A summary of the Sustainable Energy Research Programme (SusEn), 2008–

By Programme Manager Saila Seppo

Reflections by Professors Jim Swithenbank and Michel Cotsaftis

Preface

Academy of Finland research programmes are usually evaluated afterwards. This time the steering committee decided that Programme Manager Saila Seppo will write a short summary of the Sustainable Energy Research Programme (SusEn) and Professors Jim Swithenbank, University of Sheffield, UK, and Michel Cotsaftis, École Centrale d'Électronique (LACSC/ECE), France, will comment on the summary and write reflections of it.

This short summary of the SusEn research programme is based on the data derived from the Academy of Finland's online system, consortium reports and the online questionnaire and other material collected during the programme lifespan. It is difficult to produce a exhaustive summery, as some of the programme's projects are still ongoing, some projects have not yet submitted their final reports and some data and reports are still lacking.

Appendices:

1. List of funded projects
2. List of allocated funding
3. Summary of programme lifespan and coordination activities 2005–2012

1. Introduction

a. SusEn in brief

The SusEn research programme was launched in 2007 to produce new and innovative scientific knowledge of energy technology, energy systems and energy efficiency. Another aim was to direct research to developing sustainable solutions as well as know-how in identifying future energy system alternatives. In the programme, research is carried out from an international and multidisciplinary perspective, including fields such as bioenergy and nuclear power as well as medical and economic sciences. A list of the funded projects is in Appendix 1 and a list of the allocated funding in Appendix 2.

b. Steering committees

The SusEn steering committee was nominated at the beginning of the SusEn programme. It was renominated every time the members of the Academy's research councils changed (i.e. every third year). The chair of the steering committee was first Professor Timo Jääskeläinen and since 2010 Professor Tuija Pulkkinen, both representing the Academy's Research Council for Natural Sciences and Engineering.

The tasks of the steering committee are

- to submit to the responsible funding bodies a proposal for the projects to be funded in the programme
- to steer and monitor the implementation of the programme
- to plan and organise the final evaluation of the programme
- to promote the application of research results.

c. Research programme as a funding instrument

Through its research programmes, the Academy of Finland directs research and allocates research funding to fields that are considered of key importance in terms of science and society. The Academy's research programmes are designed to advance a certain field of research, raise its scientific standards and create new scientific knowledge and know-how. A major emphasis in Academy research programmes is on multi- and transdisciplinarity as well as on international cooperation. The Academy Board decides on the start-up of new research programmes. In 2013, the Academy funds twelve research programmes.

Academy research programmes are composed of several projects. As a rule, the funding is provided for at least four years.

2. Programme activities

A summary of the programme lifespan and coordination activities is in Appendix 3.

The coordination activities included launching one national and eight international calls with specific themes for funding, arranging different kinds of energy seminars and workshops in Finland and abroad, visiting SusEn research groups, requesting annual reports and reports for the evaluation process, disseminating the programme's results and arranging a foresight workshop.

The themes for funding were chosen by the steering committees and in international calls the themes were negotiated between the partners.

Morning cafés were also arranged with a view to promoting the research projects and to delivering press releases. Press releases were also published in connection with the seminars and after the funding lists were made public.

3. Programme analysis and statistics

a. Overview

The Academy of Finland allocated altogether EUR 19.3 million within the Sustainable Energy Research Programme (SusEn) in nine calls. The Academy carried out bilateral joint calls with Brazil (CNPq), Chile (CONICYT) and China (NSFC), and it also allocated money to the MATERA ERA-NET. The Academy also took twice part in the network called N-INNER of the Nordic and Northern European research organisations. In the first round, the participating countries were five national research funding bodies and Nordic Energy Research. The second round also involved five national research funding bodies and Nordic Energy Research, but Iceland was replaced by Estonia.

The Maj and Tor Nessling Foundation, the pulp and paper company UPM-Kymmene, the energy company Fortum and the oil company Neste Oil co-funded SusEn projects with EUR 0.9 million.

The SusEn research programme involved a total of 44 research projects: 30 projects from international calls and 14 projects from the national call in 2007. The Academy's funding allocation was EUR 8.8 million for the national call in 2007. The funding schedule is presented in Appendix 2.

The titles of the funded projects are listed in Appendix 1. The list is available on the SusEn website (www.aka.fi/energy). The annual reports of the projects are also posted on the website.

b. Statistics

The data collected in the Academy's online services corresponds to funding of EUR 6,732,700, which is about one-third of the total funding allocated to the SusEn programme. The amount of EUR 6,732,700 corresponds 1,620 full-time equivalent (FTE) months, that is, EUR 4,160 per month.

According to the data, the amount of EUR 200,000 produced more than three articles in conference proceedings, almost five scientific articles in international journals, more than four publications in Finland and almost one review in international journals. A little more funding is needed to produce one doctoral degree. The amount of EUR 200,000 covers one full-time equivalent (FTE) month for four years.

Of the FTE months, 10 per cent have been done by foreigners. Researchers involved in the SusEn programme spent 69 months abroad (5 in Germany, 2 in the USA, Switzerland, France, and one in the Republic of Korea, Poland, Sweden, Austria, the UK, Iceland, Holland and Singapore).

The total amount of completed degrees reported in the online services is 40 Master's, 3 licentiate and 22 doctoral degrees. The whole programme is expected to produce 120 Master's, 10 licentiate, 70 doctoral degrees.

c. Questionnaire results

The online questionnaire was sent to the SusEn researchers, and 26 researchers responded. That means that only the most active researchers responded (approx. 50% of those who received the questionnaire).

Most of the respondents said that their home institute has energy research as a priority area. The respondents felt that the public image of energy research is very good. The respondents think that energy research has changed its focus, become more internationalised and covered new topics in recent years, and multidisciplinarity has also increased. The respondents also felt that industrial cooperation has had a positive impact on their work. Some researchers thought that the impact was focused on the extent and forms of research rather than on the quality of the cooperation in general or on the results.

The most important knowledge transfer mechanisms with which the research results and know-how of energy research have been put into practice include:

- joint projects/concrete cooperation but strictly confidential
- process development/technology transfer/technology spin-offs
- participation of industry on steering groups/meetings/conferences/advisory commitments
- patents/innovations/licencing
- new experts educated/researcher exchange
- publications/reports/internet
- programmes for Strategic Centres for Science, Technology and Innovation.

According to the questionnaire and other information obtained from the project reports, the SusEn research programme benefitted researchers in the following way:

National networking
- new national contacts through SusEn seminars
- improved information on ongoing research
- improved connections to partner universities
- strengthening the national R&D network
- connections to new potential partners
- more closer link with Finnish research institutes.

The project leaders have found the programme and the seminars as an important platform for exchange of scientific knowledge between Finnish universities and research institutes, leading from a cluster of isolated units to closer national networking.

International networking

- this would not have been possible in a national programme
- increasing research network
- enabled to expand on equipment and strengthen contact network
- increased international collaboration in this field
- better international contacts.

The response shows that the programme has been an excellent platform for establishing international networks in energy research.

Scientific output

- understanding of the new challenges in energy production increased
- health effects of energy production cannot be studied separately from research on energy production methods
- offered a new opening and it was essential (applying ecological knowledge to energy framework)
- initiated a set of long-term field experiments, research on environmental impacts and ways of optimising them
- important support to group's research
- funding of doctoral works
- information on research and results from other fields
- young researchers could extend their expertise
- complete matching (gave a possibility to go deeper and to publish results, which is not often possible in 100% industrial projects).

The programme has clearly contributed to strengthening the research teams in terms of doctoral training, long-term experimental work and publishing activity. The multidisciplinary aspect of the programme has also been positively recognized.

Industrial cooperation

- cooperation with the related industrial partner (gave insights for focusing the contents of the research).

Energy production is a large industrial sector and knowledge exchange between industry and academia is a key issue to keep the required industrial relevance in research.

Research strategy

- freedom to steer the research into relevant directions from a scientific point of view
- have had a clear focus, allowed a narrower focus than in the general call research plan overview of the others.

