Commission of the European Communities

energy

Thermal waste recovery at electric power plants in the European Economic Community

Volume I: General synthesis
Volume II: Case studies

Demonstration project

Report

EUR 11660 EN

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SUMMARY

The functioning of any thermal electric power plant (classic or nuclear) results in waste into the atmosphere of large quantities of heat at low temperature levels:
- 15 to 30/40°C for plants in open circuit (river or sea);
- 25 to 40°C for plants in closed circuit (equiped with a cooling tower).

Greenhouse heating, waste heat aquaculture and building heating have been the main applications envisaged which have lead to experimental implementations. In all cases, systems of heating by waste heat are today technically developed. In addition, the quantities of waste heat rejected by power plants are such that the size of the recovery operation (surface area of greenhouses or basins) is never limited by the waste heat flow.

At present, there are 38 operations in service in the EEC nations using thermal waste from electric power plants, and 9 operations are in construction or projects that will soon materialize. The majority of these operations are today purely commercial and mainly concern:
- horticulture and market gardening in greenhouses,
- freshwater aquaculture.

The other applications are of much more doubtful profitability (building heating, agriculture), or remain for now still in the experimental stage (seawater aquaculture, waste heat irrigation, algae culture).

The countries that count the most number of commercial operations as of this date are the following:
- France (horticulture and market gardening),
- United Kingdom (horticulture, market gardening, aquaculture),
- West Germany (building heating).

Concerning greenhouse heating, interest in this type of operation somewhat faded around 1985/1986, due to start-up difficulties or the bankrupcies of certain important projects. Problems encountered more specifically concerned the organization and coördination of the activities of several small family-type enterprises over a new area of great surface. In addition, the recent drop in the price of fuel has reduced the profitability of resorting to thermal waste for heating.

Concerning freshwater aquaculture, we are currently witnessing several operations' passing from the experimental stage to the commercial stage, mainly for freshwater aquaculture. Seawater aquaculture appears less advanced, but numerous initiatives, namely in Italy, are appearing. Waste heat aquaculture activities, which are made possible only thanks to the large quantities of free heat rejected by plants should see development in coming years.

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I - THE USE OF THERMAL WASTE AT ELECTRIC POWER PLANTS

1. INTRODUCTION

Since 1974, electricity suppliers for the EEC nations have initiated research and development programs to recover the residual heat of their thermal or nuclear power plants. This research has concerned crops (horticulture, market gardening, agriculture), fish rearing (freshwater or seawater), building heating and algae culture.

A portion of this research has resulted in commercial operations (mainly in horticulture, market gardening, aquaculture); other research is still in the experimental stage (algae culture).

The objective of this study is three-fold:

- to make an exhaustive inventory of all thermal waste recovery operations in service or in construction, and to make a detailed assessment;
- thanks to this inventory and by means of detailed case studies on the most representative operations, to realize a complete technical and economic analysis of these operations;
- in view of the joint results of the assessment of operations and the technical and economic analysis, to extricate the technical and economic options to promote.

The present volume of the report (Volume I) follows these three stages:

In Chapter II is to be found a general synthesis of the thermal waste recovery operations currently being conducted by the EEC, followed by syntheses by type of activity and country, and by the detailed inventory of all the operations catalogued.

Chapter III more finely analyses the commercial viability of each of the types of activities which are the object of commercial operations (horticulture and market gardening, aquaculture, etc.) by resituating them, if necessary, in their global technical and economic context, and by trying to extricate conditions of success or failure.

Chapter IV concludes by spotlighting the strongest ideas extracted from the preceeding chapters, so as to present them in the form of technological and economic actions which could be promoted in the future.

Volume II of the report contains detailed case studies which have been carried out.

Volume III of the report contains the complete index of the thermal waste recovery operations in the EEC, grouping all the detailed questionnaires used to carry out the assessment of operations. A data-processed version of this index will be joined to this report.

2. THE USE OF THERMAL WASTE: GENERAL DESCRIPTION

In electric power plants, the vapour produced is used to switch an alternator, then it is condensed in a condensor. It is the cooling circuit of this condensor which produces waste heat, called thermal waste.

Two types of cooling circuits must be distinguished:

- open circuit: is used for power plants next to the sea or on high-flow rivers. The water pumped to cool the condensor is rejected entirely in a natural environment at a temperature 8 to 10° higher. All the water flow is available for a recovery operation. An open circuit allows the plant to have a better thermodynamic yield.

- closed circuit: is used when river flow is insufficient; the heating up of the river would be too great in open circuit, with harmful consequences for the aquatic environment.
  Calories are therefore evacuated into the atmosphere in refrigeration towers. The temperature of the cooled water is that of humid air, increased by a residual heating up, "the approach" which goes from 6°C in the summer to 20°C in the winter. The cooled water is sent back to the condensor.
  In order to avoid salt concentration, a permanent drain rejects into the river a fraction of the cooling circuit flow. A pump assures clean water back-up before entering the condensor.

  Waste recovery can be carried out on two levels:
  - either starting from the draining circuit,
  - or taking the water from the main circuit, and reinjecting it after recovery.

  A closed circuit power plant's yield is less than an open circuit plant's by a few points.

The main characteristics of the two types of circuit are summarized in the table below, for a 1300 MW nuclear power plant:

Type of circuit	Plant's yield	Water flow	Min. temp.	Max. temp.	Mean ΔT available	ΔT used	Energy equivalant
Open	38%	20 to 50 m3/s	4-5°C	40°C	11°C	<5°C	400 000 tep/y
Closed	33%	1 m3/s (draining circuit)	23°C	40°C	23°C	<5°C	10 000 tep/y

(Source: EDF)

The type of cooling circuit is independent of the fuel used by the plant. Available waste water flow and its temperature are independent of the fuel used and the plant's temperature.

Beside these technical potentialities, a thermal waste recovery operation must have a minimum of guarantees:

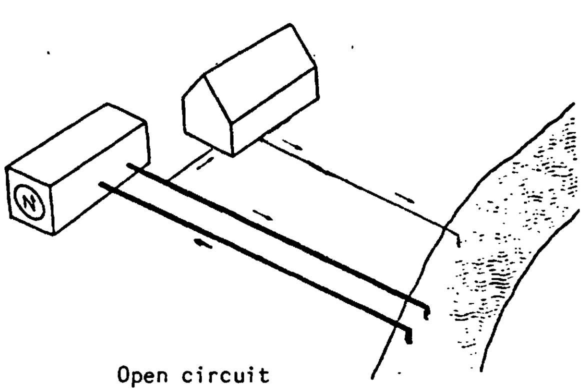
- the plant must function in base, to assure a constant and regular production in heat. Irregular functioning of the plant (waste heat temperature drop, stoppage) would cause an energy overconsumption in back-up heating for a greenhouse heating operation, or a drop in growth of fish in aquaculture, even the death of certain species. In general, nuclear power plants give this assurance;

- continuous and regular functioning must be spread over a long period (20 years), so that a commercial operation of thermal waste recovery may be economically viable and fruitful.

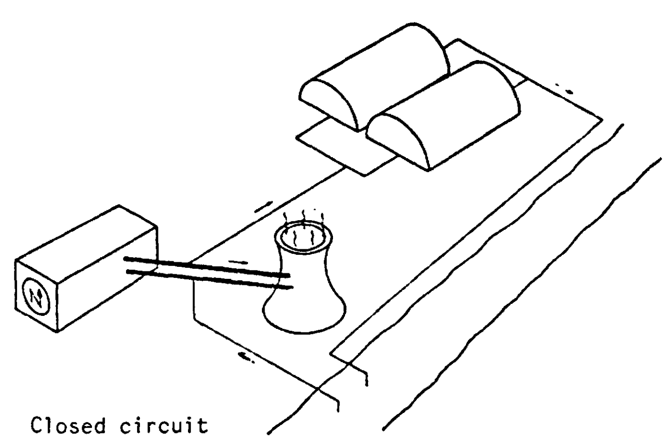
The purpose of this study is the recovery of thermal waste at electric power plants, to the exclusion of any other type of recovery. In particular, are excluded:

- the use of waste heat (90°C) or vapour supplied by an electric plant: this modifies the plant's functioning;
- the use of industrial waste;
- electric power plants of a power less than 100 MW.

Concerning operations situated nearby nuclear power plants, it should be understood that market-gardening or aquacultural products present no special risks of radioactivity. According to experts, the radioactivity of fish reared in waste water coming from a nuclear power plant is, on the contrary, lower than that of fish reared in a natural environment, because of their faster growth which esposes them to land radioactivity for a shorter time.



Open circuit



Closed circuit

II - ASSESSMENT-SYNTHESIS OF OPERATIONS

1. GENERAL SYNTHESIS

1.1 Generalities

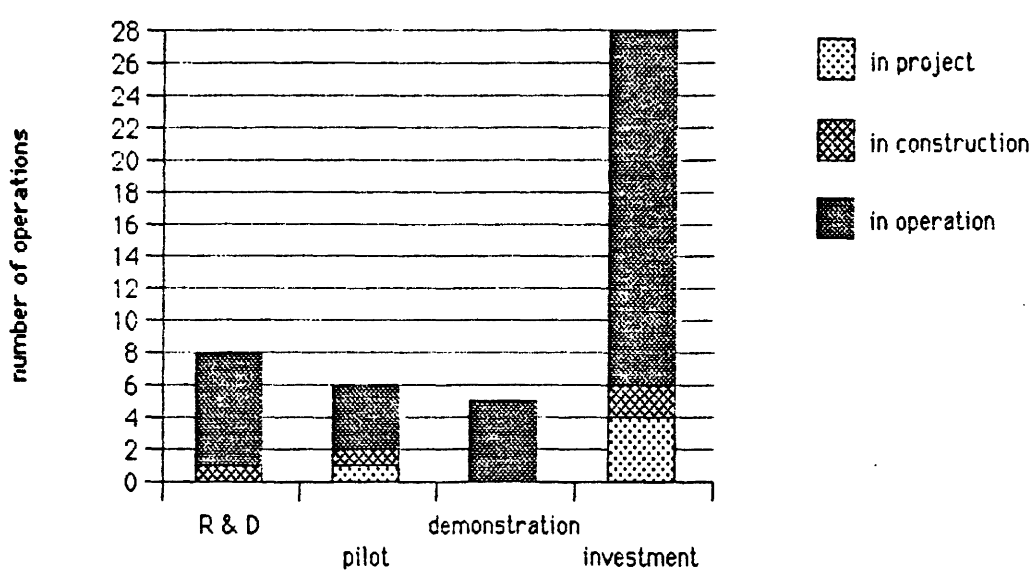
At this time there exist 47 operations using thermal waste at electric power plants, out of 39 different electricity productions sites.

Out of these 47 operations:
- 38 are in operation
- 4 are in construction
- 5 are in project, almost ready.

Projects not likely to be ready by the end of 1988 have been excluded from this inventory. (Information gathered for other more uncertain projects are mentioned in the detailed inventory.)

Four different stages may be distinguished for these operations, thus defined by the Commission:
- Research and Development: Various trials and technical upgrades;
- Pilot: Installation on a semi-industrial scale, but with technical risks which are still important (technical feasability);
- Demonstration: Installation on an industrial scale, but with economic risks which are still important (economic feasability);
- Investment: Autonomous commercial development.

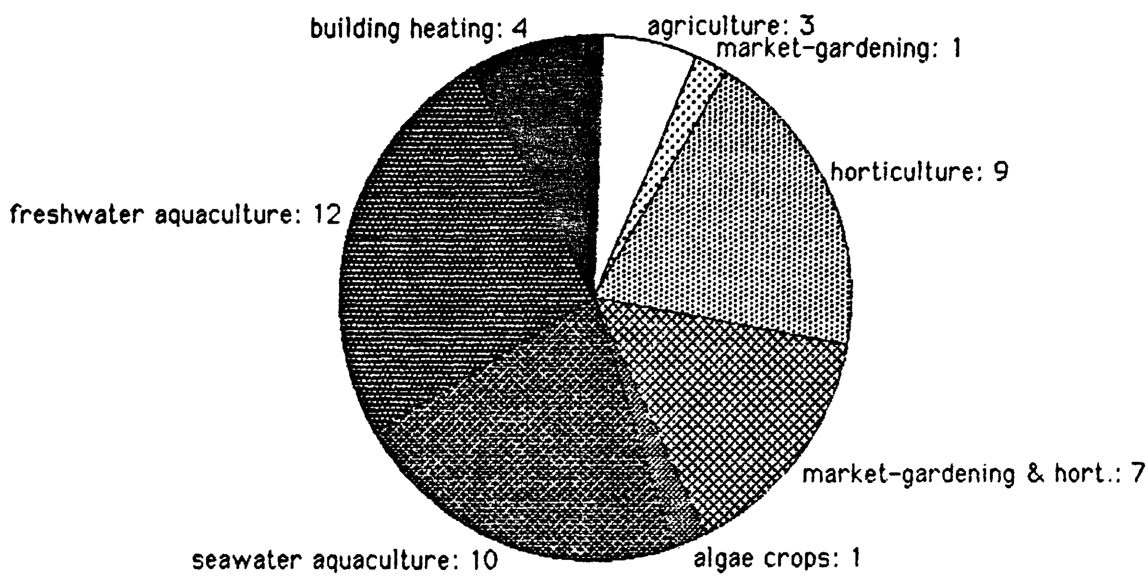
DIVISION OF OPERATIONS BY STAGE AND ADVANCEMENT



1.2 Assessment of operations

The graph below indicates the number of operations of each type:

DIVISION BY ACTIVITY

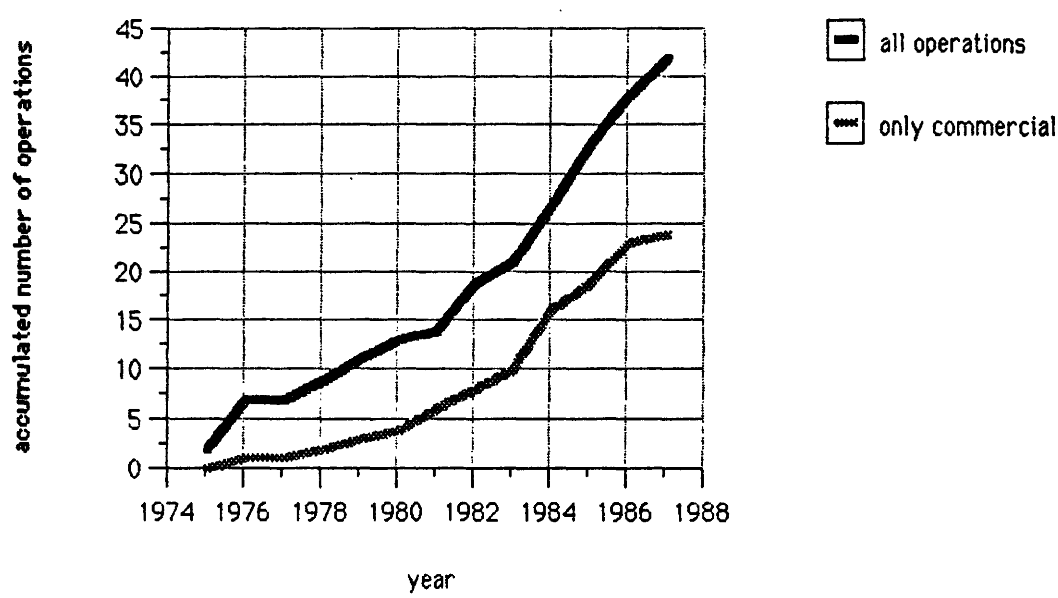


Almost 60% of the operations are today commercial (investment phase).

1.3 Historic evolution

The evolution in time since 1974 gives the following results:

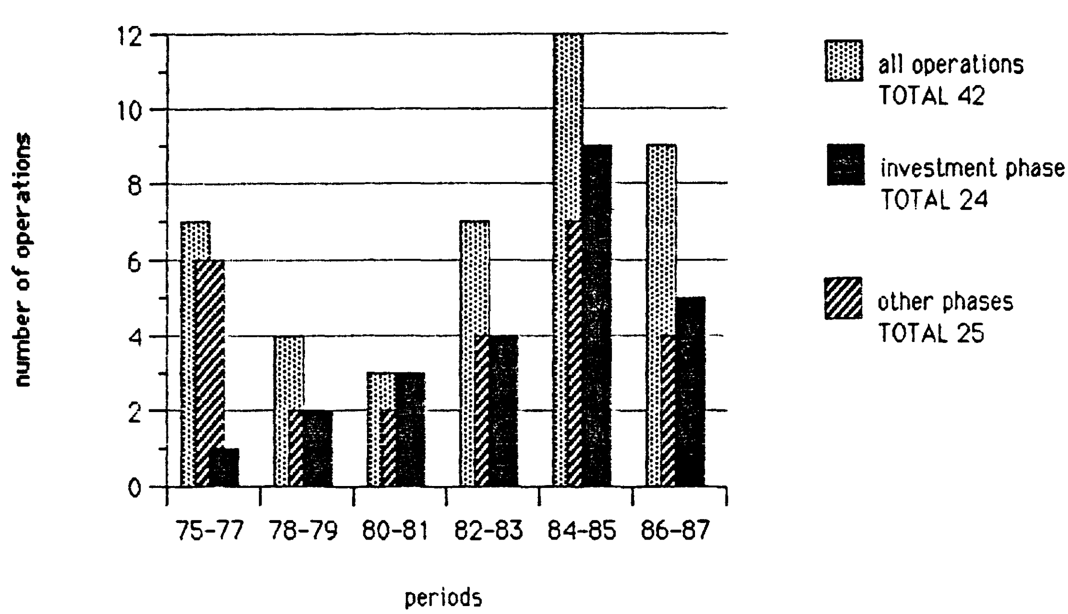
ACCUMULATION OF OPERATIONS IN TIME



N.B.: projects not included.

This graph can be refined by grouping operations' age by 2-year sections, thereby allowing the smoothing out of results. In the graph we will only take operations in function or in construction in 1987. Moreover, the same operation may appear twice if it is one in a commercial phase which has been the object of an earlier research phase on the same site (there are 7 operations of this type):

DIVISION OF OPERATIONS IN TIME



One can therefore note that:

□ In the first period (1975-1981), operations were above all of R & D, pilot or demonstration type. At this time, crop or breeding techniques were developed by electricity producers: EDF in France (Saint Laurent des Eaux), Intercom in Belgium (Tihange), the ENEL in Italy (CARPA), the CEGB in the United Kingdom (Drax), RWE in West Germany (Hortitherm, Limnotherm, Agrotherm). The first oil shock is one of the reasons for this flowering of operations.

□ Progressively, following this research, commercial operations were begun, increasing little by little, linearly between 1975 and 1983: the first commercial operations concerned small aquaculture installations (West Germany, Holland), followed shortly thereafter by an important greenhouse heating operation (Drax, in the United Kingdom).

□ After having diminished up until 1981, non-commercial operations forcefully resumed starting from 1982 with a strong increase in 1984-85, and a drop in 1986-87. This concerned research undertaken by electricity producers (second phase of the CARPA project in Italy, arrival of new nations such as Spain and Portugal), but also - and this is a new phenomenon - research conducted by professional groups (cultivating or aquaculture): the PAGV program in Holland (Agriculture Ministry), the sites of Gravelines and of Blayais in France (professional aquaculture unions), the site of Enstedvaerket in Denmark (Danish Aquaculture Institute). This trend is most pronounced in aquaculture, where research still needs to be effectuated insofar as breeding techniques.

□ In 1984-1985, the number of commercial operations initiated increased considerably: it doubled compared to the preceeding period. This was the fruit of ten years of research, and it was at this time that most of the large-scale operations began: Tihange (aquaculture and horticulture) in Belgium; Le Bugey, Dampierre, Saint Laurent (horticulture and market gardening) in France; Fiddlers Ferry, Hinkley Point, Hunterston (aquaculture) in the United Kingdom; Texel (aquaculture) in Holland.

□ Finally, one notes that in 1986-1987 there was a net drop-off in the number of commercial operations (likewise for non-commercial operations). The decrease in the cost of energy in 1986 played a role in this. A few small operations started up: Asco in Spain, Bastardo in Italy, and Hunterston in the United Kingdom (horticulture), Langerloo in Belgium, and Ratcliffe in the United Kingdom (aquaculture). During this period, one should also note the difficulties of certain operations previously initiated, even abandonments: difficulties in Francein Le Bugey (horticulture); continued postponement of for the large Hortitherm commercial project in West Germany; abandonments in the aquaculture area: Saint Laurent in France, Eggborough and Wylfa in the United Kingdom.

This decrease can be explained by several remarks:
- the drop in the cost of energy in 1986 made operations less profitable for greenhouse and building heating;
- aquaculture has not always been the object of preliminary research, thence the commercial failures. The later start-up of research (compared to greenhouse heating) explains the stagnation of commercial operations, which should witness a new start in coming years:
- certain recovery possibilites have been abandoned, as they were unfruitful or very uncertain (agriculture, algae crops).
The following chapter analyses the present situation of each type of activity in a detailed manner.

2. SYNTHESIS BY ACTIVITY

Thermal waste recovery activities can be classified in 8 types:

- AGR: agriculture: cereal or tuber crops in heated soil (wheat, corn, potatoes) or irrigated (rice) by waste heat.

- MAR: market gardening: fruit and vegetable crops (tomatoes, cucumbers, strawberries, melons, salads, etc.).

- HOR: horticulture: cut flowers and potted plants crops.

- M & H: market gardening and horticulture: when both activities are present on the same site.

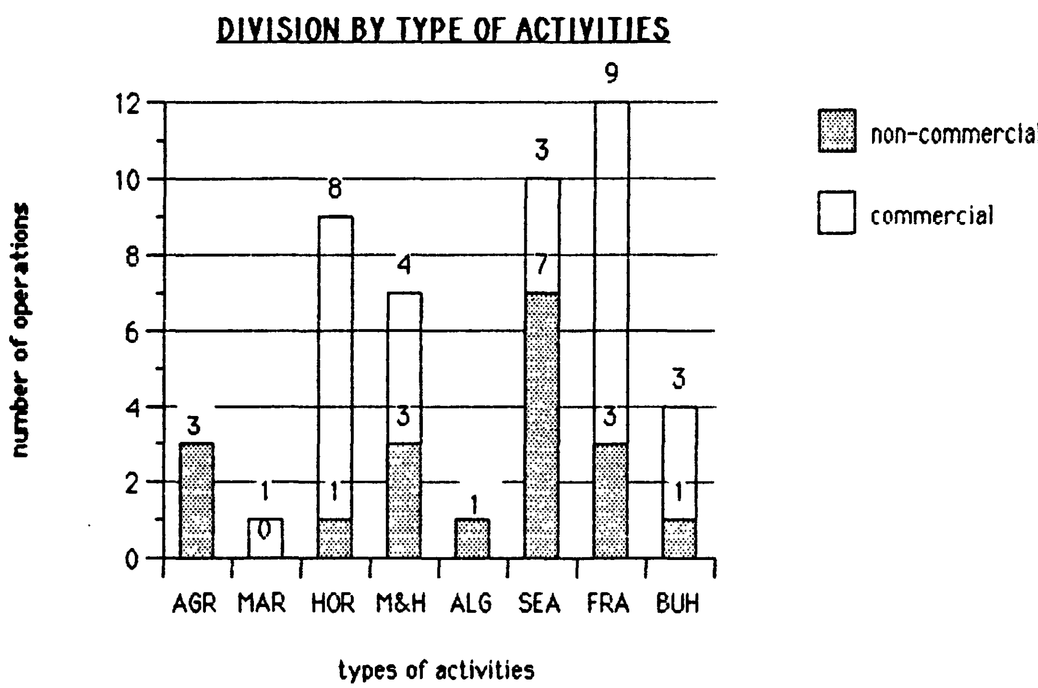
- ALG: algae crops.

- SEA: seawater aquaculture (turbot, bass, dorade, bream, eel, ...).

- FRA: freshwater aquaculture (carp, tench, tilapia, eel, silure, ornament fish).

- BUH: building heating: public (schools, swimming pools, community buildings) or private (homes).

The following graph shows the division of the 47 operations reported up till now, distinguishing the commercial and non-commercial activities:



3 major categories can be distinguished among these types of activities, in function of how far they have progressed to the commercial stage:

- activities at the commercial stage: horticulture and market gardening, freshwater aquaculture;
- transitional activities between experimental and commercial: seawater aquaculture, building heating;
- more marginal research activities: agriculture, algae culture.

2.1 Activities at the commercial stage

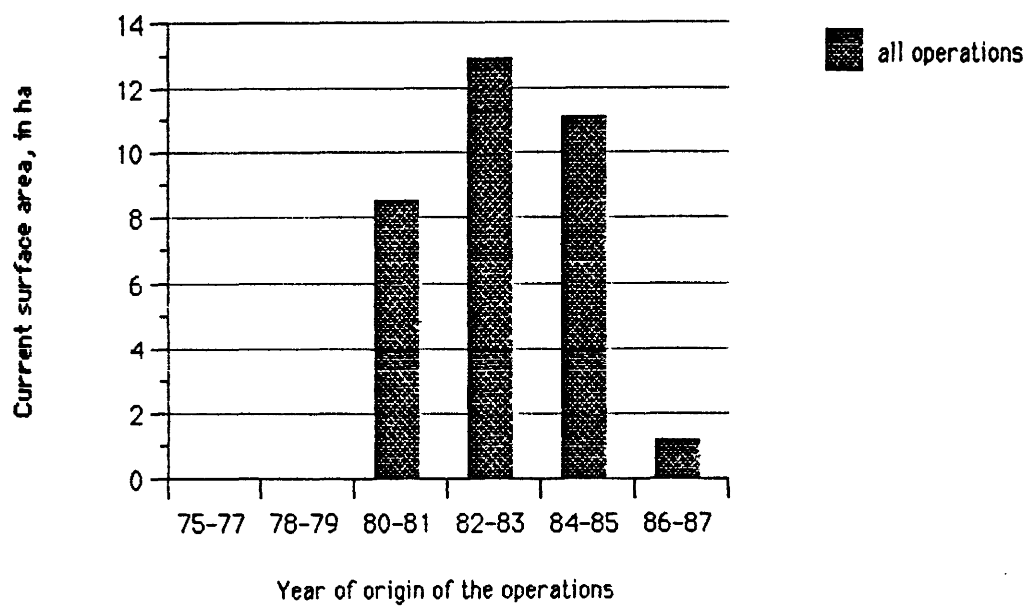
These activities are important in number of installations (28 at present) and have, for the vast majority, reached the commercial stage: these are in horticulture and market gardening, and freshwater aquaculture. It should be observed that heating and crop - or breeding - techniques are today fully developed:

□ the only operation nowadays non-commercial in horticulture and market gardening are the exception:
  - Tavazzano (the CARPA project) in Italy, but which has resulted in a commercial operation on another site (Bastardo);

- El Grao in Spain and Setubal in Portugal, the countries which are the most behind in this area;
- Le Blayais in France, which is being developed by a center for the handicaped.

Horticulture and market gardening today therefore come under the <u>commercial</u> area: at present, about 34 ha of market-gardening or horticultural greenhouses are heated by thermal waste, and this surface area concerns more than 95% of commercial operations. If we compare these surface areas to the year of origin of the operations, the following graph is obtained:

<u>SURFACE AREAS OF SET-UP GREENHOUSES, BY YEAR OF ORIGIN OF THE OPERATIONS</u>



N.B.: Commercial operations which were the object of preliminary research phases have been entered under their year of start-up of the commercial operation.

It should be noted that a strong beginning in the years 1980-81 (Drax), and a maximum in 1982-83 after reasearch operations conducted since 1974, the set-up surface is almost inexistant in 1986-87. Nevertheless, the Hortitherm project in West Germany should be starting up on a few hectares (construction is taking place while this report is being written). Still, the effects of the drop in the cost of energy are being felt: this point will be analysed further in Chapter III.

On the technical level, it is important to underline that all commercial operations are connected to power plants working in closed circuit (experimental operations, in open circuit, to heat greenhouses, all necessitate monitoring the temperature per heating pump or back-up boiler).

