substantial costs, because of the high energy demand for climate controlled transport. The current design of these containers is based on "unlimited" sea transport possibilities. The proposed project aims among other things at lowering the over-dimensioned energy use in the container. Over-dimensioning seems to have been a reaction to quality loss of perishable products, but over-dimensioning is no guarantee for avoidance of losses. In many cases a short break from the chain leads to severe product losses and therefore to waste of this energy. It can be stated that, despite its economic importance, the quality of transport of perishable products is far from optimal. Losses vary from about 5% for apples to even 35% for certain green vegetables for the Netherlands during transhipment. Worldwide, overall losses in the post-harvest phase are estimated at 25-40% even including the use of pesticides (Lioutas, 1988; Pimentel, 1997).

The current project aims at a *fundamental and radical approach* to these shortcomings. The development of a stand-alone multi-modal container based on sustainable energy, applicable as multi-modal system in the entire rail/river/road/sea chain, is expected to lead to substantial reduction of losses. The keynote is that the quality of fresh products can be guaranteed within a continuous chain, while the use of available (durable) energy is minimized, taking into account the term of transport. The synergy of product knowledge and technological innovation will lead to strategic improvements of the Dutch agro-economy in relation to a sustainable environment, especially within the transport and agro-sector. Next to this, the market for qualitative high standard products will increase in a lasting and livable environment. The project can only be realized by a consortium active in the agro-transport sector (technology and trade), development

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[1] However, the Netherlands is losing market share; Some main international agricultural trade streams are not going via the Netherlands anymore. Traffic jams, blockades, weekend driving prohibitions and an oppressing driver's record legislation are reasons for this. Speed, flexibility and reliability have to be restored (Transport & Logistiek, 10-97)

[2] At the moment in the Netherlands over 90% of the agro products are transported by road, 8% by inland waterways and < 1% by railroad (NDL, 1997).

	now	2003
Agro product		
Agro-worldtrade (total)	18000 Mfl (1995)	
NL percentage (total)	6.5%	
NL percentage vegetable export	20%	
NL percentage flower export	70%	
NL vegetable&fruit export	7200 mfl	
NL tomato-export	1400 mfl	
NL apple-export	500 mfl	
NL bell pepper export	772 mfl.	
NL flower bulb export	1,2 Mfl	
NL flower export	5 Mfl	
Increase in cooled products		36 % (M$269)
Losses in the postharvest phase	25 - 40 %	
transshipment loss in NL (*)	average 10%	
Container		
number of reefers	~ 600.000 TEU	> 2.000.000 TEU
number of CA containers	~10.000 TEU	> 100.000 TEU
Sustainable energy system		
perc. sustainable energy worldwide	7%	in 2050: 50%
cost solar--energy per kiloWatt-hour	1.5 Dfl	0.85 Dfl
cost biomass energy	1.3 Dfl	1.1 Dfl.
cost convential energy per kW-hour	0,10 fl.	> 0.1 Dfl (tax)
transp. power consumpt./day in NL	1 PJ/day (tot. 6PJ/day)	
Transport data		
transshipment loss in Europe	15 till 20 %	
Percentage of transport Betuwelijn		3 - 5 %
Percentage of transport Nord-East rail		?
Capacity MTC Valburg (200 ha)		Rail Centre ready
Capacity Barge Terminal Born (4,5 ha)	850 containers/week	
Capacity Barge Terminal Venlo		ready
Transhipment capacity Rotterdam	1.6 Mton fresh Fr &Veg	> 70% container share
Main&rising inland transport to	Germany & Russia	

Table 1.Background information;

Future expectations: Quality improvement in general (Minister van Aartsen, LNV, Boerderij 21-10-97) and in transport e.g. to Eastern Europe (AGF; 16-10-97) & increase in trade of "healthy" fresh fruit and vegetables (Protrade Germany, 1995; AGF, 12-3-98) ECO-agro crops (AgD 18-10-97) and of (sub-) tropical/soft fruits.

Claims amount to 3 million guilders a year, only for flower bulb transport. (Agr. Dagbl. 17/2/98); the transporter is hold responsible according to a juridical test case (AgD, 11-2-98)

An example from the USA: 25% of food (mainly fresh fruit and vegetables, milk, granary) does not reach the consumer, i.e. 40 billion kilo per year. A decrease of 5% should lead to one day of food for 4 million people as well as $50 million reduction of waste processing. Thus, better adjustment of activities and more flexible storage/transport means are necessary (FM 3-10-97).
A second example: 20 % of food crops is destroyed by pest during the postharvest phase worldwide (Pimentel, 1997); and what will happen after 2001 when Methylbromide will be prohibited, according to the Montreal Protocol?

Minister Wijers (EZ) aims at 10% in 2020, Shell invests 0.5 billion Dfl. (Chem. Weekblad; 11-10-97). Each year, in The Netherlands available sun energy exceeds 50 times the annual energy use (Shell brochure).

Ecological motivation: Integration of sustainable energy sources also leads to noise reduction; actually, the units have to be switched off during transshipment due to too high noise levels.

MTC Valburg is a 1.2 billion Dfl. project to improve intermodal transport. 8000 new employees will be involved (MTC nieuwsbulletin nr 1, 96 & 1,2, in 97)

In 2010 it is expected that 60-70% of container transport will take place by barge or overland by rail, road or Combiroad (Container yearbook 1996). Every day 1000 trucks leave R'dam Fruitport.

NL = Netherlands; EU = Europe; fl. = Dutch guilders; M = billion; m = million; k =thousand; TEU = 20 ft Equivalent Units; percentage is given with respect to actual percentage; (*) = apple 5% and vegetables up to 35%

of sustainable energy sources and quality assessment of crops. The entire consortium will benefit from the collaboration and fruitful outcome. More quantitative information as well as relevant references are summarized in Table 1, revealing the environment in which this concept will be realized.

P&O Nedlloyd, as container owner, cooperates in the integration of the energy concept, conditioning, quality control and logistic chain. **Carrier Transicold**, supplier of cooling and conditioning systems, takes care of development of these systems with respect to energy-input and product quality. **NDX intermodal**, as a joint venture of NS-Cargo, Deutsche Bahn and CSX Corporation is responsible for multi-modal transport, including all aspects of the chain (transport duration, transhipment, type of transport, marketing information). **Shell Solar** delivers the sun collector systems. **Ecofys** is involved as technical consultant for optimising total energy concepts containing energy saving and use of sustainable energy sources. **The Greenery**, as internationally operating marketing and sales organisation for fresh produce, is responsible for supplying vegetables and fruit. **ATO-DLO**, as project leader and R&D institution in the field of post-harvest, is responsible for both quality assessments and monitoring, conditioning of the container climate including green chemicals, logistics and marketing and for the integrated agro-container concept.

3.2 Goal of the project

In the Netherlands, as well as in Europe there are two main problems in the transport sector which become more and more important, namely first the blockage of the road and other transport means, which result in delays and, secondly, an increasing pressure on the environment. The **goal** of this project is to reduce the environmental pressure of climate controlled agro-transport, by means of both energy savings and integration of sustainable energy sources in stand-alone containers for multi modal transport. The specifications are determined by the energy needs of high-quality agro-products, the technological feasibility of climate conditioning and the logistic chain. The outcome will be an innovative concept for the transport of agro-products.

The most important outcome is the development of a universal, durable stand-alone conditioned transport container, especially for the use of fresh agro-produce, based on an integrated quality control model (figure 1). Using the model, climate conditions and energy input are optimized for different products and boundary conditions, respectively. It will be integrated in the conditioning system of the container. The transport container is supplied with energy obtained by an implemented durable energy system[3,4]. In this way, the container can be used as a stand-alone system in the chain. Stand-alone means that the container can be used on railway, inland waterway, road and sea without disturbance of conditions for the products, e.g. no transhipment of the contents of the container. To prevent further blockage of the road system and in view of the coming of the Betuwelijn and the MTC near the German Boarder, special attention will be

[3] A first indication that a substantial amount of energy can be generated by solar cells has been given by the University of Southampton together with Sainsbury's in England (Reefer systems, okt. 1997). This outcome is a good stimulant for developing the proposed transportation concept.

[4] The (Ecologically produced) product will now really get a chance to be delivered as an ECO-product at the consumer, in other words sustainable crop management.

given to transport by rail and inland waterways[5]. Tomatoes (export value 1996: Dfl. 1,388 million), apples (Dfl. 505 million) and broccoli (high value product) will be chosen as model products. Commodities like pear, bell pepper (Dfl. 772 million), cucumber (Dfl. 593 million) and numerous green vegetables (total export value has been over Dfl 5000 million in 1996, excluding minimally processed products) can more or less be represented by these model products.
Scientific and technological knowledge which has to be obtained: product adaptation under various conditions (post-harvest physiology and biochemistry), non-destructive monitoring (biophysics), climate control as function of product behaviour, energy input, temperature and atmospheric conditions (mechanical engineering, thermodynamics, fluid-dynamics), energy production (material sciences, mechanics) and chain optimization (logistics and marketing).

3.3 Project according to the aims of EET

The proposed project completely fits in theme 4 "substantial reduction of energy within the transport sector". Next to this, there are links to theme 6 "substantial use of sustainable energy" especially in case of a fully stand-alone container, and theme 5 "substantial use of renewable produce" when taking into account the complete range of products which has to be stored. Some of the most relevant values are included in table 2.

3.3.1 Economy: realization of sustainable growth

Summary:

- Worldwide applicable sustainable multi-modal container for high standard products;
- High rate of efficiency and flexible transport, based on the agro-container concept for all parties in the product and transport chain (inland waterway, railway, sea and road) see footnote 1, page 1;
- Introduction of integrated sustainable energy systems in the cargo sector;
- Substantial reduction of losses of expensive product cargo, especially at transhipment;
- Quality preservation of products through out the chain, using advanced control techniques;
- Diversification of (ECO-)products; opportunities to react on consumer trends (healthy fresh products, tropical products, etc.);
- Accessibility to new markets;
- Shift from air transport to containerized transport;
- Basic concept applicable to flexible storage facilities on the spot and for numerous products.

[5] Then reduction of energy is also necessary because of the stacking of containers in inland navigation ships (up till 4 containers high; Container yearbook 1996) through which energy has to be exchanged with the underlying containers.

Table 2. Economical justification

		costs/load (kf)	costs/year (kf)
Actual fresh agro value (average) for a 40ft cont. with a load of 25 tons		**25**	**1000**
Reduction of first order:		**profit/load (kf)**	**profit/year (kf)**
red. transhipment loss(incl. indirect effects of noise reduction)	5%	1.25	50
increase in market price due to improved quality	5%	1.25	50
red. total energy supply (cooling, ventilation, etc)	80%	0.5 (2.5 GJ)	25 (125 GJ)
Reduction of second order:			
reduction handling costs stand-alone container	25%	0.25	10
reduction logistic inefficiency (e.g. optimal planning)	25%	0.125	6
red. waste processing	5%	0.075	3.75
Total cost reduction for first and second order			**144.75**
Reduction of third order:			
Transport shift from air to sea (factor 5 difference in price per kg; per 10000 km)		100	5000
From road (fl 2.2 /km) to river (fl 0.85/km) (per 1000 km)		1.4	70
From road to rail (per 1000 km)		1	50
Energy reduction due to intermodal transport (per 1000 km)		0.6 (3 GJ)	30 (150 GJ)
Accessibility to new markets (tropical, Eastern Europe, etc.)		10	500
avoiding claims, routine inspection, quality analysis	5%		no data available
Reduction of fourth order			
Taxes e.g. for diesel — price increase	30%	0.16	8

Spin-off
temporal/ flexible storage on location
up-scaling concept to large storage facilities
safety in chain (HACCP; closed chain)
transport of cattle (stand-alone; EU main issue)

Additional hardware costs		**costs/year (kf)**
Container with CA module	200 kfl/container/10 year	20
Sustainable energy source	50 kfl/container/5 year	10
Energy storage	10 kfl/container/5 year	2
Sensor system	20 kfl/container/ 5 year	4
Green chemicals (equipment)	10 kfl/container/ 5 year	2
Green chemical compounds (25 ml/ton product; 1l is approx. 60-80 Dfl.)		2.5
Total additional hardware costs		**40.5**

Development costs	**total costs (kfl)**	
phase 1,2 &3 (till first go/no-go)	13000	
phase 4 & 5 (till prototype)	10000	
production starting costs	50000	
total development costs	73000	
Total development costs per container per 2010		**3**
Investment costs per container (= total additional hardware + development costs)		**293**
Return on investment rate		**3 year**

Market share data
number of CEET2005 containers in 2010: 50000 TEU (= 25000 40ft containers)

What are the fields of application and expertise of participants?
The project relates to the transport sector. P&O Nedlloyd is one of the largest container hardware owners in the world. Carrier Transicold is the worldwide leading company in the field of climate conditioning in transport facilities. Shell Solar is part of Shell International Renewables and trend-setter in the field of implementation of sustainable energy. NDX intermodal takes care of the most extended multi-modal transport network in Europe. The Greenery, representing over 9,000 growers, is the largest producer of vegetables and fruit within Europe.
As research, development and consulting institutions ATO-DLO and Ecofys cover all scientific aspects included in the project.

Exploitation of results; how will this be achieved?
The main result of the project, i.e. a new multi-modal agro-container concept, will actively be exploited by a consortium of P&O Nedlloyd (container hardware), Carrier Transicold (conditioning), Shell Solar (sustainable energy systems), NDX intermodal (chain optimization), The Greenery International (product and quality label), Ecofys (sustainable energy system and container design optimization) and ATO-DLO (quality conditioning and -monitoring, logistic concepts), in relation to the (financial) input of each Party. This is described in the Contract of Collaboration.
Although the costs of developing the concept is high due to substantial input of fundamental knowledge, the price/performance rate is profitable at longer term due to improved product quality, reduced energy input and efficient logistic concepts. In this context, it is important to note that the consumer trend is aiming at fresh high quality products with a sustainable mark (see vakblad AGF "vers en voorverpakt onbetwiste trends", 12-3-98).

Which applications are foreseen in other fields?
The product can be used by all institutions which are involved in storage (auctions and warehousing firms), transport (container owners, transporters, wholesalers, chain-store business) and by the producers of vulnerable products (vegetables, fruit, flowers, plants, bulbs, fish, meat and even non-agroproduce). The container will be the flexible solution for seasonal needs, temporary storage/ripening/quarantine and storage expansion facilities in The Netherlands, but also for instance in Eastern and Southern European countries near important production sites.

In what way will the outcome contribute to extension of market possibilities?
The project contributes to the extension of market possibilities by means of the guarantee of qualitatively high standard products at random locations to which a green mark of quality can be given, i.e. sustainable crop management, thanks to the sustainable way of transport. A transport system which can achieve such a result will find a worldwide market, taking into account the increasing pressure on current fossil fuels.
At present, the reefer container market is exponentially growing (growth rate about 10% per year). As a results also the energy consumption in the transport sector grows exponentially. During the last four years the number of CA conditioned containers has become *fourfold*. At present, the energy consumption of these containers is about 25% higher than convential containers. The energy consumption in the transport sector is becoming more and more an

issue. The CEET2005 concept will lead to a substantial (80%) reduction of the energy demand of conditioning systems and therefore allows growth in the transport sector while keeping the ecological impact acceptable. Since also the product quality of the CEET2005 concept will be higher, it may be expected that the concept will take a major (>30%) share in the transport market for perishable products. Parties involved in this project will profit most of these developments. For example, P&O Nedlloyd may be expected to double its share in the CA transport market. For NDX intermodal these figures turn out to be even better.

In what way will the outcome contribute to reduction and avoidance of future costs?

The project will result in lowering the transportation costs, the CO_2 emission, the energy need, noise reduction during transport and the loss of vulnerable products. In more detail, as described in table 2.

What is the influence on employment within companies involved and in The Netherlands?

For the vegetable agro-chain this project is regarded as an important initiative to improve the competitiveness of the Dutch (agro)transport and -production sectors worldwide. The project can be expected as a significant impetus to multi-modal transport. This will lead to at least a 10% increase in involved higher educated persons in involved companies, which are the main companies in The Netherlands in these sectors. As such it strengthens the position of The Netherlands as both transport and knowledge center.

What is the expectation of first commercial results?

The first commercial results are expected within 5 to 7 years, while large-scale use of the entire system can be expected within 10 years.

Does current legislation affect commercial exploitation?

Legislation on noise nuisance is positive. Current legislation has a minimal influence on commercial exploitation. In the near future legislation can speed up commercial exploitation, for example by means of ecotax or legislation for diesel engines like in Switzerland. At the moment application of numerous green chemicals (GC) is obstructed by legislation. ATO-DLO is active at both national (ministry of Public Health, Welfare and Sports) and European level to accelerate admission of GC. Among other things the prohibition of production and use of methyl bromide, as a disinfectant, in 2001 (Montreal protocol, 1991) will have an important positive influence on the permissibility of GC.

3.3.2 Ecology: realizing the ecological goals

As indicated above this proposal refers to themes 4, 6 and 5. The environmental goals are:

- substantial energy reduction (80%, figure 6);
- sustainable energy provision in multi-modal transport systems;
- negligible CO_2 emission, due to first two points;
- substantial reduction of product waste (5%);
- noise reduction down to 55 dBa is possible, making climate control storage possible

in housing environments[6];
- switch (100%) from synthetic fumigants to renewable materials of biological origin (Green Chemicals);
- change primarily from air transport to rail/water/road-transport and secondary from road transport to rail/water-transport for many products;
- availability of health promoting products at new markets (for example tropical products), but also fresh products for processing means.

