ANALYSIS OF SUSTAINABLE ENERGY SYSTEMS

STRATEGIC RESEARCH LINE

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1.A DESCRIPTION OF THE STRATEGIC RESEARCH LINE

1.A.1 DESCRIPTION OF THE RESEARCH LINE

The proposed Strategic Line "Analysis of Sustainable Energy Systems" aims at integrating CIEMAT´s research activities focusing on the sustainability assessment of energy technologies and systems including their environmental, socioeconomic and social implications. It also attempts to assess their potential role and contribution to the low carbon energy transition and identify the best supporting/enabling policies. It has the aspiration of becoming a benchmark in this type of analysis at the National and International level.

This Strategic Line encompasses the activities carried out in the Energy Systems Analysis Unit (E02), part of the activities carried out in the Solar Thermal Applications Unit (E47) of the PSA, part of the activities carried out in the Wind Energy Unit (E22), part of the activities carried out in the CISOT (M40) belonging to the Department of Environment, as well as part of the activities carried out in the Group of Risks in Geological and Technological Systems (M03) also within the Department of Environment.

The strategic line has 5 lines of activity:

- **Development of energy scenarios**. It includes the modeling of energy systems using TIMES-family[1] techno-economic optimization models used by the E02, models based on artificial intelligence such as the one developed in the E47[2], and simulation, optimization, and sensitivity analysis models (HOMER Pro-Type)[3] for the modeling of microgrids in all sectors (rural electrification, grid-connected systems, islands,…) used by the E22.
- **Sustainability analysis of energy technologies and systems**. It includes the analysis of the environmental, socioeconomic, social of the life cycle of energy technologies and systems using Life Cycle Sustainability Analysis tools, Multiregional Input-Output Analysis, Health Impact Assessment and Externalities Analysis.
- **Environmental Risk Analysis of technologies for low-carbon solutions.** It includes the development and application of methodologies for environmental risk assessment that allow avoiding, in a planned manner and from the design stage on, the materialization of hazards in systems involving the geological environment.
- **Analysis of the social dimension of sustainable energy systems**. It includes social research on the public perception of (new) energy technologies, and on the social acceptance (i.e

[1] https://iea-etsap.org/index.php/etsap-tools/model-generators/times
[2] http://mixspain.psa.es/
[3] https://www.homerenergy.com/products/pro/index.html

community acceptance; socio-political acceptance market acceptance) of energy technologies, projects, applications, and policies.

- **Analysis of Energy and Climate Change Policies**: It includes the analysis of energy and climate change policies at the regional, national and international level in line with the Paris Agreement, the 2030 Agenda and the EU Green Deal.

1.A.2 SCIENTIFIC AND TECHNOLOGICAL OBJECTIVES:

The general objective of this Strategic Line is the analysis of the energy transition in its environmental, economic, and social aspects in order to guide research and innovation in energy technologies so that they contribute and are a key pillar of sustainable development and of new models of environmental governance.

The strategic line combines engineering, environmental sciences, physics, and social sciences with developments in the field of risk governance, sustainability, and environmental policy to help meet the challenges posed by the ecological transition.

Scientific objectives

- **SO1. Development and use of models for the analysis of energy scenarios** at different spatial scales (global, national, regional or local) and temporal scales (annual, monthly, hourly, ...), different resolutions (energy system, electrical system, microgrids), different horizons (current, 2030, 2050, ...) and restrictions using different methodologies. The integration of temporal information on generation and demand technologies as well as market prices; the inclusion of generation and demand spatial information, and the simulation of the technical and economic participation in the auxiliary services of the electricity market are also scientific objectives of this research line in this area.
- **SO2. Analysis of the environmental, economic, and social sustainability of energy technologies and systems** with different methodologies and their contribution to the Sustainable Development Goals (SDGs) including circularity aspects, as well as the associated external costs.
- **SO3. Analysis and evaluation of risks** and impacts to health and the environment of activities that involve the natural environment and technologies for the exploitation of new natural resources, and the generation and storage of energy.
- **SO4. Analysis of the social acceptance of sustainable energy systems:** at different societal levels (affected communities, general public, key socio-political actors) and combining qualitative (interviews, focus groups, etc.) and quantitative surveys, delphis, etc.) research methods with stakeholder and citizen engagement strategies and tools (i.e. deliberative workshops, stakeholder panels, world cafes, etc.).
- **SO5. Analysis of Energy and Climate Change Policies:** Using the results from the above mentioned tools and methods, contribute to the analysis and formulation of energy and climate

change policies at the local, national and international level, including developing countries. It includes, among others, the development of policy instruments and strategies supporting sustainable energy transitions, on-going reform programmes, gap analysis and formulation of roadmaps and actions plans.

Other objectives

- Guide technological development at CIEMAT by analysing the environmental, economic, and social implications, their social acceptance, and their possible role in future energy systems in transition.

1.A.3 INTERESTS, ALIGNMENT AND STRATEGIC ORIENTATION

On a national scale, the Spanish Strategy for Science and Technology EECTI 2021-2027[4] recognizes as national strategic sectors those related to:

- Climate, energy and mobility: climate change, decarbonisation, mobility and sustainability
- Food, Bioeconomy, Natural Resources and Environment: from biodiversity to food use of the land and seas

The activities of the Sustainable Energy Systems Analysis strategic line are directly related to these strategic sectors and in particular with the first objective of the EECTI to place science, technology and innovation as key axes in the achievement of the Sustainable Development Goals of the Agenda 2030.

At European level, this strategic line is perfectly aligned with the objectives of the new EU Innovation Research Program Horizon Europe. The European Council noted at the Sibiu summit (May 2019) that Europe can shape its future by focusing research and innovation on ecological, social, and economic transitions and related social challenges[5]. This is precisely what this strategic line aims at. In addition, two of the preliminary Horizon Europe clusters (which correspond to the aforementioned national strategic sectors) are directly related to the activities of this strategic line:

- Climate, energy and mobility
- Food, bioeconomy, natural resources, agriculture and environment

[4] https://www.ciencia.gob.es/portal/site/MICINN/menuitem.26172fcf4eb029fa6ec7da6901432ea0/?vgnextoid=1387571a3db06610VgnVCM1000001d04140aRCRD

[5] https://ec.europa.eu/info/sites/info/files/research_and_innovation/strategy_on_research_and_innovation/presentations/horizon_europe_es_invertir_para_dar_forma_a_nuestro_futuro.pdf

Likewise, the Sustainable Energy Systems Analysis strategic line is fully aligned with the objectives of the European Green Deal[6] as well as the other priorities outlined in the political guidelines of President Von der Leyen[7], such as the new Action Plan for the Circular Economy. In this sense, the activities of the Sustainable Energy Systems Analysis strategic line provide the necessary methodological tools for the analysis and evaluation of the contribution of energy technologies and systems to the objectives of the European Green Deal.

EU efforts as outlined in the European Green Deal will not be sufficient without a strong external dimension supporting partner countries in decarbonizing their energy systems. Efforts to meet the SDG 7 targets on access to energy services, renewable energy, and energy efficiency has so far been insufficient: energy sector investments related to SDG 7 would need to more than double in order to achieve the goal. Energy demand forecasts predict that energy consumption in non-OECD countries will increase by nearly 70% between 2018 and 2050

The key objectives of the European Green Deal are summarized in the following figure which highlights the points where the activities of the Sustainable Energy Systems Analysis strategy line have an important connection.

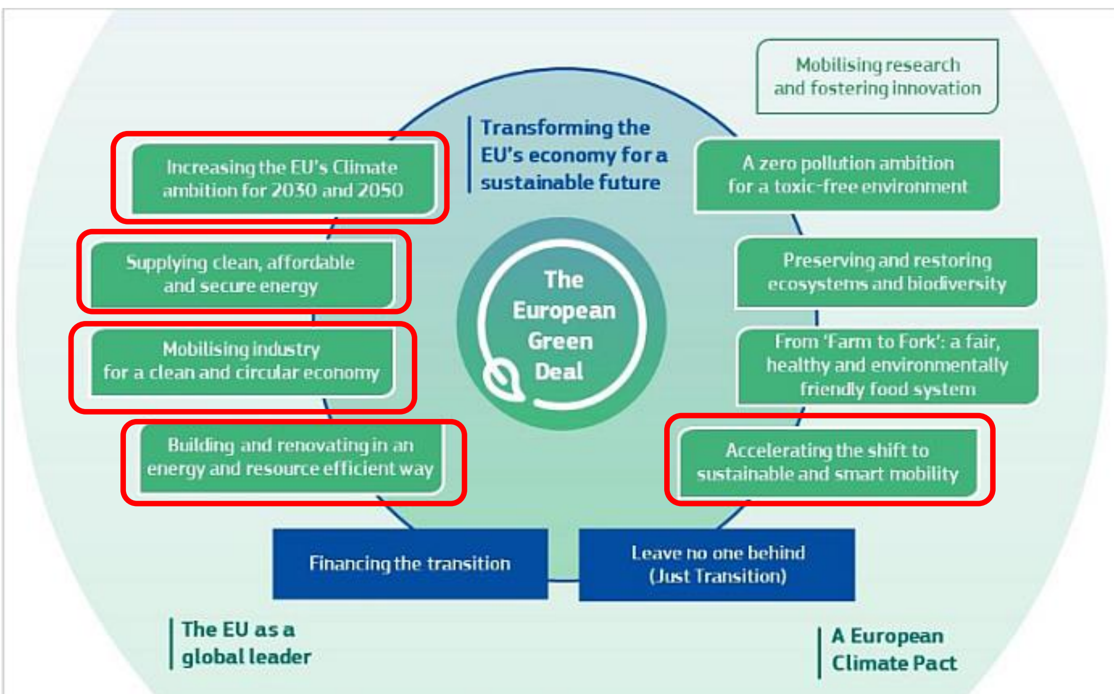

Figure 1. European Green Deal key objectives

[6] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0004.02/DOC_1&format=PDF

[7] https://ec.europa.eu/commission/sites/beta-political/files/political-guidelines-next-commission_es.pdf

Likewise, other European research programs such as the LIFE Program specify that priority be given to nature, biodiversity and circular economy programs and that the climate action program focuses on mitigation and adaptation to climate change and the energy transition. The new program for 2021-2027 includes a new sub-program "Clean Energy Transition"[8] in which the activities of the Sustainable Energy Systems Analysis Strategic Line have a perfect place.