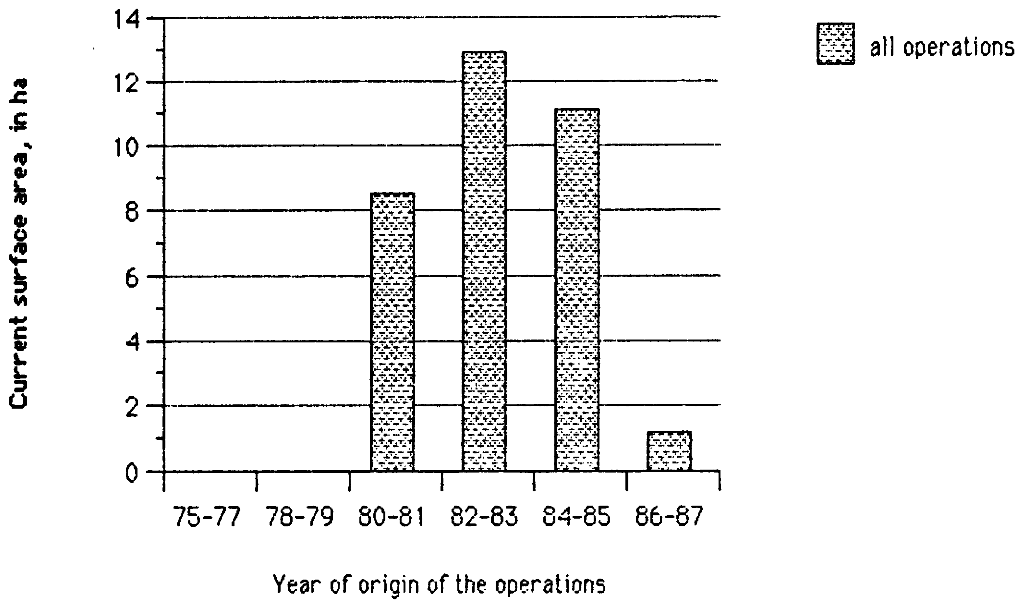
☐ Non-commercial freshwater aquaculture operation are of larger scale:

- La Casella (CARPA) in Italy is the largest in surface area;
- Limnotherm (RWE) in West Germany is a large-scale operation for which secret has been maintained, as usual developed by the electricity producer;
- on the other hand, Tapada in Portugal is a small project at the University of Porto, which should succeed.

One can nonetheless consider that breeding techniques are fully developed, as the number of commercial operations (9 operations in the EEC) proves, with a few exceptions for certain species: eel in particular.

There are at present about 4.5 ha of basins supplied in waste heat (freshwater for the most part) by electric plants, of which 40% concern commercial operations (2 ha). Comparing these surface areas to the year of start-up of the operations, the following graph is obtained:

SURFACE AREAS OF SET-UP GREENHOUSES, BY YEAR OF ORIGIN OF THE OPERATIONS



The start-up of commercial operations is earlier than in greenhouse heating. Non-commercial operations are still preponderant in surface area, which is mostly due to the start-up of the La Casella research-demonstration operation (1.5 ha of basins) in Italy in 1986.

The same phenomenon occured for greenhouse heating: commercial operations saw a high point between 1982 and 1985, then diminished in 1986-87.

2.2 Transitional activities: between experimental and commercial

□ For seawater aquaculture, research operations are great in number and sometimes very large-scale: Torre Valdaliga (CARPA) in Italy, Enstedvaerket in Denmark, Le Blayais and Gravelines in France. The breeding techniques of certain species require still more development. Some operations have been a success in the commercial sector, in particular Hunterston in the United Kingdom. We are led to believe that this research will soon result in mainly commercial operations.

□ On the other hand, building heating from waste heat, which relies on the intervention of heating pumps, remains a costly solution. Of the three operations currently functioning in the entire EEC (Arzberg, Dachelhofen, Saint Laurent), one should point out:

- the selective operations, such as heating the town hall and swimming pool at Saint Laurent des Eaux;
- the large-scale operations, attempting to implant a truly "cold" heating network to service the entire town (the two other operations).

In both cases this type of heating supposes implanting water mains, whose cost is hardly different from that of a real urban heating (isolating is not necessary, but water flow is much greater). In addition, the cost of heating pumps remains very high, to the point that this type of equipment, generally speaking, is barely competitive in comparison to traditional oil heating, as have demonstrated the numerous commercial failures over the past few years.

The economic results of the Arzberg operation in 1981/82 show a certain profitability, however mediocre (overinvestment return time: 9 years). With the fall in oil prices and maintenance costs higher than planned, this profitability has collapsed, to the point that the operation's exploitation balance each year betrays a rather large deficit on the order of 30 000 DM, to be paid in whole by the commune.

This type of operation, which supposes a certain proximity between the town and the power plant, remains therefore something of a "prestige" operation for the commune or the electricity producer.

2.3 More marginal research activities

There is no operation in investment phase for these kinds of activities: agriculture and algae crops.

☐ Agriculture includes 2 main operations:

- a demonstration operation for cultivating potatoes (heating by underground tubes) in Belgium (Ruien), which has not found any interested developer;
- a research and development operation in Italy (Trino Vercellese, CARPA) which seems to producing interesting results on cultivating rice by direct irrigation (world record in yield).

On the other hand, the Agrotherm project (West Germany) has long since been abandoned (wheat and corn crops); likewise, research conducted by EDF has not lead to satisfactory results.

To summarize, agriculture in soil heated by underground tubes is not profitable, as has been demonstrated by several series of research. Direct irrigation for cultivating rice is a more promising approach in southern countries, as has been confirmed by the continued research and demonstration phase.

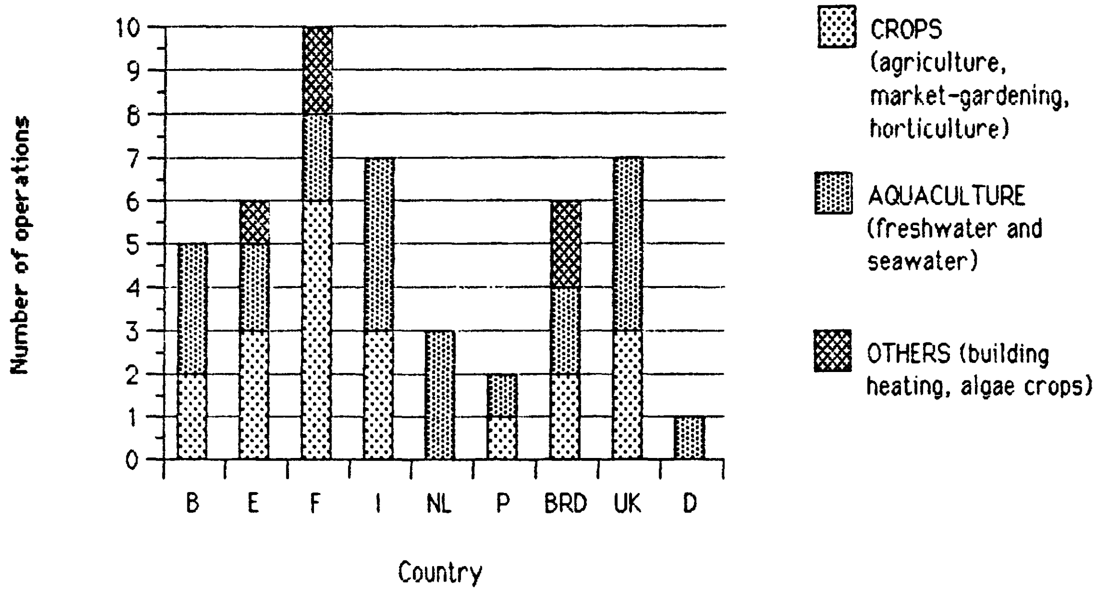
☐ Algae culture is still a very experimental area. In Tihange, research conducted by the University of Liège has been abandoned on the site and should rebegin in coming years, but in closed circuit and in laboratory. Research done in Spain, in Bahia de Algeciras, concerns 20 m2 of basins.

Possible outlets for algae culture are still uncertain: the current trend is more towards cosmetics (an important commercial area) than animal feed.

3. SYNTHESIS BY COUNTRY

The assessment of 47 thermal waste recovery operation by country is summarized in the following graph:

DIVISION OF OPERATIONS BY COUNTRY AND ACTIVITY

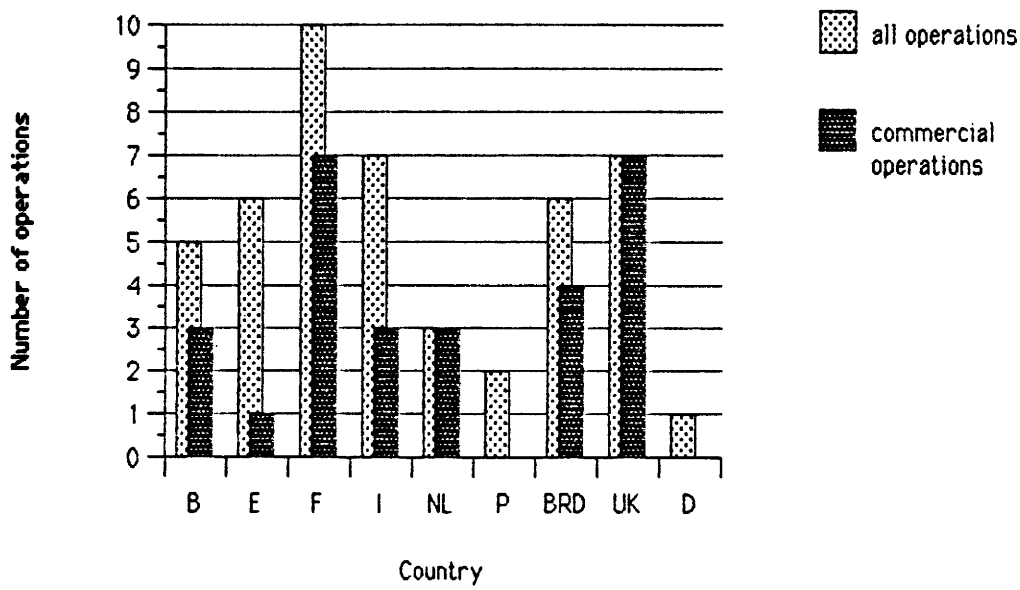


Certain countries are more strongly represented in certain activities (market gardening and horticulture in France, aquaculture in Italy and the United Kingdom, building heating in West Germany).

Three countries are absent in this assessment: Luxembourg, Ireland and Greece. Despite this, there exists in some of these countries either projects with no exact start-up date or other kinds of recovery.

The EEC nations are at different stages, as demonstrates the division of experimental and commercial operations:

SHARE OF COMMERCIAL OPERATIONS BY COUNTRY



Belgium, France, the United Kingdom, Holland and West Germany have for the most part reached the commercial stage. On the other hand, in Italy still predominant are non-commercial operations. Spain and Portugal are almost exclusively at the experimental stage.

3.1 Belgium

Electricity production

There are 4 regional producers of electricity in Belgium:
- 3 private producers: Intercom, Ebes and Unerg;
- 1 public producer: the Socolie.

Net power installed of electric power plants in 1984: 11 GW (32% nuclear). (1)

Waste heat recovery

55% of the power installed is connected to recovery operations.

Since 1976, Intercom has initiated a research program in Tihange (nuclear power plant) with the University of Liège (horticulture, aquaculture, algae culture) which resulted in 2 commercial applications in Tihange in 1984: aquaculture and horticulture. The Tihange aquaculture installation encouraged the installation of another aquaculture of the same type in Langerloo in 1986.

Intercom, starting from 1976, also initiated full-field culture research (potatoes) in Ruien, which led to a demonstration operation in 1985.

In 1984, Ebes in turn associated with the University of Louvain to undertake research on seawater aquaculture in Doel (nuclear plant).

Conclusion

Belgium has shown great interest in thermal waste recovery; but its potential is limited in number of sites, since its 4 sites already conduct such operations.

(1) Source: Eurostat, for the 12 nations of the EEC.

3.2 <u>Denmark</u>

Electricity production

The Association of Danish Utilities groups 10 independent electricity producers.

Net power installed of electric power plants in 1984: 8.1 GW (0% nuclear).

Waste heat recovery

10% of the power installed is attached to recovery operations.

In 1983, the Danish Aquaculture Institute initiated a large-scale demonstration program in Enstedvaerket in the area of freshwater aquaculture. It is at present the only operation. A project is in study; it would concern aquaculture, with no precise site.

Conclusion

Denmark is the second European producer in trout, after France. On the other hand, production of carp and other species is very limited.

There are more than 500 ha of crops in greenhouses of which it is likely most are heated by classic means. Several greenhouses likely use waste heat (90° C) taken from electric power plants (cogeneration).

The use of thermal waste to heat greenhouses does not seem to arouse much interest in this country.

3.3 Spain

Electricity production

The 21 regional electricity producers are grouped into Unidad Electrica S.A..

Net power installed of electric power plants in 1984: 22.3 GW (21% nuclear).

Waste heat recovery

18% of the power installed is attached to recovery operations.

Spain is still in the experimental stage, in that this country initiated research programs at a late date (1982), in comparison to other European countries.

Spain is interested, on the one hand, in full-field crops (El Grao de Castellon, Asco) and research in crop techniques, and, on the other hand, in seawater aquaculture (El Murterar, Bahia de Algeciras). These latter operations might well eventually result in commercial applications.

Finally, in 1986, a small horticultural commercial operation started up at the nuclear power plant in Asco.

Conclusion

Spain therefore has a priori great potential insofar as thermal waste recovery, and important breeding and crop activity. But temperature needs there are less primordial than in Northern Europe: for example, Golden Sea Produce, the turbot aquaculture developer in Hunterston (United Kingdom) is going to set up an intensive turbot aquaculture in Spain in non-heated water.

3.4 France

Electricity production

The only (public) electricity producer is Electricité de France.

Net power installed of the electric power plants in 1984: 63.2 GW (52% nuclear).

Waste heat recovery

24% of the power installed is attached to recovery operations.

This is the nation which accounts for the greatest number of operations. EDF, since 1975, has conducted much research in all areas at the Sain-Laurent-des-Eaux power plant. This research stopped in 1984 and waste water was put at users' disposition. This first period resulted in several large market-gardening and horticultural operations (Le Bugey, Dampierre, Saint Laurent, Avoine).

On the other hand, although France is an important producer of freshwater species, no operation of this kind is to be found (an ornament fish operation went bankrupt in 1986 in Saint Laurent).

Important research programs are being conducted for seawater aquaculture (Le Blayais, Gravelines), at the initiative of professional unions; these should shortly be concluded.

Finally, building heating is not very important (the town hall and swimming pool in Saint Laurent at the initiative of EDF, heating project for the Cruas town hall).

Conclusion

The potential for recovering thermal waste is still great in France for the two kinds of cooling circuits (open or closed). But the recent modification of certain nuclear plants in closed circuit (load modulation, lowering of the minimal temperature of waste in closed circuit: 15° C instead of 23° C on the average) nevertheless causes uncertitude as to the profitability of these operation for heating greenhouses.

New horticultural areas could nevertheless be created if professionals are able to resolve their organizational difficulties.

Seawater aquaculture should succeed in the coming years. On the other hand, freshwater aquaculture professionals seem little interested in such techniques.

3.5 Greece

Electricity production

The Dimossia Epichirissi Electrissmou is the only (public) electricity producer.

Net power installed of the electric power plants in 1984: 4.9 GW (0% nuclear).

Waste heat recovery

A few projects, without any precise start-up date, have been mentioned: these are the aquaculture projects on Chios Island, Ptolémais, Mégalopolis.

Conclusion

Greece possesses 2400 ha of greenhouse crops and is one of the most important producers of carp in the EEC. Thermal waste recovery operations could therefore be carried out there.

3.6 Ireland

Electricity production

The Electricity Supply Board is the only Irish electricity producer.

Net power installed of the electric power plants in 1984: 2.8 GW (0% nuclear).

Waste heat recovery

At present no project of this type is in progress. In any case, Ireland is interested in waste in general: the Lanesborough plant (60 MW), which produces electricity from peat, supplies waste heat at 99° C to heat the market-gardening greenhouses (tomatoes).

Conclusion

There are few greenhouse crops in Ireland (86 ha). This country moreover produces trouts and salmon, which are species not very concerned by the use of thermal waste.

Cogeneration seems to be of interest.

3.7 Italy

Electricity production

The ENEL (Ente Nazionale per l'Energia Elettrica) is the only electricity producer.

Net power installed of electric power plants in 1984: 36.2 GW (3.5% nuclear).

Waste heat recovery

8% of the power installed is attached to recovery operations.

There are practically no plants in closed circuit in Italy because of the proximity, for all regions of the country, either of the sea or a large river such as the Pô. For, a closed-circuit plant is indispensable for assuring the profitability of a greenhouse crop operation. What is more, this is what has been demonstrated in Tavazzano (open-circuit plant), in the framework of the CARPA project, where the only economically satisfying results have been obtained with cut flowers (gerberas) in greenhouses equiped with heat pumps to simulate the temperature in closed circuit.

The only commercial operation in horticulture started in late 1986 next to the small power plant in Bastardo (140 MW).

It should also be noted that irrigation trials by waste heat with rice seem to be of interest (Trino Vercellese).

Insofar as aquaculture, efforts have been major, but two distinct approaches have appeared:

- the ENEL is putting into place, in collaboration with research institutes, large trial stations in seawater in Torrevaldaliga, and more important in freshwater in La Casella. There is at present but one pilot production and not yet any commercial operation stemming directly from the experimented techniques.

- Professional aquaculturists and enterprises have lauched aquaculture operations in a totally independent manner: waste heat is simply drawn out of a plant's waste canal, or rearing is accomplished by floating cages placed in the sea in the summer and remounted in the winter in the waste canal: Lodivecchio (site of Tavazzano), Monfalcone.

Conclusion

Italy seems to be excelling above all in the area of waste heat aquaculture. Moreover, the ENEL has realized numerous feasability studies at the request of communes or regions for setting up greenhouse culture or aquaculture operations near electric power plants.

3.8 Luxembourg

No thermal waste heat recovery operation.

3.9 Holland

Electricity production

The Samenwerkende Elektriciteits-Produktiebedrijven groups 12 regional producers of electricity.

Net power installed of electric power plants in 1984: 16.8 GW (3% nuclear).

Waste heat recovery

16% of the power installed is attached to recovery operations.

Holland is the leader in horticulture and greenhouse market gardening. However, there are no thermal waste heat recovery operations to heat greenhouses. There are several reasons for this:
- electric power plants are almost all in open circuit;
- the drop in the price of energy makes these operations less attractive;
- professional organizations believe that extracted heat (cogeneration) or industrial waste heat (at highest temperature) are more economically profitable (thus, a vast project of 100 ha near Rotterdam);
- the PAGV research program (Flevo) on heated crops has produced a better crop yield per unit of surface with water at 30° C all year (industrial waste) than with waste heat.

On the other hand, in the area of aquaculture there are several commercial operations (Amer, Bergumermeer, Texel).

Conclusion

Heating greenhouses by waste heat has not attracted professionals. In aquaculture, operations could be initiated in that there is a large proportion of plants in open circuit, but Holland is not a great producer of fish.

3.10 Portugal

Electricity production

Electricity of Portugal is the only (public) producer of electricity.

Net power installed of electric power plants in 1984: 2.7 GW (0% nuclear).

Waste heat recovery

37% of the power installed is attached to recovery operations.

These techniques are still in the experimental stage:
- horticulture: trial station in construction in Setubal;
- freshwater aquaculture: experimental eel breeding project in Tapada do Outeiro.

Conclusion

Portugal is not very advanced in the area of thermal waste heat recovery.

3.11 West Germany

Electricity production

West Germany counts more than 200 electricity producers, but RWE (Rheinisch-Westfälisches Elektrizitätswerk) assures almost 2/3 of the country's production. There exist, namely in the Ruhr, several carbon plants, including several section functioning in base, all in closed circuit: this type of plant is a priori very adapted to greenhouse culture operations.

Net power installed of the electric power plants in 1984: 84.5 GW (19% nuclear).

Thermal waste heat recovery

6% of the power installed is attached to recovery operations.

There are few thermal waste heat recovery operations in West Germany, in spite of important efforts realized especially by RWE.

In horticulture, the "Hortitherm" project in Niederaussem has finally begun to be built, on a small scale, after 5 years during which construction commencement was continually put off. Other sites are equiped to accept greenhouses, but no project has been programed.

In aquaculture, there is a single independent commercial installation (eels, in Emden). The other operation, of large scale, "Limnotherm", also in Niederaussem, is as always managed directly by RWE, which is continuing its experiments, whose results remain secret.

Finally, in building heating, two most important operations are to be found in West Germany: an older one in Arzberg (1980), the other more recent in Dachelhofen (1987). These operations require high-powered heating pumps and are somewhat demonstration operations in that their profitability is far from proven.

Conclusion

Despite a few functioning operations, or ones on the way to being functional, many specialists (in particular, in the producers union VDEW) no longer believe in the profitability of operations using thermal waste heat. On the other hand, they favour heat-force cogeneration operations that are already common in West Germany.

3.12 United Kingdom

Electricity production

The Central Electricity Generating Board is the central organisation for the production and distribution of electricity in the United Kingdom. Moreover, there are regional producers, but they depend on the CEGB: North of Scotland Hydro Electric Board, South of Scotland Electricity Board, Northern Ireland Electricity Service.

Net power installed of electric power plants in 1984: 70 GW (12% nuclear).

Thermal waste heat recovery

6% of the power installed is attached to recovery operations.

The CEGB has lead a prestige operation in Drax (greenhouse tomatoes) since 1980. But this initiative has not lead to other large-scale operations. The other market-gardening or horticultural applications are on a small scale (Hunterston, project nearing completion in Cottham).

Aquaculture, on the other hand, is now an important activity, with major operations mainly in eel breeding (Ratcliffe, Hinkley Point) and in seawater species (Hunterston). Nonetheless, 3 aquaculture installations have been abandoned in previous years.

Conclusion

Despite great potential in number of sites, there is little recovery for greenhouse heating. The Energy Technology Support Unit (dependent on the CEGB) is not really in favour of these operations (too costly, setting-up difficulties by developers, competition from Holland and the southern countries for this type of activity). Aquaculture appears to be more promising in the eyes of this organization.

4. INVENTORY OF OPERATIONS

4.1 Summery table

This table summarizes by country and by type of activity the total number of operations (first figure), among which the number of commercial operations (second figure).

Country	Freshwater aquaculture	Seawater aquaculture	Horticulture	Market gardening	Agriculture	Algea culture	Building heating	Total by country
Belgium	2/2	1/0	1/1		1/0			**5/3**
Denmark		1/0						**1/0**
Spain		2/0	1/1	1/0*	1/0	1/0		**6/1**
France		2/0	1/1	5/4*			2/2	**10/7**
Greece								**0/0**
Ireland								**0/0**
Italy	2/1	2/1	1/1	1/0*	1/0			**7/3**
Luxembourg								**0/0**
Holland	2/2	1/1						**3/3**
Portugal	1/0		1/0					**2/0**
West Germany	2/1		2/2				2/1	**6/4**
United Kingdom	3/3	1/1	2/2	1/1				**7/7**
Total by activity	**12/9**	**10/3**	**10/8**	**8/5**	**3/0**	**1/0**	**4/3**	**47/28**
	Valorisation for commercial operations: 49000 tep/y**		Savings for commercial operations: 8000 tep/y**					

* Market-gardening and horticultural areas
** Estimate

4.2 Detailed Inventory

This inventory of operations concerns recovery operations of waste heat at electric power plants having a power of more than 100 MW.

This inventory is exhaustive for operations:
- in service,
- in construction.

Projects about to be completed have also been integrated into the list.

These operations have been classified by nation.

For each operation will be specified:
- the site, the type of plant and the electricity producer;
- the type of activity, the stage of advancement, the operation's start-up date, the size of the installations and the production in 1986, an estimate of the energies savings realized for greenhouse culture on a commercial scale. For aquaculture on a commercial scale: estimate of the energy savings realized (knowing that waste heat aquaculture can occur only if heat is free);
- a summary of the operation's technical and economic environment.

The most uncertain projects (no exact start-up date) have not been included in this inventory; they have been mentioned separately insofar as they are known.

Abandoned operations are also the object of a separate section.

BELGIUM

Site	Type of operation	Stage	Size	Production in 1986
TIHANGE nuclear Prod: Intercom	Fresh aquaculture	Commercial since 1984	1200 m2 of basins Savings: 2400 tep/y*	200 tons: Tilapias (160 tons) Carp Ornament fish
		- In 1984, Intercom associated with the Gabriel brothers, the large Belgian distributors of freshwater fish, to create a commercial tilapias exploitation ("Piscimeuse, s.a."). Research done since 1976 by the University of Liège has proved of interest. - Basins are supplied by cooling waters from the 3 nuclear sections, of a total power of 3200 MW. Water temperature is between 17 and 40° C (open or closed circuit). - The limited tilapia market led the developer to diversify his production. A doubling of production capacity is nonetheless planned for 1987.		
	Greenhouse horticulture	Commercial since 1984	10 000 m2 of greenhouses Savings: 430 tep/y**	1 million potted plants
		- 60 horticulturists (including 4 major) and Intercom associated in 1984 into Florimeuse (limited company). 3 goals guided this operation: centralization of production, facilities of distribution, savings in energy. In 1986, a restructuration of the capital allowed it to increase 66%. - Greenhouse heating is done by airothermes only. Emergency heating exists but has never been used. - A project to extend the greenhouses by 200 000 m2 is being studied for a grouping of diversified but rational productions (industrial production of the most demanded plants, associated with small specialized crops).		

* Estimate: development of 2 tep/m2 of basins (according to EDF evaluation: 400 000 tep/y for 20 ha of basins).

** Estimate in function of the greenhouse surface area, the type of crop, and the presence of back-up heating.

Site	Type of operation	Stage	Size	Production in 1986
LANGERLOO carbon Prod: Ebes	Freshwater aquaculture	Commercial since 1986	1500 m2 of basins Savings: 3000 tep/y	40 tons: Carp (60%) Trout Koi-carp Roach Eels
		-A young aquaculturist possessing a family-type exploitation in the region (300 ha of ponds, for a production of 100 tons per year) set up in 1986 at the foot of the Langerloo power plant in order to make his pond exploitation more flexible: complementary production, low-season production (winter). - The basins are supplied by cooling waters from the 2 carbon sections, with a total power of 350 MW. Water temperature is between 10 and 35° C (open or closed circuit). - Once the operation's reliability is assured, the aquaculturist envisages multiplying his production capacity by three before 1990.		
RUIEN carbon/ fuel-oil Prod: Intercom	Open-field crops	Demonstration since 1985	1 ha of field	Potatoes Cauliflower Asparagus
		-Trials performed over more than 10 years by Intercom (soil heating by underground tubes, crop trials) resulted in 1985 in this open-field crop demonstration operation. -The field is heated by polyethylene underground tubes. Water is supplied by 4 of the 6 sections of the plant (attached power: 850 MW). Water temperature is between 6 and 35° C (open circuit). - The project's initiators are looking for an agriculturist likely to set up.		

Site	Type of operation	Stage	Size	Production in 1986
DOEL nuclear Prod: Ebes	Seawater aquaculture	Research and Development since 1984	100 m2 of basins	Bass Bream Eel
		- The University of Louvain created in 1984 a Studies Union, "Biofish", with Ebes, to conduct aquaculture research in brackish water (tests in growth, sicknesses, resistance). - The basins are supplied by cooling waters from the 3 nuclear sections, of a total power of 1600 MW. Water temperature is between 16 and 32° C (open circuit). - Bass breeding has produced the best results: 1 ton produced in 1986. There is no expansion project in the immediate future.		

Abandoned operations:

- Algae crops in Tihange (University of Liège). This research will be renewed in closed circuit in laboratory.

DENMARK

Site	Type of operation	Stage	Size	Production in 1986
ENSTED-VAERKET	Freshwater aquaculture	Demonstration since 1983	1400 m2 of basins	Trout (60 tons) Salmon Turbot
		-Since 1983, the Danish Aquaculture Institute carried out both an experimental and demonstration program for seawater aquaculture. - The basins are supplied by cooling waters from the 3 carbon sections, of a total power of 800 MW. The water temperature is between 4 and 30° C (open circuit). There is a pollution problem with jellyfish which get into the installations. - No expansion project in the near future.		

- **Projects without timetable:** - An aquaculture project in study (unknown site).

SPAIN

Site	Type of operation	Stage	Size	Production in 1986
ASCO nuclear Prod: FECSA (Catalogne)	Greenhouse horticulture	Commercial since 1986	2000 m2 of greenhouses Savings: 70 tep/y	Potted plants
		-The operation began in April 1986 at the initiative of the Nuclear Association of Asco, which conducted an experimental phase on this site belonging to Fuerzas Electricas de Cataluña S.A.. Since then, an independent producer (Hivernacles Andisc, S.A.) has set up on the site. - Greenhouses are heated by "heating carpet", supplied in waste heat by 2 nuclear sections, of a total power of 1860 MW. Water temperature is between 18 and 34° C (open or closed circuit). A 40 kW heat pump regularizes the temperature. The installation possesses home fuel-oil emergency heating. -There is an expansion project for 1988.		
	Open-field crops	Research and Development	1000 m2 (being installed)	Peach tree plants
		- This crop area is being installed. It is being done conjointly by the Nuclear Association of Asco and the town of Aragon on an experimental basis. Research will concern peach tree plants.		
EL MURTERAR (ALCUDIA) carbon/ fuel-oil Prod: GESA (Palma de Maj.)	Seawater aquaculture	Research and Development since 1985	500 m2 of basins	Bream Bass
		- This R & D operation has been conducted since the beginning by Gaz y Electricidad S.A.. After this research a pilot phase will be started, with the purpose of producing 12 tons of fish in intensive. - The basins are supplied by cooling waters from the 2 carbon/fuel-oil sections, of a total power of 250 MW. Water temperature is between 18 and 31° C (open circuit).		