Worldwide product losses in postharvest are still estimated at 25-40% (Pimentel, 1997), and even amount up to 80% in Third World countries[7], but also in Western countries (see table 1). Because The Netherlands are and will stay an important trade country, these losses also have a direct influence on the Dutch transport sector. Optimization of the chain from producer to consumer is, therefore, essential to embank these losses. To prevent that one environmental problem (waste problem) is reduced, while another (increase of energy use) is increased, a durable way of multi-modal transport is chosen in this project.
The current environmental problem (product loss) is partly controlled by synthetically produced, environmentally unfriendly crop protecting means, of which some will be prohibited within a few years. Therefore, via application of Green Chemicals in combination with climate conditioning (Hurdle technology) within this project attention is paid to it.
The consortium as a whole should be able to reduce the losses, first within the Dutch-European route. The impact of such a system world-wide is presumed to be positive, for example in countries where the use of fossil fuels is restricted (e.g. Switzerland). Negative side effects for the environment can't be indicated.

3.3.3 Technology: contribute to increasing technological innovation

The contemplated technological breakthroughs :
- agro-product based dynamical climate control system;
- optimal energy concept with extreme energy efficient equipment instead of over-dimensioned current systems (imposed by sea transport); insulation and energy storage systems; robust solar/hybrid energy system;
- controlled release systems for green chemicals;
- innovative non-destructive quality monitoring systems such as PS1, NIR-imaging and photo acoustics;
- logistic and marketing concepts for multi-modal transport;
- an overall predictive integrated system control module for stand-alone multi-modal containers;
- spin-off to all (static) storage systems in The Netherlands and outside, e.g. in

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[6] Present limitations limit the noise production to 40 dBa at night and 50 dBa during daytime at the nearest house.

[7] In third world countries solar energy can already compete with traditional energy sources; the growing demand for energy and the running out of oil and gas reserves will, to the expectation of Shell, lead to 50% worldwide use of durable energy in 2050 (Volkskrant 25-10-1997, p45). Application of the container is beneficial from an energetic and product preservation point of view.

tropical countries.
There are no technological alternatives. The entire concept concerns mainly the integration of an autonomous durable energy system which is coupled to an improved climate conditioning system (cooling, ventilating and circulating techniques), which is regulated on the basis of the quality response of the product and the trajectory. Integration of durable energy systems in preservation technology is not used yet, because of uncertainty in quality maintenance, except for first trials described in footnote 3; hence the proposed consortium. Areas of application are all preservation facilities for vulnerable products. Also packed products, that only need either cool or relative humidity controlled transport, fall within this area.

Patent application of the concept will be a point of attention within the project. The concept as model based control system is sufficiently innovative for patent application. Other innovative patent application may include energy recovery for container ventilation systems, container ventilation control, air distribution system (e.g. for green chemicals) and light-based quality monitoring systems.

The technical risks are that energy produced from solely solar cells, related to the energy need of the product, is temporarily too little for multiple and stacked container transport, e.g. during sea transhipment and at transhipment sites. This means that a hybrid sustainable energy system (biofuel) will attentively be considered. It should be noted that the foreseen energy reduction (80%, tasks 2 & 3) within this concept also yields less (bio/eventually fossil) fuel energy input during sea transport and transhipment; here, the CEET 2005 concept most beneficially works for improved quality preservation and as multi-modal system from ship to rail/road/waterway and vice versa. The mentioned reduction of product losses of 5% (on average for Dutch commodities) can therefore be reached.

The input of each participant is complementary: P&O Nedlloyd optimizes the container hardware and applicability of the container, Carrier Transicold the climate maintenance, Shell Solar the durable energy, NDX intermodal the chain optimization and innovative multi-modal-marketing concepts (model and practice), The Greenery the sustainable crop management, Ecofys the development of the low-energy concept, energy storage and sustainable energy system and ATO-DLO provides the research of maintaining product quality, climate and system integration (among other things certification and logistic modelling). A balance is found between the fundamental research needed and the translation to industrial applications, as quantified in the cost-breakdown of each partner.

The co-operation of mentioned Parties is new and the duration of the co-operation will be similar to that of the project. It is expected that after completion of the project this consortium as a whole will serve the market for product delivery, service, and validation or can create a system for that purpose. The input of each partner is complementary and riscs are minimized by the strong position of each party in the market.

3.4 Available information

The state of the art in the areas wherein the container concept will be developed is described in 3.5.2.

3.4.1 Literature

* Container Yearbook 1996, CBS Heerlen
* FAO, annual report 1995.
* Scientific journals: Transport en Logistiek (2-10-97); Groente en Fruit (12-9-97); Chemisch Weekblad (11-10-97); Boerderij (21-10-97); AGF (16-10-97); Primeur (nr. 8, 97); Food Management (3-10-97); Protrade Germany (1995); Aardappelen, Groente, Fruit (AGF,12-3-98).
* Newspapers: Volkskrant (25-10-97); Agrarisch Dagblad (8-10-97 & 18-10-97&11-2-98 & 17-2-98); Financieel Dagblad (17-10-97)
* NMP+, ministry VROM

Proceedings and references herein:

* Proc. Sensors Non-destructive Testing, 1997, Orlando, Florida, NRAES-97.
* Proc. 7th International Controlled Atmosphere Research Conference, 13-16 July, 1997, Davis CA, USA.
* Proc. Part 2 of the 3rd TRAIL congress 1997 on Transport, Infrastructure and Logistics.
* Proc. of the conference Modelling of Thermal Properties and Behaviour of Foods during Production, Storage and Distribution, 23-25 June, Prague

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3.4.2 Patents

- Nederlandse octrooiaanvrage PCT/NL97/00182: 15 April 1996 "Werkwijze en stelsel voor het bepalen van de kwaliteit van een gewas".
- PCT Octrooiaanvrage PCT/NL95/00420 "Stelsel voor het regelen van de luchtsamenstelling binnen een bewaarruimte voor ademende plantaardige produkten".

3.4.3 Previous proposals

None

3.4.4 Ongoing projects

A similar project has <u>not</u> been submitted for funding through any Dutch or international subsidy programme. Work of individual partners is in some cases additional to the proposed work, but any overlap will be avoided.

Some granted projects, which provide additional information, are:

- Product gestuurde bewaartechnologie (BTOC-SBC95035)
- Modem project: Senter project nr. ITU 96007
- KLM Care-Go project: Senter project nr. ITU 95029
- 'Vers onderweg', uitgevoerd onder AKK regeling.
- Endogenous plant-antimicrobial to protect packaged strawberries (BTOC SBC96014; 1997-2000)
- Production, processing, and practical application of natural antifungal crop protectants (FAIR1-CT95-0722; 1996-1999)
- Novel combinations of natural antimicrobial systems for the improvement of quality of agro-industrial products (FAIR-CT96-1066; 1996-1999)
- Novel high oxygen and noble gas modified atmosphere packaging (MAP) for extending the quality shelf-life of fresh prepared produce (FAIR-CT96-1104; 1996-1999)
- Development and implementation of natural antimicrobial compounds in food preservation (CIPA-CT97-7080; 1997-1999)

3.5 Work programme

Within this section, the work programme which has to be carried out by the partners, as well as the planned time including the go/no go-moments will be described.

3.5.1 Work to be carried out

The activities are separated in the next 5 phases:

Phase 1. Preparation; 6 months (consortium)

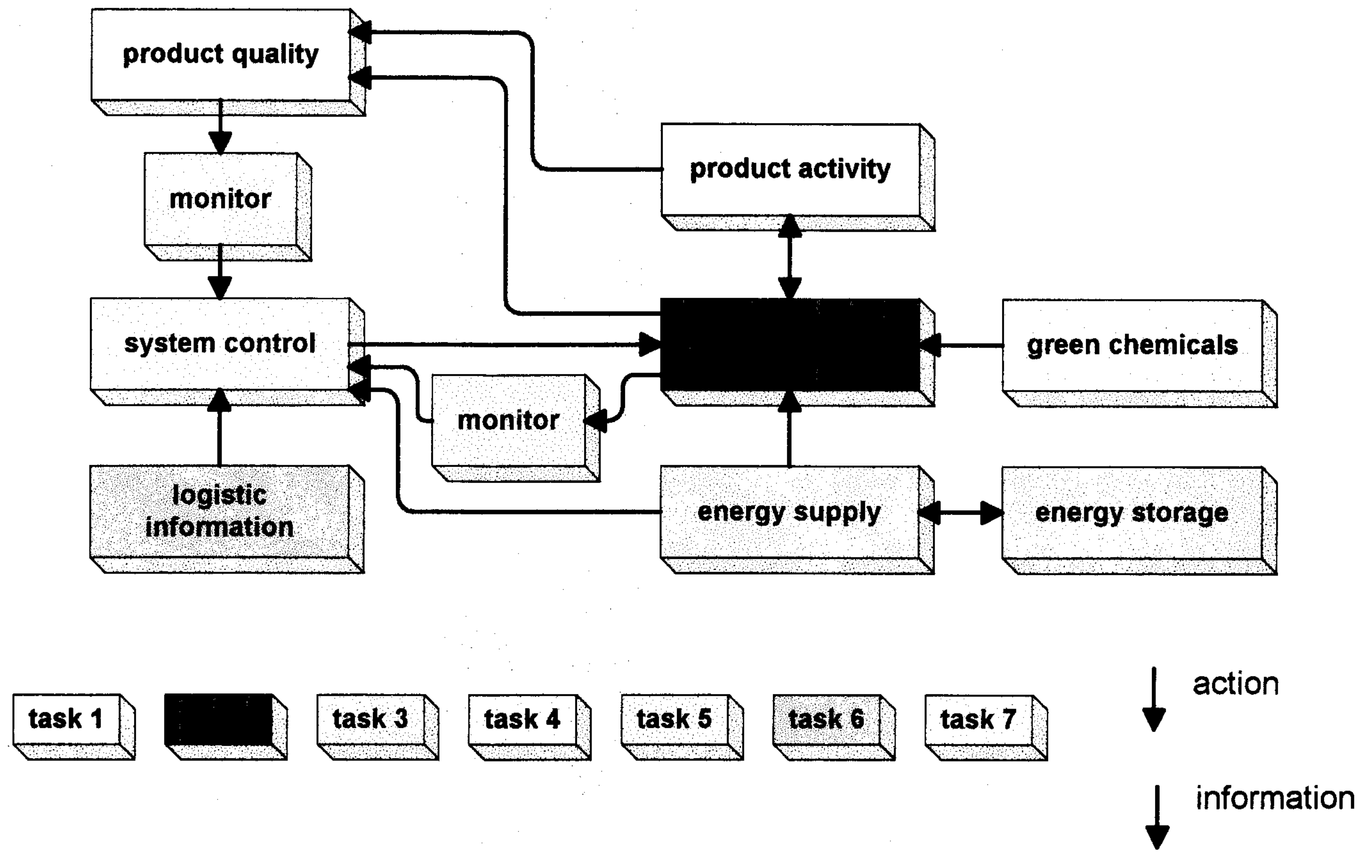
Integration of all aspects into an easy to handle work scheme; definition of input and output signals, working tools, software, preparation of facilities to be used in the next phase and first inventory studies within defined tasks.

Phase 2. Conditioning of atmosphere and product response; 18 months (consortium)

Within this phase, all aspects of the CEET 2005 are attended as described in the work approach 3.5.2 and in figure 2; work is divided in seven tasks.

Phase 3 Implementation in a test container, 12 months (consortium)

Activities described in phase 2 will be continued and integrated in a container, positioned at ATO-DLO (making use of their infrastructure). A first simulation of a realistic transport chain


product quality
monitor
system control
logistic information
product activity
monitor
green chemicals
energy supply
energy storage
task 1
task 3
task 4
task 5
task 6
task 7
action
information

will be carried out.

First go/no go

Phase 4 Optimization of the test container, 12 months (consortium)
During Phase 3, the different elements of the container concept, developed during the research, have been integrated in a first prototype of the CEET 2005 container. An inventory has been made during Phase 3 with regard to both the technical possibilities of the container and the practical boundary conditions imposed on the concept. In this stage it must have become clear whether or not the economic merits of the CEET 2005 concept, foreseen at the start of the research, are sufficient to justify optimisation and production of the container.

During Phase 4 the prototype will be thoroughly tested during simulations of expected practical transport phases, as defined in task 6. The different models developed during the first three research phases (tasks 1, 2) will be examined separately and where necessary adjusted. The system model and the control algorithms (task 7) must be justified according to detailed measurement on the microclimate and on the resulting product quality (tasks 1, 4, 5). Different possibilities for feed-back of information to the system control module will be examined. More fundamental research might be needed to tune the relevant model parameters in a real container.

Based on the finding of these evaluations, the hardware incorporated in the prototype will be optimised and redesigned (tasks 2 and 3). The energy requirement and the energy generation possibilities of the system will be evaluated and integrated in an energy module. In this phase the research will focus more on energy generation than on energy reduction, which has been given substantial attention in the first three phases. Especially the role of Shell Solar Energy therefore will increase.

Second go/no go

Phase 5 First implementation test in practice; 12 months (consortium)
Within this phase the concept (task 7) will be tested in practice. First, a container with non-vulnerable products will be tested in practice. Thereafter, a container with fresh agro-products will be tested on realistic multi-modal trajectories. These trajectories include waterways, rail and road (task 6). The influence of changing environmental conditions (solar radiation intensity, high relative humidity, varying temperature, etc.) on internal climate will be investigated in practice.

In more detail, the robustness of the container will be checked at each multi-modal transport centre (tasks 2 and 3). Energy reduction and - provision is reviewed with respect to laboratory scale experiments of task 3 in phases 3 and 4. Climate conditioning (task 2) as function of energy input and the application of green chemicals (task 4) will be related to product quality (task 1) in the entire chain. The product quality will be validated, based on monitoring both the initial quality and the quality change over the trajectory (task 5) and on the use of the developed keeping quality model (task 1). Also, consumer acceptance of sustainably transported commodities with high quality and innovative market opportunities of the concept will be attended.

Another important issue within this phase is the spin-off of this concept, such as the transport of e.g. tropical commodities, the use of the concept within temporal storage at specific sites, the upscaling of the concept to e.g. large-scale storage facilities of auctions and of transporters.

3.5.2 Approach

In phases 2 and 3 the work is divided in seven tasks including partners involved, described as follows.

Task 1 Optimization of product quality under varying conditions (The Greenery, ATO-DLO).

Task 2 Optimization of climate control under energetic and quality constraints (Carrier Transicold, P&O Nedlloyd, Ecofys and ATO-DLO)

Task 3 Development of a robust integrated sustainable energy system (Ecofys, Shell Solar, P&O Nedlloyd, ATO-DLO)

Task 4 Development of slow-release systems for green chemicals (Carrier Transicold and ATO-DLO)

Task 5 Monitoring the surrounding environment and the product's response (Carrier Transicold, Ecofys and ATO-DLO)

Task 6 Chain Optimization and Marketing Opportunities (NDX, P&O Nedlloyd, ATO-DLO)

Task 7 System control; the agro-container concept of the 21st century (ATO-DLO, Carrier Transicold and Ecofys)

The interaction of tasks is shown in figure 2 below.

In more detail the tasks and sub-tasks are described at the end of this proposal, appendix A (3.5.2. approach)

3.5.3 Time schedule and man power

In figure 3 and table 3 the coupling between project phases and tasks is scheduled in time. Initiation of integration of tasks is foreseen at the end of phase 2. This means that activities, as described in the separate tasks, continue in phase 3 but from then on in close interaction with other tasks.

The input of each partner is related to the tasks and indicated in the cost breakdown of each partner; an overview is presented below.

3.5.4 Go/no go decisions

First Go/no-go (ms 1)

After phase 3 each party will decide whether or not to continue within the consortium, based on the obtained results and the position in the market.

The following questions should be answered:

- Can quality be guaranteed within this container?
- Are costs reasonable, including expected eco taxes by the government?

