COST Action 529

Efficient Lighting for the 21st Century

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Memorandum of Understanding

for the implementation of a European Concerted
Research Action designated as
COST Action 529

"Efficient Lighting for the 21st Century"

The Signatories to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the Technical Annex to the Memorandum, have reached the following understanding.

1. The Action will be carried out in accordance with the provisions of the document COST 400/94 "Rules and Procedures for Implementing COST Actions, the contents of which are fully known to the Signatories.

2. The main objective of the proposed action, at both the basic breakthrough and the pre-competitive research levels, is to seek new concepts and materials for the lighting industry which avoid any known environmentally harmful substances through the study of the feasibility of high efficacy, novel, light source technologies.

3. The overall cost of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EURO 8 Million in 2000 prices.

4. The Memorandum of Understanding will take effect on being signed by at least five Signatories.

5. The Memorandum of Understanding will remain in force for a period of five years, unless the duration of the Action is modified according to the provisions of Chapter 6 of the document referred to in Point 1 above.

Action COST
"Efficient Lighting for the 21st Century"

A. Background

The development of significantly more efficient light sources for use in general lighting and other industrial applications has the potential to reduce substantially electric power consumption. For example, currently, more than 7.5 billion lamps operate world-wide consuming 1,000 billion kWh per year (10-15% of the global energy production world-wide). If, for an industrialised country, this amount is substantial (e.g. about 11% for France, 20% for US) it becomes very important for under-development nations for which lighting is one of the major applications of electricity (i.e. 37% for Tunisia !). Furthermore, the annual greenhouse gas (CO_2) due to this energy production is estimated to be in the order of 550 million tons. In future, it can be estimated that the need for light sources will increase by a factor of 3. More efficient light sources would

1. limit the rate-of-increase of electric power consumption ;
2. reduce the economic and social costs of constructing new generating capacity ;
3. reduce the emissions of greenhouse gases and other pollutants.

In fact, an improvement of 25% in the lamp efficacy corresponds to 750 billion kWh per year energy savings as well as 300,000 tons less greenhouse gas in the atmosphere.
Thus, the strategy of reducing energy consumption by lighting, and other current major uses, by increasing their respective efficiency of energy consumption is the most efficient and environmentally sound way that a nation's power system can absorb the predicted increase in demand without constructing new generating capacity.

A large number of studies have been completed and published on the potential of energy savings through energy conservation measures. For example, the commercial building sector, with more than 40 billion square meters of space in place, and representing, approximately, 30 to 35% of total electrical demand, is estimated to utilise approximately 40% of its energy for lighting, and another 5 to 10% for air-conditioning necessary, in major part, for cooling air and building fabric heated directly or indirectly by current light generation technologies. Various estimates have indicated a potential for energy savings of 25 to 50% in the commercial sector by utilising newly available lighting technology. From the viewpoint of lighting design, the main focus of attention has been to increase the average efficiency from the range of 40 to 50 lumens per watt achievable using older fluorescent technology towards the figure of 100 lumens per watt made available using the latest fluorescent lighting systems.

Economic dimension of lighting industry: Last year the world-wide turnover of the lighting industry is estimated to be more than 15 billion Euros. However, light sources find also wide spread application in several important industrial domains. For example, reprography, surface treatment, water and air purification, curing, and process monitoring and control. If these additional applications are taken into account the total world-wide turnover of light source related technology is 2-3 times higher than the above figure. Europe has an important industrial stake in this major global industry. It hosts the three biggest lighting companies, namely Osram, Philips, and GE Lighting. These three companies own 80% of the North American and European market and 40% of the Asian market and are true global players. For instance, the German company Osram has more employees in the US than in Europe and GE Lighting has major representations in the USA and in Europe, including its manufacturing plants and R&D laboratories located in Hungary and the U.K.