The message is that this programme funding, representing at first look a top-down controlled research instrument, has actually provided the teams with enough liberty and space for researcher-driven bottom-up initiatives.

Nordic cooperation

- good Nordic cooperation and networks within N-INNER
- N-INNER network (provided a fruitful basic research collaboration opportunity and strengthened cooperation).

Nordic collaboration is important as there are so many common nominators starting from climate constraints and ending to similar research tradition. Today, models in energy

production in these countries are still quite different, which does not limit cooperation in fundamental research.

China cooperation

- thanks to China cooperation (complimentary work was good)
- comparable to good EU projects except that we cooperated with a Chinese partner, which as an interesting experience.

New openings in energy research with China represented promising opportunities as China is investing strongly in the use of sustainable and renewable energy sources.

Latin America cooperation

- Brazil cooperation (have been able to utilise their equipment and expertise in the areas where they are strong, and vice versa)
- new perspective from South America
- Brazil cooperation (both the Finnish and Brazilian teams were supported from their national funding bodies in order to collaborate)
- international collaboration with a Brazilian university.

One of the purposes of the targeted calls was to establish long-term research cooperation with those Latin America countries that based on positive developments in the economy, are systematically investing in science and engineering. The response reflects very positive experiences of totally new research partnerships.

According to researchers, the SusEn programme had very positive impact on the groups' public image, almost as positive was also the influence on the home institute's priority areas and the groups' new research partners. The programme also had a positive effect on the industrial partners and the home institute's strategy of the groups involved in the programme.

Almost all of the respondents felt that their industrial partners have benefitted from the SusEn programme.

The respondents also strongly felt that the multidisciplinarity of the SusEn programme has benefitted their research. Some positive examples:

- combining mechanical processing with biotechnology is necessary in research of sustainable second generation biofuel production, for example
- new ideas on socio-economics and technology; this resulted to joint papers outside the main project
- energy engineering and geology/mineralogy are a nice match in a important area important to Finland
- interactions with economists and mathematical modellers directed our crop research in particular directions, and our results fed into their models.

International cooperation within the SusEn programme also benefitted students:

- more students were recruited
- research exchange/student exchange
- MSc theses completed abroad and MSc theses by visiting students from Venezuela and Lithuania
- more perspective on Finland's strategic position
- ENEN (European Nuclear Education Network) challenges
- opportunity to visit foreign institutes (e.g. CEA,atomic energy research)
- PhD students from Brazil to Finland
- experience of working with Chinese researchers.

The responses show that the supplementary international calls have increased the networking of Finnish teams with the call-specified countries leading to long-term collaboration.

According to the SusEn researchers, the quality and impact of Finnish energy research can be improved:
- not all research is energy research – putting an energy label on existing research in non-energy does not give much added value
- focus on postdoctoral researchers
- funding to focused areas of research and through international collaboration
- focusing our strengths and the current industry structure. Large-scale industry, especially energy-related industry does not change fast.
- recruit more from abroad
- Finnish R&D should be more in line with international trends, not only scattered international actors that share motives with Finland
- increased international contacts in this area are extremely important
- long-term, predictable funding important, both at universities and research institutes
- international benchmarking is very important
- both by defining some strategically important areas and identifying some excellence units that can operate in those areas
- better resources, experimental infrastructure
- more public funding is needed to research that supports Finnish industry and society simultaneously. The present trend is that industry funds more and more. It prevents

distribution of the results, which would be beneficial. Tekes funding has become far too complicated to receive, and Tekes directs major funding to exotic trends forgetting the needs of industry, which in the long term can be fatal to Finnish industry.
- with intermediate-term funding provision – a single programme will not carry far
- definitely more cooperation among institutes. Approaches should be broadened from technological issues to all aspects of energy questions. Links to climate change policies should be strengthened.
- energy research concerning energy production in Finland or energy-related basic research concerning business opportunities abroad, including new potential companies
- less focus on biomass/biorefinery, since potential is limited, often it is not sustainable. Not too much focus on nuclear energy. More emphasis on sustainable renewable energy: wind, solar, etc.?
- better strategy for forest biomass (current forest sector vs. others)
- peat, oil, coal and natural gas is taken out whatever will be possible in the coming decades and we will also use it. Would there be some kind of peat utilisation with a much more sustainable manner than the current utilisation of fossil energy?
- innovative technology research leading to world-class products on a large scale (e.g. LNG ship engines, new-generation biodiesel) or small-scale (e.g. low-emission wood stoves, real-time emission sensors in -------heavy diesel engines) should be combined with research on the climatic and health drivers that push ahead the changes in technologies.
- more interdisciplinary research involving comparisons between the climatic and health impacts of the use of new vs. old technology, cost-benefit assessment, etc.
- less bureaucracy.

These answers reflect a number of important aspects. The first is that a systematic long-term funding mechanism is needed to reinforce the fundamental research of energy in all dimensions. The second observation is that research teams represent different interests related to bio plants, to local production from wind or solar sources and to centralised nuclear power. Such share can be found everywhere in industrial countries, which underlines the fact that research must be international. The third observation is that the tools to produce energy from small local units to large complex plants have a great potential to become export products of Finnish energy industry, which is a strategic element.

d. Projects that received the highest grades in the evaluation of applications

It was interesting to study how the project applications which received the maximum grade (5) in the review (the national call in 2007) have succeeded.

It was found that all of the funded projects with the maximum grade (5) in the review have achieved excellent results. Examples of the results:

- knowledge to help policy- and decision-makers
- worldwide knowledge dissemination
- new industrial sustainable processes
- strengthening the competence of the participating groups and scientific progress in the field
- process integration has also been demonstrated to be a possible way for improved utilisation of the resources in the steel plant
- inventions and patents, significant scientific impact.

On the other hand, one application with the lowest evaluation grade (3) also resulted in a successful project. It is already clear that this research project will lead to the construction of a new production plant. It is most probable that the invention would never have emerged in this group without Academy-type funding.

e. Industrial impact

The SusEn programme received funding from industry and, consequently, industry representatives participated in the programme steering committee. This stimulated the whole steering committee and provided more knowledge to decision-making.

The industrial funding seemed to be important to researchers primarily as additional funding. Industry did not direct research, as in Tekes-funded projects. Dissemination of information between industry and academia increased, and consequently, the projects were provided with more knowledge and know-how.

All of the projects that received funding from industry continued to cooperate either with the company that granted funded or with some other company.

The industry representatives on the steering committee and the follow-up group had the opportunity to better and more widely learn about the research done at universities both

in Finland and abroad. One industry representative (from Fortum) continued in preparatory group for the new energy programme.

Industry representatives had the opportunity to learn, for example, the following:
It is important to keep research ongoing even if there is no concrete application potential to be expected. When there is a hurry to reach the same knowledge level as the competitors have (new invention), it is not possible to achieve it instantly. Basic research is important to keep the knowledge level high enough.

f. International impact

Many SusEn researchers were more actively engaged internationally than they had been before, thanks to a number of international calls and seminar presentations in Finland by Finnish or foreign researchers involved in the SusEn programme. The programme also arranged seminars in Brazil, Chile and China. More than 50 researchers were involved.

Several excellent researchers abroad learned about Finnish energy research by being evaluation panel members in several calls and by participating in international seminars.

The SusEn research programme had a joint evaluation process with Chilean CONICYT, and CONICYT learned about the evaluation process of the Academy. CONICYT had every confidence in the Academy's procedures and the applications by Chilean and Finnish researchers were processed in the Academy's online system, and the evaluation was carried out in the same ways as in the case of other Finnish applications. The N-INNER network also used the Academy's procedure in its evaluation process. The procedure was introduced to N-INNER partners at the launch of the cooperation and all agreed to use it.

Researchers benefitted a great deal from participation in the N-INNER network, because they could be more closely involved in cooperation with top groups based in Sweden. The selection process for funding was laborious, as Swedish researchers were involved almost in every application.

According to Latin America team's questionnaire, SusEn researchers were mostly very happy with the cooperation in their South American projects. However, they were more satisfied with the scientific quality of the projects carried out with Brazilian colleagues than with Chilean colleagues.