CEET2005
General time schedule

ID	Task Name	Duration
1	***PHASING***	*1d*
2	**phase 1. Preparation**	**131d**
3	preparation and inventory of work	131d
4	**phase 2. Climate condit. & product**	**392d**
5	separate task optimization	392d
6	**phase 3. integration in test contain**	**262d**
7	focus on task integration	262d
8		
9		
10	***TASK DESCRIPTION***	1d
11	**task 1. product quality**	**718d**
12	1.1 energy status product	174d
13	1.2 climate product interaction	611d
14	1.3 fruit-storage-model	611d
15	1.4 quality label	197d
16	**task 2. Climate control**	**718d**
17	2.1 microclimate	565d
18	2.2 macroclimate	677d
19	2.3 climate strategies	545d

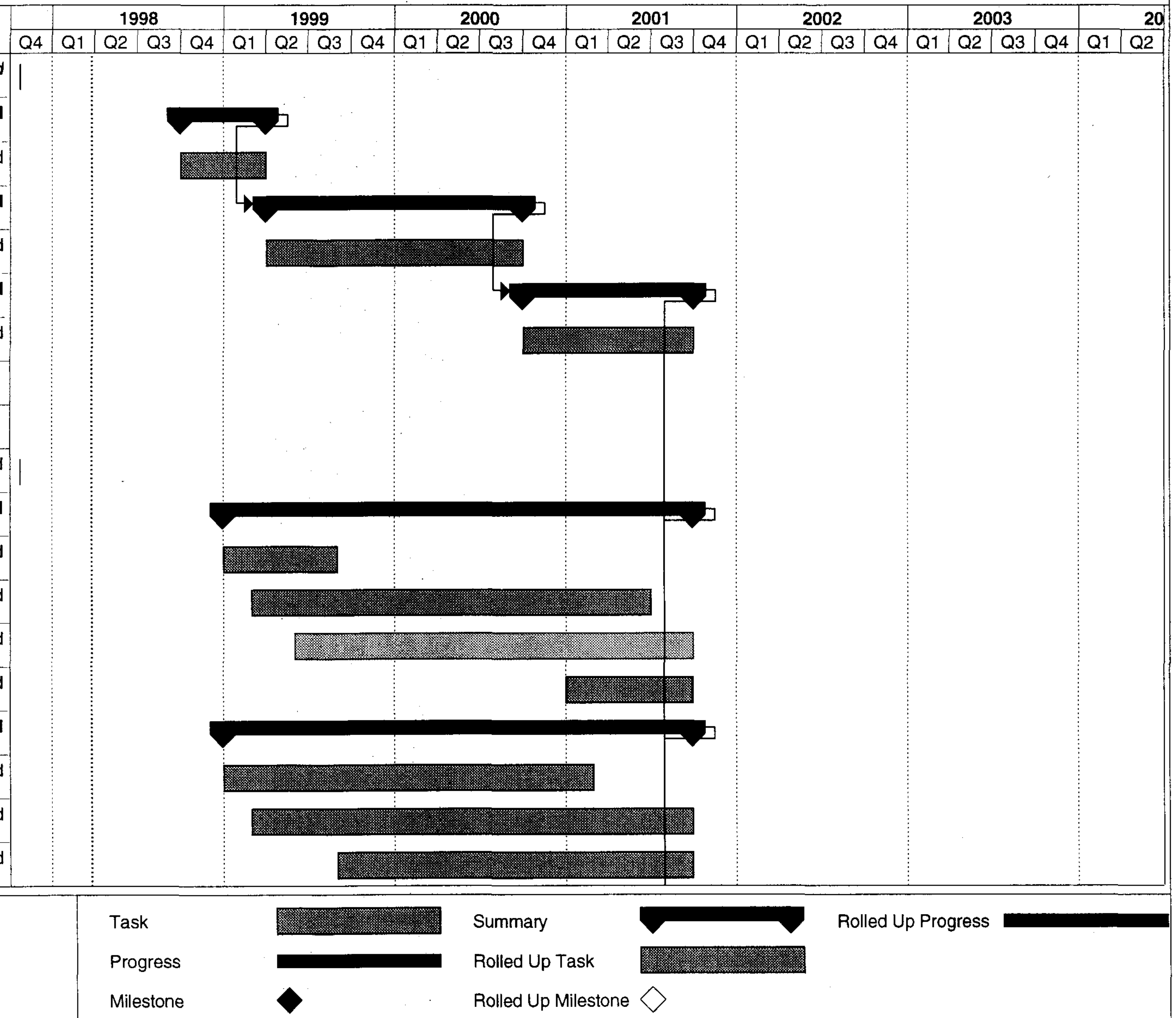


Figure 3
Date: Wed 3/25/98

CEET2005
General time schedule

ID	Task Name	Duration
20	2.4 power reduction	677d
21	**task 3. Energy system**	**718d**
22	3.1 energy provision concept	239d
23	3.2 robustness	677d
24	3.3 energy optimisation	523d
25	3.4 energy system model	262d
26	**task 4. green chemicals**	**718d**
27	4.1 selection of gr. chem	174d
28	4.2 efficacy	263d
29	4.3 phytotoxicity	348d
30	4.4 green chem. distribution	262d
31	**task 5. monitoring systems**	**719d**
32	5.1 inventory Q sensors	108d
33	5.2 feasibility implementation	220d
34	5.3 optimisation sensor	611d
35	5.4 integrated sensor	480d
36	**task 6. chain optimisation**	**718d**
37	6.1 inventory	108d
38	6.2a development chain concept	395d

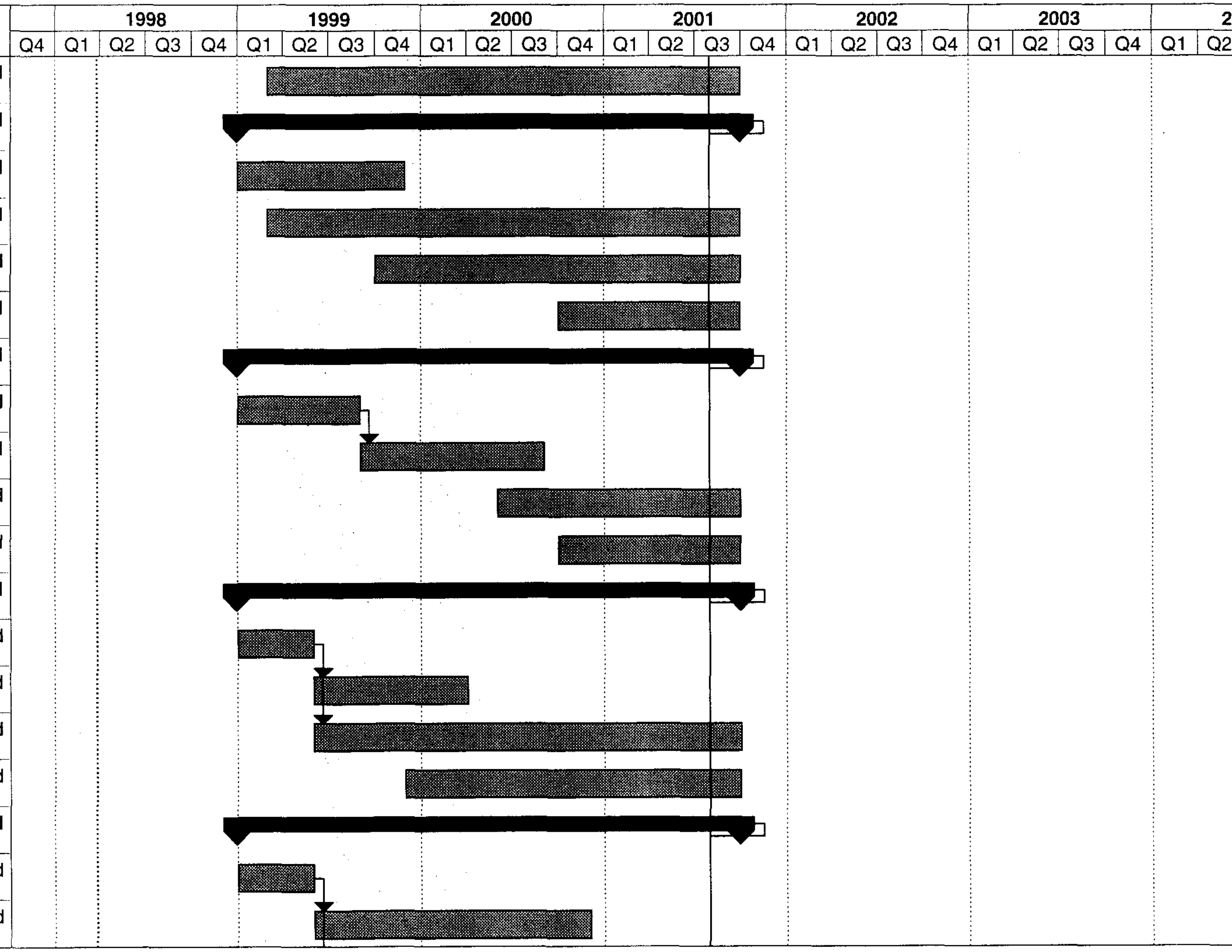


Figure 3
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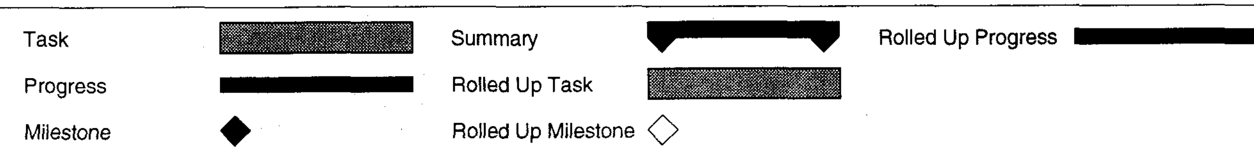
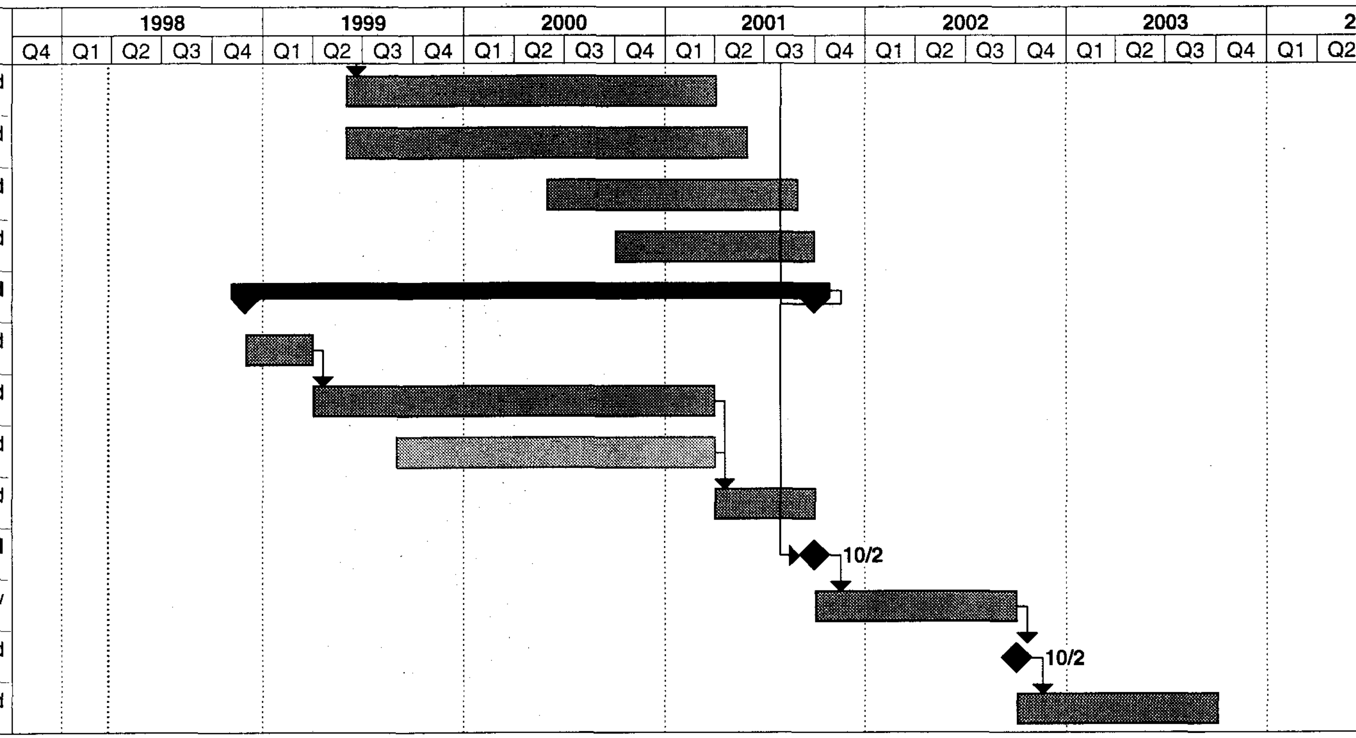


CEET2005
General time schedule

ID	Task Name	Duration
39	6.2b dev. marketing concept	481d
40	6.3 construction and programmin	524d
41	6.4 model testing	328d
42	6.5 scenario analysis	262d
43	**task 7. system control**	**742d**
44	7.1 investigation non-linear techn	88d
45	7.2 generalisation of sub-models	522d
46	7.3 development control module	414d
47	7.4 stability analysis and evaluatic	132d
48	***ms1. go/no go***	**0d**
49	**phase 4. Optimisation test containe**	52.4w
50	***ms2. go/no go***	0d
51	**phase 5. Practice test**	262d



Task		Summary		Rolled Up Progress	
Progress		Rolled Up Task			
Milestone		Rolled Up Milestone			

Figure 3
Date: Wed 3/25/98

Table 3

Man years

Project phases and tasks	**Carr. Tr**	**Nedl.**	**Shell.**	**NDX**	**Green.**	**Ecof.**	**ATO**	
Phase 1 preparation (0.5 yr)	0.3	0.05	0.05	0.3	0.05	0.35	1.8	
Phase 2 & 3 (2.5 yr)								
management							1.55	
task 1Product quality					0.2		4.35	
task 2 climate conditioning	9	2.95				0.23	4.35	
task 3 energy system	0.3	1	0.15			1	0.25	
task 4 green chemicals	1						1.2	
task 5 monitoring						0.4	2.9	
task 6 chain optimisation		2		7.2			2.15	
task 7 system control	1.9		0.1			0.23	1.75	
Go/no-go								
Phase 4 optimisation container (1 yr)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	
Go/no-go								
Phase 5 test in practice (1 yr)	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	
Total per partner	**12.5**	**6**	**0.3**	**7.5**	**0.25**	**2.21**	**20.3**	
Grand Total (m-m)								**49.06**

n.d. = not determined

- Will new markets be reached without unacceptable product loss?
- Is implementation feasible on world scale?

Second Go/no-go (ms2)
After phase 4, the outcome of the simulation will be considered for practical implementation. Again each party will decide whether or not to continue, based on the results and the position in the market.

3.5.5 Expertise, role and contribution of participants

P&O Nedlloyd

Role of P&O Nedlloyd:
For the box design, the following issues will be addressed:
- new isolation properties in relation to strength requirements of the box.
- ventilation and circulation in relation to the box design (both the box design and the unit design (Carrier Transicold) affect ventilation) and circulation.
- work in the area of the hybrid energy system. It is important to take into account practical boundary conditions to the energy system. Economic merits of different energy systems will be computed and the practical possibilities of integration of the system within the box will be investigated.

Based on studies of the expected loading level of the CEET 2005 container, a choice must be made as to the basic size of the container (20ft / 40ft hc etc.). P&O Nedlloyd will estimate and investigate the developments in this area world-wide (co-operation with other partners), e.g. investigation of possibilities for CA systems. Factors of importance are constraints to the space occupied by the equipment and the possibilities with regard to the reefer market.
In the logistics / management part of the project, P&O Nedlloyd will investigate:
- logistic conditions and requirements to the concept
- investigation of the possibilities for use on road and waterways (rivers and sea) and as flexible storage unit on location (e.g. tropical countries, East Europe)
- requirements imposed by the market, investigation of market needs.

Finally, evaluation of the developed concept within the container will be attended.
Material: In the course of the project, a container is used for integration and evaluation of the concept developed.

Shell Solar
For 100 years, companies of the Royal Dutch/Shell group have been involved in the worldwide production and development of energy sources, notably oil and gas. Today, Shell companies remain committed to the safe and efficient development of global energy sources, providing reliable and cost-effective energy supplies. As part of this commitment, Shell Solar is actively developing solar photovoltaic electricity, building on Shell's presence in some 130 countries worldwide. To meet the developmental needs of a growing world population requires increased supplies of sustainable energy. Shell Solar's philosophy is to meet the challenge of making sustainable energy available to everyone. Shell Solar has a wide experience of projects around the world, from roof applications in busy centres to

electrification schemes for isolated villages and stand-alone applications.
Role of Shell Solar: Shell Solar experienced in stand-alone application of PV systems, will be involved in the energy provision system together with Ecofys. PV test systems will be delivered to the project.

Carrier Transicold
Carrier Transicold (CTD) is one of the companies included in United Technologies Corporation (UTC). Other companies are Pratt&Whitney, Otis, UT Automotive, Sikorsky and Hamilton Standard. Products and service of CTD are heating, ventilating and air conditioning (HVAC) equipment for commercial, industrial and residential buildings, HVAC replacement parts and services, building controls, commercial and transport refrigeration equipment. Primary customers are mechanical and building contractors, homeowners, building owners, developers and retailers, architects, and building consultants, transportation and refrigeration companies, shipping operations. The 1997 revenues were $6.06 billion, up 2% from $5.96 billion in 1996. Operating profit was $458 million, up 9% with respect to 1996. Carrier is already the world largest air conditioning manufacturer.
Role of CTD: CTD is involved in tasks 2, 3 , 4 and 7, as indicated in the detailed time schedule of figure 4, included in appendix B next to the Carrier Transicold cost-breakdown.

NDX intermodal
NDX Intermodal is a stand-alone joint venture of NS Cargo, Deutsche Bahn (DB) and CSX Corporation. NDX sales and operations staff are located throughout Europe. The headquarters office is located in Amsterdam just minutes from Schiphol International Airport, convenient to major ports including Bremerhaven, Hamburg, Antwerp and Rotterdam as well as all other major markets of Europe.
NS Cargo together with NS Reizigers, operates 2,700 km of rail network across the Netherlands and handles international rail freight across the German and Belgium borders. 1995 income was Dfl 372 million, with an asset base of approximately Dfl 800 million. Netherlands Railways had a net turnover of Dfl. 4.63 billion in 1995.
DB AG operates slightly over 40,000 km of railway across unified Germany. The company had 1995 turnover of nearly DM 30 billion and is making capital investments of DM 77 billion, including specific improvements in the lanes between Emmerich and the Ruhr in conjunction with NS Cargo's Betuwe Route development.
CSX Corporation is a $10 billion international transportation company based in the United States with operations in over 80 countries around the world and is the only transcontinental U.S. intermodal company (CSX Intermodal).
NDX Intermodal in perspective: Many cargo owners in Europe have been asking for new and innovative freight transportation service. Service packages that are competitive in time and price to trucks, and a company that will be flexible and responsive to their shipping requirements. NDX was formed to meet the demands of today's modern shippers. NDX is an international marketing company, serving customers with innovative packages designed to meet their shipping needs. W provide a high quality, cost competitive service to maritime and continental customers using rail block train and shuttle services with the option for pick-up and delivery. NDX plans to have one of the most extensive transportation networks in Europe serving nearly all major markets. The planned start-up network for NDX consists of routes

serving the ports of Bremerhaven, Hamburg and Rotterdam to interior points in Germany and northern Italy.
The partnership of NS Cargo, Deutsche Bahn AG and CSX Corporation is one of a shared vision of a transcontinental European intermodal rail system: A unique combination of experience and expertise that will benefit shippers with improved service. Competitive. Reliable. Efficient. And easy to use.
Role of NDX Intermodal: NDX is mainly involved in task 6 and all of its sub-tasks, developing of fundamental logistic and marketing concepts for multi-modal transport based on the CEET2005 concept in order to optimize the technological aspects of CEET2005.