Environmental impact of lighting industry (other than greenhouse gas production): Fluorescent lamps dominate the area lighting market and 1.2 billion are fabricated each year world-wide with Japan being responsible for 20% of this total. These light sources, as do several other commercially important types, contain a small amount of mercury. As a consequence, at the end of the lamp life-time a considerable amount of "undesirable" waste is generated, for example, 80 tons of wastes containing mercury are collected each year in France. It is well known that mercury is a highly toxic material, however, if mercury were eventually to be prohibited as a lamp dosant material on environmental grounds then this would represent an even greater challenge for the development of new generations of light sources with greater efficacy than is available at the present time.

A COST action to support work in this very important area is more appropriate than other potentially applicable EU FP5 schemes for a number of reasons. At the present time there are many European teams working in the area of light source science and technology but there are no organised opportunities for information exchange between them, no regular meetings, etc. A network in the area would provide a solid basis for information exchange, identification of opportunities for collaboration and has the potential to contribute significantly to the co-ordination of efforts.

Many of the European research teams are within industrial companies and, thus, are in a domain where competitive issues cannot be avoided. Therefore it is difficult to conceive that right now any of the other established EU programs could provide a basis for co-operation between the groups, given that to date there is hardly any record of such activities in the past. The ‘big players’ Osram, Philips and GE Lighting have created a strong network around their national poles (Germany, The Netherlands, U.K and Hungary, respectively). The proposed COST action would allow these companies to coordinate their research efforts at European level which will be important to advance R&D in efficient light sources. The great potential advantage of COST lies in the relatively rapid exchange of information between scientists and technical experts and in the arrangements made concerning the distribution of tasks for the research work involved in the Action.

B. Objectives and benefits

The main objective of the proposed action, at both the basic breakthrough and the pre-competitive research levels, is to seek new concepts and materials for the lighting industry which avoid any known environmentally harmful substances through the study of the feasibility of high efficacy, novel, light source technologies.

In addition to this main objective, the proposed COST action will contribute also in the accomplishment of the following tasks:

Establishment of a database of knowledge in the area. As might be anticipated there are many published works which relate directly or indirectly to light source science and technology. However, this knowledge is dispersed widely and thus difficult to use. In the scope of this COST action it is proposed to do a critical and thorough compilation of the existing information. This information would be based in the main on published experimental results and numerical simulation codes, as well as on fundamental data necessary for more detailed studies. It is intended also that the database would attract the deposition of previously unpublished results from whatever the source. Such information would be subjected to scrutiny by experts in the respective areas for comment regarding reliability, etc., of the data.

Establishment of an interdisciplinary, expert, panel able to act as a consulting body for the industry, subject, of course, to any non-disclosure constraints. The study of total lighting systems in which the lamp is but one element, albeit an important one, is intrinsically highly interdisciplinary. Knowledge from several major domains, for example, electrical engineering, plasma physics and chemistry, chemistry and materials science, is necessary in order to proceed to an optimization of a given system according to its application.

C. Scientific program

After increasing steadily throughout the previous seventy-five years, efficiency of conversion of electric energy into light by commercial light sources appears to have reached a plateau of about 33% of the theoretical maximum. No truly revolutionary new light sources have been introduced since the mid-1960's, marked by the debut of metal-halide and high pressure-sodium arc discharge lamps. Light source developments since then have been primarily evolutionary, with incremental improvements in efficiency. Overall system gains in lighting efficiency have in the last decade primarily resulted from the substitution of more efficient sources for less efficient ones (viz. compact fluorescent replacing incandescent). To achieve the continued load-saving challenges that will be required in the future, much greater efficiency improvements, of about a factor of two, will be required. Furthermore, from an environmental point of view a drastic reduction or elimination of harmful substances is required (viz. complete elimination of mercury).