The SusEn programme arranged the first fact-finding trip to Brazil in 2006. Many researchers refused to participate at that time. On the other hand, everyone was interested to visit China. People who participated in the trip to Brazil were very content. When the SusEn programme arranged an energy seminar in Brazil in 2011, researchers were very eager to participate. Some of them even paid their travel expenses themselves. By that time, Brazil had become popular, thanks to its growing economy and world-known bioenergy knowledge and use.

The cooperation with Brazil led in 2012 to the cooperation programme NOBRE ("Network of Excellence"), which is coordinated by two universities: Åbo Akademi University in Finland and the University of São Paulo in Brazil and involves several top players in both countries. The network will have core and BIG partners who will sign up as an institution and nominate representatives. Annual seminars will be arranged: one in Brazil and one in Finland, as well as workshops and web-based lectures. The network will also promote the mobility of students and professors. Funding will be asked from governmental research funding agencies and BIG members. The network will bring new joint ventures on new areas of the bio-based economy; new critical mass to advance the use of biomass and promote actions of sustainable development; new education programmes, new professionals for a new economy; new solutions to tackle climate change.

Some of the Chilean-Finnish projects suffered from the earthquake in Chile, which led in researcher mobility to Finland. The joint project of producing biofuels was evaluated in Chile as highly successful. CONICYT wishes the launch of a new call for joint projects in energy research.

Two Chinese professors who spoke in the energy seminar in Beijing were invited to give keynote speeches in the SusEn seminar in Espoo. After the seminar, they established cooperation contacts with Aalto University.

4. Research projects: analysis and results

a. Impact on sustainable development

Researchers felt that their research had impact on sustainable development by:

<u>Industrial processes</u>

- capability, tools and expertise to develop new and existing energy processes in the focus area

- energy saving and CO2 emissions decrease in steel industry
- fundamental knowledge in the ultrastructure of wood may lead to innovations for decreasing the energy consumption in mechanical pulp production
- pretreatment method was developed applicable for wood
- increased application possibilities for Eucalyptus wood; formed to be utilised in China as well.

The answers indicate that the existing energy-intensive processes in industry can be enhanced to direction sustainable by using new raw materials, by direct burning of gas emissions and by penetrating deeper to the raw material behaviour on the microscale.

Production of energy

- more national expertise is now available to understand advanced fuel cycles that might be part of the national nuclear energy production in the long run (+ 30 years)
- it has demonstrated that some production techniques that work in lower latitudes do not work here, while others are more applicable.

There are two important aspects of centralised and local production. Centralised: next-generation nuclear processes need national operators who must have wide scientific and technical knowledge of fuel behaviour in the reactors. Local: the complicated climate effect and statistical knowledge of local weather conditions have to be included in the research of local production units.

New products

- new forest products
- a step further in producing green chemicals
- new possibilities to find new products and technologies for biorefinery-related industries.

The answers give a clear picture of the current big change in the pulp and paper industry. The wood is also a raw material for fuel production and can replace the production losses related to contracting paper consumption in western countries. This development and other biomass refining methods represent steps towards the future bioeconomy integrating the raw materials, recycled fractions and waste, end-products and energy production.

New materials

- improved durability of fuel cell generators

- better solar cell materials

- giving better materials and higher efficiencies.

This response shows that the development of energy transferring interfaces in units of local energy production lead to difficult and fundamental questions in chemistry and material physics.

Emissions

- encourages companies to develop more efficient small-scale wood combustion appliances and the public to use wood biomass for domestic heating appropriately

- new insight into CO2 versus air-quality comparison

- possibilities of CO2 emissions in blast furnace have evaluated

- due to the similar blast furnace processes global CO2 emissions are also possible to decrease using bio-based charcoal.

Emission issues related to energy production and industrial processes are becoming more important. Research teams are working to develop low-emission solutions to heating of buildings by burning and for heavy steel-making processes in industry. These are excellent examples of how industry contacts are benefitting the research activities.

b. Success stories

Researchers were asked to submit success stories of their research:

- The project led to the development of flexible DSC solar cells, improving the stability of metal substrate based DSC.

- Increased understanding of defect-related properties in CIGS solar cell materials

- Understanding of carbon corrosion in PEM fuel cells

- Significant improvements in understanding the complexity of problems associated with biorefining, for instance. Patent filed.

- Fractionation of lignosellulosic materials

- High-efficient bioethanol process

- Novel findings of the relationships between wood biomass combustion efficiency vs. particle mass emission and chemical composition vs. genotoxicity of the particles

- New possibilities in chemistry of wood fractions

- We demonstrated that co-benefits of climate policies may play an important role in the use of biomass. It promotes some biomass forms and reduces the benefits from some others. This received a great deal of attention among the academic audience.

The main achievement is that we developed strategies to valorise citrus peel. A total of 12 million tons of citrus peel are produced in Brazil annually and we explored the possibilities of commercial exploitation of the raw material.

- Analytical methods were developed that can be widely used in biorefinery research. One doctoral thesis was written.

- Increased knowledge of the influence of wood ultrastructure on the mechanical defibration energy. The research is still ongoing (e.g. we will still use sophisticated spectroscopic and microscopic equipment in the analysis), so it is too early to assess whether we will achieve scientific breakthroughs in this area.

- Several intercropping strategies for using biological nitrogen fixation of legumes to supply the nutritional requirements of the non-legume energy crop worked surprisingly poorly, because maize (for example) remains sensitive to cool spring temperatures that allow legume intercrops to thrive. In contrast, we found that maize could be grown with much lower nitrogen inputs than at lower latitudes, so its negative impacts are much lower. Similarly, we found that fibre hemp is an excellent, low-input energy crop with surprising ecological benefits that we are investigating further. Our perennial crop mixtures (galega - grass) continue and are yielding pleasing data on N2O releases, although the crop yields are not as much superior to pure grass stands as we expected.

- The SusEn project consolidated our research on bioenergy trees. We filed a Disclosure of Invention, and are currently negotiating a patent application.

- Substantial progress in utilising algae as a feedstock. Transfer of knowledge from Brazil to Finland and from Finland to Brazil.

- Described in the final report. Creating continuity for nuclear engineering E&T and Generation 4 R&D

- For the VTT reactor physics code Serpent which is based on Monte Carlo techniques. In this context, the main accomplishment has been the introduction of a novel matrix exponential method CRAM (Chebyshev Rational Approximation Method) for solving the burnup equations. This may be characterised as a breakthrough

-In the reactor material research, the objective was to clarify high-temperature corrosion and stress corrosion cracking (SCC) behaviour of numerous Super Critical Water Reactor

internal candidate materials in supercritical water conditions. Several candidate materials could be tested experimentally and modelled.

- Our deterministic modelling of zeolite membranes including M-S approach and support considerations is reaching international level. We contributed to the adsorption modelling in membranes. Membranes are prepared at Luleå University of Technology but tested in Oulu. We have obtained valuable information about their behaviour and suitability to the applications considered. We have built a great infra for studying ceramic membranes for gas/gas separation (high temperature, high pressure). We started from almost on virgin ground, so novelty was guaranteed from day one. The other side of the coin is that accumulative publication is slower than on established research areas.

- To find out how emissions will change when moving from fossil fuels to biofuels.
The main results were: 1) development of the ÅA route for Mg-silicate rock carbonation for CO2 fixation. It is currently being considered and further development at Nordkalk, Parainen, Finland, but also in cooperation with Singapore, while Portugal and Lithuania are also interested (South Africa appears to be the next on the list); 2) Improved definition of 'good' limestone material for flue gas desulphurisation based on performance testing combined with geological-mineralogical analysis of the rock material. This allows for improved selection and reduced material use; 3) Experimental methods were further developed for multidisciplinary use; 4) The method of precipitated calcium carbonate production from steelmaking slags was further refined, a patent application was filed in 2008, and the process is scaled up under Cleen CCSP 2011–2015. For TKK (Aalto University) partly in overlap with KETJU, 2007–2010. 5). A number of papers and at least five doctoral theses resulted from the work, three already defended; 6) The international visibility of the work increased as a result of the consortium effort, strengthening Finland's position in the field, as also demonstrated by on-going national and international cooperation.
The scientific results focused on the lacking features in the comprehensive process modelling of the focus area. The results in selected topic areas were completing the capability to utilise the comprehensive modelling in a scientifically justified and accurate manner.

