EUROPEAN COMMISSION

FIFTH FRAMEWORK PROGRAMME

Community Activities in the field of the specific programme for RTD and Demonstration on "Energy and Environment and Sustainable Development – Part B: ENERGIE PROGRAMME"

Development and Application of a Multi-Criteria Decision Analysis Software Tool for Renewable Energy Sources

(MCDA-RES)

Contract NNE5-2001-273

Deliverable D8: Data base of costs, technologies, environmental pressures, regional planning issues

MCDA-RES – WP2: Structuring of the Decision Model

Development and Application of a Multi-Criteria Decision Analysis Tool For Renewable Energy Resources

Public

MCDA-RES
NNE5-2001-273

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Date: **June 2003**

PROJECT FUNDED BY THE EUROPEAN COMMISSION UNDER THE EESD 5th FRAMEWORK PROGRAMME

Contents

1. INTRODUCTION

The aim of Deliverable 8 is to collect and present in a clear way indicative data about costs, technologies, environmental pressures and regional planning issues concerning renewable energy sources development. The data format used here will be concluded in the cd author ware and in the web site of the project as an additional information element. Any necessary changes in the format of this text might occur in order to be easier in use and compatible with the application of the cd and the web site.

The structure here is kept almost similar with the previous Deliverable (Del.7) in order to maintain the same characteristics and therefore to obtain a physical continuation of the database. As in Del. 7, the main categories of renewables that are presented here are solar, wind, hydro, biomass, wave and geothermal energy. Solar energy is also analysed into thermal collectors, photovoltaics, thermal electricity and passive.

The range of cost indicators is presented and there is also a future potential projection of costs. Technologies comprise the current state of the art. Environmental pressures outline all those impacts from ‘cradle to grave’ of a plan. Regional planning issues refer to all those necessary information that must be taken in a national, regional and local level for the promotion and successful implementation or renewable energy programmes.

Furthermore, an Appendix is included with the main renewable energy policies and measures for Greece, Spain and the Netherlands. Finally, a detailed description by law and responsible authority, implementation year and a brief outline of each law is presented.

2. SOLAR

2.1 THERMAL COLLECTORS

- **COSTS**

Table 2.1.1: Indicative cost of thermal collectors applications

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size (m2)	2 - 4	2 - 6	2 - 6	2 - 6	2 - 6	2 - 6	2 - 6
Capital cost (€/ domestic system)	1000-2000	1000-2000	1000-3500	1000-5500	1000-5500	900-4500	800-3500
Operation and maintenance cost (€/m2)	10 - 45	10 - 45	10 - 45	10 - 45	10 - 45	10 - 45	10 - 45
Cost of energy derived from above data, using 8% discount rate (€/kWh)	0.18-0.20	0.12-0.20	0.06-0.23	0.04-0.30	0.04-0.30	0.04-0.24	0.03 - 0.19

- **TECHNOLOGIES**

Unglazed collectors
They typically consist of black plastic or metal tubes through which water is circulated. There is no additional insulation, so temperatures are limited to about 20^{o}C above ambient air temperature. Unglazed collectors are ideally suited for applications where fairly low temperatures are required, such as heating swimming pools.

Flat plate collectors (glazed)
They consist of a flat insulated box, one side of which is transparent glass or plastic. The box contains a flat black plate to absorb solar energy. The heat transfer fluid (e.g. water or air) flows through or over this absorber plate, carrying away the absorbed heat. The glazing above and insulation below the plate reduce heat loss. The absorber plate may have a special selective coating to improve its performance. Most flat plate collectors produce temperatures of up to about 70^{o}C above ambient, and thus are suitable for domestic hot water, space heating and district heating

Evacuated tube collectors
These collectors consist of an array of evacuated glass tubes each containing an absorber, usually a black metal plate, which collects solar energy and transfers it to a heat transfer fluid. Because of the insulation properties of the vacuum, heat losses are low, and temperatures of 100^{o}C or more above ambient can be produced. So these collectors are particularly suited to higher-temperature applications.

Circulated systems
The circulation systems transfer heat from the collector to where it is to be stored or used. In a solar domestic hot water system the heat transfer fluid typically circulates between the collector and a heat exchanger in a storage tank. In some systems the water circulated between collector and storage tank by a means of a pump, whereas in others, circulation is driven by a thermosyphon effect. Pumped systems are used throughout Europe, while thermosyphon systems are used mainly in southern Europe.

Control systems

Control is necessary to ensure efficient operation and maintain the desired temperature at the point of use. The control system of a solar thermal device is usually similar to a conventional one in cost and operation. It may incorporate temperature sensors which provide information on the operation of the system and an intelligent controller which controls the operation of the pump.

- **ENVIRONMENTAL PRESSURES**

Visual amenity

Thermal collectors are usually placed on the top of the roof of building or houses. However, there are some examples of typically large thermal collectors that are usually situated in the yard. Visual amenity in the first case is rather low since the only eye contact possibility is from the air. In the second case, visual impact depends on the precise position of the construction (back or front yard) and also on the existence of short flora in the area involved.

Other mechanisms of this technology are usually placed inside walls on in the attic.

Noise

Noise impact is limited only during installation and construction period. When operation of the systems occurs there is no significant amount of noise produced.

Occupied area

Occupied area of the construction and the rest equipment of thermal collector technologies is very restricted.

Emissions

Table 2.1.2: Emissions from thermal collectors applications

Parameter	**Value**
Emission factor - CO_2 (kg/TJ)	0
Emission factor - SO_2 (kg/TJ)	0
Emission factor - NO_x (kg/TJ)	0
Emission factor - Particulates (kg/TJ)	0
Emissions during construction - CO_2 (kg / TJ)	3.580-10.502
Emissions during construction - SO_2 (kg / TJ)	27-78
Emissions during construction - NO_x (kg / TJ)	12-35
Emission during construction - Particulates (kg/TJ)	0.8-2.4

- **REGIONAL PLANNING ISSUES**

GREECE

Urban & Rural Planning

The sitting of installations for the energy exploitation of RES falls under more general legislative provisions, concerning land use and zoning regulations, which are set separately for each different region in Greece. For example, the implementation of any industrial activity in the Prefecture of Attica (and the islands of Salamis and Aegina), and, consequently, of any RES-related investment in the area, are subject to the terms and limitations stipulated in the Presidential Decree PD 84/1984.

Furthermore, industrial planning and, hence, RES planning, is exercised by regional authorities and, more specifically, it is the subject of planning regulations and competences placed in the hands of Prefectural Authorities (e.g. the Head of the Prefecture, the Prefectural Council, etc.).

The specific building requirements for any industrial complex are further subject to the authorisation of first-degree local authorities (municipalities) and, more specifically, of the local City (Municipal) Planning Department, in accordance to the guidelines of Law 1577/1985. This Law clearly defines the terms, limitations and prerequisites for the implementation of any construction project, within or outside the certified Master Plan of a given city, community or settlement, in order to protect the natural, urban and cultural environment, as well as to serve the public interest.

The general provisions for the installation or the expansion of RES-based power stations are set in the Electricity Law 2244/1994, Art. 3. Specific provisions for different RES technologies and installations are laid down in detail in the Ministerial Decision 8295/1995, Art. 1I, §§ C.

According to the provisions referred to in Art. 1I §§A, point b2, M.D. 8295/1995, a RES installation must be erected on a suitable site, for which a legal document for its exclusive use has been issued.

Installation of RES facilities in public or forestland is allowed only in those cases that this land does not fall under the provisions of §§2Ac, Art. 13 of Law 1734/1987, and, even then, it requires the issuing of a relevant ad-hoc Decision on “Authorization for Intervention”. This authorization is issued by the General Secretary (Governor) of the respective Region and its subordinate bodies (Regional Forestry Inspectorates, Forest Divisions, Forest Stations).

It should be pointed out that although an authorisation for intervention in public or forest land may be granted initially to more than one investors (interested parties), the final legal right for the exclusive use of the land under consideration can be exercised only by the investor that first receives the RES installation license, according to the provisions of the M.D. D6/F1/OIK. 8860/11.05.1998. Art. 2.

Inherently linked to the planning and sitting issues of RES-to-power projects are the corresponding licensing procedures established by Law 2244/1994 and laid down in detail in the MD 8295/1995. These procedures have been analysed extensively in Chapters 2.1.2 and 2.1.3.

NETHERLANDS

Urban & Rural Planning

In the Netherlands there is no direct planning legislation for Renewable Energy. Spatial planning for Renewable Energy can be an important issue. Wind energy (wind turbines) for instance always includes a spatial aspect.

The planning system in the Netherlands is legally regulated by the following acts:

- Spatial Planning Act (SPA)
- Housing Act (HA)

Both acts are framework laws made by the Houses of Parliament. The SPA regulates the policy on spatial planning at a national, provincial and municipal level. The provincial and municipal authorities are the competent authorities that draw up regional (province) and local (municipality) plans. The most important instrument in the HA is the building permit.

The main components of the planning system are:

- The provincial authority draws up and maintains the regional plan. Regional plans provide the framework for local planning. Although these plans in general must be in accordance with the national policy, minor differentiation is sustained. The regional plan does not generate direct obligations for the local government. However there is an approval system. This means that the local authority must take the regional plan into account.
- The local authority draws up the local plan. The provincial government must approve the plan before the plan turns into force. Only the local plan binds citizens (and companies) directly. A local plan designates the use of land and includes regulations on the buildings erected on it.

The HA contains a permit system for the building of houses and all kind of installations and plants. Therefore most renewable energy projects (wind turbines, solar energy installation and waste incineration installations) need a building permit. The local authority is the proper authority entitled to submit the building permit. The building permit will be refused when the installation is not in accordance with for instance the local plan or the Building Decree. The Building Decree contains technical regulations.

SPAIN

The basic land planning regulations

Regional Governments are responsible for town and land planning in accordance with State laws and specific regulations. The State regulates the basic terms of regional competencies, within the framework of Act 6/98. However, the Regional Governments must complete the State legislation on the land regime, on the basis of the Ruling by the Constitutional Court of 20th March 1997.

This Act modifies the classification of land, describing land as urban, liable to urban development and non-usable. The category of non-development includes land that has not yet been included in the urban process and has a clear environmental, landscape value, etc., or has agricultural, forestry or stock farming value.

Sectorial energy land planning

The basic aim of the Electric Sector Act 54/1997 of 27th November is to regulate the electricity sector. The Electricity Act 54/1997 is incorporated into the Spanish juridical system by the Directive 96/92/EC of the European Parliament and the Council, on common rules for the internal electricity market in the European Union.

As to the Special Regime (renewable energy) of electricity production covered by the Act, no explicit reference is made to matters related to the co-ordination of territorial and sectorial planning policies.

Transitory Provision sixteen of the Act makes specific mention to the preparation of a Plan for the Promotion of Renewable Energy Sources, in order that by the year 2010 renewable energy sources may cover at least 12% of the primary energy demand in Spain. This Plan was approved in the Ministry Council, 30th December 1999, for the period of 2000-2010.

The Promotion Plan of Renewable Energy Sources presents the current situation, the prediction of renewable energy consumption for the near future, the tools and sources for financing that sustain the specific objectives and also the state of art of the technologies that use renewable resources and the barriers that limit the penetration of these sources in a liberalized market.

Finally, the Electricity Act 54/1997 is modified by Act 9/2001, of 21st June, specifically in its sixth transitory disposition, which deals with the transition costs to the competitive market regime of the titleholders of electricity energy production facilities.

Local initiative in organizing renewable energy resources

Municipal By-law may be seen as an instrument of great interest in the scope of the competencies of the Local Corporations, to establish a more precise local juridical framework for land planning of renewable energy resources.

The present reality is that in the main Spanish municipalities there still exists very few *Municipal By-laws* to bring about the use and development of renewable energy, although it is true that the implementation of the Local Energy Agencies and the growing interest by some County Councils (Diputaciones Provinciales) will soon contribute to models of municipal by-laws being drafted in this field.

The first Municipal Ordinances are those Ordinances for solar panel surfaces, publicly announced by the City Halls (Ayuntamientos) of Sant Joan Despí and Barcelona.

The Ordinance of Barcelona offers the idea of regulating the incorporation of solar panel surface systems and the use of active energy at low temperature for the production of hot water for the whole municipal (Official Gazzette of the Barcelona Province nº 181. 10/07/99).

Subsequently, there is the Ordinance of the County Council (Diputación Provincial) of Seville on the "Rational and Efficient Use of Energy, Renewable Energy and Environment". The Ordinance has as its main goal the improving of the environment with a sustainable use of energy resources on the basis of European Union policies.

The main renewable energy policies in Greece, Spain and the Netherlands are presented in Appendix I.

2.2 PHOTOVOLTAICS

- **COSTS**

Table 2.2.1: Indicative cost of Photovoltaic application

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size (kWp)	0.1-1	0.4-10	0.4-10	1-100	1-100	1-200	1-500
Capital cost (€/kW)	60000-190000	22000-95000	11000-55000	4600-20000	3700-15000	3000-9000	2000-4000
Operation and maintenance cost (€/kWp/year)	100-600	100-600	50-600	25-600	25-250	20-200	15-200
Fuel cost (€/kWh)	0	0	0	0	0	0	0
Cost of energy derived from above data, using 8% discount rate (€/kWh)	3.5	2.9	1.1	0.39	0.28	0.21	0.14

- **TECHNOLOGIES**

Crystalline Silicon (c-Si)
Crystalline silicon (c-Si) is the leading commercial material for photovoltaic cells, and is used in several forms: single-crystalline or monocrystalline silicon, multicrystalline or polycrystalline silicon, ribbon and sheet silicon and thin-layer silicon.

