ATO-DLO

CEET2005

Management report of the period of 1-10-98 to 1-4-99

CONFIDENTIAL

Consortium:
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P&O Nedlloyd, P. Eekel
Carrier Transicold, T. Gaubatz
Ecofys, H. Opdam
Shell Solar Energy B.V., J.W. Hendriks
The Greenery International, J. Smits

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Contents

The Consortium conducts 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.

Work plan

1. Work carried out

1.1 Summary

Within the first phase, i.e. preparation phase, the work has been focused on defining a work plan in which all tasks are separately scheduled and interrelated, according to the project proposal. Consequently, the practical results are limited. Preliminary practical experiments have been carried out concerning controlled ventilation hardware (Carrier Transicold), selection plus first efficiency tests of green chemicals (ATO task 4), and facility trials.

1.2 Introduction

The CEET2005 project is focused to substantially reduce energy within the transport sector, according to EET theme 4. In order to realise this aim for containerised transport of agricultural products, an innovative stand-alone intermodal container will be developed based on sustainable energy. Key tasks are maintenance of product quality, optimal climate conditioning, energy savings, application of green chemicals, integration of climate and product sensors, logistics and overall system control.

The here presented report describes the work carried out in the preparation phase, thus the work plan for each task individually (mainly phase 2) and the definition of task interaction (task 7 phase 3). Also preliminary results are shown. Most challenging has been the multidisciplinary approach and discussions of scientists form plant physiology, biochemistry, microbiology, biophysics, mechanical engineering, thermodynamics, material science and logistics and marketing, activities reflected in the defined tasks.

The interaction of main issues (chosen products, container characteristics, indoor and outdoor climate and logistics) and the various tasks is described below, as outcome of discussions in the preparation phase.

1.3 Project layout

The work plan is described at the end of this report. The following persons have made contributions to the work carried out and this report:

Carrier Transicold:	T. Gaubatz, R. Kobor	
P&O Nedlloyd:	P. Eekel, E. v.d. Heuvel	
The Greenery International:	J. Smits	
Ecofys:	H. Opdam, J. Schoonderbeek	
Shell Solar Energy B.V.:	J.W. Hendriks, H. v.d. Leeuw	
ATO-DLO:	H. de Vries	M. van Ooijen
	J. Sillekens	J. Ruijsch van Dugteren
	R. v.d. Boogaard	M. Sanders
	W. v.d. Broek	R. v.d. Sman
	J. Harbinson	E. J. Smid
	S. Hoogerwerf	M. Strous
	E. de Jonge	S. Tromp
	O. van Kooten	G. Verdijck
	P.P.L.A. de Leeuw	J. Verschoor

	task 1 (product Q)	task 2 (climate control)	Task 3 (energy)	task 4 (gr. Chemicals)	task 5 (sensor)	task 6 (logistics)
Main chosen products: Apple	Dynamic O2 (<1%)/T (1C) profile RH (90-95%) Browning/ skin spots gray/blue mould	product-micro climate modelling air flow velocity/ homogenous	Reduction heat (ATP) of product:..kW Adaptation to changed climate: ..kW Delay CA, post-storage regime:.. kW Product as temperature buffer: .. kW	3 spoilage micro-org. 6 gr. Chem. Selected: *E-2-hexenal, decanal,* *hexylacetaat, ethylhexanoaat,* *geraniolo, E2pentenal*	O2/Ethanol:O2/CO2/volatile sensor Spore/substances: light scattering	current storage: < 1 year picking time: sept. traject: NL to Russia, worldwide means: boat, train
Tomato (also bunch-tomato)	R.H.vs.T(8(ripe)-10-15(unripe)C) Minimum O2 below 3-5% Impact elevated CO2 softening/shriveling chilling injury gray mould	product-micro climate modelling air flow velocity/ homogenous	Heat dissipation at high temperature Impact relative humidity control	3 spoilage micro-org. 4 gr. Chem. Selected: *decanal, E2hexenal,* *cinnamaldehyde*	Ethanol, ethylene: volatile sensor Spore/substances: light scattering	< 28 days picking: continuous NL-Spain to USA-Asia-South Am. means: train/truck future: boat
Chicory	Dynamic O2 /T (0C) profile blackening rot	product-micro climate modelling air flow velocity/ homogenous	Reduction heat (ATP) of product:..kW Adaptation to changed climate: ..kW Delay CA, post-storage regime:.. kW Product as temperature buffer: .. kW		Ethanol Spore/substances: light scattering	< 28 days picking: continuous NL-Spain to USA-Asia-South Am. means: ?
Other products (later stage) Cucumber	R.H. vs. T soft neck/ yellowing/ chilling injury					< 14 days NL to USA: most welcome
Strawberries	R.H. vs. T chilling injury			2 spoilage micro-org. Hurdle technology		15 days (hurdle techn) picking:?
Green beans (sperzieboon)	?					?
Broccoli	Dynamic O2 (1-2%)/T (0C) profile rot			4 different gr. Chem. 2 spoilage micro-org.		Senegal/Egypt to NL/EU
Q before storage	Q-parameters (handboek AQS) firmness, color Product Q variance in batch pre--harvest parameters	previous atmospheric conditioning	Pre-cooled or temp. regime at start	residues of pre-harvest treatments	standard color, firmness, aroma, class determination	handling activities class determination
Q after storage	Q-parameters (handboek AQS) firmness, color, taste, vitamin Product Q variance in batch	after-storage conditioning: e.g. cooling in supermarkets	Temperature regime at end of storage	residues of green chemicals		outlet planning lead times advertisements

	task 1 (product Q)	task 2 (climate control)	Task 3 (energy)	task 4 (gr. Chemicals)	task 5 (sensor)	task 6 (logistics)
Container characteristics						number of CA/CEET containers
size	from 60 l. container to 40 ft.	*40ft reefer (refrigerated)* optimal internal volume: ..kg lifter for Q4: container cell	Definition of solar panels Energy use cooling-CA units	quantity gr. Chem.: *25-50 ml/kg product* *~50 microgr./l gasphase*	extra volume of sensors	size: 40 ft average price per load
weight		empty container ..kg. full loaded: kg.	Extra weight & integration: Sustainable energy sources		extra weight of sensors	extra price
material		vacuum panels	Isolation characteristics (K-value)	adsorption/corrosion gr. Ch.		maintenance costs
electric ratings			Energy storage (accu's)		impact on signal transduction	tracing & tracking
Climate container						
Air distribution	homogenous respiration rates various products	micro-macro climate models pulsed/periodic settings (at a distance) acoustics for circulation over-pressure/container leakage	Homogeneity of climate (< 2 ? kW) Pulsed/periodic settings: ..kW reduction Controllable entrance/exit air shutter Isolation in kW reduction)	homogenous application gr. Chem legal aspects application toxicity Gr. Chem. as alternative	O_2/CO_2/T/R.H. sensors: gradients vs. steady state signal transduction - processor	mixed loads possible? impact on loading efficiency(costs)
Packaging of load		T-profile design and cover of pallet free space vs. loaded space	Heat recovery/opposite flows	effective quantity of gr. Chem	local and delocalized measurement	number of sea or euro pallets average price per pallet
Cleaning	product interference				background signals	
Test facilities	24 times 60 l. containers: dynamic exp 12 times 600 l. containers: static exp	high tech cell feedback system Q4		hurdle technology (CA + gr. Chem.)	lab. Sensors: Peleg, VIS, PS1, HPLC, GC & photoacoustics	
Inlfuence outdoor climate	Q vs. air pollution	ventilation deeply in ship fresh air uptake/filters impact biodiesel exhaust	Solar panels: minmum kW (average) Storage of energy (capacity&volume) Heat dissipation		electricity available for x cont. climate sensors in CA unit for control	logistics on ships
Logistics & marketing	improved quality product certification less weight loss new markets	container certification maintenance costs practical experience with CA reefers markets at bigger distances	Modal shifts Stand-alone: local application	legal aspects green mark	tracing and tracking?	product margins return flows product information flow growing markets

1.4 Publications and PR actions

- Intermodal conference & Exhibition, Rotterdam, The Netherlands, 1-3 December 1998:
  a. oral presentation "Gene modification and the impact on the world wide fresh produce trade", H. de Vries
  b. chairman session "Reefer container technology update", J. Sillekens
  c. Carrier Transicold (CA units) & P&O Nedlloyd at exhibition
- RPPC Food seminar, Rotterdam, 17 November 1998: oral presentation "De toekomst van transport van verse en minimaal verwerkte producten", H. de Vries
- Ademhalende appel zorgt zelf voor ideaal klimaat, Nieuwsblad Transport, 28 November 1998.
- Container met zonnepaneel in de maak; energiezuinig transport brengt verre markten dichterbij, Vakblad Oogst, LTO Nederland, 26 maart 1999.
- Nomination for DSM Environmental Technology Award. The award has not been presented.

2. Progress versus project planning

The work plan (see 1.3 Project lay-out) presents the results of the preparation phase which are in accordance with the project proposal.

3. Realisation project aims

So far, there are no indications that the project aims will not be met, on the contrary. First DCS results demonstrate the improved quality of e.g. apples and thus strengthen the here chosen approach (instead of more or less static CA conditioning). The controllable ventilation unit of Carrier Transicold is the first step in realisation of DCS in containers. Practical results in phase 2 will elucidate the application possibilities of CEET.

4. Bottlenecks

The withdrawal of NDX Intermodal from the CEET project - as formerly announced in the letters of August 18, 1998 and October 30, 1998 - has led to a significant reduction of activities within task 6 (logistics). The consortium together with P&ONedlloyd is still discussing to take over the NDX activities. A decision is foreseen within two months. Other bottlenecks are not foreseen, also not from competitors.

5. Milestones

Milestones are identified later on in the project (end of phase 3). The first phase has been successfully ended. Interactions between several partners have been identified and global planning and a set of deliverables have been defined.

C. Evaluation parameters

Since we have been dealing with the preparation phase, well-defined practical results have not been achieved to validate the economical, ecological and technological justification parameters as described in the project proposal. Concerning collaboration the following:

- Two plenary sessions took place, a kick-off at October 8, 1998 and a progress meeting at March 17, 1999. Next meeting will be split into a scientific seminar (a single day) and a management meeting (1/2 day).

- Collaboration between partners takes place via e-mail, phone and fax; a new internet communication facility especially for this project has recently been set-up. Security is currently of main concern. Exchange of information in this multidisciplinary group is reasonably well, but will continuously be stimulated by the co-ordinator (ATO-DLO).
- A structural change concerns the withdrawal of NDX Intermodal, see point 4 Bottlenecks; no other formal contacts are established because the team functions well.

1.3 Project layout

The work plan for each individual task is described including interrelations with other tasks at the end of this report. Within each task, the work is described for the various partners.

1.3.1 Task 1: Optimisation of product quality under varying conditions

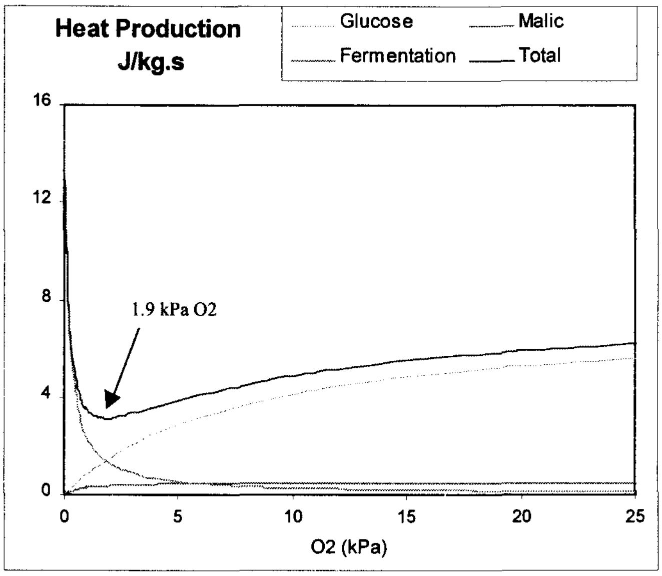
CONTRIBUTION OF ATO-DLO

a. Introduction

Main focus of task 1 is to assess product quality in a changing environment (research up till now has been more or less static). Energy metabolism and heat production (of product), adaptation versus occurrence of disorders and physiological modelling are key issues.