- Process integration within steel industry gives possibilities to increase the energy efficiency and to decrease the emissions as well. It was found by mathematical modelling and optimisation studies that top gas recycling of the blast furnace combined with CCS could constitute an interesting alternative, but the overall analysis revealed strong impact on the

total energy balance of the plant. This has to be taken into account in assessing the sustainability of the concept. An integration of steelmaking with methanol production was also an interesting concept that was studied. This alternative was found to hold great promise for the future, in particular if the blast furnace is operated with top gas recycling (making the top gas practically nitrogen free). It stimulated the interest of Finnish local environmental authorities to increase air quality monitoring in older suburban residential areas with relatively densely located detached houses not belonging to the district heating network. This increases our knowledge of the PM2.5 and PAH concentrations in previously little investigated city areas.

- We are able to increase our knowledge of biofuel sustainability by using totally new experiments and modelling. In the other project, we are able to compare the potential climate change effects of different fuels and combustion types (CO2 vs. aerosol scattering and absorption).

- New information applied to Chinese fuels help to increase the use of CO2 free fuels in power production. In China, some 90 per cent of electricity is produced from coal. Therefore, there is a great need to replace it partly by biomass which is produced on the fields but not used.

- The development of the factory simulation tool to evaluate metallurgical process chains, its emissions and energy consumption using different raw materials. According to the simulations, the use of bio-based reductants in blast furnace can be potential option to decrease fossil based CO2 emissions.

- The senior members of this project have been actively involved in policy-supporting work done by Metla. The team has contributed to evaluating the Finnish Forest Policy Programme 2015 and the National Climate and Energy Program (2008).

- Besides scientific contributions, the project was especially successful in two respects: we have provided much help and expertise to decision-makers and had fruitful cooperation with the energy industry. Work for the Finnish Government: Based on his work on emissions trading and electricity market, Minister Mauri Pekkarinen appointed a project leader (and post-doc) to work as analysts to investigate the possibilities of taxing windfall gains in power production in 2009. We presented our report directly in a session of the Finnish Government in 2009. The project leader and the post-doc were re-appointed for the second time as analysts to investigate the possibility of taxing the use of uranium in nuclear power plants. This report was presented to the Minister in February 2011. Finally, the project leader was invited to the scientific climate panel of the Finnish Government as an expert on energy and climate policies. Cooperation with energy industry: the project helped the

Helsinki-based energy company Helsinki Energy to investigate the possibilities of using torrefied wood pellets to replace coal in electricity production. We examined the social returns to torrefied wood pellet and capacity choice of torrefaction plant. Much of the work was confidential. However, many results are reported in two Master's theses written for Helsinki Energy, the social returns to torrefied pellets and suitable torrefaction capacity were studied.

c. Added value compared to Academy Projects

The SusEn programme gained added value through internationalisation, multidisciplinary approaches and industrial funding through the Academy.

The programme initiated many research projects into wider international cooperation by, for example, introducing international projects in seminars.

Bilateral international calls are very demanding, as the curriculum vitae for the partners from both countries must be of a high standard to be competitive to receive funding. In Academy projects, foreign partners are not evaluated.

In the New Indigo ERA-NET call (Energy materials or smart grids, summer 2013) involving European countries and India, Finnish researchers were the second most active after German researchers. The proposals submitted by Finnish researchers also involved researchers from countries participating in the N-INNER network.

The wide scope of the SusEn programme highly promoted multidisciplinarity. Almost all of the projects were consortia which carried out multidisciplinary research.

Researchers were heard to say in the opening seminar that they had never before learnt much about different areas of energy (e.g. nuclear energy).

Industrial funding increased pressure in the SusEn programme. Projects were keen to introduce their results to industry, often even to many companies. Agreements on cooperation were concluded, but it will take time to have final results of new products or other outcome.

The SusEn programme aimed at increasing the expertise of researchers and raising their scientific level by multidisciplinary and international research projects.

Researchers learned a great deal from each other in the seminars. When researchers showed their articles published in *Science* or *Nature* or told about their international cooperation, others could also become motivated to do the same. As the programme involves researchers at different stages of their research career, heterogeneous groups greatly contribute to learning.

The SusEn programme is expected to produce approximately 200 academic degrees. Research programmes help young researchers network with other researchers in Finland.

The SusEn programme started to set up a thematic energy network in the net. It would be a network of energy researchers working in universities and industry in Finland. It can also introduce the results of our energy research to a global audience.

5. Reflections by Professor Jim Swithenbank, University of Sheffield, UK

- These reflections focus on the Finnish Sustainable Energy Research Programme (SusEn) that has evolved to meet the local need for information, innovations and expertise in appropriate energy technologies. This is obviously a very broad area and hence the programme encompasses a wide range of research topics that are considered to be well matched to the need.
- Finland is one of the most developed countries in the world and it is unsurprising that the energy scene reflects the particular features of the country in terms of climate, culture and energy sources.
- Finland lacks domestic sources of fossil energy but has a large source of wood available in the forests (complemented by peat). The efficient exploitation of this environmentally friendly bio-material results in a significant part of the SusEn research programme. One of the fundamental problems with such biomass is that it is a low-density material compared to coal or oil, and its transport via road for long distances incurs significant cost. In the UK, the economic distance that the raw biomass or processed pellets can be transported to a power station or other consumer is about 80km, and a similar constraint will apply in Finland. This problem can be largely addressed by generating electricity or setting up a bio-refinery near the source of the material. In my view, a

significant problem with such a system is contamination of the wood. This can arise from harvesting the trees since the high-quality logs are used for pulping leaving the bark and branches to be collected from the ground as potentially contaminated 'fuel'. This soil contamination can pose a problem for boiler or bio-refinery operation and hence would be a useful topic for research. An associated problem is the effect of alkali metals contained in some biomass materials on combustion systems. In the case of some of the grasses, the sodium and particularly the potassium can lead to problems with corrosion etc. in boilers.

- Imported coal currently provides a large part of the energy for Finnish power generation, and associated problems, together with potential solutions, are discussed in my paper presented at this seminar. Since coal will continue to provide a significant proportion of the energy in most developed countries for the next few decades it is important that research on innovations in coal technology such as carbon capture and storage receive significant support. There is a tendency for some decision-makers (e.g. politicians) to overemphasise alternative technologies such as wind and neglect the traditional technologies. I believe that there is still considerable scope to increase system efficiency and thus reduce fuel use, and hence carbon emissions and fuel import costs.
- There seems to be a slight gap in the current research programme in the fields of materials and manufacturing. These topics are generally essential in taking an innovation in technology to market. The topics are often linked since new technologies often involve new and unfamiliar materials that require special manufacturing procedures. Many of these materials and their wastes can also have particular health implications that must be resolved before manufacture proceeds. Finland has been a leader in many of these areas and it is appropriate that this leading position is recognised and maintained. This topic will probably expand as bio-engineering becomes more popular. One important area that is already of particular interest to Finland, and where there is particular expertise, is the emission of submicron particles from biomass combustion and vehicle engine combustion systems. These particles have serious health implications and more interdisciplinary research is required with cooperation between engineers and medical toxicology specialists. Countries where there is a real problem include Mexico and China. In the case of China, the situation in Beijing now appears analogous to the situation in the UK in 1960, when severe smog was encountered due to coal combustion. The current work on algae is also a specific example, since the health of nearby living entities must be taken into account, including the potential for interference with DNA. We must learn from the damage that has been done to various natural systems, where mankind has introduced foreign species into established systems. Examples of this well-intentioned interference were the introduction of rabbits and toads into Australia where they have since proved to be serious pests.
- It is gratifying to learn that international cooperation has been particularly successful between Finland and countries such as China and Brazil; however, the reason for Finland's choice of

particular partner nations requires explanation and/or justification. The opportunity for research support panels to include members from other nations can also help to ensure that new topics are followed up quickly and avoid some research getting stuck in a narrow area.