The Greenery
The Greenery is an internationally operating marketing and sales organisation for fresh produce, representing over 9,000 growers in The Netherlands. Via developing in depth consumer understanding the Greenery will develop and introduce new product concepts that will fulfill the consumer needs. The Greenery has or is developing close relationships with the top 30 retailers in Europe. In the future, the accounts will be matched with groups of growers to optimally produce for the European consumer. Today, The Greenery employs over 1000 people and has offices in The Netherlands, Germany and the U.K. Year round supply of vegetables and fruits, is another corporate objective for The Greenery. Effectively this will mean that, during the counter season, product will have to be sourced from area's with more favorable climatic conditions. Expansion has recently been undertaken in this direction.
Role of The Greenery: The Greenery will take care of the delivery of agro-products. The number of pallets and related costs are presented below.

Ecofys
Ecofys energy and environment is a Dutch research and consultancy company, employing about 70 people, mainly with a technical and academic background. Projects mainly concern the practical introduction of energy conservation and renewable energy. Ecofys covers the whole range from research to consultancy, being:

* feasibility studies, market strategies
* modelling, design tool development
* product development
* project development
* installation, commissioning and maintenance
* monitoring and evaluation
* education and training
* policy studies
* consultancy

Ecofys has experience with respect to design, installation, monitoring and testing of PV-systems. In addition, activities include organisation of and contribution to workshops and production of publications and presentations. Ecofys has an important consulting function to the government and to the utilities in the Netherlands as far as renewable energy an rational use of energy is concerned. On the international level, amongst others. Ecofys is participating in activities within the framework of the EUREC-Agency and the DGXCVII Working Group Datamonitoring.

Role of Ecofys: Ecofys is mainly involved in task 3, optimal sustainable energy production (developments of sustainable energy concepts) together with Shell Solar. Thereby, Ecofys is involved in energy reduction based on development of ventilation concepts as foreseen in task 2, monitoring and modelling energy demand (task 5) and system control (task 7) considering minimal energy use within the system control.

Agrotechnological Research Institute (ATO-DLO).
ATO-DLO is a multidisciplinary research institute, playing a prominent role in enhancing the know how and technology level of agribusiness, trade and industry. ATO-DLO cooperates with a great variety of enterprises, including large multinationals, cooperatives, auctions, food processing industry, chemical industry, trade and export. The institute is involved in various national and EU research programmes.
ATO-DLO comprises a staff of over 550 research workers, including 225 scientists. The institute's facilities include 2500 m^2 technology halls, 2500 m^2 climate rooms and advanced equipment such as NMR, S(T)EM, XRD, GCMS, FTIR, DSC.
The infrastructure for dynamical storage, quality evaluation, food safety modelling tools and logistic tools is present.
ATO-DLO is the certifying organisation of Reefer containers for transport of perishable products (ATO-certification). Complementary to the ISO certification aspects like box design, unit specifications and ventilation and circulation rates are judged.
The coordination and management of the project is the responsibility of the project leader at ATO-DLO. In general, ATO-DLO has considerable experience in the management of SENTER projects and is actively participating in numerous projects. The financial department and secretarial staff are used to coordinate reporting, expense- and hour-registration from contractors and liaise with appropriate SENTER-offices.
Role of ATO-DLO: ATO-DLO is involved in all tasks; the time schedule of the entire project is applicable to ATO-DLO's activities. Relevant scientific expertise is in the field of post-harvest physiology, biophysics, microbiology, mechanical engineering, fluid- and thermodynamics, sensor technology, process control, computational dynamics, marketing and logistics; see for example references of van den Broek, Harbinson, Meinders, Peppelenbos, Schouten, Sillekens, Smid and de Vries.

3.5.6 Coordination

Each Party will be represented in the **steering committee**. The steering committee discusses progression of the project, problems arising in the course of the project, publication of results, etc. Each **6 months** the steering committee will meet to discuss the progression. Meanwhile, **researchers from all Parties** weekly discuss the contents of the research work by e-mail and if necessary at location in order to successfully integrate the work.

The steering committee is composed as follows:

P&O Nedlloyd:	P.J. Eekel/D.J. Marjoram
Carrier Transicold:	W.P. Kistner
NDX intermodal B.V.:	A.H. van Ommen
The Greenery International:	M.F. Van Ginkel
Shell Solar Energy B.V.:	J.W. Hendriks

Ecofys:	W.O.J. Böttger
ATO-DLO:	J.J.M. Sillekens
project coordinator:	H.S.M. de Vries (ATO-DLO)

The coordinator will monitor the progress for the different tasks and, if necessary, takes measures to ensure that the milestones of the project are met so that the deliverables set will be obtained. Communications to and from the EET programme office on scientific and financial matters will be handled by the coordinator, according to the EET regulations.

3.5.7 Third parties

The involvement of third parties will be mainly focused to the development of a fundamental marketing model and/or concept for multi-modal transport. These parties, e.g. Erasmus university Rotterdam, are linked to NDX intermodal (see financial scheme of NDX).

3.6 Financial aspects

A cost breakdown is given in the tables of appendix B for each Party individually. Labour (research and management), equipment, consumables, travelling and other costs are separated. Also, an overall costs breakdown is given.
It should be noted that for Carrier Transicold, the cost-breakdown is determined for all efforts in the project. Part of the presented financial budget (amounting to Dfl. 700,000; approximately 10% of the subsidy pleased by all Parties) is asked for as EET-subsidy.

Part of the project will be carried out in the laboratories of Carrier Transicold in the USA in close collaboration with P&O Nedlloyd, ATO-DLO and Ecofys. Consequently, the expertise of the Dutch partners will be stimulated. The work is carried out in the USA because there aren't comparable facilities/companies in The Netherlands where container climate conditioning and cooling, essential element of the project, can be investigated. Carrier Transicold and two other foreign companies do cover the entire market. This immediately implies that world-wide application of the container concept will be guaranteed, in case of positive outcome of the project. Together with the EET programme office and the Dutch Embassy in the USA and the American Embassy in The Netherlands, the coordinator and Carrier Transicold will investigate additional funding possibilities for the work carried out in the USA, e.g. within Dutch-USA collaboration funds. At the moment there are formal discussions between ATO-DLO and the USDA to cover these aspects.
It should be noted that within this context Carrier Transicold is willing to finance the major part of the work out of pocket; only 10% of the total subsidy funding will be claimed by Carrier Transicold.

CEET2005 may be of interest to the ministries of Agriculture, Nature Management and Fisheries (LNV), of Housing, Spatial Planning and the Environment (VROM) and of Transport, Public Works and Water Management (V&W), because of export of high quality Dutch products, new multi-modal transport technology and substantial CO_2 reduction. The coordinator will, in close collaboration with the EET-coordinator, start discussions with these ministries in what way the project can be supported after the first go/no go.

Appendix A: 3.5.2 Approach

Task 1 **Optimization of product quality under varying conditions (The Greenery, ATO-DLO)**

Key issues: product quality preservation, adaptation to variable storage conditions, reduction energy status & heat production & energy capacity of the product, post-harvest physiology

Objectives:
The objectives are reduction of the energy status of fresh agro-products - scientifically approached - as well as preservation of their quality under **both product-controlled and boundary-dependent (product history, trajectory, mixed loads, etc) variable storage conditions**. The outcome will be a generic agro-product adaptation model that will teach us how to minimize the energy demand and the effect of stress due to variable storage conditions and, thus, how to achieve reduction of damage and loss of the value of agricultural produce. Attention will be paid to three model products, apple, tomato and broccoli; all representing other commodities like pear, bell pepper and green vegetables.

Detailed scientific programme:
The spoilage of fruits and vegetables during the postharvest phase is very high. It has been estimated that the worldwide loss amounts to 25-40% (Lioutas, 1988; Pimentel, 1997). Inadequate storage is one of the responsible factors. Optimization of storage conditions has mainly been performed in an empirical way, where a number of storage conditions (temperature (T), Relative Humidity (R.H.), oxygen (O_2), carbon dioxide (CO_2), nitrogen (N_2), ethylene, etc.) have been tested. Secondly, conditions have been kept constant for a specific crop (Thompson, 1996). Temporal changes in crop viability, gradual ripening during storage and inter-crop variations have only recently been taken into account in a new storage concept (Schouten S.P. et al., 1997; ATO-DLO patent nr. PCT/NL95/00420). First results for apples are promising with respect to storage duration and, especially, shelf-life. Here, the basics of this research policy is followed, however, extended to a strategy based on minimal external energy input and duration of the trajectory.
Therefore, fundamental knowledge of fruit physiology, on basis of which storage parameters should be optimized and temporarily adjusted, needs to be further developed (Saltveit, 1997; de Vries et al, 1997). The temperature and external level of O_2 are critical. On one hand metabolic rates and energy production need to be minimized to retard senescence. On the other hand disorders and off-flavours due to either insufficient ATP production or high accumulation of metabolites like ethanol and acetaldehyde or post-anaerobically/hypaerobically produced radicals must be avoided. The mechanisms of (1) toxicity of post-hypoxic O_2 levels, studied for root tissues but completely overlooked in fruit storage (Kanellis, 1998), and (2) tolerance to extremely low O_2 levels, as implemented in quarantine treatments (Kader, 1997), need to be elucidated at low but variable temperature. This unavoidably leads to implementation of **adaptation phases** during postharvest handling of crops. It should be noted that e.g. an adaptation phase at the end of storage may enhance

product quality, via stimulation of specific secondary metabolites.
Different aspects of respiration have been widely studied and will be used as basis for the present work. Before harvest, fruits can be seen as sinks for photosynthesis products, starch and sucrose. After harvest, the control of turnover rates for these carbohydrates, and for all compounds derived from these carbohydrates, determine storage periods for fruits. The turnover rates of essential compounds will be followed as function of O_2 concentration and temperature. Avoidance of (latent) damage is related to tolerance to anoxia/hypoxia, and is presumably coupled to changes in energy metabolism (Pfister-Sieber and Braendle, 1994). In general, ATP and CO_2 production rates as function of O_2consumption will be described refining an existing gas exchange model based on enzyme kinetics (Peppelenbos, 1996a and b). Investigation of ethanol and acetaldehyde emission rates, in relation to enzyme activity (PDC, ADH, catalase) and to the energy status, allows to elucidate fermentation and post-anoxic processes (Zuckermann et al., 1997).
Next to this, a suitable marker for the effect of oxidative stress should be incorporated in the research. Ethylene is candidate for early stress symptoms; ethane as product of lipid peroxidation indicates cell membrane damage. Sensitive laser-based Photo acoustic systems are a pre-requisite for measuring small changes in gas exchange (de Vries *et al*, 1995a).
In conclusion, to be studied physiological processes, involved in quality deterioration, and related *measurable parameters* (related to task 5) are:

- Energy status of the product via *ATP* balance and *heat production and - capacity*, respiration via *O_2 consumption* and *CO_2 release*, fermentation rates as derived from *ethanol* and *acetaldehyde* levels, and *pH* regulation. Physiological and biochemical responses of several tissue types will be studied and mutually compared under variable conditions.
- Oxidative stress, caused by changing O_2 levels during and after storage, leading to imbalances in the *electron transport* chain (Foyer and Harbinson, 1997) and membrane disintegration studied via the process of lipid peroxidation leading to *ethane* and *malondialdehyde* evolution, free radical formation and accumulation of *anaerobic metabolites*.
- Natural defence mechanism based on scavenging capacity of antioxidants (generally, health promoting compounds) like *ascorbate* and *glutathione* and enzymes such as *superoxide dismutase*; making the product more resistant to initiators of damage.

Above mentioned physiological processes will be concomitantly studied for apple (as commodity favouring CA conditions comparable to e.g. pears and bananas), tomato (benefitting from control of relative humidity, next to bell pepper and cucumber), and broccoli (benefitting to CA but suffering from discoloration like other green vegetables), see also table 4. They are all highly susceptible to oxidative/temperature/humidity stress at low temperature. Within this context the feasibility of implementation of adaptation phases (*varying oxygen, carbon dioxide, temperature*, etc.) will be researched, see figure 5.
The following strategies will be developed:

Task 1.1 inventory how to reduce the energy status of the product and, consequently, minimizing the external energy demand and heat production of the product itself.

Task 1.2 study of physiological and biochemical processes under dynamic regulation of storage conditions based on low external energy input and duration of the trajectory and on energy capacity of the product as well as implementation of adaptation phases.

Task 1.3 setup of a fruit-storage-generic-model describing the quality preservation behaviour of these products.

Task 1.4 definition of a high standard sustainable quality label for these products. It will be researched what the conditions, in terms of energy demands and kind of energy sources, need to be in order to develop a generally accepted quality label for sustainably stored and transported agro-products.

The outcome of these sub-tasks will also be applicable to other commodities and to improvement of facilities of other companies involved in postharvest handling.

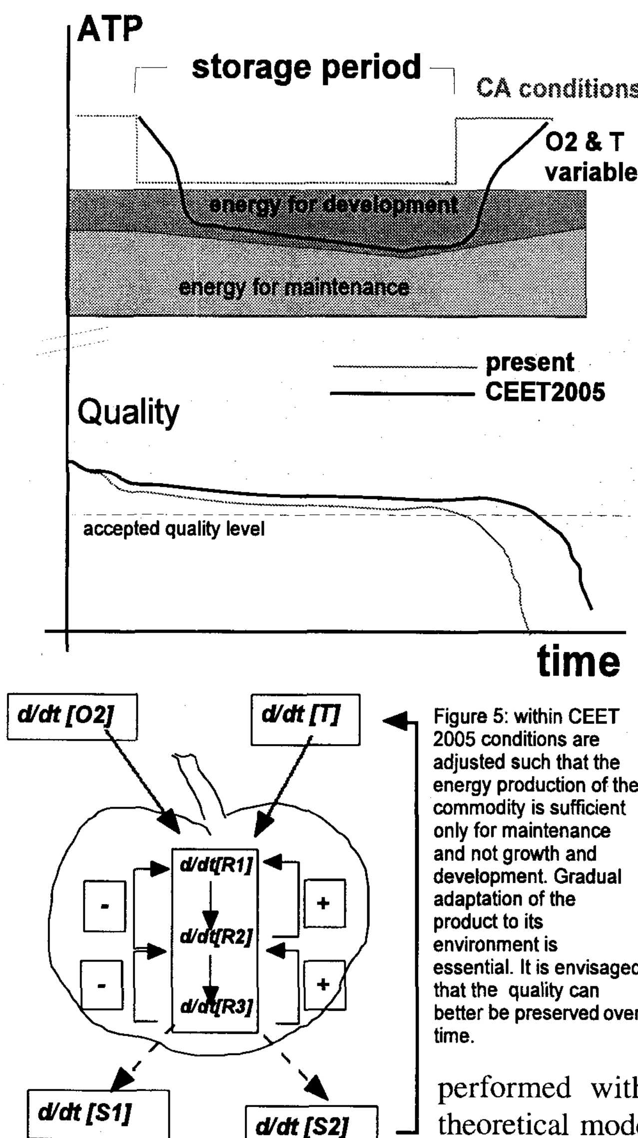


Figure 5: within CEET 2005 conditions are adjusted such that the energy production of the commodity is sufficient only for maintenance and not growth and development. Gradual adaptation of the product to its environment is essential. It is envisaged that the quality can better be preserved over time.

Infrastructure:

The Greenery International will deliver high quality agroproducts as specified before. Experiments will be carried out in the storage facilities of ATO-DLO, using flow-through containers of 70 litre each and closed-cycle-flow containers of 650 l each, divided over various temperature controlled cells. Gas mixtures are dynamically controlled by means of mass flow controllers for O_2, CO_2, N_2 etc. Consequently, temporal changing gas conditions around products can be established and simulated. Furthermore, physiological, biochemical and molecular analysis of different fruit and vegetables as well as standard quality evaluation (e.g. Computer Image Analysis) can routinely be performed within ATO-laboratories. Basic experience of theoretical modelling is available using physiological models based on enzyme kinetics and diffusion characteristics.

Task 2 Optimisation of climate control under energetic and quality constraints (Carrier Transicold, P&O Nedlloyd Ecofys and ATO-DLO)

Key issues: Energy load reduction, power reduction, climate modelling, dynamic control of ventilation and circulation, CA optimisation.

Objectives:
The goal of this task is to achieve the required climatic conditions with a substantial energy reduction. The **energy load** of containers will be reduced based on fundamental **climate models** and **optimal dynamic control** techniques. Further the possibilities for a significant **power reduction** of the unit equipment will be investigated.

Detailed scientific programme
The current state of the art in refrigerated container technology satisfies three product needs: temperature control, atmosphere control (oxygen) and humidity control, in order of priority for product quality. Due to relatively unlimited power availability on board ship, in ports and depots as well as over the road via generator set, current designs have evolved with minimal regard to total power consumption. Modern reefer containers are able to maintain a prescribed temperature level within very strict limits (typically ±0.5°C), even at high ventilation rates (fresh air intake) in tropical areas (Rudulphij and Wang, 1995). The price one has to pay for this, is a high energy consumption, due to the high circulation (internal air movement) rates involved and an over-dimensioned refrigeration unit. Data gathered by ATO-DLO show that the air circulation rate has almost exponentially increased with a factor of 250% over the last twenty years. Of course the energy required for these high circulation rates is all dissipated and requires a high refrigeration capacity.
Some of the reasons for over-dimensioning the climate control system in reefer containers, are insufficient knowledge of the (dynamic) requirements of the product, insufficient knowledge about the relation between macroclimate and microclimate and insufficient knowledge about the climate settings required to obtain a certain macroclimate. The climate settings therefore are frequently specified for the worst case scenario: very high ventilation rates for removal of CO_2 or ethylene, and very high circulation rates to guarantee a uniform microclimate in the container. It is partly also due to insufficient knowledge that techniques like Controlled Atmosphere (CA), that may be more energy efficient than conventional techniques, are only moderately penetrated in containerised transport.

