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Solar Passive Heating and Cooling

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3. PART 1 – Market Assessment of the Potential Application of Passive Downdraught Evaporative Cooling in Southern Europe

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3.1. Introduction

Part 1 of Cluster 9 builds on work from the JOULE II R&D project, which has demonstrated the technical and economic viability of the Passive Downdraught Evaporative Cooling (PDEC) technique applied to new office and commercial buildings.

The purpose of Part 1 was to undertake a market assessment of the potential for the application of Passive Downdraught Evaporative Cooling (PDEC) to new and existing non-domestic buildings in Southern Europe. PDEC is a technique which potentially could become a substitute (in whole or part) for conventional air-conditioning.

The objectives of the Market Evaluation Assessment were as follows:

1. To establish a database on existing and new non-domestic buildings in Italy, Spain, Portugal and Greece.
2. To estimate the proportion of existing buildings and new construction to which PDEC is applicable and the possible cost and energy savings in such buildings by implementing suitable measures over a period of time.
3. To determine those climatic regions in Southern Europe where PDEC is suitable and to overlay the location and size (population) of settlements on maps of PDEC applicability.

4. To predict the likely market penetration over the next 30 years within Italy, Spain, Portugal and Greece.
5. To indicate where promotional effort needs to be placed, to publish the study findings and disseminate results to key groups within the EU.

3.2. Vertical Tasks and Deliverables

This project follows an approach developed by D. M. Lush & J. L. Meikle[1], which is based on an examination of building categories and stock characteristics, and the estimation of the building categories where potential for energy savings exist. Potential is gauged against a number of parameters, which affect applicability (e.g. for PDEC, the existence of a transitional space, atrium or courtyard). These parameters are then ranked according to an assessment of their impact, with regard to energy savings and cost-effectiveness.

Eight discrete tasks have been completed, each of which has contributed to the assessment of technical applicability, market barriers, cost benefits and market penetration.

Task	Description	Deliverable
Vertical task 1.1	Pilot Exercise / Stock and Investment Assessment	Report VT1.1
Vertical task 1.2	Typological Evaluation	Report VT1.2
Vertical task 1.3	Mapping	Report VT1.3
Vertical task 1.4	Market Barriers for PDEC	Report VT1.4
Vertical task 1.5	Cost Benefit Evaluation	Report VT1.5
Vertical task 1.6	Market Penetration	Report VT1.6
Vertical task 1.7	Review & Dissemination	Presentations at Symposium and papers
Vertical task 1.8	Co-ordination	-

3.2.1. Vertical Task 1.1 - Pilot Exercise / Stock and Investment Assessment

The objective of the pilot exercise was to test the methodology on a single country (Greece), and by embarking on the process, refine the method where appropriate for its application to the other countries. Part of the pilot exercise involved checking the availability of data on building stock and investment, morphology and energy consumption and compiling statistical information on floor area and energy consumption for different building types in Greece. Most European countries produce new

[1] D. M. Lush & J. L. Meikle (1998) *Passive Solar Energy in Buildings*, published on behalf of the Watt Committee on Energy by Elsevier Applied Science Publishers pp 36-45.

building construction output data in terms of floor area (m^2). Data on the existing stock is generally less available and/or less reliable. Both physical and financial measures of the stock were used as a basis for analysis. The pilot exercise served its purpose of establishing the broad feasibility of the method, but also highlighted where the method could be improved and refined in its application to the other countries. Data was not always available in the same form, giving rise to necessary variations in approach in the different countries. The stock data for Greece is very good, but the 'uneveness' in the availability of stock data in the other countries (particularly Italy) has increased the margin of error in predicting the potential for PDEC applications.

3.2.2. Vertical Task 1.2 - Typological Evaluation (Urban Morphology)

Studies of building typology and morphology have been undertaken as part of the process of assessing the applicability of PDEC to non-domestic buildings in southern Europe. A preliminary generalised benchmark, which relates PDEC applicability to the void/floor ratio, has been derived from the study of precedents.

A method of determining the technical applicability of PDEC, based on relating the benchmark to a sample area of commercial buildings in Athens, was applied as part of a ‘pilot’ exercise. Initially, applicability was assessed in relation to two levels of intervention: minor and major (implying minimal intervention and major refurbishment respectively).

Following the pilot exercise, the method was subsequently refined to include an ‘intermediate’ level of intervention based on a building depth of 12 metres maximum. This allows the use of larger courtyards within which PDEC courtyards could be added to the side of a building.

