REQUEST FOR AN EMI R&D PROJECT 2027–2029

Country/Organisation:	Italy
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Project Title:	A High-Resolution ERA6-Based Reanalysis for Energy Applications in Italy

To make changes to an existing project please submit an amended version of the original form

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ………….	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2027	
Would you accept support for 1 year only, if necessary?	YES	NO **X**

Computer resources required for project year:		**2027**	**2028**	**2029**
High Performance Computing Facility	[SBU]	41,000,000	82,000,000	82,000,000
Graphics Processing Unit Cluster-A	[GBU]			
Graphics Processing Unit Cluster-B	[GBU]			
Accumulated data storage (total archive volume)[2]	[GB]	30,000	60,000	60,000

[1] The Principal Investigator will act as contact person for this EMI R&D Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.
[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.
[3]The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

EWC resources required for project year:		2027	2028	2029
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

Continue overleaf.

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Extended abstract

Introduction and Motivation

The increasing penetration of renewable energy sources, coupled with the growing frequency and intensity of extreme weather events, has significantly strengthened the need for reliable and high-resolution meteorological information to support the design and management of the electrical energy system.
Italy is undergoing a deep energy transition, primarily driven by the expansion of renewable energy sources. Alongside this shift, major investments are being made to improve the resilience of transmission and distribution networks, enhancing overall grid stability and reliability. This transformation is influenced both by the intrinsic variability of renewable energy sources—such as wind and solar—and by the growing energy demand, particularly during summer, when prolonged heat waves lead to increased cooling needs.
In this context, high-resolution meteorological reanalyses play a crucial role in supporting energy planning. They provide essential information for identifying suitable areas for renewable installations and for assessing weather-related risks to infrastructures. This is especially important over Italy, where complex orography and coastal interactions generate small-scale processes that drive localized extreme events.
Previous efforts led to the development of several WRF-based reanalysis datasets, including MERIDA [1], MERIDA HRES [2], and AEOLIAN [3], progressively improving the representation of precipitation, temperature, and wind fields over the Italian peninsula. These experiences clearly demonstrated the importance of kilometre-scale resolution in capturing processes relevant to hydrological risks and renewable energy production.
At the same time, new challenges are emerging. The increasing frequency of intense precipitation events, floods, and landslides—often exacerbated by urbanisation—poses growing threats to electrical infrastructures. In parallel, the accurate characterization of local wind regimes remains essential for estimating wind energy production and supporting the planning of new installations.
The forthcoming ERA6 reanalysis represents a major advancement with respect to ERA5[4], thanks to its higher spatial resolution, improved model physics, and a larger and higher-quality observational dataset. These improvements ensure a more accurate representation of key atmospheric variables such as wind, solar radiation, and temperature, which are fundamental for energy applications. However, its resolution (about 14 km) is still insufficient to resolve the fine-scale processes induced by Italy's complex terrain.
In addition, the increasing persistence of summer heat waves across the Mediterranean region is making urban electrical distribution networks more vulnerable to peak loads associated with cooling demand. This highlights the need to explicitly represent urban environments within meteorological reanalyses, including the simulation of Urban Heat Island (UHI) effects through dedicated urban canopy models.
Within this framework, the new dataset MERIDA6 (MEteorological Reanalysis Italian Dataset ERA6 based) is conceived as the natural evolution of the previous MERIDA products. While earlier reanalyses extended considerably back in time, reaching the early 1990s, the new reanalysis primarily focuses on the last 25 years, which are particularly relevant for assessing the impact of climate change on the Italian power system, especially in terms of extreme events.
This new reanalysis builds upon the sensitivity studies conducted within the ECMWF Special Project SPITRIC2 "WRF-based high resolution simulations to improve the resilience of the Italian Energy System", which examined different versions and parametrizations of WRF[5] to identify the optimal configurations for the Italian domain at convection-permitting scales.

Scientific Plan

Overview and Objectives

The main objective of the project is the development of a new high-resolution meteorological reanalysis over Italy, MERIDA6, based on ERA6 boundary conditions and advanced WRF configurations. The aim is to produce a physically consistent, long-term dataset capable of accurately representing the main variables and processes relevant for the energy sector, including precipitation, temperature, wind, solar radiation and land–atmosphere interactions, with particular attention to extreme events and urban environments.
The project builds upon previous sensitivity analyses, which highlighted the need to strike a balance between different model configurations in order to ensure good overall performance across multiple variables, rather than optimizing individual processes at the expense of others.

Model Configuration, Downscaling Strategy and Methodological Advances

The development of MERIDA6 will leverage the main outcomes of the sensitivity studies already conducted within the special project SPITRIC2. The development of MERIDA6 will leverage the main outcomes of the sensitivity studies already conducted within the special project SPITRIC2. Simulations will be performed at convection-permitting resolution (2 km) over the Italian domain shown in Figure 1 with an hourly temporal resolution. Test runs will be carried out with WRF version 4.7, as well as with previous versions, in order to identify the configuration and the model version that can provide the best performance for the estimation of the main meteorological variables.