On a global scale, the activities of this strategic line are fully aligned with the Goals of the Paris Agreement as well as with the Sustainable Development Goals (SDGs) of the United Nations 2030 Agenda[9]. The tools and methodologies developed in the Analysis of Sustainable Energy Systems Strategic Line make it possible to qualitatively and quantitatively evaluate the progress of our economy in achieving some of the SDGs, in particular SDG7, Affordable and Clean Energy, but also others directly related to SDG7 and SDG13 through the use of natural resources and the impacts produced by energy technologies, and also with the indirect impacts on the world economy of investment in sustainable energy technologies and access to energy services brought about by progress on SDG7.

Finally, all these objectives and strategic orientations acknowledge that nothing is more central than public acceptance for the transformation of the energy system, and that this applies both to the development of new and unfamiliar energy technologies, and to new applications of existing ones. A new governance of the energy system based on citizen and stakeholder empowerment and engagement is needed (i.e., Green Deal, Horizon Europe). At the national level the National Integrated Energy and Climate Plan (NECP) places citizens at the center of the energy transition. Citizens are protagonists, actors and assets, not mere passive consumers of energy without decision-making capacity, and the promotion of participatory projects becomes essential. The Analysis of Sustainable Energy Systems strategic line pays special attention to this human and social dimension of sustainability and ecological transition.

1.A.4. RELEVANCE OF THE RESEARCH LINE FOR CIEMAT

Relevance for CIEMAT's own activities

The capacities, tools and methodologies used and developed by the Sustainable Energy Systems Analysis strategic line allow cooperation with many of the research areas and lines as depicted in figure3. As for the research areas and lines developing new technologies, our unit can contribute and, in fact, have contributed in the past, with the analysis of the economic, environmental and social sustainability as well as their social acceptance and the possible role that they may play on future energy systems. These capacities also allow us to respond to the growing demand for social research aimed at identifying

[8] https://ec.europa.eu/info/news/have-your-say-new-life-programme-2020-mar-20_en#:~:text=The%20Clean%20Energy%20Transition%20sub%2Dprogramme%20of%20LIFE%20will%20be,system%20and%20a%20decarbonised%20economy.

[9] https://www.un.org/sustainabledevelopment/es/2015/09/la-asamblea-general-adopta-la-agenda-2030-para-el-desarrollo-sostenible/

barriers and facilitators and proposing methodologies for participation and consultation appropriate to the nature of this ecological transition. This allows directing technological R+D+i so that the resulting technologies are sustainable, socially accepted and relevant to the energy system in transition. The possibility of doing this type of analysis in CIEMAT in collaboration with the more technical strategic research lines allows optimizing the design process from the initial stages of development.

Figure 2 below shows the identified links with the rest of the strategic research areas in CIEMAT. Solid lines represent activities carried out in the past in collaboration with these research areas and dashed lines show potential collaborations explored in the past in joint research proposals or potential ideas for cooperation.

In cooperation with the areas of energy technologies development (in yellow in the figure) there have been collaborations in the past especially in the evaluations of sustainability of *Concentrated Solar Energy*, H*ydrogen and fuel cells* and *Bioenergy* technologies as well as in the development of energy scenarios with a focus on solar thermal technologies and in the analysis of the social acceptance of renewable, *Fission Energy* and hydrogen technologies.

With the research area of *Science and Technology for Fusion Energy*, there is a well-established line of cooperation in the areas of energy system modelling, externalities assessment, socioeconomic impact assessment and social acceptance. Energy Policy Analysis activities have also been materialized in two consecutive research projects coordinated by researchers of this Strategic Line with a focus on concentrated solar power (CSP).

With the research area of *Climate Change and Air Quality* there are, and there have been in the past, collaborations especially in the area of evaluation of pollution related externalities. Other potential links with the strategic area of *Materials for Energy* have been explored in the past in the form of joint proposals that have not been until now funded. With the area of *Scientific Computing* there are potential collaborations in the activities related to Energy System modelling.

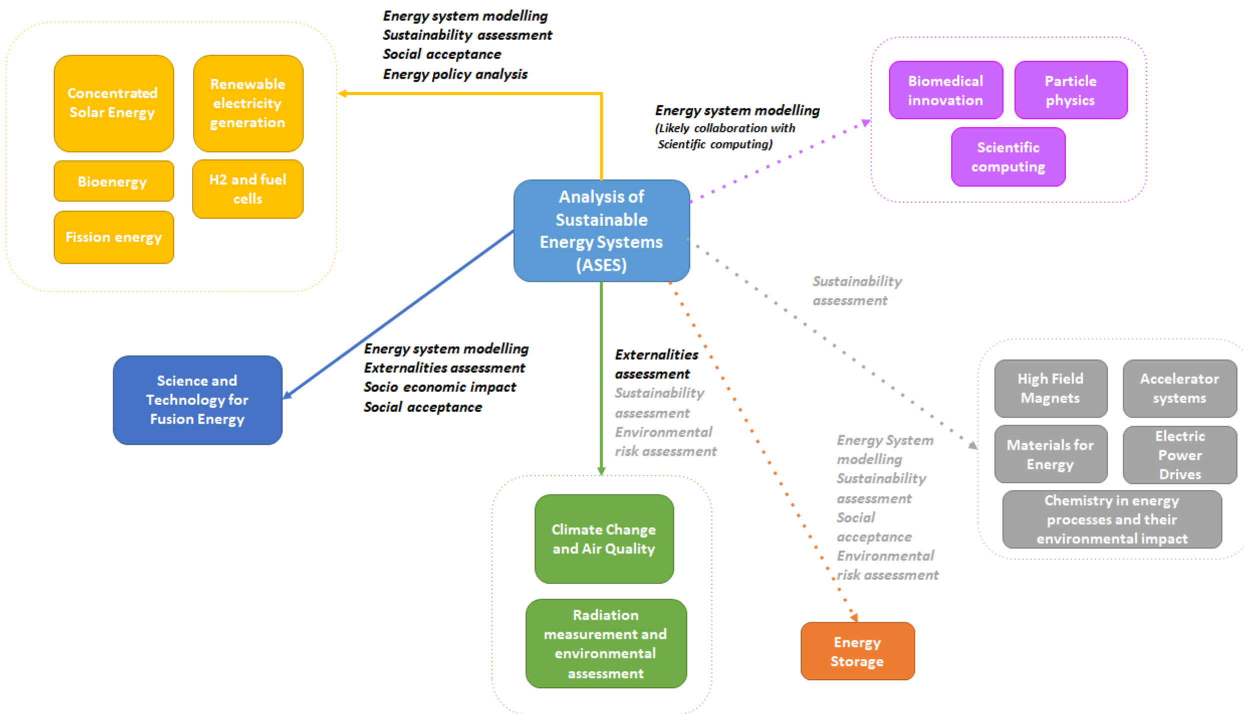

Figure 2. Relationship of the Analysis of Sustainable Energy Systems strategic line with the rest of the strategic areas of CIEMAT

Relevance to outside activities

Having this type of capabilities, tools and methodologies at CIEMAT gives the center the possibility to support informed decision-making by those responsible for national energy and technology policy. This is part of CIEMAT's mission to contribute to the sustainable development of Spain and the quality of life of citizens through the generation and application of scientific and technological knowledge.

The cross-cutting nature of this strategic line reinforces CIEMAT's capacity to respond to the challenges posed by the ecological transition at the national and international level. Transdisciplinary approaches of this nature are gaining more and more prominence in the main national and international R&D programs.

1.B. BACKGROUND AND PREVIOUS EXPERIENCES

1.B.1. CURRENT AVAILABLE RESOURCES IN CIEMAT

1.B.1.1. Units and Research groups involved

This research line comprises the following CIEMAT's research groups, integrated in two different departments, Energy and Environment.

- Energy Systems Analysis Unit (E02). Energy Department

The aim of the Energy Systems Analysis unit of CIEMAT is to provide economic assessment of the costs and benefits associated with the production and consumption of energy produced by different fuel cycles, and to study possible strategies for promoting the introduction of cleaner energies into the market through their environmental and socio-economic implications.

To that end, our unit conducts careful assessments of past, current and future environmental and socio-economic impacts of energy technologies including:

- Life Cycle Sustainability Assessment (LCSA) in order to assess the environmental sustainability of the different energy technologies.

- Quantification of environmental externalities using the the ExternE methodology

- Analysis of the potential impact that any energy project may have in terms of stimulating local economy as well as creating new employment opportunities. Input-Output methodology is the methodology used by the Energy Systems Analysis unit to estimate the associated total impact (direct and indirect effects) on the economy as well as in job creation.

Once the environmental and socio-economic externalities have been identified, quantified and monetized, social cost-benefit analysis provides the analytical framework used by the Energy Systems Analysis unit to systematically calculate and compare the social costs and benefits associated with a certain project, decision or government policy.

Energy models contribute to define the medium and long term energy system composition under different policy and climate scenarios taking into account future technology developments and costs. These tools are used by the Energy Systems Analysis unit in energy system prospective assessments at the national and global scale.

- Solar Thermal Applications Unit (E47). Energy Department

Electricity market decarbonization using renewable energies is essential to significantly reduce greenhouse gas (GHC) emissions. However, the identification of the optimum electricity mix for each country is a challenging and complex task due to the many boundary conditions that must be taken into account, thus demanding the use of advanced analysis and computing tools.

Many countries have already or are developing national energy and climate plans to optimize their energy transition process, also adapting it to the existing local renewable potentials. In the case of the European Union, the target of achieving the 100% of decarbonization of all energy sectors by 2050 has already been politically decided. In all cases, being wind and photovoltaic technologies the cheapest ones and due to their intrinsic non-dispatchability behaviour, decarbonization scenarios beyond 80-90% of GHG emission reduction face difficulties to progress as a certain level of base backup power will always be necessary. The optimization of the electricity mix has been approached using different strategies and models, pursuing in all cases to be able to guarantee supply security, grid stability, and sustainable development.

A methodology based on induction projection planning and artificial intelligence is being developed for this purpose. This methodology is based on historical data and genetic algorithms, a method to search for optimal solutions in the field of artificial intelligence. This methodology applies a multi-objective optimization assessment of the electricity mix that minimizes production costs together with curtailments and, at the same time, guarantees at any moment the power supply and the achievement of politically defined decarbonization targets (2030, 2040 and 2050). This methodology is suitable for any country and target objectives.

- Wind Energy Unit (E22). Energy Department

Wind Energy generation has been the first one to achieve high levels of integration in the grid that pointed to some of the issues aforementioned, which need to be addressed firstly at a model basis. The experience in the Wind Energy Unit in modelling systems with high amounts of wind generation comes from decades working on isolated systems, where these issues arouse firstly. During the last years, this activity, along with the work on isolated systems, has also derived into modelling larger systems, including mainly (but not only) large amounts of wind and solar PV generation into the grid, including storage systems as well.