Analysis of sample areas of predominantly commercial buildings in major cities in Spain, Italy and Portugal has revealed the proportion of the building stock which is suitable for different levels of PDEC intervention. Clearly, minor and intermediate interventions are likely to be most cost effective, and will be taken up most quickly. In Spain, 35 – 46% of all buildings are capable of having either minor or intermediate PDEC interventions. This compares with 22% in Italy, 27% in Greece, and 33% in Portugal.

If major interventions are included then the overall applicability of PDEC is very significant. The study indicates that, for all the cities studied, between 62% and 82% of all buildings are suitable for the application of PDEC. This indicates that the *technical* potential for PDEC applications is very significant. However, local micro-climate characteristics (Vertical Task 1.3), market barriers (Vertical Task 1.4), and the cost of the systems (Vertical Task 1.5), will influence the final potential market penetration (Vertical Task 1.6).

3.2.3. Vertical Task 1.3 - Mapping

Mapping of the potential for PDEC in Southern Europe as part of the PDEC JOULE project[2], was used as a starting point, and focuses on Spain, Italy, Greece and Portugal. A full description of the mapping studies is included in Report VT 1.3. The following description of the methodology and results provides a brief summary.

The aim of this task was partly to develop a methodology in order to obtain applicability maps (it is obvious that a PDEC system sized together with a conventional HVAC system in a city will not provide the same results in other locations). A general methodology, summarised below, has been developed to extend the results to other regions, related to the climatic characteristics of these locations. These results provide a preliminary evaluation about the opportunity of using the PDEC systems as an alternative or a complement to conventional air conditioning systems.

A new approach has been developed, based on the current developed mapping methodology, and using simulation tools, in order to achieve customisable charts, for specific buildings, systems and control strategies.

It is necessary to select as many locations as desired and possible. The climatic data must be obtained for these locations, on an hourly basis if possible, in order to simulate the building and system. Other locations can be extrapolated by using mean climatic data (as those provided by the WMO).

The information provided is valid not only for designers and builders, but will also allow the governmental agencies to evaluate the potential role of PDEC in their overall energy policy and eventually to promote incentives oriented to its development and practical implementation.

The aim of the applicability mapping was to obtain the energy savings including:

- Compressor energy consumption.
- Fan energy consumption.
- Exhaust fan energy consumption.
- CO2 savings

A simulation tool has been used to assess energy consumption. Two different situations have been simulated, the building with conventional HVAC system and the building with PDEC tower plus HVAC system. The results for the same office building located in Seville and Athens are described below.

This study has been done supposing existing shafts have sufficient dimensions to install a conventional PDEC tower or purposely attached shafts could be installed in façades. In both cases the

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[2] Contract No. JOR3-CT-950078 1996-1999 (Unpublished)

net saving percentages are given for minor intervention, this means that the dimension from the light well to an external wall is less than 12.0m.

With these data the energy consumption saving in existing office buildings is assessed by multiplying the total surface by the corresponding figures in Table 1. In addition the energy consumption saving in existing buildings with major intervention, which would imply perforation of light wells to meet PDEC requirements, can be assessed following the morphology and statistical methodology suggested.

Table 1: Energy savings per square meter in Athens and Seville

Athens	
South	23.81 kWh/m^2
West	22.36 kWh/m^2
North	32.6 kWh/m^2
East	22.84 kWh/m^2

Seville	
South	40.62 kWh/m^2
West	39.13 kWh/m^2
North	49.24 kWh/m^2
East	39.93 kWh/m^2

On the one hand PDEC energy savings related to building envelope gains (perimeter zone) has been taken as an average value between the energy savings in all the orientations, on the other hand, PDEC energy savings related to internal gains has been supposed equal to the savings in north oriented zone, because this zone has low gains related to outdoor conditions.

In conclusion:

	Athens	Seville
Energy savings related to internal gains	**32.6 kWh/m^2**	**59.2 kWh/m^2**
Energy savings related to building envelope gains	**25.3 kWh/m^2**	**42.2 kWh/m^2**

3.2.4. Vertical Task 1.4 - Market Barriers to PDEC

This section brings together comments on the market barriers to PDEC and their applicability in commercial buildings in the four countries. Where appropriate, quantitative indicators are included. The detailed assessment of market penetration is discussed in a separate report.