Thin Films
Thin film photovoltaic cells use layers of semiconductor materials only a few micrometers thick, attached to an inexpensive backing such as glass, flexible plastic, or stainless steel. Semiconductor materials for use in thin films include amorphous silicon (a-Si), copper indium diselenide (CIS), and cadmium telluride (CdTe).

Group III-V Technologies
These photovoltaic technologies, based on Group III and V elements in the Periodic Table, show very high conversion efficiencies under either normal sunlight or concentrated sunlight. Single-crystal cells of this type are usually made of gallium arsenide (GaAs). Gallium arsenide can be alloyed with elements such as indium, phosphorus, and aluminium to create semiconductors that respond to different energies of sunlight.

High-Efficiency Multijunction Devices
Multijunction devices stack individual solar cells on top of each other to maximize the capture and conversion of solar energy. The top layer (or junction) captures the highest-energy light and passes the rest on to be absorbed by the lower layers. Much of the work in this area uses gallium arsenide and its alloys, as well as using amorphous silicon, copper indium diselenide, and gallium indium phosphide. Although two-junction cells have been built, most research is focusing on three-junction (thyristor) and four-junction devices, using materials such as germanium (Ge) to capture the lowest-energy light in the lowest layer.

Fabricating Solar Cells and Modules
A variety of technical issues are involved in the fabrication of solar cells. The semiconductor material is often doped with impurities such as boron or phosphorus to tweak the frequencies of light that it responds to. Other treatments include surface

passivation of the material and application of antireflection coatings. The encapsulation of the complete PV module in a protective shell is another important step in the fabrication process.

Advanced Solar Cells

A variety of advanced approaches to solar cells are under development. Dye-sensitised solar cells use a dye-impregnated layer of titanium dioxide to generate a voltage, rather than the semi-conducting materials used in most solar cells. Because titanium dioxide is relatively inexpensive, they offer the potential to significantly cut the cost of solar cells. Other advanced approaches include polymer (or plastic) solar cells (which may include large carbon molecules called fullerenes) and photo-electrochemical cells, which produce hydrogen directly from water in the presence of sunlight.

Balance of System (BOS) Components

The balances of system (BOS) components include everything in a photovoltaic system other than the photovoltaic modules. BOS components may include mounting structures, tracking devices, batteries, power electronics (including an inverter, a charge controller, and a grid interconnection), and other devices.

- **ENVIRONMENTAL PRESSURES**

The main impacts from PV systems include:

- Impacts from construction activities (effects on local ecosystems and habitats, etc.)
- Visual intrusion
- Public and occupational health impacts
- Decommissioning

Burdens during production of PV cells

<u>Occupational And Public Health Hazards</u>

Wide ranges of materials, some of which are potentially toxic and hazardous, are used in the photovoltaic industry. There is only a small risk to public health during normal operation and, therefore, hazardous emissions are likely only during accidental releases (e.g. from venting of equipment) or under abnormal circumstances (e.g. power failure or fire). Emissions to soil and groundwater may occur from inadequate storage of materials.

<u>Resource Depletion</u>

Silicon cells are made from abundantly available raw materials (quartzite and quartz sand), but CIS cells use indium and CdTE tellurium (scarce resources). Therefore, large-scale production of these cells could lead to resource depletion.

Burdens during construction and operation of PV cells

Land use and its impact on natural ecosystems

The impact of land use on natural ecosystems is dependent on specific factors such as the area of land covered by the PV system, the time of construction of the plant, the type of land and biodiversity in the area. The main factors affecting land requirements for a ground-mounted centralised PV system are the insulation levels and the system efficiency.

The main impacts on ecosystems are likely to be during the construction and transport stages. Helping to re-establish the previous biodiversity on the site by artificially supporting the flora and fauna from adjacent areas to re-conquer the plant site may also mitigate the impacts of the construction process.

Visual intrusion

Visual intrusion is highly dependent on the type of the scheme. The large land areas required for centralised multi-megawatt schemes could result in a significant visual impact. The visual impact of small stand-alone schemes is much lower, particularly for roof-mounted schemes. Indeed, in areas where there is currently no grid, the visual impact of a small stand-alone PV system may be significantly less than the infrastructure (pylons, cables and transformers etc.) required to connect such areas to the grid.

Public health hazards

For modules mounted on rooftops or integrated into building facades, fires in the building could lead to atmospheric releases of pollutants from the modules, posing a hazard to public health.

Impacts from the decommissioning of PV systems

The toxicity of cadmium raises concerns over the disposal of the modules. These could pose a public health hazard if not recycled or disposed of according to hazardous waste regulations.

Impacts could be avoided by recycling the modules. The PV industry expects that extensive recycling will become commonplace, as is the case with semiconductors. Collection of modules from medium and large systems should pose no major difficulty, but might prove more difficult for modules used in smaller applications, particularly in remote areas (IEA, 1998).

Emissions

Table 2.2.2: Emissions from Photovoltaic application

Parameter	Value (kg/kWp)	Value (kg/Tj)
Emission factor - CO_2 (kg/TJ)	0	0
Emission factor - SO_2 (kg/TJ)	0	0
Emission factor - NO_x (kg/TJ)	0	0
Emission factor - Particulates (kg/TJ)	0	0
Emission factor – VOCs* (kg / TJ)	0	0
Emissions during construction - CO_2 (kg / TJ)	432-2138	4000-20000
Emissions during construction - SO_2 (kg / TJ)	5.47-6.76	75-95
Emissions during construction - NO_x (kg / TJ)	4.52-6.07	61-83

*non volatile organic compounds

- **REGIONAL PLANNING ISSUES**

Regional planning issues concerning photovoltaics are described as above in the general framework of urban and regional planning for solar collectors.

2.3 THERMAL ELECTRICITY

- **COSTS**

Table 2.3.1: Indicative cost of thermal electricity application

	Parabolic Through	Power tower	Dish/Engine
Size	30-320 MW*	10-200 MW*	5-25 kW*
Operating Temperature ($^oC/F$)	390/734	565/1049	750/1382
Annual capacity factor	23-50%*	20-77%*	25%*
Cost €/m^2	630-275*	475-200*	3100-320*
€/W	4,0-2,7*	4,4-2,5*	12,6-1,3*

*Values indicates changes over the 1997-2030 time frame

- **TECHNOLOGIES**

Parabolic Trough systems use parabolic trough-shaped mirrors to focus sunlight on thermally efficient receiver tubes that contain a heat transfer fluid. This fluid is heated to 390 ^oC (734 ^oF) and pumped through a series of heat exchangers to produce superheated steam, which powers a conventional turbine generator to produce electricity.

Power Tower systems use a circular field array of heliostats (large individually-racking mirrors) to focus sunlight onto a central receiver mounted on top of a tower. This thermal storage capability renders power towers unique among solar technologies by achieving dispatchable power at load factors of up to 65%. In this system, molten-salt is pumped from a “cold” tank at 288 ^oC (550 ^oF) and cycled through the receiver where it is heated to 565 ^oC (1,049 ^oF) and returned to a “hot” tank. The hot molten-salt can then be used to generate electricity when needed. Current designs allow storage ranging from 3 to 13 hours.

Dish/Engine systems use an array of parabolic dish-shaped mirrors (stretched membrane or flat glass facets) to focus solar energy onto a receiver located at the focal point of the dish. Fluid in the receiver is heated to 750 ^oC (1,382 ^oF) and used to generate electricity in a small engine attached to the receiver. Engines currently under consideration include Stirling and Brayton cycle engines.

- **ENVIRONMENTAL PRESSURES**

The main impacts are on amenity and are related to the large land area required. Other impacts, such as burdens on water resources, are associated with the conventional steam generating plant and heat transfer fluids used in some of these systems. The main potential burdens that have been identified are:

- Impacts from construction activities (emissions, noise, occupational accidents, effects on local ecosystems and habitats)
- Visual impact
- Noise
- Land use and subsequent ecological impacts

- Water resources
- Occupational hazards

Impacts during construction

The impacts associated with the construction of stand-alone schemes are minimal, whilst those associated with large-scale schemes are equivalent to those from any civil engineering project of a similar scale. The main impacts have been listed below:

- There will be atmospheric emissions from: all plant and equipment used on site; transportation of the workforce to and from the site, and transportation of construction materials by heavy goods vehicles. These emission levels are likely to be low relative to those from other life cycle stages (EC, 1995a).
- Transport of workers and materials is generally by road. This additional traffic will also produce noise, increase public road accidents, etc. However, because of the remote location of these schemes, these effects are likely to be small.
- There will also be an increased level of visual intrusion during the temporary construction period, from site activity and vehicle movements of all personnel, plant and equipment.
- Occupational accidents may occur, though these are common to any construction activity.

Visual intrusion

The visual impact of parabolic trough and power tower systems can be significant, because a considerable area is occupied by the mirror systems. There are also associated buildings for the generation plant, cooling towers and (in the case of the power tower system) the tower itself. Deployment away from residential areas (as has been the case to date) would reduce this impact. Avoiding sitting in areas regarded as particularly scenic can further reduce this adverse effect.

The visual impact of parabolic dish systems will be smaller than those above. Their relatively small size offers more options both for being incorporated unobtrusively near to residential areas.

Noise

The inclusion of steam generating plant, particularly in power tower and parabolic trough systems, means that noise will be generated from fans, pumps and turbines. However, noise would only be generated primarily during the day, because at night (when people are most sensitive to noise), the plant will be unable to operate (unless thermal storage is incorporated). In addition, the remote location (typical for such schemes) will mean that noise is unlikely to have a significant impact because of the large distances from residential dwellings.

Noise occurs from parabolic dish systems under normal operating conditions. However, they are likely to be less noisy than the stand-by diesel generating sets, which they displace, and which would be required for generation during the night.

Land use and impact on ecosystems

To date most sites used or considered for solar thermal systems are in arid desert areas, which typically have fragile soil and plant communities. Unless due care and attention are taken during the planning, construction and operation phases, the effects of the scheme on vegetation and soil could enhance the potential for soil erosion and habitat loss. The shade offered by the reflectors from both sun and wind would change the microclimate around the scheme, with possible beneficial effects on vegetation. Providing such schemes are not deployed in ecologically important areas, it is unlikely that any of the above changes would be considered significant.

Finally, the concentration of light and heat energy in power tower systems could pose a danger to local fauna.

Water resources

Parabolic trough and power tower systems using conventional steam plant to generate electricity will have a requirement for cooling water. This could place a significant strain on water resources in arid areas.

There may be some pollution of water resources. During normal operation, concentrations of some compounds in the water will increase, largely as a result of evaporation of the water. Discharged water may also contain biocides. There will be some ‘thermal’ pollution, although the significance of both this and any chemical pollution will depend on the characteristics of the local receiving body of water. Pollution of water resources may also occur due to accidents or unsound operating practices (e.g. uncontrolled flushing of the heat transfer and heat storage systems or plant washing), which can lead to the discharge of pollutants including hydrocarbons, oils, corrosion inhibitors, bactericides and glycols. Such incidents can be minimised by good operating practice.

Occupational hazards

Power tower systems have the potential to concentrate light to intensities which could cause eyesight injuries or even blindness if it is reflected into the eyes of operators. Under normal operating conditions, this should not pose any problem, because the operators would not be in the danger area.

The accidental release of heat transfer fluids (water and oil) from parabolic trough and power tower systems could form a health hazard. The hazard could be substantial in those power tower systems that use liquid sodium or molten salts as the heat transfer medium.

Emissions

Table 2.3.2: Emissions from thermal electricity application

Type of System	Emission Factor	**Value**
Solar Trough		
	Emission factor - CO_2 (kg/TJ)	0
	Emission factor - SO_2 (kg/TJ)	0
	Emission factor - NO_x (kg/TJ)	0
	Emission factor - Particulates (kg/TJ)	0
	Emission factor – VOCs* (kg / TJ)	0
	Emissions during construction - CO_2 (kg / TJ)	10499
	Emissions during construction - SO_2 (kg / TJ)	76
	Emissions during construction - NO_x (kg / TJ)	36
Solar Tower		
	Emission factor - CO_2 (kg/TJ)	0
	Emission factor - SO_2 (kg/TJ)	0
	Emission factor - NO_x (kg/TJ)	0
	Emission factor - Particulates (kg/TJ)	0
	Emission factor – VOCs* (kg / TJ)	0
	Emissions during construction - CO_2 (kg / TJ)	7240
	Emissions during construction - SO_2 (kg / TJ)	58
	Emissions during construction - NO_x (kg / TJ)	23
Solar Dish		
	Emission factor - CO_2 (kg/TJ)	0
	Emission factor - SO_2 (kg/TJ)	0
	Emission factor - NO_x (kg/TJ)	0
	Emission factor - Particulates (kg/TJ)	0
	Emission factor – VOCs* (kg / TJ)	0
	Emissions during construction - CO_2 (kg / TJ)	7546
	Emissions during construction - SO_2 (kg / TJ)	36
	Emissions during construction - NO_x (kg / TJ)	17

*non volatile organic compounds

- **REGIONAL PLANNING ISSUES**

Same as above, thermal electricity planning is described under the same framework.

2.4 PASSIVE

- **COSTS**

DESIGN

Passive, hybrid and low energy cooling techniques

Table 2.4.1: Indicative cost of Passive, hybrid and low energy cooling techniques

Night ventilation	**1995**
Capital cost (€/m^2)	0-95
Fixed operation and maintenance cost (€/m^2)	5.6

Ground cooling with air	**1995**
Capital cost (€/m^2)	20
Fixed operation and maintenance cost (€/m^2)	1.6

Slab cooling with water	**1995**
Capital cost (€/m^2)	20
Fixed operation and maintenance cost (€/m^2)	1.6

Evaporating cooling	**1995**
Capital cost (€/m^2)	52-94
Fixed operation and maintenance cost (€/m^2)	3.5-7

ENERGY SAVING TECHNOLOGIES

Artificial lighting

Comparative technical information related to energy and lighting service is indicated here for the most commonly used lamps in the residential sector.