The type of analysis performed during these years for hybrid wind and solar PV systems takes into account different aspects, from the demand and resource characterization, to the optimization of the most suitable configuration, going through the characterization of the different technologies involved. The time and spatial frame for these studies is an important issue, needing to be as detailed as possible, considering the different design and computing constraints. Present work goes into different approaches in this sense, taking advantage of the developments in the existing data sources and computing resources, coping for example with the definition of the different possible scenarios according also to the different design objectives.

- Sociotechnical Research Center CISOT (M40). Environment Department

CISOT has a long tradition of research in the social acceptability of energy technologies, including renewable technologies (wind, CSP), CO2 capture, use and storage technologies, or nuclear technologies (fission and fusion). We conduct studies on the social acceptance of energy facilities, technologies and policies combining quantitative (surveys, delphis, etc), and qualitative research (interviews, focus groups, etc.) with case studies.

The final aim is identifying public responses to energy facilities, technologies and policies, as well as the influential factors associated with their acceptance (perception of costs and benefits, perception of the consequences of their development and their attributes, associated emotions, previous beliefs and values, sociodemographic profile, etc.). Issues of distributive justice (with a focus on community benefits) and procedural justice (with a focus on public participation) are also envisaged in our research.

Our research approach combines the development of conceptual models with the design and implementation of innovative methodological approaches to improve both the academic understanding and the practical implications of the social acceptance of energy technologies.

- <u>Risks in Geological and Technological Systems Unit (M03).</u> Environment Department

The objectives and the strategic orientation of this line are based on the development and application of methodologies for environmental risk assessment that allow avoiding, in a planned manner and from the design stage on, the materialization of hazards in systems involving the geological environment.

Technologies to implement low-carbon solutions as are carbon capture, utilization and storage (CCUS), bioenergy with carbon dioxide capture and storage (BECCS), high-enthalpy geothermal energy, geothermal energy combined with CCUS, and energy storage in geological formations (e.g., ynthetic methane, hydrogen or compressed air) present formal similarities among them, since the assessments to be developed must combine the geological site characteristics with the technological system. This allows a very useful complementation not only in these projects but in all those with which they present analogies.

Understanding and assessing the environmental risks of these are a task with significant challenges, as the subsurface is often poorly investigated and there is poor control of the risk components related to uncertainty, both in knowledge and data, especially in the initial phases. So, the main objectives of this research line from a methodological point of view are:

- The development of global methodologies to integrate new knowledge throughout the life of the projects.
- The implementation of tools to assess risks in a probabilistic manner.
- The treatment of uncertainties, both their identification and classification according to their nature and importance, as well as their propagation.
- The need for new approaches for the treatment of uncertainties: Bayesian Networks, Machine learning, ...

1.B.1.2. Human resources already involved

Unit	Name		% of dedication to the strategic line
S01. Development and use of models for the analysis of energy scenarios			
E02	Alberto Perula	7256	80%
	Rodrigo Camarillo	External	100%
	Yolanda Lechón	4512	40%
E47	Javier Bonilla	5526	25%
E22 **Subtotal S01**	Luis Arribas	4484	25% **2.70 FTE**
S02. Analysis of the environmental, economic, and social sustainability of energy technologies and systems			
E02	Natalia Caldés	5034	100%
	Carmen Lago	3753	100%
	Daniel Garraín	5976	75%
	Israel Herrera	5467	100%
	Ana Rosa Gamarra	6873	100%
	Santacruz Banacloche	7059	80%
	Yolanda Lechón	4512	25%
Subtotal SO2			**6.25 FTE**
SO3. Analysis and evaluation of risks			
M03	Sonsoles Eguilior	4395	100%
	Antonio Hurtado	5171	100%
	Julio A. Rodrigo-Naharro	5208	100%
	Fernando Recreo	Emeritus	40%
Subtotal SO3			**3.40 FTE**
SO4. Analysis of the social acceptance of sustainable energy systems			
M40	Christian Oltra	5153	30%
	Roser Sala	5065	10%
	Sergi López	6891	10%
	Silvia Germán	5897	20%
	Lila Gonçalves	6586	60%
	Ana Prades	3544	20%
Subtotal SO4			**1.50 FTE**
SO5. Analysis of Energy Policies			
E02	Natalia Caldés	5034	50%
	Yolanda Lechón	4512	25%
Subtotal S05			**0.75 FTE**
TOTAL ASES			**14.50 FTE**

1.B.1.3. Equipment and experimental facilities

This research line does not need expensive equipment or experimental facilities. For our type of analysis, we rely mainly on computing equipment and facilities such as workstations, and CIEMAT supercomputing facilities such as Grid computing, High performance computing and cloud computing, as well as on specialized software:

Energy modelling software

- HOMER Pro (https://www.homerenergy.com/products/pro/index.html)
- TIMES code (https://github.com/etsap-TIMES/TIMES_model)
- VEDA software (https://veda-documentation.readthedocs.io/en/latest/)
- GAMS software (https://www.gams.com/)
- Python programming language (https://www.python.org/)
- DEAP software (https://github.com/deap/deap)

Sustainability assessment software

- Simapro (https://simapro.com/)
- GaBi (http://www.gabi-software.com/spain/index/)
- Ecoinvent (https://www.ecoinvent.org/)
- Superpro (https://www.intelligen.com/)
- Social Hotspot Database (http://www.socialhotspot.org/)
- EXIOBASE (https://www.exiobase.eu/)
- WIOD (http://www.wiod.org/home)

Risk assessment software:

- ArcGis (https://www.arcgis.com/index.html)
- Goldsim(https://www.goldsim.com/)
- Petrasim (Tough and Toughreact) (https://www.rockware.com/product/petrasim/)
- Modflow (https://www.usgs.gov/software/modflow-6-usgs-modular-hydrologic-model)
- free open-source software (Python, R, bayesian networks)

Social sciences software

- SPSS (Statistical Package for Social Sciences) (https://www.ibm.com/es-es/products/spss-statistics)
- MAXQDA (software package for qualitative and mixed methods research) (https://es.maxqda.com/

1.B.2. COLLABORATIONS, ALLIANCES AND EXTERNAL PROJECTION

This research line has an extensive network of collaborators all around the world. We engage with them in the framework of research projects, research networks and scientific committees.

Participation in research projects and collaboration with:

Universities

Spain

University of Oviedo (https://www.uniovi.es/)
University of Leon (https://www.unileon.es/)
University of Castilla-La Mancha. GEAR group. (https://blog.uclm.es/grupogear/)
Autonomous University of Barcelona (https://www.uab.cat)
University Pompeu i Fabra(https://www.upf.edu)
University Rovira i Virgili (https://www.urv.cat/)
University of Huelva (http://www.uhu.es/)
University of Alicante (https://www.ua.es/)
University of Navarra (https://www.unav.edu/)
University Carlos III Madrid (https://www.uc3m.es/)
University Las Palmas de Gran Canaria (https://www.ulpgc.es/)
Polytechnic University of Madrid. Agroenergy group (GA-UPM). (http://www.upm.es/observatorio/vi/index.jsp?pageac=grupo.jsp&idGrupo=178)
Polytechnic University of Madrid. School of Mines and Energy (http://www.minasyenergia.upm.es/)
University of Seville (https://www.us.es/)

Europe

Technical University of Vienna (https://www.tuwien.at/)
Instituto Superior Tecnico Lisboa (https://tecnico.ulisboa.pt/)
University la Rochelle (https://www.univ-larochelle.fr/)
University of Geneva (https://www.unige.ch/)
University of Surrey. Dept of Environmental Psychology (https://www.surrey.ac.uk/environmental-psychology-research-group/)
University of Lisbon. Institute of Social Sciences (https://www.ulisboa.pt/en/unidade-organica/institute-social-sciences)
UCL. University College London.Energy Institute Models. (https://www.ucl.ac.uk/energy-models/)
University College Cork. Environmental Research Institute. MaREI. SFI Research Centre for Energy, Climate and Marine research and innovation.(https://www.marei.ie/)
University of Stuttgart, Institute of Energy Economics and the Rational Use of Energy - IER. System-analytical Methods and Heat Market (https://www.ier.uni-stuttgart.de/)
Lulea University of Technology (https://www.ltu.se/)
University of Evora – BES Chair Renewable Energy (www.en.catedraer.uevora.pt/)
University of Reading – School of Construction Management and Engineering (www.reading.ac.uk/cme)
Yasar University - Dept of Energy Systems Engineering (http://ese.yasar.edu.tr/en/)

World

UAEM CIICAP Autonomous University of Morelos State, Mexico. Research Center in Engineering and Applied Sciences. (http://www2.ciicap.uaem.mx/)
UNAM IER. NationalAutonomous University of Mexico. Renewable Energy Institute (https://www.ier.unam.mx/)
National School of Engineering of Tunis (ENIT) – MOED Lab (http://www.enit.rnu.tn/)
Faculty of Mines. National University of Colombia. Medellín, Colombia. (https://www.medellin.unal.edu.co)
GRYCC . Faculty of Engineering. Universidad de la Salle, Bogotá, Colombia. (https://www.lasalle.edu.co)
Mechanical Engineering Department. Universidad del Atlántico, Barranquilla, Colombia. (https://www.uneatlantico.es)
Xi'an Shiyou University (China) (http://english.xsyu.edu.cn)

Research Centers

Spain

IGME (Geological and Mining Institute of Spain) (http://www.igme.es/)
INIA -CIFOR. National Institute for Agricultural and Food Research and Technology. (http://www.inia.es)
CSIC- IPP. Spanish National Research Council. Institute of Public Policies and Public Goods. (http://ipp.csic.es/)
CSIC- ICA Spanish National Research Council. Institute of Agricultural Sciences (https://www.ica.csic.es/index.php)
ICGC (Cartographic and Geological Institute of Catalonia) (https://www.icgc.cat)

Europe

BRGM French geological survey (https://www.brgm.fr)
JRC Petten (https://ec.europa.eu/jrc/en/about/jrc-site/petten)
JRC Ispra (https://ec.europa.eu/jrc/en/about/jrc-site/ispra)
JRC IPTS Seville (https://ec.europa.eu/jrc/en/about/jrc-site/seville)
Fraunhofer-ISI Unit Actors and Social Acceptance in the Transformation of the Energy System del (https://www.isi.fraunhofer.de/en/competence-center/energietechnologien-energiesysteme/geschaeftsfelder/transformation-energiesystem.html
Fraunhofer-ISI Business Unit Global Sustainable Energy Transitions https://www.isi.fraunhofer.de/en/competence-center/energiepolitik-energiemaerkte/geschaeftsfelder/globale-energiewende-nachhaltige-entwicklung.html)
SCK-CEN. (https://www.sckcen.be/)
DIALOGIK (https://www.dialogik-expert.de/)
Norwegian University of Life Sciences NMBu (https://www.nmbu.no/)
CEPN Nuclear Protection Evaluation Centre (https://cepn.asso.fr/)
VUJE (https://www.vuje.sk/)
STUK Radiation and Nuclear Safety Authority (https://www.stuk.fi/)
REC Regional Environmental Center (http://www.rec.org/)
IASS. Institute for Advanced Sustainability (https://www.iass-potsdam.de/)
ENEA.Italian National Agency for New Technologies, Energy and Sustainable Economic Development. (https://www.enea.it/)
VTT. Technical Research Centre of FinlandTransition to carbon-neutrality Unit. (https://cris.vtt.fi/en/organisations/ba2b12-transition-to-carbon-neutrality)