In terms of impact, barriers can be divided into those that cannot readily be overcome and those that can. The principal barriers that cannot readily be overcome are:

- **technical barriers** – these mainly comprise whether PDEC is technically feasible, whether the buildings in which it could be introduced are air conditioned and, in the case of existing buildings, how frequently major refurbishments are undertaken.
- **regulatory and institutional barriers** – it is believed that regulations are currently not a constraint but where, for example, fire and air quality regulations for one reason or another disallow PDEC they will be a major and serious barrier. There are currently no institutional barriers or incentives for the use of PDEC in terms of, for example, grants, loans or tax incentives.

Other barriers are:

- **economic and financial barriers** – the principal immediate financial barrier to the adoption of PDEC is willingness to pay for introduction or adaptation. The survey suggests that – relatively stringent - simple payback periods of 5-7 years are likely to be the maximum acceptable. Financial barriers can be overcome or at least addressed by institutional incentives for the use of PDEC or disincentives for the use of alternatives – grants, loans or fiscal instruments.
- **Information, awareness and capacity barriers** – initially, awareness is the most important barrier for PDEC and its advocates to overcome. The evidence is that neither designers nor developers are well informed about PDEC, its attributes and its implications. The main route to improving awareness is information; dissemination programmes will need to be designed and implemented for different audiences and will take time. Only after PDEC has been implemented on a significant basis will capacity be developed for design, installation and repair and maintenance (including spare parts).

The table below summarises the results of this review of market barriers.

Table 2: Summary of barriers

	Greece	Italy	Portugal	Spain
Technical	o technical potential: 81% o air-conditioned; new buildings: 96% o air-conditioned major refurbs: 77% o frequency of refurbs: 14 years	o technical potential: 70% o air-conditioned; new buildings: 72% o air-conditioned major refurbs: 47% o frequency of refurbs: 12 years	o technical potential: 82% o air-conditioned; new buildings: 66% o air-conditioned major refurbs: 84% o frequency of refurbs: 12 years	o technical potential: 75% o air-conditioned; new buildings: 93% o air-conditioned major refurbs: 93% o frequency of refurbs: 12 years
Regulatory and institutional	No significant barriers known	No significant barriers known	No significant barriers known	No significant barriers known
Economic and financial	Simple payback period: 5 years	Simple payback period: 5 years	Simple payback period: 5 years	Simple payback period: 6 years
Tenure and use	Proportion of existing stock and newbuild assumed feasible for PDEC: 50%	Proportion of existing stock and newbuild assumed feasible for PDEC: 50%	Proportion of existing stock and newbuild assumed feasible for PDEC: 50%	Proportion of existing stock and newbuild assumed feasible for PDEC: 50%
Information, awareness and capacity	All of these currently very high	All of these currently very high	All of these currently very high	All of these currently very high

The summary suggests that while there are technical barriers, PDEC is theoretically applicable in a large proportion of existing buildings in all four countries (70% or more of the stock). Air-conditioning is standard in a high proportion of buildings – both new and major refurbishment projects – and a significant proportion of the building stock is refurbished each year – 7 or 8% of the stock. PDEC will also be a feasible option in a high proportion of new buildings – higher than in existing buildings because the constraints are less. But the annual newbuild rate is lower. Typically 1 to 3% of the existing stock is built each year.

There are currently no regulatory barriers that preclude PDEC though, in all cases, care will need to be taken to prevent spread of fire and there may, in future, be more stringent controls on noise and air quality in buildings. Well designed PDEC systems can, in any case, address all these issues and in many cases provide an enhanced indoor environment.

Work could be done – on regulatory or institutional issues – to encourage PDEC. Currently there is little or no encouragement for natural cooling systems in most buildings or planning codes or standards (though this is being considered in Greece). But environmental awareness is increasing and the role of buildings in contributing to the urban environment is better understood. It is likely that incentives will be required to increase the rate of uptake of natural cooling systems. These can range from providing free or low cost design and technical information and design advice schemes to grants or loans to cover (some of) the cost of design and installation.

The issues of mixed use and mixed tenure in commercial buildings is important but poorly documented. The Consultants believe that this would be a significant barrier to mass take up of PDEC but – for other reasons (see above and below) – this is unlikely, at least in the short term. In the first instance buildings in single use, occupation and tenure should be targeted.

Probably the most important constraint on the implementation of PDEC is lack of awareness and information on it as a design approach and technology. It is fundamental to any implementation strategy that major efforts will need to be put into raising awareness and providing technical information to designers, developers and contractors. It is encouraging, however, that there is a high degree of interest from survey respondents for more information. It is these enthusiasts that need to be identified and targeted.