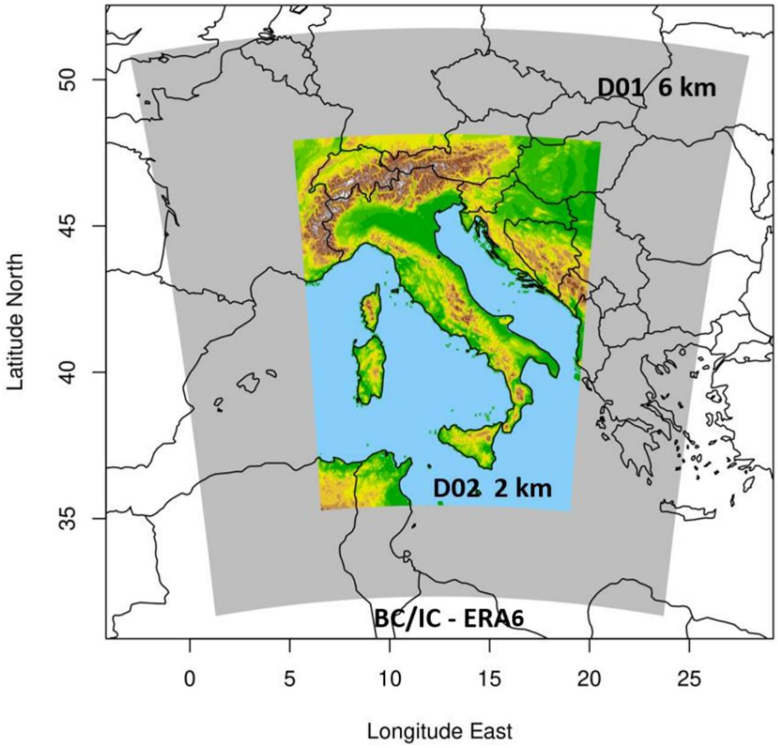

Figure 1: Domain of the new meteorological reanalysis over the Italian peninsula. The domain has two grids (d01 and d02) with resolutions of 6 and 2 km, respectively, of which the final MERIDA6 product represents the one on the innermost d01 grid.

A key methodological component of the project is the adoption of a multi-scale dynamical downscaling strategy, in which ERA6 provides the large-scale forcing for high-resolution WRF simulations over Italy. This approach allows the project to fully exploit the improved quality and consistency of ERA6 while overcoming its spatial limitations, enabling the explicit representation of local-scale processes such as extreme precipitation, orographic effects, and terrain-driven wind patterns that are crucial for energy applications.

Special attention will be paid to the representation of land–atmosphere interactions. The Noah-MP Land Surface Model [6] will be used to improve the simulation of soil and vegetation processes, while the choice of the Planetary Boundary Layer scheme will be based on the results of the sensitivity analyses, selecting the option that provides the best performance in reproducing near-surface main meteorological variables such as 2m temperature, 10m wind speed and precipitation etc.

This effort will be complemented by the use of high-quality static datasets of vegetation and soil together with improved soil initialization techniques developed within ECMWF Special Project SPITRIC2, which have already shown a significant reduction in temperature biases in critical areas such as the Po Valley.

Overall, this modelling framework is designed to produce a physically consistent and high-quality long-term dataset, capable of significantly improving the representation of extreme weather events and local-scale atmospheric processes across the Italian territory.

Urban Modelling

A key element of MERIDA6 is the explicit inclusion of urban processes. The Single Layer Urban Canopy Model (SLUCM, [7]) will be employed to represent the interactions between the urban surface and the atmosphere. Urban areas will be described through a combination of datasets and parameters as urban fraction derived from satellite observations, and indicators of urban morphology such as building height and street width.

This approach will allow a more realistic simulation of temperature fields in cities, improving the representation of urban heat islands and their temporal evolution. As a result, the model will be better suited to capture temperature extremes in urban environments, providing valuable information for assessing heat-related stress on electrical networks and for analysing peaks in energy demand associated with cooling.

Sensitivity Analysis and Validation Strategy

The development of MERIDA6 will rely on a robust validation framework based on a set of representative case studies of extreme weather events affecting Italy. These will include convective and synoptic precipitation events, major floods occurred in Italy in recent years, intense windstorms such as Storm Vaia, and prolonged heat waves, with particular attention to their impact in urban areas.
For each case, dedicated simulations will be performed and systematically compared with observational datasets. The evaluation will focus on the model's ability to reproduce key aspects of atmospheric variability, including the spatial localization of precipitation peaks, the accuracy of near-surface temperature, and the intensity and variability of wind fields. Particular emphasis will be placed on the representation of the urban heat island effect.
Results from previous sensitivity studies have already demonstrated that high-resolution configurations provide clear benefits, improving the localization of extreme precipitation, the realism of wind patterns in complex terrain, and the representation of urban thermal structures.