Site	Type of operation	Stage	Size	Production in 1986
EL MURTERAR		- If the pilot phase is a success, a commercial exploitation of a minimum of 100 tons of fish a year will be envisaged sometime around 1988.		
BAHIA DE ALGERCIRAS fuel-oil Prod: CSE (Seville)	Seawater aquaculture	Pilot	250 m2 of basins	Bream Prawn Bass Turbot
	Algae crops	Pilot	18 m2	Phytoplankton
		- This operation, initiated in 1984 by the Cia. Sevillana de Electricidad, concerns both algae crops and aquaculture. - Basins are supplied by cooling waters from the 2 fuel-oil sections, of a total power of 750 MW. Water temperature is between 24 and 33° C (open circuit). - The pilot phase of this operation should have been concluded in December 1986. Lacking additional funding, the project should not be prolonged.		
EL GRAO CASTELLON 2 fuel-oil sections Prod: HE (Madrid)	Open-field crops: exterior and greenhouse	Research and Development	1400 m2 heated (of which 360 m2 in greenhouse)	Tomatoes Peppers Strawberries Lemons
		- Hidroelectrica Española initiated this research program in 1982. Crops in heated soil, covered or not by a plastic tunnel, were tested against crops in non-heated soil, covered or not. - Soil heating is supplied by cooling waters from the 2 fuel-oil sections, of a total power of 1080 MW. Water temperature is between 26 and 41° C. - Passing to a pilot or demonstration phase is still being studied at present.		

FRANCE

Site	Type of operation	Stage	Size	Production in 1986
DAMPIERRE EN BURLY nuclear Prod: EDF	Market-gardening and horticulture	Commercial since 1983	125 000 m2 of greenhouses (plastic, glass) Savings: 2200 tep/y	30 million young market-gardening and horticultural plants
		- Dampierre en Burly is by far the largest waste heat exploitation in France. It groups nine developer-members of the CUMA (Coopérative d'Utilisation de Matériels Agricoles) of Noues, the coöperative which is in charge of managing the area. - Crops are heated by underground or elevated tubes. The installations are connected to the 4 nuclear section of a total power of 3560 MW. Water temperature is between 20 and 30° C (closed circuit). - The CUMA has had financial problems due to an insufficient number of developers.		
LE BUGEY nuclear Prod: EDF	Greenhouse horticulture	Commercial since 1984	50 000 m2 of greenhouses Savings: 1500 tep/y	Potted plants
		- In 1984, eight horticulturists from the Rhône-Alpes region joined to build and develop 5 ha of horticultural greenhouses. Their coöperative went bankrupt. The installations were repurchased by a company specialized in geothermal science (Géotherma), which is at present restarting horticultural production on the site. - The greenhouses are heated by "heating carpet", supplied by the cooling waters from 2 of the 5 nuclear sections (power connected: 1800 MW). Water temperature is between 15 and 30° C (closed circuit, load modulation). The installation disposes of an LPG back-up and emergency heating, which currently supplies 30% of the energy necessary. - The goal is to produce 2.5 million potted plants in 1987. At present, there is no expansion planned.		

Site	Type of operation	Stage	Size	Production in 1986
AVOINE (CHINON) Prod: EDF	Greenhouse horticulture	Commercial since 1985	8500 m2 of greenhouses Savings: 240 000 tep/y	11 million young plants 326 000 potted plants
		- A Mixed Economy company managed the Avoine site. The surface area developed, currently reduced, will greatly increase in 1987, since 22 000 m2 of greenhouses are being built for horticulture and market gardening (cucumbers). The Avoine Mixed Economy Company for Energy handles commercializing products. Investments are realized by the Rural District of Véron. - The installations are attached to the 4 nuclear sections, of a total power of 3600 MW. Water temperature is between 15 and 37° C (closed circuit). The waste heat's minimal temperature necessitates back-up heating by several decentralized boilers functioning for the time being in LPG, while awaiting hook-up to the natural gas network. - Towards 1990, Avoine plans to have a developed surface area of 7 ha.		
BLAYAIS nuclear Prod: EDF	Market gardening Greenhouse horticulture	Pilot since 1983	3000 m2 of greenhouses	Salads Cucumbers Green plants
		- This installation was developed by handicaped workers helped by monitors. This is why it has remained on a pilot scale (no real commercial production). - The installations are attached to 2 nuclear sections, of a total power of 1800 MW. Water temperature is between 7 and 30° C (open circuit). The installation uses two 75 kW heat pumps on a permanent basis, and a back-up in winter by electric airothermes and a gas boiler. - There exists a diversification project towards aquaculture (related to the operation that follows).		
	Estuary-water aquaculture (freshwater/ seawater)	Research and Development since 1982	200 m2 of basins	Eels Sea bass Sturgeon

Site	Type of operation	Stage	Size	Production in 1986
BLAYAIS		- Since 1982 the Professional Union of Fishermen of Gironde has been experimenting on the breeding of fish in estuary water. At first, experiments on elvers and eels took place which were not very satisfactory on the commercial level. Tests on sea bream have been abandoned because of too high water salinity variation. - Incidents in the supply of waste heat have occured: poor functioning of waste heate supply pumps, late switch-off in case of an incident in a section. The prolonged cut-off of water supply leads to important fish mortality for the species reared. - Tests on bass and sturgeon have been conclusive, and should eventually result in the start-up of a 100 ton pilot farm (sea bass and sturgeon).		
GRAVELINES nuclear Prod: EDF	Seawater aquaculture	R & D, Pilot and since 1984	2100 m2 in intensive 360 m2 for research	Sea bass (27 tons) Sea bream Turbot Shrimp Shell fish
		- Created in 1984 at the initiative of the SERAG (Syndicat Mixte pour l'Etude d'un Réseau d'Aquaculture à Gravelines), the operation is two-speed, in two phases done conjointly: - An R & D phase managed by the IFREMER (Institut Français de Recherche dans le domaine des Eaux de Mer) is attempting to diversify the species in intensive breeding and to characterize the upstream and downstream water quality by an aquacultural activity. - A pilot/demonstration phase managed by AQUANORD (maritime coöperative company), which has lead to the abandoning of sole (biological reason) and the intensive breeding of sea bass. - The basins are supplied by cooling waters from the 3 nuclear sections, of a total power of 2700 MW. Water temperature is between 9 and 30° C (open circuit). The main technical problems that have needed to be resolved are: the chlorinating of the waste heat (treatment by sulphate); the gaseous oversaturation generated by heating up (degasination).		

Site	Type of operation	Stage	Size	Production in 1986
GRAVELINES		- In the short term, an aquacultural pilot development is planned: sea bass and bream hatchery operational by the end of 1987, looking for 3 or 4 commercial developers (purpose: production of from 250 to 300 tons). The site in the long run could produce 1000 tons of fish.		
CRUAS nuclear Prod: EDF	Market gardening and horticulture	Commercial (in project)	10 ha 1.5 ha at first stag	0
		- This project is being conducted by the Ardèche Syndicat Départemental d'équipement. Its purpose is to set up developers on the site. The union is servicing the land and will resell lots to greenhousemen. - The installations will be supplied by the cooling water from 3 of the 4 nuclear sections (attached power: 3900 MW). Water temperature is between 24 and 36° C (closed circuit).		
	Building heating	- The same project also includes heating Cruas communal buildings.		
ST-LAURENT DES EAUX nuclear Prod: EDF	Market gardening and horticulture	Commercial since 1984	20 000 m2 of greenhouses Savings: 600 tep/y	Tomatoes: 150 tons Cucumbers: 15 tons 10 000 salads 700 000 roses
		- In 1974, EDF initiated a vast research program on the use of thermal waste heat (crops, aquaculture, building heating). This program ceased in 1984 and resulted in the installation of 3 market gardeners and a rose florist, organized in CUMA. - The greenhouses are heated by elevated tubes or airothermes, supplied by the cooling water from 2 recent sections (2 older graphite gas ones), of a total power of 1760 MW. Water temperature is between 15 and 40° C (closed circuit, load modulation). The greenhousemen have just set up an LPG back-up heating (having to supply 30% of the energy needs). - One market gardener is having serious difficulties. The two others manage to subsist. Cultiviating roses seems the most profitable.		

Site	Type of operation	Stage	Size	Production in 1986
ST-LAURENT DES EAUX	Building heating	Commercial	Town hall and swimming pool in St. Laurent - Tests done by EDF have resulted in these two installations, which are today functioning.	

Projects without timetable: - Waste heat recovery at the Cattenom site (the plant has just started up): undetermined types of operations.

Abandoned operations: - Martigues-Ponteau: seawater aquaculture (classic thermal plant, functions for no more than 100 h/y).

GREECE

No operation in service, in construction or in project near conclusion.

Projects without timetable:	Chios Island (aquaculture), Ptolémaïs, Mégapolis: projects proposed by the Dimossia Epichirissi Electrismou to the Commission.

IRELAND

No operation in service, in construction or in project near conclusion.

ITALY

Site	Type of operation	Stage	Size	Production in 1986
TAVAZZANO fuel-oil Prod: ENEL	Market gardening and horticulture	Demonstration 1980-1986	15 000 m2 (covered or not)	Strawberries and asparagus under plastic tunnel Cut flowers in green-house Open-field corn
		- The most interesting results have been obtained in cut flowers and in strawberries (yield and precocity). - The installations include airothermes and underground tubes, supplied by cooling water from one of the 4 fuel-oil sections (of a power of 75 MW). Water temperature is between 13 and 30° C (open circuit). Certain greenhouses are equiped with a heat pump to simulate a closed circuit. - The first phase of research is terminated. A second phase is envisaged for the period 1988-1992.		
	Freshwater aquaculture	Commercial	6800 m2 of basins Savings: 13 600 tep/y	Eel
		- This is a totally independent commercial operation situated in Lodivecchio. - Waste heat is taken out of the Tavazzano power plant canal. - Eel production (enlarging) is kept secret.		
TRINO VERCELLESE nuclear Prod: ENEL	Open-field crops	Demonstration since 1985 (CARPA)	5 ha	Rice
		- This research began in 1985. Results on rice reached 7 tons/ha, that is 15 to 20% better than for non-heated water. This yield is probably the highest in the world.		

Site	Type of operation	Stage	Size	Production in 1986
TRINO VERCELLESE		- Waste heat, used directly to irrigate crops, comes from the cooling circuit of a nuclear section, of a power of 250 MW. Water temperature is between 13 and 30° C (open circuit). 4 heat pumps, 250 kW each, allow for functioning during plant interruption. - Research work will conclude in December 1988.		
LA CASELLA fuel-oil Prod: ENEL	Freshwater aquaculture	Research and Development since 1987 (CARPA)	15 000 m2 of basins Hatchery of 108 troughs	Freshwater species
		- Extremely large installation terminated in 1987; no test results as yet. - The basins are supplied by cooling water from the 4 fuel-oil sections, of a total power of 1280 MW. Water temperature is between 12 and 30° C (open circuit). The hatchery is heated by 3 heat pumps, 45kW each, with water circulating in closed circuit.		
TORRE-VALDALIGA fuel-oil Prod: ENEL	Seawater aquaculture	Research and Development since 1980 (CARPA)	1200 m2	Sea bass Shrimp
		- The yield obtained for sea bass is 10 kg/m3. It is possible to effectuate 2 shrimp breeding cycles a year. - The basins are supplied by cooling water from 2 of the 4 fuel-oil sections (attached power: 640 MW). Water temperature is between 18 and 35° C (open circuit). The hatchery is heated by 3 heat pumps, 11 kW each, with water circulating in closed circuit. - The coming years will be devoted, in particular, to hatchery techniques.		

Site	Type of operation	Stage	Size	Production in 1986
BASTARDO fuel-oil Prod: ENEL	Greenhouse horticulture	Commercial since 1987	15 000 m2 Savings: 520 tep/y	-
		- This is the first commercial operation in Italy, resulting from the CARPA project. This installation will produce, in particular, ornamental plants on 7500 m2. The developer is a coöperative, the Floro Vivaistica Umbria. - Greenhouse heating will be mixed: underground tubes and airothermes with the possibility of cooling in the summer. The installations will be supplied by cooling water from the 2 fuel-oil sections, of a total power of 150 MW. Water temperature is between 20 and 35° C (closed circuit). An emergency heating will be installed. - Projects for a vast horticultural area exist on the same site.		
MONFALCONE fuel-oil and carbon Prod: ENEL	Seawater aquaculture	Commercial since 1983	2500 m2 of basins Savings: 5000 tep/y	Sea bass Sea bream
		- Totally independent commercial installation; investments in 1983 amounted to 2.5 billion liras. - Waste heat is pumped in the plant's canal. A geothermal drill at 22° C is also used (by exchanger) to adjust the temperature (heating in winter, cooling in summer). - The main activity is alevinage with 600 000 heads (sea bass and sea bream) in 1987. Pre-enlarging: 250 000 heads. - 1.5 million heads are planned in 1988.		

Projects without timetable:

- Numerous feasability studies have been realized by ENEL at the request of regions or communes;
- Greenhouse crops: Pietrafitta, Porto Tolle, La Caselle, Caorso, S. Barbara, Rossano Calabro, Mercure, Porto Torres.
- Seawater aquaculture: Rossano Calabro, Vado Ligure, Sulcis, Porto Torres, Torrevaldaliga.

LUXEMBOURG

No operation in service, in construction or in project near conclusion.

HOLLAND

Site	Type of operation	Stage	Size	Production in 1986
BERGUMER-MEER Gas Prod: EPON	Freshwater aquaculture	Commercial since 1978	475 m2 Savings: 950 tep/y	Carp: 30 tons Trout: 15 tons
		- In 1978, the OVB (professional aquaculture organization) lead this operation both at the research and commercial level. - Basins are supplied by cooling water from the 2 sections of the plant, of a total power of 680 MW. Water temperature is between 4 and 30° C (open circuit). This plant must cease activity in 1988. Production will be moved to Amer (site below). - No production increase is planned.		
AMER Gas/fuel-oil/carbon Prod: PNEM	Freshwater aquaculture	Research and Development Commercial	300 m2 Savings: 600 tep/y	Carp Trout
		- The OVB set up on the site in 1980 in order to conduct mainly research activities. This site at present carries out part of the production realized earlier at Bergumermeer, a plant which will be closed. - Basins are supplied by cooling waters from 5 of the 8 sections of the plant: power attached to the installations: 1971 MW. Water temperature is between 5 and 30° C (open circuit). - All production will be transfered to this site in 1988.		

Site	Type of operation	Stage	Size	Production in 1986
TEXEL Gas/fuel-oil Prod: PEN	Seawater aquaculture	Commercial	3100 m2	Eels Sea bass Sea trout: 250 tons
		- This aquaculture installation, managed by Texvis B.V., does not directly use the thermal waste heat from an electric power plant, but the waste heat (30° C) from a desalinating installation, itself drawing vapor from an electric power plant.		

Abandoned operations:

- The PAGV research program conducted by the Agriculture Ministry has not lead to any commercial operation. It ceased in 1986.

PORTUGAL

Site	Type of operation	Stage	Size	Production in 1986
SETUBAL fuel-oil Prod: EDP	Greenhouse horticulture	Pilot (being built)	360 m2 of greenhouses	-
		- The LNETI (National Laboratory of Energy and Technology) is at the origin of this pilot site. - Greenhouse heating will be mixed, heating carpet and airothermes. The installations will be supplied by the cooling water from the 4 fuel-oil sections, of a total power of 1000 MW. Water temperature is between 18 and 29° C (open circuit). - The goal is to progressively increase the surface area exploited and to realize commercial exploitations on other sites by 1989.		
TAPADA DO OUTEIRO Carbon Prod: EDP	Freshwater aquaculture	Pilot (project)	-	Eels
		- This project is due to the initiative of the University of Porto, and will concern eel production. - The basins will be supplied by the cooling water from the 3 sections of the plant, of a total power of 150 MW (open circuit).		

WEST GERMANY

Site	Type of operation	Stage	Size	Production in 1986
NEURATH lignite Prod: RWE	Greenhouse horticulture "Hortitherm"	Commercial since 1983	5000 m2 of greenhouses Savings: 220 tep/y	Potted plants
		- In 1979, in the framework of the "Hortitherm" project, RWE built the first greenhouse of 1000 m2 on the site, soon expanded to 5000 m2. These tests on thermal waste heat recovery in horticulture terminated in 1983, resulting, on the one hand, in the "Hortitherm" operation at the NIEDERAUSSEM (cf. see below) and, on the other hand, in the renting of greenhouses existing in Neurath to a horticulturist. - The greenhouse is heated by specific airothermes, supplied by the cooling water from 3 of the 4 sections of the plant (total power of the plant: 2100 MW). Water temperature is between 25 and 40° C (closed circuit). - No expansion is planned at the NEURATH site.		
NIEDERAUS-SEM lignite Prod: RWE	Greenhouse horticulture "Hortitherm"	Commercial (project since 1982)	140 000 m2	-
		- The greenhouse construction project in NIEDERAUSSEM dates to 1982, following tests done in NEURATH in the framework of "Hortitherm". RWE wanted to build the first section of 14 ha only when all the parcels had found a buyer. This lead to the postponement of greenhouse construction. From year to year, the number of interested greenhousemen was insufficient, on account of the drop in price of oil. Nevertheless, in 1986, land servicing (pipes) was carried out. - The greenhouses should be heated in the same way as at NEURATH, supplied by the cooling waters from 5 of the 8 section of the plant (total plant power: 2700 MW). Waste water temperature is between 25° C and 40° C (closed circuit). - Construction of the first greenhouses has begun, but on a small surface area (1.5 ha) compared to the initial project (2 successive sections of 14 and 13 ha).		

Site	Type of operation	Stage	Size	Production in 1986
NIEDER-AUSSEM	Freshwater aquaculture "Limnotherm"	Research and Development since 1974	14 basins of 60 m3 and 22 basins of from 5 to 20 m3 4200 m2	Carp Tilapia Silure Eel Perch, etc. (60 to 80 tons/year)
		- The first tests, conducted entirely by RWE, began in 1974. In 1975, with the support of the Federal Ministry of Research and Technology (BMFT), the construction of 22 basins, sheltered, was begun. 14 basins in concrete were built in 1979. A new hangar for alevinage was added in 1986. The installation is managed by a team dependent on the RWE. - The basins are supplied by cooling circuit water, such that the contents of the basins is renewed every 2 hours. Water oxygenation is effectuated on a permanent basis by air-blowing in the basins. There also exists an emergency stock of pure oxygen, offering an autonomy of 5 hours in case the supply of water coming from the plant was cut. - The results obtained have been kept secret by RWE, for whom Limnotherm remains both a prestige operation and an occasion to accumulate specific know-how (several patents pending). RWE does not seem to envisage either going on to an actual commercial stage or giving up its installations to an aquaculture enterprise.		
ARZBERG Carbon/Gas Prod: EVO	Building heating	Commercial since 1979	Municipal and private buildings	Substituted heating power: about 3 MW
		- Since 1979, the municipal swimming pool (open-air) is heated by waste heat coming from the plant (about 1 km away). After this, other buildings were attached: a school grouping, a small collective building, a few individual houses and offices. The operation is due to the initiative of the municipality and is now managed by the Stadtwerke Arzberg (also responsable for drinking water, sewers, etc.).		

Site	Type of operation	Stage	Size	Production in 1986
ARZBERG		- The single main takes water from the cooling circuit of the 3 section of the plant, of which two (carbon) function on a quasi-permanent basis (except in summer). Water temperature is between 25° C and 40° C (closed circuit). Each building is heated by one or several heat pumps placed in diversion from the main, while the cooled water is led towards the principal main. - A few other buildings must still be attached to the network (including a gym). A project to heat the entire old city existed (representing about 20 MW thermal), but has been abandoned.		
EMDEN carbon/gas Prod: PEAG	Freshwater aquaculture	Commercial since 1979	22 basins of from 5 to 90 m3 Savings: 1900 tep/y	Eel (15 tons)
		- The current private developer, installed on the site since 1973, obtained between 1975 and 1979 the help of the Hamburg Bundesforschungsanstalt für Fischerei (Federal Institute of Research on Aquaculture), which helped him develop, from a technical and economic point of view, his eel breeding. - The private developer alone reoccupied the installations in 1979, producing 10 tons of eel that year. The 22 basins are directly supplied by the cooling waters from 2 of the 5 sections of the plant: power attached to the installations: 700 MW. Water temperature is between 8 and 25° C (open circuit). - An expansion project concerning elvers (young eels) breeding is planned for 1987.		

Site	Type of operation	Stage	Size	Production in 1986
DACHEL-HOFEN carbon Prod: BAG.	Building heating	Commercial since 1986	Municipal buildings	

- The town of Schwandorf (Bavaria) decided to use the cooling waters from the Dachelhofen power plant situated on the commune to heat public buildings. The installations were operational at the end of 1986. This operation is very important, since it concerns heating a hospital, 2 swimming pools, 3 schools, 1 day-care center, 2 gyms, 2 presbyteries, 2 multiuse halls and several municipal or regional buildings.
- 2 of the 4 sections of the plant (attached power: 480 MW) supply waste heat whose temperature is between 15 and 35° C. Buildings are heated by 5 heat pumps: 3 by gas of 850 kW, 1 by gas of 300 kW, 1 by electricity (power unknown), and back-up boilers (data unknown). The heat pumps are sufficient as long as the outside temperature does not go below -5° C.
- No expansion is planned for the network, which is already large.

Projects without timetable:

- Grundremmingen: 5 ha plot serviced in waste heat
- Ibbenbüren: plot serviced in waste heat.

Abandoned operations:

- Agrotherm research program (RWE) in Neurath

UNITED KINGDOM

Site	Type of operation	Stage	Size	Production in 1986
DRAX carbon Prod: CEGB	Greenhouse market gardening	Commercial since 1980	80 000 m2 of greenhouses Savings: 2000 tep/y	Tomatoes
		- At the initiative of the CEGB and a distributor of food products, this market-gardening area was created in 1980 to produce out-of-soil tomatoes. Since then, Exel Produce (developer) has greatly diversified in the importation, conditioning and distribution of vegetables. - The greenhouse is heated by airothermes supplied by cooling waters from 3 carbon sections, of a total power of 2000 MW. Water temperature is between 26 and 40° C (closed circuit). - The only expansion projects at present concern the import and conditioning activity.		
HUNTERSTON nuclear Prod: SSEB	Seawater aquaculture	Commercial since 1984	4000 m2 of basins Savings: 8000 tep/y	100 tons of Turbot
		- Hunterston is the only large-scale commercial operation in the EEC concerning seawater aquaculture. Golden Sea Produce Ltd., a company specialized in the breeding of marine species, set up on the site; it currently produces 100 tons of turbot, and effectuates research on other species (sea bass, Dover sole, sea bream). - The basins are supplied by the cooling waters of a nuclear section. Water temperature is between 17 and 26° C. - GSP plans production of 120 tons in 1987.		

Site	Type of operation	Stage	Size	Production in 1986
HUNTERSTON	Greenhouse horticulture	Commercial since 1986	2000 m2 of covered buildings Savings: 60 tep/y	2 million potted plants
		- Since May 1986, Prestige Plants Ltd. has set up on the site with the purpose of producing micro-plants for apartment plants, necessitating high-level temperature but little lighting (micro-plants resold to traditional greenhousemen). - PPL has reoccupied the abandoned eel breeding installations (crop tables posed on old basins, in which water circulates). A heat pump of a power of 27 kW raises the water temperature up to 23° C. - The purpose is to attain a surface area of 1 ha by 1988.		
RATCLIFF ON SOAR carbon Prod: CEGB	Freshwater aquaculture	Commercial since 1986	1100 m2 of basins Savings: 2200 tep/y	Eels
		- The aquaculturist, Trent Eels PLC, just set up on the site, with the goal of producing 55 tons of eel in 1987. - The basins are directly supplied by the cooling waters of the 4 sections of the plant, of a total power of 2100 MW. Waste water temperature is between 24° C and 38° C (closed circuit). - No expansion planned at present.		
COTTHAM Carbon Prod: CEGB	Greenhouse horticulture	Commercial (project)	2000 m2	-
		- This is a project to set up the Burn Moor Nurseries company to produce potted plants. The site is capable in the long run of receiving 8 ha of greenhouses. This operation will follow up a pilot phase which took place from 1983 to 1986. - The greenhouse will be heated by airothermes supplied by the cooling waters from 4 sections, of a total power of 2000 MW. Water temperature is between 16 and 40° C (closed circuit).		

Site	Type of operation	Stage	Size	Production in 1986
HINCKLEY POINT nuclear Prod: CEGB	Freshwater aquaculture	Commercial	Unknown	Eels
		- Detailed data on this operation has not been received. Nonetheless, the developer projects producing 500 tons of eels per year.		
FIDDLERS FERRY carbon Prod: CEGB	Freshwater aquaculture	Commercial since 1987	500 m2 of basins Savings: 1000 tep/y	Carp
		- A private developer set up in 1985 on the site. After a pilot phase in association with the CEGB, the developer decided to go on to a commercial phase (for production of 40 to 50 tons of carp). - The basins are supplied by the cooling waters from 2 of the 4 sections of the plant: power attached to the installations: 1000 MW. Waste heat temperature is between 15 and 35° C (open or closed circuit). The plant shut down for 2 days without damaging carp breeding. - This commercial phase has just begun.		

Projects without timetable:

- Reopening carp breeding in Eggborough, which has been abandoned.
- Freshwater aquaculture in Rugeley.

Abandoned projects:

- Wylfa (eel); Trawsfynydd (carp).

4.3 Other operations excluded in the inventory

4.3.1 Denmark

Several horticultural installations supplied in waste heat (90°C) by electric plants.

4.3.2 France

Pierrelatte: 15 ha of market-gardening and horticultural greenhouses heated by the refrigeration water from the isotope repair factory of the Commissariat à l'Energie Atomique (hot water between 70 and 85°C).

Industrial thermal waste heat: Carling (2.5 ha of greenhouses heated by the waste heat of CDF chemical).

Trash incineration: projects for several implantations in Brittany, project in Aspach (Bas Rhin), for greenhouse heating.

4.3.3 Ireland

Extracted waste heat (90°C) at the Lanesborough electric power plant (peat incineration) to heat market-gardening greenhouses (tomatoes).

4.3.4 Italy

In aquaculture, different commercial operations in service or in project:

= Calvizano, on thermal waste heat of a steelworks (eels, white sturgeon, catfish)
= Vimercate, oxygen factory (eel)
= Ansedonia (near Grosseto), on geothermal drills: 3 independent companies, each producing about 100 t/y (eel, bass, bream)
= Monfalcone, Ittiomar company, enlarging in cage in the sea or in the plant's canal (bream, mules).

4.3.5 Holland

Vast heating project of 100 ha of greenhouses heated both by waste heat (90°C) supplied by an electric power plant and by industrial waste heat (Rotterdam region).

4.3.6 West Germany

Hamburg-Stapelfeld: 15 ha horticultural area heated by a trash incineration installation (50°C).

Ensdorf (EEC demonstration project): horticultural greenhouses heated by the cooling waters from the ashes of a carbon power plant (60°C).

4.3.7 United Kingdom

Use of waste heat from a whisky distillery in Glengarioch to heat 1.5 ha of greenhouses (tomatoes).

III - TECHNICAL AND ECONOMIC ANALYSIS OF THE COMMERCIAL OPERATIONS

1. HORTICULTURE

1.1 Horticultural activity in the EEC

1.1.1 Different horticultural productions

There are several types of productions:

□ potted plants: the most common are chrysanthemum, perlagonium-geranium, cyclamen, azalia, begonia, petunia, etc.. Consumer infatuation for these products caused market expansion (it doubled in France between 1979 and 1983).

□ cut flowers: roses, gladiolas, tulips, carnations and other flowers sold cut also make up the market in expansion.

□ nursery products: these are ornament plants for the outside (gardens, balconies, collectivities). Traditionally cultivated in open field, the current evolution is going towards cultivation in containers in shelter.

1.1.2 Structure of horticultural production

In the 10-nation Europe, there were in 1983 about 44 000 glasshouse horticultural exploitations, for a total covered surface area of about 12 400 ha. The table below details the structure for the principal nations in 1983:

Country	Number of exploitations	Glasshouse surface area (ha)	Average surface area per exploitation (m2)
RFA	9 437	2 132 ha	2 260 m2
France	8 026	1 668 ha	2 080 m2
Italy	9 400	2 798 ha	2 980 m2
Holland	**7 686**	**4 066 ha**	**5 290 m2**
Belgium	2 777	572 ha	2 060 m2
United Kingdom	4 396	626 ha	1 420 m2
10-nation Europe	43 851	12 403 ha	2 830 m2

(Source: 1983 Inquiry, EEC Agriculture Direction)

The major information of this table is that in Holland, the leader in this activity, the average surface area is double that of the other countries.

1.1.3 European production and the horticultural market

Horticulture represents a production turnover of more than 7 billion ECU (1985, 10-nation Europe), that is between 3 and 4 % of the total turnover of Community agriculture. Production's average value per m2 is about 58 ECU/m2.