Table 2.4.2: Indicative cost of artificial lighting

	General incandescence 100 W		**Tungsten halogen 100 W**		**Compact fluorescent 20 W**	
	1995	2010	1995	2010	1995	2010
Lifetime duration (h)	1000		2000	2500	8000	10000
Price (€)	0.5	0.3	9	3	18	9.2

Thermal energy storage

Table 2.4.3: Indicative cost of storage heating system

Storage heating system	Typical storage Temp. (^oC)	Installation cost
Room storage		
Ceramic, brick	700-815	20-30 (€/kWh)
Central storage		
Ceramic or rock	700-815	25 (€/kWh)
Pressurized water	4.19	22-23 (€/kWh)
Unpressurized water	-5 to 99	20-21 (€/kWh)
Eutectic salts		10-150 (€/kWh)
Building fabric		
Floor warming	38	10-20 (€/m^2)

- **TECHNOLOGIES**

DESIGN

General building design can minimise solar gains and entry of hot ventilation air. This involves careful distribution of glazing, use of shading devices, and input of cool ventilation air

Night ventilation uses natural means or mechanical power to blow outside air at night in a building and cool its thermal mass allowing it then to absorb internal or external heat during the following day.

Evaporative cooling uses wetted pad or water spray on which air is blown to decrease its dry bulb temperature. Evaporate cooling can be 'direct' if inlet air is blown directly on the wet media. In this case evaporative cooling provides sensible cooling while increasing latent heat content of air. Evaporative cooling can also be indirect, when outside air cooled directly through the evaporative cooler transfers its " coolth " to the indoor air to be conditioned through an air to air heat exchanger. In that case, evaporating cooling provides sensible cooling while keeping constant the latent capacity of air.

Night sky irradiative cooling uses irradiative heat transfer towards night sky to cool a thermal mass (usually water) component of a building (usually roof mounted). Night sky temperature can be typically 15°C cooler than dry bulb ambient temperature. Cooled mass will be used as heat sink for building internal and external gains during the following day. Such systems can be entirely passive (water bags called roof ponds) or require some mechanical power to pump water up and down and use water to air heat exchanger to distribute cold air inside the building.

Ground cooling with air uses long-term thermal inertia of ground (a few meters below ground level yearly temperature only a few degrees around mean yearly temperature) to extract " coolth " in the summer (and possibly heat in the winter as well) through air to ground heat exchangers. These heat exchangers are usually made of buried pipes networks in which outside or building air is blown to be cooled.

Slab cooling with water uses building slabs (usually concrete) as cooling energy distributors and emitters. Water is pumped through closed loop piping network in the slab at typical temperature range of 15°C to 18°C. These fairly high temperatures are possible because of the large cooling emission area. They increase the overall efficiency of the cooling process whatever is the cooling source of the system, active or hybrid/low energy.

Chilled ceiling and displacement ventilation use mixture of irradiative and convective cooling distribution-emission technologies to keep commercial building cool with significantly lower energy consumption than with conventional convective systems. The main cooling needs is provided by a radiant chilled ceiling that operates through the same process as radiant cooling slab but with increased emission efficiency due to the fact that cold air drops from ceiling. Additional latent cooling needs are provided through cooled fresh ventilation air that can thus be kept to minimum required flow rate for indoor air quality purposes. In these displacement ventilation systems air is supplied at inlets near the floor at 18°C with very low speed (typically 0,2 m/s). It can then spread evenly on the floor surface and makes its way up at the vicinity of internal heat sources. It is then exhausted through the ceiling.

Slab cooling with air uses the thermal inertia of building mass for cooling energy storage by circulating cooled air through channels in the building horizontal (floor, ceiling) and possibly vertical (interior and exterior walls) slabs. The building structure will then be a heat sink for internal or external sensible cooling loads. The cooling source is usually nighttime air but other hybrid or low energy cooling sources could also be used.

Ground cooling with water uses fairly low temperatures aquifer water (typically 10°C), when it is available, as cooling source. Such systems require two (or more) wells to pump water up from and return it down to the aquifer. This primary loop transfers cooling energy to the secondary building cooling distribution loop through a water-to-water heat exchanger. This system can be supplemented if needed by additional cooling systems.

Daylighting

Daylighting is achieved by control strategies and adapted components which fall mainly into three categories:

- conduction components - spaces used to guide or distribute light towards the interior of a building
- pass-through components (e.g. windows) - these allow light to pass from one room or section of a building to another
- control elements - specially designed to control the way in which light enters through a pass-through component.

FABRIC COMPONENTS

Envelope

Traditionally, insulation materials consist of lightweight fibrous or cellular materials with pockets of air or gas (which have low thermal conductivities) to reduce conductive heat transfer, e.g. glass fibre, mineral wood and expanded plastics.

Recent innovations have been in transparent insulation (TI) and dynamic insulation (DI) materials. These combine good insulation capabilities with other useful properties.

Windows and Glazing

There exist a number of technologies and materials to improve the energy performance of windows compared to conventional double-glazing windows. They can be classified into:

- glass materials and coatings,
- fills of the glazing unit,
- frames, edges and window design.

Promising existing and emerging technologies are:

<u>Low-emissivity (low-e) coatings</u>
Low-e coatings consist of very thin, transparent layers of metals or oxides deposited on glass or plastic. These coatings reduce the ability of the material to transfer heat through infrared radiation to the outside (decreasing the overall U-value). The original low-e coatings permit transmission of the full solar spectrum. Therefore they are applied for solar heating applications.

Spectrally-selective low-e coatings are also available, which selectively transmit visible light and reflect solar infrared. Because of their higher daylight transmittance than overall solar transmittance they are desirable for daylight utilisation while reducing cooling load. Low-e coatings can also be combined with tinted glasses or reflective coatings to improve performance.

<u>Switchable glazing technologies ("smart" windows)</u>
These materials have variable solar-optical properties, which can be passively or actively altered. Their application in architectural glass allows dynamic regulation of solar energy transfer through the fenestration for visual comfort, thermal comfort, peak load management, the control of glare, privacy and daylight.
There are different types of chromogenic materials under consideration for use in buildings, based on different physical principles. The most relevant are:

- *Photochromic coatings*: change the solar transmittance as a function of light intensity (like sunglasses). Primary benefit: improving visual comfort.
- *Thermochromic materials*: change their optical properties as a function of their temperature (like liquid crystal temperature indicators), from transparent when

cool to a white, reflecting/diffusing state when heated. Liquid and gel based materials as well as thin-film solid state devices are investigated.

- *Electrochromic materials*: are multi layer films whose optical properties can be controlled using an applied voltage (like flat display panels). These have the greatest versatility since occupants can control their transmittance at any moment actively. However, they are potentially more complex and difficult to fabricate and more expensive than single layer chromogenic materials.
- *Gasochromic glazing*: in these systems a low concentration of hydrogen in a neutral gas such as nitrogen is dissociated by a catalyst and intercalated into a tungsten oxide layer. This turns deep blue, but does not block visibility. Bleaching is achieved with oxygen.

Gas-fills

Filling the gap between the glass panes with low conductivity gas such as argon or krypton at atmospheric pressure improves the window performance by reducing conductive and convective heat transfer. They are mostly used in conjunction with low-emissivity coatings.

Transparent insulation materials (TIM)

Two main types of TIM exist, which allow a further reduction of the U-value. They are typically used as fill in a double-pane glazing assembly:

- *Aerogel*: Silica aerogel is a micro-porous material that traps air in tiny holes. It has excellent insulating properties, good optical clarity and relatively high solar transmittance. Currently two prototypes are available: (1) monolithic aerogel in tiles, which are highly transparent but very fragile. (2) granules of varying diameter, which are cheaper but with strong light scattering and therefore transmitting only diffuse light.

- *Honeycomb or capillary structure*: Honeycomb or capillary structures made of plastics or glass have a high solar transmittance and reduce heat losses by suppression of convection and infrared radiation. No clear view through is possible, however, through redirecting solar radiation a good illumination of the room behind can be achieved.

Evacuated windows

The "fill" strategy with the lowest conductance is the use of vacuum between low-e coatings. Only a very small distance between the glass panes is necessary, but the long-term integrity of seals and the structural stability of the unit (due to pressure differences) are difficult to master in a cost-effective manner.

Electrically heated glazing

Electrically heated glazing is a component, which has a selective coated glass inside the glazing package. Usually the coated glass is the innermost pane of the package. The coating consists of a metal-oxidised layer. The electric current will be supplied to the layer to heat the glass. The layer must be in the safe gas gap behind the tempered glass. The main idea of the electrically heated glass is to prevent the "cold draught" of the cold glazing surface. The element can be used for heating, too. An additional special purpose for the element is melting of snow.

Superwindows
Superwindows combine technologies for solar control and heat loss reduction. They were originally developed for residential applications in cold climates. Three- or four-pane glazing units with multiple low-e coatings, gas fills and special frame construction reach U-values of 0,4-0,5 W/m²K for centre-of-glass values and 0,7-0,9 W/m²K for the total window U-value. Their overall energy performance provides net energy benefits for any orientation in most parts of Europe. In addition to energy savings, these units also provide a great improvement in thermal comfort.

Frames, edges and window design
The most common materials for the frame are wood, aluminium and plastics (PVC) and glass fibre.
Window design can be classified into three types:

- box - windows
- multiple-glazing windows
- laminated windows

Unwanted air infiltration occurs through three different kinds of cracks and gaps:

- between the frame and the glazing unit
- between the frame and the building wall
- between the glass panes and the edge spacers

I think there is no infiltration between the edge spacer and the glass pane. The sealant, e.g. PIB (polyisobutylene), prevents the infiltration between the spacer and glass.
For an excellent overall energy performance of the window the following devices are important:

- distance holders for multiple glazing made of low conducting, non-metallic materials
- long-term tight edge seals
- low-conducting, tight frames

Alternative strategies include:

- directional selective materials for daylight use: directional selective materials redirect the incoming sunlight to spread it more usefully within the space**.** Current technologies include prismatic devices, holographic films, oriented coatings, imbedded structures within the glass substrates
- highly transparent plastic foils in the space between the glasses
- gluing solar control film to an existing glazing
- movable, not-permanent shading-devices: thin reflecting folios, rolling shutters etc.

ENERGY SAVING TECHNOLOGIES

Ventilation

Ventilation can be achieved naturally or using mechanical techniques. Natural ventilation has been used since immemorial time. At its simplest form, it relies on window opening and infiltration. The creation of good natural ventilation that provides comfortable living and working conditions but does not waste energy is a more sophisticated process. This involves careful design that takes into account microclimate conditions, including airflow patterns round the buildings.

Conventional mechanical ventilation, air distribution and heat recovery systems have been used for many years in industrial and commercial buildings. Modern improvements include treatment of the incoming air to remove pollutants, better control of air movement and airflow, and various procedures to save energy. Removal of pollutants is generally by filtration. Energy saving can involve conventional or more innovative heat recovery systems, ground pre-conditioning of the supply air, energy efficient fans, dynamic insulation etc.

Artificial lighting

Incandescent Lamps

Incandescent lamps consist of a bulb containing a wire filament, which is heated and emits light. Incandescent lamps may have different types of bulb finishes to modify the brightness of the filament; internal reflecting substances on the bulb to control the direction of the light: halogen gases and special tungsten filament. The number of starts does not affect the life of the lamp. They create comfortable colour lighting, are easy to dim, operate over a wide range of temperature and are cheap to purchase.

Linear fluorescent lamps

A fluorescent tube is a low-pressure discharge lamp which consists of a glass tube coated with phosphors, trace amounts of mercury and an electrode at each end of tube. An electric current flows between the electrodes creating a low intensity arc which excites the mercury vapour and produces mostly non visible (UV) radiation which in turn excites the phosphors which then emit visible light. Fluorescent have higher efficacy than incandescent lamps, producing 3 to 5 times as much light for a given input power and thus producing much less heat. Their life, although much longer than incandescent (6 to 8 times) depends on the wattage and the number of starts. They are not suitable for precise light beam control neither dimmable. They require additional ballast.

Compact fluorescent lamps

Compact fluorescent lamps (CFLs) usually consist of 2 or 4 small fluorescent tubes with a plug-in base or they may be a self-contained lamp (i.e. incorporating a ballast) with a screw in base or bayonet cap. They use the same rare earth as conventional fluorescent tubes to produce light similar to incandescent sources. CFLs are available in low wattage (7 to 26 W) and offer savings of up to 80% when used to replace incandescent. With conventional ballast, CFLs can generate 60 to 70 Lm/W. the average life expectancy is over 6 times that of an incandescent lamp.

Induction lamps

The only major new lamp type introduced recently, the induction lamp, is similar in efficacy, to a fluorescent tube , but with a much longer life (50 000 hours). They are very expensive and currently in limited use.

High intensity discharge lamps

These lamps consist of an arc tube in which the discharge occurs, surrounded by an outer envelope. They require control gear for starting and to maintain stable operating conditions. They fall into 3 distinct families: high pressure sodium (HPS), high pressure mercury (HPM) and metal halide (MH).

HPS have sodium within the arc tube and are the most efficient, producing a golden light of warm appearance but poor colour rendering. HPM are significantly less efficient than HPS but relatively simple and inexpensive. Improvements to both efficacy and colour properties result from the addition of metal halides to the mercury within the tube. These MH lamps are almost as efficient as HPS and have a good colour rendering. They are used to light high spaces (sport facilities...)