Power consumption in transport refrigeration equipment is affected predominately by five factors:

1. the number of control parameters being addressed (temperature, oxygen, humidity). As a minimum, temperature control is always in effect. Some cargoes benefit from humidification or dehumidification and these systems generally are activated after the box initially reaches temperature setpoint. An emerging technology in the market is the control of oxygen in the box. This is mainly used to transport highly perishable cargoes long distances. As additional control parameters are activated, power consumption increases;
2. box load (driven by ambient temperature and product respiration);

3. the base design capacity for frozen product;
4. outside air ventilation;
5. internal box air flow needs.

These factors will be addressed in the following research tasks.

In order to decrease the energy load in climate controlled containers, fundamental research is needed to gain the necessary insight in the complex interactions of the climate control in reefer containers (Brookes, 1995).

Research focuses on the following main issues:

Task 2.1 Interaction between the microclimate and the product.

In this subtask the effects of local parameters (air velocity, temperature, relative humidity, gas composition) on the physical transport mechanisms of the product (heat transfer, water loss etc.) is investigated. Based on detailed analyses, generic models will be developed to describe the transport mechanisms adequately, dependent on basis properties of the product (composition, ripening state, etc.) (Sillekens et al., 1997). In these analyses, the influence of the packaging system on the microclimate and the influence of the local macroclimate on the packaging system are important aspects (Van der Sman and Sillekens, 1998).

Task 2.2 Optimisation of the macroclimate.

In order to design an adequate control strategy, a mathematical model of the system under consideration is required. Presently, models of climatic conditions are generally based on the assumption that the inside air is well mixed, which leads to an over-simplification of the system and to non-optimal control strategies (such as the aforementioned high circulation rates) (Peng, 1996). In order to reduce the energy load of a reefer container, knowledge of the spread in climatic conditions in relation to circulation and ventilation rates, air distribution hardware and loading patterns over the container is required. Also the interaction with the product (Task 2.1) is an important parameter. Experimentally validated Computational Fluid Dynamics is one of the main techniques that will be applied in the investigation.

Task 2.3 Evaluation of climate control strategies.

Based on the developed micro- and macroclimate models, alternative climate control strategies will be investigated. First, a substantial reduction of the circulation and ventilation rates is envisaged. Secondly, new control strategies like pulsed circulation and ventilation (using the thermal mass of the transported products as a capacitor) will be developed. The merits of these strategies on the energy consumption are believed to be enormous.

Outside air ventilation is a very influential factor on power consumption. Since outside air can be very hot and humid relative to the macroclimate being maintained inside the container, large increases in load on the system and consequent increases in power usage frequently occur.

The hardware facilities are currently not suited for ventilation or circulation control. The ventilation-rate can only be manually adjusted, and the dependency of ventilation on the load of the container can not be taken into account (no feedback). The research intended for this element is to develop an automatic means of adjusting the volume with feedback systems such that factors that change the volume amount during transport through the chain are recognized and the volume is adjusted to maintain a set value. Evaluation of numerous air management means will be needed to determine a volume control device that can be infinitely adjusted , but that also maintains zero leakage during transport of cargo that does not require ventilation but instead demands zero outside air leakage, such as loads being transported under controlled atmosphere with 1% oxygen setpoints. Similarly, air circulation in containers is insufficiently controlled to obtain a substantial energy reduction. Methods will be developed and analysed to make independent control of circulation and ventilation possible.

In order to objectively evaluate different Control Atmosphere systems (scrubbers, absorbers etc., see e.g. Wild, 1995), scientific research on the performance of the systems, both from a thermodynamic and energetic as from a qualitative point of view will be performed. The theoretically possible energy savings (regeneration etc.) will be assessed and strategies for improvement will be formulated.

Due to the availability of climate models, an optimal control algorithm, (e.g. Model Based Predictive Control), can be designed. Dynamic ventilation strategies, such as use of ventilation for cooling purposes will be incorporated (Verdijck, 1998).

Task 2.4 Power reduction of equipment.

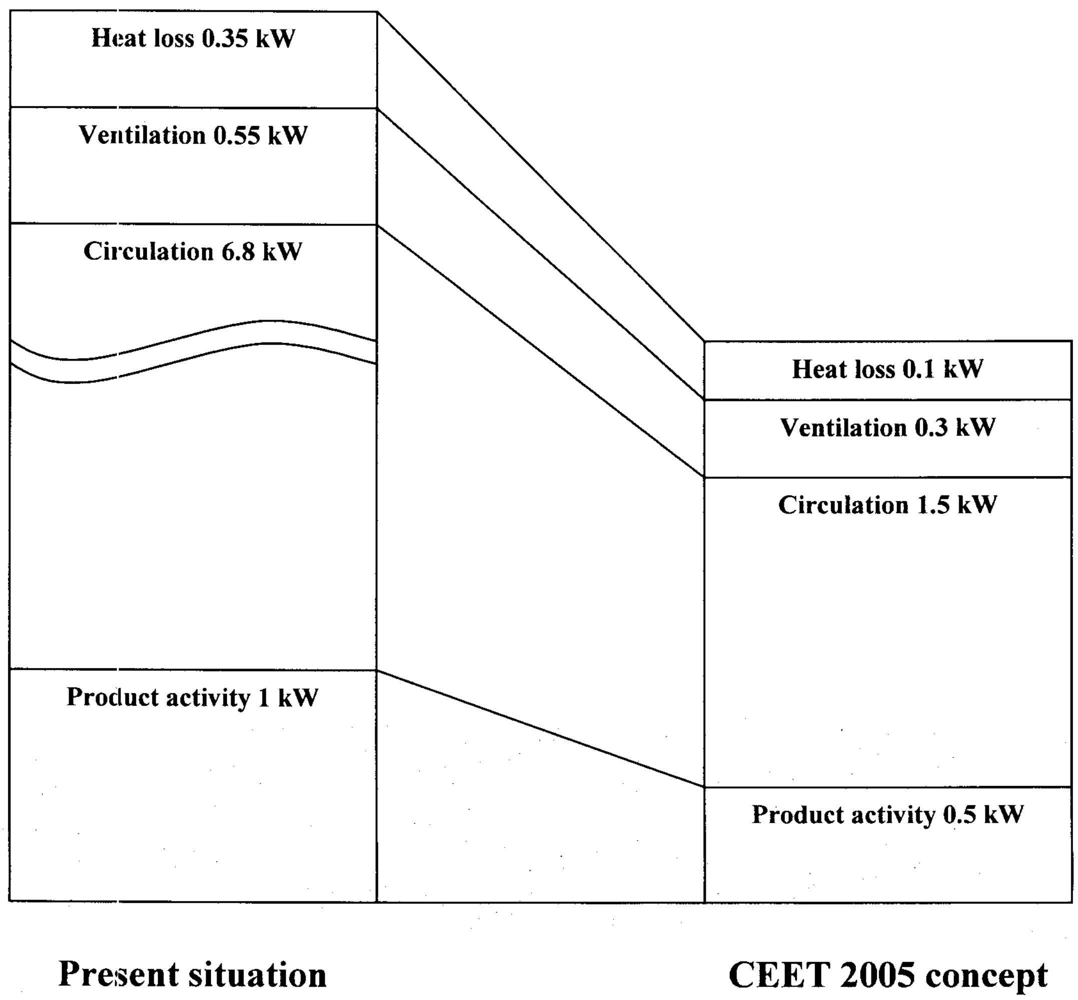
The purpose of this Task will be to refocus the design activity on minimal power consumption while maintaining parameter control capability comparable with current technology.

The frozen capacity design point determines compressor size and consequently motor horsepower. Due to the positive slope characteristic of capacity as a function of box temperature, the design of most system components at the low box condition creates excess capacity at the perishable (chilled) box temperatures (where the majority of the product quality effort of this program will be focused). Consequently, the system is oversized in the chilled range and capacity reduction techniques need to be employed. The type of system employed has a large impact on power consumption. The most efficient systems deployed today use suction pressure modulation. None the less, the power consumption of these systems is still quite high (7000 watts or more) compared to the capacity needed and there is a large opportunity for power reduction (25% or more) with new technologies. Variable speed technology currently being applied to stationary commercial applications will be developed to meet the more demanding environmental requirements of transport refrigeration. While the technology is not new, research into the needed design changes to it for application in a marine, high vibration and shock environment with variable power supplies have not been made. Some research has been made in the US automotive industry with this technology for application to electric cars. Our intention is to build on this research with one of the companies involved with a large US automobile manufacturer and develop a product for the container market. In addition, it is believed possible to improve refrigeration cycle performance for the frozen design point at lower motor horsepower through the application of rotating compression technology and vapour compressor cycle enhancements such that the motor horsepower needed for perishable products is considerably reduced from current technology. Based on the current state of these new technologies and possible improvements within the timeline of this program, evaluations will be made on how to best optimize their integration to achieve lowest power consumption.

Since the fan motors are within the box air flow stream, the motor power consumed to circulate the air is added to the heat load of the box. Any reduction in evaporator fan power decreases total system power and also has a second order effect of reducing system load and consequently compressor power consumption. The total fan power on current units is approximately 1600 watts and while only modest (5-10%) reductions are believed achievable by the use of the same variable speed technology planned for the base of the unit, it is anticipated that additional power reductions can be accomplished with this technology by reducing circulate rates during certain parts of the chain or throughout the chain for certain products. The research carried out in task 2.3 will be the main driver of what circulation rate reductions can be made to minimize evaporator fan power.

For loads requiring other control parameters besides temperature, such as humidity or oxygen, techniques will be investigated to reduce power usage as well.
Relative to humidity control, humidification systems of current application that use controlled droplet atomization of water into the air stream are very power efficient and will not be considered as part of this program. However, several current designs used in the industry employ a reheat style dehumidification system, which uses a considerable amount of power. This system uses the defrost heaters. The control method artificially loads the evaporator resulting in lower coil temperatures and moisture removal with subsequent reheat of the air to setpoint before delivery to the cargo. This imposes a 3000-4000 watt power load on the system. As part of this program new dehumidification concepts will be developed employing air bypass or evaporator size modulation techniques to control evaporator leaving air humidity without use of reheat and there by eliminate most of the defrost heat load for products such as flower bulbs or certain chilled vegetables that are require dehumidification. For the Dutch agricultural industry, which is a major shipper of bulbs and fresh flowers by marine containers, this could result in considerable reduction in environmental pressure.
For loads requiring oxygen control, systems in use today employ either membrane separation or pressure swing adsorption technology to control the level of oxygen. Both use 1-2 horsepower compressors to supply high pressure air to the system for separation of oxygen. In either system, the compressor motor is the dominate power consumer. Lower pressure systems and higher efficiency motors will be investigated as part of this program to determine the feasibility of reducing power consumption on the system without sacrificing oxygen removal rates.

Infrastructure:
Carrier Transicold has it construction and test facilities for climate conditioning equipment in Syracuse, N.Y., USA. P&O Nedlloyd is owner of reefer containers of both 20 and 40 ft and has the technical knowledge to reconstruct the container according to the outcome of this concept. A 40ft container can be conditioned in the facilities of ATO-DLO, in order to realize the desired climate and to analyse air distribution in the container, e.g. filled with pre-stored products. Thereby, small-size windtunnel facilities and a high tech conditioning cell are available at the ATO premises.



Efforts in Task 2 will lead to a substantial reduction of the energy load of a container. In the figure above, the contributions of the factors to the energy consumption is displayed for the current situation and for the situation in the CEET 2005 concept. The starting point for these calculations is transport of agro products in a 40 ft high cube container. Inside temperature setting 5°C, outside temperature 15°C, ventilation 100 m^3/h, circulation 5000 m^3/h. The different contributions of improvements in the refrigeration unit design are taken into account in each factor.
Next to these technical factors on the energy consumption of a container, also logistic factors play an important role. The project aims at an significant shift to less energy expensive transport modes, with great economic and ecological merits. Effects of logistic are not taken into account for this figure.

Task 3 **Development of a robust integrated sustainable energy system (Ecofys, Shell Solar, P&O Nedlloyd, ATO-DLO)**

Key issues: Sustainable energy, hybrid energy systems, energy storage, isolation.

Objectives:
The objective of this task is to develop a system that is capable to deliver the required energy for the climate control system of the transported products.

Detailed scientific programme
While in Task 1 methods are developed to reduce the energy status of the products and in Task 2 methods are developed to reduce the energy consumption of the climate control system, in this Task 3 research is focussed on providing the energy demand with sustainable energy sources.
At present, the energy consumption of a 40ft high cube reefer container, loaded with a product like apples, typically is 5 to 10 kW, of which about half is due to the product activity and about half is due to ventilation and circulation. As a result of the research performed in Task 1 and 2, the energy consumption should be substantially reduced to a typical value of 2 kW, see figure 6. Covering the roof of the container with state of the art solar panels, with an efficiency of 12%, yields an average power of 0.3 kW with a 3 kW peak load, under Western European conditions. The use of solar panels therefore does not seem to be the only option as an energy system.
Besides, present crystalline solar panels are quite vulnerable and do not seem to fit in the rough container transport world. Amorphous solar panels are less sensitive, but at present only have an efficiency of about 4%. Robustness of the energy provision and handling of the container will, therefore, be researched.
Solar panels seem a good starting point to develop a energy system for an autonomous agro-container (see e.g. Thomas, 1997). In order to prevent shortage of energy, energy storage and alternative energy resources (e.g. hybrid systems (Seeling, 1997)) must be investigated.

Research therefore focuses on the following main issues:

Task 3.1 Development of an energy provision concept.
What resources (PV, bio-diesel, hybrid) are best suitable for the container concept. How can abundant energy best be stored, given boundary conditions on available space, logistics etc..

Task 3.2 Improvement of the robustness of the energy system.
Investigation of the specific mechanical burden put on the system. Possibilities for integration given logistic boundary conditions. Optimization of robustness versus material use.

Task 3.3 Energetic optimization of the box design.
Research on possibilities for isolation improvement. Minimisation of heat-bridges given boundary conditions on mechanical strength of the design.

Task 3.4 Development of energy system models.
Energy system models are needed for an adequate total system control (see Task 7).

Infrastructure:
Shell Solar has production lines for PV systems. Ecofys has facilities to test PV systems under variable environmental conditions. ATO-DLO is equipped with software tools to optimize the energy configuration of the container.

Task 4 Development of slow-release systems for green chemicals (Carrier Transicold, P&O Nedlloyd and ATO-DLO)

Key issues: Selection of green chemicals, dose-response relations, application technology

Objectives:
The goal of this task is to implement the **use of green chemicals** in the climate control system of the container. In principle this is an **energy efficient means of preventing deterioration** of the perishable product, since the requirements for temperature and humidity control can become less strict.

State of the art
Over the last decade a burst of research activity by academia has been directed on the development of effective alternative crop protectants. Very often these are sought for in natural sources (i.e. living organisms ranging from microorganisms to insects, plants and animals) because a wide variety of interesting antimicrobial compounds have been found to function in their natural defence systems. From an agro-industrial point of view, plants are a very obvious source of natural antimicrobials and are known to contain antimicrobial or medicinal metabolites. In many instances, these compounds play a role in the natural resistance or defence against microbial or other diseases. Some have a particular taste or smell, due to which they have already found use in the perfume and fragrance industry. Herbs and spices have been used ever since ancient times as "taste makers" but also as food preservatives. A wealth of literature exists describing their favourable properties and identifying the active components. In general, herbs and spices and several of their active ingredients have been Generally Recognised As Safe (GRAS), either because of their traditional use without any documented detrimental impact or because of dedicated toxicological studies. Their application in postharvest crop protection may be facilitated by this feature although appropriate toxicological evaluations cannot be passed-by in any legislation.
Current investigations at ATO-DLO (e.g. Hartmans *et al.*, 1997; Oosterhaven *et al.*, 1996; Smid *et al.*, 1995; Gorris and Smid, 1995; Smid *et al.*, 1996a; Smid *et al.*, 1996b) concentrate on the development and practical use of plant essential oils that characteristically have a wide spectrum of antifungal activity and thus may be feasible green chemical sources generating alternatives for one of the largest volumes of pesticides used.

Detailed scientific programme:
In this project *green chemicals* derived from plant sources will be selected for postharvest protection of container stored apples, tomatoes and broccoli. For apples the most important postharvest pathogens are *Penicillium expansum* (blue mould), *Botrytis cinerea* (gray mould) and *Monilinia fructigena.* The major pathogens affecting postharvest life of tomato fruit are

Alternaria alternata, *Botrytis cinerea* and *Rhizopus stolonifer* (Sommer *et al.*, 1992). These fungi do not grow when the water activity (a_w) drops below 0.88, 0.93 and 0.93, respectively (Lacey, 1989). Calyces are usually the first part of the tomatoes on which visible growth of fungi. The major fungal postharvest pathogens for broccoli are soft rot bacteria like *Pseudomonas marginalis* (Canaday, 1992)
In general, growth of these fungi is suppressed to a certain extent by elevated levels of CO_2. However, full suppression of growth, or even inactivation is never achieved by modified or controlled atmospheres (high CO_2, low O_2). In addition, modified or controlled atmosphere conditions are always optimized on basis of product quality and not solely on the antifungal effect. Therefore, product derived volatiles with antifungal activity can add to the general antimicrobial effect of modified or controlled atmosphere conditions.

Major postharvest pathogens of apple, tomato and broccoli.