Intracommunity exchanges account for nearly 2 billion ECU (29% of production) with important disparities between countries:
- Holland exports 75% of its production;
- France has a domestic cover rate of about 20% only.

Globally, 10-nation Europe had surplus exportation (5% of production). This surplus has increased since the Community expanded to twelve.

On the other hand, in the specific sector of cut flowers (carnations and roses) competition is great due to imports from Africa (Kenya), Israel and Colombia.

Turnovers generated by greenhouse horticulture are very variable:

Types of crop	Turnover in ECU/m2
- cut flowers (roses, carnations)	30
- potted plants (geraniums, begonias)	65
- young horticultural plants	130

1.2 Energy and heating

1.2.1 Energy needs in horticulture

Horticultural activity is a great consumer of energy, and it represents an important share of turnover, as the following results demonstrate:

Region of production	Type of production	Average energy consumption	Energy cost (1) in ECU/m2/y	Average turnover in ECU/m2	Energy share in % of turnover
Temperate	Potted plants	550	8.5	65	13%
Temperate	Cut flowers	450	7.0	30	23%
Mediterranean	Cut flowers	300	4.5	30	15%

(1) with a price of 0.015 ECU/kWh (Dutch gas = 0.010 ECU; French domestic fuel oil = 0.025 ECU/kWh, for "horticultural" quantities)

These figures obtained are average figures: thus, a French greenhouse heated by domestic fuel oil can devote more than 20% of its turnover to expenses in fuel.

The share of heating in the original investment is also important:

For a modern greenhouse of 5000 m2, intended for cultivating potted plants, the division of the different posts is as follows:

Double glass greenhouse	50 %
Rolling tablets, heating with irrigation trough	30 %
Total greenhouse investment:	**80 %**
Boiler 2000 kW (500 kF):	10 %
Heating distribution	10 %
Total heating:	**20 %**
GENERAL INVESTMENT TOTAL:	**145 ECUS/M2**

Heating therefore represents 20% of the initial investment.

- In France, nearly 70% of horticultural greenhouses are heated.
- In Holland, the quasi-total of horticultural greenhouses are heated.

1.2.2 Different energy solutions

Classic heating

Classic heating by boiler is carried out by means of different fuels. Use varies according to country.

- In Holland, greenhouses are almost exclusively heated by natural gas.
- In France, fuels used are more varied:

Fuel	In % of the total energy consumption
Domestic fuel oil	36%
Heavy fuel oil n° 2	32%
Natural gas	20%
Carbon and others (household trash, thermal waste, geothermal)	12%

Energy savings programs conducted since the second oil shock have allowed energy consumption to diminish fairly greatly: thus, in Holland the energy consumption of the 8000 ha of heated greenhouses (horticultural and market-garden) has evolved in the following manner:

Date	Energy consumption (Mtep)	Consumption per surface unit (kWh/m2/y)
1979	2.9	400
1982	2.0	280

These savings have been able to have been realized thanks to:
- the installation of thermal screens for the night;
- the installation of boilers with better yield.

Alternate solutions

Horticulturists are also interested in alternate energy sources: geothermal, trash incineration plants, wood waste, heat pumps, industrial waste, thermal waste from electric power plants (waste heat or warmer waste heat).

Thus, in France, in February 1986, there could be counted:

Type of heating	Number of existing operations	Covered ha in 1986	Number of projects
Waste heat-electric plants	4	13	3
Warm waste heat (isotropic separation)	1	9	1
Geothermal	2	5	3
Household trash	0	0	2
Together	**7**	**27**	**9**

In Holland, an inventory of electric power plants capable of supplying "extracted" heat (waste heat or vapor) or residual heat from incineration factories or industrial waste demonstrates a potential deposit of 2.8 Mtep, a figure which theoretically covers Dutch horticultural and market-gardening needs (for about 300 kWh/m2/y). An ambitious project to attach 350 producers (100 ha of greenhouses concentrated near Rotterdam) to an electric power plant ("extracted" heat: heat-force cogeneration) and an oil refinery was the object of a feasability study having produced interesting results.

Techniques of heating by thermal waste

Several techniques of heating by thermal waste are used:

- by elevated metalic tubes
- by underground pipes
- by shaft (heating carpet)
- by run-off.

Often, several types of heating are used simultaneously.

The most often used systems are heating by shaft ("heating carpet", under crop tablets or on the ground, according to the crops (Asco (E), Castellon (E)), and by airothermes (Tihange (B), Hortitherm (RFA), Tavazzano (I), Cottham (UK)). Often, 2 systems are used at the same time: the airothermes are sometimes attached to the back-up boiler (Bastardo (I), Chinon (F), Le

Bugey (F)).

Generally speaking, some developers estimate that results are better when the crop is heated at its base (the bottom of the pot for ornament plants, on the ground for cut flowers).

Underground tubes, less frequent because they are more adapted to a freeze-free crop than to a "warmer" crop, also respond to this principle. This is the technique used for young plants crop in Dampierre, Burly (F).

Run-off on a wall recipient poses crop moisture (too great humidity) and lighting (deposits on the wall recipients) problems, and has not been used outside the experimental stage.

Effects of modifying the functioning of electric power plants

Electric power plants attached to horticultural installations, outside of experimental installations, work in closed circuit. An electric power plant functioning in base in closed circuit assures a theoretical minimum temperature of 23°C. This minimal temperature is determinant for horticultural installations in Northern Europe. But, for almost 2 years, in France, the electricity producer EDF has modified the functioning of certain sections of its nuclear power plants, thereby allowing it to modulate plant load in mid-season. Market-gardening and horticultural developers must then tolerate important raises in consumption of back-up heating (the case of Saint Laurent and Le Bugey), as the temperature may now descend to 15°C. At present, Le Bugey, over one year, is heated more than 30% by its back-up compared to 10% initially planned.

Thermal waste and cogeneration

Heat-force cogeneration allows one to withdraw waste heat (90°C) or vapour produced by an electric power plant. The differences with thermal waste are the following:

- higher temperature, therefore exchange surfaces that are less important in order to heat the greenhouses.
- reduction in yield of the electric plant.
- billed energy: in Holland, 10% less than the price of gas; in France, the transfer price of the electricity that would have allowed the production of this energy.

Most important, cogeneration presents the advantage of being adaptable to a traditional greenhouse heating system, on an existing installation, since the temperature level is comparable to heating with a classic boiler. This energy can therefore be brought to users situated several dozen kilometers away (whereas thermal waste necessitates installing new ones very near the plant).

What is more, cogeneration allows the use of plants in open circuit to heat greenhouses, whereas thermal waste from such plants does not. On the other hand, the profitability of cogeneration is less.

Electricity producers of certain countries, such as West Germany, nonetheless favor cogeneration over thermal waste for heating greenhouses. In Holland, cogeneration is almost the only envisageable solution, in view of the large number of plants in open circuit and the concentration of greenhouses in certain regions.

1.3 Use of thermal waste in horticulture

1.3.1. Economical analysis

Overinvestment

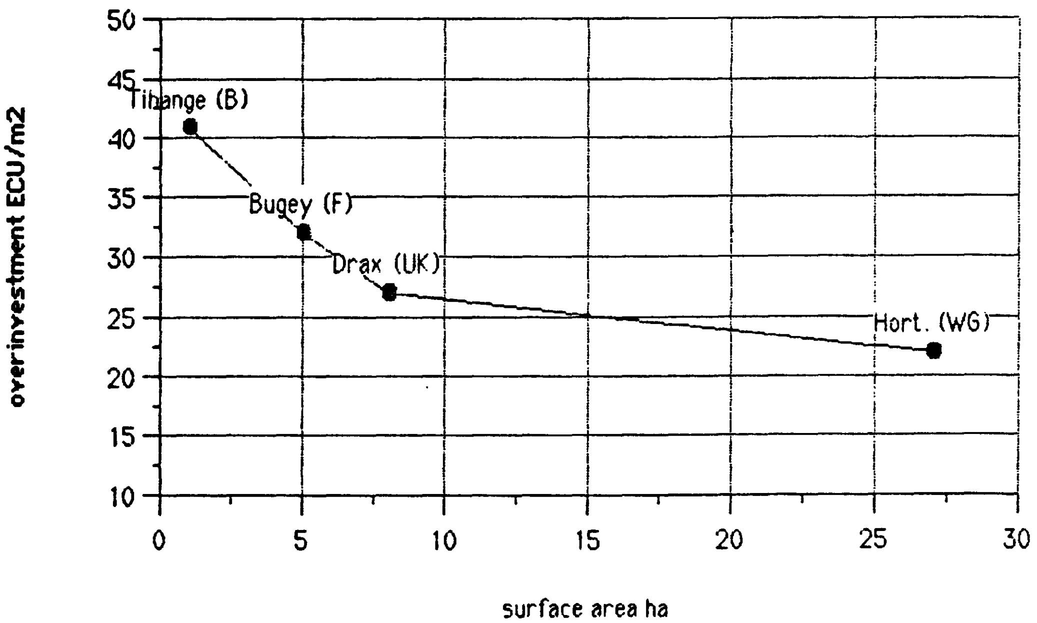
The table below recapitulates the investment overcosts for a few horticultural installations (or market-gardening, if these are equivalent installations), compared to a classic installation. These overcosts mainly concern the waste heat network; they have been evaluated without taking into account subsidies accorded by public authorities or various organizations (real overcost has therefore been less important for developers).

Installation	Date	Surface area	Investment overcost	Overcost per surface area unit (1) (in ECU/m2)
Le Bugey (F)	1984	5 ha	10 MF	32
Tihange (B)	1984	1 ha	16 MFB	41
Hortitherm (RFA)	1987	27 ha	465 000 DM/ha	22
Drax (UK)	1980	8 ha	£ 850 000	27

(1) 1987 comparison: 1987/1984 = 1.1; 1984/1980 = 1.6

The important savings realized by the largest surface areas is underscored by these results, that can be represented thanks to the following graph:

OVERINVESTMENT IN FUNCTION OF SURFACE AREA



Energy savings and return time

Energy savings realized thanks to the use of thermal waste depend on several factors:
- the assigned temperature of the greenhouse (variable according to crops);
- the climate of the area in which the installation is situated (temperate or Mediterranean region);
- the isolation of the greenhouse: double glass, thermal screen.

Our reference here are greenhouses operating (thermal screen) in temperate areas: average consumption is then 350 kWh/m2/y (average figure used in Holland, market-gardening and horticulture combined).

We also assume that there are no pumping charges (which reduce energy savings): this is the case of most of the sites. Neither do we include electric consumption if the heating system used is made up of airothermes.

Concerning back-up heating, we distinguish 3 hypotheses, in % of total thermal energy: 0%, 15% and 30%, which largely depends on the plant's mode of functioning (in base or not).

Finally, two price levels will be used to appreciate the effect of the drop in the price of energy (the energy of reference is natural gas):

Year	Average price Holland (Df/kWh)	Average price France (F/kWh)	Average price used (ECU/kWh)
1985	0.04	0.15	0.02
1987	0.02	0.08	0.01

(1 Df = 3.0 FF; 1 FF = 6.9 ECU)

The following results are therefore obtained, in terms of energy savings realized (in ECU/m2/y):

Year	Back-up heating:	0%	15%	30%
1985		7	6	5
1987		3.5	3	2.5

Return times depend on the size of the installation. Obtained by year:

RETURN TIME	Year 1985			Year 1987		
Size of installation	Back-up heating			Back-up heating		
	0%	15%	30%	0%	15%	30%
1 ha	6	7	8	12	14	16
5 ha	4.5	5.5	6.5	9	11	13
20 ha	3.5	4	5	7	8.5	10

N.B.: these are return times for the total investment, without deducting accorded subsidies.

With present-day prices of energy, return times have doubled, going on the average from 5 to 10 years. This can be an important limitation in implanting new areas using thermal waste. Moreover, it should be noted that the profitability of new areas imposes a certain size (more than 5 ha), which is in general too large for a single developer.

1.3.2 Restrictions related to financing

The financing needs of horticultural greenhouses are great: one must today count on about 145 ECU/m2 for a modern greenhouse, equiped with a thermal screen and piloted by computer (hygrometry, CO_2, luminosity, temperature).

In addition, cultivation for a new installation requires about 20% in additional financing (about 30 ECU/m2, for a potted plants activity).

Overinvestment related to thermal waste also accounts for about 20% of the "classic" investment, which is large; but this figure can be reduced by subsidies by national or regional public authorities, as is illustrated by a few examples:

Operations	Subsidies in % of overinvestment	Overinvestment assumed by developers in % of classic investment
Le Bugey (F)	30%	14%
Dampierre (F)	80%	4%
Tihange (B)	75%	5%

As a result, this aid from public authorities improves the investment return times; overinvestment related to thermal waste is therefore not a preponderant factor in the present success of operations. What is more, the financial difficulties of horticulturists using thermal waste seems to be due to the profession it slef (the failure of the operation in Le Bugey is thus analysed by its directors).

1.3.3 Restrictions related to organization

Organizational restrictions are preponderant:

□ The horticultural profession is still of a very family nature (40% of the manpower in France). Exploitations are of small size (less than 3000 m2 in the whole EEC, not including Holland), too small for the use of thermal waste. Production groups are common (coöperatives), but mostly for distribution and commercialization, and very few to coördinate production.

□ Holland's success in horticulture is in large part due to an organization which is different:
- 2 large very concentrated horticultural areas: Aalsmeer (near Amsterdam) and the Westland (near The Hague). The average surface area of the exploitations is 5000 m2, that is double the average surface area in all the EEC. This concentration allows for an organization and rationalization of production on two complementary levels:

  - mass production of the most common plants;
  - a series of small secondary productions, allowing a very large variety of plants to be offered on the same emplacement.

Thanks to this organization, conditions of distribution and commercialization are very much facilitated.

In other countries, professional organizations are seeking to promote an organization in this direction:
- in France, the Comité National Interprofessionnel de l'Horticulture is trying to encourage producer groups working on this principle;
- in Belgium, the professional union which created the horticultural operation in Tihange, an expansion project for this area over 20 ha with:
  - for 2/3 of the surface area, industrial production of about twenty of the most demanded plants;
  - for 1/3 of the surface area, small exploitations of specialized crops, whereby greenhousemen rent out the installations.

2. MARKET GARDENING

Greenhouse market gardening, from a technical viewpoint, is often compared to horticulture. The main differences are that:

- in certain cases, "freeze-free" heating may be sufficient, for young plants for example;
- investments are lighter: plastic tunnels, plastic greenhouses, single glass glasshouses for tomatoes;
- this activity is often quite seasonal in that these crops are not profitable in the winter when traditional crops do not supply the market;
- the m2 turnover is much lower than for horticultural production.

2.1 Market-gardening activity in the EEC

In 1984, the covered (under greenhouse) surface area for fruit and vegetable crops was the following for the main countries:

Country	Number of developers	Covered surface area (ha)	Average surface area per developer (m2)
Italy	15 540	**7 239**	4 660
Holland	7 354	**4 627**	**6 290**
France	10 564	3 867	3 660
Greece	10 040	2 434	2 420
RFA	4 538	3 003	**6 620**
United Kingdom	6 416	1 324	2 063
Belgium	3 452	1 040	3 000
EEC Total	58 086	21 449	3 690

We find here a phenomenon which is similar to horticulture, although less pronounced: the average surface area is much greater in Holland and West Germany.

The heating of installations depends on the climatic conditions of the country:
in Holland, 85% of the greenhouses are heated;
in France, 60% of the greenhouses are heated.

2.2 Main types of crops concerned by thermal waste

All market-gardening crops do not react positively to heating, or show no significant increase in yield compared to a non-heated crop.

The main species commercially cultivated are the following:

□ Tomatoes: the tomato is cultivated in the traditional way under heated greenhouses. This is the only fruits and vegetables crop which has as of today resulted in commercial operations using thermal waste: Drax (GB), Saint Laurent des Eaux (F).

□ Other vegetables: cucumbers, eggplants and green peppers theoretically have interesting yields in heated greenhouses. But these production are rather secondary. They can be used to back up a main production of tomatoes, for example.

□ Young plants: the activity of multiplying young plants (market-gardening, horticultural or nursery) seems promising. The Dampierre area, in Burly, has specialized in this. Moreover, research conducted (in particular, by the PAGV program of the Dutch Agriculture Ministry) has shown this activity to be profitable.

Other crops, and in particular strawberries, have been the object of experimental work; they have proven not to have a significant yield in comparison to non-heated crops. In any case, concerning strawberries, interesting results have been obtained in Italy (Tavazzano) on a winter varierty, but the economic profitability is less than for horticultural crops.

2.3 Profitability of the use of thermal waste

The average m2 turnover is on the order of 20 to 30 ECU/m2 for tomatoes. This figure is too low to absorb the overinvestment related to the use of thermal waste. In effect, if we compare cultivating tomatoes in comparison to horticulture for an installation on the order of 5 ha, the following results are obtained:

Type of activity	T/m2 (ECU)	Overinvestment/m2 (ECU) of T/m2	Overinvestment in %
Market gardening	25	30	120%
Horticulture	65	30	46%

On the other hand, energy consumption is less in market gardening, with a traditional heating:

Type of activity	Consumption in kWh/m2/y	Consumption in % of consumption of the horticulture (potted plants)
"Freeze-free" market gardening	80	15%
Lettuce+tomatoes market gardening	250	45%
Cucumber+melon market gardening	300	55%
Cut flowers horticulture	450	82%
Potted plants horticulture	550	100%

This then prolongs even more the return times in the use of thermal waste.

Even in Drax, where the operation for use of thermal waste is a success, diversification activity, with the import and conditioning of vegetables, has become as important as the production of tomatoes in terms of turnover.

Finally, market fluctuation for market-gardening products is great and producers confront important unknowns, when their average m2 turnover is already weak.

Case of the young plant

Multiplying young plants (market-garden, horticultural or nursery) is an activity capable of making a greater turnover (up to 140 ECU/m2). The Dampierre area in Burly, thanks to this activity, has witnessed significant expansion. In addition, this activity does not generally necessitate large investments: a freeze-free crop is sufficient, which is adapted to the use of thermal waste, and does not necessitate back-up heating, as opposed to tomato cultivation in Saint Laurent, for example.

3. SYNTHESIS: MARKET GARDENING AND HORTICULTURE

3.1 Profitability indicators

Several data are essential to appreciate the interest of thermal waste recovery operations in market gardening and horticulture:

□ the type of activity, which therefore determines:
- an energy need per m2 and per year: n
- an average annual turnover per m2: t

□ the size of the operation, characterized by its surface area S; this size gives an idea of the scale of overinvestment related to thermal waste per surface unit o, which is a function of this surface (size savings);

□ the price of energy: p

□ the site on which the operation occurs, and in particular the need in back-up heating, if the waste's minimal temperature is too low:
that is, w, the percent of energy need supplied by thermal waste.

The main dimensions can have the following values:

Variable	Nature	Minimal value	Maximal value
n	Energy need	250 kWh/m2/y	550 kWh/m2/y
t	Turnover	25 ECU/m2	140 ECU/m2
o	Overinvestment	22 ECU/m2	50 ECU/m2
p	Price of energy	0.01 ECU/kWh	0.02 ECU/kWh
w	Need supplied by thermal waste	70%	100%

To measure the interest of thermal waste in function of these variables, two indicators can be defined:
- an operation's return time: relation between the overinvestment and the energy savings realized:

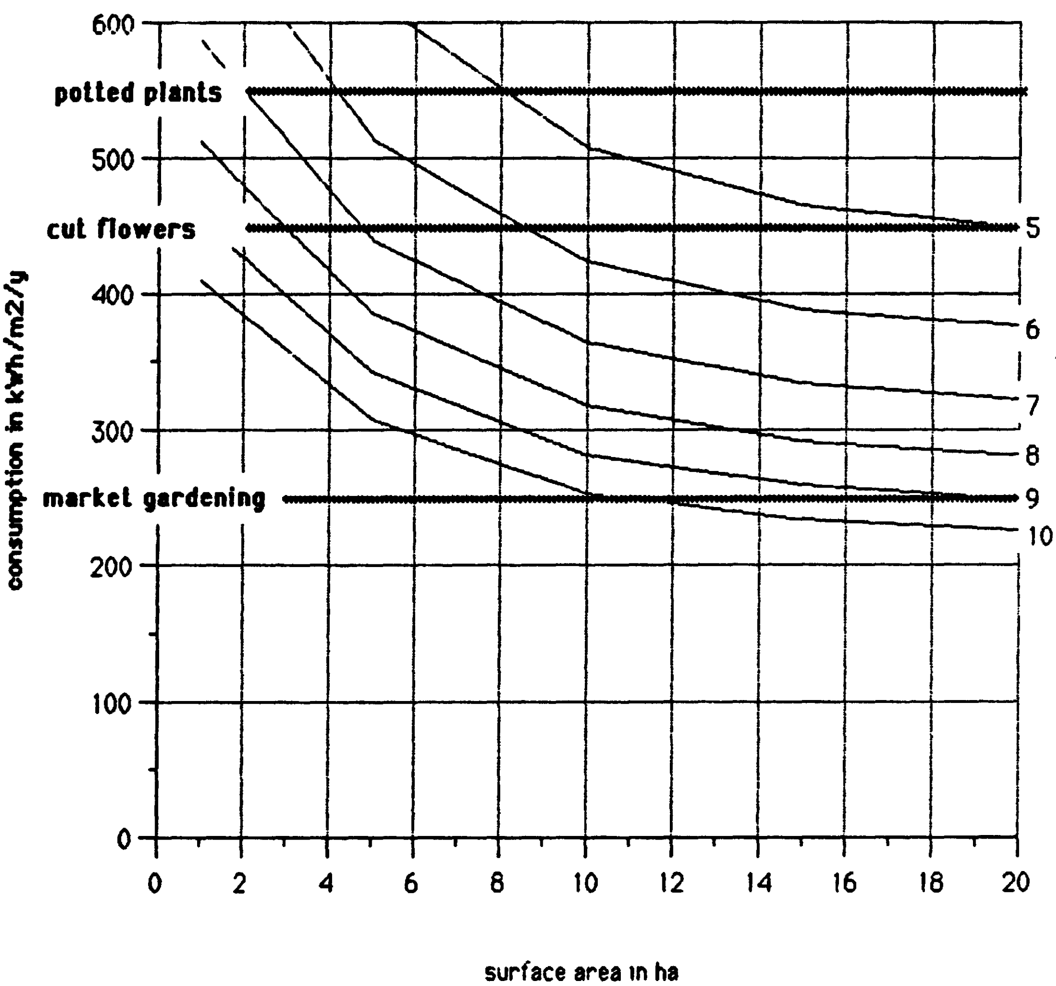
$$RT = \frac{o}{wnp}$$

- an overinvestment's collection time by the annual turnover: relation between the overinvestment and the annual turnover:

$$CT = \frac{o}{t}$$

3.2 Analysis for a price of energy at 0.01 ECU/kWh (in 1987) and an energy need 100% covered by thermal waste

☐ Return time RT: the following graph represents the curves of the same return time in function of the installed surface area and the energy consumption per surface unit:

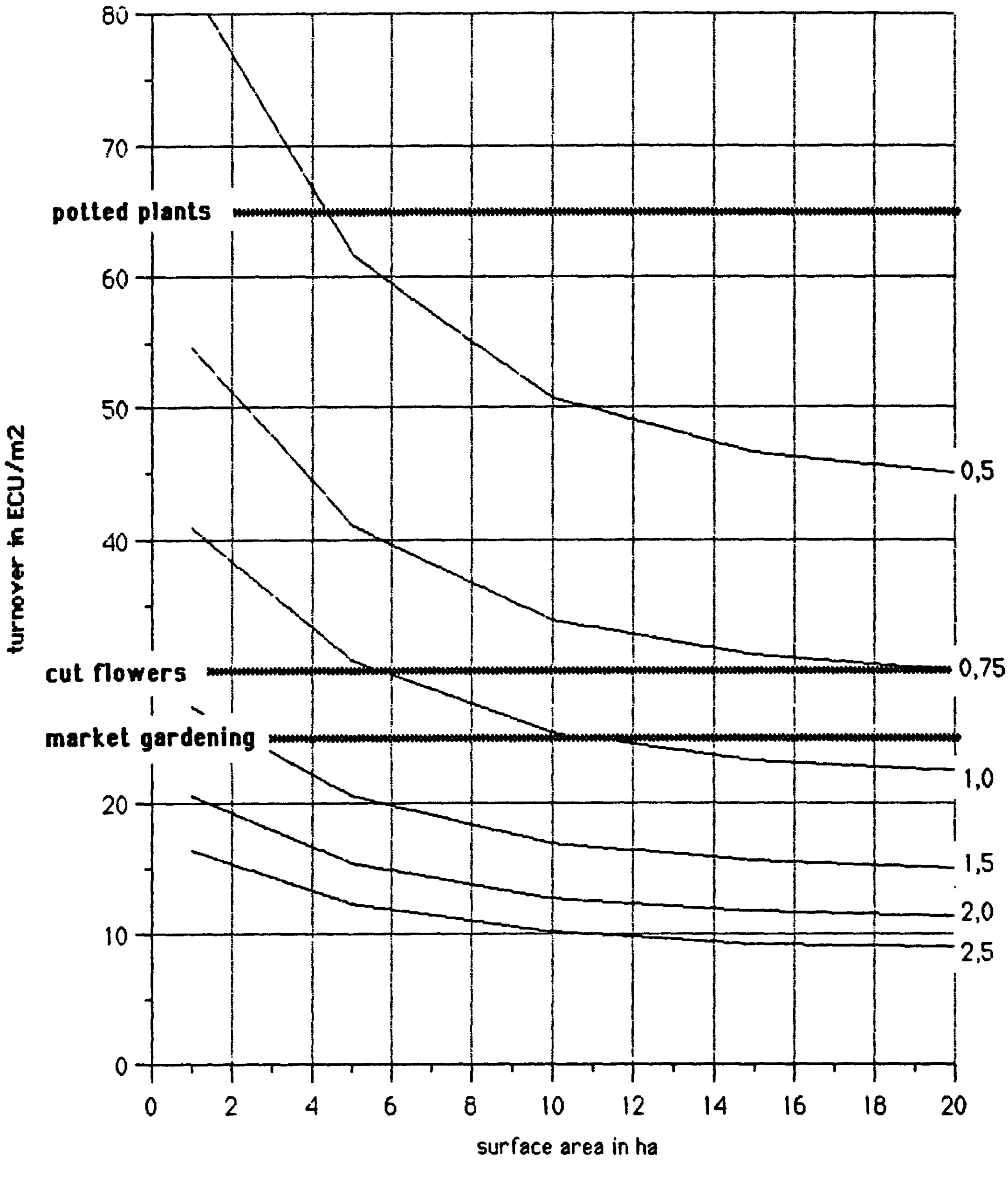


- A return time which is less than 5 years can therefore be attained only for a potted plant type crop, and of a surface area greater than 8 ha.

- A return time which is less than 6 years can be attained by all horticultural activity (cut flowers and potted plants) of a surface area greater than 8 ha.

- Market gardening is difficultly competitive: return time of 10 years for a surface area of 10 ha.

☐ <u>Collection time CT</u>: the following graph represents the curves of the overinvestment's collection time by the turnover in function of the surface area installed and the turnover per unit of surface:



- From a surface are of 4 ha, overinvestment represents 6 months of activity for the potted plant.

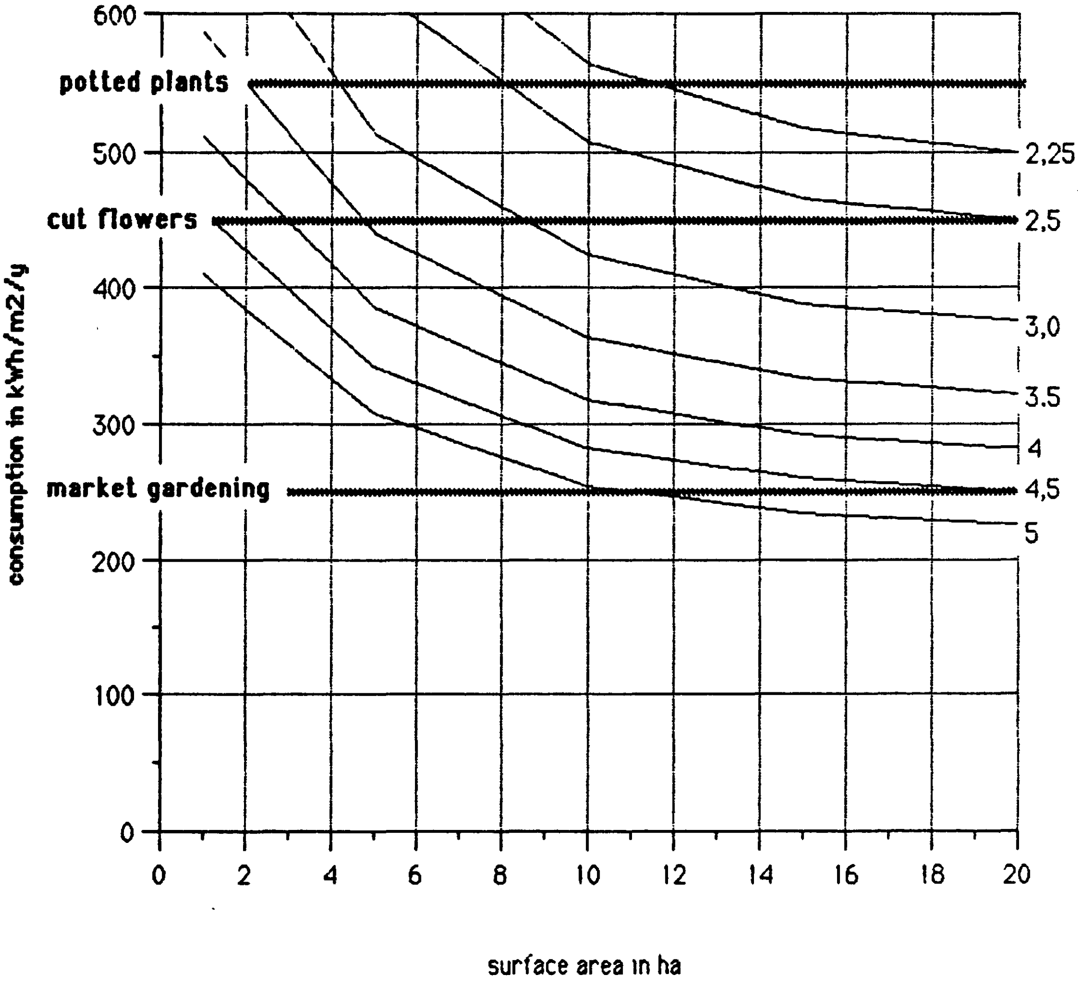
- In cut flowers, overinvestment represents 1 year of activity for an exploited surface area of at least 6 ha.