On the left a simulation of heat production for apple is shown as function of oxygen concentration, revealing a minimum at 1.9 kPa at room temperature (fig. 1.1). Time and temperature dependency are not yet taken into account, however will be dealt with in phase 2. Also, the influence of adaptation on heat production and product quality will be researched.

Fig. 1.1

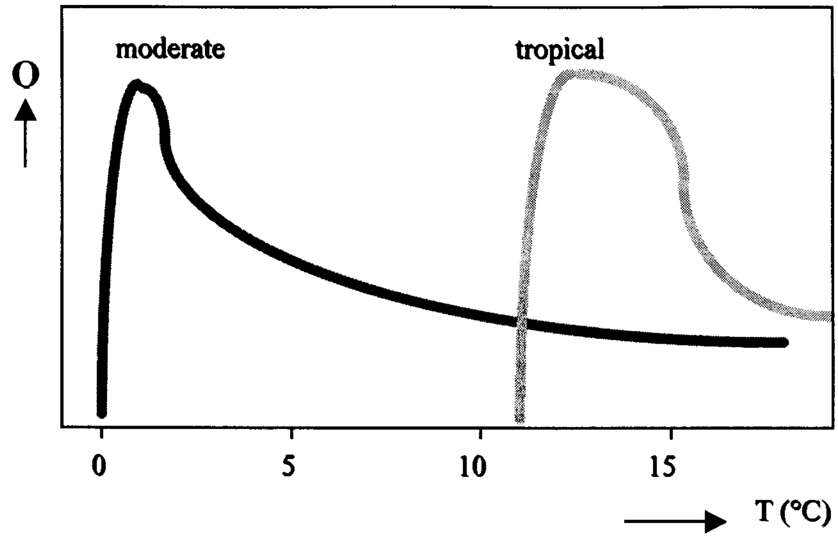


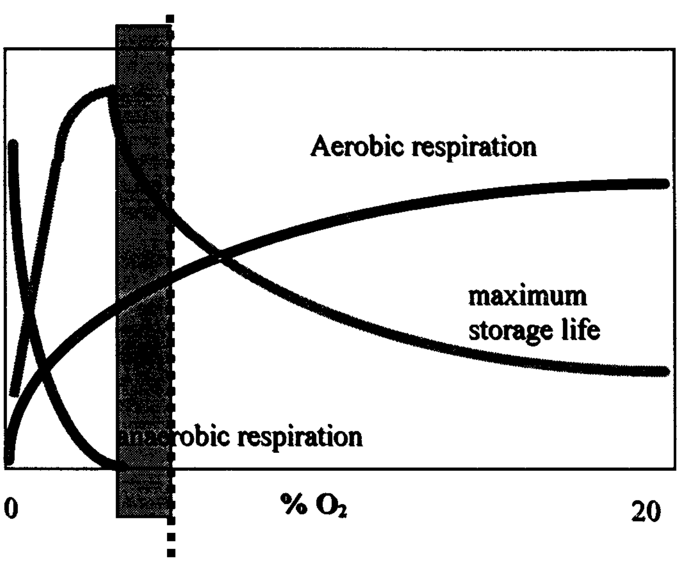
For product quality (Q) behaviour, three areas of climate control will be addressed:

- control of solely temperature (left, well-defined maxima exist for products from moderate climates like apple and from sub-tropical regions like tomato), fig. 1.2
- controlled atmosphere (CA) conditions (T, O2 and CO2 will be kept constant, vertical dashed line in figure 3)
- conditioning on basis of product response (T, O2 and CO2 will be dynamically adjusted (vertical rectangular box) on basis of metabolic changes in the product), see fig. 1.3.

Thereby, consequences of **climate variances spatially** (connection with task 2 & 3) in the container and new **temporarily changing** climate regimes will be researched for mainly apple, tomato and chicory. Current CA research and knowledge of disorders will be used as starting point for the products which will be researched within CEET2005.

fig. 1.2 & fig. 1.3





b. Definition of initial product quality, current CA (or MA regimes) and of current disorders and spoilage within CA conditions

An overview is presented in tables 1.1, 1.2, 1.3 and 1.4.

Table 1.1 Quality indices

	Apple	Chicory	Tomato
Appearance external	Bitter pit Brown spots Bruises Cracks in the skin Decay Insect injury Mechanical injury Rot Scald Skin spots Stem or blossom-end cracks Freezing injury	Insect injury intact leaves Marginal browning Length of leaves Mechanical injury Red discoloration Rot Sharp cut Tipburn	Bruises Growth cracks Insect injury Mechanical injury Rot Scars Small blossom Smooth blossom Sunscald Zippering
Appearance internal	Senescent breakdown CO_2 –damage Internal browning Water core	Blackheart Pit length versus leaf length	Black pits Hollow
Color	Ground color % blush	White – Yellow and bright color	Green shoulders Grey Irregular color patterns
Firmness	Firmness Crispness Absence of mealiness	Firmness	Firmness Not overripe Soft spots
Shape	Regular	Regular	Regular

Table 1.2 Optimal CA conditions*

	Apple		Chicory		Tomato	
	Min	Max	Min	max	min	max
T (°C)	-1.1	4.4	0	1	13	16
RV (%)	90	98	90	100**	95	100
O2 (%)	2	3	3	4	3	3-5
CO2 (%)	1	3	4	5	0	0-3
Time (days)	40	240	14	28	7	13
Effect CA	excellent, depending on cultivar		good		good, depending on picking time	

* according to CA conference proceedings UC Davis, 1997 and book "Controlled Atmosphere Storage of fruits and vegetables", A.K. Thompson, CAB Int., 1998

** 90-95 recommended by PGF (Sprenger Institute)

Table 1.3 Storage disorders

	Apple	Chicory	Tomato
T Chilling injury (°C)	< 1.5 *	< -0.5	< 13
T Freezing injury (°C)	< -1	< 1.1	< -0.5
Off flavors O2 CO2		> 10 % CO2 < 0.25 % 4-10 %	
Weight loss (%)	> 1	> 6	>2
Ethylene	Sensitive	Sensitive	Very sensitive
Production of ethylene at atm. conditions (ppm)	> 100	< 0.1	1-10

* Cultivar dependent

Table 1.4 Tomato

Major off-flavor components	Main flavor Components
2-methyl-2-butanal	n-hexenal (lipid oxidation; rapid release)
hex-trans-2-enal	Trans-2-hexanal
	2-isobutylthiazole (ripening)
	Farnesylacetone
	Geranylacetone
	1-penten-3-oneexanal
	cis-3-hexenol
	6-methyl-5-hepten-2-one
	Acetaldehyde
	Hexenal acetone
	Eugenol (steady during ripening)
	Ethanol (steady during ripening)
	Methylbutanol

Apple

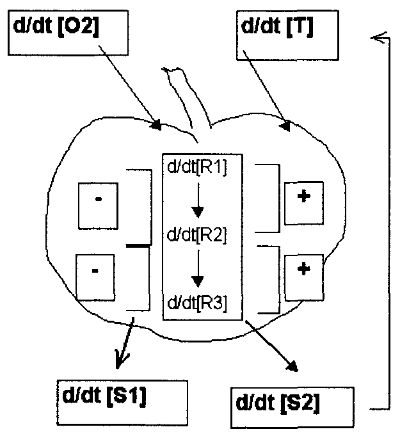
Major off-flavor components	Main flavor components
	Ethyl-2methylbutyrate (ripe fruit)
	Hexanal (not ripe)
	Trans-2-hexanal (not ripe)
	n-propanol
	Trans-3-hexenol
	n-hexyl propionate
	n-amyl acetate
	2-methyl-butan-1-ol
	(E,E)-alpha-farnesene
	Pentyl acetate
	Butyl acetate
	Hexyl acetate
	Ethyl butanoate
	Hexyl hexanoate
	Butyl hexanoate
	Propyl octanoate
	Ethyl 2-methylbutanoate

Chicory: no information available about flavor components.

c. Dynamic Control Systems (DCS): description of first results for apple

A dynamical approach to climate conditioning will provide the living product the opportunity to adapt to the changes in climate (fig. 1.4). Up till now, the approach has been focused on keeping the climate constant during storage. Consequently, the atmosphere will abruptly change at the moment that the products are stored; the same happens at the moment the products are taken out of the storage environment. Thereby, sudden changes in storage climate exist especially during transport. So far, only the change in climate conditions are monitored and readjusted to the prescribed values, however, the changes in product quality have not been considered.

fig. 1.4a



For long term storage at auctions, a first dynamic approach is tested. The oxygen content is slowly reduced till first signs of fermentation – via ethanol emission - are determined. The oxygen level is raised that high that ethanol could not be measured anymore and, thereafter, lowered again.

First results for apples and cabbage are promising. For apples, firmness is much better retained during storage. At the shelf (or distribution phase), this becomes even more significant as compared to practical advised conditions (ULO = Ultra Low Oxygen). For cabbage, the discoloration of outer leaves is better suppressed, resulting in less weight loss and improved overall quality.

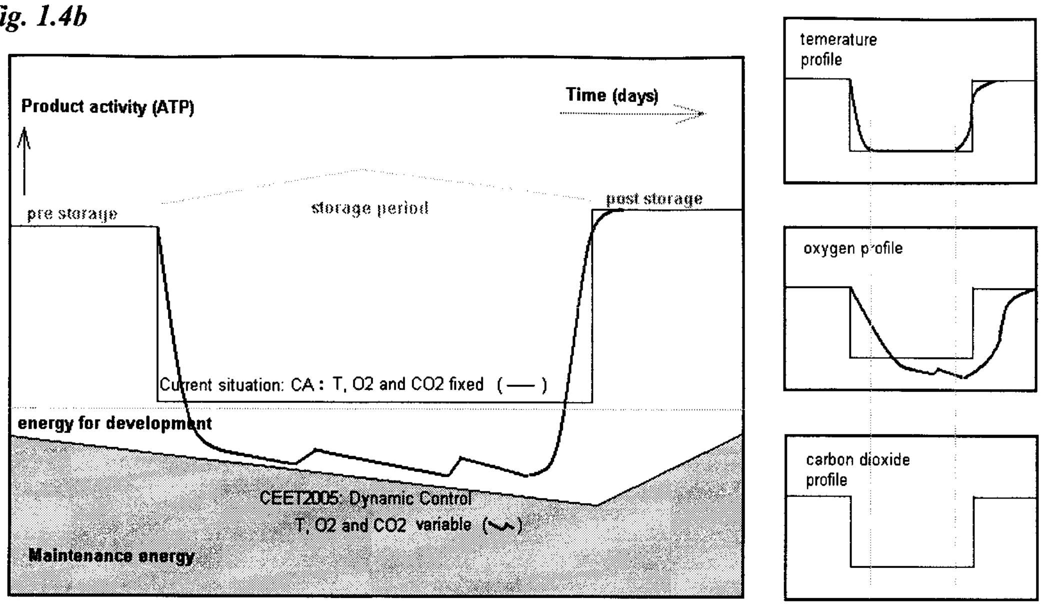
d. Working scheme and time planning for adaptation research

For the dynamical approach, a distinction is made between the following three categories.

- products with low energy metabolism during storage; apple and chicory
- products with high energy metabolism during storage; tomato.

Thereby, the tomato is very susceptible to dehydration (tissue breakdown) and condensation (fungal growth), like cucumber, paprika and numerous (sub-)tropical products. Chicory is severely susceptible to internal disorders, discoloration and rot.

fig. 1.4b



The working scheme is based on:

- at the moment of storage: slowly reducing the level of oxygen till fermentation starts at constant and low temperature
- balance the level of oxygen around the fermentation limit and the level of CO2 to further reduce metabolism but avoid disorders.
- at the end of storage: first rising the temperature and then slowly increase the oxygen concentration to avoid deterioration and to improve quality (enhance aroma development)

e. Deliverables (relation to sub-task definition as defined in the project proposal)

Task 1.1 heat release over the entire storage period

The heat release of products under current and dynamical approach will be experimentally quantified as described above. Consequently, heat dissipation in the container will be researched in collaboration with the method described in task 2.