CRES. Centre for Renewable Energies and Savings. (http://www.cres.gr/kape/)
IEECP. Institute for European Energy and Climate Policy (IEECP) (https://ieecp.org/)
TNO. Energy TransitionUnit. (https://www.tno.nl/en/focus-areas/energy-transition/)
IFE. Institute for Energy technology. Renewable Energy Systems Department (https://ife.no/en/division/renewable-energy-systems/)
PSI. Paul Scherrer Institute. Energy Economics Group (https://www.psi.ch/en/eem)
CMA. The Centre for Applied Mathematics. (https://www.cma.mines-paristech.fr/)
DTU. Energy Economics and System Analysis (https://orbit.dtu.dk/en/organisations/energy-economics-and-system-analysis
DLR German Aerospace Centre – Institute of Solar Research. (https://www.dlr.de/sf/en)

World

NREL National Renewable Energy Laboratory. Energy Analysis Research Area (https://www.nrel.gov/analysis/)
IRESEN. Institute of Research on Solar Energy and New Energies– Thermal Systems Dept (www.iresen.org)
CDER. Centre for Development of Renewable Energies (www.cder.dz)

Industry

Protermosolar (Asociación Española para la Promoción de la Industria Termosolar) (https://www.protermosolar.com/)
ESTELA (European Solar Thermal Electricity Association) (https://www.estelasolar.org/)
Grupo COBRA. https://www.grupocobra.com/
Onyx Solar Energy SL (www.onyxsolar.com)
ALUR Alcoholes del Uruguay (http://www.alur.com.uy/)

Consultants

TRINOMICS (http://trinomics.eu/)
E4ESMA. (https://www.e4sma.com/)

Think tanks

Real Instituto Elcano. (http://www.realinstitutoelcano.org/)

Government

MITECO. Ministry for the Ecological Transition and Demographic Challenge (https://www.miteco.gob.es/es/)
IDAE. Institute for Energy Savings and Diversification (https://www.idae.es/)
Ministerio de Industria Energia y Mineria Uruguay (https://www.gub.uy/ministerio-industria-energia-mineria)

Membership of international committees:

ETSAP. IEA TCP Energy Technology Systems Analysis Program https://iea-etsap.org/. Member of the executive Committee. Contracting party representative.
EERA E3s. European Energy Research Alliance Joint Programme Economic, Environmental and Social Impacts of the Energy Transition. https://www.eera-set.eu/component/projects/projects.html?id=43
EERA tJP. European Energy Research Alliance Transversal Joint Programme Digitalization for Energy. https://www.eera-set.eu/component/projects/projects.html?id=183

EERA. Bioenergy. European Energy Research Alliance Joint Programme Bioenergy. (https://www.eera-bioenergy.eu/)
IEA WIND TCP: International Energy Agency Wind Technology Collaboration Programme. https://community.ieawind.org/home

Participation in networks:
Red MENTES. Modelización Energética para una Transición Energética Sostenible. https://redmentes.es/
Red SUMAS. Sustentabilidad Energética, Medioambiente y Sociedad. http://www2.ciicap.uaem.mx:8080/rs/
Energy & Society Network (European Sociological Association) https://www.ufz.de/energyandsociety/
DERLab: association of leading laboratories and research institutes in the field of distributed energy resources equipment and systems. https://der-lab.net/about-derlab/
Technological platforms: PTECO2 (https://www.pteco2.es/es), GeoPlat (https://www.geoplat.org/), Reoltec (Wind) (https://reoltec.net/), Futured (Grid)(https://www.futured.es/), Technological Platform of Fission Energy (CEIDEN) (https://ceiden.com/).
RENUWAL Red iberoamericana para el tratamiento de efluentes con microalgas (http://www.cyted.org/es/renuwal)
RED REMEDIA Scientific Network on Greenhouse Gas Mitigation in the Agroforestry Sector (https://redremedia.org/)
CO2-Geonet. THE EUROPEAN NETWORK OF EXCELLENCE ON THE GEOLOGICAL STORAGE OF CO2. (http://www.co2geonet.com/)
The Advances in Cleaner Production Network (ACPN) (http://www.advancesincleanerproduction.net/)

Figure 3. Network of collaborators of the Analysis of Sustainable Energy Systems strategic line

1.B.3. INDICATORS OF RESULTS

1.B.3.1. Industrial Research Projects

All the funded research projects in which the researchers of this strategic research line of CIEMAT have been involved in the last 5 years (2016-2021) are resumed in the following table, including the project name and type, project budget, time duration, partners and a brief resume of the activities developed by CIEMAT.

NAME	PROJECT BUDGET	DURATION	TYPE (*)	ROLE OF CIEMAT
URBANOME. Urban Observatory for Multi-participatory Enhancement of Health and Wellbeing https://cordis.europa.eu/project/id/945391	4974015	2021-2025	I H2020 GA: 945391	Environmental and socioeconomic impact assessment of policies
PILOT STRATEGY	10,022,547	2021-2025	I H2020	Co-Leader of WP5 and 6. Safety and performance analyses. Social Acceptance Socioeconomic impact assessment
ELHYPORT: Hydrogen fuel cells with advanced membrane-electrode assemblies for their integration in low power and portable applications	214170	2020-2024	N Spanish Ministry of Science and Innovation	LCA and socioeconomic impact assessment
Powering System flexibility in the Future through Renewable Energy Sources (POSYTYF) https://posytyf-h2020.eu/	4 726 577,50	2020-2023	I H2020 GA:883985	Scenario definition, system modeling and specifications for Dynamic Virtual Power Plant for actual and future power systems
CONTAMINA. Aceptación pública de medidas para la	27114,00	2020-2022	N	Project Leader

reducción de la contaminación atmosférica urbana			CSO2012-32379 Spanish Ministry of Science and Innovation	Public and stakeholders acceptance
New Hybrid Renewable Technologies	9 M€	2020-2022	N	Hybrid capacity Map, and more
ALGATEC. Desarrollo de Tecnologías avanzadas de microalgas para una economía circular		2019-2022	N Autonomous Community of Madrid.	LCA and circularity assessment
RETOPROSOST. Producción sostenible y simbiosis industrial en la Comunidad de Madrid http://cib.csic.es/es/project/2-produccion-sostenible-y-simbiosis-industrial-en-la-comunidad-de-madrid-reto-prosost-2-cm		2019-2022	N P2018/EMT445 9 Autonomous Community of Madrid.	LCA and circularity assessment
STRATEGY CCUS. Strategic planning of regions and territories in Europe for low-carbon energy and industry through CCU. https://www.strategyccus.eu/	2 959 533.75	2019-2022	I H2020 GA 837754	Social and stakeholders acceptance LCA and socioeconomic impact assessment
RETOS-AIRE. Air pollution mitigation actions for Environmental Policy Support. http://retos-aire.ciemat.es/	72600	2019-2022	N Ministry of Science and Innovation	Externalities from air pollution
HIBRI2. Sistema integrado de control para el abastecimiento de energía mediante sistemas híbridos en comunidades aisladas de Cuba. Fase II. http://hibri2.ciemat.es/	298320	2019-2021	I AECID 2018/ACDE/00 0600	LC, Simulation of the whole system
BIOBOR: Bornizo for Bioeconomy: Tools for forest management and		2018-2021	N RTI 2018 - 094413-R-C21	LCSA

environmental assessment for the valorization of virgin cork.			Ministry of Science and Innovation	
MUSTEC. Market uptake of Solar Thermal Electricity through Cooperation. https://www.mustec.eu/	2396526	2017-2021	I H202 GA 764626	Project coordinator Leader of WP1, 3 and 9 Social Acceptance
EUROFUSION WP SES Socioeconomic studies https://collaborators.euro-fusion.org/collaborators/socio-economic-studies/		2017-2020 2021-2025	I	Social studies leader/participant Economic studies leader/participant
ACEPTA. Acetacion pública de medidas para la recucción de la contaminacion atmosférica urbana	49622,00	2017-2019	N RTI2018-098451-B-I00 Spanish Ministry of Science and Innovation	Project leader Public and stakeholders acceptance
ENOS (Enabling onshore CO_2 storage in Europe). http://www.enos-project.eu/	10,857,737	2016-2020	I H2020 GA: 653718	Develop risk models and validate them based on monitoring.
CLIMACT. Transition to a low carbon economy in schools. http://www.climact.net/		2016-2019	I Interreg Sudoe Programme through the European Regional Development Fund (ERDF)	LCA and externalities assessment
PUBLENEF. Supporting Public Authorities for implementing Energy Efficiency Policies. https://publenef-project.eu/		2016-2019	I H2020 GA: 695923	WP3 leader.
ELIGE. Efficient and LIght Energy Fuel Cell Power http://projects.ciemat.es/es/web/elige/inicio		2016-2019	N	LCA of portable fuel cells

CAPTURE. Competitive Solar Power Towers. http://capture-solar-energy.eu/thecompetitivesolarpowertowersproject/	6461970	2015-2019	I H2020 GA 640905	LCA
REPARA 2.0 Desarrollo de nuevas técnicas y sistemas de información para la REhabilitación sostenible de PAvimentos de carreteRAs. http://www.proyectorepara.com/	59300	2015-2019	N CDTI	LCA of road rehabilitation
HoNESt. History of nuclear energy and society HoNESt | History of Nuclear Energy and Society (honest2020.eu)	3052269,10	2015-2018	I H2020 GA 662268	Risk perception Social Acceptance Public engagement
BIOSOL. Development and demonstration of a Hybrid CSP-biomass gasification boiler system https://www.dbfz.de/projektseiten/biosol		2015-2018	I ERA NETMED	WP4 leader. Sustainability assessment
SPEGE (Safety in unconventional gas extraction projects)	55,660	2015-2017	N Spanish Ministry of Economy and Competitiveness CTM2014-59828-R	Evaluation of the pollutants present in the return water. Analysis and evaluation of risks to the environment
LIFE+RESPIRA. Reduction of exposure of cyclists to urban pollutants https://www.liferespira.eu/		2014-2017	I	Action C4 leader. Calculation of externalities from air pollution Citizen Engagement
REELCOOP. REnewable ELectricity COOPeration https://www.reelcoop.com/	7287845	2013-2017	I FP7-ENERGY GA 608466	WP8 leader.Sustaina

				bility assessment
METAFPERCOM	39930,00	2014-2016	N Spanish Ministry of Science and Innovation	Risk perception. Citizen engagement
HYACINTH. Hydrogen Acceptance in the transition phase [Inicio - Hyacinth ProjectHyacinth Project]	661584,00	2013-2015	I FCH-JU 621228	Public and stakeholders acceptance