Product	Major postharvest pathogens	Disease
Apple	*Botrytis cinerea* *Penicillium expansum* *Monilinia fructigena*	gray mould blue mould
Tomato	*Alternaria alternata* *Botrytis cinerea* *Rhizopus stolonifer*	gray mould
Broccoli	*Pseudomonas marginalis*	soft rot

Task 4.1 Selection of green chemicals for different products

Recent investigations at ATO-DLO have indicated that among the emitted volatiles a number of these compounds possess significant antifungal activity. From the pool of Head space compounds a number will be selected on basis of their *in vitro* antifungal activity. For apples, growth of *Penicillium expansum*, *Botrytis cinerea* and *Monilinia fructigena* will be monitored in the presence of different concentrations of 10 different aromatic volatiles, using the ATO-DLO assay-system. To investigate if suppression of growth results from fungistatic or fungicidal activity, the three most active compounds will be screened further using a spore-viability assay for again *Penicillium expansum*, *Botrytis cinerea* and *Monilinia fructigena*. This *in vitro* screening procedure will allow us to select at least three apple derived compounds with antifungal activity towards *Penicillium expansum*, *Botrytis cinerea* and *Monilinia fructigena*.

In comparison with apples, the number of volatiles associated with tomatoes and broccoli is limited. Therefore, both product-associated and unrelated aromatic compounds will be tested on the storage pathogens relevant for the respective products. A similar selection procedure will be executed for the selected compounds.

Deliverables

Selection of (product derived) aromatic volatiles with antifungal activity against the major postharvest pathogens of apple, tomato and broccoli.

Task 4.2 In situ *activity of selected plant derived antifungal compounds*

The selected antifungal compounds will be further tested for their efficacy on stored apples, tomatoes and broccoli. This will be done by using laboratory-scale storage experiments under optimal and sub-optimal storage conditions, with and without artificial inoculations of the produce. All *in situ* test will be performed under a normal air atmosphere. Test compounds will be applied at different doses. The antifungal effect of the treatments will be monitored visually and by standard microbiological methods.

Deliverables

The *in situ* screening will provide information about the efficacy of the selected antifungal volatiles when applied on the product. The minimal dose at which full suppression of fungal spoilage occurs will be determined for three products at two different temperatures.

Task 4.3 Phytotoxicity of the selected antifungal compounds

In general, secondary plant metabolites display a variety of biological activities. Compounds may show, in addition to the desired activity (antifungal), an undesired activity such as phytotoxicity. Therefore, all selected compounds with sufficient *in vitro* (see **Task 4.1**) or *in situ* (see **Task 4.2**) antifungal compounds will be screened for phytotoxic effects, to a maximum dose of two-times to concentration at which full suppression of fungal spoilage is observed.

Treated product will be evaluated on basis of relevant quality characteristics such as colour, appearance, browning, and lesions.

Deliverables

Execution of task 4.3 will show the dosing levels at which at the selected antifungal compounds can be safely used with respect to phytoxicity.

Task 4.4 Innovative technology for application and distribution of antifungal volatiles

For scaling up to a full-size container, different delivery systems for application of the volatile antifungal compounds will be screened for performance. Specific attention will be given to the even distribution of the compounds and the monitoring. In the initial test period, the volatiles will be monitored using GC-analysis.

Also, the feasibility of a carrier for controlled release of the selected antifungal volatiles will be envisaged.

Deliverables

An injection system for green chemicals, and eventually a carrier for controlled release, will be obtained.

Infrastructure:

Carrier Transicold has facilities to contruct injection systems for Gr. chem. ATO-DLO has laboratory facilities to test the efficacy of green chemicals on micro-organisms and to determine effect of phytotoxicity.

Task 5 Monitoring the surrounding environment and the product's response (Carrier Transicold, Ecofys and ATO-DLO)

Key issues: Monitoring techniques for product quality and activity, measurement of climate characteristics (spread in conditions, velocities) and distribution of green chemicals.

Objectives:
Measuring and modelling internal and external conditions of the products both before and during transport in order to tune the conditions for obtaining a desired quality at the place of destination with a minimum energy input, in more detail:

1) Determining which processes within the product can be measured non-destructively before and during transport and can be used for optimization of climate control.
2) Determining how the external climate and gas composition should be measured in order to be able to respond adequately to changes in gas composition and local climate variations for maintaining product quality.
3) Modelling and feedback between measurements and processes within the product.

The outcome will be a series of candidate sensor systems that are able to measure the required control and process parameters from the product. However, these sensor systems are boundary dependent (energy consumption, low-cost, employability, robustness, accuracy, sensitivity, precision, size and shape). Furthermore, robust calibration models will be obtained which are suitable to handle product and season variability.

Detailed scientific programme:
Fruits and vegetables are life commodities prone to changes in metabolic homeostasis during storage and transport. These changes are caused by both intrinsic and extrinsic conditions. Metabolic processes reflect these changes and are thus linked to post harvest quality development of fruits and vegetables. It should be noted that development of sensors applicable to relate product quality with internal plant processes is still in its infancy. New sensors for non-destructive testing of metabolic processes related to quality are being researched at present (Proc. Sensors Non-destructive Testing, 1997; Meinders et al, 1997 and 1998) At ATO-DLO a new technique for determining metabolic (photosynthetic) rates based on light absorption has been patented (Genty and Harbinson, 1996; ATO-DLO patent nr. PCT/NL97/00182) and can be used to monitor and predict quality related processes in plant material like rose and cucumbers (Schouten R.E. *et al.*, 1997). Also the application of photo acoustics to determine trace gasses like ethene, which reflect an upcoming change in metabolic homeostasis, have been studied (de Vries *et al.*, 1995b); miniaturization of suitable laser sources (e.g. using OPO's) is currently investigated. Another technique required for product quality monitoring is the class of optical techniques such as infrared and Raman spectroscopy. Especially near infrared imaging (NIRI) spectroscopy appears an excellent candidate (Van den Broek *et al.*, 1997). This technique can detect, in remote sensing, product constituents and moisture (dry matter) of inhomogeneous product samples. Due to the large

main processes	parameter	available sensor	innovative sensor	especially important for	attention to which disorder?	expected benefit to dynamical conditioning	expected benefit to gr. chem. if relevant
respiration	O2	Paramagn.		"all Fr. &Veg."	botrytis	excellent	good
	CO2	IR		apple/pear	browning	excellent	good
	ATP	HPLC			decay		
	electron transport		**PS1**	cucumber, tomato bell pepper			
fermentation	ethanol, acetaldehyde	GC	**photoacoustics**	all fr & veg cut vegetables	browning/skin spot	excellent	
acidification	pH	electrodes		cabbage	off-odors	good	
ethylene synthesis	ethylene	GC	**photoacoustics**	broccoli/kiwi	discoloration	good	
lipid peroxidation	ethane		**photoacoustics**		cavity formation/		
	malondialdehyde	GC			scald/chilling		
radical scavenging	anti-oxidants	HPLC		broccoli	discoloration/	fair	
	enzymes	HPLC			senescence		
photosynthesis	photon		**PS1**	green fruit and vegetables	yellowing	good	
general stress	fluorescent tracers		**marker RNA's**	potted plants all fr&veg		good	
dehydration	H2O		**NIR imaging**	tomato/ bell pepper	shriveling/botrytis	good	good/good
chilling injury	temperature	PT100	**PS1**	cucumber, bell pepper, chicory	yellowing blackening	good	
investation	spores (fungi&bact)		**electronic nose**	all fr & veg	rot	fair/good	excellent
	ethylene		**photoacoustics**	flower (bulbs)			
quality/appearance	color, bruises cracks, putrefaction alteration	UV, VIS, NIR and Raman	**NIR/infrared imaging**	all fr & veg	browning, keeping quality	good	good

Table 4. Summary of main processes and corresponding sensor technology for measuring product quality in relation to its changing environment (see also task 1).

path length, this technique is less sensitive to product contamination on the surface. When the acquired information is combined with that measured from internal product conditions e.g. photosynthesis via PS1, a close monitoring of the product is possible.
In order to control the surroundings of fruits and vegetables at minimal energy input whilst maintaining quality control it will be necessary to know which processes need to be followed. This will be done mainly in Task 1. In this task it will be necessary to determine which processes can be followed non-destructively and which processes can be determined before the start of the transportation in order to know the quality of the products to start with. All processes to be studied can be found in table 4.
The sensor list should be consummated and screened for the required boundary conditions. This allows a consolidated choice of promising sensor candidates and the possibility to combine sensors (sensor fusion). Furthermore, the sensor has to be tested for stability against adaptable product and season variability. Even different climate conditions can influence the sensor measurements. This requires robust sensor systems and accompanying calibration models.
Another important research topic is the location where the sensor systems should be deployed with respect to the complete chain from auction to the final destination. How can the product's history be measured when it enters the container and how must this information be included in the product and climate monitoring during transport?
The main research in this task will be subdivided in 4 sub tasks:

Task 5.1 study which techniques can be utilised to determine primal quality of the products before initiation of transport, in order to off set all subsequent actions

Task 5.2 study which techniques, for quality, climate and energy consumption/production (heat flow, temperature) monitoring, can be utilised within a container environment in a practical way and transfer the necessary information to the system control.

Task 5.3 development of robust sensor systems and incorporation of product, season variability and interaction with the container climate.

Task 5.4 integrated sensor: study which techniques can be further developed and combined to supply the system control with sufficient information to plan environment control.

Infrastructure:
Carrier Transicold is equipped with climate monitoring facilities. ATO-DLO develops plant-response-oriented quality sensors already for some years.

Task 6 Chain Optimization and Marketing Opportunities (NDX, P&O Nedlloyd, ATO-DLO)

Key issues: Chain Optimisation (chain configurations, Distribution concepts, impact on cost development), Market development (development and production costs, market demand; performance indicators; economical, environmental, quality and logistical)

Objectives

The objectives are based on the merits of the multi-modal container and boundary conditions such as product price, trajectory, energy costs and ecological regulations

* Development of an innovative logistic concept around the multi modal container for the core markets
* Development marketing and introduction concepts for the multi modal container in existing logistic concepts
* Both maritime and continental markets will be served equally

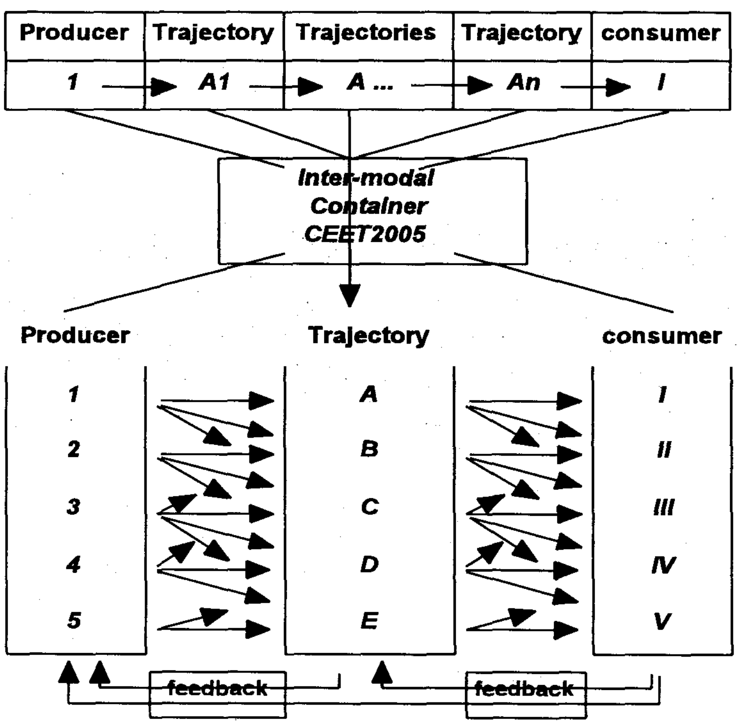
Deliverables:
The outcome of this research project will be:

1. A **strategic dynamic multi modal network model** for assessment of successful combinations of distribution chains and container configurations
2. A detailed overview of relevant **logistical and economical boundaries** for the new container concept to determine the technical implications for the new container concept

State of the art in chain modeling and distribution
Harland *et al.* (1993) propose a supply chain methodology to analyse chains which consists of five stages: 1) understand the network and its environment, 2) identify effectiveness requirements of important end customer groups, 3) identify the chains to be analysed and their core operations, 4) analyse chains and 5) design performance measures. Slats *et al.* (1995) state that operations research models and techniques are well suited to analyse the local performance of an integrated logistic chain but for the analysis of integrated chains suitable OR models should be determined by the information structure required and by the information technology available. Bythaway and Braganza (1992) developed the Cranfield Enterprise Model, which comprises a structured view of the information available in a logistic chain and proposes a functional decomposition of relevant logistic operations.
For reasons of lead time (decay of the produce), reliability and flexibility, nowadays in The Netherlands about 90% of all fresh produce transportation activities concern road traffic (NDL 1997). The share of inland shipping is about 8%, the share of rail transport is very small (less than 1%). For reasons of road congestion and a restrictive government policy towards road transports, in the future multi-modal distribution chains will become important. The share of inland shipping of fruit and vegetables in containers and rail transport will increase which leads to longer lead times (caused by terminal operations) (Tienen et al, 1998; NRLO 1998, Kreutzberger 1997) and the necessity of optimized distribution conditions. New carrier loads are being developed to optimize multi modal transport (RoadRailer) and (inter-)urban distribution (use of small standardized transport, Binsbergen & Visser 1997). Point of attention here is that in a new generation of terminals, container handling is more automated and robotised (Kreutzberger 1997). Also, alternative distribution concepts like underground distribution (Binsbergen en Visser 1997) are being developed. It is important to notice that the success of reusable containers depends largely on the presence of a closed chain. In both directions, the container must have sufficient added value, which places restrictions on the usability of the container concept for certain chains.
Within the framework of food safety and the responsibility of producers for their product facing claims due to improper handling (Fleischmann 1997), tracking and tracing systems become more important and it may be expected that in the near future the movement of and

the conditions within the containers must be monitored.

Detailed scientific program:
Slats *et al.* (1995) state that logistic chain modeling provides support for a large range of applications, such as analysing bottlenecks, improving customer service, configuring new logistic chains and adapting existing chains to new products (e.g. a new multi-modal transport container). The market opportunity for the new technology investigated in general and for the application into an intelligent CA-container in particular depends on the economical and ecological attractiveness of the concept.
A strategic chain model will be built to evaluate the concept on these aspects and optimize chain and container configurations. The model will integrate all relevant distribution concepts and (combinations of) transport modalities and evaluate container usage on a wide variety of aspects and can therefore be regarded as an innovation in itself, see figure 7 at the left site.



Some important input parameters are: quantity and batch size of the transported products, chain configurations, distribution concepts, development and production costs and production cost and market demands on economical and logistical performances. Output parameters are: optimal chain-container configurations, economical performance (e.g. profitability, pay-back time), environmental performance (e.g. emission, transport distances, energy use), logistical performance (e.g. lead time, congestion time, inventory effects, information flows, stacking, overall planning systems) and quality performance (e.g. reduction of spoilage, mixed loads). Chain optimization can have its effect on the configuration of the CEET2005 concept, e.g. in the field of energy transfer between containers. For tracking and tracing systems, the container must be equipped with communication devices which makes monitoring by means of satellite communications possible.

Specification of activities
Task 6.1 Definition of:
* Requirements and performance indicators CEET 2005.
* Selection of Product - Market segments including requirements per product type. (fruit,

vegetables, flowers, plants and other to be defined products)
* Selection of 2 prime logistic chains to be selected (Continental and Maritime).
* Market criteria; geographical, modality, etc.
* Assumptions and scenarios for future development in distribution and technical developments.
* Feasibility and indicative market potential including requirements and limitations.

Task 6.2 Development of;
* A relevant chain concept which covers both maritime and continental transportation based on output task 6.1.
* Marketing concept which should be based on 3 cornerstones:
A.) Requirements of the prime chains including P&O Nedlloyd and NDX intermodal.
B.) Set up to deal with the non transparency of the logistic and transport markets, the specific and individual customer requirements as well as the specifics and limitations from the supply side.
C.) Set up to become a practical and ready to use tool if and when the product will be marketed on a commercial basis.

Task 6.3 Construction and programming of:
* The chain concepts.
* Marketing concept and structure.
* Collect all relevant data for quantitative and qualitative market assessment.

Task 6.4 Matching, testing and feedback:
* Container design versus requirements chain concepts.
* Container design versus economical and other market criteria.
* Feedback and recommendation for container specs and design.

Task 6.5 Scenario and commercial feasibility analysis;
* analysis for designed chains and final product specifications.
* analysis for commercial viability of the product.
* Scenarios for commercial development, including structure and detailed market approach.

Infrastructure
NDX as intermodal oriented joint venture of NS Cargo, Deutsche Bahn and CSX Corporation is the company focused on logistic and marketing aspects of innovative multi-modal transport. P&O Nedlloyd has the knowledge and expertise of integrated sea, road, rail and river transport. ATO-DLO uses software tools, such as *ARENA*, to develop and use up to date scientific models on marketing and logistics to construct and analyze strategic dynamic supply chain alternatives.

Task 7 Development of integrated dynamic control strategies (Carrier Transicold, Ecofys, ATO-DLO)

Key Issues: supervisory constraint handling strategies, adaptive predictive control, non-linear control.

Objectives
The goal of this task is to develop supervisory control strategies for the integrated system. The control strategies must continuously determine the best conditioning strategy to keep the quality of the product at least as good as required. This strategy is based on minimization of energy use; boundary conditions are related to the prescribed transport chain and the type and quality of the produce. A schematic of the control structure is presented in the figure 8 below.

Detailed scientific programme
Based on the knowledge developed in the other Tasks, an overall system model and overall optimisation and control algorithms will be developed. The target of the control strategy is to optimise transport given quality, energy savings and logistics. Only on the base of a proper mathematical description and weighting of these boundary conditions (constraints) an adequate result is possible.

At present, most advanced control algorithms rely on process models to perform the control calculations. However, in industrial systems the models employed either only describe the steady state, or are dynamic linearized black box models (Lee, 1993).