Questions to be answered are:

- Is heat release dependent on adaptation profiles for temperature, oxygen and CO2?
- What is the consequence of temporarily increase in oxygen on overall heat production?

Task 1.2 fruit post-harvest physiology

Heat release is related to energy metabolism of products. Adaptation research is focused on minimum energy budgets necessary to keep running essential processes in the products, so-called maintenance energy. A fundamental approach will be undertaken to what are essential processes and how these are related.

Related questions are:

- How is the structural organisation of fruits to avoid damage in terms of radical formation (OH-radicals, ethyl- or methyl- radicals origination from ethanol or acetaldehyde), anti-oxidant capacity (glutathione, ascorbate, SOD) and lipid peroxidation (mebrane leakage, ethylene and ethane formation)?
- What are triggers to irreversibly change deterioration processes, in what way do signals transduce and how is the impact of these triggers minimised?
- Are we able to identify indicators of irreversibly changing processes in very early stage?

Task 1.3 generic model development
Description of processes as researched in task 1.2 and generic model development based on self-organisation models – describing the interaction of a diversity of processes – will be combined. Here, the approach of climate modelling will be linked.

Questions concern:
- Are we able to construct a model based on energy metabolism in which the effects of temperature, oxygen and CO2 are visualised?
- Can this model be coupled to a generic description model that describes the organisation of fruit processes?
- What information is obtained from coupling of these models with climate control models and how will that influence product quality?

Task 1.4 Sustainable quality label
This will be described later on in the project.

f. Resources
- 24 times 60 l. containers for flow through experiments
- 12 times 600 l. containers for CA experiments
- standard lab test equipment (GC, HPLC, photo acoustics)
- shelf life climate room

CONTRIBUTION OF THE GREENERY INTERNATIONAL

Progress
1. A study was made concerning the most interesting products for testing container transport. Main criteria for product selection are:
   - importance of the product in import and export
   - existing and competing air transport
   - value per product volume

On the basis of those criteria the following products were selected:
   a. Tomatoes and tomatoes on the vine
   b. apples (variety Elstar and ....)
   c. chicory

Bell pepper is another commercially most interesting test product due to the fact of large quantities being exported from the Netherlands to the USA by boat and the high packaging costs (per box) to maintain quality at a suburb level. On the contrary chicory is of much lesser commercial importance. Because of this a change from chicory to bell pepper is well arguable.

2. As the packaging is concerned, the boxes mostly used by the Greenery are selected for the trials and delivered at the experts of ATO-DLO. That is for:
   - tomatoes: a 40 x 30 cm cardboard box
   - apples: a 60 x 40 cm cardbox (corrugated) box
   - chicory: 50 x 30 cm and 40 x 30 cardbox boxes

Coming actions
- Deciding about a changeover from chicory to bell pepper as test product.
- Deciding about apple varieties.
- Quality information at specific stages of the supply chain from grower to retailer will be made accessible and will be supplied to the experts of ATO-DLO
- Product samples will be delivered to ATO-DLO for running trials

Expected input of other partners
Optimal climatic conditions in the supply chain and methods to maintain these conditions.

Bottlenecks and issues for the coming agenda
Not foreseen.

CONTRIBUTION OF CARRIER TRANSICOLD

Overview
In support of the CEET 2005 project, Carrier Transicold has conducted several tasks in support of specific tasks outlined in the project proposal. Most of the engineering activity related to the development of a computer controlled fresh air exchange mechanism. Other work was mostly planning and exploratory in nature. In addition, Carrier Transicold is supplying a controlled atmosphere testing and algorithm development.

Task 1 Activities
In support of Task 1, Carrier Transicold is providing an Everfresh controlled atmosphere container refrigeration unit. This unit will be mated to a container and will be utilized for the development of optimal product storage conditions. These optimal storage conditions will form the basis of later algorithm development.

1.3.2 Task 2: Optimisation of climate control under energetic and quality constraints

CONTRIBUTION OF ATO-DLO

This chapter gives details on the planning of the model development, described in subtasks Task 2.1 & 2.2, defined in the project proposal. The planning of subtasks 2.3 & 2.4 will be described together with the planning of task 7.

a. Introduction
Objective of this task is to deliver a simple model, describing the climatic conditions inside the container, for use by the supervisory controller, to be developed in Task 7.

b. Scientific programme
The final model will be built using a bottom-up approach. In this approach model will be developed at three levels:
1. product level
2. micro level (packaging)
3. macro level (container)

Low level models will be simplified and aggregated into the models at a higher level. This results finally in a simple, but reasonably accurate macro-model for use by the supervisory controller.

Parallel to this work, using a top-down approach, a crude model will be developed, which will be used in Task 7 in the earlier stages of the development of the controller. The model parameters will be approximate, but the structure of the model is assumed to be representative for the final model. It should be noted that the bottom-up approach may add some extra degrees of freedom to the crude model for the description of critical points in the load.

c. Work breakdown and Planning
The planning is broken down in 3 subtasks, related to the three levels of model description, mentioned above. A further breakdown of these subtasks is given below:

Table 2.1 Product level

P.1	Development of measurement method for measuring heat of respiration, transpiration rate, and metabolism. (in co-operation with Task 1 and 5)
P.2	Analysis of climatological (respiration and transpiration) properties of product
P.3	Analysis of absorption of green chemicals by product (in co-operation with Task 1 and 4)
P.4	Analysis and modelling of respiration and metabolism of the product

Table 2.2 Micro level

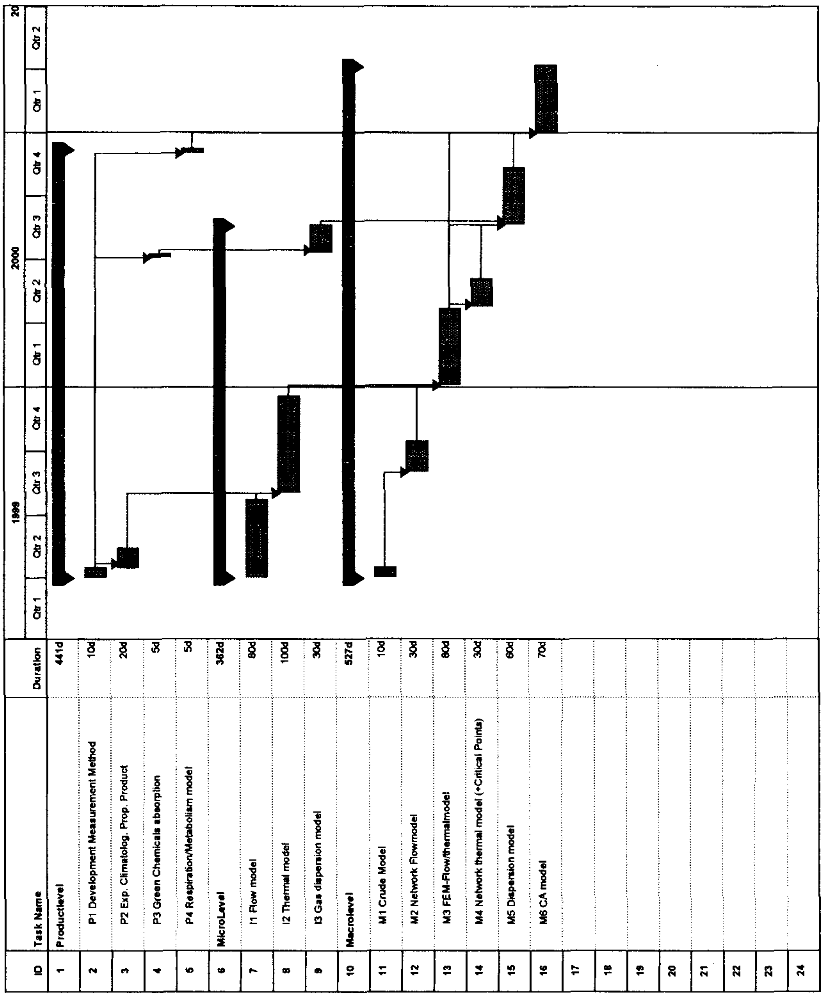
I.1	Development of airflow model
I.2	Development of thermal and humidity model.
I.3	Development of gas dispersion model (volatiles and gasses)

Table 2.3 Macro level

M.1	Development of crude macromodel
M.2	Development of network airflow model
M.3	Development of Finite-Element (FEM) model of airflow, temperature and humidity
M.4	Development of network thermal/humidity model + critical points
M.5	Development of network model for gas dispersion
M.6	Development of final network model including Controlled Atmosphere (CA)

It should be noted that the subtasks at the product level will mainly be done in task 1. The contribution from task 2 will be the co-design of the measurement system and the data-analysis of the experimental results.

Table 2.4 The scheduling of the task



d. Deliverables

In co-operation with Task 1 and Task 5 will be delivered:

1. System for measuring heat of respiration, transpiration rate, O_2/CO_2 consumption/production ↔ volatiles production/consumption (subtask P.1)

As input for Task 3 will be delivered:

2. Estimation of energy load imposed by the product load (subtask M.1).

As inputs for Task 7 will be delivered:

3. Crude model of macroclimate with limited degrees of freedom and approximate estimates of parameters (subtask M.1).
4. Accurate macro-model including critical points, describing airflow, temperature and humidity (subtask M.4).
5. Accurate macro-model describing dispersion of green-chemicals and metabolites (subtask M.5).
6. Accurate final macro-model describing changes of T, R.H., O_2, CO_2 , and volatiles in container (subtask M.6).

e. Resources

1. Measurement system, as mentioned in deliverable 1.
2. Windtunnel, which will be operational for this project after some modification, for flow measurements on packaging scale.
3. Hi-tech cell for measurement of airflow T and R.H. on pallet/container scale.
4. Container for experimental validation of macro-model.
5. FIDAP-simulation tool for development of detailed models at micro and macro-scale.
6. Matlab-simulation tool for development of network models at container scale.

f. Interfacing with other tasks / partners.

Task 1:

- Co-development of measurement system for respiration and transpiration properties, for use of model development.
- Co-development of model describing heat of respiration and transpiration, for input to task 2.
- Development of model describing the products metabolism of volatiles (ethylene, ethanol, green chemicals, etc.), for input to task 2.
- Development of model describing the gas exchange (O2, CO2) of product with environment, for input to task 2.

Task 2 (Carrier Transicold):

- Formulation of boundary conditions (airflow, temperature, R.H., C.A.) for models at container scale.
- Estimation of energy load by cooling system.
- Co-development of submodel describing the ventilation of outside air.
- Co-development of submodels describing the cooling and C.A. systems.

Task 3 (Ecofys):

- Output from task 2: first estimate of energy load from product.
- Co-development of thermal model of energy system, as input to task 2 and 7.
- Estimation of energy load by radiation and outside temperature, as input to task 2 and 7.
- Estimation of improvement of K-value of container, as input to task 2.

Task 4:
- Description of green chemical absorption by container, packaging and product, as input to task 2.
- Description of delivery system for green chemicals as input to task 2.
- Output to task 4: Description of dispersion of green chemicals for design of delivery system.

Task 5:
- Co-development of measurement system for respiration and transpiration properties, for use of model development.
- By means of models developed in Task 2 the necessary sensors and their optimal locations in the container and cooling system will be determined.

Task 6 (including the Greenery and P&O Nedlloyd):
- The type of stacking, type of packaging and use of pallets, will be determined. This will give direction to the research on the airflow in the container.
- The course of temperature, humidity and solar radiation during typical logistic chains will be input for model calculations.
- Description of environment of container in hold of a ship will be determined, as input for macro models in task 2.

Task 7:
- Output from task 2 to 7 will be models, described in deliverables 3-6.
- In co-operation means of model identification during operation of container will be investigated.