Ballast (control gear)

Ballast provides starting and operating voltages to discharge lamps and limits the amount of current during the operation of the lamp. They may include capacitors to correct the power factor. Standard electromagnetic ballast consists of an insulated wire coil wrapped around a metal core. Energy efficient electromagnetic ballast (low loss) are made with heavier wire and a better grade steel and can provide full light output at reduced wattage. The introduction of electronic ballast for fluorescent tubes has produced significant improvements in energy efficiency, around 20%. Electronic ballast converts input frequency to a higher frequency, resulting in more efficient ballast and also allowing for light output modulation.

Luminaries

The main change in luminaries technology is the change in light control from refraction and diffusion to reflection using mirror optics. This could lead to a great deal of improvement in efficiencies, provided that glare can be controlled properly.

Lighting control systems

Lighting control systems range from simple measures such as localised manual switches positioned close to the areas which they control, to more complex automatic systems based on time control, occupancy linking or photoelectric daylight linking. Their development has made dimming more readily available.

Side effects of improved lighting efficiency

Any reduction in energy use to provide a given lighting service, achieved by increasing the efficiency of the lighting system will reduce the incidental internal gains, which contribute to space heating. Apart from the light losses through windows, all lighting energy turns into heating and therefore the reduction in incidental gains will be not far from the energy saved. Still the efficiency of lighting as a space heater depends upon the correlation between demand for lighting and demand for space heating.

Building management systems and controls

Time Control Methods (for heating)

- Time switches turn on and off the heating (or water heating) system at pre-selected periods (of the day, of the week)
- Optimisers: these controls start the heating system in a building at a variable time to ensure that, whatever the conditions, the building reaches the desired temperature when occupancy starts.

Temperature control methods

- Frost protection generally involves running heating system pumps and boilers when external temperature reaches a set level (0°C) or less in order to protect against freezing
- Compensated systems: which control flow temperature in the heating circuit relative to external temperature thus allowing a rise in the circuit flow temperature when outside temperature drops.
- Thermostatic radiator valves: these units sense space temperature in a room and throttle the flow accordingly through the emitter (radiator and convector) to which they are fitted
- Modulating control: can be applied to most types of heat emitters and is used to restrict the flow depending on the load demand and thus controlling the temperature.
- Proportioning control: involves switching equipment on and off automatically to regulate output
- Other methods are thermostats, occupancy sensing (described hereafter for lighting control) and user interactive control

Lighting control systems

Different control systems exist, either based on time control or a required level of non-luminance or use of lighting.

- Zoning: Lights are switched on in zones corresponding to the use and layout of the illuminated areas, in order to avoid lighting a large area if only a small part of it requires light.
- Timed control: to switch on and off automatically in each zone to match a prerequisite schedule for light use.
- Occupancy sensing: In areas which are occupied intermittently, occupancy sensors can be used to indicate whether or not anybody is present and switch the light on or off accordingly. Detection systems are based on ultrasonic movement or infrared sensing.
- Light level control: this consists of switching or dimming artificial lighting to maintain a light level measured by a photocell. It is particularly necessary to give value to ambient day lighting.

Building Management systems

These technologies consist of both hardware and software. The hardware is typically represented by one (or more) control and processing units and by a number of other peripheral devices (which control the operation of say, heating or cooling systems, artificial light-sources or other appliances and which can also be represented by sensors, thermostats, etc.) connected to the control units. The control unit, based on the information supplied by some of the peripherals or based on pre-set instructions, runs the system. The control unit can be as simple as a relay or a timer switching on or off an electric water heater or as sophisticated as a microprocessor operating on «fuzzy logic». Commands can be sent from the central unit to the peripheral units through Ethernet cable, power-lines or telephone lines, or fibre-optic cables. The material «medium» through which commands and messages between the various parts of the system are exchanged is called BUS.

The software is simply the program and the instructions that allow the control unit to manage the operations of the peripheral devices and of the appliances.

Thermal energy storage

Thermal Energy Storage (later referred as TES) deals with the storing of energy by cooling, heating, melting, solidifying or vaporising a material, the energy becoming available as heat when the process is reversed

In practice it is useful to characterise the different types of TES depending on the storage duration:

ST-TES: Short term storage is used to face peak power loads of a few hours to a day long in order to reduce the sizing of systems and or to take advantage of energy tariffs daily structure (also called diurnal storage)

MLT-TES: Middle or long term storage is recommended when waste heat or seasonal energy loads can be transferred, with a delay of a few weeks to several months, to cover seasonal needs (also called seasonal storage). Seasonal heat storage systems comprise:

- *Hot convective storage*: still at the pilot stage, tests in France, Denmark and the US at temperatures between 120 and 180°C, demonstration in the Netherlands at 90°C
- *Warm convective storage*: has been largely associated to solar energy and is being little developed
- *Cold convective storage*: some impressive projects carried out in this field in China, Canada and Sweden. The stores are almost always connected to heat pumps.
- *Conductive storage*: these stores are being developed in Sweden and numerous small ones in Switzerland for individual dwellings or small communities

Last but not least, TES can be separated **into High and Low Temperature TES**, low temperature TES being defined to mean the storage of heat that enters and leaves the reservoir at temperatures below 120°C, storage of «cold» being also considered within this category. Storage of this type may permit efficient utilisation of heat that otherwise would have been partially or entirely wasted. In principle, Low Temperature TES permits the storage of heat obtained from solar radiation from day to night or from summer to winter. It permits the storage of heat from central power plants, from hours of low to hours of high demand on both a diurnal and seasonal basis.

It also permits the storage of cold for air conditioning purposes from night to day, from winter to summer. On a diurnal basis, the storage efficiency may well be above 90%, while on a seasonal basis it will usually not be much above 70%. Low Temperature storage has wide application in domestic water systems

- **ENVIRONMENTAL PRESSURES**

Land use

Due to the limited application area, environmental pressures in passive technologies are concentrated in a very small location generally in residential, public or industrial sector buildings.

Visual intrusion

Nowadays, modern architecture designs have smoothened any passive application technology that could provoke visual impact. Colours, materials and proper shapes are used in order to embrace any visual impact regarding passive construction.

Impacts during construction activities

- Emissions of dust and materials into the air from construction activity.
- There will be atmospheric emissions from: all plant and equipment used on site (transportation of the workforce to and from the site, and transportation of construction materials by heavy goods vehicles).
- The noise generated from vehicles and equipment on site may disturb local ecosystems as well as any nearby residents.
- There will also be an increased level of visual intrusion during the temporary construction period from site activity and vehicle movements of all personnel, plant and equipment present.

Emissions

Table 2.4.4: Emissions from building management systems

Building management systems			
(T/PJ)	CO2	SO2	NOx
Residential	56	0.18	0.32
Non-Residential	64	0.41	0.23

Table 2.4.5: Emissions reduction from insulation technologies in some EE countries

Insulation reduction				
	CO_2 (mtonnes)	SO_2 (1000tonnes)	NOx (1000tonnes)	Particulates (1000tonnes)
Indicative countries				
France	55	155	63	14
Germany	150	184	112	35
Italy	36	153	69	48
The Netherlands	40		30	
Spain	27			
UK	75	200	51	

- **REGIONAL PLANNING ISSUES**

The same framework as above outlines the passive planning issues.

3. WIND

- **COSTS**

Table 3.1: Indicative cost of wind application

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size (MW)	0.025	0.19	0.25	0.41	0.65	0.725	0.85
Capital cost (€/kW)	2250 - 3242	1568 - 2017	1176 - 1512	700 - 910	600 - 780	536 - 700	525 - 700
Operation and maintenance cost (€]/kW)	50 - 75	40 - 60	30 - 45	20 - 30	17.6 - 26.4	16.6 - 25	16 - 24
Cost of energy (8% discount rate – (€/kWh)	0.22 - 0.57	0.11 - 0.28	0.067 - 0.17	.030 - .077	0.025 - 0.065	0.022 - 0.058	0.021 - 0.054

- **TECHNOLOGIES**

The most common wind turbines in operation today generate power from two or three blades revolving around a horizontal axis and are mounted on towers. Such horizontal-axis wind turbines usually include a gearbox, generator, and other supporting mechanical and electrical equipment.

Horizontal Axis Wind Turbines
Most of the technology is related to horizontal axis wind turbines (HAWTs). All grid-connected commercial wind turbines today are built with a propeller-type rotor on a horizontal axis (i.e. a horizontal main shaft).

Vertical Axis Wind Turbines
Vertical axis wind turbines (VAWTs) are a bit like water wheels in that sense. (Some vertical axis turbine types could actually work with a horizontal axis as well, but they would hardly be able to beat the efficiency of a propeller-type turbine).

Upwind Machines
Upwind machines have the rotor facing the wind. The basic advantage of upwind designs is that one avoids the wind shade behind the tower. By far the vast majority of wind turbines have this design.

Downwind Machines
Downwind machines have the rotor placed on the lee side of the tower. They have the theoretical advantage that they may be built without a yaw mechanism, if the rotor and nacelle have a suitable design that makes the nacelle follow the wind passively. For large wind turbines this is a somewhat doubtful advantage, however, since you do need cables to lead the current away from the generator.

Most modern wind turbines are **three-bladed designs** with the rotor position maintained upwind (on the windy side of the tower) using electrical motors in their yaw mechanism. This design is usually called the classical Danish concept, and tends to be a standard against which other concepts are evaluated. The vast majority of the turbines sold in world markets have this design. Another characteristic is the use of an asynchronous generator.

Two-bladed wind turbine designs have the advantage of saving the cost of one rotor blade and its weight, of course. However, they tend to have difficulty in penetrating the market, partly because they require higher rotational speed to yield the same energy output. This is a disadvantage both in regard to noise and visual intrusion. Lately, several traditional manufacturers of two-bladed machines have switched to three-bladed designs.

One-bladed wind turbines save the cost of another rotor blade. One-bladed wind turbines are not very widespread commercially, however, because the same problems that are mentioned under the two-bladed design apply to an even larger extent to one-bladed machines.

Wind turbines are rated by their **maximum power output in kilowatts (kW)** or megawatts (1,000 kW, or MW). For commercial utility-sized projects, the most common turbines sold are in the range of 600 kW to 1 MW – large enough to supply electricity to 600-1,000 modern homes. The newest commercial turbines are rated at 1.5-2.5 megawatts. A typical 600 kW turbine has a blade diameter of 35 metres and is mounted on a 50 metre concrete or steel tower.

- **ENVIRONMENTAL PRESSURES**

Visual amenity

Visual intrusion from wind turbines is extremely site-specific and depends on a number of factors, including:

- The physical size of the turbine
- The distance from the turbines to the receptor
- The numbers and design of the turbines
- The layout of the wind farm
- Indigenous population density within the zone of visual influence
- The number of visitors
- The landscape type and the availability of alternative 'unspoilt' areas
- Weather conditions and local topography
- Individual's attitudes to scenery and natural beauty, perceptions of the existing level of visual amenity and attitudes to wind energy.

Visual impacts are only normally important for residents and tourists up to a distance of about 10 kilometres, with the main effects on amenity being concentrated within a few kilometres of the wind farm. Nonetheless, visual amenity can prove an important issue for wind turbines in areas of high landscape quality. However, there has been considerable opposition to the visual impacts of wind farms. In general, this occurred with early schemes where the developers had not given sufficient consideration to the choice of sites. Tree planting or similar screening close to the observer can mitigate the visual impact of turbines. Furthermore, the selection of certain colours, structures and layout of turbines can help to minimise intrusiveness. Provided care is taken in site selection and turbine layout, and careful planning conditions are enforced, the true visual impacts of wind energy schemes are generally small and extremely localised. Finally, the opposition to such schemes can be further reduced by involvement of the local community at the planning stage and also through participation.

Land use

Individual wind farm turbines are separated by 5 - 10 diameters, in order to reduce interaction effects. The total area of a wind farm can thus be considerable. For example, wind turbine densities of 18 turbines per square kilometre are typical (corresponding to a total area of one square kilometre for a 6-8 MW wind farm). However, the area actually occupied by individual wind turbines is relatively small, typically only 40 m^2 per turbine, or less than 0.1% of the wind farm area (though this increases to around 1% if access roads and equipment housing is included). Therefore, the level of impact depends on whether the land between turbines can be used. There are numerous examples of agricultural practices continuing in wind farm areas and evidence suggests that neither wild nor domesticated animals will be affected by a wind farm (UKDOE, 1993).

Noise

Although noise will arise from turbine manufacture, transportation and construction, the dominant source of noise is from the operation of the turbines. These emit two major types of noise: aerodynamic and mechanical. Aerodynamic noise is generated by the passage of air over the moving blades. Mechanical noise can be generated by all of the moving parts in the nacelle.

The potential impact of a noise source depends upon a number of factors, which include:

- The level of emissions relative to background noise
- The nature of the noise (tonal and broad band content)
- Topography and meteorological conditions
- The number of people exposed to the noise source
- Individual tolerance of noise in general and attitude towards the development

Therefore, the impact of noise is extremely site-specific. To date, noise has been one of the principle concerns over the introduction of wind energy. In cases of inappropriate sitting, impacts have occurred and these have resulted in considerable public opposition

The noise generated from wind turbines is much less than that from other industrial activities and, as such, it does not normally come into the regime covered by national regulations. As an example, the noise level at nearby houses due to wind turbines is often less than 40 dB(A) L_{Aeq}. As an indication of the relative level of this noise, it is less than the background noise level outside 97% of UK homes (UKDOE, 1993).

Electromagnetic interference

The rotating blades of wind turbines can scatter electromagnetic signals causing interference in a range of communication systems. The signals can be reflected from turbine blades, so that nearby receivers pick up both a direct and reflected signal (Eyre, 1995).