3.2.5. Vertical Task 1.5 - Cost Benefit Evaluation

The cost model

A spreadsheet cost model was constructed to calculate the cost of providing an intervention using the data from the surveys. The model draws directly on the data provided in the morphology surveys and produces a cost for a minor, intermediate and major intervention. The costs depend on the type of intervention, the number of towers, the number of floors in the building and the cross sectional area of the tower. From the total cost of the intervention, the cost per square metre has been calculated and the results are laid out in the following tables which show the range of costs and more significantly the median and upper and lower quartiles.

In Task 1.1 the savings were calculated on the basis of the stock depth profile. This gave an overall savings ratio of 37% from internal gains and 63% from external gains. Combining the above figures in these proportions and averaging the results for each country gives the annual energy savings per m2 per year. From the average energy costs we can also show the energy cost savings.

Relating capital costs to annual energy savings, we can derive the median cost (half cost more and half cost less) to install PDEC and the capitalised energy saving over 20 years. The net cost of the PDEC system can then be compared to the typical cost of a comfort cooling installation. By comparing individual building costs from the survey data we can see the percentage of buildings in which PDEC would be a cheaper option than comfort cooling (In Greece only 17% but in Spain 48%).

INRA Belgium, a market research organisation, has produced a report for the European Electricity Prices Observatory on Electricity costs in Europe which is available at http://www.inra.com/. Costs are broken down into residential and non-residential and into bands of levels of annual consumption. We have taken the average cost for non-residential use, band 4, < 0.5GWh per year and band 6, 1 to 9GWh per year and show the resulting cost per KWh. Applying these costs to the potential energy savings found in section 3.3 gives a range of potential annual savings from €59 million in Portugal to €490 million in Italy.

Conclusions from the Cost Benefit Evaluation

Although stock data is widely available for residential buildings in most countries there is much less data available for non-residential buildings. For those countries that provide some data on non-residential buildings, it is mainly by numbers of buildings, it is very difficult to make estimates of stock areas and particularly difficult to break it down by stock use with any degree of accuracy. We have provided probable ranges for commercial buildings in each of the countries and used the figures from the lower end of the range in our assessment of potential energy savings attributable to PDEC.

The pilot survey in Athens allowed us to demonstrate the methodology for determining the proportions of the stock that might be suitable for each of the PDEC interventions. We were then able to relate energy savings to depths of buildings and to gross up the results to estimate the potential energy savings, cost savings and reductions in CO2 emissions for the entire stock.

The table below summarises the stock areas and potential energy savings and shows that energy savings could be around 1.5% to 2.5% of the national annual electricity consumption.

Table 3: Summary of PDEC savings

Country	**Commercial buildings area millions m2**	**National electricity consumption millions KWh**	**PDEC potential energy savings millions KWh**	**Energy saving as % of national electricity consumption**	**Reduction in CO2 emissions tonnes pa**	**Potential value of energy saving pa € million**
Greece	39	46,099	**1,124**	2.44%	**766,596**	**85.4**
Spain	116	201,159	**3,341**	1.66%	**1,472,654**	**257.9**
Italy	161	283,737	**4,637**	1.63%	**2,809,643**	**490.4**
Portugal	25	41,146	**720**	1.75%	**391,414**	**59.0**

We have also shown that PDEC is likely to be a cheaper option than comfort cooling in 18% of buildings in Greece, 24% in Portugal, 48% in Spain and the majority of buildings in Italy.

3.2.6. Vertical Task 1.6 - Market Penetration

This section produces estimates of the likely penetration of PDEC applications in both new and refurbished commercial buildings in Greece, Italy, Portugal and Spain in the period 2005 to 2025. A figure of 1% initial take up in 2005 has been adopted for all four countries for both new and refurbished buildings. The 1% has been applied to 5% of the total stock in 2005 that is reckoned to be subject to major refurbishment; and to 0.9% of the total stock in 2005 that is reckoned to be the new build rate for commercial buildings.

Market penetration tabulations are provided in Appendix A of Report VT 1.6 for:

- the areas of refurbished and new offices to which PDEC could be applied in 2005

- low, medium and high estimates of market penetration in terms of floor area at five year intervals from 2005 to 2025
- low, medium and high estimates of the value of annual energy savings for the same snapshot years
- low, medium and high estimates for the annual savings in energy and CO_2 emissions for the same years.