CONTRIBUTION OF P&O NEDLLOYD

As P&O Nedlloyd, we are at the moment discussing with a foam supplier a special kind of foam panels with a better K-value then the present foaming system. In this respect we have to find a way to have a proper size for this panel which we can fit into the side- and roofpanel of the reefer container.

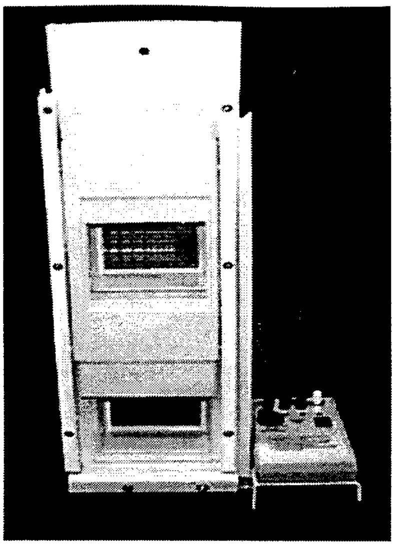
Also we are looking to the possibility to have a combination of the new developed foam panel and the present foam panels. Mid April we will have a discussion with the Containers Manufacturer in China regarding the manufacturing possibilities.

At the moment we do not have effective results regarding improvement on K-value and strength test of the new panels. We hope to have some test panels later this year on which we will do the necessary tests. When the results are satisfactory, we will hopefully build the container which then should be available by the end of this year.

CONTRIBUTION OF CARRIER TRANSCICOLD

Task 2 Activities

Most of Carrier Transicold's efforts were focused on efforts to reduce power consumption under normal operating conditions. Key to this endeavour is actively controlling the amount of fresh air brought into the container to vent products of respiration and fermentation. Current container refrigeration units have a static, manually positioned, air exchange system.



In order to match the required outside air flow with the product requirements, Carrier Transicold developed a stepper motor driven, micro-processor controllable vent system. The system, shown at left, fits into the refrigeration unit in a standard position, completely inter-changeable with an existing air exchange module.

The remaining key aspect to the system is to develop the proper algorithm for control. This will require additional sensor inputs in order to set the vent opening to the proper level to support optimal product quality. An appropriate air flow sensor has been identified, but an ethylene sensor may be the most desirable.

Numerous other activities have been conducted at lowering power consumption. For the short run, the size of the compressor is being re-evaluated to determine if a slightly smaller compressor would have sufficient capacity for the application, while reducing the part load power draw. Additionally, the specifications for a variable speed drive for both the fans and the compressor have been sent to Toshiba. Toshiba, whose air conditioning subsidiary recently merged with Carrier, is an industry leader in variable speed motor drives.

1.3.3 Task 3: Development of a robust integrated sustainable energy systems

CONTRIBUTION OF ATO-DLO

Within task 2, climate conditioning, energy reduction of the current circulation and ventilation systems is focused at. The development of integrated sustainable energy systems is coupled to that outcome. So far, a list of key issues is defined:
- How is ventilation achieved deeply in the ship?
- Ventilation versus optimised loading of CEET-containers in the ship? How is the contribution of circulation rates related to ventilation rates and how does that effect total energy demand?
- In what way is heat dissipation due to product metabolism related to efficient low temperature control?
- Is ventilation based on heat recovery systems feasible/ as well as the use of opposite flow streams; what percentage of ventilation energy can be covered by means of a heat recovery system?
- Is pulsed (Jet-stream) circulation possible in the containers or is flushing directly in the pallet feasible via T-profiles?
- Is the use of acoustic waves possible for circulation possible?
- In case of leakage: is over pressure feasible from an energetic point of view? What are in general the consequences of container leakage for optimal conditioning?
- Are vacuum panels available (costs, efficiency) and what are the consequences for the internal loading volume of the container?
- Energy supply system: solely solar panels and/or bio-diesel?
- What are consequences of using bio-diesel; exhaust gases: how are these gases flushed to the outside environment without influencing container conditions? What filters and catalysts are necessary or beneficial for climate control?
- The official ATO-certification: should that be redesigned in the CEET container?

CONTRIBUTION OF ECOFYS

a. Work carried out in phase 1 (Preparation)

The main activities of Ecofys during the phase 1 were focussed on the collection of knowledge in the field of post harvest physiology of fresh fruits and vegetables. Furthermore knowledge was gathered on the design and daily use of the containers. In meetings the demand for circulation, ventilation and heat were discussed. Moreover a first preliminary study was performed on suitable energy systems.

b. Work programme

In the near future Ecofys will co-ordinate activities among the direct partners of task 3 (Shell Solar, ATO/DLO, Ecofys).
In order to develop a robust integrated sustainable system the activities will be focussed on:

- Definition of requirements (e.g. energy demand (from task 1 and 2 and physical conditions (robustness)).
- Communication with activities in task 7 in order to define adequate output variables for task 7.
- A rough concept of a new energy configuration system.

CONTRIBUTION OF SHELL SOLAR ENERGY B.V.

Shell Solar's actual involvement will only start once with the final design of the container. Hence to date the only activity has been the participation in the kick off meeting of October 8, 1998. Regretfully the meeting of March 17, 1999 could not be attended.

Work planning is to be arranged once the final design of the container is known.

1.3.3 Task 4: Development of slow-release systems for green chemicals

CONTRIBUTION OF ATO-DLO

a. Objectives.
The aim of task 4 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.

b. Results Task 4.1 Selection of green chemicals for different products

In the first six months of the project green chemicals derived from plant sources have been selected for post-harvest protection of container stored apples, tomatoes and chicory. The post-harvest pathogens which are most commonly associated with the selected products are listed in Table 4.1. *Pseudomonas marginalis* may be replaced by *Erwinia carotovora*, both spoilers of chicory.

Table 4.1. Relevant post harvest pathogens and their temperature related growth characteristics.

	Optimum (°C)	*Minimum (°C)*	*Maximum (°C)*
Pseudomonas marginalis	25-30	0-1	38-40
Botrytis cinerea	22-25	0-5	33-35
Penicillium expansum	20-25	0-1	
Monilinia fructigena			
Alternaria alternata	25-28	2.5-6.5	31-32
Rhizopus stolonifer	25-26	5	32-33

On basis of an extensive literature screening and experience, 8 plant-associated compounds with antimicrobial activity were selected (Table 4.2). These compounds are at present being tested for their *in vitro* antifungal and antibacterial activity. The selection criteria applied were the following:

- Reported antimicrobial activity, not necessarily on the micro-organisms listed in Table 1.
- Presence in the selected products
- Reported safe use as flavour (GRAS-status)
- Delivery via gasphase possible
- Obtainable in large quantities

Table 4.2. Selected green chemicals and the intended products for application.

	Chicory	*Tomato*	*Apple*
Carvacrol	X	X	
Thymol	X		
Trans-2-Hexenal	X	X	X
Decanal			X
Hexyl acetaat			X
Ethyl hexanoaat			X
Geraniol			X
Trans-2-pentenal		X	X

c. Deliverables

Task 4.1

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

Task 4.2

- 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 porducts at two different tempratures.

Task 4.3

- 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.

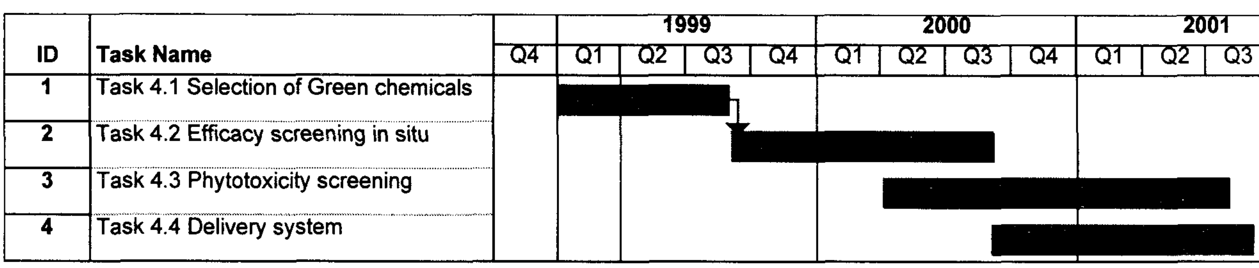
Task 4.4

- An injection system for green chemicals, and eventually for controlled release, will be obtained

d. Requirements from other tasks and partners

Execution of task 4 will be performed in close collaboration with task 2 (climate control), task 5 (monitoring systems) and task 7 (system control). Other partners directly involved are Transicold and P&O Nedlloyd.

e. Time schedule



CONTRIBUTION OF CARRIER TRANSICOLD

Task 4 Activities
While ATO-DLO is developing the green chemicals for the control of pathogens, Carrier Transicold is working on the delivery mechanisms. The current humidity management system employed by Carrier may not lend itself to this task, so Carrier has undertaken a project to develop a new humidity mist delivery system which may be more flexible. The goal of this project is to develop a system that would substantially reduce the droplet size, thus enhancing evaporation. Development activity in this area should be completed within the next quarter.

1.3.5 Task 5: Monitoring the surrounding environment and the product response

a. Aim
The objective of task 5 within CEET 2005 is to develop sensors that can monitor product traits and the product environment such that these measurements provide the required information to be able to control product quality. To be able to decide on the nature of the sensors to be developed within the project, we have made an inventory of the current knowledge on product quality, quality deterioration and maintenance of product quality, and on the available technology to monitor the product and its environment. The sensors to be developed should

detect warning signals of product deterioration. Such signals can subsequently be used to control the product environment and thus prevent further quality loss.

b. Strategy

Two types of sensors will be developed for monitoring product traits in the container. Firstly, a *volatile detection system* will be developed to measure signs of product deterioration, anaerobiosis, ripening or levels of green chemicals. Secondly, a *particulates detector* will be developed to detect the presence of fungal spores. In addition, the product environment needs to be monitored to ensure the proper conditions for maintenance of product quality. Therefore, we have chosen to develop a combined *CO_2/O_2 sensor*, since manipulations of the CO_2 and O_2 concentration in the air are an important means of controlling product respiration and ripening. All sensor systems require sophisticated *signal processing and calibration*. Finally, we will assist in developing a system for the *measurement of heat production* in conjunction with respiration. This type of measurement system is required to provide data for the climate control model.

The sensor limitations will be established in the course of phase 2. The requirements of the sensors depend on the concentrations of volatiles in the container, which are unknown at present, as they depend on the final climate control regime such as e.g. the rate of refreshment of air determining the concentration of volatiles released from the products.

CO_2/O_2 Sensor

For this sensor, two detection systems will be combined in one housing:

A 4.23μm infrared absorption measurement system which has a CO_2 sensitivity of 0-5% combined with a singlet/triplet lifetime O_2 sensor that can have practically any sensitivity range depending on the sensor material used.

Both sensing elements are robust, low-cost, accurate and compact. They can be used independently if required. The O_2 sensor can be fibre-optic based. The double sensor system will be provided with RS232/485 and 0-5V non-linearized analogue outputs.

Particulates Detector

The particulates detector will be a simple detection system for fungal spores, indicating pathogen or saprotroph attack. Basically this detector will consist of a light scattering system using a LED or laser diode light-source(s) combined with photodiode(s) to detect light scattered by particulates as they traverse the light beam. This simple design is expected to be reliable and robust. The complicated aspect of this task is the characterisation and analysis of the signals from the detectors. Different sized and shaped particles will have different scattering signatures which must be distinguished by the system. The sensor will be provided with buffered unprocessed analogue outputs from the detectors and processes outputs via RS232/485.

Volatiles Detection

The volatile detection system can be used to provide warnings of deterioration of the product, anaerobic metabolism and also to control the level of green chemicals. Volatiles of interest are ethanol, ethylene, NOx, methyl jasmonate, hexenal etc and substances used as green chemicals such as aliphatic aldehydes, terpenes and phenolics.

For the development of this system we will follow two tracks:

The development of ethanol/ethylene sensors based on the use of heated metal oxide sensors. This existing technology should be improved: a 100-fold improvement of the sensitivity is required if the sensors are to be used to trigger anaerobic respiration.