The electrical devices that may be affected include:

- Television broadcasts
- Microwave links, which are used by a range of large organisations for communications
- VHF Omni-directional Ranging (VOR) used for aircraft navigation
- Instrument Landing System (ILS) used by aircraft on approach to landing
- Radar
- Safety of Life at Sea (SOLAS) transmissions
- LORAN - a long range navigational system which uses a low frequency
- Cellular radio for portable telephones
- Satellite communications

Only the first four categories are likely to be affected in practice (Taylor and Rand, 1991; Eyre, 1995). However, this still constitutes a high density of signals for many areas and therefore a potential constraint to deployment. Most of the potential problems can be avoided by mitigation measures or by assessing for sensitive sites prior to development

Ecology (birds, terrestrial ecosystems)

The major potential impacts on birds are behavioural disturbance (e.g. from construction activities, from the physical presence of the turbines) and collisions with rotating turbine blades. The effect of disturbance on bird populations is thought to be very small and most attention has focused on the effects of bird strike.

The risk of collision between turbine blades and birds is minimal both for migrating birds and for birds from local habitats. However, in ecologically sensitive areas or areas designated for their ornithological value, developments should be carefully examined. An environmental assessment of a proposed project can easily identify any such area.

The land used for the sitting of wind farms may lead to the loss of natural habitats or agricultural land. In less intensively farmed land (such as upland pasture or forests) or non-agricultural areas, there may be impacts on unmanaged ecosystems. The long-term loss of the land (from turbines, ancillary buildings and access tracks) and the temporary construction activities could affect terrestrial ecosystems. Construction activities have the greatest potential effects. However, these are generally small and reversible, with rapid reform of the disrupted land from the surrounding system after work has finished. The only exceptions are where access roads lead to increased intrusion and where there are very fragile ecosystems

Emissions

Table 3.2: Emissions from wind application

Parameter	**Value**
Emission factor - CO_2 (kg/TJ)	0
Emission factor - SO_2 (kg/TJ)	0
Emission factor - NO_x (kg/TJ)	0
Emission factor - Particulates (kg/TJ)	0
Emission factor – VOCs* (kg / TJ)	0
Emissions during construction - CO_2 (kg / TJ)	1794
Emissions during construction - SO_2 (kg / TJ)	4.2
Emissions during construction - NO_x (kg / TJ)	5.6

*non volatile organic compounds

- **REGIONAL PLANNING ISSUES**

Wind projects falls under the above urban and regional planning issues.

4. HYDRO

- **COSTS**

In the past, hydropower stations were often built as a part of large dam projects. Due to the size, cost, and environmental impacts of these dams (and the reservoirs they create), hydro developments today are increasingly focused on smaller-scale projects.

Table 4.1: Indicative cost of hydropower application

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size (MW)	0.001-10	0.001-10	0.001-10	0.001-10	0.001-10	0.001-10	0.001-10
Capital cost (€/kW)	850-4500	830-4000	810-3500	800-3000	790-2500	770-2000	750-1800
Fixed operation and maintenance cost (€/kW)	15-25	15-25	15-25	15-25	15-25	15-25	15-25
Fuel cost (€/kWh)	None	None	None	None	None	None	None
Cost of energy derived from above data, using 8% discount rate (€/kWh)	0.02-0.17	0.02-0.15	0.019-0.13	0.019-0.12	0.019-0.1	0.019-0.08	0.018-0.07

- **TECHNOLOGIES**

Hydropower technology has been extensively deployed throughout the world at both large and small scale for electricity generation, and at small scale for mechanical power. This generally places hydropower at an advantage over other renewable technologies for new deployment, since operational or abandoned schemes are often available within the target country. Operational, design and construction experience may well also be available there. The technology is technically and commercially mature. Small-scale hydro schemes can make a useful contribution to rural electrification strategies, presenting a suitable alternative to decentralized diesel generation, particularly where fuel supply is a problem.

Small-scale hydropower schemes (generally considered as those with installed capacity of <10MW/site) generate electricity or mechanical power by converting the power available in flowing water in rivers, canals or streams. The principal requirements are:

- a suitable rainfall catchment area
- a hydraulic head
- a means of transporting water from the intake to the turbine, such as a pipe or millrace
- a turbine house containing the power generation equipment and valve gear needed to regulate the water supply
- a tailrace to return the water to its natural course
- a mechanical or electrical connection to the load to be supplied.

Large-scale hydropower schemes follow the same principle of operation, but generally include large dams and storage reservoirs, to retain water for generation as required to match demand. Pumped-storage hydropower stations involve the pumping and discharge of water through turbines between an upper and a lower reservoir. Generation can thereby be matched to the demand on a distribution network, with benefits of rapid peak load response and network voltage stabilization. Such systems are however a net energy consumer, and should not be considered only as renewable projects.

- **ENVIRONMENTAL PRESSURES**

Impacts from construction activities

The main impacts have been listed below:

- Emissions of dust and materials into the water from construction activity will result in an increase in both suspended matter and turbidity downstream. This may have impacts on aquatic species and may also reduce the river's attractiveness to the public. The excavation can exacerbate all these impacts and dredging involved in preparing the impoundment area. Well-planned operations should reduce emission levels.
- There will be atmospheric emissions from: all plant and equipment used on site, transportation of the workforce to and from the site, and transportation of construction materials by heavy goods vehicles. This additional traffic, often in remote areas, will also produce noise, increase public road accidents, etc. In addition, in many cases it is necessary to build additional access roads. These roads may have knock on effects, particularly in remote areas, by altering the access to the area. Water transport is an alternative for transporting materials, etc. but is generally more expensive and slower.
- The noise generated from vehicles and equipment on site may disturb local ecosystems as well as any nearby residents. At some sites, significant noise may be generated if, for example, blasting is required during excavation.
- There will also be an increased level of visual intrusion during the temporary construction period from site activity and vehicle movements of all personnel, plant and equipment present.
- Occupational accidents may occur, though these are common to any construction activity. The construction sector has one of the highest occupational accident rates per employee (EC, 1995b).
- There are also impacts from the impoundment reservoirs, (i.e. from the small dams that comprise the intake pools for high-head schemes or the dams/weirs for low-head schemes). The flooding of land may affect agriculture, local infrastructure and archaeological or conservation sites (including areas of cultural or religious significance). The flooding will cause a visual impact on the landscape and may produce changes in the local water table and alter the local ecosystem through changes to both aquatic and terrestrial habitats. The construction of a weir or dam will cause significant ecological disruption to the flora and fauna in and around the river, though non-sensitive species usually recover within six months (Carpenter, 1994).

Visual intrusion

For well developed sites, the visual intrusion of small-hydro schemes is minimal. Nonetheless, these effects, whilst small, can be important, as suitable sites for small hydro schemes may be in environmentally sensitive areas or areas of natural beauty. For all schemes, the buildings and structures provide the most obvious source of visual impact.

With high-head schemes, the distance between the headworks and the tailrace may be as much as 1000 metres and the diverted water flow in a channel or pipe can give rise to a striking linear feature. However, the visual appearance of the water channels need not be detrimental to the landscape. The headrace must possess an incline, which is determined by the requirements of the turbine. Where a penstock pipeline is proposed, this will usually follow the most direct route, but where feasible the pipeline can be buried or screened. In order to minimise the length of the tailrace, the scheme will normally site the turbine house on or near the river bank and this may be relatively easy to screen by tree planting. In practice, the turbine itself can be partially buried underground (IEA, 1998).

Low-head schemes tend to have a more pronounced visual appearance. The formation of a storage reservoir, even a small one, is a marked alteration to the visual appearance of an area, though it is the concrete dam which usually has the most impact. To some extent, this can be avoided by retrofitting installations into existing reservoir dams, as this involves negligible additional visual intrusion. Indeed, at an existing site, the visual impact will usually be limited to the local area of the turbine house. Sympathetic design, the use of existing buildings and traditional materials should all minimise visual impact. Other visual impacts are the intake and outfall screens, sluice gates and fish passes. There will also be an access track required to the turbine building and possibly to the intake location. An important visual impact is to retain a residual flow of free falling water over existing weir structures during low flow periods. In addition, the aesthetics of the scheme may become more positive, if the site is allowed to age into the surrounding area over time (i.e. vegetation growth over buildings, etc.).

Impacts to ecosystems from changes in water quality and flow

Hydro schemes can disrupt aquatic ecosystems, particularly with diversion schemes in the length of river between the water abstractions and return point. Of all the potential impacts, those on fish populations (both commercial and recreational fisheries) are generally perceived to be the most important. A key part of the design process is to prevent such impacts, and technological measures exist to mitigate most significant impacts.

The impacts on fish migration can be minimised in a number of ways:

- The use of fish passes to allow the upward migration of fish. These should be installed on rivers with migratory species.
- The installation of grids (or other diversion methods) across water intakes and tailraces prevents the entry of fish into the turbine. Good practice uses double sets of screens and guides across the flow, so that intakes are not left unscreened

during cleaning operations. It is important that such mitigation measures are installed in an appropriate system, for example, fish may be trapped by rapid water flow if grids are used on their own. For this reason, louvre diversion screens are often used upstream of the grid, to divert descending smolts away from intakes, especially where the water velocity is sufficient to carry fish into a by-pass channel. Advances in developing technologies (such as acoustic barriers) will further improve mitigation efficiency.

The changes in water flow, as well as increases in sediment and other matter in suspension can lead to the disappearance of habitats. The alteration of water flow, such as the broadening of the stream bed and reduction of current may lead to indigenous fish species being reduced or replaced. For instance, there may be a disappearance of fast water fish (salmonid, trout etc.) with losses in recreational fisheries (albeit small), though this may be countered by increases in calm water species (e.g. bream). Schemes that cause a reduction in water flow have the potential to affect the concentration of water-borne pollutants (which could also act as a barrier to fish migration) and pathogens. There will also be changes in other aquatic species and local habitat with variations in the local types of animals, birds and vegetation. These changes are likely to be very localised and minor, though proposals for sites in areas of ecological importance should be rigorously examined or avoided because of the impact on sensitive plant and animal life.

A completed hydroelectric scheme is unlikely to have serious effects on the local flora and fauna, but the effect on local drainage should be investigated. The ecology of an area can also be affected permanently by the establishment of a mill-pond behind the dam on a low-head scheme. This may flood several hundred square metres of original habitat, but will result in a new habitat which will attract other fauna (e.g. dragonflies, waterside birds and fish).

Water quality

Hydropower schemes can affect water quality in a number of different ways, though individual impacts from any development are very site-specific. High-head upland schemes can exercise a large measure of control on the river flow between the diversions and return points, which may be a considerable distance apart. In contrast, hydropower developments on lowland rivers may have little effect on flows as water tends to be abstracted immediately above the weir and discharged immediately downstream of it.

The introduction of a small-scale hydro scheme may affect the aeration levels in the river. For some schemes, aeration of the water either at the turbine or at the weir increases dissolved oxygen levels and therefore improves water quality. However, for some dams, the installation of hydropower schemes can reduce aeration levels, which can have a detrimental effect on aquatic ecosystems.

Hydro schemes may change the level of suspended solids in the river water, thereby affecting siltation, erosion, visual amenity and aquatic ecosystems. Impounded water generally becomes sediment heavy, whereas discharge water is sediment deficient. These changes can alter the sediment load of the river and thus alter deposition and erosion characteristics. The disruption of natural flow patterns may cause increased deposition or erosion, which can affect species and agriculture downstream. In addition, the release of water from hydroelectric schemes can enhance local river bed scour, leading to enhanced sedimentation downstream. The changes in solid levels may affect a number of fish and other aquatic species and can be particularly important in spawning areas.

Impacts on recreational activities

Small-scale hydro schemes may affect recreational activities, although the overall balance of advantages and disadvantages can vary from scheme to scheme. Some of the possible affected activities include fishing, hiking, skiing, boating, hunting, picnicking and swimming. Impacts include:

- The scheme may have visual and aesthetic impacts, adversely effecting recreational activities; for instance, the loss of aesthetic or wilderness values (caused by developments in scenic and pristine areas) can affect the pleasure of hiking.
- The scheme may present a physical barrier to certain activities; for example changes in flow direction, bank side works and revetment may affect angling and it may become impossible to fish. Public rights of way may be temporarily or permanently altered and there may be barriers to commercial or recreational traffic, or impacts on navigation.
- Any reductions in current can have an influence on canoeing or other fast water activities. Sailing and rowing may be affected by changes in flow directions and water levels.

Emissions

Table 4.2: Emissions from hydropower application

Parameter	**Value**
Emission factor - CO2 (kg/TJ)	0
Emission factor - SO2 (kg/TJ)	0
Emission factor - NOx (kg/TJ)	0
Emission factor - Particulates (kg/TJ)	0
Emission factor – VOCs* (kg / TJ)	0
Emissions during construction - CO2 (kg / TJ)	2400
Emissions during construction - SO2 (kg / TJ)	7
Emissions during construction - NOx (kg / TJ)	19

*non volatile organic compounds

- **REGIONAL PLANNING ISSUES**

Hydropower application planning issues are as presented above under the same framework for RES.