- Since doctoral students now tend to be recruited from a more international pool than previously, their funding needs must be critically assessed and analysed. In many countries, there is now a shortage of high calibre students interested in careers in engineering, partly due to the perceived weak rewards and status of such jobs in Western countries. Thus, in many cases, first-class students graduating with a degree in engineering are head-hunted to take up more lucrative careers in banking etc.
- The review of the relationship between industry and the academic research community indicates that this is particularly strong in Finland, with ideas being taken-up and marketed quickly. In particular, process integration has proved successful within particular industries. The next step should be research into "over the fence" integration of adjacent industries. Thus surplus energy or materials in one industrial plant should be utilised by an adjacent plant whenever possible.
- Turning to nuclear power, the situation is currently being assessed at an international scale. Finland has a relatively large nuclear power programme and is fully involved in the exciting international developments in this important field.

My final conclusion is that, in the longer term, mankind still needs a reliable source of nuclear power located in space where the waste material can be safely abandoned. The energy must be sent to the earth by radiation and then be efficiently and cheaply converted to electricity for distribution. The sun can fulfil a key part of this system, and plenty of radiant energy already arrives at the earth. The great need at present is the development of low-cost photovoltaic systems complemented by storage and efficient use of the harvested power. This priority status justifies substantial and sustained support for work in the field of energy.

6. Reflections by Professor Michel Cotsaftis, École Centrale d'Électronique (LACSC/ECE), France

By its volume, the SusEn programme is a midsize one both in terms of involved money and of time span. It corresponds to relatively high specialisation with an average of more than EUR 4,000/FTE month. It is, however, a large programme in terms of specific projects involved (44) spanning over three large domains, that is, biology, chemistry and electronics. The programme generated a lively international cooperation and various useful links have been initiated. After the five-year period, it is interesting to proceed to evaluating the benefits from it.

Most academic and research elements have already been discussed in the report and are based on collected data from the participating groups. Here, one will be concerned with two aspects of strict scientific contribution and possible impact on industrial activity.

The first problem is to locate relevance of the problem with respect to very large and yet imprecise objective of 'improving' efficiency of industrial and economic activity with respect to the two fundamental parameters, heat and pollutants release. They are obviously related through chemical and biological interactions, but their growth is reaching a level where consequences might be dangerous. In fact, the fuzziness of the results weakens the sharpness of the statements fixing univocally limit thresholds to be respected in the future. Very roughly, because of the multiple origins of pollution which can be related to heat-producing sources and to so many chemical reactions in industry, which are illustrating the extremely dispersed time and space scales playing a role in the problem, direct analysis indicates that there exist three classes of actions

1) Finding better efficiency with new materials
2) Defining new types of sources
3) Adjusting at each level sources and sinks

to deal with such a question. The difficulty is in implementation at correct scale when respecting strong optimisation constraint imposed by economic and survival conditions. Many studies have already been produced dealing with transformation from present centralised and continuous high-production systems toward modulated and adaptable, localised and less polluting ones for both energy and products. In parallel, a large effort is the concentration on production of less demanding fashionable and controllable materials and systems. In this context, remarkable contributions have been delivered by the SusEn working groups both in the direction of non-

conventional sources and of improvement of classical ones, providing in particular a clear insight into clever uses of gas and chemical or organic compounds.

Nevertheless, these are extremely specialised studies which stay aside the preliminary key points concerning unavoidable interaction problems between connected sources and sinks.

It can be wondered if a more focused programme directly related to the Finnish economy would not have been more appropriate at present time, being accounted that Finland grasps the main three ingredients, wood, water and nuclear energy, but is weak concerning sunshine and wind. For instance, the identification of micro-alguae for biodiesel production and even specialising more on their coupling with specific bacteria can only be a small contribution to the existing very large worldwide effort on the subject and is very far from Finland's positioning. More generally, biomass research even within international collaboration (Brazil) might not be so rewarding, even with the evident, possible use of wood pulp.

Analysis of wood biomass combustion is, however, quite appropriate as it greatly affects not only the mass emission but also the chemical composition and toxicity of the emitted pollutants. There are interesting and applicable results are that calculated CO2 emissions are lowest for wood pellets and geothermal energy, the use of which is currently increasing in new detached houses in Finland. In contrast, pollutant emissions, and thus health impacts, are much higher with wood pellets compared to geothermal energy. With regard to costs, the optimal choices depend on the energy needs of the house. With energy-efficient houses, direct electricity supported by a heat pump or masonry heater is the cheapest option, while geothermal energy is cost-effective especially in old houses consuming a lot of heating energy. The observation that in a conventional masonry heater there is slow combustion of log-wood with partial restriction of air supply and firebox overload, an operation largely increasing emissions of carbon monoxide (CO). But the quantitative impacts on health and climate with regard to heating of residential buildings are not determined. The remark that "further analysis of heat and pollutants release is depending on the nature of heating systems with very variable results because costs, health, and climate impacts often go against each other, while at some points they go side by side" is almost evident and does not need a big research programme to be stated. This clearly shows the limit of the only model 'technical' analysis as a final policy choice is also depending on different decision-makers (e.g. house owner and society) implied in the process to identify conflicting interests.

The other problem of fixation of carbon dioxide (CO2) as carbonated minerals in Finland is interesting as it meets recent active research on CO2 capture and storage, being recognised that

steelmaking is also one of the most energy-intensive industrial processes globally and gives rise to about 6 per cent of the fossil CO2 emissions in the world (1 ton of (primary) steel production requires almost 20 GJ of energy and causes at least 1.7 tons of CO2 emissions). Discussion of the various options with different material states may offer valuable solution as Finland has large resources of suitable magnesium silicates (xMgO.ySiO2.zH2O) in Europe. The serpentinites of Outokumpu-Kainuu ultramafic rock belt alone could be sufficient for the fixation of several Gt (gigatons) of CO2. However, the final reduction of emission cannot be achieved without substantial increase in production costs.

When considered in its globality, the SuSEn programme has been exploring different possibilities of acting on actual dynamics of heat and pollutants fluxes in industrial and residential activities. Studies extended from scientific to rather applied domains but results are not conclusive enough for technical decisions. Some of the results are much more concerned with the Finnish situation and are fully in line with the expectable choices of the Academy of Finland. Other less depending results are developed for different and perhaps more academic purposes. The explored fields are deliberately outside the main stream of optimal regulation of large plant ensembles and distribution networks which are posing today still unsolved but unavoidable theoretical problems.

7. References

1. Webropol questionnaire
2. Final reports in the Academy's online services
3. Consortium reports
4. Programme memorandum

Appendices:

1. List of funded projects

2. List of allocated funding

3. A summary of programme lifespan and coordination activities in 2005–2012

Appendix 1.

The following projects (Finnish partners) are funded within the Sustainable Energy Research Programme:

National call in 2007

ALGISEL Algae for Biodiesel Production
Tamminen Timo, Finnish Environment Institute, €350,180
Oksman-Caldentey Kirsi-Marja, VTT Technical Research Centre of Finland, €300,030
*Annual report **2009** **2010***

BEET Electricity Markets, Emissions Trading and Incentives in Bioenergy Technology
Ollikainen Markku, University of Helsinki, €240,600
Lankoski Jussi, Agrifood Research Finland, €182,880
Stoddard Fred, University of Helsinki, €317,720
*Annual report **2008** **2009** **2010***

BIOHER Biomass and Fuel Oil in Heating Systems: Greenhouse Gas and Particle Emissions and Health Risks
Salonen Raimo, National Public Health Institute, €152,240
Hillamo Risto, Finnish Meteorological Institute, €150,000
Hirvonen Maija-Riitta National Public Health Institute, €153,840
Jokiniemi Jorma, University of Kuopio, €150,000
Pekkanen Juha, National Public Health Institute, €150,000
Tuomisto Jouni, National Public Health Institute, €144,000
*Annual report **2008** **2009** **2010***