The processes related to the container concept - of biological (the ability of a living creature to adapt to a changing environment), technological and economical nature - can only be mathematically described with dynamic, non-linear, multivariable models. The first development of these models date back to the mid-1980s, to Santa Fe. Scientists like Kaufmann (1991), Holland, Anderson and Arrow shared the vision of a common framework for complexity. They all did research at the edge of order and chaos. However, only recently, practical control strategies and analysis tools for these kind of processes are being developed (Martin Sanchez & Rodellar, 1996, Zheng, 1997).

Using the overall system model, mutual influences of the system and the system environment will be evaluated. The insights in the system behaviour will be used to design system control strategies. Research in first instance will focus on the merits of different control concepts (adaptive model predictive control, generic model control, fuzzy control, extended strategies), given the vast amount of information that will be available. Apart from information from the monitoring system and information imbedded in the system models, also effects of e.g. the current and foreseen weather and of the outside climate will be incorporated. Based on tracking and tracing equipment installed in each container and using information of the planned transport chain, weather forecasts for the duration of the transport will be distilled. This can be based on average global climatic information, but it is envisaged that more detailed information will be available via satellite connections (van Tienen *et al.*, 1997).

The resulting optimisation problem will be investigated. From a scientific point of view, the complex non-linear irreversible interactions between different aspects of the container concept yield a challenging optimisation problem (Duan *et al.*, 1997). In order to evaluate the developed control strategies, stability and performance analyses will be performed over the operation range of the multimodal container.

Research therefore focuses on the following main topics:
Task 7.1 Investigation and analysis of dynamic non-linear control techniques.

Formalisation of the typical aspects of transport control of agricultural products. Definition of the control problem. Choice of a suitable control method.

Task 7.2 Generalisation and integration of sub-models.

Research results achieved in the other Tasks are generalised and mathematically described.

Task 7.3 Development of the system control module.

Evaluation of optimisation techniques, given constraints. Development and implementation of the optimal algorithm.

Task 7.4 Stability analysis and evaluation of the efficiency of the developed algorithms.

Infrastructure:
See mainly other tasks. Especially of importance are software tools to construct adaptive control models, etc. Expertise is available at Carrier Transicold and ATO-DLO.

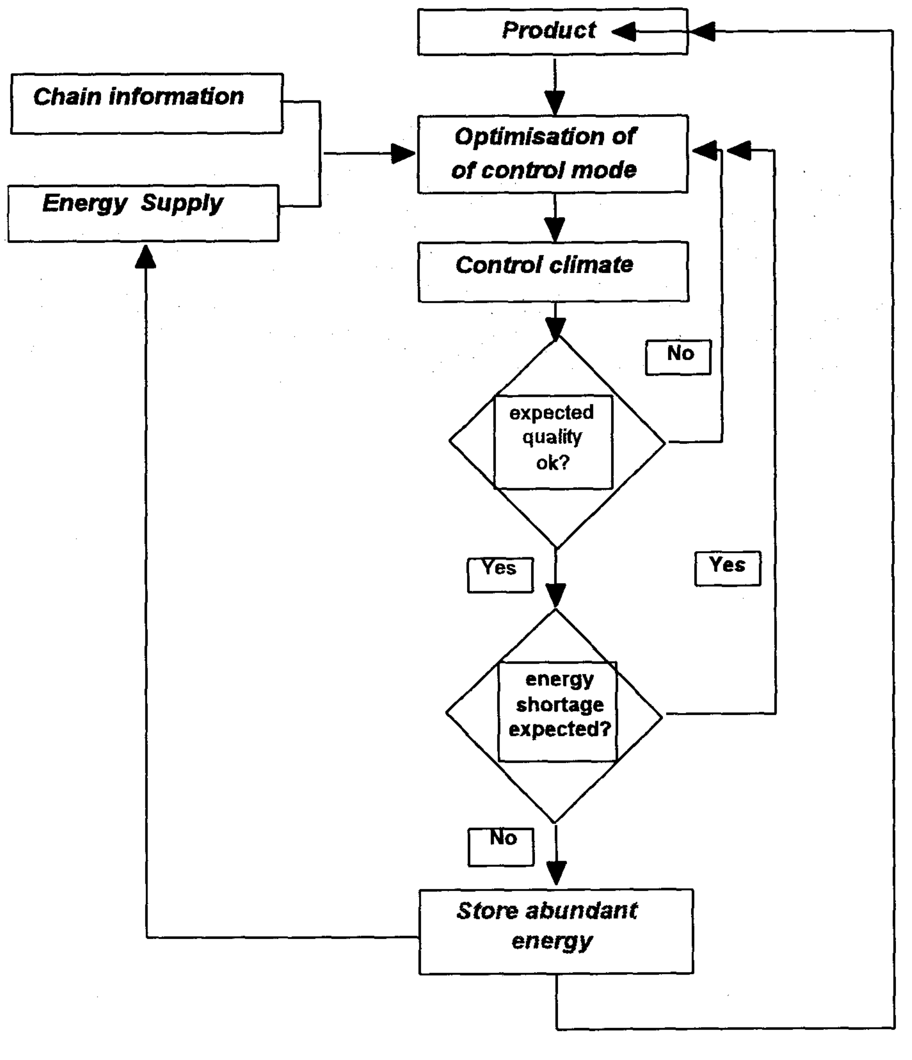


Figure 8. Schematic block diagram of Task 7. Note the structural similarities with figure 1 of this research proposal.

Appendix B: 3.6 Financial aspects

Cost-breakdown for each partner is included:

- P&O Nedlloyd
- NDX Intermodal
- The Greenery International
- Shell Solar
- Carrier Transicold
- Ecofys
- ATO-DLO

Next to this, the overall cost-breakdown for all partners is added.

Cost breakdown

for P&O Nedlloyd (Dfl.)

	Phase 1(6 mth; 1998.75 -2000.25)			Phase 2 (18 mth; 2000.25-2001.75)			Phase 3 (12 mth; 2001.75-2002.75)			**total**	**Subs. (%)**	**Tot. * Subs**	**Partner bijdrage**
	# my	rate		# my	rate		# my	rate	total				
Personnel costs													
Senior researc	0.5	175875	87938	3.5	178888	626108	2	186586	373172	**1087218**			
Material costs						42000				**42000**			
Travelling			2500			7500			5000				
total			**90438**			**675608**			**378172**	**1144218**	**40.0%**	**457687**	**686531**

Notes
Phase 1: 0.5 is over 0.5 year
Phase 2: 3.5 my is spread over 1.5 years (thus, the rate is an average of year 1 and 2)

Expert rate	gross		128700
	social fee		12000
	total		140700
	General management surcharge (25%)		175875
	Yearly increase (3%)	year 1	175875
		year 2	181151.3
		year 3	186585.8

Material cost breakdown:

hardware cost (US$ 20000 à 2.05)	41000
transport costs	1000

ndx intermodal

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O/ref avo 25398/1
Yr/ref OPD/97/311/25/3/98B
Subject Cost break down NDX CEET 2005 project

Direct phone ++ 31- 20 - 3475320
Direct Fax ++ 31- 20 - 3475329

Amstelveen, 25 March 1998

Dear mr. De Vries

Enclosed you find a breakdown of the costs related to the NDX involvement in the CEET 2005 project covering the period 1 October 1998 u/l 1 October 2001.

NDX Estimated cost	Man years	Unit cost	Total in Nlg.
Total man years involved	7,5		
Man years NDX staff	3,5	700	490.000
Man years Third parties *	3,5	1750	1.225.000
Man years NDX Co-ordination activities	0,5	700	70.000
Travel & Accommodation costs			217.000
Cost of supportive materials	P.M		20.000
Equipment, Machinery needed	P.M		20.000
General cost NDX (25% over NDX staff costs)			140.000
Total estimated costs in Nlg.			**2.182.000**

- The estimated costs for third parties are based on the cost level of Erasmus University ETECA project bureau. It could be well possible that also other parties will be involved.
- The involvement of third parties will be mainly focused to the development of a marketing model and/or concept.

Yours sincerely,

A.H. van Ommen
Marketing Manager

NDX intermodal

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O/ref avo 30398/1
Yr/ref
Subject Additional information NDX cost forecast CEET 2005 project

E-mail ndx@ndx.nl

Amstelveen, 30 March 1998

Dear mr. De Vries

In addition to my letter with reference avo 25398/1, from 25 March 1998 I would like to inform you regarding the following:

The relative high amount of travel and hotel expenses is based on:

1.Extensive field research in Europe.
Beside desk research extensive field research is required due to the fact that the European logistics and transport markets are segmented, non transparent and based on very individual and specific requirements. Therefore Interviews have to be executed including cargo owners, transport companies and consignees as well as companies involved in storage and distribution.
2.The planning, organisation and execution of actual testing of the prototype reefer box.
On site preparation, checking and monitoring will require frequent transport of team member throughout Europe.

The NDX cost estimate for the project participation is based on the development of fundamental logistical concepts in relation to the new reefer box. Therefore the assumed level of subsidy is 62.5%.

Yours sincerely,

A.H. van Ommen
Marketing Manager

Cost breakdown

for Shell Solar (Dfl.)

	Phase 1(6 mth; 1998.75 -2000.25)			Phase 2 (18 mth; 2000.25-2001.75)			Phase 3 (12 mth; 2001.75-2002.75)			**total**	**Subs. (%)**	**Tot. * Subs**	**Partner bijdrage**
	# my	rate		# my	rate		# my	rate	total				
Personnel costs													
Senior researc	0.05	185600	9280	0.15	192000	28800	0.1	198400	19840	**57920**			
Material costs									50000	**50000**			
Travelling													
total			**9280**			**28800**			**69840**	**107920**	**40.0%**	**43168**	**64752**

Notes
Phase 1: 0.5 is over 0.5 year
Phase 2: 3.5 my is spread over 1.5 years (thus, the rate is an average of year 1 and 2)

Expert rate	**hour rate**	
	1998	116
	1999	120
	2000	124

Material cost breakdown:	
Dummy systems	0
PV systems in phase 3 for two containers	50000

Ji

Cost breakdown

Transport container 21st century

Rates for The Greenery (Dfl.)

	1999		2000		2001		2002
Senior researcher	302678	3% inflation	311758	3% inflation	321111	3% inflation	330744

	Phase 1(6 mth; 1998.75 -2000.25) # mj			Phase 2 (18 mth; 2000.25-2001.75) # my			Phase 3 (12 mth; 2001.75-2002.75) # my			total	Subs. (%)	Tot. * Subs	Partner bijdrage
Personnel costs													
Senior resea	0.05	302678	15134	0.125	316435	39554	0.075	325928	24445	**79133**			
Material costs						67500			72500	**140000**			
total			**15134**			**107054**			**96945**	**219133**	**55.0%**	**120523**	**98610**

Notes

Phase 1: 0.05 is over 0.5 year
Phase 2: 0.15 my is spread over 1.5 years

EET subsidy percentage: 55% is an average of 75% fundamental research (62.5% subsidy) and 25% industrial research (40% subsidy)

Material (=agro products) cost breakdown:

Essential information 1 pallet = 30 boxes = 1000 Dfl.
1 box = 80 apples = 16 kg (averaged)

Storage parameters Temperature (T)
oxygen, carbondioxide
relative humidity (RH)
green chemicals (Gr.Ch.)
4 different products
] combinations of these parameters and time resolved (dynamic adjustment)

Standard experiment for 2 times 2 different conditions (T1, T2, Gr. Ch.1, Gr. Ch. 2) for apples:
2 (cultivar origins) x 4 (storage conditions) x 4 (product evaluation) x 15 (number of products) x 2 (repetition) = 1000 apples = 12 boxes = 1/3 pallet

2.5 years of experiments in storage facilities of ATO-DLO (670 l. static container system & 60 l. flow-through container & one 20ft container):

A. 2 cells with flow-through containers of 60l l.
2 (T controlled storage cell) x 12 (flow-through containers) x 60/2 (volume container/ load efficiency) x 104/4 (# weeks over 2 years/ #weeks per experiment) =
20000 kg of apples = 1200 boxes = 40 pallets = 40 kDfl. (over 2 years)

B. 2 cells with static containers of 670 l
2 (T controlled cells) x 8 (static containers) x 8 (boxes per container) x 104/8 (#of weeks over 2 years/#of weeks per experiment) =
1600 boxes = 50 pallets = 50 kDfl. (over 2 years)

C. 20 ft container
26 cubic meter = 26000 kg/ 3 (product/ load efficiency) x 3 experiments (3 cultivars) = 50 pallets = 50 kDfl. (over 0.5 year)

Thus total product costs are: 40 + 50 +50 = 140 kDfl

Carrier Transicold Work estimate

Description	Timing	Manmonths	Labor Cost (Guilders)	Travel (Guilders)	Material (Guilders)	Total (Guilders)
Phase 1 : Preparation	11/97 - 10/98	0.75	20270	8000	0	28270
Phase 2 : Conditioning + Product Quality	10/98 - 12/00					
Temperature control System volume control and power reduction						
1. Control circulation		18	486490	40000	40000	566490
Develop VS drive Develop SW control algorithm						
2. Control Ventilation						
Develop flow control Develop SW algorithm		22	594598		2000	596598
3. Develop low power Humidity control						
Optomize control logic Develop non heater based De-humid.		0.75 3	20270 81082		500	20270 81582
4. Establish CA controls		1.5	40541			40541
5. Modify CA/Humidity SW		5	135136		2000	137136
6. Optomize energy consumption		21.5	581085			581085
Develop VS compressor drive Develop SW algorithm for lowest energy						
Evaluate low pressure membrane		2.5	67568	4000	2000	73568
Metric PSA power		4	108109	4000		112109
Develop low power CA		26	702707	12000	12000	726707
Develop energy source interface		3.5	94595			94595
7. Integrate Subsystem controls		17	459462			459462
Green chemical control						
1. Automatic injection and volume control of amount		12	324326			324326
Phase 3 : Test container	12/00 - 1/01	6	162163		24000	186163
Optomize system control		6	162163		16000	178163
Phase 4 : Field trial of final design	12/01 - 12/02	4	108109		36000	144109
				Grand Total		4351175

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Work estimate

1. Control circulation		1	I	18	486490	40000	40000	566490
Develop flow control		1	I	22	594598		2000	596598
6. Optomize energy consumption		1	I	21.5	581085			581085
Develop low power CA		1	I	26	702707	12000	12000	726707
7. Integrate Subsystem controls		1	I	17	459462			459462
1. Automatic injection and volume control of amount		1	I	12	324326			324326
Phase 3 : Test container	12/00 - 1/01	1	I	6	162163		24000	186163
Optomize system control		1	I	6	162163		16000	178163
Phase 1 : Preparation	11/97 - 10/98	1	I	0.75	20270	8000	0	28270
Optomize control logic		2	P	0.75	20270			20270
Develop non heater based De-humid.		2	P	3	81082		500	81582
		2						
4. Establish CA controls		2	P	1.5	40541			40541
5. Modify CA/Humidity SW		2	P	5	135136		2000	137136
Evaluate low pressure membrane		2	P	2.5	67568	4000	2000	73568
Metric PSA power		2	P	4	108109	4000		112109
Develop energy source interface		2	P	3.5	94595			94595
Phase 4 : Field trial of final design	12/01 - 12/02	2	P	4	108109		36000	144109
Description	Timing	3	Subsity Category	Manmonths	Labor Cost	Travel	Material	Total
Phase 2 : Conditioning + Product Quality	10/98 - 12/00	3						
Temperature control System volume control and power reduction		3						
Develop VS drive		3						
Develop SW control algorithm		3						
2. Control Ventilation		3						
Develop SW algorithm		3						
3. Develop low power Humidity control		3						
Develop VS compressor drive		3						
Develop SW algorithm for lowest energy		3						
Green chemical control		3						
Total Industrial research				129.25	3493265.6	60000	94000	3647266
Total Precompetitive development				24.25	655409.6	8000	40500	703910
			(R, I, P)		(Guilders)	(Guilders)	(Guilders)	(Guilders)
Grand Total								4351175

Total manmonths/ Total manyears	154	13			
Total labor cost (Guilders)		4148675			
Total labor cost (US $)		2053800			
Total travel cost (Guilders)			68000		
Total travel cost (US $)			33663		
Total material cost (Guilders)				134500	
Total material cost (US $)				66584	

Subsity calculation check 4351175

R = pure research, no commercial product development intended 62.5%

I = industrial research, activities leading to the devleopment of technology and products to be commercially introduced (40%)

P = pre competitive devleopments, improvements in existing technology for competitive advantage (25%)

Total Industrial research from above =	
at 40% =	1458906
Total precompetitive above =	
at 25% =	175977
Total subsity if work was all done in Holland (Guilders)	1634884
Total subsity if all work was done in US (10% of total EET award , 7,000,000 guilders) = 700,000 guilders	700000

Agro-Container Concept of the 21st Century , EETP97132
EET: Economy , Ecology and Technology Program

ID	Task Name	Duration	Start	Finish	Predecesso
1	**Agro Container**	**775d**	**Thu 10/1/98**	**Wed 9/19/01**	
2	**1. Product Quality**	1d	Thu 10/1/98	Thu 10/1/98	
3	**2. Optimize Climate Control**	**475d**	**Thu 1/21/99**	**Wed 11/15/00**	
4	**Control ventilation**	**180d**	**Thu 1/21/99**	**Wed 9/29/99**	
5	Design Flow Control	80d	Thu 1/21/99	Wed 5/12/99	
6	Develop Control Algorithm	100d	Thu 5/13/99	Wed 9/29/99	5
7	**Control Circulation**	**140d**	**Thu 5/13/99**	**Wed 11/24/99**	
8	Develop VS Evap Motor Drive	40d	Thu 5/13/99	Wed 7/7/99	5
9	Develop SW control algorithm	100d	Thu 7/8/99	Wed 11/24/99	8
10	**Develop Low Power Humidity controls**	**105d**	**Thu 7/8/99**	**Wed 12/1/99**	
11	Establish Optomized Humidification contrc	5d	Thu 11/25/99	Wed 12/1/99	9
12	Develop Non Heater based De-Humidifica	60d	Thu 7/8/99	Wed 9/29/99	8
13	Establish CA controls	30d	Thu 12/2/99	Wed 1/12/00	11
14	Modify CA and Humidity SW	100d	Thu 1/13/00	Wed 5/31/00	13,12
15	**Optimize Energy Consumption**	**245d**	**Thu 9/30/99**	**Wed 9/6/00**	
16	Develop VS Compressor Drive	40d	Thu 9/30/99	Wed 11/24/99	12
17	Develop SW algorithm for lowest energy	100d	Thu 11/25/99	Wed 4/12/00	16
18	Evaluate low pressure membrane	15d	Thu 11/25/99	Wed 12/15/99	16
19	Metric PSA power consumption	30d	Thu 12/16/99	Wed 1/26/00	18
20	Develop Low Power CA	160d	Thu 1/27/00	Wed 9/6/00	19