*national (N), international (I)

1.B.3.2. Scientific Production

The scientific production during the last 5 years of the research groups comprising this research line are presented in the following table:

UNIT	SCIENTIFIC JOURNALS	CONFERENCES	Ph.D THESIS/MASTER THESIS
E02	25Q1, 11Q2, 6Q3, 3Q4	61	3 PhD thesis 6 Master Thesis
E47	-	4	-
E22	-	2	5 Master Thesis
M03	4Q1, 1Q2, 2Q3	5	3 PhD thesis
M40	7Q1, 6Q2, 4Q3, 3 Q4	35	1 PhD thesis 1 Master Thesis
TOTAL	36 Q1, 18Q2, 12 Q3, 6 Q4	107	7 PhD thesis 12 Master thesis

As an example, some of the most recent or relevant publications include:

- Herrera I, Valencia G, Duarte J. Exergo-environmental assessment and multi-objective optimization of waste heat recovery systems based on Organic Rankine cycle configurations. Journal of Cleaner Production, Volume 28, March 2021, 125679.
- Hurtado, A.; Eguilior, S.; Rodrigo-Naharro J.; Ma, L; Recreo F. 2021. Chapter book: Risk assessment and mitigation tools. in "CO2 Injection in the Network of Carbonate Fractures". Springer. ISBN 9783319270197.
- Turcanu, C-. Prades, A., Sala, R., Perko, T, Oltra, C. (2020). Fusion energy: A deeper look into attitudes among the general public. *Fusion Engineering and Design*. Volume 161
- Upham, P., Bögel, P., Dütschke, E., Burghard, U., Oltra, C., Sala, R., ... & Brinkmann, J. (2020). The revolution is conditional? The conditionality of hydrogen fuel cell expectations in five European countries. *Energy Research & Social Science*, *70*, 101722.

- Blanco J, Bonilla J, Zarza E, Alarcón-Padilla DC. Optimization of CSP Development in Spain using Inductive Projection Planning Tool based on Artificial Intelligence. *CSP4Climate Online International Conference*, The Cyprus Institute, December 2020.
- Garraín D, Herrera I, Rodríguez-Serrano I, Lechón Y, Hepbasli A, Araz M, Biyik E, Yao R, Shahrestani M, Essah M, Shao L, Rico E, Lechón JL, Oliveira AC. Sustainability indicators of a naturally ventilated photovoltaic façade system. *Journal of Cleaner Production*, Volume 266, 1 September 2020, 121946.
- Lechón Y, De la Rúa C, Rodríguez-Serrano I, Caldés N. Socioeconomic implications of biofuels deployment through an Input-Output approach. A case study in Uruguay. *Renewable and Sustainable Energy Review*s, Volume 104, April 2019, Pages 178-191.
- Ma L.; Hurtado A.; Eguilior S.; Llamas Borrajo J.F. 2018. A Model for Predicting Organic Compounds Concentration Change in Water Associated with Horizontal Hydraulic Fracturing. *Science of the Total Environment*. Elsevier. 625, pp.1164-1174.

1.B.3.3. Training

The training capabilities of the research groups involved can be grouped in two types: participation in masters and specialized courses and training of students at different stages of the academic period (degree, master and PhD thesis).

The courses and training activities

- Lectures in masters:
  - Oil & Gas Engineering Master (UPM) : years 2015-2020. http://www.minasyenergia.upm.es/es-master-propio-en-ingenieria-de-petroleo-y-gas.html
  - Renewable Energy and Environment Master (UPM): years 2015 - 2020. https://www.erma.etsidi.upm.es/master-energias-renovables-erma-upm.html
  - Renewable Energy and Electricity Market (EOI): years 2015 - 2020. https://www.eoi.es/es/cursos/16525/master-en-energias-renovables-y-mercado-energetico-merme-madrid
  - Renewable Energy, Fuel cells and Hydrogen (UIMP CSIC): years 2007-2018. http://www.ictp.csic.es/ICTP2/es/master_energias_renovables
  - Executive master in Energy Management (ESCP Europe): 2017-2018. https://escp.eu/programmes/executive-masters/Executive-Master-in-Energy-Management
  - Maestría en Sistemas Integrados de Gestión (Universidad Libre, Colombia) 2021. (http://www.unilibrecucuta.edu.co/portal/posgrados/maestrias-unilibre-cucuta/maestria-sistemas-integrados-de-gestion.html)
  - Master in Waste Management and Resources Recovery (UAM): 2020-2021.https://www.uam.es/Ciencias/Master_GTR_Asuntos_Academicos/1446767022617.htm?language=es

- EUROPEAN JOINT MASTERS IN MANAGEMENT AND ENGINEERING OF ENVIRONMENT AND ENERGY. ME3 (http://www.minasyenergia.upm.es/attachments/article/2354/Flyer%20ME3%202017.pdf) : years 2013-2018

- Internal courses
    - Ecodiseño , Etiquetado Ambiental y Eficiencia Energética: 2017
    - Principios de la Economía Circular y aplicaciones del Análisis de Ciclo de Vida: 2019
    - Análisis de ciclo de vida y cálculo de la huella de carbono: 2020
- Other courses:
    - Uso de la herramienta SimaPro en la resolución de casos prácticos (Unisalle, Colombia). 2018
    - Análisis de Ciclo de Vida (ACV) y uso de herramientas en la evaluación ambiental de procesos (Unisalle, Colombia): 2018
    - Análisis de Ciclo de Vida (UAEM, México): 2018.
    - Responsabilidad social y empresa ciudadana (Universidad Nacional de Colombia): 2018
    - Análisis de Ciclo de Vida y Uso de Herramientas en la Evaluación Ambiental de Procesos (UNAM. CONACyT): 2017
    - Análisis de Ciclo de Vida y Huella de Carbono (UAEM, México): 2016

Training of undergraduate students:

UNIT	Number of Students
M03	2 PhD students
E47	-
E22	2 master students
E02	20 degree students + 6 master students + 4PhD students
M40	5

1.B.4. Particular SWOT of the research line

The following table summarizes the different strengths, weaknesses, opportunities and threats of the research line as a SWOT diagram.

STRENGHTS	WEAKNESESS
▪ Good international positioning. ▪ Interdisciplinarity and transferability. ▪ Experience in coordinating H2020 projects. ▪ Wide network of collaborations in Latin America. ▪ Limited need for investment in equipment.	▪ Reduced size below the critical size for some of the activities (modelling in particular) ▪ Long term temporality of the contracts ▪ Discontinuity policy in the contracts ▪ Administrative obstacles to access regional funding (CISOT) (lack of legal entity) ▪ Lack of (institutional) prioritization of strategic research areas that would support a suitable allocation of human resources (CISOT)
OPPORTUNITIES	**THREATS**
▪ Thematic of growing interest. ▪ National need. ▪ Ready for the new challenges. Emerging developments in: Rare earths, Geothermal energy, Energy storage, Green Hydrogen ▪ Alignment of activities with the European Union's scientific policies and lines of action ▪ Emergence of new research opportunities to support the achievement of SDG7 and SD13 in Latin America, Africa, Asia and the Pacific.	▪ Loss of capabilities ▪ Loss of opportunities ▪ Stagnation ▪ Cross-cutting research on a broad scope of applications requiring specific expertise: risk of dispersion (CISOT) ▪ Lack of continuity in national policies. ▪ Current R&D system disadvantages small groups

1.B.5. LINE Coordination scheme

The research line will be governed by a committee that will meet regularly and will be composed by the people responsible for the 5 scientific objectives. This committee will be responsible for updating the scientific orientations, ensuring the exploitation of synergies and looking for financing opportunities.

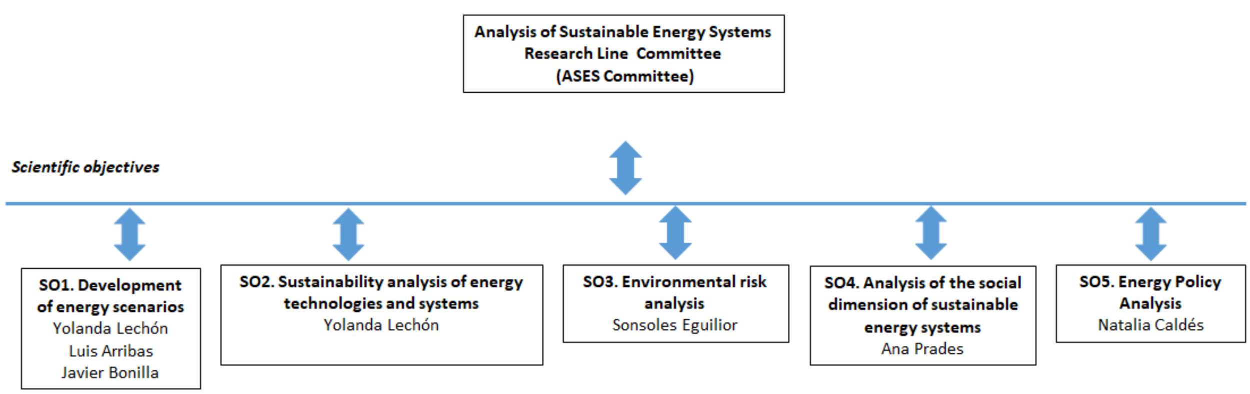

Figure 4. Governance structure of the Analysis of Sustainable Energy Systems strategic line

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

1.C ACTUATION PLAN (2021-2025)

1.C.1. DESCRIPTION OF ACTIVITIES ASSOCIATED TO OBJECTIVES

In order to take advantage of our strengths and opportunities and overcome our weaknesses and threats, this research line has developed a clear action plan for the next 5 years. It is oriented to strengthen our capabilities and improve our national and international recognition. In the design of the action plan we have tried to maximize the synergies between the different research activities by hybridizing, combining and linking methods, tools and disciplines. The action plan is structured in 5 layers corresponding to our 5 scientific objectives. A total of 10 actions have been identified. An overview of these actions is shown in the following table.