- In market gardening, overinvestment represents 1 year of activity for an exploited surface area of at least 10 ha.

3.3 Analysis for a price of energy at 0.02 ECU/kWh (in 1985) and an energy need 100% covered by thermal waste

Between 1985 and 1987, the price of energy decreased by half, making thermal waste recovery operations less attractive. It is therefore interesting to see what the profitability was at the time, and what it would be if the price of energy were again to increase.

The following graph therefore presents the curves of the same return time, for a 1985 energy price level:

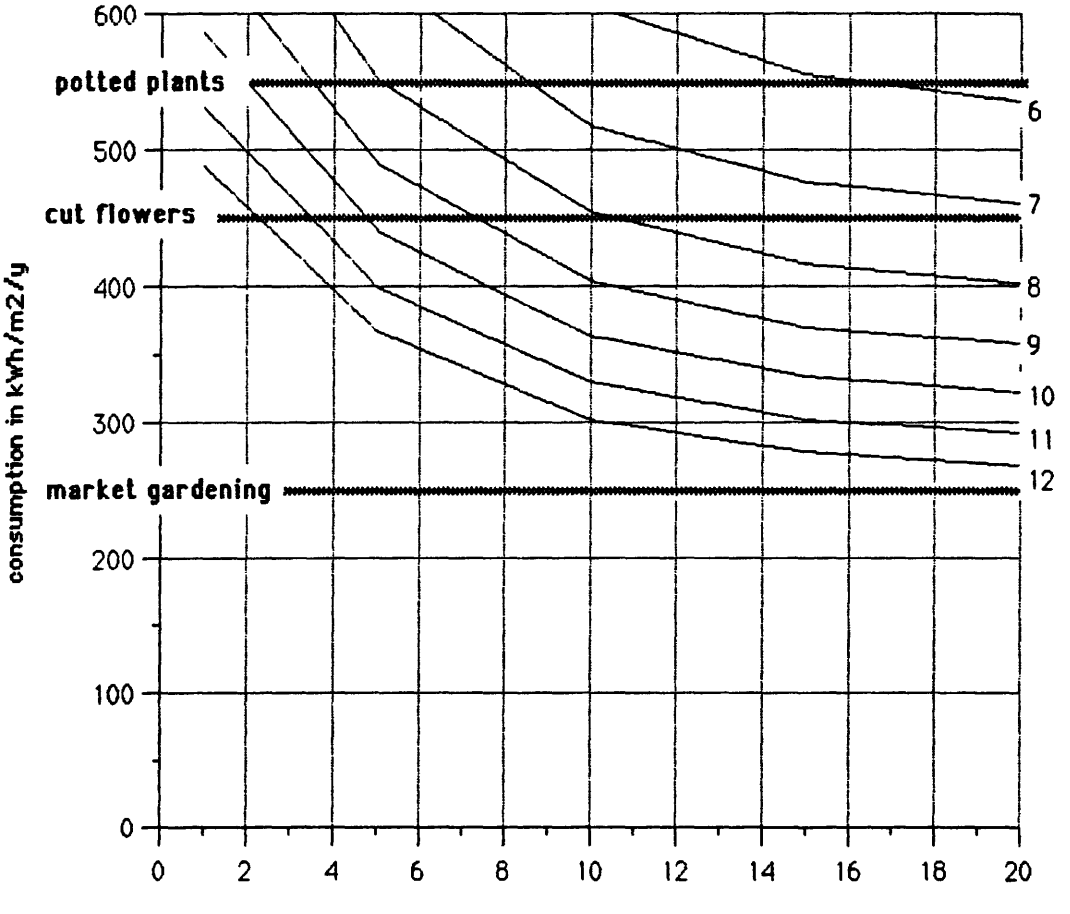


- Based on 4 ha, a potted plant activity therefore had a return time of less than 3 years.
- Likewise, based on 8 ha, a cut flowers activity had a return time of less than 3 years.
- Market gardening attained a return time of 5 years only for sufaces greater than 10 ha.

3.4 Analysis for a price of energy at 0.01 ECU/kWh (in 1987) and an energy need 70% covered by thermal waste

At times, waste temperature is not sufficient for wholly heating a greenhouse; this is the case if the power plant functions in open circuit, or if the plant's load is seasonal (as is the case in France for the past two years for certain nuclear plants, such as Le Bugey and Saint Laurent des Eaux), which lowers waste temperature and necessitates a back-up heating for certain crops.

The graph below therefore presents the curves of the same return time for an energy need 70% covered by thermal waste; the remaining 30% is supplied by the back-up heating:



Differences with a complete heating by thermal waste are the following:

- the recovery time of an 8 ha potted plant activity goes from 5 to 7 years;
- the recovery time of an 8 ha cut flowers activity goes from 6 to 9 years;
- market gardening is no longer competitive at all.

3.5 Conclusion: technical and economic options to promote

Thermal waste recovery in greenhouse crop is therefore profitable only:

- for a crop activity realizing a turnover of at least 30 ECU/m2 (potted plants, cut flowers, young plants);

- for a crop surface area of at least 8 ha.

It is moreover necessary to take account of an eventual resorting to back-up heating (if the waste temperature is too low and the crop type requires it). A back-up heating covering 30% of the total energy need increases the return time to 3 years, and not 2. This is why greenhouse heating is not really profitable but for installations connected to power plants functioning in closed circuit, and in base.

Traditional market gardening, of little turnover, is not very profitable; on the other hand, the activity of multiplying young plants, despite weak energy needs, has the advantages of having a strong m2 turnover and of not necessitating back-up heating.

The types of operations which may be commercially practicable are the following:

- □ Horticultural areas of at least 10 ha, preferably intended for potted plants, with a coördinated production project following a precise commercial plan (associating one large crop with small specialized crops, for example).

- □ The activity of multiplying young plants, and more generally, activities having a strong turnover per unit of surface area, outside of their energy needs.

4. AQUACULTURE

4.1 Freshwater aquaculture activity in the EEC

4.1.1 Species bred and market types

Freshwater species are meant for 4 very different types of markets:

- repopulating: targets a fishing-company and public authorities clientele to repopulate ponds and rivers;

- bait: is a specific market for sport fishing, an activity which is currently in expansion in the European Community (in particular in West Germany and Italy);

- consumption: accounts for the main market, which is relatively stagnant; efforts have been undertaken to promote transformed products (frozen, prepared dishes, mousse, pâtés). The fresh fish market is traditional, and not likely to evolve.

- ornament: is a very dynamic market, with a large variety of fish and a strong added value.

The table below summarizes, for each type of market, the species concerned:

Type of market	Main species concerned
Repopulating	Carp, trout, tench, pike, perch, roach, ...
Bait	Minnow
Consumption	Salmon, trout, carp, eel, silure, catfish, tilapia, ...
Ornament	Basically: Japanese carp, platys, xyphos
	Other varieties: extremely numerous

Upstream from these productions, hatching is also an important activity: the hatchery makes the eggs hatch to produce "juveniles". This activity is more and more necessary for intensive aquaculturists, for whom reproduction in natural environment is insufficient, and where loss of eggs is very important (presence of predators).

4.1.2 Production and the European market

The table below presents the situation in the European market for carp, which is the most produced species (outside of trout, but this fish is not very concerned by rearing in waste heat).

Country	Production	Imports	Exports	Consumption
Italy	3 100	700 (1)	0 (1)	3 800
RFA	6 000	2 400	60	8 340
Greece	3 000	380	0	3 380
France	2 000	220	700	1 520
Others	200	260	0	460
10-nation EEC	14 300	3 300 (2)	150 (2)	17 500

(1) Trade between the other EEC countries and third-party countries
(2) Trade with third-party countries only
(EEC data: 1985)

The EEC therefore has a cover rate on the order of 80%. The commercial deficit is due to the large imports from Eastern block countries.

The production level of other species is less. Some countries are specialized: eel and ornament fish in Italy, salmon in Ireland and the United Kingdom.

Sales price may greatly vary according to species (variations of from 1 to 4). Species concerned by breeding in waste water are mentioned in bold type and classified in order of increasing sales price:

Species	Sales price (ECU/kg)
Carp	**1.6**
"Portion" trout (consumption)	2.5
Roach	**2.6**
Tench	**3.5**
Tilapia	**3.9**
Silure	**5.0**
Pike	5.5
"Fresh" trout (repopulation)	5.8
Eel	**5.8**
Salmon	6.5
Ornament	**0.1 ECU/piece**

(Wholesale prices in France in 1986)

4.2 **Profitability of waste heat aquaculture**

4.2.1 Traditional aquaculture

Traditional pond aquaculture produces yields that are very different according to the type of activity:

Type of activity	Yield (carp) (kg/ha)
Extensive (average)	100 kg/ha
Extensive (maximum without supply)	250 kg/ha
Intensive (fertilizer supply)	600 kg/ha
Intensive (food supply)	1000 kg/ha

Intensive aquaculture basin yields vary between 50 and 100 kg/m3, with an economic optimum of 60-70 kg/m3.

4.2.2 Advantage of waste heat aquaculture

The use of the cooling waters from an electric power plant to rear fish is not motivated by energy savings that might occur, since intensive aquaculture heated traditionally would be too costly and exists only for ornamental fish, on a very small scale. Waste heat from electric plants have therefore permitted the development of new breeding techniques to enable:

- the breeding of fish at their optimal growth temperature throughout the year (whereas coldwater aquaculture is seasonal);
- the acceleration of fish growth, and therefore greater production at equal capacities.

The table below presents the temperature levels required for the principal species:

Effects on growth	Carp Tench Koï-carp	Trout	European silure	American catfish	Tilapia
Dangerous	<0°C	<0°C	<0°C	<4°C	<17°C
No growth (hybernation)	16°C	6°C	18°C	18°C	17-20°C
Average growth	16-21°C	6-12°C	18-21°C	18-24°C	20-25°C
Optimal growth	**26-30°C**	**17°C**	**18-21°C**	**18-24°C**	**25-31°C**
Slowed growth	30°C	18-19°C	20°C	34°C	31-33°C
Dangerous	-	24°C	-	-	>33°C

But breeding techniques do not just include higher temperature. Waste heat breeding also requires appropriate feeding, oxygenation and sanitary conditions. Certain species pose no breeding difficulties (carp); others are much more delicate (eel).

The profitability of different species must therefore take account of both these technical problems and market conditions. The table below presents the advantages and inconveniences of the principal species reared in waste water:

Species	Technical aspects	Commercial aspects
CARP	- Very rapid growth (more than tilapia) - Easy transformation (70% of the fish is recuperated by net)	- Large traditional market
	but: - No parental guarding of eggs (100 000 eggs per head). Great loss in natural environment. - Some problems of illness (out of certain lots)	**but:** - Major competition from Eastern block countries - Stagnant market (despite efforts to promote transformed fish)
TROUT	- Good production in waste water in winter	- Very important European market
	but: - Water quality problems (very clean water is necessary in order to avoid disease) - Low optimal temperature for growth (17°C)	**but:** - Moderate sales price - Classic breeding that is already very developed (the use of waste water is interesting only as back-up, out of season
EEL	- Theoretically excellent yield in waste water	- Very good added value fish
	but: - Necessitates particular installations (nets over basins, protecting the accesses to pipes) - Very numerous problems of disease - Refusal by certain lots to be fed	**but:** - Numerous bankrupcies of eel farms (in the United Kingdom in particular): technical problems have not been resolved - Fine technique (on the other hand, major breeding in Italy, using industrial waste)

Species	Technical aspects	Commercial aspects
TILAPIA	- Rapid growth - Little disease - Parental guarding of eggs (300 eggs per head) the hatchery can be in a natural environment, without loss **but:** - Difficult transformation (in net, only 30% of the fish is recuperated)	- Good sales price - Better flesh than carp **but:** - Very limited market (a few hundred tons in Rungis)
SILURE GLANE	- Good yield in waste water **but:** - Disease problems (less than for eel)	- Good added value - Fish whose flesh is similar to eel **but:** - Potential market is not well known
TENCH	- Necessitates a high temperature (optimum 22°C) **but:** - Slow growth - Difference in growth between males and females	- Moderate traditional market (1270 tons in France) - Good sales price
ROACH	- Easy breeding (as carp)	- Moderate traditional market (1800 tons in France) **but:** - Mediocre sales price

4.2.3 Economic aspects

Aquaculture installations are fairly costly. The example of Tihange can be taken as a reference:
1200 m3 of basins:
- cost of installation: 700 000 ECU (1984)
- cost of water mains: 860 000 ECU (1984)
  (of which 630 000 ECU in subsidies)

The entire installation therefore came to about 1 500 000 ECU.

This figure should be compared to the turnover such an installation can generate, in function of the type of species bred. We will reason on a yearly production of 150 t:

Type of species	Turnover (ECU)	Turnover in % of investment
Carp	240 000	16%
Tilapia	585 000	39%
Silure	750 000	50%
Eel	870 000	58%
Conjoint production:		
- 10 t: Ornament		
- 140 t: Tilapia	1 150 000	77%

These results show therefore clearly the importance of the turnover generated.

Carp, in particular, is not very profitable, especially compared to traditional pond rearing.

On the other hand, ornament fish are a very interesting back-up production.

4.2.4 Conjoint pond and waste water breeding

Many traditional aquaculturists (carp, tench, roach, ...) are first of all pond owners who develop these thanks to fish breeding. Aquaculture is a back-up activity for them, with a minimum of restrictions. For, this activity is by nature seasonal (6 months per year). A waste heat back-up installation can therefore be attractive for these developers, as it allows them to have a winter production, and to fatten other species at higher added value. With this in mind, a waste heat aquaculture may be profitable, as it improves the developer's traditional turnover. What is more, in that this activity requires very special know-how (good "empiric" knowledge of the metabolism and sanitary conditions for the fish), waste heat aquaculture will have better chances at succeeding.

The same reasoning holds for rearing eels, which are rather delicate: waste heat aquaculture would have a better possibility of succeeding if it were exploited by a producer who has classic eel breeding experience; in Italy, one of the only installations producing eels is that of an independant professional aquaculturist (Lodivecchio, on the Tavazzano site).

4.3 Seawater aquaculture

This type of aquaculture is similar to freshwater breeding; the main differences are the following:

- breeding techniques are still in part in the experimental stage;
- species bred have a higher sales price.

The detailed update on advances in breeding techniques and the possibility of their leading to commercial operations is presented below:

□ Turbot: Turbot breeding is the most advanced, and in the past 2 years has resulted in the first commercial operation (100 ton/y in Hunterston (UK)). It has a very good sales price: between 7 and 9 ECU/kg. On the other hand, in Gravelines (F), this breeding remains still experimental. Other commercial operations, following the Hunterston example, should succeed in coming years (the annual European market is 10 000 tons).

□ Bass: Bass has an even greater sales price than turbot: 11 ECU/kg. This is why Hunterston gives importance to developing breeding techniques for this fish. The developer believes he will soon succeed. In addition, the sites of Gravelines and Le Blayais in France and Torrevaldaliga in Italy have produced excellent experimental results in intensive breeding. This success should become concrete in the near future in the form of commercial breeding.

□ Dorade: The rearing of this fish is less advanced. Hunterston remains secretive on the subject; Le Blayais has indicated a technical failure. Gravelines, on the other hand, is at the demonstration stage, with a certain hope. The feasability of breeding dorade remains to be technically demonstrated, but satisfying results might still be obtained.

□ Sole: Hunterston remains secretive; Gravelines has abandoned trials. Sole rearing is therefore in the realm of experiment.

□ Shrimp: Shrimp breeding remains experimental and marginal. It appeared interesting because of the possibility of conducting two consecutive production cycles each year. But, according to the directors of the Torrevaldaliga (Italy) station where trials have been conducted for several years, intensive shrimp rearing has not produced good results. A too high density in the basin causes production yield to tumble, and the cost of feeding becomes prohibitive. Shrimp is better suited for a production complement in semi-intensive breeding.

□ Eel: The breeding of eel, which reproduce in seawater and then return to freshwater by going up streams, poses many more complex problems: the cycle and mechanisms of reproduction remain unknown, and have never yet been able to be reproduced in artificial breeding. At present, all eel breeding is done starting from elvers fished at sea. The difficulties in breeding eels (in freshwater) are due in particular to the disparity in behavior between the different lots of elvers: certain lots refuse artificial feeding, others may be very sensitive to diseases. In addition, a strong disparity is to be noted between the speeds of growth of the different individuals and the different lots. These inconveniences could probably be overcome if it were possible to master reproduction or to practice a selection according to varieties or origins. Enlarging eels (in freshwater) has created many inconveniences and still remains very experimental, with the exception perhaps of:

- Italy: a commercial enterprise in Lodivecchio, on the Tavazzano site (production kept secret)

and other sites supplied in geothermal waste water or coming from an oxygen factory, which is outside the framework of this study (Ansedonia, Vimercate, Calvizano).
- the United Kingdom: despite the abandonment of Wylfa, two commercial operations are being conducted: in Ratcliffe (55 t/y) and above all in Hinkley Point (detailed data secret, but expansion to 500 t/y seems to be planned).

The following table sythesizes these commentaries:

Species	Stage
Turbot	Commercial with risk (1 operation)
Eel	Commercial with important risks (3 operations)
Bass	Should go to commercial stage
Dorade	Should go to commercial stage
Sole, bream	Experimental
Shrimp	Not profitable

4.4 Conclusion: technical and economic options to promote

These options can be on four levels:

□ In the commercial area:

- *for consumption fish:* large-scale operations (minimum of 100 tons per year), concerning breeding high sales price fish, with complementary species. This activity should preferentially be a back-up compared to a traditional aquaculture.
- *for ornament fish:* associate quantity (for "basic" fish) and variety: large-scale aquacultural area grouping, on the one hand, a few aquaculturists massively producing "basic" fish, and, on the other hand, a series of small specialized aquaculturists.

□ Transitional between the experimental and commercial area:
commercial investment for species which should affirm their commercial profitability: turbot, bass, eel, silure.

□ In the experimental area:
research for species for which rearing techniques are not yet completely developed, above all for seawater species (dorade, sole, bream, eel).

IV - CONCLUSIONS

□ Following a research and experiment stage since 1974, thermal waste recovery resulted in, starting from 1982, a large number of commercial operations (at present: 28 operations out of 47 inventoried). A net decrease in the number of operations initiated during this period is to be noted in 1986-87. This is due, in large part, to the drop in energy prices, which makes heating greenhouses by thermal waste less profitable, as well as building heating, already of mediocre profitability in earlier years.

In comparison to the study realized in 1984, a certain discouragement by professionals in these two sectors is to be noted. Operations which seemed promising at that time have been mixed successes, even failures, generally due, in the case of greenhouses, to organization problems specific to the profession.

□ In aquaculture, the same phenomenon is to be noted, whereas the drop in energy prices cannot be invoqued: the current period is mostly characterized by the developing of breeding techniques which should lead to commercial operations in the coming years.

□ Agriculture in heated soil has been abandoned in that it is of little interest. On the other hand, agriculture in irrigated soil continues to be the object of research (rice in Trino Vercellese); but this remains experimental.

□ Algae culture is quasi-inexistant. Yet, major commercial interests might be at stake (in particular, cosmetics). But, the technologies remain very experimental; waste heat recovery for this type of operation therefore seems premature.

□ The economic analysis of commercial operation has shown the importance of the turnover generated by the type of activity: thermal waste recovery installations are relatively costly, both in greenhouse heating and in aquaculture. Crops or breeding at low turnover per surface area unit make paying off the installations longer. This is why market gardening (tomato) is less profitable than horticulture (potted plant) or young plants culture; rearing carp is less profitable than rearing eels or bass.

□ For greenhouse crop professionals, the use of thermal waste is still a costly technique. They prefer at present to conserve traditional heating modes, remaining on their production sites, or to use warmer waste water (cogeneration, industrial waste) rather than to be obliged to set up next to an electric power plant, or to have to completely reorganize their production, distribution and commercialization.

□ Finally, again concerning greenhouse heating, guaranteeing heat supply is not always enough: sporadic functioning of the power plants or load modulation. This is an important limitation which decreases the profitability of operations.

□ The technical and economic options to promote can be prescribed according to three fundamental axes:

- the conclusion of research and demonstration programs for activity types which have not yet lead to commercial operations, and which appear promising:
  - freshwater aquaculture: *eels.*
  - seawater aquaculture: *dorades, soles, breams.*

- going towards activities capable of generating a high turnover, on a commercial scale:
  - horticulture: *potted plants*
  - young plants culture: *market gardening, nursery and horticultural.*
  - freshwater aquaculture: *tilapias, silures, eels, ornament fish.*
  - seawater aquaculture: *turbots, bass.*

- large-scale commercial operations in front line sectors, capable of assuring a complemental production in function of an exact commercialization strategy:
  - *expanded range of potted plants.*
  - *specialization in young plant.*
  - *varied production of ornament fish.*

Volume II

Case Studies

1 - Horticulture in Le Bugey (France)

2 - Market and horticultural area in Dampierre en Burly (France)

3 - Market and horticultural area in Saint Laurent des Eaux (France)

4 - Freshwater aquaculture in Tihange (Belgium)

5 - Hortitherm (West Germany)

6 - Urban heating in Arzberg (West Germany)

7 - Market gardening in Drax (United Kingdom)

8 - Aquaculture in Hunterston (United Kingdom)

9 - The CARPA project (Italy)

10 - Horticulture in Bastardo (Italy)

1. **Horticulture in Le Bugey (France)**

1.1 Introduction

Eight horticulturists from the Rhône-Alpes region gathered around the nuclear power plant in Le Bugey to create a horticultural area of 5 hectares of greenhouses with the intent of producing and commercializing potted plants. The coöperative within which they joined was to realize an annual turnover of 25 million francs.

In 1984 the technical study was concluded and greenhouse construction was imminent. The project seemed exemplary of the use of waste water, for two reasons mainly:

- The operation was large-scale (5 hectares of greenhouses).

- It was the result of the determination of horticulture professionals.

The construction of greenhouses was therefore realized. However, financial difficulties occurred early into the operation. The cooperative went bankrupt at the end of 1985, and the greenhouses were repurchased by a limited company, the Le Bugey Horticultural Society, of which GEOTHERMA (research unit specialized in the use of subsoil water) is the main stockholder. This group restarted greenhouse operations in late 1986.

1.2 Background

In 1980 eight horticulturists together envisaged a project of a horticultural zone heated by a geothermal deposit near Bourg-en-Bresse. The deposit, meant to heat homes, turned out to be insufficient and was abandoned. The horticulturists, wishing to keep their group together, then sought a replacement energy solution in the region. They became interested in the nuclear power plant in Le Bugey, located halfway between Bourg-en-Bresse and Lyon, whose waste waters were not being developed.

The project itself became reality at the end of 1981 on the following bases.

- SAFER (Socété d'Aménagement Foncier et d'Equipement Rural) was responsable for acquiring the land and fully servicing it (including supplying waste water). It would then resell the different lots to greenhousemen;

- AUTEC (Association pour l'utilisation des eaux chaudes du Le Bugey) was created in 1983. This non-profit association, which grouped horticulturists, completed the technical, commercial and financial studies necessary for the project's elaboration;

- The horticulturists decided to create a coöperative (December 1983) which would be in charge of coördinating production and commercializing products. The horticulturists individually retained responsibility for production.

Greenhouse construction began in July 1984 and ended in April 1985. The horticulturists placed their plots progressively in crop during construction, so that at the end of greenhouse installation work the first plants were being commercialized.

But the first difficulties became apparent to operators starting in 1985: the average turnover realized per square meter was much lower than that predicted; what is more, the operator with the largest surface area, unable to find the necessary funding, never was able to put his area into crop. Two solutions to save the Le Bugey horticultural zone were then proposed by the C.N.I.H. (Comité National Interprofessionel de l'Horticulture) in September 1985:

- a global solution intended to unburden operators of investments related to installations (land, bring in waste waters, greenhouse) by having these rebought by a Société d'Economie Mixte which would include EDF, Crédit Agricole and District de la Plaine de l'Ain. This company would have rented the greenhouses to a commercial company whose capital would have been detained by the zone's horticulturists.

- a partial solution whereby the horticulturists would rebuy the lots of operators in difficulty.

None of these solutions came about: rebuying the greenhouses of the operator in difficulty could not be accomplished, and the global solution was too long to set up. The operator in difficulty declared bankrupcy in October 1985, leading the coöperative to do the same a few weeks later.

After a long negotiation phase, the greenhouses were repurchased in July 1986 by a limited company, the Société Horticole du Bugey, whose capital was as follows:

- GEOTHERMA: 58%
- Geofinancial company: 22% (mother company controling 95% of GEOTHERMA)
- A financial company of Crédit Agricole: 18%
- Small stockholders (including certain operators): 2%

GEOTHERMA is a research organisation specializing in the use of subterranean waters, and especially geothermal science.

In September 1986 maintenance and investment complement work were begun. The first reculturing occurred in October 1986. In January 1987,
80% of the total surface area was filled, with a goal of 100% by March 1987. The goal for the 1987 fiscal year is to realize a turnover of 20 million francs.

1.3 Technical description

The greenhouse, of classical construction, has a surface area of 47,000 square meters. It is located about 1.5 kilometers from the power plant. The last two sections of the plant, each having a power of 900 MW and functioning in closed circuit, are attached to the installation (the first three sections of the plant are in open circuit). Water temperature is between 20°C and 34°C. An automatic system chooses the section whose waters are hottest. Yield is 2 m3/s.

Heating is carried out by heating carpets (plastic sheaths covering return circuits) under the culture's shelves. Base pot heating is the technique which gives the best crop results. (Airothermic heating at low temperature only would be too dry for plants.) The minimum required in the greenhouse is 18°C.

Back-up and emergency heating functioning by LPG is connected to the installation. It provides water at 70-80°C and supplies airothermes. It is designed to supply:
- 60 kWh/m2/year in back-up
- 50 kWh/m2/year in emergency

Since 1984 this heating has functioned three times on an emergency basis because of interruptions in heat supply (one time for 12 days, two for 3 days).

It is foreseen that in the long term luminosity, CO2 output and hygrometry will be piloted by computer. For the time being, CO2 output is controlled automatically.

1.4 Analysis of the technical evolution

A new technical problem has arisen since December 1986. The operator assumed that EDF made changes in the system of controlling certain sections of the plant, but this could not be confirmed by EDF. It appears that the plant now regulates its production in electricity on the two last sections of the plant (in closed circuit). These supply the horticultural installations in waste water.

The result of this is a drop in temperature, at identical water flow. Whereas formerly discharge temperature was always greater than 20°C, it now can fall to 14-15°C. This leads to an increase in LPG consumption to have the back-up heating function.

Between October 1986 and the summer of 1987, total consumtion amounted to 730 tons of LPG, that is 9.3 GWh. This consumption corresponds to more than 30% of the total energy need.

This consumption seems too great in the eyes of the developer. He is currently studying the advisability of changing his heating system (working by furnace, in closed circuit, for example)

1.5 Economic aspects

Investments

The financial mounting of the operation was carried out as follows:

- Land conversion and servicing (waste water conveyors included) were the responsibility of SAFER, which then resold lots to horticulturists, after deduction of subsidies. The total amount of the investment figures as follows:

EDF subsidy	2 000 kF
Agriculture Ministry subsidy	600 kF
Local collectivities subsidy (La Plaine de l'Ain district)	500 kF
SAFER contribution	6 900 kF
Conversion total:	10 000 kF

- The total cost of the operation for the horticulturists (that is, of the water conveyor and of the greenhouse construction) was 1000 F/m2. This corresponds to the upper limit of the cost of constructing a modern greenhouse (crop tables, climatic regulation by computer), since the price margin indicated by professional organisms is from 900 to 1000 F/m2, for a 2500 m2 greenhouse. The overcost of 140 F/m2 due to the water conveyor was made up for by savings on the scale realized in Le Bugey (5 hectares).