It is possible to define the theoretical optimum light source in terms of maximum luminous efficacy at 100% radiant power efficiency for a "white" light source having good colour rendering capabilities. If one were to specify a blackbody-like spectral power distribution in the visible, with zero radiant emission at any other wavelength, then at 100% radiant power efficiency, the luminous efficacy is about 200 lumens per watt (lm/W). However, it proves to be possible to do better than that; radiation in the far red or far blue is not effectively utilised by the eye for either colour response or brightness response, although these extremes are customarily considered part of the visible spectral band. Acceptably good colour-rendering properties may be achieved in a light source which is radiating in just three narrow wavelength bands: blue, green, and red. Most coloured objects have sufficiently broad reflectance spectra that they reflect light in two or more of these bands, and the eye-brain system accepts a colour definition dependent on the ratio of these two intensities of reflected light. Provided the wavelengths of the emission bands are chosen to be those corresponding to the maximum of the action spectra for the eye response to red, green, and blue, the brightness sensation perceived by the eye can be maximised simultaneously with the colour response.

Light sources with such spectra can simultaneously have higher luminous efficacy than any continuous-spectrum source while maintaining nearly equivalent colour-rendering properties. For instance, consider an ideal source radiating at 450, 555, and 610 nm: the eye response has the values of 51.5, 683, and

343 lumens per radiant watt at the three wavelengths respectively. The composite efficacy at 100% radiant power efficiency is approximately 300 lm/W, with the apparent "colour" of the light being the same as that of a blackbody at 3000K (3000K "colour temperature"), and colour rendering comparable to a 3000K blackbody. This figure of 300 lm/W then represents the probable upper limit for luminous efficacy of a three-wavelength-emitting source having colour rendering acceptable for nearly all lighting applications. The 100 lm/W plateau is only one-third of this level, suggesting that a substantial improvement in light source efficacy may be possible.

The inability to develop dramatically-improved light sources in recent decades has not resulted from lack of effort by the lamp manufacturers themselves. All of the major lamp manufacturers in the US and Europe have for many years maintained significant applied research and advanced development groups unburdened by day-to-day problem-solving responsibilities, but immersed in a highly-focused corporate climate. These groups have been, and continue to be, well aware of the limitations of existing lamps, materials and processes, and have been free to seek out better light-generating phenomena on which to base dramatically-improved products. If such phenomena were known at the present time then these groups would have explored them, modified them as necessary, and exploited them in commercial products.

It seems, therefore that a fundamental reason for the present plateau in efficiency of light sources is that the industry has outrun the scientific base that has supported the technology since its inception: atomic physics and spectroscopy, and electron and plasma science, electronics and electrical engineering. Thus, the development of revolutionary new light sources having double the efficiency of current light sources can be based on the detailed study of the global system (light source – power supply). Seeking new materials able to support higher temperatures and pressures, with a better resistance to hard UV radiation and corrosive action of the discharge components (radicals, ions…) is a challenge for the future. In fact as shown in figure 1, "materials" are everywhere in the lamp.