The development of non-specific microbalance gas sensors (electronic nose). These microbalance sensors are based on the adsorption of volatiles onto coated resonant quartz crystals oscillators or Surface Acoustic Wave (SAW) resonators. The mass of the gas molecules will change the resonance frequency of the crystals or SAWs, and hence the change in resonance frequency gives a measure of the concentration of gaseous compounds. The choice of different coatings (metallic substituted tetraphenylporphyrins and phthalocyanines) will result in different affinity for various gases.

If the first approach is not successful, we will focus on the second. The system will be provided with RS232/485 and analogue outputs.

Signal processing and testing
All aforementioned sensor systems require signal processing and calibration. A calibration is the process of modelling the relationship between the sensor signal and the concentration of a compound. The signal processing will include linearization of the sensor output with respect to the concentration of the gas of interest (CO_2 / O_2 / ethanol / ethylene etc.). In the linearization step it will be required that the raw sensor signal is disposed of unwanted signal contributions such as noise and other measurement artifacts.

An alternative for signal linearization is the use of non-linear calibration techniques that can handle non-linear signals. These techniques will only be utilized when the linearization of the signal leads to unsatisfied results.

The test or validation step is the place where the sensor prototype is tested for precision, robustness and cross-sensitivity. Precision focuses on the repeatability and reproducibility of the analysis. Repeatability is the variation in the method when the same measurement procedure is repeated e.g. within a day. Reproducibility is the variation in the method when it is repeated on different days. A robustness test measures the performance of the sensor for small changes in the measurement circumstances (temperature, humidity, pressure etc.). Cross-sensitivity is the phenomenon when several gases bring about the same signal pattern.

Heat Production in Products
We will design and construct a system for the measurement of heat production by products. In this system heat production will be measures in parallel with the gas composition to be able to model heat production in various gaseous environments as related to respiration of products.

c. Deliverables
The deliverables for phase 2 will be prototype versions of the CO_2/O_2 sensor, the particulates sensor, the volatile sensor and the system for measuring heat production. The sensor systems will be provided with software for data acquisition, signal processing, calibration and sensor testing. The prototype sensor systems will work in stand-alone mode.

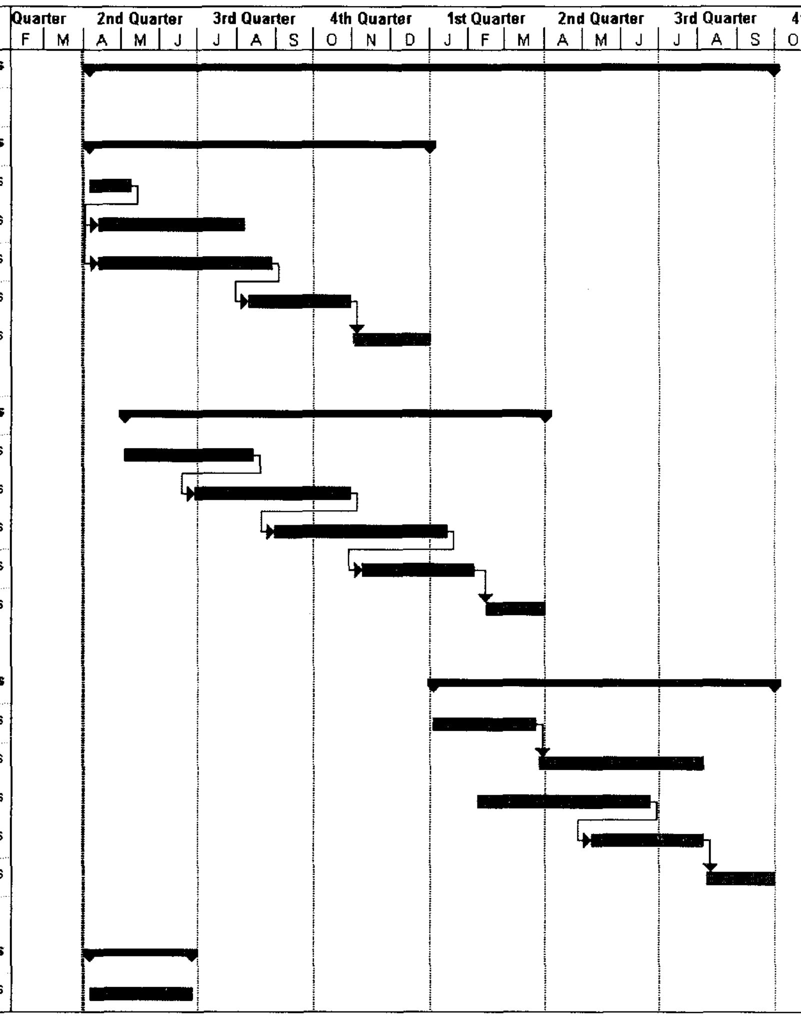
d. Boundary conditions
In order to measure product quality and product environment under container circumstances, the utilised sensors must be tested for sensitivity, durability, reliability, robustness, low energy consumption and must be low-cost. Further boundaries for the sensors to be developed are set by the fact that direct measurements on products in a container are hard to realise, as products in a container are packed in boxes and a container should be able to function stand-alone. Thus, the implementation of sensors that need to be in contact with or close to the product is physically limited. In contrast, measurements of the volatiles in the air surrounding the product in a container seem much more attractive and feasible.

e. Requirements from other Tasks and partners
Before testing the sensor prototypes we will need input from Task 1 and Task 4 about the strategy for sensor testing with respect to the product. From Task 7 we need information of how the sensors need to be connected with the control unit.

The requirements from other partners are coming from Carrier Transicold. We will need information about the electronics in the cool compartment. The sensors require electricity and the sensor output must be given back to the control unit. Furthermore, we need advice about housing material for the sensors and where to position them in the cool compartment.

f. Time Schedule

ID	Task Name	Work
1	**CEET Task 5: 2e phase**	**352 days**
2		
3	**O2/CO2 sensor**	**85 days**
4	Electronics	20 days
5	Electronic tests	20 days
6	Signal processing	15 days
7	Software developmen	20 days
8	Validation	10 days
9		
10	**Particulates sensor**	**122 days**
11	Electronics	12 days
12	Electronic tests	40 days
13	Signal processing	20 days
14	Software developmen	40 days
15	Validation	10 days
16		
17	**Volatiles sensor**	**135 days**
18	Electronics	35 days
19	Electronic tests	20 days
20	Signal processing	20 days
21	Software developmen	40 days
22	Validation	20 days
23		
24	**Heat production**	**10 days**
25	Electronics	10 days



1.3.6 Task 6: Chain optimisations and marketing opportunities

a. Introduction

This document contains the working plan of task 6 for phase. The subject of task 6 is logistics and is responsible for setting the logistic and economic boundaries for the new agro-container which will be developed within the project.

During phase 1 task 6 resulted into

- a global overview of the advantages and disadvantages of the agro-container to be developed and;
- an initial selection of promising product-region-combinations for using the new container.

These results will be described first.

b. Results of phase 1

The first aim during phase 1 was to develop a good and clear overview of all pros and cons of the agro-container to be developed. Why would we use the container anyway? A number of internal meetings and some important remarks from the project partners resulted into the following overview.

Table 6.1: Expected pros and cons of the new agro-container.

Advantages	Disadvantages
• **Energy savings** • Higher product quality (compared to traditional conditioning) • Less loss of product weight and less decay • Monitoring during transport • Extra service for shipping-company • Modal shift (competing with road and air) • Market development	• **Maintenance** • Extra handling shipping company • Cost (?)

The costs of the container are not known yet but they are expected to be higher than the cost of conventional reefer containers. One of the objectives within phase 2 will be to quantify as much as possible these advantages and disadvantages of applying the container within certain supply chains. In other words, the present-day view on the pros and cons of the container is expected to evolve during the project and converge finally into a certain quantitative estimation.

The second aim of phase 1 was to make an initial selection of promising product-region-combinations for using the new container. A project-region-combination is a product combined with its origin and destination, for example tomatoes from The Netherlands to Germany. For making a well-founded selection, a number of selection criteria was defined. These selection criteria are written down in Table 6.2.

Table 6.2: selection criteria for promising product market combinations

Product characteristics	Market characteristics
• **High value density** • High margin • High benefit of new container compared to conventional reefers	• **Long distance markets** • Growing market with emphasis on product quality • New markets (e.g. replace air transport by sea transport) • Return flows

The choice for these selection criteria can be explained as follows. The higher the value density of the product, the higher its gross margin and the higher the product's benefit of the new container concerned the product quality, the more suitable the container is expected to be for transporting the product. For products with a high value density, logistic cost are only a small part of total purchasing cost at the retail outlet, so increased logistic cost will just count a little. For products with a high gross margin some slack exists for making extra logistic cost. The argument for the criterion of a high benefit concerned product quality is rather trivial.

Potential markets (i.e. geographical markets or regions) are markets on a long distance, growing markets with an emphasis on product quality or new markets because of a modal shift. This can be explained as follows. First, if a market is on a long distance, the benefit of the new container for the product quality is expected to be higher. Second, if there is a growing market with an emphasis on product quality, the benefit for the product will count more. And finally, because of the realization of a better product quality, fast and expensive transport modes like airplane or trucks may be replaced by slower cheaper ones like marine transport or barging. In some cases these savings on distribution cost can enable new sales markets. An example is the distribution of cucumbers from the Netherlands to the USA. Shipping them by airplane is often too expensive, among others because of the low value density of the product. Using conventional reefer containers, cucumber can be transported for two weeks at most, and only with a very high initial quality. This implies that marine transport is not always a suitable transport mode for transporting cucumbers to the USA. However, if the new container can help to realize a higher possible transportation time, marine transport will become an attractive alternative.

Finally, a necessary condition for a market to be a suitable market for using the new container is the existence of sufficient return load. Otherwise, transportation cost may become too high.

Based on these selection criteria, a first selection of promising product-region-combinations was made. It was tried to correspond as much as possible to the (partly technological based) choice for the products apple, chicory and tomato which was already made in an earlier stage by project management. This resulted into the matrix in Table 6.3.

Table 6.3: Initial selection of promising product-region-combinations

	High value density	High margin	Product benefit	Long distance market	Growing market	New market	Return flows
Tomato, NL-USA	+	+	+/- (?)	+	+	Now air	
Paprika, NL-USA / NL-Japan	+	+	-	+	+		
Apple, NL-UK	-	+/-	+	-	-		
Chicory, NL-Singapore/USA	+/-	+/-	+	+		+	
French beans, Egypt-NL	+	?	+ (?)	+	+		
Cucumber, NL-USA	-	+/-	+	+		+	

As can be seen this table has not been completely filled in yet. The existence and volume of return flows is not known yet. The scores are based on discussions with the Greenery, the project team, and with a product expert of ATO.

c. Aim of research for phase 2

The aim of phase 2 is to quantify the added value of using the new agro-container within agricultural supply chains. Part of this will be a financial cost benefit analysis. To achieve a good estimation of the added values and of the economic feasibility of the new container, the following activities have to be performed.

Task 6.1: selection of 'case Supply Chains'

It must be decided which product-region-combinations will be the promising ones for the project. For this purpose Table 6.3 must be completed and communicated with all project partners. Important characteristics of the product-region-combinations will be described, like volumes, main players, trends etc.

After this, for each product-region-combination a concrete supply chain must be selected and generically described in terms of actors, activities, equipment, lead times, volumes, conditions (e.g. temperatures), etc. These supply chains are going to function as 'case supply chains' for assessing the added value of using the new agro-container. Practical implementation questions from the other tasks within the project can be directly linked to these 'case supply chains'. Part of this task will also be describing opportunities and threads within these supply chains.

This task will result into a detailed description of three or four candidate supply chains for using the new agro-container.

Task 6.2: quantification of container characteristics

To be able to asses the added value of the container it is necessary to quantify relevant characteristics of the container first (e.g. What will it cost, how much energy will it use, and which gain of product quality can be realized?). This task will result in a quantified overview of container characteristics.