Bioref Matematical Analysis and Multi-objective Optimization of an Urban Bio-Refinery Plant under Temporally Changing Technical, Social and Juridical Boundary
Hurme Markku, Helsinki University of Technology, €196,070
Aittamaa Juhani, Helsinki University of Technology, €196,070
Dahl Olli-Pekka, Helsinki University of Technology, €196,070
Annual report 2008 2009 2010

CaDeWo Catalytic Decomposition of Wood
Leskelä Markku, University of Helsinki, €365,720
Tamminen Tarja, VTT Technical Research Centre of Finland, €132,120
*Annual report **2008** **2009** **2010***

CARETECH Carbonates in Energy Technology
Zevenhoven Ron, Åbo Akademi University, €251,440
Eklund Olav, University of Turku, €140,580
Fogelholm Carl-Johan, Helsinki University of Technology, €153,730
*Annual report **2008** **2009** **2010***

EFFDRI Reduction of Losses in Electric Drives

Arkkio Antero, Helsinki University of Technology, €198,870
Luomi Jorma, Helsinki University of Technology, €199,440
*Annual report **2008** **2009** **2010***

FOBIT Forest-based Fuel and Material Demand and the Overall Climatic Impacts
Pingoud Kim, VTT Technical Research Centre of Finland, €184,360
Uusivuori Jussi, Finnish Forest Research Institute, €119,860
Valsta Lauri, University of Helsinki, €251,440
*Annual report **2008** **2009** **2010***

GREENSTEEL Hidden Potential for Gross Reduction in the Energy Demand and Emissions in Steelmaking
Saxen Henrik, Åbo Akademi University, €229,270
Holappa Lauri, Helsinki University of Technology, €184,690
Härkki Jouko, University of Oulu, €186,010
*Annual report **2008** **2009** **2010***

NETNUC Critical Analysis of New Generation Reactors
Kyrki-Rajamäki Riitta, Lappeenranta University of Technology, €409,500
Heikinheimo Liisa Sofi, VTT Technical Research Centre of Finland, €545,220
Salomaa Rainer, Helsinki University of Technology, €345,160
*Annual report **2008** **2009** **2010***

SUSFUFLEX New, Innovative Sustainable Transportation Fuels for Mobile Applications: From Biocomponents to Flexible Liquid Fuels
Lassi Ulla, University of Oulu, €164,600
Keiski Riitta, University of Oulu, €160,580
Kordas Krisztian, University of Oulu, €114,320
Mikkola Jyri-Pekka, Åbo Akademi University, €157,720
*Annual report **2008** **2009** **2010***

Economic-ecological Optimization of Timber and Bioenergy Production and Sequestration of Carbon in Norway Spruce Stands
Tahvonen Olli, Finnish Forest Research Institute, €449,160
*Annual report **2008** **2009***

Multiphase Fluidized Bed Processes in Sustainable Energy Technologies
Hyppänen Timo, Lappeenranta University of Technology, €515,440
*Annual report **2008** **2009** **2010***

Revolutionary Electricity Distribution System Based on Power Electronics
Partanen Jarmo, Lappeenranta University of Technology, €474,880
*Annual report **2008** **2009** **2010***

Northern European Innovative Energy Research (N-INNER) call:

Synthesis and Durability of CNT-based MEAs for PEMFC (Nanoduramea)
Kauranen Pertti, VTT Technical Research Centre of Finland, €205,560

Kauppinen Esko, Helsinki University of Technology, €184,020
Annual report ***2008*** ***2009*** ***2010***

Optimizing Lipid Production by Planktonic Algae (LIPIDO)
Tamminen Timo, Finnish Environment Institute, €218,870
Oksman-Caldentey Kirsi-Marja, VTT Technical Research Centre of Finland, €130,640
Annual report ***2009*** ***2010***

Evaluation Platform for Polymer Solar Cells
Österbacka Ronald, Åbo Akademi University, €137,100
Annual report ***2008*** ***2010***

MATERA ERA-NET-call

Defects in Chalcopyrites: Advanced Characterisation (DECK)
Tuomisto Filip, Helsinki University of Technology, €200,000
Annual report ***2008*** ***2009*** ***2010***

International joint call with the National Natural Science Foundation of China (NSFC): Funding decisions 17 October 2007:

Novel Methods to Model and Reduce Toxic Element and Fine Particulate Emissions and Operational Problems in Co-combustion of Biomass and Coal
Aho Martti, VTT Technical Research Centre of Finland, €244,560
Annual report ***2008*** ***2009*** ***2010***

Flexible Dye-Sensitized Solar Cells
Lund Peter, Helsinki University of Technology, €274,560
Annual report ***2008*** ***2009*** ***2010***

Joint call with the Chilean National Commission for Scientific and Technological Research (CONICYT):

Optimal Treatment Process of Lignocelluloses to Bioethanol
Mikkola Jyri-Pekka, Åbo Akademi University, €125,000
Peiponen Kai, University of Joensuu, €125,000
Annual report ***2008*** ***2009*** ***2010***

Upgrading Biogas for Vehicle Use
Rintala Jukka, University of Jyväskylä, €125,000
Mikkola Jyri-Pekka, Åbo Akademi University, €125,000
Annual report ***2008*** ***2009*** ***2010***

Polysaccharide-based Biofuels and Smart Biomaterials: Sustainable Production Integrated with Pulp and Paper Processes
Fardim Pedro, Åbo Akademi University, €250,000
Annual report ***2008*** ***2009*** ***2010***

Functional Genomis of Tree Biomass
Helariutta Yrjö, University of Helsinki, €211,600
*Annual report **2008** **2009** **2010***

Joint call with the Brazilian National Council for Scientific and Technological Development (CNPq): Funding decisions 17 September 2009:

Feasibility of Finnish and Brazilian Biomasses in Advanced Biorefineries
Fardim Pedro, Åbo Akademi University, €290,030

Effect of Fibre Wall Chemistry on Energy Demand in Wood Defibration
Jääskeläinen Anna-Stiina, Helsinkí University of Technology, €286,390
Tamminen Tarja, VTT Technical Research Centre of Finland, €303,210
*Annual report **2009** **2010***

The effects of Intensive Bio-fuel Production and Use on Regional Air Quality and Global Climate
Kulmala Markku, University of Helsinki, €490,860

Production of Green Diesel from Algaes
Murzin Dmitry, Åbo Akademi University, €290,310
*Annual report **2010***

Conversion of Pectin Rich Residues to D-galacturonic Acid and Other Platform Chemicals Using Solid State Fermentation and Metabolically Engineered Fungal Microorganisms
Richard Peter, VTT Technical Research Centre of Finland, €429,240
*Annual report **2010***

Northern European Innovative Energy Research (N-INNER) II. call: Funding decisions 17 Septembe 2009:

Efficient Production of Fuels from Biomass
Mikkola Jyri-Pekka, Åbo Akademi University, €338,450
*Annual report **2010***

High Permeance Nano Porous Tubular Zeolite Membranes for Efficient Separation of CO2 and Methanol at Demanding Conditions
Tanskanen Juha, University of Oulu, €273,110
*Annual report **2010***

Joint call with the Brazilian National Council for Scientific and Technological Development (CNPq): Funding decisions 18 December 2012:

Novel Optical Materials for Solar Energy Conversion and Storage
Hölsä Jorma, University of Turku, €411,604

Biomass Supercritical Water Gasification Integration with CHP Units – Definition of Novel Social and Political Constraints for Enlarged Multi-objective Optimisation (BioSCWG)
Järvinen Mika, Aalto University, €465,293

Improving Process Understanding and Widening of Feedstock Database for Thermal Biomass Conversion (IMUSTBC)
Konttinen Jukka, University of Jyväskylä, €486,085
Vakkilainen Esa Kari, Lappeenranta University of Technology, €93,286

A Theory for Sustainable Smart Grids: Combining Communication Theory, Power Systems, Signal Processing and Economics from a Complexity Science Perspective
Latva-aho Matti Sakari, University of Oulu, €347,183

Molecular Redox Couples and Hole Conductors for All-printed Solid-state Flexible Dye Solar Cells (SOLID)
Lund Peter, Aalto University, €294,648