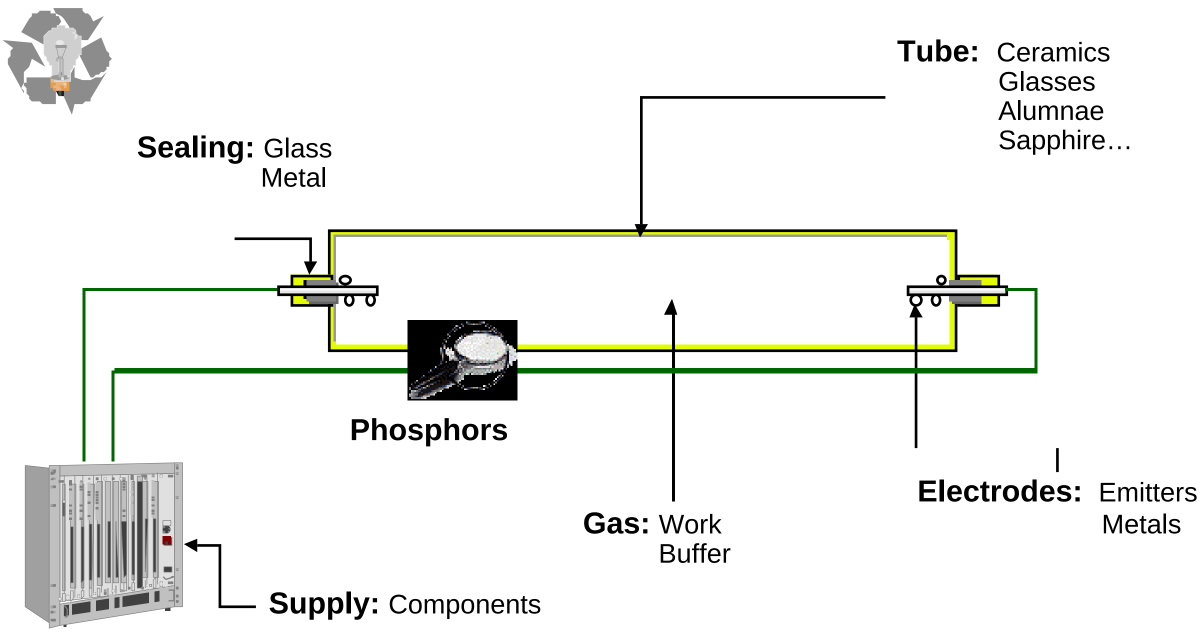

Figure 1: In a discharge lamp "materials" are everywhere from the plasma to the power supply

In order to make advances in this area we propose to split this COST action into 3 big work-packages (WP) divided to several task groups (TG) summarized in Figure 2:

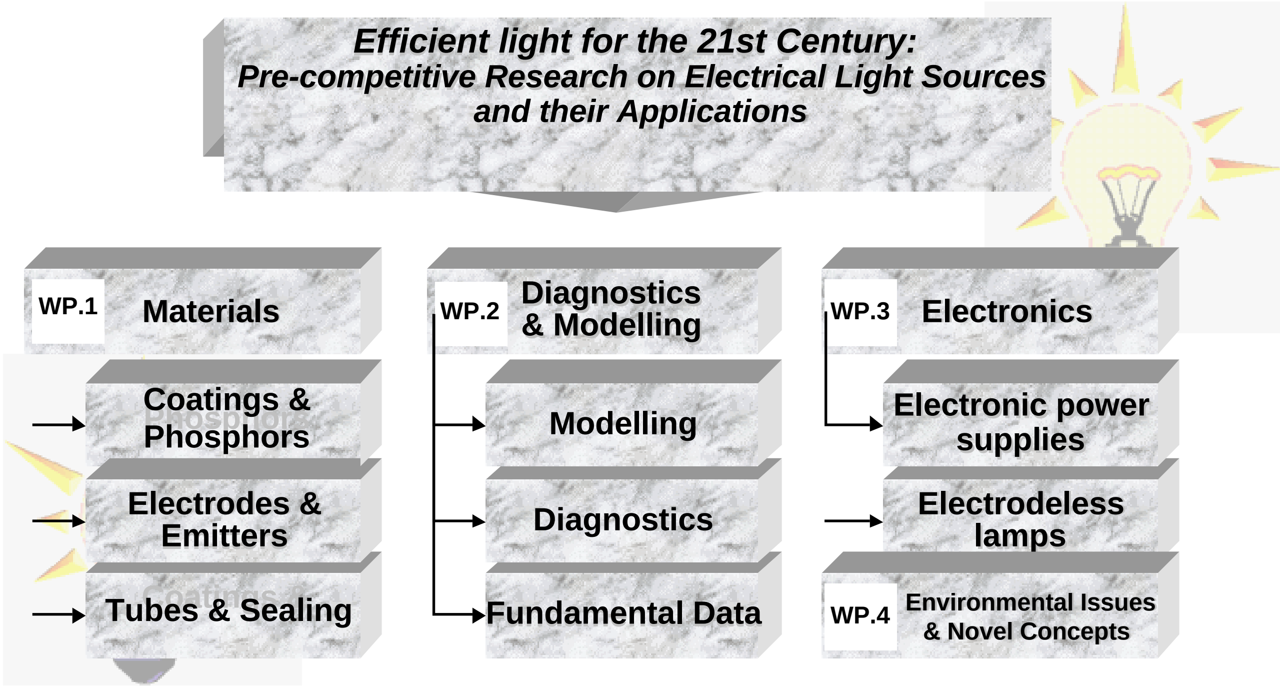

Fig 2: Work package organisation of the COST

WP.1 Materials – Coatings & Phosphors: Present-day luminescent materials employ a Stokes-shift of photon energy in the absorption of one photon of ultraviolet light and the subsequent emission of the one photon of visible light. Even in the case of 100% quantum efficiency there is energy loss resulting from the difference in photon energy of the absorbed and emitted photon. One of the objectives of this work package will be to identify new materials for more efficient phosphors capable of effective quantum efficiencies greater than unity, requiring less than 5 eV of ultraviolet energy per emitted visible photon. Furthermore, new materials for novel cathodes with lower extraction potential and less severe sputtering are required. Finally, new ceramic materials are required which would allow the use of novel emitters, such as barium, and new metal halide mixtures.
Electrodes: Many of the existing lamps types have electrodes. In many case the lamp's life-time is limited by the life-time of these electrodes. In the scope of this project new cathodes will be sought with higher performance leading to enhanced efficacies and lumen maintenance. In parallel, a better understanding of electrode erosion mechanisms is needed in order to increase the reliability of the lamp. This work package is open to any theoretical and experimental work on this subject.
Tubes & Sealing: The study of tubes and sealing is another important factor in improving life-span and recyclability.

WP.2 Diagnostics & Modelling - Modelling: Modelling is a fundamental element of any optimisation process. A well validated numerical code, i.e., experimentally validated code, can be used to predict optimal operating conditions of a device and thus save precious efforts imposed by an empirical "try-and-reject" method. We note also that a detailed numerical model of a system can lead to the identification of new physical phenomena often neglected up to that time. This work package is open to any type of computer simulation (LTE models, fluid codes, collisional-radiative simulations, monte-carlo and hybrid models…).
Diagnostics: Experimental measurements are necessary for the study of any system. In the case of light sources spectroscopic and electrical measurements are particularly useful to achieving a better understanding of the device physics. Furthermore, computer modelling need confident experimental data for validation. Finally, experimentation is the best way to determine various fundamental data necessary for both modelling and theoretical work. This work package is open to any type of experimental technique (emission and absorption spectroscopy, laser techniques, imaging and tomography, electrical measurements, probe methods…).
Fundamental Data: The extension of modelling applications to provide understanding of discharge systems of greatest apparent potential depends crucially on the availability of atomic, molecular, and optical (AMO) data. Research seeking to generate such data is of interest to the project.

WP.3 Electronics - Electronic Power Supplies: Presently, the older design inductive lamp ballasts are starting to be replaced by electronic power supplies. The new electronic ballasts occupy considerably less volume and are lighter than the long established designs. In addition, the electronic ballast saves the electrical network from undesirable harmonic distortion due to the non-linearity of the electrical discharge.

Electrodeless lamp types: have become an important technology for the lighting industry. These lamps are driven in the radio or microwave frequencies and pose serious electromagnetic interference problems (EMI).

WP4. Environmental Issues: This work package deals with any environmental hazard induced by lamps and includes, for example, the development of new methods for recycling wastes containing considerable amount of heavy metals (mercury, cadmium…). A non negligible portion of these materials could be reused after recycling, reducing the financial charges derived from the storage of lamp wastes in "terminal waste class" discharges; as an illustration of this problem, the mean cost of hazard material storage in France is 150 Euro per tonne). A second objective of this work package will be to prepare an evaluation of the environmental impact of lamps, and lighting in general, in European countries.