In all cases annual and cumulative figures are provided. The low estimates are based on an average annual increase over the period of 5% per annum based on the values in 2005; the medium estimates are based on an average annual rate of 10%; and the high estimates are based on an average annual rate of 20%. It should be noted that, at the high rate, the entire 2005 existing stock and newbuild production to which PDEC is applicable is modified by 2025. The Consultants believe that the medium rate provides the most plausible results and these figures are used in the following tables.

Based on the foregoing, some 11% of both annual refurbishments and annual new build production will incorporate PDEC interventions.

Report VT 1.6 also presents the cumulative market penetration rates in terms of floor areas for the same years. This data indicates that, by 2025, some 6.5% of the total 2005 commercial building stock will incorporate PDEC interventions.

Total annual financial benefits resulting from energy savings in both refurbishment and newbuild commercial buildings projects are set out in table 8. Other tables in the report (not included here) summarise the energy savings in kWh, and the reductions in CO_2 that will result from the energy savings.

Typically, buildings represent around 50% of national energy consumption and commercial buildings may represent 10 – 20% of that. It is likely, therefore, that the contribution of PDEC to savings in the energy consumption by, and the CO_2 emissions from, commercial buildings in the four countries are likely to be of the order of 0.5 to 1.0% in 2005 rising to 8 to 15% in 2025.

Table 4: Value of annual energy savings (€) 2005 to 2025 from cumulative PDEC installations

Country	2005	2010	2015	2020	2025
Greece	291,922	701,131	1,360,166	2,421,549	4,130,917
Italy	1,319,320	3,168,712	6,147,175	10,944,020	18,669,387
Portugal	189,607	455,394	883,447	1,572,830	2,683,087
Spain	673,379	1,617,307	3,137,511	5,585,815	9,528,833

Table 5: Annual benefits energy savings and CO2 reductions 2005 to 2025 from cumulative PDEC installations compared to national consumption in 2000

Country	2005	2010	2015	2020	2025
Greece	0.08%	0.19%	0.37%	0.66%	1.12%
Italy	0.04%	0.11%	0.20%	0.36%	0.62%
Portugal	0.06%	0.13%	0.26%	0.47%	0.79%
Spain	0.06%	0.13%	0.26%	0.47%	0.79%

3.2.7. Vertical Task 1.7 - Review and Dissemination

Lack of awareness and understanding of design based approaches to passive cooling (like PDEC) and natural ventilation, has been identified as one of the major current constraints on the wider take up and implementation of these energy saving techniques. In the evaluation of market barriers (Section 1.4), the authors state that:

> *'Probably the most important constraint on the implementation of PDEC is lack of awareness and information on it as a design approach and technology. It is fundamental to any implementation strategy that major efforts will need to be put into raising awareness and providing technical information to designers, developers and contractors. It is encouraging, however, that there is a high degree of interest from survey respondents for more information. It is these enthusiasts that need to be identified and targeted. '*

Dissemination has therefore been a major focus of the different parts of the project, and the following dissemination tasks and actions have been implemented:

- A two-day symposium and workshop Natural Cooling by Design combining the topics of all three projects in Cluster 9 was held at the Architectural Association, London on 21-22 March 2003. The event was attended by over 100 participants, which represented a wide international audience of architectural and engineering practitioners, researchers and students. There were ten key presentations and a panel discussion which included shorter presentations and commentaries.

The second day included a demonstration of the software with detailed technical discussion of its inputs, mode of operation and output. The timetable, list of participants and extracts from the presentations in the two-day event are included in an appendix to this report. The entire proceedings were recorded on video.

- One of the major project deliverables is 'Roof Cooling Techniques- a Design Handbook'. This has been developed within part 3 of the project, which investigated the design implications and applicability of various roof cooling techniques. The deliverables also include the software that was developed as part of the Cluster 9 project for the evaluation of roof cooling systems and the production of applicability maps and performance data.
- The structure and contents of the Handbook were tested with architects specialising in sustainable environmental design. Both Handbook and software have provided inputs to building design projects and Masters Dissertations at the Architectural Association Graduate School, London.
- Publication and distribution of Handbook and software have been arranged with James & James (Science Publishers) Limited, London.
- The following papers have been presented at conferences during the course of the project *Solar Passive Heating and Cooling.* These papers are reproduced in full in Appendix 1 of Horizontal Task 4.
- A number of papers have been accepted for presentation at the PLEA 2003 International Conference to be held in Santiago, Chile in November 2003.
- Internet sites giving access to various aspects of the results of the project can be located at:

http://www.brunel.ac.uk/research/solvent/

http://www.aaschool.ac.uk/ee/newsevents/conf.html