Task 6.3: modeling the supply chain and quantification of the pros and cons of using the container within a supply chain

The effects of using the new container within the 'case supply chains' will be quantified as much as possible. This will be done by building a quantitative model for simulating the activities within the supply chain. Typical performance indicators are expected to be cost (transport, handling, maintenance etc), energy use, lead times, and product quality. Defining the performance indicators explicitly will be part of the research.

This task will result into a tool for assessing the added value of using the container within a certain supply chain. Moreover, a final judgement will be presented whether using the container within the selected supply chains is advisable.

d. Project planning

In Figure 6.1 a work breakdown structure is presented. The total work to be done is estimated on 214 man days work. As can be seen, the emphasis lies on the modeling part which will be the core of the research.

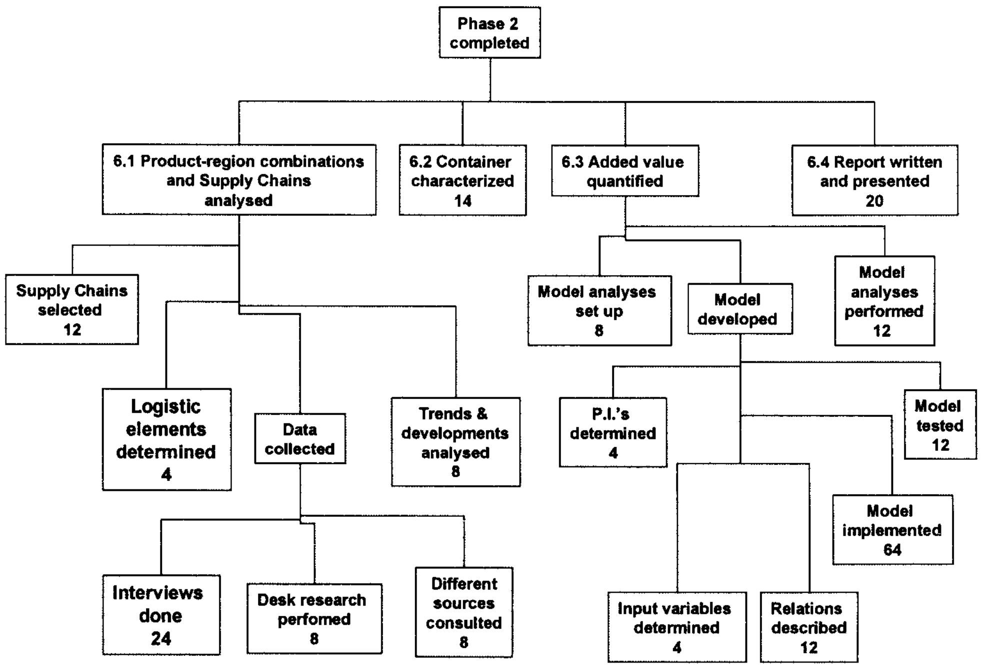


Figure 6.1: Work breakdown structure (measured in man days work)

In Table 6.4 an overview is presented of all tasks which have to be performed. Moreover, an expected lead time is stated. This lead time is measured in working days. Finally, order relations have been stated which define when a particular task can start or must end.

Table 6.4: List of project tasks

Task	Expected lead time	Order relations
6.1.1 Supply chains selected	15	
6.1.2 Logistic elements determined	10	
6.1.3 Interviews done	45	After 1.1 and 1.2
6.1.4 Desk research performed	15	After 1.1 and 1.2
6.1.5 Different sources consulted	15	After 1.1 and 1.2
6.1.6 Trends & developments analyzed	15	After 1.1 and 1.2
6.2 Container characterized	25	As late as possible
6.3.1 Model analyses set up	15	After 1.3, 1.4, 1.5 and 1.6
6.3.2 Performance indicators determined	10	After 3.1
6.3.3 Input variables determined	10	After 3.1
6.3.4 Relations described	25	After 1.3, 1.4, 1.5, 1.6, 2, 3.2 and 3.3

Task	Expected lead time	Order relations
6.3.5 Model implemented	100	After 3.1, 3.2, 3.3 and 3.4
6.3.6 Model tested	20	After 3.5
6.3.7 Model analyses performed	20	After 3.6
6.4 Report written	50	After 3.7

Based on this list of project tasks a Gantt Chart has been produced. This Gantt chart is presented in Figure 2.

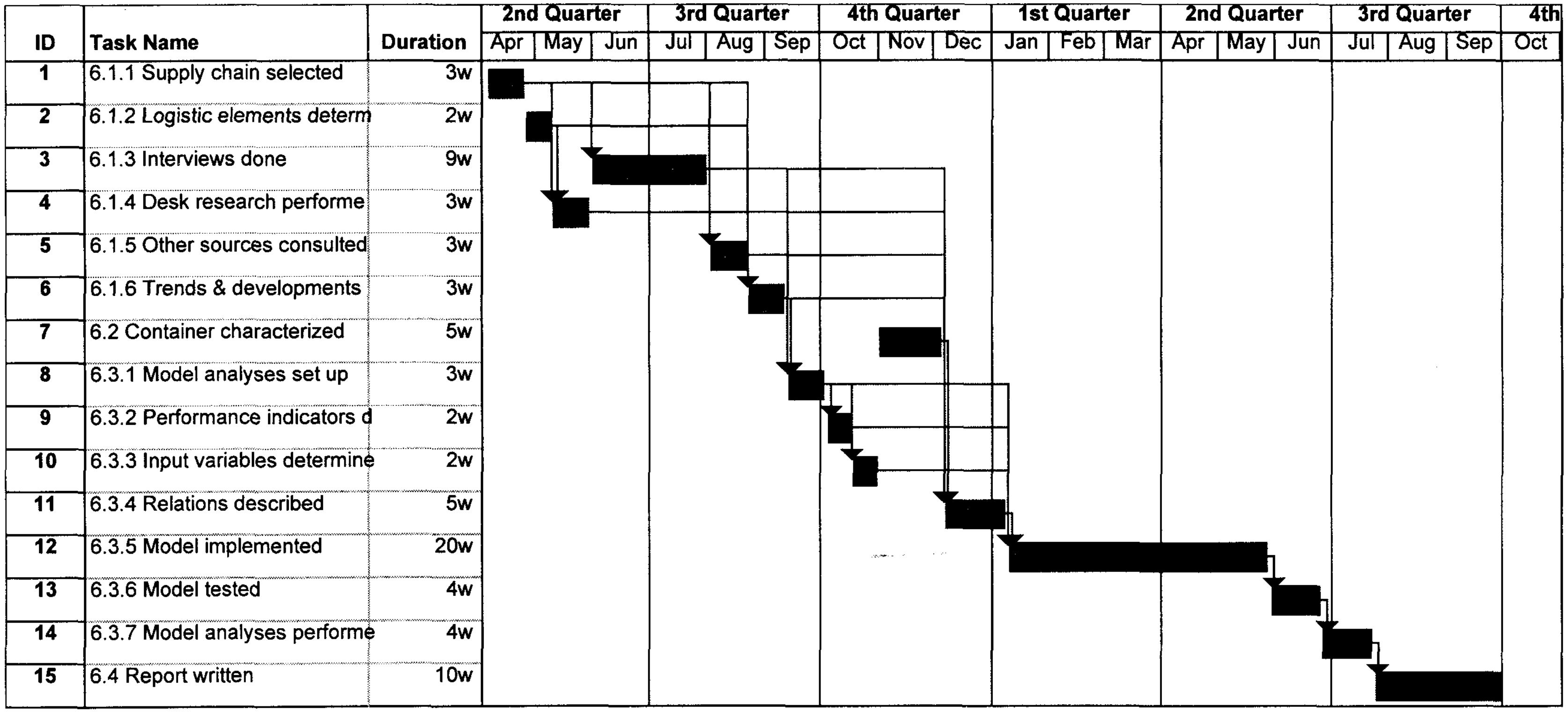


Figure 2: Gantt chart

e. Requirements from other tasks
Especially in task 6.2 (quantification of container characteristics) input from the other tasks will be needed. The following tasks are expected to answer the following questions:

Task 1:
- Which gain of product quality can be realized?
- Which reduction of product weight loss and product decay can be realized?

Task 2:
- Which reduction of energy use can be realized?

Task 3:
- What will be the cost of the new climate control system.
- What kind of maintenance will it ask for?

Task 4:
- How much will cost the release system for green chemicals?
- Which gain of product quality can be realized?

Task 5:
- How much will the monitoring system cost?
- What kind of maintenance will it ask for?

1.3.7 Task 7: Development of integrated dynamic control strategies

a. Introduction
The development of the control algorithms that is part of both Task 2 and Task 7, will be discussed in this document. The global structure of the system and a time-schedule is presented. Furthermore the necessary input from other tasks and partners will be indicated.
In the CEET 2005 project Supervisory Optimising Control algorithms (SOC-system) will be developed for transport of agro materials (apples, chicory and tomatoes) in a container. In Figure 7.1 the different layers of process control and optimisation are illustrated in the case of container transport. The container hardware consists of local controllers that are available in the control systems of Carrier Transicold. The settings are the setpoints for this hardware control system. The SOC-system consists of two subsystems that determine the optimal settings for these hardware. The optimising control system or the primary subsystem will be developed in task 2 and the supervisory control system or the secondary subsystem will be developed in task 7. The primary subsystem determines the optimal climate setpoints that will be used by the container hardware. These setpoints are calculated the optimal trajectories for the climate conditions, energy usage and product quality attributes that are determined by the secondary subsystem.

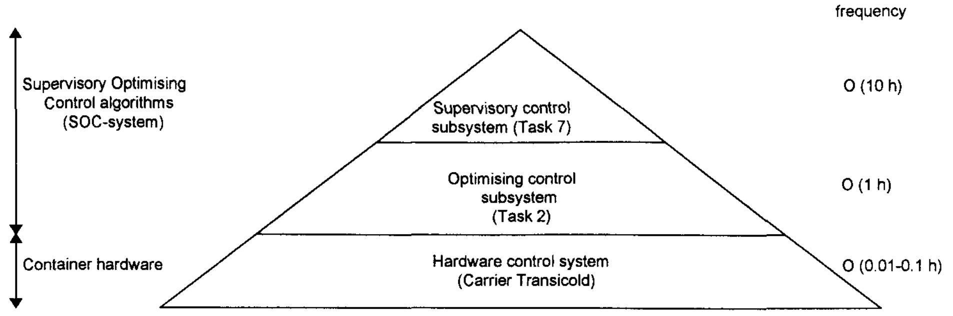


Figure 7.1: Layers of process control and optimisation

The current control system of the container receives setpoints from the user as is shown in Figure 7.2. In current operation the setpoints are determined only once in the beginning of the transport. The additional layer that will be developed in this project will improve the transport of agro-material by conditions to guarantee optimal quality against lowest possible cost. The system is also illustrated in Figure 7.3.