SCIENTIFIC OBJECTIVE	ACTION	EXPECTED OUTCOME	NEEDS
SO1. Development and use of models for the analysis of energy scenarios.	Action 1. Formation of a solid group on energy modelling	Improved modelling framework of the Spanish energy system	1 expert in TIMES modelling 1 predoctoral researcher for artificial intelligence optimization tool Computing resources (Workstations)
SO2. Analysis of the environmental, economic, and social sustainability of energy technologies and systems	Action 2. Increase the capabilities of integrated modelling	Integrated hybrid sustainability assessment tool	Continuation of the contracts for temporary personnel Licences for LCA software
	Action 3. Acquire skills in circularity analysis	Á methodology that allows estimating the circularity of energy technologies including the intermediates produced in their value chain.	Circularity extensions of the currently used LCA software tools
	Action 4. Acquire skills in social life cycle assessment (in cooperation with SO4)	Adaptation and application of the sLCA method to the special characteristics of energy technologies.	1 predoctoral researcher
	Action 5. Critical raw materials in the Spanish energy context	Adaptation of the EC methodology in Spain and the exploration of new materials for replacing the most important CRM	1 predoctoral researcher
	Action 6. Construction, standardization and maintenance of Inventories database for life cycle analysis of energy systems.	Development of nationally relevant and updated LCA database of energy technologies.	Continuation of the contracts for temporary personnel LCA software licences

	Action 7. Health Impact Assessment of Air Quality and Costs-Benefit analysis of the mitigation strategies	Development of a GIS-based method for the assessment of air pollution induced health related externalities.	Continuation of the contracts for temporary personnel
SO3. Analysis and evaluation of environmental risks	Action 8. Development and application of a consistent methodological risk assessment framework	Development of an integrated environmental risk assessment tool	New human resources required: 1-2 Scientists with a background in earth sciences statistics. 1-2 PhD students.
SO4. Social acceptance of sustainable energy systems.	Action 9. New models and methods for the social acceptance of sustainable energy systems	Development of conceptual and methodological social acceptance frameworks	1 PhD student
SO5. Analysis of energy and climate change policies	Action 10. Assessment of energy and climate change policies in less developed countries	Development of an energy and climate change policies assessment framework tailored for less developed countries	1 PhD student

SO1. Development and use of models for the analysis of energy scenarios.

Action 1. Formation of a solid group on energy modelling

Action plan

The objective is to become a national benchmark in energy modelling and to be able to respond to national needs in this matter by supporting the competent ministries with tools and knowledge.
To that end, the actions envisaged are:

- Form a group of two persons with expertise in TIMES modelling: a predoctoral researcher already incorporated and an external expert working at CIEMAT temporarily that would need to be hired.
- Incorporate a predoctoral researcher to contribute to the development of the artificial intelligence optimization tool. The main skills to gain expertise in are Python programming and artificial intelligence techniques for multiobjective optimization of energy systems.
- Improve and update the CIEMAT's owned TIMES-Spain model.
- Explore the synergies with the other two modelling tools: the artificial intelligence optimization tool run by the E47 unit and the HOMER-Pro Type model run by the E22 unit. Anticipated synergies are in the area of electricity demand estimation by TIMES used as an input to the

artificial intelligence model, and the use of the HOMER- Pro Type model for: increased time and spatial resolution; better representation of the power sector with respect to demand response and self-consumption; a more operational modelling of the electric interconnections; improvements of other model characteristics, processes and technologies: district heating, energy storage, and new technologies envisaged in 2050; evaluating different sector related energy investments, obtained from the TIMES model, and their related business cases.

Innovation/Singularity

Currently, energy system modelling is performed in the country using a TIMES model evolved from the original TIMES-Spain model. This model is run by a consultant company hired by the Ministry for Ecological Transition and Demographic Challenge. Having this expert group at CIEMAT will strengthen the modelling capabilities of the administration without relying on external consultant companies. Furthermore, the TIMES-Spain model enables the possibility of undertaking energy-related policy evaluations prior to their final approval to evaluate their efficiency and possible systemic effects. In addition, the model can be used for creating sectoral evolution reports, roadmaps and technology studies for supporting decision-making.

Expected Technological outcomes

The main outcome expected from this activity is an improved modelling framework of the Spanish energy system that will be complementary to the national tool TIMES-SINERGIA and can be used by CIEMAT to produce national energy scenarios, improve the national modelling capabilities and evaluate the potential impact of novel technologies in the energy sector. Moreover, the owned tools could be easily adapted for undertaking specific reinforced projects in the field of sector coupling optimization within industrial hubs, optimization of high voltage grid investments, allocation of new installed capacity or support of P2X development projects and smart grid projects.

Feasibility/Sustainability

The feasibility of this activity is strongly linked to the hiring of an additional person for the TIMES modelling group and the incorporation of a predoctoral researcher for the artificial intelligence optimization tool. Similar modelling groups supporting national energy systems scenarios exist in other European countries, namely Ireland (MaREI 5 modellers), UK (UCL 15 modellers), France (ECM 9 modellers), Finland (VTT 10 modellers), etc. The proposed size of this modelling group is below the size found in other countries for similar groups but will allow starting a meaningful modelling activity in the centre. The sustainability will be ensured by the funding obtained from the participation in research projects calls.

SO2. Analysis of the environmental, economic, and social sustainability of energy technologies and systems

Under SO2 there are 6 actions that will address the improvement of sustainability assessment capabilities of the strategic research line by either hybridizing the currently used methods or by starting new research activities in topics currently not covered but considered very relevant in the field.

Action 2. Increase the capabilities of integrated modelling

Action plan

The objectives are exploring the possibilities of joining optimization models developed under SO1 and input-output models or LCA models and investigating the hybridization of sustainability assessment tools such as hybrid Life Cycle assessment and extended Multiregional Input Output Analysis (MRIO).

Another line of action to be performed is a methodological improvement when assembling energy investment vectors in the MRIO Analysis. Our goal is to automate the process by creating default energy investments vectors of every representative energy technology, applicable to any MRIO table.

Innovation/Singularity

Linking optimization models and sustainability assessment tools allows incorporating sustainability criteria in the optimization problems as well as evaluating the sustainability of future energy scenarios. Different sustainability assessment methodologies present different strengths that can be maximized and limitations that can be mitigated by combining them in a proper way. There is a growing research literature addressing different hybridization approaches.

Expected Technological outcomes

The main outcome of this action is the development of an integrated hybrid sustainability assessment tool.

Feasibility/Sustainability

This action can be undertaken with the current human resources of the research line but will require funding in the form of externally funded research projects to guarantee the continuation of the contracts. Licences for the use of LCA software will be required as well.

Action 3. Acquire skills in circularity analysis

Action plan

The objective is to deepen in the concepts, methods and models to assess the innovations and new processes in the pathway to circular economy. Circularity analysis has been used by the ASES research line only very recently but is deemed very relevant for the assessment of energy technologies. The need to change the linear model of production to a model which reduces environmental pressures driven by consumption makes essential the implementation of strategies of material recovery, waste and pollution minimization when developing new technologies. The aim would be to incorporate the analysis of circularity to the sustainability assessment performed by the ASES research line.

Innovation/Singularity

New methodologies combined with Life Cycle Analysis are being explored in order to incorporate the analysis of circularity and be able to identify hotspots in the production chain and choose the best strategies to recover, re use, recycle, remanufacture, and valorization of material. Similarly, several approaches in combination with MRIO models are currently being investigated.

Expected Technological outcomes

A methodology that allows estimating the circularity of energy technologies including the intermediates produced in their value chain.

Feasibility/Sustainability

This action can be undertaken with the current human resources of the research line but will require funding in the form of externally funded research projects to guarantee the continuation of the contracts. Additionally, licences for circularity extensions of the currently used LCA softwares will be needed.

Action 4. Acquire skills in social life cycle assessment (in cooperation with SO4)

Action plan

A social life cycle assessment (S-LCA) is a method that can be used to assess the social positive as well as negative impacts along the life cycle of a product or service. S-LCA makes use of generic and site-specific data, can be quantitative, semi-quantitative or qualitative, and complements the environmental LCA and LCC in a Life Cycle Sustainability Assessment.

This action will aim at acquiring skills in sLCA as well as at applying this method to different energy technologies. This will be made in collaboration with the SO4 as it entails the use of social assessment methods.

Innovation/Singularity

sLCA is still in an early phase of development but it has the potential to complement the other sustainability assessment tools used in this strategic research line in order to have a holistic assessment of the sustainability of energy technologies.

Expected Technological outcomes

The expected outcome is the adaptation and application of the sLCA method to the special characteristics of energy technologies.

Feasibility/Sustainability

This action can be undertaken with the current human resources of the research line but will require funding in the form of externally funded research projects to guarantee the continuation of the contracts. Additionally, licences for sLCA databases (namely Social Hot Spot Database but perhaps others as well) will be required.

Action 5. Critical raw materials in the Spanish energy context

Action plan

Critical raw materials (CRM) are closely linked to clean technologies. Currently they are irreplaceable in solar panels, wind turbines, electric vehicles or energy-efficient lighting.

The main objective of this action is the exploration of the environmental implications of replacing those CRM in specific energies, such as wind or photovoltaic in the framework of research projects in this area in collaboration with technological partners. Additionally, we would like to reassess the critical raw materials list developed by the EC in the light of the Spanish energy context.

Innovation/Singularity

European Commission (EC) has developed and updated the list of current CRM based on supply, and environmental and economic variables. This methodology would be adapted to Spanish conditions in order to obtain more reliable figures for improving the sustainability of renewable energies in Spain.

Expected Technological outcomes

The main outcome of this action is the adaptation of the EC methodology in Spain and the exploration of new materials for replacing the most important CRM. In this context, it would be desirable to join the European Raw Materials Alliance (www.erma.eu).

Feasibility/Sustainability

This action will require the incorporation of new human resources for its full development. A PhD student would be desirable and will also require funding in the form of externally funded research projects.

Action 6. Construction, standardization and maintenance of a nationally relevant database for life cycle inventories of energy technologies.

Action plan

The objective is to develop and maintain a database of life cycle inventories of energy technologies that incorporate the national specificities and allows optimizing the national energy mix.

Innovation/Singularity

Developing, standardizing and managing databases of inventories of the life cycle of energy systems is fundamental for the evaluation of the social, economic and environmental impacts of energy technologies. Many often available datasets are either outdated or do not represent the national situation. Some initiatives have been initiated in the past at the national level but none has materialized yet.

Expected Technological outcomes

The main outcome of this action is the development of nationally relevant and updated LCA database of energy technologies.