D. Organisation and Timetable

D1 Organisation

Each Work Package (WP) and Task Group (TG)of the Action will be co-ordinated by a Work-Package Director (WPD) and Task Group Managers (TGM). The duty of these persons is to co-ordinate the work of the participating teams. The WPD and TGM will collect the results from the teams participating in a WP and will report on the progress of the project to the Management Committee (MC). The WPD will introduce the teams who would like to join a particular WP of the action and will make a recommendation to the MC as to whether the request should be accepted or rejected.

The MC members will originate both from industry and academic institutions (a parity of 50-50 is suggested). The MC will have a Chairman, a vice-Chairman and a Secretary. The Chairman and Vice-chairman should originate from an industrial company and an academic institution, one from each. The MC of the Action will comprise the WPDs, TGMs and the National Representatives (NR). The role of the NRs (at least one per participating country) would be to collate the information arriving at the MC level which concerns the progress of the project and to feed this information back to all national teams in their respective countries. To this end we differentiate the inward information flux (collected by the WPDs) from the outward one (disseminated by the NRs). However, as the number of participants per country is limited, the functions of the WPD and the NR can be assumed, if necessary, by the same person. In a similar way the functions of Chairman, Vice-Chairman and Secretary would not be incompatible with those of a WPD or NR position.

The roles of the MC are various and include:

- control and co-ordinate the progress of the action;
- approve by vote the annual reports;
- decisions to create, or to close, a Work-Package according the needs of the Action;
- acceptance or rejection of new applicants wishing to join the team (COST countries) according to WPD proposals, and remit motivated proposal from participants from non-COST countries who desire to join the Action;
- decide the place and time of Annual Workshops as well as take care of the related budgetary matters;
- distribute, after examination, requests for funding an exchange of researchers between teams.

Further bye-laws and tasks of the MC will be decided at the first plenary meeting of the MC.

D2 Timetable

After the signing of the MoU the Action is considered as open, but a call for proposals relating to specific projects in the scope of this Action will be open for 6 months following. Any institution wishing to join the action will present one or more requests to the MC specifying to which WP they propose to be participants. The MC will forward to the WPD these requests for examination. After the 6 month period new teams can request participation in the Action but in such cases their request will be examined in accordance with the timetable of the project.

After the signing of the MoU, and the opening of the action, an informal meeting of the representatives of the main teams participating from the beginning of the Action, will be held. The objective of this meeting would be to identify the Work Package Directors, the Chairman, Vice-Chairman and Secretary of the MC.