Microalgae to Fuels
Murzin Dmitry, Åbo Akademi University, €362,632

Bioconversion of Pectin-rich Residues to Fuels and Chemicals
Richard Peter, VTT Technical Research Centre of Finland, €412,041

Improved Technologies for Enzymatic Lignocellulose Breakdown to Sugars in Biorefineries
Saloheimo Markku, VTT Technical Research Centre of Finland, €434,003

Joint call with the Chilean National Commission for Scientific and Technological Research (CONICYT): Funding decisions 31 January 2013:

Computational Studies of Light-Absorption Processes in Dye-Sensitized Solar Cells
Sundholm Dage, University of Helsinki, €329,008

Optimal Production of Bioethanol from Macroalgae via Photo-chemo-enzymatic processing – OPTIFU
Mikkola Jyri-Pekka, Åbo Akademi University, €366,271
Kordas Krisztian, University of Oulu, €278,000

Environmental Impact Analysis and Sustainability – Efficiency-based Criteria for Solar Energy Projects in Northern Chile
Kukkonen Jussi, University of Jyväskylä, €277,918

Assessment of Solar Energy Potential in Urban Areas
Lund Peter, Aalto University, €256,619

Bulk Hetero Junction (BHJ) Solar Cells Based on Thienylvinylene Oligomers
Efimov Alexander, Tampere University of Technology, €438,556

Appendix 2.

Funding in SusEn programme

	Date	Academy funding/€	Other sources/€	Themes in call	Number of projects	Funding period
National call 2007	19.11.2007	8 800 000	900 000		14	mainly 2008-2011, also 2008-2010,
ERA-NET MATERA	19.11.2007	200 000			1	2008-2011
N-INNER I. call 2007	19.11.2007	876 000		Funding is granted for basic research projects researching basic innovative energy.	3	2008-2010
Joint call with National Natural Science Foundation of China (NSFC)	17.10.2007	490 000		Environment and energy	2	2008-2010
Joint call with Chilean CONICYT 2007	9.1.2008	962 000			4	2008-2010
N-INNER II. call 2009	17.9.2009	611 000		Research topics are related to renewable energy systems and energy efficiency in society, industry, distribution, production and buildings contributing to combating climate change.	2	2009-2012
Joint call with Brazilian CNPq 2009	17.9.2009	2 100 000		1. Sustainable terrestrial biomass systems for energy 3. Biomass based production in biorefineries 2. Energy efficiency in pulp and paper production	5	2009-2012
Joint call with Brazilian CNPq 2012	18.12.2012	3 310 000		Bioenergy and biomass Solar energy Ocean Technologies and Hydroelectricity Wind energy Nanotechnology and materials for energy and fuels applications Energy storage	8	2013-2015, 2013-2016, for 3-4 years
Joint call with Chilean CONICYT	31.1.2013	1 950 000		1.Wave energy 2. Solar energy 3. Geothermal energy 4. Smart grids 5. Energy storage 6.Algae technologies	5	2013-2015, 2013-2016, for 2-3 years
		19 299 000	900 000		44	

Appendix 3.

A summary of the programme lifespan and coordination activities in 2005–2012

YEAR 2005

The preparation of the Research Programme on Sustainable Energy was mandated by the Board of the Academy of Finland in December.

YEAR 2006

The Preparatory Group was nominated. The group had representatives from the Academy's four research councils. The group also included external experts.

Programme Manager Saila Seppo was nominated to take charge of the preparation and management of the programme.

The Preparatory Group prepared the first draft of the programme memorandum describing the goals and themes of the programme. This draft served as a basis for negotiations with other funding bodies including Tekes (Finnish Funding Agency for Technology and Innovation), ministries, private foundations and companies and foreign research funding agencies.

At the national level, Tekes was consulted several times to study possibilities for joint funding, but none of their ongoing or starting initiatives was possible to merge with the SusEn programme. However, the Maj and Tor Nessling Foundation was interested in funding those projects that suited under their funding priorities. As a result of a number of negotiations, the possibility to receive funding from industrial companies finally verified. The pulp and paper company UPM-Kymmene, the energy-company Fortum and the oil company Neste Oil were willing to co-fund SusEn projects.

Negotiations with a number of European funding agencies were conducted, and these discussions led to closer contact with the Nordic countries. This resulted in so-called N-INNER energy research funding cooperation.

In November, the Board of the Academy made a decision to launch the Research Programme on Sustainable Energy Research. The total Academy allocation for funding the programme was EUR 9.0 million.

The SusEn steering committee was nominated. The committee had representatives from the Academy's four research councils. The committee was chaired by Professor Timo Jääskeläinen

(Academy), and all potential external funding bodies had one representative. One representative from Tekes and one from the Ministry of Trade and Industry were invited as external experts to strengthen the cooperation with Tekes and the ministry as well as the scientific expertise, especially in the initial phase of the programme, when the objectives were set and the funding decisions made.

The first negotiations to launch a joint call in energy research started (separately but simultaneously) with basic research funding agencies in Chile (CONICYT) and Brazil (CNPq).

YEAR 2007

The programme memorandum was published and the three themes for the programme were selected: New technologies for energy production, Effective energy systems, and Efficiency in energy use.

The call for proposals was announced in January. The call was national (Finnish) and it was organised at two stages (at the first stage, letters of intent containing only the research plan, then full proposals). A total of 89 letters of intent were submitted to the SusEn programme. Unfortunately, only few applications were received under the theme “Efficiency in energy use”. The steering committee selected 43 research plan proposals for the second stage.

The scientific evaluation panel was arranged in Helsinki on 12–13 June 2007. The attendees of the panel meeting were:

Professor Robert Dibble, University of California (Chair), mechanical engineering, combustion modelling Professor Fraser A. Armstrong, University of Oxford, chemistry, inorganic chemistry

Dr Paul Howarth, University of Manchester, nuclear energy

Professor Birgit Kamm, Forschungsinstitut Bioaktive Polymersysteme, bioaktive polymersystems

Professor Stef Proost, Katholieke Universiteit Leuven, transport and environment

Professor Birger Solberg, Norwagian University of Life Sciences (UMB), ecology and natural resource management

Professor Lieven Vandevelde, Ghent University, electrical energy, systems, automation

Professor Robert G. Watts, Tulane University, mechanical engineering

Professor Margot Weijnen, Delft University of Technology, energy policy and management

Dr Upul Wijayantha, Loughborough University, chemistry, solar cells

The external evaluators, whose evaluation reports were available in the panel meeting to help the panel work, were:

Professor Michael Golay, MIT Department of Nuclear Science and Engineering, nuclear energy

Professor Leila Parsa, Rensselaer Polytechnic Institute, electrical, computer and systems engineering

Professor Peter J. G. Pearson, Imperial College London, energy policy and technology

Professor Ian Colbeck, University of Essex, environment and society

Professor Stanley W H Cowley, University of Leicester, physics and astronomy

The full applications to the SusEn research programme (call deadline: 28 April 2007) and four applications for the call "Funding of joint research projects with the National Natural Science Foundation of China" were evaluated. Altogether 47 applications were discussed one by one. The distribution of the ratings was as follows:

5 = outstanding	11
4 = excellent	15
3 = good	15
2 = satisfactory	4
1 = poor	2

The steering committee reserved EUR 200,000 to fund one project in MATERA ERA-NET call "Materials for Sustainable Use in Renewable Energy". The call was open in April 2007 and the applications were evaluated outside the Academy by the MATERA ERA-NET panel.

Later, the funding consensus was confirmed by the Steering Committee in Helsinki in October. Three commercial companies (UPM-Kymmene, Neste Oil and Fortum) and Maj and Tor Nessling Foundation allocated EUR 0.9 million to fund SusEn projects.

Altogether 14 projects were approved for funding. Three of the funded projects were conducted by individual teams, eleven were consortia.

It is justified to implement small international calls in connection with a research programme in order to more comprehensively cover the thematic area in question.

A joint call with the Chilean funding agency CONICYT was implemented in October (1–31 Oct). On the basis of this call, four research projects were funded for three years.