Feasibility/Sustainability

This action will require funding in the form of externally funded research projects to guarantee the continuation of the contracts.

Action 7. Health related externalities from Air Pollution

Action plan

The aim of this action is to continue a line of collaboration initiated in the past with the Strategic Research Area "Climate Change and Air Quality" related to the evaluation of externalities arising from air pollution. This collaboration has materialized in two recent research projects (LIFE+RESPIRA project and RETOS-AIRE project). The objectives are the quantification of the effects on health caused by the exposure to air pollutants in terms of mortality and morbidity, and perform a cost benefit analysis of the potential mitigation measures.
Air quality health impacts are estimated from concentrations calculated by an air quality model and using concentration response functions (CRFs). The advantages resulting from the implementation of strategies included in policies can be expressed in terms of health outcomes reduction as well as external benefits. As a result, the net benefit of the implementation of different can be determined in a cost-benefit analysis.

Innovation/Singularity

The assessment of the air quality and air pollution mitigation strategies at different levels, regional, national, local and urban level are assessed combining the results from air quality models and applying recent epidemiological findings on CRF functions for different health endpoints, and updated monetization techniques for the calculation of external costs.
A GIS-based method will be developed and applied to several case studies in order to test its suitability at different levels.

Expected Technological outcomes

The main outcome of this action is a GIS-based method for the assessment of air pollution induced health related externalities.

Feasibility/Sustainability

This action will require funding in the form of externally funded research projects to guarantee the continuation of the contracts.

SO3. Analysis and evaluation of environmental risks

Action 8. Development and application of a consistent methodological risk assessment framework

Action plan

The main outputs and objectives of this research line is the development and application of the consistent methodological framework above referred to that must help to ensure that there is no significant risk of leakage or damage to human health or the environment. The specific areas of application are linked to:

- CO_2 geological Storage;
- H_2 geological storage;
- High Enthalpy Geothermal resources development.

Innovation/Singularity

Within the different fields of action, scientific and technical progress will be made in the following areas:

1.- Deepening on the predictive knowledge of the behavior of the system, especially on a large scale and in the long term.

2.- Obtaining optimal models from experimental data and from the Comprehensive Risk Assessment models already developed for monitoring and data analysis (contamination data, etc.)

3.- Validation of Models (application to real locations with available experimental data)

4.- Matching of the comprehensive risk assessment model with site monitoring records:

- Detection of the ranges and combinations of geological formation performance data and engineering parameters linked to monitoring variables (KPI) that predictively define safe behaviour and environmental risk.
- From the data of the system, system performance modelling through RR.BB simulations to predict the values that would be obtained in a hypothetical monitoring network (predictive inferences). With this, it will be possible to define security zones linked to values of different site parameters.
- Once real monitoring data have been obtained, and using Machine Learning, go up through the Bayesian Network (abductive inferences) to redefine the ranges and combinations of parameters that lead to risk situations.

6.- Development of studies that link the characterization values of geological formations with the intermediate environmental impacts of pollutants

7.- Integration of RR.BB. with a GIS for the calculation and representation of the final impacts

8.- Development of expert systems based on global and partial probabilistic models and behavioural models, which allow decision-making by users through friendly interfaces

Expected Technological outcomes

The main outcome of this action is the development of an integrated environmental risk assessment tool

Feasibility/Sustainability

This action will require the incorporation of new human resources for its full development. The aspects linked to CO_2 geological Storage are financed with external funds until 2026 and can be carried out with the current human resources. The developments linked to geothermal energy and hydrogen storage will be developed linked to new research projects with external funds that include the incorporation of new human resources.

SO4. Social acceptance of sustainable energy systems.

Action 9. New conceptual and methodological frameworks for the social acceptance of sustainable energy systems

Conceptual and methodological developments are proposed to gain further knowledge on sustainable behavior and on the social acceptance of sustainable energy systems.

Action plan

- Studying the social acceptability of: a) energy projects at the local level (community acceptance); b) energy measures and policies (socio-political acceptance); and, c) energy applications (market acceptance), including renewables, hybridization of renewables, CO2 capture and sequestration, hydrogen, fusion energy, etc.
- Identifying determinants of energy behaviour, including citizen's capability to contribute to the transformation of the energy system (energy citizenship): socio-economic, gender, political and cultural factors.
- Development of methods and techniques for citizen and stakeholder engagement in energy related policies, programs, and projects (stakeholder panels, deliberative workshops, citizen science, urban living laboratories, world café, consensus conferences, etc.).

Innovation/Singularity

Most energy system interventions require that humans modify existing attitudes and behaviors or adopt new ones for individuals and households. Energy behavior is complex — it often involves a combination of personal, motivational and contextual factors. The combination of the social and behaviour change approach into energy system research is critical yet underutilized and can help adopting a more comprehensive understanding of sustainable energy systems.

Expected Technological outcomes

There are no expected technological outcomes.

The main outcome in this area include a) carrying-out of projects and studies in particular contexts of application that would generate new evidence in Spain; b) development of innovative social acceptance conceptual and methodological frameworks to assess the social acceptance of sustainable energy systems; b) design and implementation of innovative participatory methods to engage stakeholders with sustainable energy systems.

Feasibility/Sustainability

Activities in this area will be closely linked to the participation in European projects.

SO5. Analysis of Energy and Climate Change Policies.

Action 10. Assessment of energy and climate change policies in less developed countries

Besides the ongoing activities focused at the EU level, a development of an energy and climate change policies assessment framework tailored to the needs and particularities of less developed countries is proposed. The proposed new action aims at supporting the green energy transition in third countries (in line with targets laid out in the NDCs) and achieving universal access to affordable, reliable, sustainable and modern energy services.

Action plan

- Develop specific analytical tools and assessment frameworks to support the planning and implementation of sustainable energy and development strategies in emerging and developing countries.
- Assess the potentials and possible diffusion pathways for off-grid and on-grid renewable energy technologies, the evaluation of local value creation potentials for energy technologies and the development of policy instruments and strategies supporting sustainable energy transitions in developing countries taking into consideration their specific needs and constraints.

Innovation/Singularity

So far, most of CIEMAT´s research expertise and capabilities have been applied to support the energy transition at the National or European level. However, CIEMAT expertise could also contribute to the green energy transition and to the achievement of the 2030 agenda globally. CIEMAT has a valuable in-depth experience in many research areas that can be extremely useful and relevant in supporting the external dimension of the EU Green Deal.

Expected Technological outcomes

There are no expected technological outcomes. The main outcome in this area is the development of reinforced capacities to support decision makers in developing countries to succeed in their energy transition through support to regulatory, policy and governance reforms, enhancing public planning and transfer suitable experience from the EU energy transition.

Feasibility/Sustainability

This action will require the incorporation of additional human resources (1 PhD student).

1.C.1.2. Indicators of scientific activity

Activity	Indicator range (2021-2024)
SO1. Action 1	Publications in scientific journals included in JCR: 5 Communications to conferences: 10 PhD thesis: 2 (one in TIMES modelling already started and another one in artificial intelligence)
SO2. Actions 2-7	Publications in scientific journals included in JCR: 20 Communications to conferences: 15 PhD thesis: 2 (One in sLCA in cooperation with SO4 and another one in critical raw materials)
SO3. Action 8	Publications in scientific journals included in JCR: 6-8 Communications to conferences: 5-6 Book Chapters: 2-3 PhD thesis: 1-2
SO4. Action 9	Publications in scientific journals included in JCR: 10 Communications to conferences: 10 Book Chapters: 5 PhD thesis: one in Sustainable behaviour
SO5. Action 10	Publications in scientific journals included in JCR: 3 Communications to conferences: 5

1.C.1.3. Training

Training activities are expected to continue as it were until now. The objectives would be the following:

- Direction of PhD thesis: 8 (2 SO1, 2 SO2, 2 SO3, 1 SO4, 1 SO5)
- Direction of master thesis: 10
- Direction of graduate final projects: 10
- Lectures in masters: 8 per year
- Lectures in internal courses: 3 per year. Some foreseen courses in 2021 are:
  - Circular economy- Towards a new model of production and consumption. CIEMAT. 2021
  - Environmental footprint of products and organizations as a tool to promote more sustainable products and services. CIEMAT. 2021
  - Citizens' contribution to the low carbon economy. CIEMAT. 2021

1.C.1.4. Transfer of Knowledge

The knowledge generated in the activities described in the Action Plan will be transferred to the society. The knowledge transfer activities proposed are the following:

- Intellectual Property Registration of the software developed for electricity mix optimization applying artificial intelligence.

- Electricity mix optimization studies for Protermosolar and ESTELA.
- Support in energy system scenarios development to the Ministry of Ecological Transition and Demographic Challenge when required
- Support to the Ministry of Ecological Transition and Demographic Challenge in the evaluation of air pollution externalities when required
- Support to the Ministry of Ecological Transition and Demographic Challenge in the Life cycle assessment of energy technologies when required
- Intellectual Property Registration of the software developed for risk assessment.
- Technical support to the Spain government, when required, on the environmental risks associated with projects in the aforementioned areas.

1.C.1.5. Dissemination/internationalization

The following dissemination activities are proposed for the 2021-2025 period in this line:

Activity	Targeted audiences and dates
Publication of news, results, projects and related information on the CIEMAT web site	Public in general (continuous)
Organization of scientific events (workshops, meetings, panels) on related topics	Scientific audience. Dates dependant on the research projects
Creation of a web portal and social media accounts in twitter and LinkedIn	Public in general (continuous)

1.C.1.6. Alliances, collaborations

In the next 5 years, it is expected that the network of contacts and collaborators will be maintained and even enlarged as we will engage in additional activities as detailed in the action plan. Anticipated new alliances are expected in the areas of social life cycle assessment, circularity assessment and critical raw materials. In this context, it would be desirable to join the European Raw Materials Alliance (ERMA).

1.C.2. RESOURCES REQUIRED

1.C.2.1. Human resources required

Personnel	Action
1 expert in TIMES modelling 1 PhD Student for optimization of energy systems applying artificial intelligence	Action 1
1 PhD Student Social Life Cycle Assessment	Action 4
1 PhD student for critical raw materials	Action 5

1-2 Scientists with a background in earth sciences / statistics.	Action 8
1-2 PhD students. Associated with Action 8 in some of the development fields (CO2 geological storage / H2 geological storage / development of high enthalpy geothermal resources).	Action 8
1 PhD student Sustainable Behaviour	Action 9
1 PhD student. Green energy transition in developing countries	Action 10

1.C.2.2. Equipment and material resources required

- Specific actions

Equipment/system	Justification	Action
Computing resources (Workstations)	Required for the execution of the optimization based on artificial intelligence	Action 1
LCA software and databases Computing resources	Required for the execution of the proposed tools	Action 2-7
Computing resources (Workstations)	Requirements for the application of the developed codes to real sites (large amount of data)	Action 8
Software update: GoldSim, Petrasim (with Tough and ToughReact modules)	Development of risk assessment codes and detailed analyses	Action 8
On-line platform licences (Zoom)	On-line deliberative workshops, focus groups, etc.	Action 9

1.C.3. ACTIONS PROPOSED TO GET THE RESOURCES

1.C.3.1. Human resources

The required human resources will be financed by grants associated with national and international projects in the form of project-financed contracts as well as by the incorporation of predoctoral researchers in the calls launched by CIEMAT annually.