- Traditionally, ONIFLHOR, the national organism of the market and horticultural profession dependent on the Agriculture Ministry, accords a subsidy for greenhouse installations whose size is greater than 2500 m2. This subsidy varies according to the projects:

  - basic 15% on the total investment, to which can be added according to the case:
  - 5% young farmers,
  - 5% producer groups,
  - 5% high-return investments.

To finance the remainder, banks (and in particular Crédit Agricole) traditionally accept that horticulturist autofinancing be weak: on the order of 10%. It should be noted that Crédit Agricole's policy tends nowadays to ask for larger autofinancing (15%) by horticulturists as a guarantee of better solvency on their part.

But in 1984 in Le Bugey the average autofinancing requested of horticulturists was on the order of 10%, save a young farmer for whom it was his first setting-up, and who benefited from improvement loans, which are more advantageous: these allowed him to invest 5 MF without autofinancing.

Advantages related to recuperating energy

So as to appreciate the advantages related to recuperating energy, the economic ratios indicated for 1984 were as follows

- Annual savings realized by using waste waters: 47 F/m2;
- Return time on overinvestment (140 F/m2) compared to a classicequivalent installation: 3 years;
- Average cost of the kWh of 8 centimes, based on a 490 kWh/year consumption, taking into account:
  - amortization of the network of hot water distribution and back-upheating;
  - overcost related to the increase in heat exchange areas (polytube heating pad);
  - maintenance charges;
  - LPG consumption in back-up/emergency;
  - A savings in energy consumption estimated at 1700 tep/year.

In fact, since recultivation in 1986, LPG consumption in back-up/emergency has cost 1 500 kF, that is 30 F/m2. Back-up/emergency had originally been evaluated at 110 kWh/m2/year, when in fact it is 190 kWh/m2/year, that is an additional cost of 12.5 F/m2. This additional consumption increases return time by 1 year (4 years).

Analysis of the difficulties of grouping horticulturists

It is the shared opinion of all the partners (EDF, CNIH, Banks) that the difficulties of grouping producers reside within the horticultural profession, but are not related to the use of the waste waters of the Le Bugey station: the investment overcost was in effect absorbed by savings realized due to the scale.

Two aspects are essential in the case of Le Bugey:

- The installation is very large in size (and therefore in investment costs): 5 ha of greenhouses wherease more than 90% of horticultrural operators in France are less than 1 ha (national average: 2500 m2);
- It is a producer group, an initiative that Crédit Agricole and the CNIH want to favour in France. The Le Bugey experience was somewhat "pilot" in this area.

The operation's success was conditioned by the good start-up of all the operators starting from the first year; the objective was to realize a turnover on the order of 500 F/m2 (that is 25 MF). The financial resources of the coöperative depended to a great degree on this objective.

In effect, the coöperative was responsible for marketing, production planning, supplying stocks, commercialization and delivery of products (operators were only responsible for production, quality and quantity).

One can therefore estimate the yearly financial needs of this coöperative, according to the average figures indicated by the CNIH, and which correspond to the Le Bugey case:

Posts	% of turnover	cost in F/m2
- Supplies (plants,fertilizers)	45%	225 F/m2
- Distribution, delivery	10%	50 F/m2
- Coöperative staff expenses	10%	50 F/m2
TOTAL	65%	325 F/m2

Moreover, the 1985 results were as follows:

- One horticulturist exploiting 8000 m2 (the largest in area: 16% of the total surface) never was able to cultivate. He was quickly placed in receivership (fiscal insolvancy).
- The area's average turnover (covering 5 hectares) was 200 F/m2 (instead of the 500 F/m2 expected).

The mean difference on the order of 125 F/m2 compared to the coöperative's financial needs explains the difficulties it was soon confronted with.

A (confidential) audit by the CNIH estimated that the viability of 5 companies out of 7 (not including the developer who never cultivated) was never assured. The general diagnosis was as follows:

- The initial financial organisation was insufficient insofar as responding to needs;
- The turnover predicted starting from the first year (500 F/m2) was too optimistic;
- The amortization charges for the installations weighed to heavily on the horticulturists.

This is why the CNIH proposed a global solution to modify the judicial structure of the area: repurchase all the installations (land, water conveyors and grennhouses) by a mixed economic company (possible partners: EDF, Crédit Agricole, Plaine de l'Ain district). This would have unburdened the horticulturists of the amortization charges. In addition, in order to have a commercial policy which is more homogeneous than with a coöperative structure, these greenhouses would not have been directly rented to developers, but to a commercial company whose capital would have been held by these developers.

This solution, fairly complex to put in place, could not be worked out for lack of time, while judicial procedures were in progress.

1.6 Current situation

The Le Bugey Horticultural Company, current developer of the area, foresees a turnover of 20 MF for 1987, the year of recultivation. This figure is more realistic than that of 1984 (25 MF).

The horticultural company envisages producing 2.5 million potted plants on 90% of the surface area and 500,000 young geranium plants on the rest.

The area is easily accessible by highway, being 40 km from Lyon and 60 km from Bourg-en-Bresse. The market of the Rhône-Alpes region is targeted in particular. This market represents:

- 8% of French imports, which amounted to 2481 MF in 1985;

- 12% of French consumption, which amounted to 16 208 MF in 1985.

The Le Bugey Horticultural Company, with a long-term turnover goal of 25 MF, is therefore aiming for the following parts of the market (accounting for the 1985 figure update, and for the Rhône-Alpes region):

- about 10% of the region's imports;

- about 1% of the region's consumption.

The company currently employs 40 people in production and 20 in administration-commercialization.

2. Market and horticultural area in Dampierre, Burly (France)

2.1 Introduction

EDF has favorized the creation of a market and horticultural area of 120 ha near the Dampierre station in Burly (Orléans region) which went into operation in 1984. 11 horticulturists set up, and at present exploit 11 ha of greenhouses and plastic tunnels.

The Dampierre area has become known for its crop of young market and horticultural (seedling) plants, which are proving to be a strong market.

But the insufficient number of developers has lead to financial difficulties for the CUMA, the developers' joint organisation, which controls the waste water network.

2.2 Background

In 1974, Electricité de France offered to put the thermal waste of the future Dampierre power plant in Burly at the disposal of the agricultural organisations of the Loiret region.

These organisations then assigned SAFER (Société d'Aménagement Financier et d'Etablissement Rural) the responsability of acquiring the land bordering the power plant. SAFER the in 1975 adjoined an area of 120 ha, the Domaine des Noues, likely to be serviced later in waste waters.

At the same time, at Saint-Laurent des Eaux, the experimental station initiated by EDF was studying the technologies of heating and the performances of different cultures.

At the end of 1980, the first horticulturists declared themselves candidate for the purchase of lots of the Domaine.

The operation was then implemented in 1981:
- SAFER financed the implementation of the heating network: it was the project manager for all servicing (highways, drinking water, draining, financed by the Dampierre commune in Burly). Various organisms accorded subsidies: EDF, Agriculture Ministry, Center Region and the Loiret Department (on the basis of creating jobs).
- The CUMA of Noues was created. The goal of this CUMA (Coöpérative d'Union de Matériels Agricoles) was to repurchase the heating network from SAFER and manage it. Each buyer of a Domaine lot was obliged to be a member of the CUMA and participate in its financing in proportion to the area acquired.

The zone's evolution since the beginning of the project is the following:

Phase	Number of developers (ha)	Area attributed (ha)	Area cultivated
Project	19	120	
Land acquisition (83)	13	80	-
Developer start-up (83)	10	65	2
Current situation (87)	11	87	12

Out of the 19 developers who had intended to become buyers, 13 in fact bought land, and 10 started development. Today, 11 developers are on the site, and the area covered is therefore 12 ha (essentially, plastic tunnels; glasshouses represent less than 3 ha). The developers' activities are varied: market, horticulture, tree nursery, flowers.

About half the developers produce "young plant" (article of plants multiplication), for which the area has become specialized. It is beginning to play a significant role in terms of commercial positions.

Nonetheless, the Noues CUMA is still aware of the insufficient number of developers. A competition is in the project stage whereby three young laureats would be offered a grant to help them set up on the site.

2.3 Technical description

The Dampierre power plant in Burly includes 4 nuclear station, in closed circuit, each 890 MW in power. Cooling waters are taken at the exit of the condensers of the 4 stations, at a 1 m3/s flow rate and a temperature between 20 and 40°C; they supply all the plots by water conveyors 70 cm in diameter. In that the pressure (2 bars) and gravity are sufficient, there is no need for pumping. The maximum distance between greenhouses and the power plant is on the order of 1 500 m.

At present, 12 ha of land are covered, including:
- 3 ha of glasshouses,
- about 9 ha of plastic tunnels.

Heating the plastic tunnels is carried out by buried plastic tubes, spaced 20 cm apart. Glasshouse heating is carried out by a return circuit of elevated tubes throughout the grennhouse space.

There is no temperature regulation by flow modification or cold water pumping: lukewarm water circulates on a permanent basis, with the same flow. In addition, as the Loire water is very "heavy" in silt, a stoppage in waste water circulation, in the summer for example, would risk clogging the supply networks.

In past winters, the greenhouses have **always remained freeze-safe without any additional** heating. The **installations** function **without** emergency **heating**. **When** a gas pipeline **was** installed near the domaine, operators asked the GDF to be hooked up to the network, which was carried out at the beginning of 1987. Emergency heating installations are now being envisaged, depending on the decision of each operator in function of his type of crop (resistance to cold, seasonality).

2.4 Economic aspects

Investments

The various infrastructure work is the responsibility of several organisations, and financed in parts:

- Installation of the heat network and land preparation (heat network study, clearing, drainage):	
- Subsidies (EDF, Agriculture Ministry, Center Region, Loiret Department)........	4.4 MF
- Financial contribution of SAFER........	3.5 MF
- Land servicing is the responsability of the Dampierre commune in Burly (roadways) and the Agriculture Ministry (drinking water, drainage ditches)........	3.3 MF
- Supplying low voltage electricity, supported by the CUMA........	0.3 MF

- Infrastructure TOTAL........	11.5 MF
	=======

The CUMA is committed to paying 3.8 MF of infrastructure investments. Here it has become owner of the heat network, which was bought from SAFER (3.5 MF).

CUMA Functioning

The CUMA (Coopérative d'Union de Matériel Agricole) is a structure which allows farmers to buy and manage materials in common.

The CUMA has been financed:
- in part thanks to farmers' social shares: 12 000 F/ha
- the rest thanks to Crédit Agricole loans, for a total of 3.8 MF, for 7, 15 and 20 years.

The CUMA working budget totals about 500,000 F/year, of which around 320,000 F is devoted to reimbursing loans. The rest of the sum is used for installation maintenance and the administration.

The CUMA is today financed by contributions:

Contributors	Amount of contribution F/ha/month	Surface area concerned	Annual total
Farmers	500 F	81 ha (1)	486,000 F
SAFER	200 F	21 ha (2)	52,800 F
Total			538,800 F

(1) One farmer (6 ha) no longer contributes; financial difficulties.
(2) Surface area not acquired by farmers; the remaining area is considered not very exploitable and does not contribute to the working of the CUMA.

It should be underlined that the arrival of a Dutch group in 1986 (repurchase of 10 ha of land from uninstalled farmer) has been of great help for the CUMA.

Crop activities and commercial results

Currently, 11 companies are in place on the site and employ a total of 82 salaried workers (not counting a certain number of seasonal workers). The subsidy of the Center Region and the Loiret Department on the basis of "development and job creation" requires that the area create 100 jobs by the end of 1988 (over a 5 year period). This figure should be reached.

6 companies out of 11 are specialized in "young plant" (horticulture, market, ornament). 4 are area leaders:

Name	Type of products	Quantity produced per year	Number of salaried workers	Turnover
PLANT PRODUCT Nurseries	Ornamental plants in containers, meant for wide distribution	700,000 containers	10	5 MF
GAEC HORTIPLANT	Seedlings in clods and in patches of salads, cabbage, leeks, tomatoes, light tobacco	35,000,000 seedlings	6	6 MF
ENERGIE THERMIQUE Nurseries S.B.	Young ornamental plants in clods	8,000,000 young plants	14 + seasonal	8.5 MF
SLUGRO Estab. (Dutch company)	Seedlings in clods of horticultural plants: geraniums, petunias, impatiens, primulas, cyclamen.	30,000,000 seedlings	30 + seasonal	15 MF (20% of the French market)

The other companies employ 2 to 5 salaried workers, and realize a turnover of between 1 and 3 MF.

2.5 Future outlook

The CUMA's difficulties have been ironed out thanks to the arrival of the Dutch company. There remain however about 20 exploitable ha which have not been sold. The idea of the CUMA is therefore to attract new developers. For a young developer, who must start up an installation, this must by necessity require important financial help ((about 1 MF to install 5000 m2).

The CUMA therefore foresees organizing a competition to choose three winners who would be the most capable by their technique and their know-how in generating high-grade cultures, with a turnover goal on the order of from 600 to 800 F/m2. These laureats would each be attributed 300,000 F, and their installation would be partially financed by public funding (departmental, regional, national,...). This competition is for now in the project stage, without financial arrangement.

3. **Market and horticultural area in Saint Laurent des Eaux (France)**

3.1 Introduction

Saint Laurent is the number one French operation developing waste waters from an electric power plant. EDF has been conducting trials there since 1975 in all areas (agriculture, market-gardening, horticulture, aquaculture, premise heating).

EDF then gave up its installations to independent developers (market and florist), with the goal of creating a 25 ha horticultural and market area.

Today, a little more than 2 ha are being exploited, with no intent to expand in the near future.

3.2 Background

In 1975, EDF decided to set up a trial station for waste water use near the Saint Laurent des Eaux power plant, including at the time 2 graphite-gas units (from 390 to 450 MW), in open circuit. The start-up of 2 sections, each 900 MW, in closed circuit was already planned for 1981. In Saint Laurent, EDF found partners interested in this study, in a region traditionally market garden oriented: the Chamber of Agriculture, SAFER and the Regional Coucil (Center Region). Trials were run both on existing waste and on a simulation of waste from the 2 future sections, by raising waste temperature by heating pumps. This research concerned both heating techniques and the different possibilities of using waste water (aquaculture, premise heating). The experimental work concluded in 1984, leading to the various applications listed below:

- *in premise heating:*
  - heating the open-air swimming pool of the commune of Saint Laurent, by water/water exchangers, without raising the temperature;
  - heating the village hall since 1985 with 3 60 kW heating pumps

- *in aquaculture:*
  A pilot eel breeding lead to no commercial application (difficulties in breeding; similar trials had been lead at the thermal stations of Martigues-Ponteau and Ambres). The installations were thereafter alloted to a developer raising ornamental fish; this latter operation has been a commercial failure (the developer has left his installation). Since then, there has been no more aquaculture in Saint Laurent.

- *in agricultural, market and horticultural cultures:*
  - the experimental corn and light tobacco cultures have not lead to any application. The viability of such cultures has not been demonstrated;
  - trials on salads, and especially tomatoes, in greenhouse, have been more fruitful: in 1984, two farmers (who were participating in the trials) repurchased existing installations (5300 m2 each), to grow tomatoes and, marginally, cucumbers;
  - trials on cut flowers in greenhouse or plastic tunnel have also lead to the installation in 1982 of a rose florist who rebought the installation.

The three developers joined to form the CUMA (Coopérative d'Union des Matériels Agricoles) in 1984, to manage the waste water network, which was accorded them by the EDF; a young market gardener has joined them since then. At present, 23 000 m2 are covered by greenhouses or tunnels. The site potentially disposes of 25 ha.

3.3 Technical description

The installations are connected to the two latter sections of the plant, in closed circuit, each 900 MW in power, and at a distance of about 1 km from the installations. The temperature of the cooling waters is as usual between 23 and 40°C.

Before the winter of 85/86, the temperature fell to 23°C, necessitating a back-up in mid-season in the greenhouses (the plant no longer functions in base temperature).

The installations are as follows:

Dealer	Glasshouses (m2)	Plastic houses (m2)	Plastic tunnels (m2)	Total exploited (m2)
Market gardener 1 (tomatoes, salads)	5 300	-	1 000	6 300
Market gardener 2 (cucumbers, tomatoes)	5 300	-	1 400	6 700
Market gardener 3 (tomatoes)	-	3 000	1 000	4 000
Rose florist	-	3 200	3 000 (non-heated)	6 200
Total	10 600	9 200	6 400	23 200

These installations are heated by smooth outdoor tubes. The glasshouses (for the 2 market gardeners) are, in addition, equiped with 2 airothermes each.

In view of the drop in temperature in mid-season, dealers have installed in 1987 back-up and emergency heating:

- For the 2 main market gardeners: 2 mixed fuel/gas heaters (LPG), respectively 1 750 and 2 325 kW in power, which have been dimensioned for a surface area of 10 000 m2;
- For the rose florist: 3 generators of air heated by gas (LPG), each 140 kW in power;
- The last market gardener does not dispose of back-up heating.

These installations work in back up about 3 months a year, from January to March. They are also allowed to work in emergencies, as during 8 days of stoppage for the 2 sections of the plant.

Only the first market gardener had his heating function in 1987 (the other heaters were installed later): he consumed 20 tons of propane (278 MWh) for a working time of 2 months (March-April).

3.4 Economic aspects

Investments

- *First market gardener:* the total initial investment amounted to 1.5 MF, including installing the waste heating (350,000 F) and the back-up heating (250,000 F). The dealer obtained the maximum subsidy from ONHIFLOR: 440,000 F, this is 30% of the total amount of the investment. The rest was entirely supplied by an improvement loan accorded by Crédit Agricole.

- *Second market gardener:* the initial investment is the same as for the first market gardener: 1.5 MF, including waste heating and back-up heating.
  This dealer obtained only 240,000 F in subsidies on behalf of ONHIFLOR, that is 16% of the initial investment. The Crédit Agricole improvement loan financed 70% of the investment (complement of the ONHIFLOR maximum). The dealer therefore autofinanced 14% of the investment.

- *Third market gardener:* economic precisions are not available. This dealer seems at present to be having financial difficulties.

- *Rose florist:* the investment amounted to a total of 750,000 F (3,000 m2 of greenhouses in flexible plastic, transformed into hard plastic). The maximum ONHIFLOR subsidy (30%) was obtained. Crédit Agricole provided the remaining 70%.
  The dealer is at present confronting a problem of financing the plastic tunnels (3000 m2) he set up, and which are still without heat: Crédit Agricole refuses to finance the installation in its whole.

Management of waste heat network

The waste heat network, extended to dealers by EDF, is maintained by a CUMA (Coopérative d'Union de Matériels Agricoles), grouping the 4 develòpers of the area. The CUMA working budget is paid by the developers on the order of 3500 F/year/ha.

Till now there have been no expenses, but iron sewers, at the level of the greenhouses, should soon be replaced (leaks due to oxidation; the water seems very oxygenated). The part of the network going from the power plant to the zone is in cemented cast iron, and is proving satisfactory

Crop activities and commercial results

The production realized in 1986 is the following:

Dealer	Type of crop	Quantity produced
Market gardener 1	Tomatoes (from 15/2 to 15/8) Salads (from 1/10 to 31/12) Note: the production of tomatoes and of salads is alternately done in winter/summer	85 t 8 000 parcels of salad
Market gardener 2	Tomatoes (on 4 300 m2) Cucumbers (on 1 000 m2)	60 t 15 t
Market gardener 3	(Information not available)	
Rose florist	Roses	30 000 stems produced 15 to 30 flowers/year according to the varieties

It should be noted that the exchange rate for tomatoes fell dramatically in 1987 (it went from 7.50 F/kg in June 1986 to 3.50 in June 1987). The market gardeners are highly subject to market fluctuations, independent of their production yields (12 to 16 kg/m2/year).

The rose florist has chosen to engage in "high quality" production: the varieties of roses at higher adjusted value sell on the average at 2 times the price of an ordinary rose. He has thereby found a means of competing with the Province-Côte d'Azur region, the leader in rose production in France (58% of the total French surface area, which is on the order of 300 ha.

3.5 Future outlook

No extension is foreseen in the immediate future (the horticultural area has a capacity of 25 ha). However, the area is situated in a traditionally market and horticultural region. The attractiveness of the area is therefore not enough to bring in professionals, especially in the context of the drop in energy prices since 1986.

4. Freshwater aquaculture in Tihange (Belgium)

4.1 Introduction

The Tihange aquaculture operation is the follow-up of tests done since 1975 by the University of Liège and Intercom (producer of electricity, Tihange nuclear power plant), then in association with the British firm, Tate and Lyle (sugar industry). It resulted in 1983 in the constitution of a limited company - the "Piscimeuse" - whose majority stockholders are the Gabriel brothers, the major Belgian distributors of freshwater fish.

A 5000 m2 installation of basins fed by a mix of river water (la Meuse) and cooling water should lead to a production of from 300 to 400 tons of tilapias. This African fish, for which there exists a market in populations of African or colonial origin, therefore represented a new commercial path to explore.

The actual market for tilapias, more reduced than initially planned, lead the developer to diversify his production towards other species, such as carp and ornamental fish.

The commercial results have been, despite all, satisfactory. The developer predicts a doubling of his exploitation surface area for 1987.

4.2. Background evolution of the operation

The Centre d'Etudes pour la Récupération des Energies Résiduelles (CERER) was created in 1975. This association grouped the University of Liège, the Agronomic University of Gembloux, the Agriculture Ministry and Intercom-Liège. It was half financed by the National Institute of Industry and Agriculture, the other half by Intercom. At that time, only one section of the central was functioning (at present: 3 sections).

The association's research consisted of three axes:

- aquaculture: in particular, farming and enlargening tilapia, a fish traditionally consumed in Belgium since the time of the African colonies. Research as also done on eels;
- greenhouse horticulture;
- algae crop.

In 1980, the firm Tate and Lyle became interested in breeding tilapias. Its economic activity in developing nations (sugar cane) caused it to become interested in the agricultural development of these countries, for which it had a study office. It therefore built a pilot station to produce about 10 tons a year of tilapias.

The success of the pilot operation lead the partners (Intercom and Tate and Lyle) to look for a developer to undertake a commercial exploitation with it. They came into contact with the Gabriel brothers, who are the largest freshwater fish merchants-distributors in Belgium.

In 1983, the second section of the central became operational, thereby offering a better guarantee of security in the supply of waste heat. In effect, contrary to European species, an interruption in the supply of waste heat in the cold period would bring about the death of the tilapias. This therefore played a decisive role in the decision to start up the operation.

At the same time, horticultural research lead the Wallonie professionals to become interested in Tihange site. They planned, in association with Intercom, to build and develop 1 hectare of greenhouses.

The two operation were therefore conjointly conducted in 1983. A lumited company, the "Florimeuse", was created to develop the greenhouses. Likewise, the "Piscimeuse" company was created for aquacultural activity.
Its capital was distributed as follows:

- Intercom: 5%
- Tate and Lyle: 10%
- Gabriel brothers: 35%
- Regional Investment Company of Wallonie: 50%, which must progressively buy up the Gabriel brothers.

The conjunction of the two operations has allowed the water main for all the installations to be built at the same time, with a global financing. The University of Liège has also been associated with this operation so as to supply the installations in algae crop.

Construction of the installations was terminated in the summer of 1984, and production soon began. In 1985, the installation was connected to the central's third section which had just been completed.

The tilapia market seems to be more limited than initial predictions. In 1986, the developer therefore adopted a diversification policy for its production: besides 160 tons of tilapias, it also produced 40 tons of carp, tench, minnow, and also directed himself towards ornamental fish.

4.3. Technical description

The installation cover a 9000 m2 land area. They include:

- basins (1200 m2) for fish enlarging;
- fish farming ponds.

The basins are supplied by cooling waters from the three central section, 800 MW, 1100 MW and 1300 MW in respective power. These sections function in open or closed (more often) circuit, according to climatic conditions. Water temperature is always between 20°C and 40°C.

Water flow used (directly, without exchangers) is 2500 m3/h. Water temperature fall, in the installations, is on the order of 1°C to 2°C. Three 44 kW pumps each supply the installations in non-heated water to obtain the optimal temperature in the basins (25° to 30°C).

The largest basins are elongated, in "hairpin", to allow a current. Fans (either rotating propellers supplied by an electric motor, or airation baffles supplied by an air turbin) allow water oxygenation (this diminishes fish "stress").

Plastic basins under a hangar allow the young fish to enlarge until their transfer into the large basins, and the breeding of ornamental fish.

An ornamental fish hatchery has just been installed.

4.4. Analysis of the technical evolution

The installation functions without emergency heating (which is impossible because of the flow used). This makes the developer totally dependent on the reliability of waste heat supply. The 1985 connecting of the central to the third section provides an enhanced guarantee from this point of view.

In effect, on the whole, for about a third of the year, there are only two sections which function. The third is being overhauled. For, in the winter a half-hour interruption of the heat supply would be enough to cause important damage (in 1984, an interruption caused 23 tons of fish to be lost). Being permanently connected to the two operational sections therefore provides greater security.

Nevertheless, round-the-clock surveillance is necessary. A remote electronic alarm permanently controls the water temperature of the large basins. An on-duty alert permanence is assured in turn by the three salaried workers of the enterprise. Currently, there still occurs on the average two alerts a week.

What is more, incidents of various types, other than a strict breakdown of the waste heat supply, and not always electronically detectible, can occur.
For example:

- One of the sections sometimes begins a water chlorination cycle without warning the aquaculturist that he has to change sections. It should be pointed out that chlorine can kill certain species, such as the koï carp (Japanese carp).
- The central regularly cleans the exchangers by means of abrasive marbles injected in the water circuit. In January 1987, some of these escaped from the filters and clogged the arrival of water of a few small basins on a night when temperatures were below zero (the gates for these basins were half closed). In the morning, the basins were completely frozen. In effect, these basins are not connected to an electronic alarm.

The aquaculturist is therefore entirely dependent on the regularity and quality of the waste heat supply. Most species bred can survive as long as the temperature does not go below 0°C, but their growth is nil at low temperature. On the other hand, for tilapia (main production in Tihange) the lowest temperature not to be gone below of is 17°C. In practice, 17°C is therefore the minimum temperature imposed. The optimal temperature of global growth of all the species is 24°C

The incidents cited above underscore the problems of coördination and information between the plant and the developer. What in fact is necessary for these incidents to be less frequent is that the plant directors have a "Piscimeuse" reflex each time they modify the normal functioning of the plant. Intercom's participation in the capital of the "Piscimeuse" does not therefore seem to be a sufficient solution from this point of view.

4.5 Economic aspects

Investments

The water main cost 65 MFB, for which:

- Intercom obtained a subsidy on behalf of the regional collectivities of 50 MFB;
- The remaining 15 MFB, being the responsibility of the users, was distributed on the basis of flow used:
  - pisciculture: 10000 kFB
  - horticulture: 3750 kFB
  - algae culture: 1250 kFB

The complete installation cost a total of 40 MFB for the pisciculturist, of which:

- 30 MFB for the pisciculture installation;
- 10 MFB for the water main.

The Ministry of Agriculture accorded it a subsidy of 7 MFB. Moreover, the Belgian economic expansion law offered interesting financement possibilities: the public powers took responsibility for a part of the interests on the long term loons. In the case of Tihange, this could have corresponded to a contribution of 7.4 MFB (thus, equivalant to the 7 MFB cited above). This was refused in reason of the first subsidy accorded. But the developer today thinks that this second solution would have been more advantageous, from the point of view of the availability of fund, in particular.

Development and commercial results

The results of Piscimeuse since 1984 have been the following:

Year	Production (in tons)	Tilapias sales (in tons)	Results of exploitation	Comments
1984	70 t (mainly carps)	20 t	small loss	Loss of 23 tons following an interruption in the supply of heat
1985	120 t (carps and tilapias)	60 t	good profits	Losses from 1984 reimbursed at 50% by insurance
1986	260 t (mainly tilapia: 160 t)	130 t	very slight profits	Tilapia overproduction. 1985 fish farming produced a yield greater than the production capacities in enlarging.

Production overload caused proportionally higher food and oxygenation expenditures because of modification of fish metabolism. The following table compares, for tilapia, the optimal and real conditions in Tihange for 1986.

Post	Optimal conditions	Real conditions	% real/ optimal
Basins load	60 kg/m3	110 kg/m3	+ 80%
Food consumption per kg of fish (cost 20 FB/kg)	1.5 to 2 kg	2.5 to 3 kg	+ 50%
Total electricity consumption (oxygenation)	1.4 MFB/year (estimated)	1.740 MFB/year (real consumed)	- 25%

The supplementary exploitation overcost due to basins overload is therefore on the order of 22 FB/kg of fish, that is 20% of the cost price (110 FB/kg).