5. BIOMASS

- **COSTS**

HEAT PRODUCTION

Table 5.1: Indicative cost of biomass heat production application

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size (MWt)	5	5	5	5	5	5	5
Capital cost (€/kW)	1300	1200	1000	940	800	600	500
Operation and maintenance cost (€/kW)	26	24	20	19	18	12	10
Fuel cost (€/kWh)	0.0055	0.005	0.005	0.005	0.0045	0.004	0.004
Cost of energy derived from above data, using 8% discount rate (c€/kWh)	6.9	6	4.9	4.7	3.8	2.8	2.3

ELECTRICITY PRODUCTION

Table 5.2: Indicative cost of biomass electricity production application

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size (MW)							
Top: Gasification				6	32	33.3	53
Centre: Co-firing				50			50
Bottom: Steam cycle	2-15	5-50	5-25	28	5-25	5-25	5-25
Capital cost (€/kW)							
Top: Gasification	20	20	20	20	20	20	20
Centre: Co-firing				5000	2100	1470	1200
Bottom: Steam cycle				1050			900
Operation and maintenance cost (€/kW) *Top: Gasification*					0.011	0.008	0.006
Centre: Co-firing				0.006			0.005
Bottom: Steam cycle	0.01	0.01	0.01	0.01	0.01	0.006	0.006
Fuel cost (€/kWh)							
Top: Gasification					0.01-0.024	0.01-0.018	0.01-0.015
Centre: Co-firing				0.01-0.03			0.01-0.015
Bottom: Steam cycle				0.01-0.04	0.01-0.03	0.01-0.03	0.01-0.02

- **TECHNOLOGIES**

HEAT PRODUCTION

Technology for biomass heat can be split into a number of categories which are listed below.

Domestic heat production

Single stoves and furnaces have, together with central heating, the biggest share of the biomass market in Europe (e.g. in Austria 67%), it is an established market, but decreasing. At present there is a great variation in the quality of wood burning equipment. While state of the art boilers produce extremely low emissions, standard equipment for domestic heating has unacceptably high emissions.

Micro grids

Micro grids are down-scaled district heating units that have seen significant growth rates recently in some countries (e.g. Austria), due to their commercial advantages.

District Heating:

- *small scale plants*
- *large scale plants*

These plants are operating in the Nordic countries in large district heating systems.

Process heat in industry

Wood fuel use in the forest industry and the pulp and paper industry is routine business.

ELECTRICITY PRODUCTION

To generate electricity from biomass two systems, of quite different character, need to work together. These are a supply system that produces, collects and delivers the fuel, and a power station that generates, and sells, the electricity. This section of the module describes briefly the current and future technologies that can be used in these systems and the way in which the two influence each other.

Technologies for biomass combustion

There are two main types, grate and fluidized bed combustion. The first is a traditional technology developed for coal combustion and the combustion of municipal solid waste whilst the second is a fairly recent innovation. A third possibility is powder suspension firing, a modern technology used for coal combustion.

In grate firing the fuel burns in a layer on a grid. Air for combustion is blown both through the grid and over the top of the fuel layer. Various types of grids or grates have evolved to move the fuel through the boiler and eventually remove the ash. Some grates vibrate, some move slowly forward on chains whilst others have a reciprocating action. Whilst reliable, and relatively inexpensive, grate firing systems are also somewhat inflexible and are usually designed to cope with a limited range of feedstock.

In a fluidized bed boiler the fuel burns in a bed of sand or other mineral that is violently agitated by the combustion air. The fuel is fed at a controlled rate to keep the temperature of the bed at 800 - 900 ^{o}C. Steam tubes in the walls of the boiler and the economizer remove heat. This type of boiler is proving very popular for medium to large industrial boilers for coal and other solid fuels and is taking an increasing share of the market.

Power generation technologies

Conventional steam cycle plant

In this technology biomass is burned in an excess of air to produce heat, which is in turn used to raise high-pressure steam in a boiler. The energy stored in the steam is converted into electricity by expanding it through a turbine, which in turn drives an electrical generator. For pure electricity generation the steam is expanded down to a very low pressure in a condenser. If CHP is required then the steam condenses at a higher pressure in the water heater. The higher the steam temperature and pressure used the greater is the efficiency of the overall plant.

Gasification and other advanced processes

Advanced conversion processes offer methods of power generation with higher efficiencies than combustion-based steam cycles. These high efficiencies are achieved by first converting the solid biomass to liquid or gaseous fuels then burning these intermediates in engines or gas turbines. The heat is thus converted to power at a higher temperature than in the steam cycle making advanced conversion processes thermodynamically more efficient.

Co-firing with fossil fuels

The concept is to fire a proportion of biomass with a fossil fuel in an existing power plant. The way in which the biomass is fired depends upon the proportion:

- for minor quantities (2- 5%) the biomass can be mixed with the coal at the inlet to the mill;
- for larger quantities (5 - 25%) the biomass should be shredded finely and fired through dedicated burners. This involves considerable expense and energy, and
- for major quantities (above 25%) there will be a substantial impact on the furnace and ash behavior that will probably necessitate gasifying the fuel and firing it through a gas burner. This will involve substantial expense.

- **ENVIRONMENTAL PRESSURES**

For all technologies, the major environmental burdens are (IEA, 1998):

- Impacts from the construction of the combustion plant (emissions, noise, accidents, land use, effects on local ecosystems, etc.)
- Collection and transportation of waste (noise, transport emissions, accidents, etc.)
- Impacts on agricultural and forestry practices from crop or residue removal (soil condition, runoff, etc.)
- Impacts on amenity from the site (visual intrusion, odour, noise, etc.)

ENERGY CROPS

Many of the impacts, particularly those associated with cultivation will vary according to the type of crop, in particular whether it is an annual or perennial crop or one that is harvested in cycles. In addition, the significance of many of the impacts associated with cultivation will depend on the type of land that the energy crop plantation is compared with (arable farming, unfarmed land, etc.). The main environmental impacts are:

- Impacts from cultivation of the energy crop (use of agrochemicals, soil erosion and visual intrusion)
- Impacts from the construction of the combustion plant (emissions, noise, accidents, effects on local ecosystems, etc.)
- Collection and transportation of the energy crop (noise, transport emissions, accidents, etc.)
- Atmospheric emissions from combustion
- Solid waste
- Impacts on amenity from the site (visual intrusion, noise, etc.)

Agrochemical use

Herbicides

Herbicides may be used to prepare ground prior to planting coppice and again in the first and second years after planting, because uncontrolled weeds can seriously reduce the successful establishment of the crop. However, applications in further years should not be required because the coppice should be established and canopy closure should occur. The use of herbicides in the initial stages leads to a loss in floral diversity but, as the coppice becomes established, floral diversity should return (ETSU, 1994). Herbicides could also enter surface waters through atmospheric drift, surface runoff, erosion and/or direct spills. These impacts will depend on the diluting power of the receiving water body. Good farming practice can minimize these impacts.

Fertilizers

The rates of application of fertilizer are likely to vary significantly with climate, soil conditions and the type of crop. The main impact of fertilizer use is nitrate leaching into water bodies, particularly ground water. In waters used as a drinking supply, nitrate levels are generally monitored and controlled to a maximum concentration due to the risk of methemoglobilemia (blue baby syndrome) in infants. High nitrate levels in streams, rivers and lakes can lead to eutrophication. Overall the impact of energy crops in this respect is likely to depend on the type of land use, which the energy crop replaces. If the land was previously used for arable crops, then fertilizer use and consequent nitrate leaching is likely to be reduced. However, if energy crops are grown on land which was previously unfertilized, the introduction of fertilizers would bring about the potential for nitrate leaching.

Pesticides

The use of pesticides, insecticides and fungicides is very site specific and, in many cases, their use may be considered impractical due to the low-value nature of the crop. It is possible that, since coppice provides a semi-stable habitat, it may be possible to develop more natural mechanisms to control pests and diseases (ETSU, 1994).

Soil erosion

The impacts of soil erosion and runoff of soil into streams and rivers can include: increased water turbidity, stream scouring, silting and increased concentrations of nutrients or pesticides. Most of the soil removed by erosion is expected to settle in stream beds and reservoirs, where it could lead to an increased need for dredging and clogging of drainage ditches as well as having an impact on flood control measures. Soil remaining suspended in the water could increase its turbidity, which, in the case of surface waters used for public water supply, could increase the amount of water treatment needed. The impact on aquatic fauna will depend on the stream size and existing characteristics but it may be adverse for small clear-water streams, where suspended sediment concentrations can be a long-term stress on aquatic organisms.

Biodiversity and Habitat

The impact of energy crops on habitat and biodiversity depends not only on the previous land use and cultivation but also on the nature of the energy crop. Plantations of perennial woody coppiced crops allow an understorey and ground vegetation to develop, so that there is some floral diversity and a habitat for insects and birds. The need for margins at the edges of fields and wide paths through plots (to allow harvesting) also provides a diversity of habitats.

Impacts from plant construction

The construction phase (excavation, civil works, mechanical and electrical work, etc.) is a potential source of many environmental burdens.

- There will be atmospheric emissions from all plant and equipment used on site. However emissions from these will be low in comparison with those arising during operation of the plant.
- Noise will be generated from construction site vehicles and equipment, which may disturb local residents and ecosystems. Typical sites for energy crops would usually mean that there would be few local residents.
- There will be increased visual intrusion from site activities.
- There will be emissions from road transport of personnel and material, with atmospheric pollutant, dust, noise and increased traffic.This can be particularly important, as many plants are located in rural areas. However, these impacts will be of limited duration.

Visual intrusion

Energy crops are likely to be grown in a rural or semi rural environment. There are three aspects of energy crops, which may cause visual intrusion:

- The energy crop plantations themselves
- Silos or barns for energy crop storage
- The combustion plant

AGRICULTURAL AND FORESTRY WASTE

Dry combustion of straw

Impacts from plant construction

The construction of the power plant (excavation, concreting, mechanical and electrical work, etc.) is a potential source of many environmental burdens. The impacts will be equivalent to a civil engineering project of a similar scale. They include:

- Atmospheric emissions from all plant and equipment used on site. Emissions from these activities will be low in comparison with those from operation of the plant
- Noise from work-site vehicles and equipment, which may disturb local residents and ecosystems
- Increased visual intrusion from site activities
- Emissions from road transport of personnel and material, with atmospheric pollution, dust, noise and increased traffic. This can be particularly important, as many plants are located in rural areas.

Impacts on agriculture

Even in the absence of energy recovery schemes, straw will generally be removed from the field for alternative uses. However, if no market exists for the straw, it may be ploughed back into the field (assuming burning is banned).

The combustion of straw does produce an ash residue, which has some value as a fertiliser and can be returned to the soil. However, this requires an additional transport phase to the original cereal field and is unlikely in practice, because the ash residue is not a complete fertiliser. Therefore, it is more likely to be used as a base for agricultural fertilisers.

Dry combustion of forestry waste

The removal of forestry residues for energy recovery has a number of positive and negative impacts on forestry practices and on the forest ecosystem. These must all be considered in evaluating the use of this waste as a source of energy. The benefits of removing forest residues are:

- Sites are less likely to develop disease problems when cleared of residues
- The removal of residues makes forests more visually attractive during the post-harvesting period. This has a positive impact on local amenity
- Sites are easier to replant (though young trees subsequently have less shelter)
- The risk of forest fire is reduced in drier climates

- It encourages good practice. In some areas, residues are collected, bulldozed into heaps and burnt. The use of residues for energy recovery prevents such activities because of the greater economic benefits of using the waste

Balanced against these benefits are a number of potential burdens, including:

- Clearing residues may remove a source of nutrients from the forest
- The loss of the residues from the forest floor generates more surface runoff, which in turn can lead to soil erosion. This process may compound the problem of nutrient loss from brash removal
- The residues act as a mat, over which machinery can operate. When this is removed, compaction damage can occur, which indirectly affects tree growth by increasing surface run-off and soil erosion and by reducing root growth. Such compaction effects can be largely mitigated by vehicle design (i.e. larger wheels with a higher surface area and thus lower ground-pressure). However, on certain soils (such as peat) there may still be residual compaction problems even when ewer machinery is used

Dry animal waste

The potential benefits and impacts from the combustion of dry animal wastes are similar to the discussion presented above for straw and forest residues. All carbon dioxide emissions from combustion are of a biomass nature and the waste generally has low sulphur content.

For most animal waste schemes, the waste must be stored, to build up a buffer of waste. This may cause some problems. For example, there have been some concerns regarding the storage of poultry litter because of potential odour or pathogen spread. However, such potential problems can be mitigated. To reduce odour, the heat produced at on-farm facilities can be used in poultry houses, allowing ventilation rates to be increased and resulting in a drier litter. To prevent pathogens, the stored waste can be composted, which raises its temperature and destroys many of the pathogens present.

Wet animal waste

Impacts on agriculture and local ecosystems

Untreated, livestock slurries represent a potential source of pollution, especially of water courses. Even after a primary treatment (i.e. typically, the waste is left for a minimum of four months before spreading on land) over-application of such waste can result in excess nutrients, leading to groundwater or surface water contamination.

Using the waste as an energy source can diminish these and other potential problems:

- Odour problems will usually be diminished (because of the need to collect as much of the methane as possible), but there may be some residual odour close to the storage area.
- Nitrate leaching is reduced provided the waste is treated sufficiently before being used as a fertiliser

- The risk of spreading pathogens and parasites is diminished and this is particularly important in cases where the liquid is spread on pastures on which animals graze, because it reduces the risk of cross infection

Emissions

HEAT PRODUCTION

Table 5.3: Emissions form biomass heat production application

Parameter	**Value**
Emission factor - CO_2 (kg/TJ)	1836 - 2463
Emission factor - SO_2 (kg/TJ)	5.3 - 7.8
Emission factor - NO_x (kg/TJ)	38.4 - 166
Emission factor - Particulates (kg/TJ)	2.5 - 79.3
Emission factor - VOCs * (kg / TJ)	7.3 - 111
Emissions during construction - CO_2 (kg / TJ)	240
Emissions during construction - SO_2 (kg / TJ)	1.9
Emissions during construction - NO_x (kg / TJ)	0.7

*non volatile organic compounds

ELECTRICITY PRODUCTION

Table 5.4: Emissions from biomass electricity production application

Parameter		Value
Emission factor - CO_2 (kg/TJ)		
	Top: Gasification	3900
	Centre: Co-firing	
	Bottom: Steam cycle	5510
Emission factor - SO_2 (kg/TJ)		
	Top: Gasification	13
	Centre: Co-firing	
	Bottom: Steam cycle	23.5
Emission factor - NO_x (kg/TJ)		
	Top: Gasification	118
	Centre: Co-firing	
	Bottom: Steam cycle	497
Emission factor - Particulates (kg/TJ)		
		10
		238
Emission factor – VOCs* (kg / TJ)		
	Top: Gasification	3.6
	Centre: Co-firing	
	Bottom: Steam cycle	333
Emissions during construction - CO_2 (kg / TJ)		
	Top: Gasification	722
	Centre: Co-firing	
	Bottom: Steam cycle	722
Emissions during construction - SO_2 (kg / TJ)		
	Top: Gasification	6
	Centre: Co-firing	
	Bottom: Steam cycle	6
Emissions during construction - NO_x (kg / TJ)		
	Top: Gasification	2.3
	Centre: Co-firing	
	Bottom: Steam cycle	2.3

*non volatile organic compounds

- **REGIONAL PLANNING ISSUES**

Biomass projects planning issues falls (see above) under the general description of planning regarding RES.