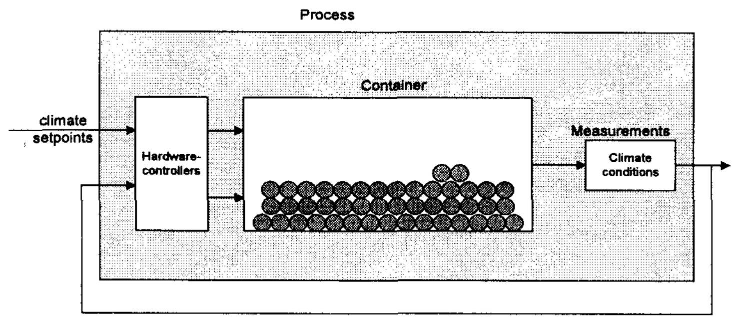


Figure 7.2: Existing control structure

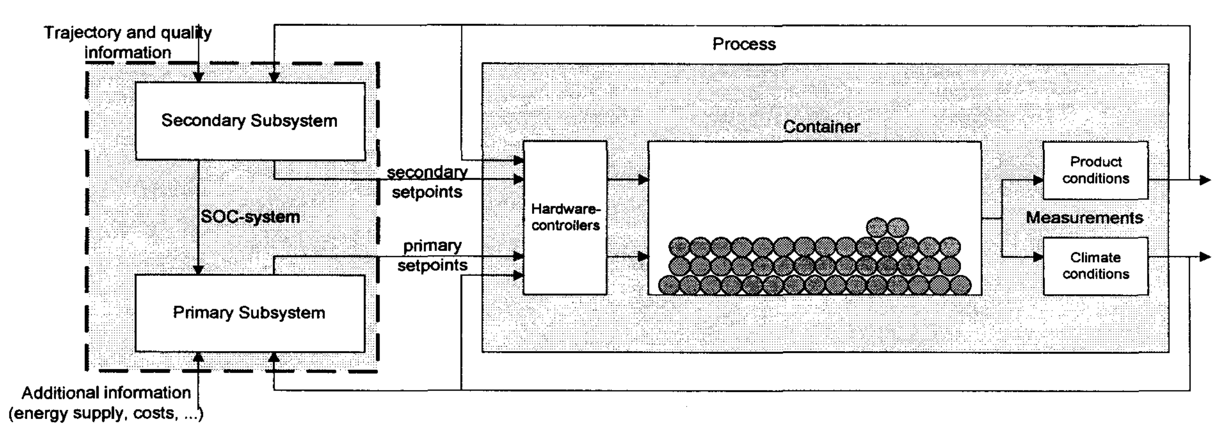


Figure 7.3: Proposed control structure

The SOC-system uses:

- monitoring information about product quality and product behaviour (Task 1, 4 and 5),
- information on energy supplies (Task 3),
- information about the trajectory of the container (Task 6).

This information is used to determine the optimal container settings. The main difference between the existing and the new structure is the direct use of product, logistic and energy information in determining the optimal setpoints for the hardware controllers. The existing hardware controllers try to reach and maintain these setpoints in the container. In Figure 7.4 the proposed structure is presented in relation with the other tasks in the CEET 2005 project.

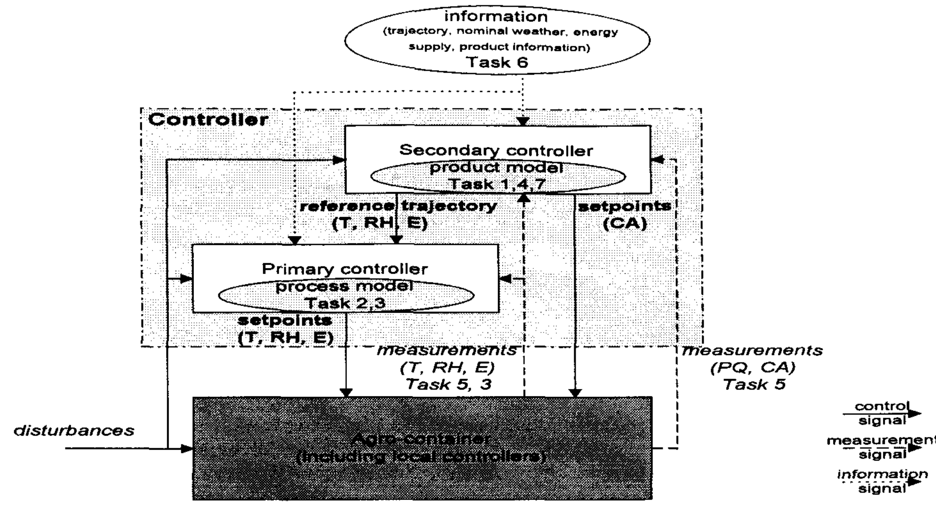


Figure 7.4: Global control structure

In controlling a multivariable process, the problem often is that there are more outputs than controllable inputs. This is the main motivation for the division in the primary and the secondary subsystems in the SOC-system. The primary subsystem controls the most important outputs exactly using only part of the controllable inputs of the agro-container. The secondary subsystem keeps the other outputs within specified limits using the remaining controllable inputs of the agro-container. This corresponds with a partial control problem. In Table 7.1 a possible division for the in- and outputs of the agro-container is presented. A multivariable approach will be used in both subsystems, because all inputs affect all outputs. In Table 1 only the most direct coupling between individual in- and outputs are presented (e.g. air-temperature with the main product quality attribute and air-humidity with weight-loss).

SOC-system	Controllable inputs for the agro-container	Outputs from the agro-container
Primary subsystem	Air-temperature	Overall product quality attribute
	Air-humidity	Weight-loss
	Energy usage for ventilation	Cost of transport that can be manipulated
Secondary subsystem	O_2/CO_2/other	Remaining product quality attributes:
	Green chemicals	Texture, microbial activity, taste, smell,

Table 7.1: In- and outputs of the agro-container

The primary controller from Figure 7.3 determines the optimal actual settings for the temperature and humidity of the air inside the container, and the amount of energy that is available to realise this target. These settings are used to control exactly the main product quality attribute and the cost of transport that can be manipulated, i.e. amount/frequency of ventilation. The task of the primary subsystem is to optimise between process conditions and energy usage. This task requires an optimisation algorithm and a predictive model to foresee future effects. This will probably lead to the use of Model Predictive Control (MPC) techniques in the primary subsystem. The secondary subsystem performs the supervisory task. It determines the setpoints for the remaining controllable inputs and calculates the targets for the primary subsystem. In order to perform these tasks an optimisation algorithm will be used.

b. Objectives

The main objective of this task is to develop supervisory optimising control software (SOC-system) for agro-containers that optimises the transport of agro-products. This implies that the SOC-system:

- Determines optimal setpoints for the hardware controllers;
- Optimises product quality and cost in the agro-container;
- Monitors product quality and cost.

c. Time schedule

The time-period for the development of the SOC-system consists of three parts that largely correspond with the phases as defined in the CEET 2005 proposal. The deviations are due to the fact that information from other tasks is essential for the development of the system. In Figure 4 the time schedule is presented.

Part 1: Preparation and global SOC-system structure development

The duration of this phase is from 1 October 1998 until 31 May 1999. The deliverables are:

- Described work plan review phase 1;
- Structure of the SOC-system developed;
- SOC-system structure tested and tuned in a simulation study using simple models for temperature, humidity and product quality.

Part 2: Conditioning of climate and testing the SOC-system

The duration of this phase is from 1 June 1999 until 31 May 2000. The deliverables are:

- Described work plan review phase 2;
- Final structure of the SOC-system developed;
- Primary subsystem tested and tuned in a simulation study using models for temperature, humidity and product quality with variance;
- Primary subsystem tested and tuned in the climate room.

Part 3: CA-control and implementation in a test container

The duration of this phase is from 1 June 2000 until 30 September 2001. The deliverables are:

- Final report;
- Final algorithms of the SOC-system and documentation;
- SOC-system tested and tuned in a simulation study using models for temperature, humidity, product quality and gas conditions;
- SOC-system tested and tuned in a container.

ID	Task Name	Duration	Start	Finish
1	SOC-system development CEET	782d	Thu 1-10-9	Sun 30-9-0
2	Part 1: Preparation and global SOC-system structure	173d	Thu 1-10-9	Mon 31-5-9
3	Preparation	131d	Thu 1-10-9	Thu 1-4-9
4	Development of structure of the SOC-system	21d	Fri 2-4-9	Fri 30-4-9
5	Development of simulation	10d	Mon 3-5-9	Fri 14-5-9
6	Simulation with the SOC-system structure	11d	Mon 17-5-9	Mon 31-5-9
7	Part 2: Conditioning of climate and testing the primary	262d	Tue 1-6-9	Wed 31-5-0
8	Preparation of the available models	44d	Tue 1-6-9	Sat 31-7-9
9	Development of final structure of the SOC-system	22d	Thu 1-7-9	Sat 31-7-9
10	Development of primary unit	110d	Mon 2-8-9	Fri 31-12-9
11	Testing the primary unit	174d	Fri 1-10-9	Wed 31-5-0
12	Part 3: CA-control and implementation in a container	347d	Thu 1-6-0	Sun 30-9-0
13	Preparation of available models	152d	Thu 1-6-0	Sun 31-12-0
14	Development of SOC-system	153d	Tue 1-8-0	Thu 1-3-0
15	Implementation of the SOC-system	195d	Mon 1-1-0	Sun 30-9-0

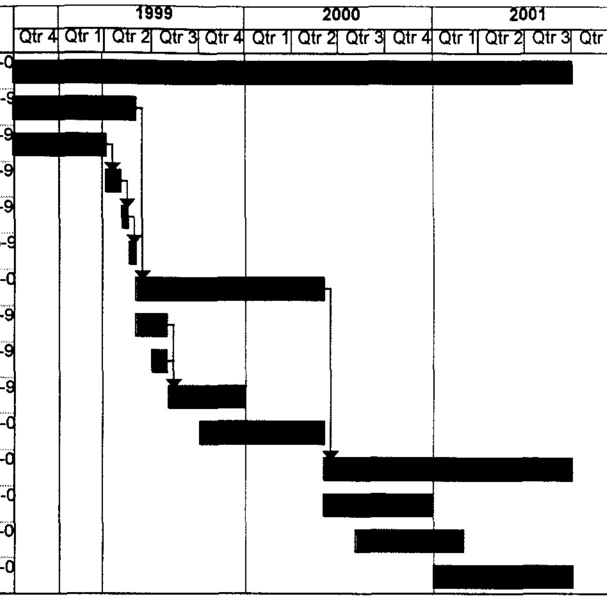


Figure 4: Time schedule of the SOC-system development

d. Deliverables

At the end of part 3 as scheduled in this report, the programmed SOC-system with corresponding documentation is implemented and tested in a testing-environment. The SOC-system is a tested prototype that is fitted into the container located at ATO. The deliverables are:

- The tested SOC-system software of the prototype consisting of the primary and secondary units, and additional managing software;
- A report presenting the results and possibilities of the tested SOC-system;
- A technical report presenting technical details on the structure, algorithms and tuning of the SOC-system.

e. Boundary conditions

The boundary conditions for the development and practical use of the SOC-system are:

- The availability of sufficient computing conditions for the system (either central in theagro-container or decentral);
- The benefits of the additional layer are higher for longer transport chains;
- The benefits of the additional layer depend on type of product and quality, and the information about it.

f. Requirements

The requirements for the development of the SOC-system are listed for the three parts in the SOC-system development.

Part 1: Preparation and global SOC-system structure development

No.	Input	Date	Correspondent	Check
1.	Structure local controllers	1 May 1999	Carrier Transicold	
2.	Lead time approximation	April 1999	Task 6-ATO	
3.	Selection product quality for apples	April 1999	Task 1-ATO	
4.	Simple model of product quality of apples in relation with process conditions (T and RH)	15 April 1999	Task 1-ATO	
5.	Estimate heat production	April 1999	Task 1-ATO	
6.	Estimate transpiration rate	April 1999	Task 1-ATO	
7.	Simple model of process conditions (T and RH)	March 1999	Task 2-ATO	o.k.
8.	Simple energy model	15 April 1999	Ecofys	
9.	Green chemicals as control input?	March 1999	Task 4-ATO	o.k.