The extension project (doubling production capacity to attain 250 tons per year in optimal conditions) is therefore an economic imperative from this point of view.

4.6 Future outlook

The initial Tihange project was a quasi monoproduction (of Tilapia). The restricted potential market, in addition to the basins' overload, lead the developer to diversify his production.

Piscimeuse is present at the four major types of market of freshwater fish:

- repopulating ponds and rivers: carp, tench;
- outlet for leisure fishing: minnow;
- consumption: carp, silure, tilapia;
- ornament: Japanese koï carps, platys, xyphos, Chinese veils.

The consumer market is the chief market targeted by Piscimeuse.

1986 production had the following structure for the species concerned:

- 160 tons of tilapias;
- 30 tons of carps;
- some silure.

The tilapia market has been overestimated: 130 tons were sold in 1986 out of the 160 tons produced. Piscimeuse has been making an effort to promote fish, realizing brochures and recipe books.

Carp production in Tihange occurs in back-up: the main activity of the Gabriel brothers is transporting live fish, and in particular carp coming from Eastern block countries.

Breeding trout is impossible: the water of the Meuse is not clean enough. Eel breeding is envisaged as a middle course possibility, but the extremely great technical difficulties make the developer prudent.

In 1987, efforts will therfore be made in the direction of silure, which could be commercially interesting if the problems of illnesses are resolved.

Ornament fish have the best added value: in 1986 in Tihange, this activity represented less than 0.5% of the tonnage, but almost 10% of the turnover. The developer has just installed an ornamental fish hatchery to intensify this production. The general market is very dynamic.

But ornamental fish sellers are looking to supply themselves in both:

- "basic" fish (platys, xyphos), in large quantity;
- a varied selection of small quantities of more "exotic" fish.

A supplier who proposes all of this supply is therefore the best placed commercially. But the compromise between intensive production and hightly varied selection is delicate.

At present, "Piscimeuse" only produces "basic" fish.

5. Hortitherm (West Germany)

5.1. Introduction

The "Hortitherm" operation, conducted by the electricity producer RWE, groups 2 distinct sites:

- at the Neurath power plant, with a 5000 m2 greenhouse, which has been used to set up the design of waste heat heating, and which is a demonstration operation.
- at the Niederaussem power plant, with a horticultural area of 270,000 m2 in greenhouses, in two sections (13 and 14 hectares), which should be able to be built and then developed by independent horticulturists, in a strictly commercial framework.

In 1984, RWE thought it had been rather successful in uniting enough horticulturists to be able to undertake the construction of the first section of the Niederaussem area.

However, what with the drop in oil prices, most of the horticulturists withdrew, and greenhouse construction has still not begun. The goal now is to start up a first installation starting from October 1987, of 1.5 or 3 hectares, according to the number of horticulturists participating in the operation.

5.2 Background

RWE's different trials to recover thermal waste began in 1973 with:

- the "Agrotherm" program (reheating soil for cultivation in open field) near the Neurath plant: 16 million DM, financed by the BMFT (Bundes- ministerium für Forschung und Technologie). The operation was a failure and stopped;
- the "Limnotherm" program near the Niederaussem plant, still working, conducted and financed by RWE;
- the "Hortitherm" program near the Neurath and Niederaussem plants and whose expenses, covered by RWE, currently amount to 6 million DM. Work planned in Niederaussem will lead to investments of 18 million DM for 27 hectares of greenhouses.

The first greenhouse of the Hortitherm program was built in Neurath in 1979. The 1000 m2 surface was used for the first tests and increased to 4000 m2 in 1981 in light of the good technical results. Crop tests were done on vegetables, cut flowers and potted plants, cultivated on shelves. Since 1983, the Neurath greenhouse (5000 m2) has been rented to a horticulturist, who mainly produces pottet plants. In the middle of 1986 a financial dispute lead RWE to change its tenant, who had accumulated unpaid rent. The new tenant is also a horticulturist who only produces potted plants. This Neurath installation is, at the same time, a "showcase" for RWE, which receives numerous visitors. Numerous new and impressive technologies have been tried there so as to test their economic profitability.

The renovation of the Hortitherm project of Niederaussem (a few kilometers from Neurath) began in 1982. A surface area of 27 hectares of greenhouses (13 and 14 hectares, respectively) has been planned.

Construction, first planned for 1983, could only begin once all the parcels of the first section (14 hectares) had been acquired. In 1984, construction start-up was once again delayed, since only half the surface area had been taken, with 6 to 7 professionals, of whom 3 had already signed sales promises. Before work began the price of oil fell, leading to the withdrawal of several candidates, and the goal of uniting enough greenhousemen to undertake construction of the first section was totally compromised. In 1986, preparatory work along with the installation of piping were nevertheless realized despite great costs, in particular caused by the fact that pipes had to pass under a railroad track.

Construction of the first greenhouses is definitively scheduled for October 1987, but only concerns a small surface area at first, with 1 or 2 greenhousemen (1.5 hectares per greenhouseman).

The delay in constructing the Niederaussem greenhouses nonetheless remains the most significant event in this project's history, and raises a certain number of questions (see: Analysis of the economic evolution).

5.3 Technical description

The design of the Hortitherm greenhouse heating, such as it has been developed in Neurath, and such as it is to be used in the Niederaussem installations, relies on the following points:

- no back-up heating; greenhouses are supplied by several sections (3 in Neurath, 5 in Niederaussem), which all function in base and in closed circuit.
- airothermic heating of particular design: a large enclosed canal is situated along the greenhouse walls and its upper surface is entirely composed of exchangers supplied with waste heat. Greenhouse air is propulsed by fans inside this canal, and escapes above, along the walls of the greenhouse, after having been reheated by the exchangers. Temperature regulation is carried out based on the variation in speed of rotation of the fans.
- the heating system is dimensioned to obtain a temperature of 18°C inside the greenhouse, with an outside temperature of -12°C, with a water temperature of 26°C.
- water circulation most often takes place without pumping charges, in that the over-pressurization in the cooling circuit is sufficient. The pumps are used in cold weather to increase water flow and thermal transfer.

The greenhouses are related to the power plant by a double main, since the cooled water is sent back to the plant. For the Niederaussem installations, the main measures 1.4 m in diameter over a distance of 1.2 km and a flow of about 9000 m3/h is planned.

The heating system seems to be entirely satisfactory, and its performance has progressively been improved (see below: Analysis of the technical evolution).

What is more, in that the Neurath installation is somewhat of a prestige operation for RWE, the most advanced technical solution are put into practice and tested. Thus, various investments have been realized, in particular with experimentation on:

- semi-moveable shelves;
- additional shelves heating (non-profitable);
- measuring and adjusting the CO_2 levels;
- automatic watering network;

- thermal and solar isolation screen (non-profitable from the single thermal point of view, although it allows one to protect certain fragile cultures from direct sunlight in summer;
- artificial lighting (profitable for early budding, non-profitable for prolonging light periods in winter);
- central computer allowing one to optimize the growth parameters of the plants, according to the type of crop: permanent measures (light, temperature, CO2 rates, humidity rates) with actions on the different parameters.

All these improvements are in no way necessary, and are not necessarily justified economically. The semi-moveable shelves, for example, are all the more profitable in that the cost of heating is high, since they allow one to increase crop surface in a given greenhouse. For a greenhouse whose heating costs are weaker, as is the case with thermal waste, semi-moveable shelves are of lesser interest than in a traditional greenhouse.

5.4. Analysis of the technical evolution

Even without the start-up of the Hortitherm project in "real size", the Neurath greenhouse, in commercial exploitation for several years now, has allowed for the acquisition of a certain experience on materials and techniques.

The heating system's performances have progressively been improved. The relation between electric energy consumed (by the pumps and fans) and thermal energy supplied has progressively gone from 1/15 to close to 1/28 on the average yearly at present.

Major experience has also been acquired in protecting the different componants of the heating system against corrosion. In effect, the agressivity of the cooling circuit waters has forced the installation to be successively modified:
- all the metalic mains have been replaced by PVC ones;
- the pump vanes are now in bronze;
- the exchangers' water circulation tubes are in bronze (as if often the case for this type of equipment).

On the other hand, sealing-off problems are rare. A filter associated with a settling pot suffice to protect the exchangers' circuits.

5.5 Economic aspects

For the Niederaussem project, the producer of RWE electricity, who designed the plans for the whole installation, set up the entire infrastructure (roads and water mains) for an estimated cost of 65 000 DM/hectare; RWE furnishes waste heat, and asks greenhouse tenants for a rent in counterpart for all these services, as well as for the land of which it is the owner. The investment costs concerning the greenhouses are charged to the developers who set up there.

The average investment costs for greenhouses in West Germany break down as follows:

Posts	Average cost (thousands of DM/ha)
Complete envelope (foundations, steel structure, glass)	600-700
Technical building	150
Electric installation and computer	250-300
Automatic watering	150-250
Double windowing (overcost)	500
Solar and thermal screen	200-300
Crop tables	300-500
Heating installations:	
- classic system	400-500
- Hortitherm system	700-800
TOTAL (with all perfections):	
- classic installation	2550-3200
- Hortitherm installation	2850-3500

Source: RWE

This greenhouse configuration for producing potted plants leads to an average cost of 2.5 to 3.2 million DM per hectare for the traditionally heated installations. In the case of producing cut flowers, investments are less in that crop shelves are superfluous. The average investment costs for a traditionally heated installation are then somewhere between 2 and 2.3 million DM per hectare.

Overinvestment due to the heating system is evaluated by RWE at about 400 000 DM/hectare. The fixed exploitation expenses are the following:

- rent: 90 000 DM/hectare/year,
- overcost in electricity: 50 000 DM/hectare/year (for an overconsumption in electricity of 25 kWh/m2/year, that is a heat supply of 700 kWh/m2/year.

5.6. Current situation

According to the latest information (September 1987), work has finally begun and a first section of 1.5 hectares will be in crop before the end of the year, with a single developer. A 3400 m2 building is also being constructed. The same developer has taken an option on a second 5 hectare section. Other horticulturists are still in negotiation with RWE for additional sections, but no decision has yet been taken.

6. Urban heating in Arzberg (West Germany)

6.1 Introduction

The installation of urban heating by "cooled water" in Arzberg (Bavaria) has long been the only one of this type in Europe.

A single main brings the plant's waste heat to the town, where it is used as the cooling source for the heating pumps. The operation, started up at the initiative of the commune, initially concerned a swimming pool and a school grouping. It was progressively extended to other buildings of limited size. In 1987, heating power available from all the heating pumps is on the order of 3 MW.

In 1984, a project extending the network to the entire old city existed, representing a thermal power of about 20 MW. This project, which became a political issue, did not come about after the team in office lost the municipal elections.

The economic performances of the installation were mediocre, but the technique set a precedent in that another installation, of similar design, was set up in Schwandorf, in the same region.

On a technical level, important lessons have been learned from this first installation.

6.2 Background

The waste heat main was put in place in 1979 after several preliminary studies. At the same time, since 1980, the plant provides vapour and hot water (80-100°C) to a porcelaine plant situated nearby.

The following table presents the different users who successively hooked up to the "cooled network".

User	First put in service	Electric power installed (heating pumps)	Back-up/ emergency heating energy
Open-air swimming pool	1979	60 kW	Fuel
School grouping	1980	360 kW	Fuel
12-apartment building	1981	80 kW	Electricity (direct)
Pharmacy	1981	23 kW	Fuel
2 houses	1982	2 x 13.6 kW	2 x earthen-ware stoves
Offices	1983	43.4 kW	Gas
4 houses	1987	(total) 76.2 kW	2 x electric and 2 x none
Together		669.8 kW	

Other extension projects have existed for several years, in particular:
- a gym (connection planned for 87/88),
- a community building (connection date no fixed),
- a church (connection date not fixed),
- the city hall (connection date not fixed)

Moreover, once again using the Arzberg plant, there exists a vast project to supply the town of Waldsassen, situated nearly 20 km away, with waste heat. This project is the object of an EEC subsidy request.

6.3 Technical description and energy assessment

The Arzberg electric power plant exists on the same spot since the beginning of the century. It has been regularly modernized. At present, it includes 3 sections, of which 2 are by carbon of 107 and 220 MW, functioning in "mean load", as well as a section by natural gas of 130 MW, used at peak periods.

Waste heat is taken by choice from one of the three sections. One of the carbon sections works in open circuit when the river flow is sufficient. The taking of waste heat therefore occurs in principle on a section functioning in closed circuit, with a temperature between 25 and 35°C. The electricity consumed by the pump (40 kW in actual power) is supplied freely by the OVE electricity producer.

The concrete main, buried but not isolated, leads waste water to the town, about one kilometer from the power plant. The temperature drop during this trajectory in winter is on the order of 1°C. There is only one main. Waste heat is in the end poured into a small stream which crosses the town, and which flows into the plant's upstream river. The temperature of the stream water is at minimum 10°C, but this introduction is of negligeable influence on the river's temperature. The water circulating in the main is not chlorinated, but just filtered. Moreover, after the river was accidentally polluted a few years ago, the river's ecosystem was damaged and the river contains almost no more fish.

To heat the buildings and the swimming pool, a fraction of the waste heat is removed and is then used as a cooling source for the heat pump. The waste heat, slightly cooled, is then reinjected into the principal main. The different uses are situated one after the other along the single main, such that the waste heate temperature descends progressively. The heat pumps of the most distant buildings therefore function in conditions (weakest performance coëfficient) that are not as good as those for the buildings situated upstream.

The following table presents the different users and the heat pump systems in service:

User	Number of heat pumps	Unit power	Monovalent/bivalent
Open-air swimming pool	1	60 kW	Bivalent, fuel back-up
School grouping	3	120 kW	Bivalent, buffer stockage (1 to 2 hour autonomy), fuel back-up
12-apartment building	1	80 kW	Monovalent (electricity in emergency)
Pharmacy	1	23 kW	Bivalent, fuel back-up
2 houses	2	13.6 kW	Monovalent
Offices	1	43.4 kW	Bivalent, gas back-up
4 houses	4	18.8 to 23.4 kW	Monovalent

The coëfficients of daily mean performance are between 4 and 5.5, with the exception of the swimming pool (5.5 to 6.5) because of the low level of the temperature of the water to heat (33°C).

Electricity consumption of the heat pumps, by user:

Year	79	80	81	82	83	84	85	86
Swimming pool	102	154	125	89	-	100	92	36
School grouping		260	677	722	752	819	763	547
12-apt. building			34	57	37	70	62	37
Pharmacy			11	12	9	13	17	13
2 houses				2	5	8	6	6
Offices					37	34	20	25
Total	102	414	847	882	840	1044	960	664

With an average C.O.P. of 4.5 for all the heat pumps, and based on 1985 electricity consumption, heat supply amounts to about 4300 MWht, that is 370 tep.

Savings in primary energy amount then to 157 tep/year (with 4500 kWhe = 1 tep).

Consumption in back-up energy is not known. It should be noted that total or individual consumption of thermal energy is not known either. It can therefore only be roughly evaluated based on electricity bills and heat pumps consumption.

In the early years of its functioning, the town and the producer of electricity put into place a system of metering energy to demonstrate the operation's profitability. Since then, this system has been dismounted, but the same figures for energy assessment are always put forward when details have been asked for. As the number of users has increased since then, without any major additional investments, the economic performances of the installation theoretically have to have been improved. The following chapter presents elements of the economic assessment.

The first thermal and economic assessment, according to measurements effectuated in 1980, was the following (the network was servicing only the school grouping and the swimming pool).

(in thousands of DM)	Thermal waste, heat pumps and fuel	Fuel (referential solution)
Emergency consumption:		
Fuel (1000 l)	110	561
Electric MWh	734	-
Annual savings in fuel: (1000 l)	-	451
Annual energy costs (elec.: 0.135 DM/kWh tax not inc. fuel· 0 63 DM/l)	190	399
Annual maintenance costs	21	15
Annual write-off of the installations	144 39	39
Annual assessment	394	453

The price of fuel has greatly dropped since then (about 0.30 DM/l in 1987), which makes the economic interest of the installation nil.

6.4 Analysis of the technical evolution

The experience acquired at the technical level resides around two poles:

- at the level of the technical problems encountered on the equipment;
- at the level of the errors made at the time of design of the installation.

Important technical problems were encountered with the high-power heat pumps, set up in the school groupings and at the swimming pool. They had been designed and made by local artisans. The directors thought that heat pumps made in series (Escher, Wyss, Siemens,...) would not present as many obstacles. Difficulties were at two levels:

- compressors: choking the compressors' valves, destruction of the joints' waterproofness. These problems were resolved on the more recent models;
- corrosion, due to a poor compressor/exchanger compatibility: the accelerated corrosion of the evaporators, because of the accumulation of deposits in certain bends; electrolytic reactions; impurities in the heat-transporting fluid coming from the soldering.

Insofar as the installation's design, the directors emphasize that if it were necessary to redo a similar installation, they would plan a double main rather than a single one. In effect, with a monomain installation, the succession of heat pump hook-ups leads to a progressive cooling of the waste heat, thereby reducing the performances of the heat pumps. A double main would allow a constant temperature level in the arrival main to be kept and the water cooled by each heat pump in the return main to be rejected. This formula also allows one to envisage an ulterior extension of the network, whereas in Arzberg the profitability of ulterior hook-ups is limited as a result of the drop in temperature of the waste heat.

Finally, the waste heat main has broken down on 3 occasions, causing a stoppage of supply for 2 to 3 days, and important repair costs. These successive cuts occured in 1986 and 1987 where the main arrived at the river. The exact reason for these cuts is not known.

6.5. Economic aspects

Investment costs

The community covered the investment in the heat network (minus certain subsidies). Insofar as each heating installation is concerned, investment costs in the heat pump, modifying the existing installation, as well as connecting the heat network, were the responsibility of the various owners.

The following table presents the different investment costs:
- in 1981, after operation start-up, according to the various posts (source: EVO, Bayreuth);
- from 1979 to 1986, year by year, investments the municipal services were in charge of (Stadtwerke Arzberg); the total sum spent in 1979, 1980 and 1981 reached 618 830 DM, which corresponds to waste heat retrieval and canalization investments: 625 000 DM, according to the EVO;
- investment costs that are the responsibility of the buildings' owners, concerning the installation of heat pumps and the adaptation of the heating installations.

Investments in 1981 (in DM) (Source: EVO, Bayreuth)		Annual investments which Stadtwerke Arzberg covers (Source: Stadwerke Arzberg)		Investments the owners cover (Source: Stadtwerke Arzberg)	
Removal waste heat:	123 000	79:	460 273	Pool:	130 907
Canalization:	502 000	80:	15 784	School:	987 362
Pool install.:	159 000	81:	142 773	12-apt. bldg.:	76 000
School install.:	830 000	82:	-	Pharmacy:	18 000
Studies div.:	71 000	83:	-	2 houses:	36 000
		84:	(67 300) (subsidy)	Offices:	24 000
Total:	1 685 000			4 houses:	72 000
(Subsidy)	600 000	85:	-		
		86:	36 951	**Total:**	1 344 269
		Total:	655 781 (without subsidy)		
		Total:	588 481 (with subsidy)		

Total investments in 1987 amount to about 2 million DM (without counting the subsidy). In addition to an annual savings of 157 tep, this represents an investment of 12 7000 DM per tep saved and per year, which is very high.

Development costs

Development costs for each user (cost of electricity and maintenance) are not known. Profitability can therefore not be calculated. However, as the transformation realized by the private owners in Arzberg is similar to the water/water heat pump installation (without the cost of drilling a well), it can be assumed that it is of acceptable profitability.

On the other hand, absorption costs for the pipe remain the community's responsibility. The commune taxes each waste heat user. This tax, used to maintain the duct, depends on the consumption in electricity of the heating pumps.

The amount of this tax has greatly varied since the installation was first put into service:

until 30/9/83:	0.005 DM/kWh
from 30/9/83 to 31/12/85:	0.024 DM/kWh
since 1/1/86:	0.012 DM/kWh

This tax is in addition to the price of electricity, which is on the order of 0.12 DM/kWh. The heating pumps benefit from a particular tarification and are separately metered.

The following table presents the annual assessment of developing the installation for the commune (source: Stadtwerke Arzberg).

Year	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**
Investment	460 273	15 784	142 773	-	-	(67 300)	-	36 951
(-) Amortization over 20 years	23 015	23 804	30 942	30 942	30 942	30 942 (27 577)	30 942 (27 577)	32 789 (29 424)
(-) Maintenance	-	-	3 085	3 670	4 013	3 648	3 794	4 082
(+) % on sales	510	2 075	4 243	4 422	8 693	25 141	23 075	9 344
Annual result	-22 505	-21 729	-29 784	-30 190	-26 262	-9 449	-11 661	-27 527

Note: figures in parentheses: with subsidy

During 8 years of development, annual losses by the commune were between 9 500 and 30 000 DM. This large deficit will probably continue for several more years until the installation is amortized

The tax collected by the commune from the users covers the installations's maintenance expenses. These remain relatively high mainly because of the frequent break of canalization, whose repair costs have been the following:

break of 12/5/86:	722 DM
break of 11/6/86:	804 DM
break of 21/4/87:	1 780 DM

6.6 Future outlook

The Arzberg installation is now a reference, since in the same region, in Schwandorf, a similar installation, of great size, has recently been put in service (heating about 20 public buildings).

Arzberg remains a heavy burden for the commune. It is planned that other buildings be hooked up, but its development will remain limited if only from its "monomain" design.

7. Market Gardening in Drax (United Kingdom)

7.1. Introduction

The market gardening greenhouse in Drax (Yorkshire) can be considered the pride of the CEGB (Central Electricity Generating Board, electricity producer) from the viewpoint of use of power plant cooling waters.

The CEGB associated with a distributer of food products in 1978 in view of creating a dealership company, "Exel Produce", and of building 8 ha of greenhouses next to the Drax power plant, so as to produce open-field tomatoes, thereby associating a high-performance heating technique with an advanced culture technique.

Results have been satisfactory. But the miners strike in 1984/85 in the United Kingdom lead to the shut-down of the Drax power plant for 13 months, causing Exel Produce to equip itself with a heater to heat the greenhouses.

Exel Produce has developed, parallel to its production, a vegitable import and distribution activity (which in 1987 will represent more than 50% of its turnover). Current extension projects only concern developing this commercial and distribution activity.

7.2 Background

The CEGB, in collaboration with the Agriculture, Fisheries and Food Ministry, conducted between 1975 and 1978 a series of research projects in market gardening cultures under greenhouses heated by waste heat from the Eggborough power plant (in the same region as Drax).

Following this research, the CEGB in 1978 combined with Express Dairy (filial of the Grand Metropolitan Group specialized in producing and distributing milk and cheese products) to create in Drax (carbon plant in Yorkshire) a pilot installation of 0.2 hectares. Express Dairy was interested in these energy problems: for a few years it had been doing horticultural trials in a small greenhouse heated by the thermal wastes of one of its cheese factories. This 2-year pilot phase demonstrated the profitability of a technique having provided the best results in Eggborough: open-field "Sonatine" tomatoes culture by the Nutrient Film Technique (NFT), and heating by airothermes.

Results were good from the very first year - so good that a filial was created in 1979 (Exel Produce: capital held at 51% by Express Dairy and 49% by the CEGB) to exploit 8 ha of greenhouse in Drax.

Land conversion and waste heat servicing began in 1980, followed by the installation of the greenhouse and its culture and heating system. Work ended in October 1981 and exploitation soon began.

Economic results have been good, since starting from 1983 Exel Produce has made a profit. But in 1984 the miners strike began in the United Kingdom. The Drax plant was shut down from May 1984 to April 1985. This interruption caused important losses (£ 500 000, about 50% of turnover), in that it occured just at the beginning of the most favorable culture period in terms of sunlight (from May to November). Moreover, an energy alternative had to be quickly found. Exel Produce thus equiped itself with a fuel oil boiler 18 MW in power.

At the same time, Exel Produce has sought to diversify its activities since this date: it had already taken on its own to pack and distribute its own products. It therefore began to import (from Holland, France and Spain) tomatoes and other vegetables (cabbage, celery) to condition and distribute them.

In October 1985, reorganization of Grand Metropolitan Group (GMG) lead Express Dairy to resell its 51% of capital in Exel Produce to the Glass Glover Group, distributor of market gardening products, and also a filial of GMG.

Today, the results of Exel Produce are very good (excellent profits). Buildings of 2 500 m2 in surface area to install a modern conditioning production line are being built. On the other hand, there are no more greenhouse extension or culture diversification projects, at least in the near future.

7.3. Technical description

Heating system

The reasons for choosing Drax as the development site (beside the "showcase" aspect for the CEGB, in a highly mining region and being greatly concentrated in carbon power plants) were the following:

- Hooking up to two 660 MW sections, functioning in base, in closed circuit, with a cooling waters temperature always between 26°C and 40°C;
- Vast flatlands areas available (potentially 32 ha) nearby the plant (the current greenhouses are about 500 m from the plant).

The greenhouses are connected to two of the three sections of the plant. An underground main 1.2 m in diameter leads the waters to the greenhouse, passing under a railroad line (drilling was therefore necessary over 130 m). A parallel main brings the waters back towards the cooling towers. Waste heat supply is therefore not carried out on the draining circuit (as is the case in France), but directly in deviation from the cooling circuit.

Underground mains below the greenhouse (90 cm in diameter) lead the water to the airothermes, which number 80 per hectare. At full flow, pumped water throughput is 90 000 m3 per day.

Culture technique

Out-of-soil culture allows one to economize on plantation and harvesting costs. This technique is relatively elaborate:

- Seeds are placed in a germination tray, with water renewed slowly and regularly, until 1 to 2 mm of roots appear.
- The plants are then planted individually in polyfoam-type 4 cm side blocks. For 10 days these plants are placed under sodium lamps and fed by a nutritive solution.
- The polyfoam blocks are then each planted into 7.5 cm blocks of Rockwool-molten spun rock and kept that way for 4 weeks, during which time roots develop and grow out of the Rockwool rock.
- Then, the rocks are fixed in polyethylene trays placed on galvanized supports. The tomatoe plants stems develop along vertical wires until a height of about 2 m. Each stem then develops 10 "bunches" of tomatoes. The roots bathe in a nutritional solution (Calcium, Potassium, Nitrogen, Phosphates, ...) which circulates regularly. The dose of mineral salts, the temperature, the pH and the conductivity of this solution are piloted by computer.

This improved mastering of the root environment leads to an improvement in the quality of the tomatoes and the yield, which attains 34 kg/m2/year. For the same yield for the m2, the costs of nutrition by a traditional technique would be multiplied by 3 (at present, these costs are £ 0.25/m2).

7.4. Analysis of the technical evolution

The only technical evolution in Drax concerns the installing of emergency heating as a result of the 1984 miners strike.

This domestic fuel oil boiler 18 MW in power has been attached to the installations without modifying the heat distribution system. The cost of fuel oil consumption at the time of this strike, during the production periods, amounted to £ 250 000. This corresponds to the consumption of 1.5 million litres (by comparison, the average consumption in the United Kingdom for an identical greenhouse heated on a permanent basis would be 4.5 million liters per year).

No emergency heating had been planned at the start of the project in view of the Drax plant's characteristics (connection to 2 sections functioning in base). In effect, short interruptions of the heat supply (accidental) would be of no harm for cultivating the tomatoes (such an incident has occured only once since the start-up, without any damage).

The installation of an emergency heating substantially modifies the costs of investment.

7.5 Economic aspects

Investments

In 1980, the total investment (greenhouse and waste heat mains) cost 3 million pounds (in addition to the £ 250 000 the 0.2 ha pilot installation cost).

A classic greenhouse would have cost 2.25 million pounds. Overinvestment was therefore estimated at about £ 750 000.

Installing the emergency heating in 1984 cost £ 150 000. If this sum is revalued at 1980 prices, on the basis of a pound index at 10% per year, the emergency heating therefore increases the initial overinvestment by more than 10%.

Advantages related to energy recuperation

A conventionally heated greenhouse consumes about 55 l/m2/year. The consumption in electricity for the Drax greenhouses (mainly for the pumps and airothermes) represented in 1980 half of the expenses in energy of a conventional greenhouse, that is a savings at that time on the order of
£ 200 000/year. On this basis, the return time estimated at that period was therefore about 4 years.

Commercial results

Starting from 1983, Exel Produce was making profits. The 1884/85 miners strike cost (total production shut-down) £ 500 000, that is approximately half the turnover. From 1985, the situation was restored, thanks in particular to the diversification of activities: importation of tomatoes (but also some cabbage, celery) from Holland, Spain, France and the United States in order to condition and distribute them.

The following table summarizes each of the two activities in tons and turnover for what was realized in 1986, and what is planned for 1987:

Type of activity	1986 (in tons)	Turnover realized in 1986 (in M£)	Turnover planned in 1987 (in M£)	% increase 1986/87
Tomatoes production	2 500 t	1.8 M£	1.8 M£	0%
Tomatoes imports (+ other vegetables)	2 300 t	1.2 M£	2.0 M£	+ 67%
Total	4 800 t	3.0 M£	3.8 M£	+ 27%

Exel Produce at present produces tomatoes only in summer (between March and November). In winter, sunshine is insufficient for ripening and artificial light is not profitable. The import-distribution of tomatoes is therefore more advantageous. Exel Produce directly distributes its tomatoes to supermarkets, after having conditioned them.