The first N-INNER call was implemented in 2007, and in addition to the Academy of Finland, the participating funding bodies were: the Swedish Energy Agency (Sweden), Forschungszentrum Jülich (Germany), the Danish Council for Strategic Research (Denmark), Orkustofnun (Iceland), the Research Council Norway (Norway), and Nordic Energy Research. Three research projects under the N-INNER network were incorporated into the SusEn research programme and funded for three years.

YEAR 2008

The SusEn projects started in January. All projects were asked to set up a follow-up group. The projects were advised to set up their follow-up groups in a way that would benefit the project's objectives in the best possible way. Projects that received funding from industry, invited a representative of the funding company to participate in the follow-up group. There were no other instructions how to build a follow-up group. The opening ceremony took place in Helsinki in February. The seminar was organised for two days. The first day was open to a wider audience and the second day was designed for researchers. On the first day, the programme introduced the programme in general and highlighted the keynote presentations by the Ministry of Trade and Industry, by an industry representative and a Tekes representative and by university professors. On the second day, all research projects were presented briefly. The presentations were posted on the SusEn website.

Since the beginning of 2007, the programme manager had visited the programme's projects. The aim of the visits was to hear the wishes and expectations of the principal investigators and the researchers towards the programme as well as to find out how their research has proceeded. The need for seminars and workshops was also discussed. The teams did not wish any overwhelming activities, while the annual seminars and more targeted workshops were regarded important in terms of the coherence of the programme.

A joint energy workshop with CNPq was organised in Brazil, and Finnish and Brazilian researchers discussed energy areas that could be potential themes for a joint call. A joint call with CNPq was opened at the end of the year. The funding decisions were made in 2009, and five research projects were funded both in Brazil and in Finland.

A two-day seminar "Power and Energy" was organised in the Helsinki Metropolitan area in June jointly with two other Academy research programmes (Sustainable Production and Products, and

Power and Society in Finland). At the seminar, researchers from different fields discussed topics such as “is there enough of energy?”, “who makes energy?” and “who decides on the energy?”. The seminar was very interactive and received a lot of positive feedback. The seminar was held in Finnish with a view to facilitating a better understanding of science that is not so well-known. The seminar was very popular and the seminar programme was written with carefully thought words. Energy researchers were sent a message and asked whether they wanted to speak at the seminar. Surprisingly, several foreign researchers answered that they are willing to speak at the seminar, though they were requested to speak in Finnish. A Chinese researcher whose mother tongue is Chinese said that he was practicing Finnish every day for a month.

All SusEn projects were asked to submit an annual report on their work. The reports were posted on the SusEn website (www.aka.fi/en-GB/A/Research-programmes/Ongoing/energy/Annual-Reports/).

YEAR 2009

In spring, the second N-INNER call was launched, and in addition to the Academy of Finland, the participating funding bodies were: the Research Council of Norway, the Swedish Energy Agency, the Danish Council for Strategic Research, the Estonian Science Foundation, Projektträger Jülich and Nordic Energy Research. Among the projects that were selected to be funded by the N-INNER steering group meeting were two projects involving a Finnish researcher. These projects were partly funded by the Academy of Finland and they were incorporated into the SusEn programme.

Two “value-chain” seminars were arranged during the year together with three other Academy programmes. The idea was to connect researchers from completely different fields (Sustainable Production and Products, The Future of Work and Well-being, Finnish Companies and the Challenges of Globalisation, and SusEn) and to give them an opportunity to interact and learn from each other’s research. The seminar was held in Finnish, as it is easier to understand lectures on sciences unknown to oneself in one’s own mother tongue. In addition to talking about their science, the lecturers were advised to also present unscientific thoughts associated with the seminar theme. The seminar was very successful, including with a lot of discussions. At the seminar, a paper-version feedback questionnaire was distributed and as a result of the feedback received, a second seminar of the same type was arranged. After the second seminar, researchers still wanted to have another seminar of this type, but it was not arranged.

A two-day annual seminar was arranged in Helsinki in October. The keynote speaker was Professor Mircea Guina from Tampere University of Technology with the topic “High-efficiency III-V solar Cells: Opportunities and Challenges”. All SusEn projects had oral presentations in the seminar.

A two-day energy seminar was arranged in Beijing together with the Chinese funding agency, the National Natural Science Foundation (NSFC). The seminar had three themes: Solar Energy, Wind Power, and Biomass Energy. Finnish and Chinese researchers presented their own research results and, more widely, also research carried out in their own country in this field.

Annually, the N-INNER projects orally presented their results to the steering committee of the N-INNER network.

YEAR 2010

The programme manager continued her visits to the projects of the programme. The aim of the visits was to hear the wishes and expectations of the principal investigators and the researchers towards the programme as well as to find out how their research has proceeded. The need for seminars and workshops was also discussed.

The SusEn programme arranged a one-day annual seminar in Helsinki in May. There were three keynote speakers:

Outi Krause, Vice Dean, Aalto University, School of Science and Technology: “Energy Research in Aalto University”

Jyrki Luukkanen, Professor, University of Turku, Finland Futures Research Centre: “Future Energy”

Sirkka Vilkamo, Deputy Director General, Ministry of Employment and the Economy: “Energy Technology Research in the EU in the 2010s”.

Three parallel sessions were arranged for workshops. The chairs of the workshops were Professors Hannu Hänninen, Kari Törrönen and Peter Lund. The themes were: traditional energy sources, renewable energy sources, rational use of energy. The perspectives were: basic research in Finland, Finland and EU policy, energy policy in Finland year 2050. Afterwards, the presentations were posted on the SusEn website. The results of the workshops were published on the SusEn website and they were also sent to the press and the relevant ministries. All projects presented their work on poster sessions. This seminar was very popular as was the opening seminar of the SusEn programme, too.

All SusEn projects were asked to send an annual report on their work. The reports were posted on the SusEn website.

YEAR 2011

The SusEn programme arranged a two-day seminar in the Aalto University campus together with the N-INNER network. The three keynote speakers were:

Professor Mikko Hupa, Åbo Akademi University: “Fundamental Research as Basis for Energy Technology Innovations”

Professor and Dean Chen Yan, Shantou University: “Status and Prospect of Fundamental Research for Wind Turbine Technology in STU”

Professor Shi-Zhong Li, Tsinghua University: “Status on Biomass Energy Development in China”.

The SusEn projects that were co-funded together with the Academy with Chiliean , Brazilian or Chinese funding body and the N-INNER projects gave an oral presentation of their research. Other projects presented their work by posters.

This international seminar succeeded very well; seminar participants co-worked and discussed very actively. All presentations were posted on the SusEn website.

A seminar was arranged on 1 November together with two other Academy research programmes. The seminar was held in Finnish. The idea was to connect researchers from completely different fields (Photonics and Modern Imaging Techniques, The Future of Living and Housing, and SusEn) and to give them an opportunity to interact and learn from each other’s research.

A Brazilian-Chilean-Finnish energy seminar was held in November in Rio de Janeiro, Brazil. Several workshops were arranged to plan the coming calls between the Academy and CNPq and the Academy and CONICYT. CNPq’s attitude was to have a bilateral call with the Academy. Otherwise a trilateral call would have been a possibility.

YEAR 2012

The Academy of Finland announced two joint calls within the SusEn programme; these were together with Brazilian CNPq and Chilean CONICYT. A total of 15 research project proposals were received in the Academy-CNPq call and 13 research project proposals in the Academy-CONICYT call. The Academy negotiated with the sister organisations to have a joint evaluation. CNPq answered that the time limit made it not possible. The Academy started negotiations with CONICYT and finally had an agreement on how to manage the joint evaluation process. It was decided to carry out the evaluation according to the Academy’s procedure and to use the Academy’s online service. The applications submitted to the joint calls with CONICYT and CNPq were all evaluated in Santiago.

After the panel meeting, the Academy agreed on the applications to be funded by video conference with CONICYT and by emails with CNPq. CNPq had evaluated the joint applications by themselves as well. Eight research projects were co-funded with CNPq, and five research projects were co-funded with CONICYT.

A foresight workshop on energy research was arranged in Helsinki on 3 December 2012. The work to launch a new energy research programme was started.