Part 2: Conditioning of climate and testing the SOC-system

No.	Input	Date	Correspondent	Check
10.	Preliminary model lead time and outside conditions	31 July 1999	Task 6-ATO	
11.	Selection product quality for all products	31 July 1999	Task 1-ATO	
12.	Preliminary model of product quality of apples in relation with process conditions (T and RH)	31 July 1999	Task 1-ATO	
13.	Simple model of product quality of all products in relation with process conditions (T and RH)	31 July 1999	Task 1-ATO	
14.	Parameter heat production apples and estimates other products	31 July 1999	Task 1-ATO	
15.	Parameter transpiration rate apples and estimates other products	31 July 1999	Task 1-ATO	
16.	Preliminary model of process conditions (T and RH)	31 July 1999	Task 2-ATO	
17.	Preliminary energy model	31 July 1999	Ecofys	
18.	Identification measurements and procedure	30 June 1999	Task 2,5-ATO	
19.	Settings of the hardware controllers can be manipulated in the container available for ATO	30 June 1999	Carrier Transicold	
20.	Selection of measurable process conditions (T,RH)	30 June 1999	Task 5-ATO	

Part 3: CA-control and implementation in a test container

No.	Input	Date	Correspondent	Check
21.	Final model lead time and outside conditions	31 December 2000	Task 6-ATO	
22.	Selection of measurable CA conditions	1 October 2000		
23.	Final model of product quality in relation with process conditions (T and RH)	31 December 2000	Task 1-ATO	
24.	Parameter heat production all products	31 December 2000	Task 1-ATO	
25.	Parameter transpiration rate all products	31 December 2000	Task 1-ATO	
26.	Final model of process conditions (T and RH)	31 December 2000	Task 2-ATO	
27.	Final energy model	31 December 2000	Ecofys	
28.	Interaction microbiology with product quality and process conditions	1 October 2000	Task 3-ATO	
29.	Characteristics of measurement dynamics (T,RH)	1 June 2000	Task 5-ATO	
30.	Characteristics of measurement dynamics (CA)	31 December 2000	Task 5-ATO	

Appendix task 7

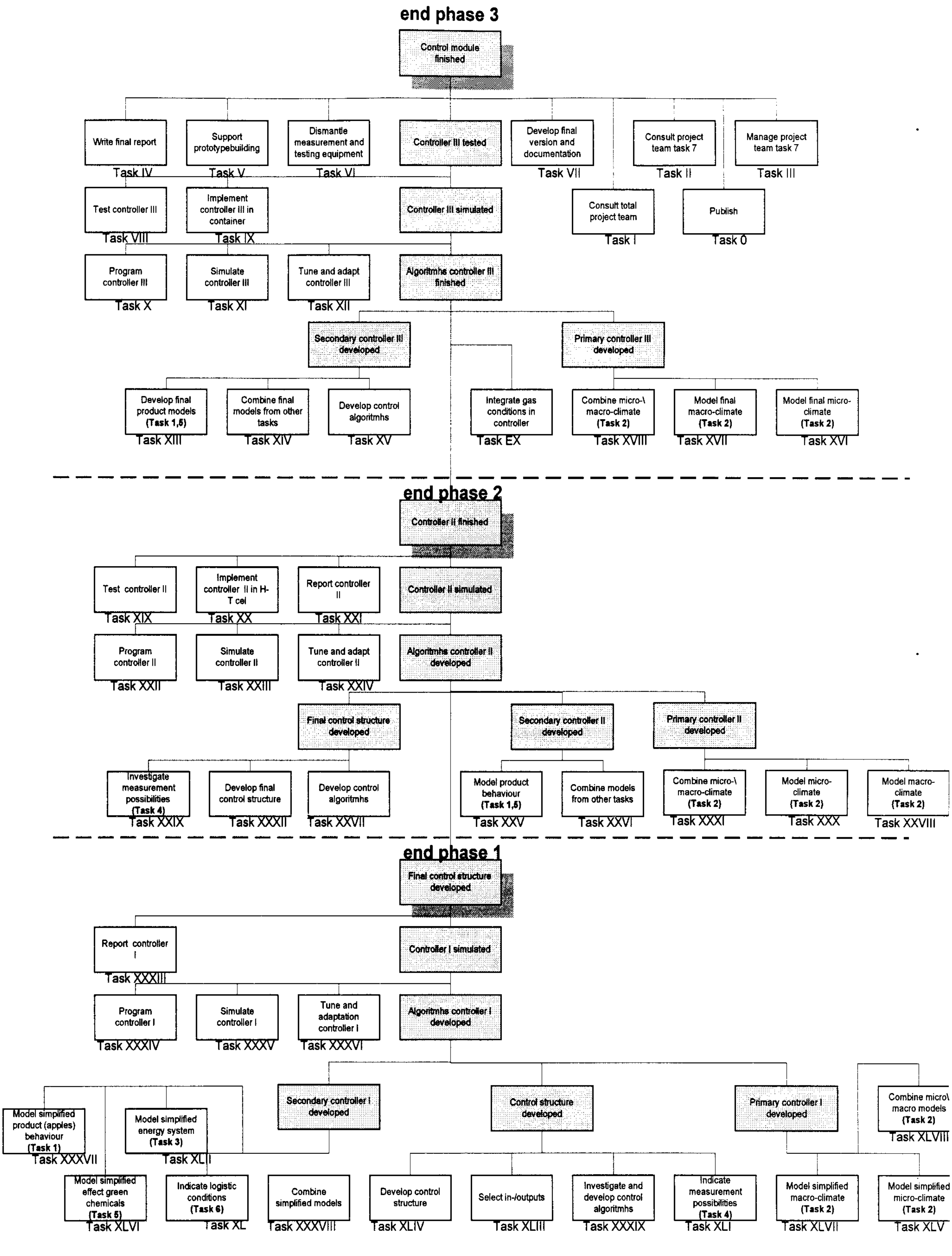
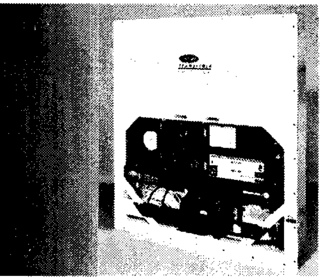
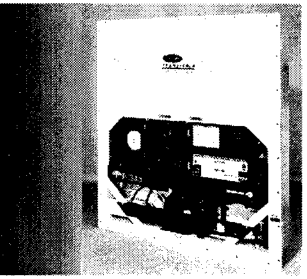


Figure 1: Structure task 7



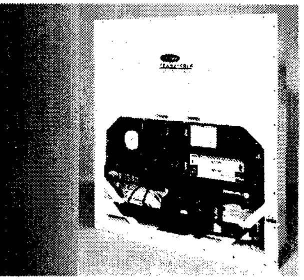
CEET 2005 Program Update

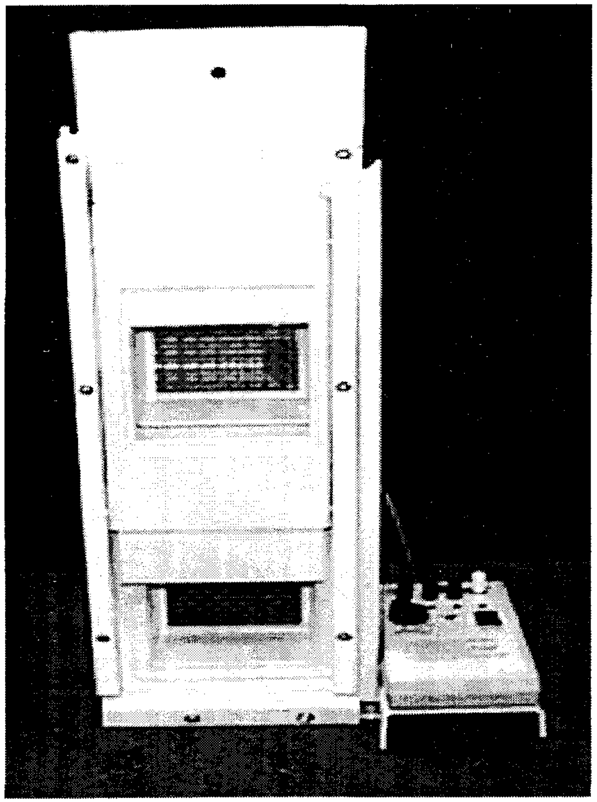
Carrier Transicold Activities
March 17, 1999



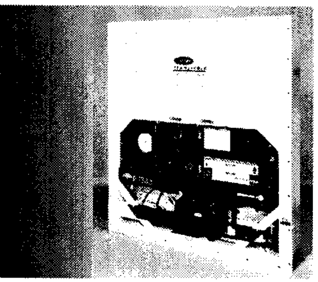
- Flow control development
- Atmosphere control
  - Humidity
  - Composition control
  - Other activities
- Power reduction

Carrier Transicold



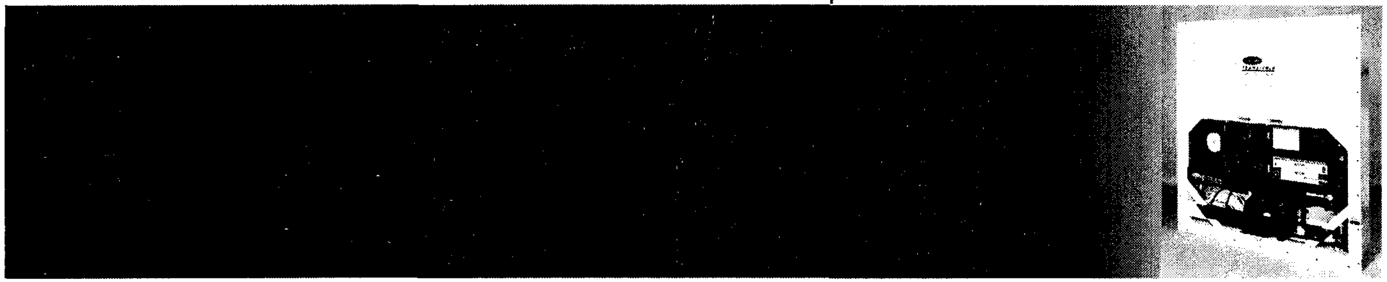


- Stepper motor driven
- Numerous control options
  - Air volume
  - CO_2 sensor, etc
  - Percent open
- Frozen setpoint over-ride



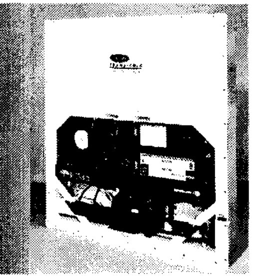
- Further applications of the present system
- Work on continued system improvements
  - Sensors
  - Droplet size
- Evaluation of “greeen chemical” application required

- Everfresh unit to be provided to ATO for testing and evaluation of control algorithms by the end of March
- CTD making continued improvements to the system
  - CO_2 sensor
  - Control algorithms



- Evaluating other means of controlling the internal atmosphere
  - Scrubbers
  - Filters
  - Alternative active control methods and technologies

Carrier Transicold



- Toshiba alliance
  - Variable speed motor controls
- Compressor
- Fans
- Motors
- Coils

CEET 2005: Sensors

task 5

CEET meeting, 17- 3 -1999

Riki van den Boogaard, Willie van den Broek, Jeremy Harbinson, Joost Ruijsch

Phase 1: Review

- Identification of factors related to the maintenance of product quality
- Identification of warning signals of product deterioration
- Identification of suitable technology:

    sensitivity

    durability

    reliability

    maintenance

    costs

Phase 2: Tasks

Main tasks

- CO_2/O_2 sensor: product environment
- Volatiles detection: signs of product deterioration, anaerobiosis, ripening or levels of green chemicals
- Particulates detector: presence of fungal spores

Subsiduary task

- Heat production in products: instrumentation to provide data for models

Task 1: CO_2 and O_2 sensor

Two detectors in one housing

- CO_2 : infrared absorption, sensitivity 0-5%
- O_2: singlet/triplet lifetime measurement,
  any desired sensitivity

Task 2: Volatiles

Volatiles detection: signs of product deterioration, anaerobiosis, ripening or levels of green chemicals

- ethanol/ethylene: heated metal oxide sensor under development, required increase of sensitivity: 100 fold
- microbalance sensors: adsorption of volatiles onto coated SAW or quartz crystal, changes in resonance frequency, choice of metallated substituted tetraphenylporphyrins and phthalocyanines as coatings
- characterisation and analysis of signals

Task 3: Particulates & Task 4: Heat production

ato-dlo

Particulates indicative of fungal spores, indicating pathogen or saprotroph attack, timing the use of green chemicals

- detection of light scatering by particulates when passing an LED or laser diode light beam
- characterisation and analysis of signals

Measurement of heat production of products in different environments to support models

- calorimitry combined with measurements of gas composition