The total United Kingdom market totals 320 000 tons, of which 40% is imported. Exel Produce produces therefore 1.3% of the United Kingdom production. Its import activity allows it to hold an equal part of sales for the domestic market (1.5%), whereas its strictly production activity corresponds to 0.8% of the domestic market.

What is more, this import activity allows it to establish a client loyalty: Exel Produce is capable of supplying tomatoes regularly throughout the year.

Exel Produce permanently employs 50 people and approximately 100 seasonal workers in summer.

7.6 Future outlook

The strategy of Exel Produce today is to increase its vegetable import and distribution capacities. For this purpose, a 2500 m2 building is currently being converted so as to install a modern conditioning line which is entirely automatic.

Exel Produce therefore does not have any immediate greenhouse extension (despite a potential site of 32 ha) or production diversification (aubergine, cucumber) projects as it had envisaged several years ago.

8. Aquaculture in Hunterson (United Kingdom)

8.1. Introduction

Golden Sea Produce Ltd. is a company specialized in breeding sea fish, both at the R and D and commercial level. In 1984 it rebought the eel breeding installations in Hunterston (nuclear power plant near Glasgow) to develop an intensive turbot breeding.

Today, it porduces 100 tons of turbot a year there. Golden Sea Produce Ltd. possesses important technological know-how concerning this production (and in particular young fish breeding). Turbot is one of the best priced fish on the market.

This installation - for which it has not been possible to obtain detailed financial information (for reasons of confidentiality and commercial strategy) - is currently the only one in the Community which produces sea fish on a commercial scale.

8.2 Background

A textile industry company tried in 1975 and 1980 to produce eels at the Hunterston site in seawater. It constructed there the waste heat mains and the basins. Eel breeding has been abandoned, posing too many difficulties, in particular on the biological level.

In 1984, Golden Sea Produce Ltd. repurchased these installations. This filial company of the Norwegian group Norsk Hydro is specialized in breeding salmon and marine species. In Scotland it produces 1100 tons of salmon (in classic aquaculture). At the same time, since 1973 (date of its creation) it has been conducting research on breeding bass, bream, sole and turbot.

The hatching and fish farming of turbot have been the object of an advanced technological renovation. Results obtained previously spurred the G.S.P. to seek a site where it could breed turbot on a commercial scale, taking account of the fact that waste water (optimum between 14°C and 18°C) provided the best yield: turbot breed two times more quickly therein. The Hunterston site, in the region in which G.S.P. was implanted, satisfied this need.

After the repurchase of the installations, progressively, in 1985, G.S.P. built a hatchery to produce its fish, then a second series of basins (open-air) below the old covered installation. Today, it has attained 4000 m2 in actual basins surface area, for a production 100 tons of turbot a year. The success of this operation has lead G.S.P. to implant another turbot breeding area in Spain (in non-heated water).

It should also be noted that in 1986 a horticulturist (Prestige Plants Ltd.) set up next to G.S.P.. It bought another 2000 m2 building containing basins where an enterprise was experimenting in breeding sole, and which also had been abandoned. This horticulturist uses cultivating tables posed directly on the old breeding basins and heated in the following manner: he cultivates young plants for potted plants (intermediary cultivation activity between the germination laboratory and the traditional horticulturist). This requires a temperature of 23°C, obtained by raising the waste heat temperature by a 27 kW heating pump.

8.3 Technical aspects

Heating technique

The Hunterston power plant includes two nuclear sections: one in open circuit (cooling waters between 14°C and 26°C) and one in closed circuit, now being built. Only the open circuit section is currently connected to the installations.

The water temperature is ideal for breeding turbot (water between 14°C and 18°C).

A series of 22 to 44 kW pumps allows:
- the pumping of waste water to the basins (a distance of about 500 m from the plant);
- the pumping of cold water (coming from the sea) to regulated the temperature.

Water flow in the basins is about 1000 m2/hour.

The draining circuit of the plant's second section (closed circuit) should shortly be connected to the waste water basin of the first section. Modifying the temperature of the waste (20°C at minimum) is going to create difficulties for G.S.P. (increasing cold water pumping), whereas it is an advantage for the horticulturist (diminuation of the working costs of the heating pump).

An imminent meeting between the South of Scotland Electricity Board (owner of the plant), the aquaculturist and the horticulturist may allow this problem to be resolved.

Turbot breeding

The chlorination of the plant's waters is continuous and fluctuating. Turbot does not tolerate chlorine well beyond 1 ppm. The problem is resolved by a stronger water airating when this Cl level is surpassed. Airating is simply done by injecting air into the bottom of the basin with a tube.

Turbot breeding demands attentive care, and most often empiricism: for example, it is necessary to cover the basins so as to avoid fish stress and to reduce feeding in the summer so as to compensate the lack of oxygen in the water.

It is important that the turbot be fed enough. On the average, 3.5 kg of food per kg of fish bred is necessary. Intensive breeding in waste water allows one to obtain a commercial size in about 2 to 3 years, as opposed to at least 5 years in non-heated water.

Hatching is the activity wherein G.S.P. has most developed its know-how, but this information remains confidential.

8.4 Economic aspects

Developer's general activities

The activities of Golden Sea Produce Ltd., which employs 70 people, can be situated at several levels:

- important traditional production: 1100 t of salmon per year;
- new commercial production that are the fruit of its research: turbot breeding in Hunterston (6 people on the site), followed by implantation in Spain;
- oysters and clams hateries: one site in Scotland. Production sold to European ostrei-culturists;
- research and development work on marine species breeding: bass, bream and sole are the object of research programs that, in the long run, should lead to intensive commercial production, as seen with turbot.

Investments

Golden Sea Produce Ltd. completely financed the operation. The purchase of the former installations (water mains and basins) cost £ 300 000. No aid or subsidy was needed (the situation is the same for the horticulturist:
he financed without help the £ 100 000 necessary for his installation).

The extension of the installation (basins, hatcheries) was accomplished little by little. The corresponding figures are unavailable.

Advantages related to recuperating energy

Golden Sea Produce Ltd. has declared that in non-heated waters such a turbot breeding activity would not be profitable. Only the thermal waste permits economic profitability in light of the region's climate. This restriction does not apply to Spain, where G.S.P. is going to implant another turbot breeding, in the form of classic aquaculture.

8.5. Future outlook

Turbot, "thin" skinned fish, benefit from an excellent sales price:

- £ 5/kg for a 1 kg fish;
- £ 6/kg for a 3 kg fish.

In comparison, salmon sells for about £ 4.5/kg. Bass would sell at a higher price (about £ 8/kg), but intensive production appears to be not yet ready (illnesses, slow growth).

Golden Sea Produce has applied a continuous but prudent expansion strategy, in function of results:

Year of exploitation	Production (in tons)	Increase compared to preceding year
1985	50 t	-
1986	70 t	+ 40%
1987	120 t	+ 70%

In March 1987, the rhythm of production was 100 t/year, with an annual European turbot market on the order of 10 000 tons per year. Sales took place at fish distributors, mainly in Dunkerque (France).

9. The CARPA project (Italy)

9.1. Introduction

Since 1980, the Italian national electricity producer ENEL has been conducting research projects on the recovery of thermal waste in four different areas:

- Greenhouse market gardening and horticulture
- Waste heat irrigation
- Freshwater aquaculture
- Seawater aquaculture.

All research work has been grouped under the term "CARPA project" (CARPA = Calore Residuo per la Produzione di Alimento), but in facts corresponds to four implantations that are entirely distinct. Moreover, the stage of advancement for each activity is highly varied.

The greenhouse market gardening and horticulture research began in 1980 in Tavazzano, near Milan. After a research program which took 5 years concerning lettuce, asparagus, strawberries, gerberas and melons , the site is now awaiting new credit for a 2nd research phase, which would more particularly be concerned with out-of-soil and young-plant tree crops.

The results obtained in Tavazzano have been used to actualize techniques used in Bastardo, a commercial installation functioning since November 1986 (see case study devoted to Bastardo).

Research work on irrigation by waste heat has been taking place in Trino Vercellese (near Milan) since 1985 for a 3-year period. This is an installation cultivating rice in summer and lolium italicum in winter, an aquatic plant used to feed livestock.

At the La Casella site, near Piacenza on the banks of the Pô, exists a very large freshwater aquaculture installation put in service in 1987. The installation is awaiting its working budget to start large-scale research. From 1975, experiments were conducted on floating cages in the plant's waste heat canal. Work was centered on catfish and carp.

Aquaculture work in freshwater has been going on in Torrevaldaliga, in Civitavecchia near Rome, since 1980, concerning bass mainly.

Each operation will be individually treated in this chapter.

9.2 Greenhouse crops in Tavazzano (near Milan)

Background

Research was conjointly done by ENEL and the ISPORT (Agriculture Ministry) between 1980 and 1986. At present, the experimental installations are in a semi-abandoned state.

The site directors have proposed a second research cycle which would concentrate on out-of-soil (as in Drax, Great Britain) and young tree plants cultivation. This second phase would imply a complete reconstruction of the installations. A decision must soon be made by the ENEL direction in favor - or not - of the experimental research at the Tavazzano site.

Technical description

The installations are situated in the immediate proximity of the Tavazzano plant, running by fuel oil (or natural gas) and including two 220 MW sections and two 160 MW sections, all in open circuit (13° to 30°C). The greenhouses are connected to one of the 160 MW sections. The waste heat flow is 150 liters per second.

The total surface area of the installations attains 15 000 m2, on which are situated:
- 4 glasshouses
- 7 plastic tunnels
- 2 parcels of crop in open field.

The experimentation method relies mainly on comparing crop results between non-heated and heated greenhouses, and between different heating systems. What is more, certain tunnels or greenhouses are equiped with a heating pump to increase the temperature of the waste heat so as to simulate the connecting to a power plant functioning in closed circuit.

The surface areas and heating systems are the following:

4 greenhouses 250 m2 each, of which:
- 2 run-off and fan-tube greenhouses
- 1 electric heating greenhouse (control)
- 1 heating pump greenhouse: soil heating by underground tubes, and air by airothermes.

7 tunnels 500 m2 each, with simple or double plastic covering, of which:
- 3 non-heated tunnels (control)
- 1 tunnel heated by the soil (underground tubes)
- 1 tunnel with soil heating (tubes) and air heating (airothermes)
- 1 tunnel equiped with a heating pump, with soil heating (tubes) and air heating (airothermes).

2 parcels of open-field crop, 500 m2 each, heated by underground tubes.

Remarks on the technical level

The run-off greenhouses were abandoned after 4 years, for they presented numerous inconveniences:
- too high humidity
- reduction in luminosity because of the development of algae on the glass.

Heating the air by fan-tubes turned out to be not very efficient and was also abandoned.

Insofar as the tunnels, the double plastic covering separated by an air film (with a small fan) revealed itself to be much better than simple covering. This solution was adopted for the commercial installations in Bastardo.

The other technical options have proven satisfactory: soil heating by underground tubes, heating the air by airothermes, heat pumps. The optimal technical solution depends on the type of crop and the levels of temperature required.

Results of experimental crops

Work centered mainly on lettuce, asparagus and strawberries in tunnel; melons and gerbera (cut flowers) in greenhouse; corn in open field.

The results were:
- mediocre or insignificant for the lettuce, asparagus, melons and corn;
- technically good for the strawberries, particularly in winter thanks to a variety necessitating little light;
- technically and economically good for the gerberas, but which necessitated a high temperature and therefore a plant in closed circuit.

These experiments resulted in the commercial installation of Bastardo: potted plants, closed circuit.

During the research work, the installation imployed 2 researchers, 2 technicians and 2 to 5 workers.

Remarks on the future of the installation

The ENEL direction's agreement to continue research work is related to an important project concerning the Tavazzano plant. Replacing the old fuel oil sections by two 640 MW carbon sections is planned. One of the aspects of this project consists of supplying a portion of the urban heating network of Milan (situated 30 km away) from Tavazzano.

If the second phase of research is started, the present installations (except 6 tunnels) will be replaced by a single multi-tunnel greenhouse, in double plastic covering, 2000 m2 in surface. Heating would be assured both by underground tubes or shelf heating, and by airothermes. Half the greenhouse would be supplied in base temperature (open circuit), the other half in mean temperature (simulation of a closed circuit, with a heating pump).

9.3 Waste heat irrigation in Trino Vercellese

Background

The installation has been in operation since 1985. The current phase of research will terminate in December 1988.

Technical description

Two parcels are at present cultivated on a total surface of 100 000 m2, with:
- rice on 15 000 m2,
- lolium italcum (livestock feed) on 20 000 m2.

The waste heat used for irrigation comes directly from the power plant. This includes a single 250 MW nuclear section, in open circuit (13°-30°C). Waste heat flow is 132 l/second.

The study method also consists of comparing the culture results obtained in warm irrigation to those obtained in cold.

Results obtained

The results obtained on the lolium italicum crop are satisfactory on the technical level (10% production increase). But if one takes into account this product's saturated market, this type of crop does not appear to be profitable and trials will not be followed up.

With rice, yield reached 70 quintals per hectare, which is a world record. Rice cultivation appears very satisfactory, but the varieties cultivated up till now have only a limited market, in Italy only.

It is planned that rice cultivation on all parcels of the installation be continued, testing different varieties.

Remarks on the technical aspect

Irrigation by waste heat presents important difficulties insofar as flow control:
- if the water flow is too weak, the temperature drops rapidly in cold weather, leading to a lowering in the growth of crops and a risk of freeze;
- if the water flow is too great, it provokes an accelerated soil erosion, and the land degenerates.

A balance must be found between these two obstacles by optimizing water flow and selecting certain types of crops.

9.4 Freshwater aquaculture in La Casella (near Piacenza)

Background

The freshwater aquaculture installation which has just been started up in 1987 is probably one of the most important in Europe. Since 1975 research has taken place on this site, using 9 floating cages posed in the plant's waste canal. Work was mainly carried out on carp and catfish, and produced interesting results.

Technical description

The La Casella plant, on the banks of the Pô, includes four 320 MW sections, in fuel oil, in open circuit. The annual functioning time is 5000 h/year for each section, with 2 or 3 sections always working (availability: 98%). The cooling circuit flow is 36 000 l/sec (that is, 9000 l/sec per section). The water used by the aquaculture installation is pumped in the small waste canal by electric pumps. Each pump has a flow of about 250 l/sec (90 electric kW), for a nominal flow for the installation of 400 l/sec (only one or two pumps function in normal time). The temperature is between 12 and 30°C ($\Delta T = +8$°C).

The installations themselves include:
13 000 m2 of basins,
5 000 m2 of ponds and basins in earth,
a hatchery.

The 16 breeding basins, with walls in concrete and bottom in silt, are divided into ten 600 m2 basins and six 1200 m2 basins. The depth is on the order of 1 m. Moreover, 10 basins in concrete, covered, are planned for the production of unicellulaire algae, meant for feeding fish.

A large 17 000 m3 pond is mainly used to store waste heat to allow for a functioning in closed circuit on weekends or when the plant would be stopped, or in case of the accidental pollution of the Pô. This plan of action gives the whole installation an autonomy of a few days. What is more, other basins in earth will allow for breeding and winter survival experiments.

The hatchery is situated in a 2000 m2 building and includes 60 1 m x 1 m troughs and 48 2 m x 2 m troughs. Water supply in independent from the rest of the installation and is accomplished by wells. A 100 m3/hour capacity biofilter and a sand filter allow working in closed circuit. Three electric 30 kW heat pumps assure water heating at two different temperature levels (20 and 28°C), thereby allowing the temperature of each of the 108 troughs to be adjusted separately. Biology laboratories complete the installation.

The entire installation represented an investment of 7 billion liras. If these installations had been intended for intensive production, it could be on the order of 400 tons of carp a year.

Tests in progress, tests planned

Tests effectuated since 1975 in floating cages mainly concerned catfish. Production results were satisfactory, but because of the strong concentration and important current, the fish tended to wound each other with their pointed flippers, causing infections and illnesses.

Two series of trials have been conducted up to now to test the installations:

- enlarging carp since 1985: a 700 kg lot of carp (unit weight: 28 g) bred since 1985 has today reached a total weight of 20 tons (unit weight: 3 kg);
- in hatchery in 1987: a 1 kg lot of civellas in 4 months reached 5 kg, with a unit weight of between 0.2 and 20 g, and an average weight of 2 g. The study concerned adapting civellas to artificial feed.

In the future, work will mainly center on carp, catfish, Chinese carp and eel. Research areas concern a priori:

- optimizing the use of waste heat,
- basins management technique,
- improving the quality of the fish (selection, genetic improvements),
- shifting reproduction periods (alevins in February/March, commercial size in November/December), which implies artificial insemination in the winter,
- larva feeding, by dry and self-produced natural food.

The annual functioning budget strictly depends on the feed costs, and therefore the type of breeding that will be realized:

- basic: 600 million liras,
- feed: 0 to 1 billion liras,
- research: 250 million liras,
- energy costs: 150 million liras;

that is, between 1 and 2 billion liras per year.

The energy costs basically represent consumption in electricity. The electric power installed (pumps, heat pumps, etc.) is on the order of 1 MW. In normal use, the electric power absorbed is between 200 and 400 kW.

Research work is the object of contracts with different universities, in particular those of Milan, Parme, Ferrare, Padoue and the CNR (Conseil National de la Recherche).

9.5. Seawater aquaculture in the Southern Torrevaldaliga

Background

The Torrevaldaliga installations, near Rome, have existed since 1980. These are research installations and a pilot installation, assuring a limited production.

Technical description

The installations are situated on a 2000 to 3000 m2 plot, between the plant and the sea. The plant includes 4 fuel oil sections (2 x 320 MW, 220 MW, 160 MW), in open circuit. Waste heat is taken in a waste canal of the 4 sections at a temperature between 15 and 35°C. The flow drawn is 360 l/sec.

There exist a dozen concrete basins 100 to 150 m2 each, that is 1200 m2 in total (1 m in depth). A 20 trough hatchery is adjacent to the installation. The hatchery water is heated by 3 heat pumps 11 kWe each (C.O.P. = 4.5, that is 50 kWt).

The installation employs in total about 20 people, of whom:

- 2 ENEL technicians
- 5 employees for maintenance and night and weekend surveillance
- 12 part-time researchers.

Trials in progress

Hatchery production amounts to 500 000 alevins per year, of which:

- 400 000 bass,
- 50 000 sargus,
- 50 000 sea bream.

Breeding basins production reaches about 2 tons a year in shrimp and bass. Shrimp production will not be continued because of poor yield in intensive breeding, despite 2 production cycles per year. On the other hand, bass has given good results.

The bass production cycle is the following:

- from December to the end of March: natural production of eggs (50 kg, of which 40 kg are useable); most of the eggs are sold;
- putting into hatchery as soon as the eggs are collected;
- after 15 days of life: size selection and transfer to outside basins with simultaneous production of plankton (algae, then rotiferes, then arthemias). The plankton is self-produced in the outside basins, after initiation of the crops in laboratory;
- after 30 days of life: artificial feeding;
- after 60 to 90 days of life: sales of almost all the plot (of which repopulation in sea by ENEL: 120 000 heads).

A small part of the alevins are then put in basin for enlargement:

- 25% of the lot are sold after 13 months of life (July of the following year);
- 50% of the lot are sold after 18 months of life (Christmas);
- the remaining 25% are sold after 25 months (July).

All together, the production sold after enlarging reaches about 2 t/year.

Trials on sea bream should begin in 1988. The surface area of the basins will be increased by 800 m2.

Research between 1980 and 1986 mainly concerned feeding, alevinage techniques, vaccinations, the role of vitamin C and the impact of the different chemical componants contained in the water. For the second work phase (1988-1992), research will by priority concern alevinage techniques, feeding, stress and the economic approach for a reheated seawater aquaculture installation.

What is more, there exists a project at the plant in Northern Torrevaldaliga (2 km away): this concerns enlarging in floating cages placed in an artificial basin of 2 ha for which water circulation flow is known (currents, tides). Breeding in cages placed in the sea poses mechanical problems (water currents that are too strong). Breeding in pond poses problems of pollution due to fish density (not enough current).

10. Horticulture in Bastardo (Italy)

10.1 Introduction

The Bastardo operation is the first commercial project realized in Italy, at the initiative of the ENEL. It is the follow-up of the R and D work of the CARPA project, and in particular those effectuated in Tavazzano, near Milan. On a plot of about 2 ha in all, made available by the ENEL, potted plant production began in November 1986 under double-covering tunnels. These tunnels were equiped with soil heating and airotherme heating, which also allowed air cooling during the 3 hottest months of the year.

At present, 16 tunnels are in place. The construction of four more greenhouses is planned, to be put in service in late 1987/early 1988. In all, the surface area will total 7600 m2.

The developer is a coöperative, "Agritermica", created specially to exploit the site. 7 people are at present working there, and 10 are planned for 1988 after the construction of 4 greenhouses.

The first operation has benefited from very important financing by the region.

10.2 Background

Between 1980 and 1986 ENEL undertook R and D work in the area of market gardening and horticulture in Tavazzano. This work was part of the CARPA project and experimented on techniques put in operation at the Bastardo site.

In 1981/82, the commune where the Bastardo plant is situated sollicited the Umbria regional government to study developing the use of the plant's thermal waste.

In 1984, the region requested the ENEL to carry out a feasability study for the implantation of greenhouses heated by the plant's waste.

In 1985, in view of the results of the feasability study, the ENEL was empowered by the regional government to design the horticultural area project. At the same time, the region soight financing as well as a competent developer for the installation.

After the region united all the necessary funds (100%), the construction of the installations was given over to the ESAU (regional agricultural development organism), which supervised all work.

Insofar as the search for a developer, the region established contacts with a horticultural coöperative ("Floro Vivaistica Umbria"). A few members of this coöperative decided to create another coöperative exclusively devoted to developing the Bastardo site ("Agritermica"). The old coöperative, with a turnover of about 4 billion liras, continued its activity, both in production and import/export. A non-competitor agreement was signed between the two coöperatives so that they would not produce the same type of plants.

This procedure, along with the region's intervention, is traditional in Italy and has already been practiced in numerous sites for which the ENEL has done feasability studies.

Investment costs covered by the coöperative are greatly reduced in that they are limited to 12%

of the total investment and, what is more, payment is effectuated over 10 years.

The total cost of the installation (four 2500 m2 greenhouses in all, sixteen 5100 m2 tunnels in all, and 2000 m2 of open-field crop) is estimated at 1.6 billion liras. The planned turnover for the whole installation totals 600 million liras per year.

10.3. Technical description

The Bastardo electric power plant includes 2 fuel oil sections 75 MW each, functioning about 7000 hours per year. The cooling circuit, commun for the 2 sections, is closed and includes 5 cycles of fan-forced circulation. It is planned that the plant be converted to carbon in 1989 or 1990.

The horticultural installation is connected to the common cooling circuit, and therefore to the two sections. In view of the water pressure, pumping is unnecesary. Water temperature is between 20 and 35°C, and is on the average 23°0C.

Crop areas are composed of:
- 16 plastic double envelope tunnels 316 m2 each, built in late 1986;
- 4 plastic double covering greenhouses 624 m2 each, which will be built in late 1987. Two of them will be equiped with heat pumps. The other two will be heated as the tunnels.
- an open-air crop area of 200 m2, already used (without heating), but whose heat piping will be installed in late 1987.

The following table presents the characteristics and the heating system of the tunnels and greenhouses:

	Tunnels	Greenhouses A, B	Greenhouses C, D
Number	16	2	2
Surface area	316 m2	624 m2	624 m2
Cultivable area	190 m2	530 m2	530 m2
Volume	790 m3	2 550 m3	2 550 m3
Global thermal coefficient	3.1 W/m3°C	1.9 W/m3°C (1)	1.9 W/m3°C (1)
Soil heating	Yes	Non	Yes
Air heating	Airotherme	PAC + airotherme	Airotherme

(1) with thermal screen

The plastic double covering

The greenhouses and tunnels are covered by a plastic double film. The two walls are separated by an air layer insufflated by a small fan. This solution, tested in Tavazzano, proved of great interest technically and economically. The covering lifetime is on the order of 5 years.

The airothermes

The airothermes, developed by ENEL and of entirely new design, are also meant to assure the cooling of the greenhouses and tunnels when the outdoor temperature is too high.

There is one unit per tunnel, placed at one of the extremities. These are the same fans that assure the circulation of hot air and cooled air. Hot air is produced in the classic way by a battery supplied in waste heat from the central. Cooled air is produced by water evaporation, by means of a forced circulation of air between plastic strips onto which cold water flows. This system also allows the air humidity to be increased.
The circulation of air in the tunnels is assured by three large plastic shafts suspended at the top of the tunnel and which transport air to the other end of the tunnel.

The main characteristics of the airothermes are presented in the following table:

Outside dimensions	about 2 m x 5 m x 1.5 m
Thermal power	53 kW
Electric power (fans)	3.5 kW
Water temperature (in/out) 23°C/15°C	
Water flow	15 m3/h
Air flow	40 000 m3/h
Area developed of the heating battery	200 m2
Area developed of the cooling/ evaporation panels	8 m2

Heat pumps

The water/water heat pumps will be installed in 2 of the 4 greenhouses in order to be able to cultivate plants that are more sensitive to cold. The characteristics are the following (each greenhouse will include 2 units functioning at the same time):

Electric power	2 x 18.6 kW
Thermal power	2 x 80 kW
Temperature of water entering the evaporator	23°C
Temperature of water exiting the condensor	50°C
C.O.P.	4.3
Capacity of storage tank	2.5 m3

Back-up/emergency heating

Hot air fuel oil generators, of very simple design, capable of being moved from one tunnel to another, are used for back-up and emergency heating in case the tunnels' temperature falls below 15°C (20°C for the 2 greenhouses equiped with heat pumps). At present, there are a dozen of these generators on the spot. A single generator assures the maintenance in temperature of a tunnel.

The division of time in use between the different functioning modes, over 1 year, is as follows:

- 40%: heating by waste heat
- 5 to 7%: fuel oil back-up heating
- 30%: summer cooling
- 23 to 25%: no heating or cooling.

A metering system will be installed in late 1987. To be measured are the climatic conditions (temperature, humidity, soil temperature), as well as the thermal energy sent by the plant and the consumption in electricity. The cost of these measurement systems totals 100 million liras, entirely covered by the ENEL.

10.4 Analysis of the technical evolution

Production under tunnels began in November 1986 with fuel oil heating. Waste heat heating has been operational since February 1987. Since then, certain technical problems have arisen:

- The plastic shafts assuring the transport of hot air from the airothermes to the other end of the tunnels tore on several occasions because of friction against the metal frames due to the shafts' vibrations. After different trials, it is planned that all the flexible shafts will be replaced by rigid plastic ones, resulting in an additional expense of 1 million liras per tunnel.

- The current efficiency of the air cooling and humidification system is mediocre. It is envisaged that the plastic strips will be replaced by special paper bands which will allow a better distribution of the water on surfaces exposed to warm air.

10.5 Economic aspects

Overcost due to heating by thermal waste recovery is estimated at 250 million liras. The annual savings in energy is estimated at 110 million liras. The result is a return time of 2.3 years for this overinvestment. Taking account of an installation lifetime estimated at 15 years, the operation's internal profitability rate (I.P.R.) totals 41%.

	Tunnels	Greenhouses C, D	Greenhouses A, B (PAC)	Full-field	Total
THERMAL NEEDS: (MWh)	1 303	349	420	295	2 367
HEATING BY THERMAL WASTE:					
Electricity (MWh)	153	44	132	0	329
Fuel oil (MWh)	0	0	2	0	2
TOTAL IN ENERGY BASIC (TEP/YEAR)	38	11	32	0	81
TRADITIONAL HEATING (FUEL OIL):					
Electricity (MWh)	34	20	20	3	77
Fuel oil (MWh)	1 736	465	557	393	3 151
TOTAL IN ENERGY BASIC (TEP/YEAR)	158	45	53	35	291
ANNUAL SAVINGS: 210 TEP/YEAR					

Source: ENEL

It should be noted that this table shows a savings of 35 tep/year for heating by thermal waste of the open surface area (full field). In fact, it is unlikely fuel oil was consumed for this type of use. What is more, the consumption of fuel oil for the tunnels in service is assumed to be nul in this calculation. Actually, according to the developer, fuel oil heating is used during 5 to 7% of the year.

10.6 Production outlook

The first production cycle which began in November 1986 concerned about fifteen varieties of potted plants, mainly azaleas, cyclamen and pelargonium. For the first 12 months, production attained 73 000 pots. The full-field surface will also be used in half-season and summer for the cultivation of potted plants. The planned turnover when the whole installation will be working is 600 million liras per year.

The Italian potted plant market totals 2000 billion liras a year, that is about 35 000 liras/inhabitant/year. At present, 70% of the market is occupied by imports from Holland, Belgium and Denmark.

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