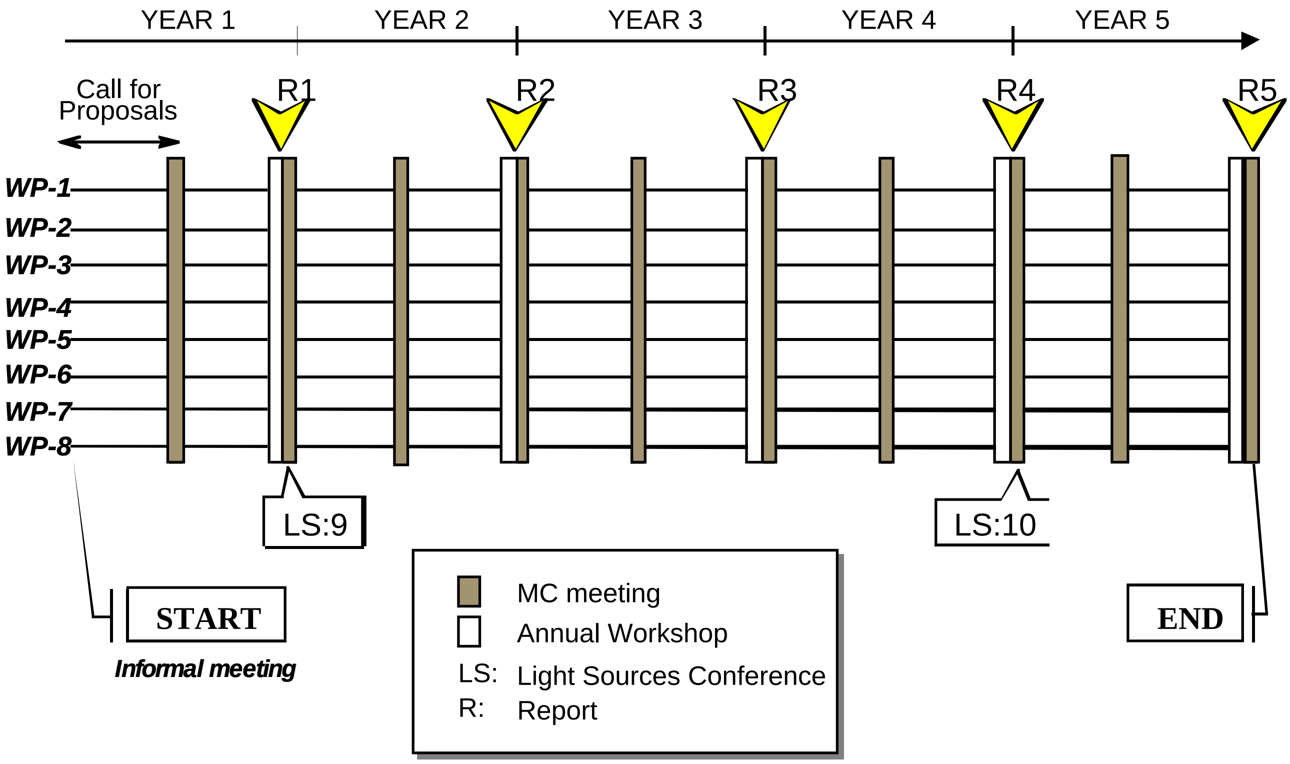

Figure 3 illustrates the proposed timetable of the Action.

The MC would meet twice per year in order to co-ordinate the tasks of each work group and to evaluate the advancement of the project. At each of these meetings (except the first one) Work-Package Directors will report on the advancement of the work within their group. From the second calendar year, and during the first meeting of each year, the committee will allocate "researcher's exchange funding" (Short term scientific missions). The duration of the meeting will be a maximum of one and half days.

The objective of the Annual Workshops (2 or 3 days events) is to give the opportunity to each researcher participating in the Action to present his work in a "poster" form. General review talks given by the Work-Package Directors (or their representatives) on the advances made by their work group. After each Annual Workshop a Proceedings booklet would be published. Partial financial support from the Action's funding will be given to the workshop's participants (including the MC members).

The International Symposium on Light Source Science & Technology is an important event within this area and operates on a 3 year cycle. This international event is completely independent from the proposed COST Action. However, this meeting brings together the leading lamp scientists from the lighting industry (70% of participants) and the academic world. As a consequence the respective COST Annual Workshop will be incorporated into this important event.

The total duration of the proposed Action is 5 years. The proposed duration will be necessary in view of the interdisciplinary nature of the Action and the scope of the envisaged experimental work. It will allow to better fit in nationally funded proposals. It will take time to integrate the proposed interdisciplinary research activities in the beginning and to conflate the results and to draw conclusions at the end of the Action. Also, a shorter duration incurs the problem that some of the nationally funded projects will not finish in time for the results to be available at the end of the Action.

E. Economic dimension

The following COST countries have actively participated in the preparation of the action or otherwise indicated their interest:

- Austria
- France
- Germany
- Greece
- Hungary
- Netherlands
- Portugal
- United Kingdom

On the basis of national estimates provided by the representatives of these countries and taking into account the co-ordination cost to be covered over the COST budget of the European Commission, the overall cost of the activities to be carried out under the Action has been estimated in 2000 prices, at roughly Euro 8 million.

This estimate is valid on the assumption that all the countries mentioned above, and no others, will participate.

It is important to note again that the three largest world-wide lighting companies are based in these countries (Philips: Netherlands, Osram: Germany and General Electric Lighting Europe: Hungary and UK) and all have indicated their interest to participate actively in this Action.