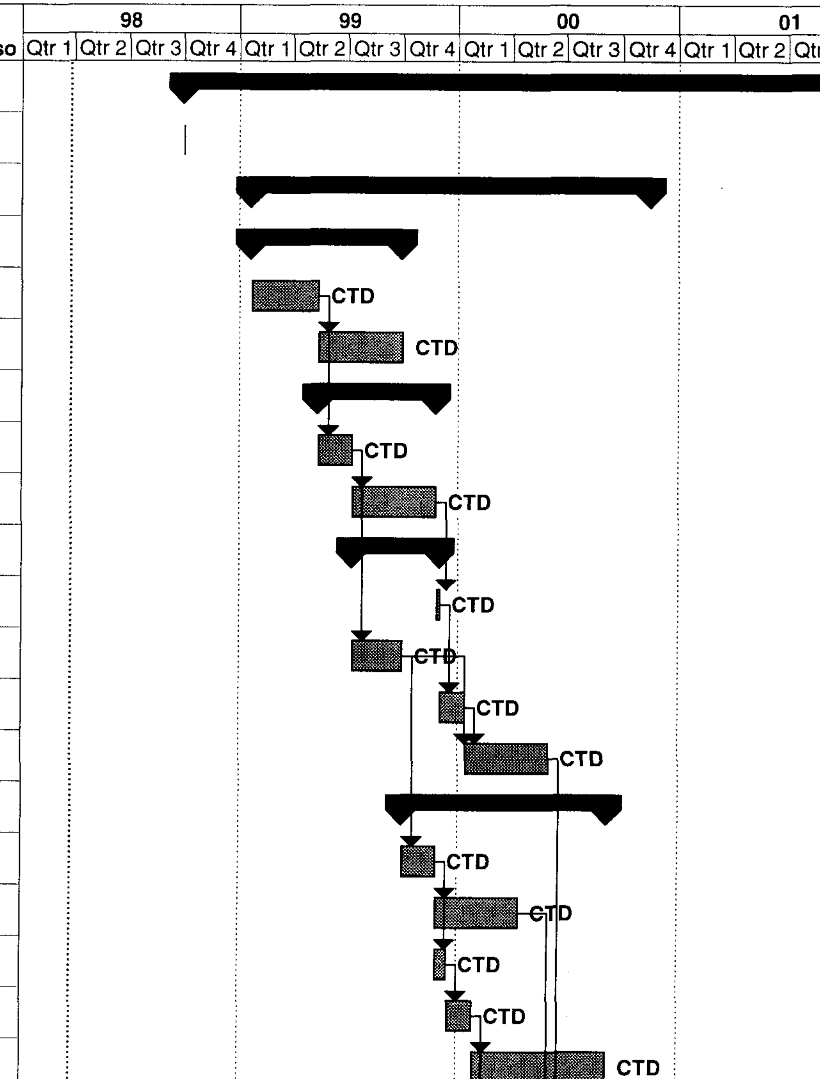

Figure 4
Carrier Transicold
Date: Wed 3/25/98

Task
Progress
Milestone
Summary
Rolled Up Task
Rolled Up Milestone
Rolled Up Progress

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Agro-Container Concept of the 21st Century , EETP97132
EET: Economy , Ecology and Technology Program

ID	Task Name	Duration	Start	Finish	Predecesso
21	Develop Energy Source Interface	30d	Thu 1/27/00	Wed 3/8/00	19
22	Integrate Subsystem controls	120d	Thu 6/1/00	Wed 11/15/00	17,14
23	**3. Develop Sustainable Energy System**	1d	Thu 10/1/98	Thu 10/1/98	
24	**4. Develop Slow-Release System**	**220d**	**Thu 11/16/00**	**Wed 9/19/01**	
25	Develop & Test in Container	220d	Thu 11/16/00	Wed 9/19/01	22
26	**5. Develop Process Monitoring Systems**	**80d**	**Thu 3/9/00**	**Wed 6/28/00**	
27	Green chemical distribution	80d	Thu 3/9/00	Wed 6/28/00	21
28	**6. Chain Optimization**	1d	Thu 10/1/98	Thu 10/1/98	
29	**7. System Control**	**60d**	**Thu 4/5/01**	**Wed 6/27/01**	
30	Climate Conditioning	60d	Thu 4/5/01	Wed 6/27/01	25SS+100d

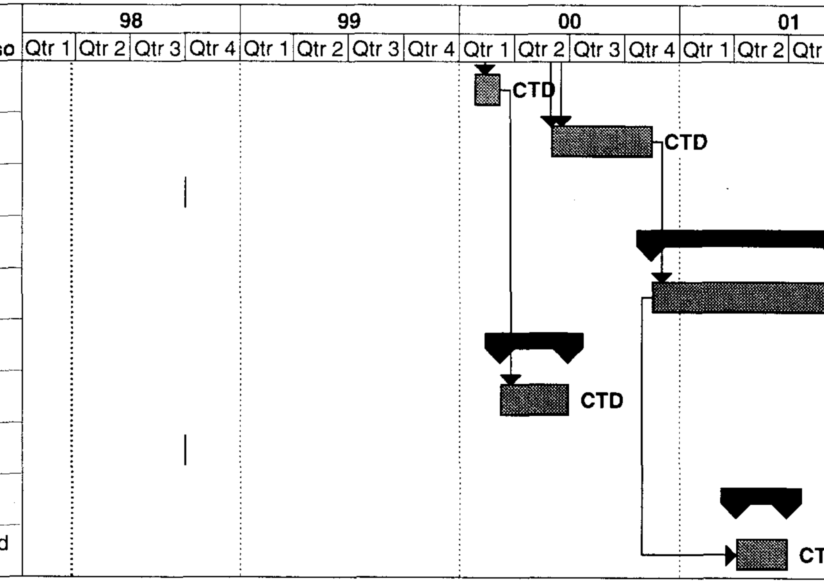

Figure 4
Carrier Transicold
Date: Wed 3/25/98

Task | Progress | Milestone | Summary | Rolled Up Task | Rolled Up Milestone | Rolled Up Progress

Cost breakdown

for Ecofys

Fundamental research (62.5%)

task number	number hours	rate (Dfl)	total (Dfl)	subsidy	Contr EET	Contr. Ecofys
2	441	170	74970			
3	1912	170	325040			
5	735	170	124950			
7	441	170	74970			
total	3529	170	599930	62.5%	374956	224974

Note: hours are equally spread out of 3 years

CEET2005

Cost breakdown

Rates for ATO-DLO (Dfl.)

	1998		1999		2000		2001		2002		2003
Senior researcher	300000	2% inflation	306000	2% inflation	312120	2% inflation	318362.4	2% inflation	324729.6	2% inflation	331224.2
Researcher	230000		234600		239292		244077.8		248959.4		253938.6
Senior assistent	180000		183600		187272		191017.4		194837.8		198734.5

	Phase 1(6 mth; 1998.75 -1999.25) # mj			Phase 2 (18 mth; 1999.25-2000.75) # my			Phase 3 (12 mth; 2000.75-2001.75) # my			total	Subs. (%)	Tot. * Subs	Partner bijdrage
Task 1 Product quality													
Senior research	0.1	303000	30300	0.5	309060	154530	0.4	316802	126721	**311551**			
Researcher		232300	0	1	236946	236946	0.7	242881	170017	**406963**			
Senior assistent	0.1	181800	18180	1	185436	185436	0.75	190081	142561	**346177**			
Material costs						253000			142000	**395000**			
Travelling costs			500			3000			2500	**6000**			
total	0.2		**48980**	2.5		**832912**	1.85		**583798**	**1465690**	**62.5%**	**916057**	**549634**
Task 2 Climate conditioning													
Senior research	0.3	303000	90900	0.6	309060	185436	0.4	316802	126721	**403057**			
Researcher		232300	0	2.05	236946	485739	1.2	242881	291458	**777197**			
Senior assistent		181800	0		185436	0		190081	0	**0**			
Material costs			5000			80000			29500	**114500**			
Travelling costs			500			3000			2500	**6000**			
total	0.3		**96400**	2.65		**754175**	1.6		**450178**	**1300754**	**62.5%**	**812971**	**487783**
Task 3 Energy													
Senior researcher		303000	0	0.15	309060	46359	0.1	316802	31680	**78039**			
Researcher		232300	0		236946	0		242881	0	**0**			
Senior assistent		181800	0		185436	0		190081	0	**0**			
Material costs										**0**			
Travelling costs										**0**			
total	0		**0**	0.15		**46359**	0.1		**31680**	**78039**	**62.5%**	**48774**	**29265**
Task 4 Green chemicals													
Senior research	0.1	303000	30300	0.05	309060	15453	0.05	316802	15840	**61593**			
Researcher		232300	0		236946	0		242881	0	**0**			
Senior assistent	0.3	181800	54540	0.5	185436	92718	0.6	190081	114049	**261307**			
Material costs			3000			12000			20000	**35000**			
Travelling costs			500			500			500	**1500**			
total	0.4		**88340**	0.55		**120671**	0.65		**150389**	**359400**	**62.5%**	**224625**	**134775**
Task 5 Monitoring													
Senior research	0.2	303000	60600	0.85	309060	262701	0.6	316802	190081	**513382**			
Researcher		232300	0	0.45	236946	106626	0.4	242881	97153	**203778**			
Senior assistent		181800	0	0.35	185436	64903	0.25	190081	47520	**112423**			
Material costs						125000			27000	**152000**			
Travelling costs			200			3000			2000	**5200**			
total	0.2		**60800**	1.65		**562229**	1.25		**363754**	**986783**	**62.5%**	**616740**	**370044**
Task 6 Logistics													
Senior research	0.1	303000	30300	0.1	309060	30906	0.05	316802	15840	**77046**			
Researcher		232300	0	1	236946	236946	1	242881	242881	**479827**			
Senior assistent		181800	0		185436	0		190081	0	**0**			
Material costs						17500			2500	**20000**			
Travelling costs						2500			3000	**5500**			
total	0.1		**30300**	1.1		**287852**	1.05		**264221**	**582373**	**62.5%**	**363983**	**218390**
Task 7 System control													
Senior researcher		303000	0	0.3	309060	92718	0.45	316802	142561	**235279**			
Researcher		232300	0	0.5	236946	118473	0.5	242881	121441	**239914**			
Senior assistent		181800	0		185436	0		190081	0	**0**			
Material costs						12000				**12000**			
Travelling costs										**0**			
total	0		**0**	0.8		**223191**	0.95		**264002**	**487193**	**62.5%**	**304495**	**182697**

Management over 3 years			
project leader	1.65	312120	514998
ATO- coordinatc	0.5	312120	156060
travelling			20000

	total	Subs. (%)	Tot. * Subs	Partner bijdrage
TOTAL COSTS ATO-DLO OVER THREE YEARS	**5951290**	**62.5%**	**3719556**	**2231734**

Material costs for ATO-DLO

Task	Consumables		Equipment					
number	item	per task in Dfl	item	Price Dfl.	% in use	depreciation per year	depreciation per 2.5 years	per task
1 (& 4,5,6)	flow through	48214	flow through (2 rooms)	1452716	80		93539	395166
see below	static	40714	static (2 rooms)	1000000	80		73587	
	cold room (2)	32143	cold room (2 rooms)	12000	80		12000	
	shelf life-room	7143	shelf life-room (1 room)	15000	55		2576	
	teflon tubing, connections,		HPLC	90160	10	1800	4500	
	calibr. gas, etc	25000	GC	52103	40	6600	16500	
	photacoustic cons	5000						
	CO2/O2 microsensor	1250						
	software (origin, etc.)	3000						
	30 respiration cuvettes	30000						
2	high tech cell	17500	high tech cell	25000	30		2000	114500
	modification high tech cell	10000						
	modification windtunnel	10000						
	climate sensors	25000						
	CFD software licences	50000						
4	microbiol. media	22562	autoclaph	40000	20	1600	4000	35000
	gases		flow board	25000	20	1000	2500	
	buffers		incubator	12000	30	720	1800	
	reagentia		cool-incubator	16000	20	640	1600	
	plates		water basket	800	15	24	60	
	pipettes		microscope	5000	10	100	250	
	green chem.		balance	5500	10	110	275	
			refrigerator	1680	45	151.2	378	
			ice-maker	3000	5	30	75	
			spectrophotometer	20000	15	600	1500	
5	NMR rental	20000	VIS-NIR spectra camera	94000	100	18800	47000	152000
	sensor elements PS1	25000	Electronic nose (hardware)	50000	100	10000	25000	
	variable sensor arrays	20000						
	licences (lab-view, neural network box tool, etc)	15000						
6	1 computer	4750						19750
	software licences	15000						
7	Matlab/simulink software l	12000						12000
all tasks						**Grand total**		**728416**

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3.2 Total budget

	Fundamental Research	Industrial Research	Pre-competative Research	Total
Personnel costs				
ATO-DLO	5178590	0	0	5178590
NDX Intermodal	560000	0	0	560000
P&O Nedlloyd	0	869774	0	869774
The Greenery	4870	58436	0	63306
Shell Solar	0	46336	0	46336
Ecofys	599930	0	0	599930
Carrier Transicold				see below
total (excl. Carrier)	6343390	974546	0	7317936
Consumables costs				
ATO-DLO	439276	0	0	439276
NDX Intermodal	20000	0	0	20000
P&O Nedlloyd	0	42000	0	42000
The Greenery	140000	0	0	140000
Shell Solar	0	50000	0	50000
Ecofys	0	0	0	0
Carrier Transicold				see below
total (excl. Carrier)	599276	92000	0	691276
Equipment costs				
ATO-DLO	289423	0	0	289423
NDX Intermodal	20000	0	0	20000
P&O Nedlloyd	0	0	0	0
The Greenery	0	0	0	0
Shell Solar	0	0	0	0
Ecofys	0	0	0	0
Carrier Transicold				see below
total (excl. Carrier)	309423	0	0	309423
Costs of third parties				
ATO-DLO	0	0	0	0
NDX Intermodal	1225000	0	0	1225000
P&O Nedlloyd	0	0	0	0
The Greenery	0	0	0	0
Shell Solar	0	0	0	0
Ecofys	0	0	0	0
Carrier Transicold	0	0	0	see below
total (excl. Carrier)	1225000	0	0	1225000
Travel & accomodation costs				
ATO-DLO	44000	0	0	44000
NDX Intermodal	217000	0	0	217000
P&O Nedlloyd	0	15000	0	15000
The Greenery	0	0	0	0
Shell Solar	0	0	0	0
Ecofys	0	0	0	0
Carrier Transicold				see below
total (excl. Carrier)	261000	15000	0	276000
General Costs				
ATO-DLO	0	0	0	0
NDX Intermodal	140000	0	0	140000
P&O Nedlloyd	0	217444	0	217444
The Greenery	1218	14609	0	15827
Shell Solar	0	11584	0	11584
Ecofys	0	0	0	0
Carrier Transicold				see below
total (excl. Carrier)	141218	243637	0	384855
Carrier Transicold				
Personnel costs	0	3493266	655410	4148676
Total material costs	0	94000	40500	134500
Travelling	0	60000	8000	68000
General costs	0	included	included	0
total for Carrier Transicold	0	3647266	703910	4351176
Grand total	**8879307**	**4972449**	**703910**	**14555666**
Requested subsidy for:				
Consortium excl Carrier Transicold	5549567	530073	0	6079640
Carrier Transicold	0	700000	0	700000
Total requested subsidy	**5549567**	**1230073**	**0**	**6779640**
Total partner contribution	**3329740**	**3742376**	**703910**	**7776026**

Hereby agreed and signed by all Parties,

P&O Nedlloyd B.V.

Rotterdam, the Netherlands

Mr. D.J. Marjoram
General Manager Engineering and Maintenance International Container Management

....
(date)

NDX Intermodal B.V.

Amstelveen, the Netherlands

Mr. H. Apeldoorn
Financial Director

....
(date)

Shell Solar Energy B.V.

Helmond, the Netherlands

Dr. G. Boxhoorn
General Manager

....
(date)

The Greenery International

's-Hertogenbosch, the Netherlands

Mr. W.L.Th.A. van der Mee
President and C.E.O.

....
(date)

Carrier Transicold Company

Syracuse, New York, USA

Mr. W.P. Kistner
Director of Container Engineering

....
(date)

Ecofys Energy and Environment

Utrecht, the Netherlands

Dr. A.J.M. van Wijk
Director

....
(date)

ATO-DLO

Wageningen, the Netherlands

Dr. H.J. Huizing
Director

....
(date)

Carrier Transicold Company

Syracuse, New York, USA

Richard Laubenstein

Mr. R. Laubenstein
Vice-president of Container
Products Group

3/27/98
....
(date)

Ecofys Energy and Environment

Utrecht, the Netherlands

Dr. A.J.M. van Wijk
Director

....
(date)

ATO-DLO

Wageningen, the Netherlands

Dr. H.J. Huizing
Director

......30/03/'98..........
(date)