6. WAVE

- **COSTS**

Table 6.1: Indicative cost of wave power application

Technical data	1995	2000	2005	2010
Typical unit size (MW)	2	3.5	3.5	3.5
Capital cost (€/kW) lowest	1600	1470	1400	1400
Operation and maintenance cost (€/kW)	32	45	45	45
Fuel cost (€/kWh)				
Cost of energy derived from above data, using 8% discount rate (€/kWh)	0.08	0.07	0.06	0.06

- **TECHNOLOGIES**

Shoreline devices

Shoreline devices have the advantage of relatively easier maintenance and installation and do not require deep-water moorings and long underwater electrical cables. The less energetic wave climate at the shoreline can be partly compensated by the concentration of wave energy that occurs naturally at some locations by refraction and/or diffraction. The three major classes of shoreline devices are the oscillating water column (**OWC**), the convergent channel (**TAPCHAN**) and the **Pendulor.**

The **OWC** comprises a partly submerged concrete or steel structure, which has an opening to the sea below the water line, thereby enclosing a column of air above a column of water. As waves impinge on the device, they cause the water column to rise and fall, which alternately compresses and depressurises the air column. This air is allowed to flow to and from the atmosphere through a turbine which drives an electric generator. Both conventional (i.e. unidirectional) and self- rectifying air turbines have been proposed. The axial-flow Wells turbine, invented in the 1970s, is the best known turbine for this kind of application and has the advantage of not requiring rectifying air valves.

The **Tapchan** comprises a gradually narrowing channel with wall heights typically 3 to 5 m above mean water level. The waves enter the wide end of the channel and, as they propagate down the narrowing channel, the wave height is amplified until the wave crests spill over the walls to a reservoir which provides a stable water supply to a conventional low head turbine.

The **Pendulor** device consists of a rectangular box, which is open to the sea at one end. A pendulum flap is hinged over this opening, so that the action of the waves causes it to swing back and forth. This motion is then used to power a hydraulic pump and generator.

Nearshore devices

Nearshore devices are situated in shallow waters (typically 10 to 25 m water depth). Again the OWC is the main type of device with several designs having been deployed worldwide.

Offshore devices

Offshore devices are situated in deeper water, with typical depths of more than 40 m.

Some of the representative devices that have been deployed are shown below:

- The Swedish Hosepump has been under development since 1980. It consists of a specially reinforced elastomeric hose (whose internal volume decreases as it stretches), connected to a float which rides the waves. The rise and fall of the float stretches and relaxes the hose thereby pressurising sea water, which is fed (along with the output from other Hosepumps) through a non-return valve to a central turbine and generator unit.
- The McCabe Wave Pump consists of three rectangular steel pontoons which move relative to each other in the waves. The key aspect of the scheme is the damper plate attached to the central pontoon, which ensures that it stays still as the fore and aft pontoons move relatively to the central pontoon by pitching about the hinges. Energy is extracted from the rotation about the hinge points by linear hydraulic pumps mounted between the central and two outer pontoons near the hinges. The device was developed to supply potable water (by reverse osmosis) but can also be used to generate electricity (via a hydraulic motor and generator).
- The floating wave power vessel is a steel platform containing a sloping ramp, which gathers incoming waves into a raised internal basin. The water flows from this basin back into the sea through low-head turbines. In these respects it is similar to an offshore Tapchan but the device is not sensitive to tidal range.
- The Danish Wave Power float-pump device uses a float which is attached to a seabed mounted piston pump; the rise and fall motion of the float causes the pump to operate driving a turbine and generator mounted on the pump. The flow of water through the turbine is maintained as uni-directional through the incorporation of a non-return valve.

- **ENVIRONMENTAL PRESSURES**

Wave energy devices could have some environmental impacts in the following areas:

Hydrodynamic Environment: devices could act as coastal protection and change the flow patterns of sediment, which would require sensitive site selection.

Devices as Artificial Habitats: devices could attract and promote populations of various marine creatures.

Noise: This would come primarily from the Wells turbines of shoreline/nearshore OWCs, though these can be sound proofed.

Navigational Hazards: adequate visual and radar warning devices can be built into most devices.

Visual Effects: these would occur only for shoreline/nearshore devices.

Leisure Amenity: devices could provide calm waters thereby promoting some water sports (e.g. canoeing and scuba diving).

Conversion and Transmission of Energy: there may be visual and environmental impacts associated with the line required for transmitting electricity to shore and to the grid.

With careful sitting, most of these impacts would be small and easily reversible.

Emissions

Table 6.2: Emissions from wave power application

Parameter	**Value**
Emission factor - CO2 (kg/TJ)	0
Emission factor - SO2 (kg/TJ)	0
Emission factor - NOx (kg/TJ)	0
Emission factor - Particulates (kg/TJ)	0
Emission factor – VOCs* (kg / TJ)	0
Emissions during construction - CO2 (kg / TJ)	6840
Emissions during construction - SO2 (kg / TJ)	67
Emissions during construction - NOx (kg / TJ)	28

*non volatile organic compounds

- **REGIONAL PLANNING ISSUES**

Wave energy regional planning is described as above, under the general framework for RES.

7. GEOTHERMAL

- **COSTS**

HEAT PRODUCTION

Table 7.1: Indicative cost of geothermal heat production application

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size $(MW)_{th}$	18 - 80	18 - 80	18 - 80	10 - 14	10 - 100	10 - 110	10 - 120
Capital cost (€/kW)	314 - 510	285 - 426	300 - 800	250 - 700	250 - 650	250 - 600	250 - 600
Operation and maintenance cost (€/kW)	51 - 74	37 - 103	3 - 12	10 - 90	10 - 80	10 - 75	10 - 75
Fuel cost (€/kWh)	0	0	0	0	0	0	0
Cost of energy derived from above data, using 8% discount rate (€/kWh)	0.04 - 0.06	0.03 - 0.06	0.03 - 0.06	0.03 - 0.06	0.03 - 0.05	0.03 - 0.04	0.03 - 0.04

ELECTRICITY PRODUCTION

Table 7.2: Indicative cost of geothermal electricity production application

Technical data	1980	1985	1990	1995	2000	2005	2010
Typical unit size $(MW)_e$	0.5 - 60	0.5 - 60	0.5 - 60	0.5 - 60	1 - 100	1 - 100	5 - 150
Capital cost (€/kW)	3215 - 3930	3476 - 2844	2390 - 1956	2227 - 1882	2220 - 1880	2220 - 1800	2200 - 1800
Operation and maintenance cost (€/kW)	490 - 400	435 - 355	300 - 245	278 - 228	250 - 200	250 - 200	200 - 150
Fuel cost (€/kWh)	0	0	0	0	0	0	0
Cost of energy derived from above data, using 8% discount rate (€/kWh)	0.10 - 0.12	0.09 - 0.10	0.06 - 0.08	0.06 - 0.07	0.06 - 0.07	0.05 - 0.06	0.05 - 0.06

- **TECHNOLOGIES**

Exploration
Geological, geochemical, and geophysical techniques are used to locate geothermal resources.

Drilling
Drilling for geothermal resources has been adapted from the oil industry. Improved drill bits, slimhole drilling, advanced instruments, and other drilling technologies are under development.

Direct use
Geothermal hot water near the Earth's surface can be used directly for heating buildings and as a heat supply for a variety of commercial and industrial uses. Geothermal direct use is particularly favored for greenhouses and aquaculture.

Geothermal heat pumps
Geothermal heat pumps, or ground-source heat pumps, use the relatively constant temperature of soil or surface water as a heat source and sink for a heat pump, which provides heating and cooling for buildings

Electricity production
Underground reservoirs of hot water or steam, heated by an upwelling of magma, can be tapped for electrical power production.

Advanced technologies
Advanced technologies will help manage geothermal resources for maximum power production, improve plant operating efficiencies, and develop new resources such as hot dry rock, geopressured brines, and magma.

- **ENVIRONMENTAL PRESSURES**

Geothermal schemes can have a number of local impacts on the environment, although many of these can be mitigated by following good practice. The main impacts from geothermal schemes arise from both initial development stages (exploration, drilling and construction) and generation. They include:

- Visual intrusion
- Noise
- Gaseous emissions
- Water pollution
- Ground subsidence

Impacts from exploration, drilling and construction

These initial development phases can have a number of impacts on the local environment. The construction of access roads to drilling sites and the development of the field itself can involve destruction of forest and vegetation leading to loss of habitats and disturbance to ecosystems. In tropical areas with high rainfall, this loss of vegetation can result in erosion (Hunt and Brown, 1996). The latter can be minimized by careful planning (to reduce the number of steep banks that are exposed) and planting of fast growing trees or other vegetation to bind the soil and prevent erosion.

Noise

Noise occurs during exploration drilling, construction and production phases. Noise levels from these operations are:

- Air drilling - 120 dBa (85 dBa with suitable muffling);
- Mud drilling - 80 dBa
- Discharging wells after drilling (to remove drilling debris) - up to 120 dBa
- Well testing - 70 - 110 dBa if silencers used
- Well bleeding - 85 dBa (65 dBa if the a rock muffler used)
- Diesel engines (to operate compressors and provide electricity) - 45 to 55 dBa if suitable muffling used
- Heavy machinery, e.g. for earth moving during construction - up to 90 dBa

The potential impact of noise depends not only on its level but also on the proximity of receptors (people, animals, etc.) to the site and the nature of the noise. Noise is attenuated with distance (by about 6 dB every time the distance is doubled), although lower frequencies (e.g. noise from drill rigs) are attenuated less than higher frequencies (e.g. steam discharge noises). The characteristics of the site (e.g. its topography) and meteorological conditions will also have an influence.

Water pollution

Surface water pollution
Once heat has been extracted from geothermal fluids, they are either discharged (into waterways or evaporation ponds) or reinjected deep into the ground. In the case of surface disposal pollution problems may occur due to:

- The large volumes of fluid involved
- The relatively high temperature of the fluid
- The toxicity of the waste fluid

Ground water contamination and soil contamination
Contamination of shallow groundwater reservoirs can occur:

- From drilling fluids
- If the well casings in reinjection wells fail, allowing the fluid to leak into shallow aquifers
- If evaporation ponds and holding ponds are not impermeable

This can be avoided by careful design, proper monitoring during operation and attention to quality control during drilling and construction.

Depletion of ground water
Groundwater can be depleted under certain circumstances in high temperature geothermal fields. A cold ground water zone usually overlays most such systems and, in certain cases, cold water may flow downwards into the field, leading to a drop in the ground water level. This effect can be avoided by maintaining the reservoir pressure. The groundwater level may also fall as a result of breaks in the casing of disused wells but the effect of this can be minimized by monitoring the condition of such wells and repairing them promptly (Hunt and Brown, 1996).

Ground subsidence

In the early stages of a geothermal development, geothermal fluids are withdrawn from a reservoir at a rate greater than the natural inflow into the reservoir. This net outflow results in the rock formations at the site becoming compacted (particularly in the case of clays and sediments), leading to subsidence at the surface. Key factors causing subsidence include:

- A pressure drop in the reservoir as a result of fluid withdrawal
- The presence above or in the upper part of a shallow reservoir of a geological rock formation, which has a high compressibility
- The presence of high permeability paths between the reservoir and the formation (and through to the ground surface)

Landscape impacts

Land use

Long fluid transmission lines are not practical (because of losses in pressure and temperature), so power plants must be built on the site of geothermal reservoirs. At the site, land is required for:

- Well pads
- Geofluid pipelines
- Power station, cooling towers and electrical switchyard

The actual area of land covered by the total development can be significantly higher than the area required for these components. In many cases, the land between the well pads and pipes may continue to be used for other purposes. The impact on land use thus depends on the type of development and the original use of the land.

Visual intrusion

Geothermal plant must be located close to the resource, so that there is often little flexibility in the sitting of the plant. Geothermal plants generally have a low profile. However, at some sites the relatively low steam generating temperature leads to a low generating temperature, and higher amounts of heat are rejected in comparison with conventional plant. This can give rise to large plumes of water vapour from the cooling towers.

The visual impact of a plant may be significant, as geothermal fields are often situated in areas of outstanding natural beauty, and any associated natural thermal features (e.g. geysers and hot pools) may be a tourist attraction or of historical interest or cultural significance. Visual impact may be particularly high during drilling due to the presence of drill rigs.

Degradation of nature thermal features

Natural features associated with high temperature geothermal systems are geysers, fumaroles, hot springs, hot pools, mud pools and ‘thermal’ ground with special plant species. These features may be important either for their cultural or ecological significance or as tourist attractions. Exploitation of a system leads to a decline in the reservoir pressure, which can result in a decline of such features (in size and/or vigor), or even their death.