The following proposals have been presented and are in evaluation:

NAME	PROPOSAL BUDGET	DURATION	TYPE (*)	ROLE OF CIEMAT
ECF4CLIM. A EUROPEAN COMPETENCE FRAMEWORK FOR A LOW CARBON ECONOMY AND SUSTAINABILITY THROUGH EDUCATION	4896710	4 years	I EUROPEAN UNION GREEN DEAL CALL H2020-LC-GD-2020	PROPOSAL COORDINATOR LEADER OF WP 1 AND 5
STORIES. STORAGE RESEARCH INFRASTRUCTURE ECO-SYSTEM	6999980	4 years	I EUROPEAN UNION GREEN DEAL CALL H2020-LC-GD-2020	PARTICIPATION IN WP4.
FLEXERGY. FLEXIBLE BIOENERGY-RES HYBRID SYSTEM BASED CHP PRODUCTION TO ACCELERATE THE DECARBONIZATION OF THE EUROPEAN ENERGY SYSTEM	5887192	3 years	I EUROPEAN UNION GREEN DEAL CALL H2020-LC-GD-2020	LEADER OF WP5
BOND. BRINGING ON INNOVATION FOR DEVELOPMENT IN AFRICA	10414964	4 years	I EUROPEAN UNION GREEN DEAL CALL H2020-LC-GD-2020	LEADER OF WP7
SINERGYS. SUSTAINABLE INTEGRATED RENEWABLE ENERGY SYSTEMS FOR POSITIVE HEATING AND COOLING	5994914	4 years	I EUROPEAN UNION GREEN DEAL CALL H2020-LC-GD-2020	LEADER OF WP5
MATEMAD. OPTIMIZED URBAN MATERIALS FOR MORE LIVEABLE AND SUSTAINABLE CITIES: CHARACTERIZATION IN THE CASE OF MADRID	78224	3 years	N NATIONAL R+D+i PROGRAMME 2020	PARTICIPATION IN SP3.
RECYCLEAN.RECYCLED MATERIALS FOR DEEP CLEANING OF BIOGAS		3 years	N NATIONAL R+D+i PROGRAMME 2020	PARTICIPATION IN SP1. LCA AND CIRCULARITY ASSESSMENT

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

INNOVA.CHALLENGES IN ENERGY RESEARCH: NEW SOLUTIONS FOR CARBON NEUTRAL SUSTAINABLE ENERGY		4 years	N NATIONAL R+D+i PROGRAMME 2020	LEADER OF TASK 4
FOTOVOL3R.: CIRCULARITY OF PHOTOVOLTAIC SYSTEMS BY RECYCLING, REPAIRING AND REUSING PHOTOVOLTAIC MODULES.	151207	3 years	N NATIONAL R+D+i PROGRAMME 2020	SUSTAINABILITY AND CIRCULARITY ASSESSMENT
EFFICIENT RENEWABLE ENERGY TO FIGHT RURAL DEPOPULATION		1 year	N La Caixa	
SERENA_CO2. GEOLOGICAL STORAGE OF CO2 SAFETY PREDICTION THROUGH NEURAL NETWORKS.	99.100,00 €	3 years	N NATIONAL R+D+i PROGRAMME 2020	PROPOSAL LEADER. ENVIRONMENTAL RISKS ASSESSMENT.

Additionally, the Strategic Research Line ASES participates in the following expressions of Interest (MDI) to the calls open by the Ministry for Ecological Transition and Demographic Challenge and the Ministry of Industry.

TITLE	**MDI**	**MINISTRY**
Geotermia en el Archipiélago Canario	MDI Flexibilidad del sistema energético, infraestructura eléctrica y redes inteligentes y despliegue del almacenamiento energético https://energia.gob.es/es-es/Participacion/Paginas/DetalleParticipacionPublica.aspx?k=386	Ministry for the Ecological Transition and Demographic Challenge
Herramientas de Predicción y Planificación para la Integración de Energías	MDI Energía Sostenible en Islas https://energia.gob.es/es-es/Participacion/Paginas/DetalleParticipacionPublica.aspx?k=383	Ministry for the Ecological Transition and Demographic Challenge

Renovables en las Islas Canarias		
RETOS-Redes de Energías Térmicas Renovables para la Transición Energética en las Ciudades	MDI Programa de Impulso de proyectos tractores de Competitividad y Sostenibilidad Industrial https://industria.gob.es/es-es/participacion_publica/Paginas/DetalleParticipacionPublica.aspx?k=362	Ministry of Industry, Commerce and Tourism
Fin de vida de proyectos fotovoltaicos	MDI Economia circular https://www.miteco.gob.es/es/prensa/2101271_tcm30-522146.PDF	Ministry for the Ecological Transition and Demographic Challenge
ALMIN (Almacenamiento de energía renovables en minas abandonadas)	MDI Flexibilidad del sistema energético, infraestructura eléctrica y redes inteligentes y despliegue del almacenamiento energético https://energia.gob.es/es-es/Participacion/Paginas/DetalleParticipacionPublica.aspx?k=386	Ministry for the Ecological Transition and Demographic Challenge

1.C.3.2. Funding schemes and opportunities

In addition to the ongoing projects, and the already presented proposals enumerated above, the following possibilities to obtain external funding can be identified. Some of them are listed below.

Horizon Europe

- Cluster 5. Horizon- CL5- 2021-2022. Opportunities have been identified in but are not restricted to the following calls:
    - HORIZON-CL5-2021-D2-01-13: Strengthening Social Sciences and Humanities (SSH) research communities in climate, energy and mobility disciplines
    - HORIZON-CL5-2021-D3-01-02: Sustainability and educational aspects for renewable energy and renewable fuel technologies
    - HORIZON-CL5-2021-D3-01-03: Market Uptake Measures of renewable energy systems
    - HORIZON-CL5-2021-D3-01-19: Clean Energy Transition
    - HORIZON-CL5-2021-D3-02-09: Carbon-negative sustainable biofuel production
    - HORIZON-CL5-2021-D3-02-15: Solutions for more sustainable geothermal energy
    - HORIZON-CL5-2022-D3-01-08: Supporting the action of consumers in the energy market and guide them to act as prosumers, communities and other active forms of active participation in the energy activities
    - HORIZON-CL5-2022-D3-01-13: Energy system modelling, optimisation and planning tools
    - HORIZON-CL5-2022-D3-03-09: Recycling end of life PV modules

- HORIZON-CL5-2021-D3-01-15: Integration of CCUS in hubs and clusters, including knowledge sharing activities
- HORIZON-CL5-2022-D3-01-15: Decarbonising industry with CCUS
- HORIZON-CL5-2022-D3-02-02: AU-EU Energy System Modelling
- HORIZON-CL5-2021-D3-02-01: AU-EU Water Energy Food Nexus
- HORIZON-CL5-2022-D3-01-05: Demonstration of innovative plug-and play solutions for system management and renewables storage in off-grid applications
- HORIZON-CL5-2022-D5-01-10: New generation of full electric urban and peri-urban Bus Rapid Transit systems to strengthen climate-friendly mass transport (2ZERO)

EUROFUSION programe 2021-2025

EURATOM Research and Training Programme 2021-2025

Other Union Programmes

- LIFE programme (https://ec.europa.eu/easme/en/section/life/calls-proposals)
- INTERREG SUDOE 2021-2027 (https://www.interreg-sudoe.eu/programa/acerca-de-interreg-sudoe)
- INTERREG MED 2021-2027 (https://interreg-med.eu/)

National R+D+i program 2021-2025.

- National R+D+i program oriented to the Societal Challenges 2021-2025
- Ministry of Science and Innovation Strategic Lines call (https://www.ciencia.gob.es/stfls/MICINN/AEI/ficheros/EN_Topics_para_la_convocatoria_de_proyectos_estrategicos.pdf)

The following lines have been identified as possible funding opportunities:

- *Line 5. Next generation batteries*

"Research will focus on developing advanced materials and/or technologies for such disruptive storage systems, considering **circular economy** aspects such as the substitution and/or more efficient use of critical materials (e.g. cobalt, vanadium, lithium, natural graphite, etc.), the reduction of their environmental impact, sustainability and recycling"

- *Line 6. Efficient solar light conversion to fuels and chemicals*

"Proposals should involve different disciplines and aim to the understanding of the reaction mechanism and the nature of the active sites. Benefits and impacts for the environment of the novel technologies should be supported by the corresponding **life cycle analyses**"

- *Line 7. Smart building technologies*

"Proposals are expected to cover some or all of the following aspects: (...) Demonstrate the **sustainability** of the solutions in the following aspects: environmental, social, and economic"

- *Line 8. Smart urban and metropolitan mobility strategies*

"The aim of this topic is to boost the development of applications based on new technologies in vehicles, management and infrastructure oriented to mobility that takes into account **sustainability,** safety, **social cohesion** and use of urban space".

- 12. Sustainable fuels

"An interdisciplinary approach is required for the production of innovative, sustainable fuels based on improved catalytic processes and chemical product efficiency, novel catalytic reaction mechanisms or process **sustainability.**(...) Proposals should address several of the following impact criteria and provide metrics to measure and monitor success: (...) Disseminate novel technologies to facilitate industrial adoption and to expand **social awareness**"

Collaboration with Ministries

Possible collaboration with the Ministry for the Ecological Transition and Demographic Challenge in topics related to:

- Life Cycle Assessment of storage technologies continuing the collaboration line started with the Technical Assistance to IDAE " SCREENING DE ESTUDIOS DE ANÁLISIS DE CICLO DE VIDA (ACV) DE TECNOLOGÍAS DE ALMACENAMIENTO" MENOR/2020/0655
- Energy modelling of the Spanish Energy System continuing the collaboration line started with the Technical assistance to the European Commission DG REFORM "Improving Energy System Modelling Tools and Capacity" REFORM/SC2020/069.

Collaboration with the industry

- Electricity mix optimization studies for Protermosolar and ESTELA.