Expected Outcomes
The resulting MERIDA6 dataset will provide a new long-term high-resolution meteorological reanalysis for Italy, offering a substantial improvement in the representation of extreme events and fine-scale processes. It will deliver reliable and consistent information for solar and wind energy assessment and planning, as well as an enhanced characterization of urban climate and heat stress conditions.
More broadly, MERIDA6 is designed to become a unified meteorological reference for the Italian energy sector, supporting applications ranging from infrastructure resilience to renewable energy integration. It will effectively bridge the gap between global reanalyses such as ERA6 and the local-scale processes that strongly influence the Italian energy system.

Energy-Oriented Outputs and Final Applications
In addition to the standard meteorological variables, a key added value of MERIDA6 will be the provision of derived variables specifically tailored for the energy sector. These variables will be designed to directly support stakeholders involved in the planning, operation, and management of the electrical energy system, bridging the gap between atmospheric modelling and practical energy applications.
In particular, the dataset will be post-processed to derive indicators relevant for both wind and solar energy production. For solar applications, MERIDA6 will provide surface radiation components and derived photovoltaic power indicators, including capacity factor and potential energy production. These estimates will account for cloud cover, atmospheric conditions, and seasonal variability, enabling a more accurate characterization of solar resource availability across the Italian territory.
For wind energy, this includes hub-height wind speed fields, wind power density, and capacity factor estimates, computed using representative turbine power curves. These variables will allow a direct assessment of the spatio-temporal variability of wind energy potential, supporting site selection, resource assessment, and long-term planning of new onshore and offshore installations.
By providing these energy-oriented variables, MERIDA6 will significantly reduce the gap between meteorological data and energy system applications. Stakeholders will be able to access not only high-resolution atmospheric fields, but also directly usable quantities for estimating renewable energy production and associated variability.
Furthermore, the availability of long-term, physically consistent time series will allow robust statistical analyses, including the assessment of interannual variability, extreme events, and long-term trends in renewable energy potential. Ultimately, MERIDA6 will provide a comprehensive and user-oriented dataset that supports decision-making processes across the entire energy value chain.

Justification of the computer resources requested

Regarding the goal of running a high-resolution reanalysis for the whole Italian Country with WRF model, the tests carried out at the ECMWF's AC server allowed estimating the required resources for this project as follows:

- A single, 2-day WRF run submitted as a parallel job requires about 45,000 SBU
- 182 runs are required to reconstruct a years of reanalysis dataset
- Each run requires a disk storage of about 29 GB after cleaning of unnecessary variables.

This results in a total amount of requested resources for the period 2000-2026 of 205M SBU and 150 TB for the 3-year project.

Technical characteristics of the code to be used

The required codes for this project are the WRF ARW model v4.7 and earlier versions (from v3.9 onward), which has been already installed on the ECMWF's AC server. The scripts to prepare the input files and launch the simulations are developed in R language.

[1] R. Bonanno, M. Lacavalla, e S. Sperati, «A new high-resolution Meteorological Reanalysis Italian Dataset: MERIDA», *Q. J. R. Meteorol. Soc.*, vol. 145, fasc. 721, pp. 1756–1779, 2019, doi: https://doi.org/10.1002/qj.3530.

[2] F. Viterbo *et al.*, «MERIDA HRES: A new high-resolution reanalysis dataset for Italy», *Meteorol. Appl.*, vol. 31, fasc. 6, p. e70011, 2024.
[3] S. Sperati *et al.*, «A new Wind Atlas to support the expansion of the Italian wind power fleet», *Wind Energy*, vol. 27(3), pp. 298–316, 2024.
[4] H. Hersbach *et al.*, «The ERA5 global reanalysis», *Q. J. R. Meteorol. Soc.*, vol. 146, fasc. 730, p. 19, 2020.
[5] W. C. Skamarock *et al.*, «A Description of the Advanced Research WRF Model Version 4», UCAR/NCAR, mar. 2019. doi: 10.5065/1DFH-6P97.
[6] C. He *et al.*, «The Community Noah-MP Land Surface Modeling System Technical Description Version 5.0», UCAR/NCAR, 2023. doi: 10.5065/EW8G-YR95.
[7] Y. Takane, Y. Kikegawa, K. Nakajima, e H. Kusaka, «SLUCM+BEM (v1.0): a simple parameterisation for dynamic anthropogenic heat and electricity consumption in WRF-Urban (v4.3.2)», *Geosci. Model Dev.*, vol. 17, fasc. 23, pp. 8639–8664, dic. 2024, doi: 10.5194/gmd-17-8639-2024.