In some cases, thermal features of particular interest or cultural value may be specially protected (e.g. through designation as National Parks), and be off limits to development. At other sites the only way to minimize degradation would be to minimize the reduction in reservoir pressures during exploitation.

Emissions

HEAT PRODUCTION

Table 7.3: Emissions from geothermal heat production application

Parameter	**Value**
Emission factor - CO_2 (kg/TJ)	2160.5
Emission factor - SO_2 (kg/TJ)	0
Emission factor - NOx (kg/TJ)	0
Emission factor - Particulates (kg/TJ)	0
Emissions during construction - CO_2 (kg / TJ)	280.9
Emissions during construction - SO_2 (kg / TJ)	0.6
Emissions during construction - NOx (kg / TJ)	8.6
Emission during construction - Particulates (kg/TJ)	1

ELECTRICITY PRODUCTION

Table 7.4: Emissions from geothermal electricity production application

Parameter	**Value**
Emission factor - CO_2 (kg/TJ)	1944.4
Emission factor - SO_2 (kg/TJ)	0
Emission factor - NOx (kg/TJ)	0
Emission factor - Particulates (kg/TJ)	0
Emissions during construction - CO_2 (kg / TJ)	2527.8
Emissions during construction - SO_2 (kg / TJ)	5.6
Emissions during construction - NOx (kg / TJ)	77.8
Emission during construction - Particulates (kg/TJ)	8.9

- **REGIONAL PLANNING ISSUES**

Geothermal applications planning issues are included in the above general description of urban and regional planning.

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European Photovoltaic Industry Association http://www.epia.org/

European Small Hydropower Association http://www.esha.be/

European Wind Energy Association http://www.ewea.org/

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Appendix I

The main renewable energy policies in Greece, Spain and the Netherlands

GREECE

Aid to Market Penetration of Renewables

Incentive systems have been implemented to increase market penetration of renewables and co-generation: the Development Law 2601/98, which replaced the previous one (Law 1892/90), and the Operational Programmes for Energy and Competitiveness. These mechanisms provide a maximum 35% grant for investments in power generation and a maximum 75% deduction from taxable income for the residential and service sector using solar heating systems.

Greece does not intend to establish a green certificate system in the near future but considers it a viable option.

Policy: **Grants Renewable Energy Industry**
Effective from: 1998

Feed-in Tariffs

Law 2773/99 establishes buyback systems for electricity generated from renewables in the interconnected and non-interconnected networks. In the interconnected network the Public Power Corporation (PPC) pays the generator a price, which is composed of energy and a capacity charges. The energy charge is 90% of the energy part of the medium-voltage domestic end-use tariff and the capacity charge is 50% of the capacity part of same tariff. In the non-interconnected islands PPC pays only for energy, not capacity. The price paid by PPC is 70% of the low-voltage end-use tariff, except for co-generators using renewable energy who receive 90% compensation. In 2001, the average buyback tariff was €0.0616 per kWh in the interconnected system and €0.0731 in the islands.

Policy: **Feed in**
Contact: Regulatory Authority for Energy
Effective from: 1999
URL www.rae.gr

Operational Programme for Energy (OPE) : fiscal incentives for renewables and energy conservation

The Operational Programme for Energy (OPE), established within the framework of the 2nd Community Support Framework, provided capital cost grants for the promotion of renewable energies and energy conservation. Up to 1999, 125 renewable energy projects were approved (130 MW wind, 72 MW small-hydro, 46 MWh biomass district heating, 42 MW CHP with biomass, 5 MWh rest biomass projects, 42 solar central active systems, 8 projects for PV systems and 5 projects for passive solar systems). In addition, approximately 300 projects for energy conservation and substitution of fossil fuels and electricity by natural gas in the industrial and tertiary sectors were approved. By the completion of OPE, a 4.3% and 2.2% energy saving in the industrial and tertiary sector respectively is expected.

Policy: **Grants Renewable Energy Industry**
Contact: Ministry for Development
URL www.ypan.gr

Priority Network Dispatching for Renewables

Law 2773/99 gives renewables a priority in network dispatching if the installed capacity does not exceed 50 MW or in the case of hydropower 10 MW. The priority right also covers the power surplus of auto-producers within these same capacity limits. The Law obliges the Transmission System Operator and the Public Power Company to provide connection to new generators but, in practice, the development of wind power in some mountain and island areas is slowed down by the need to simultaneously extend transmission networks.

Policy: **Net Metering / Connection**
Contact: Regulatory Authority for Energy
Effective from: 1999
URL www.rae.gr

SPAIN

Feed-in Tariffs

A series of royal decrees during the 1990s provided support for electricity generation from renewable energy sources, waste and CHP, based on feed-in tariffs. The 1994 decree determined the fixed tariff for solar electricity at ESP 10.42/kWh (EUR 0.06/kWh). The Royal Decree (Real Decreto) 2818/1998 increased the tariff for solar electricity to EUR 0.22 to 0.39/kWh. In 2002 it was revised (Real Decreto 1436/2002, of 27th December) and a new price, at which a utility or supplier has to purchase renewable electricity from private generators, was fixed. It ranges from € 0.0605 per kWh (for secondary biomass) to € 0.36 per kWh (for PV under 5 kW). In 2003, wind electricity producers, for instance, can receive either a fixed tariff of EUR 0.0621/kWh or the average hourly market price of electricity plus a bonus of EUR 0.0266/kWh.

Rates are specified to both capacity and output credits. Output credits are the highest for wind and solar plants: EUR 0.07/kWh over a 5-year period. Capacity credits are the highest for waste incineration plants; output credits for them vary, depending on the size of the plant and on the relative importance of any co-fired fossil fuel, and decrease yearly. Buyback rates for such plants are about EUR 0.06/kWh in the first year. Buyback rates also depend on continuity of supply to avoid surges in power sold to the grid. The legislation also provides for guaranteed access to the electricity grid, with agreed rates for connection.

Policy **Feed in**
Contact: Ministry of Economy
URL www.mineco.es/

Low interest loans

Investment assistance to RES (focused mainly in solar thermal and photovoltaic) and energy efficiency and conservation measures by low interest loans given by the Official Credit Institute (ICO) together with the Institute for Energy Diversification and Conservation (IDAE). This financial assistance applies for both individuals and firms, and establishes a discount of 2-5 points in interest rates for investment projects. The total budget has shifted from 9.62 million euro in 2001 to 179.7 million euro in 2003. One of the relevant characteristics of the scheme is that it has reached an agreement with several banks in Spain to guarantee that the payback of the loan is made with the revenues coming from selling electricity, avoiding thus one of the main problems of RES investment, the initial investment and the long payback period.

Policy: **Consumer Loans**
Effective from: 2001
Contact: Institute for Energy Diversification and Conservation
URL: www.idae.es

R & D Grants

Under the Technical Research Encouragement Programme (PROFIT), the Ministry for Science and Technology established in year 2000 (and modified in 2001 by Order 23, BOE num. 74 of 24th March 2001) a series of incentives and subsidies for researching in RES. The phases covered are among others: industrial research, technical viability, pre-competition development of technologies, demonstrative projects and all of them can be from different areas such as energy conversion, electricity generation, transportation of energy, alternative fuels for transport, etc.

Policy: **R & D Grants**
Effective from: 2000
Contact: Ministry for Science and Technology
URL: www.mcyt.es

Aid to market penetration of renewable energy

For third consecutive year, IDAE has launched a call for applications for subsidies for RES investments in solar thermal and photovoltaic energy. The budget for this action in the case of solar thermal was of 10,818,217.88 euro for 2002. The subsidy goes from 210.35 to 300.51 euro per square metre depending on the efficiency of the collectors used. The total amount of the subsidy goes up to 40% of the total costs, plus 10% in case of medium or small size enterprises.

As happened with solar thermal, the IDAE also dedicated 10,818,217.88 euro for photovoltaic energy. The subsidy covers up to 40% of the installation costs, plus 10% for medium and small size enterprises, being of 5.53 euro per Wp for isolated installations, 2.07 for grid-connected of more than 5 kWp of power, and 2.25 for those with less than 5 kWp of power.

Apart from the subsidies from the central government, due to the decentralised structure of Spain, every of the 17 autonomous communities have its own energy policy, this fact makes possible to combine subsidies from different administrations, whenever the total amount is below 50% of the installation costs. We focus here in the case of Catalonia, where these aids are canalised through the Catalan Institute of Energy (ICAEN). Following the Catalan Energy Plan, the regional government issued Order TIC/77/2003 of 6th February (published in DOGC num. 3833 of 28th February 2003) that regulates access to subsidies for RES and energy efficiency measures from individuals and firms.

Policy: **Aid to market penetration of renewable energy**
Contact: IDAE and ICAEN
URLs: www.idae.es
www.icaen.es

Spain is considering introducing a green certificate in the near future. However, so far there is only one utility supplying green electricity as such, Electra Norte, S.A. (www.electranorte.es) which is considering establishing in the meantime an *ad hoc* certificate issued by Bureau Veritas.

Regulation: Solar Ordinances

The IDAE is working closely with the Economics Ministry to encourage the use of solar collectors for water heating. One of the measures taken is the Municipal Ordinance on Solar Thermal Energy (Ordenanza Municipal sobre Captación Solar para usos Térmicos), which will ask new buildings and those under integral rehabilitation of those municipalities to adopt it, to cover at least 60 % of the demand for sanitary hot water with solar collectors. This ordinance is already running in 11 municipalities in Catalonia, with about 2 million inhabitants, and is expected that before the end of 2003 will affect 3 million people. Another measure is the inclusion in the Technical Code of Buildings of the obligatory use of solar energy in certain cases.

Policy: **Regulation**
Effective from: voluntary, firs Ordinance from year 2000 in Barcelona.
Contact: IDAE
URL: www.idae.es
URL Barcelona: http://www.mediambient.bcn.es/cat/web/cont_leg_anexmedi.htm

NETHERLANDS

Energy taxes

The Regulated Energy Tax was introduced in 1996 for households and medium-small enterprises to encourage energy conservation and renewable energy use by making fossil energy more expensive. Green energy has been exempted from tax since 1999. In 2001 the energy tax (REB) on fossil electricity for small consumers (<10.000 kWh) was further raised to 5,8 EUROcts/kWh, with an exemption for RES. With this tax level, green products may become cheaper than regular electricity. The energy tax exemption applies only to renewable electricity possessing a green certificate.

The Dutch government decided to apply an annual indexing (to inflation) to all energy taxes and excise duties from 1 January 1999.

Policy: **Fossil Fuel Taxes**
Contact: Ministry of Finance

Liberalisation of Electricity Market - Green certificates scheme

The Liberalisation of the Green Electricity Market was introduced on July 1st, 2001 to facilitate transparent trade in renewable electricity.

- A Green Certificates system replaced the Green Label System, implemented since January 1998. The system is managed by the national grid-operator (Tennet). From January 1, 2002 imported renewable electricity may also apply for a Dutch Green Certificate.

-The exemption from the energy tax only applies to renewable electricity possessing a green certificate.

- Consumers are free to choose their energy supplier. They pay an additional tariff when they buy green electricity, but in return are exempted from the energy tax. Currently tariffs vary between 2.7 and 4.5 Euro ct/kWh. The green electricity is cheaper or as expensive as regular electricity. On average green electricity is sold at a premium rate of about 3.6 Euro ct (exc. VAT) above the normal price.

Policy: **Fossil Fuel Taxes**
Contact: Ministry of Economic Affairs
Effective from: July 2001

R&D subsidies Economy, Ecology and Technology

The EET-programme with the budget of 31.8 mln EURO per year is expected to run until end 2002. It grants subsidies for co-operative R&D projects in which Economy, Ecology and Technology are integrated. It focuses on big projects (budget around € 0.5 mln per year) with a national impact. Research results should be ready for market implementation in 5-15 years.
Percentage subsidy:
62.5% for fundamental research
40% for industrial research
25% for applied research (commercialisation)

One of the main themes of the EET-programme is renewable energy.

Policy: **R&D**
Contact: Programmabureau EET, Ministry of Economic Affairs, Ministry of Housing, Spatial Planning and the Environment
Effective from: 1997
URL www.novem.org/biofinance/index.htm

Renewables for Government Buildings

By 2004, 50% of electricity consumption in all government buildings will be derived from renewables sources. An important instrument is central purchasing of green electricity.

Policy: **Government Purchases**
Contact: Ministry of Housing, Spatial Planning and the Environment
URL www.minvrom.nl

Tax Credit

Tax Credit: Companies can deduct from the taxable profit 40% to 52% of investments in equipment related to energy conservation and renewable energy. The eligible equipment is stated on the list "Energielijist" of the Environmental Impact Assessment (EIA).
The tax credit for wind energy equipment is up to 52.5% since 2001. In 2002 the amount of tax expenditure is € 209 mln.

Policy: **Corporate Tax Incentive**
Contact: Senter / Ministry of Finance
Effective from: 1 January 1997
URL www.senter.nl, www.minfin.nl

VAMIL Depreciation scheme

VAMIL depreciation scheme allows enterprises to decide when they want to depreciate investments in specific environmentally benign equipment. This may reduce income and company taxes. An interest and liquidity advantage is gained by shifting the payment of taxes to the future. Accelerated depreciation is only applicable to equipment, which is included in the yearly updated VAMIL list " Milieulijst". The equipment must be new and should be available in the Netherlands (ex.: biomass preconditioning , biomass burning equipment, solar PV-systems, etc). The incentive is applicable to all taxable Dutch enterprises.
In 2000, tax expenditure under VAMIL amounted to NLG 250 mln (€113.45 m); in 1999 47% of investments were related to energy.

Policy: **Corporate Tax Incentive**
Contact: Senter, Novem / Ministry of Housing, Spatial Planning and the Environment
Effective from: 1992
URL www.novem.org