REQUEST FOR A SPECIAL PROJECT 2025–2027

MEMBER STATE: The Netherlands

Principal Investigator[1]: Dr. Jason W. Williams

Affiliation: Royal Netherlands Meteorological Institute (KNMI)

Address: *Utrechtseweg 297.,NL-3731 GA De Bilt Netherlands*.
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Other researchers: Dr. Phillipe le Sager, Dr. Twan P.C. van Noije

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Project Title: EC-EARTH-V3 HYWAY

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.)	2025	
Would you accept support for 1 year only, if necessary?	YES	NO ☐

Computer resources required for project year:		**2025**	**2026**	**2027**
High Performance Computing Facility	[SBU]	6000k	6000k	5000k
Accumulated data storage (total archive volume)[2]	[GB]	3TB	3TB	3TB

EWC resources required for project year:		**2025**	**2026**	**2027**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			

[1] The Principal Investigator will act as contact person for this Special 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.

Number of vGPUs[3]	[#]			

Continue overleaf.

Principal Investigator: Jason Williams.....

Project Title: Climate Impacts of a hydrogen Economy - the pathWAY to knowledge (HYWAY)

Extended abstract

Hyway is an EU-funded project with a focus on the impact of the energy transition on non-CO2 climate forcing gases/aerosols and air-quality. HYway will be the most comprehensive study on environmental effects of large-scale hydrogen (H_2) usage to date. HYway is led by a team of experienced scientists who have already conducted extensive research on the climate effects of H_2. To fully understand the climate effect of H_2 emissions, HYway will constrain the H_2 budget by novel work on surface emissions, measurements of leaks and soil uptake fluxes, and application of a global atmospheric model ensemble combined with observations to quantify the atmospheric sources and sinks of H_2. To improve monitoring tools for H_2 leakages, HYway will develop novel emission modelling and installation-level emission measurements. We will measure the H_2 soil sink using flux chambers and instrumented drones, and we will use this knowledge to improve process-based models of the sink. The Global Warming Potential of hydrogen and its Effective Radiative Forcing will be quantified, including the component contributions from methane, ozone, stratospheric water vapour and aerosols. HYway will also quantify several environmental effects associated with H_2 emissions such as stratospheric ozone depletion and air pollution. HYway will build on existing methods to create realistic future scenarios to fully explore the climate and environmental impacts of a hydrogen economy, including co-emissions and associated reductions in fossil fuel-related emissions. By evaluating the potential climate and environmental impacts of a H_2 economy, HYway will provide critical information to policymakers and stakeholders, allowing them to make informed decisions about the role of H_2 in the transition to a low-carbon economy.

EC-Earth-HYWAY will support the KNMI contribution to EU-HYway by using the EC-Earth-v3 Earth System model as a member of the ensemble studies. The ensemble includes leading Earth System Models which have been used for previous CMIP intercomparison studies (e.g. EMAC, UKCA, NorESM). Some development of EC-Earth-v3 is needed in the first instance, such as including H_2 as a transported tracer, updating the dry deposition parameterization to include loss of H_2 and updating the chemical scheme to improve the distribution of formaldehyde (CH_2O) which acts as a chemical source for H_2. Model simulations will be performed using the standard set-up for EC-Earth at 3° x 2° and 34 model levels up to the top of the atmosphere. Existing emission scenarios will be adopted in the first instance to allow a rapid start to the project (such as those used for CMIP-6). For assessing the performance of the participating models, a 10-year nudged simulation between 2010-2019 using a fixed H_2/CH_4 surface distribution will be used to validate each of the ensemble members for the most important trace gases such as O_3, NO_2, CO, CH_2O and NH_3. This requires 3-hourly global output for post-processing to allow the exploitation of surface, aircraft and satellite observations available for the period. One year of simulation of EC-Earth-V3 in this configuration costs approximately 200 kSBU on the Bologna system. The request for SBU has been calculated by upscaling this to account for

the total number of simulation years throughout the project. Therefore a 10-year simulation is expected to need 2000 kSBU.
After the near-past validation step, sensitivity simulations will be performed in 2026 where numerous H_2 emission inventories are employed to investigate global inhomogeneities in the distribution and subsequent effects on air-quality and Radiative Forcing. The use of H_2 for industry will introduce changes in local H_2 mixing ratios due to leakage, with H_2 being a very diffuse gas. Moreover, some H_2 production is from the industrial processing of NH_3, which also leaks and is associated with Nitrate particle formation and thus changes in Radiative Forcing. Present day simulations will be performed where different emission scenarios are adopted, as well as future estimates of the speed of the energy transition and different leakage rates. Each respective sector will be applied at different times to determine which sector imposes the largest impact on global climate. Moreover, by switching on the H_2 transition across different global regions to mimic variability in the development of H_2 infrastructure, the impact of the timing of the energy transition on global atmospheric composition will be determined.

Table 1: An overview of the planned experiments and timing for the EC-EARTH-V3 HYWAY ECMWF special project between 2025-2027. Sensitivity #1 pertains to Near Past simulations, Sensitivity #2 to the present day simulations and Sensitivity #3 to the 2050 time-slices.

	2025	2026	2027
Near Past	Code development 2010-2019 transient nudged simulation		
Sensitivity #1	2*H_2 emission 2*perturbed CH_4 emission Perturb regions/sectors		
Present Day		10-year present day simulation	
Sensitivity #2		Different emission scenarios Apply a new dry dep param. 25% perturbation on emissions and soil sink Geographical location of H_2 transition	
Time slices			2050 time slices with/without H_2 economy
Sensitivity #3			Investigate future dry/wet periods for changes to impact. Investigate Climate Impacts from different H2 sectors .

A second set of 10-year transient simulations will then be performed during 2026 employing a new parameterization for describing the loss of H_2 to the soil. Perturbations to both the soil sink and direct emission fluxes by 25% will be performed to provide an uncertainty on the simulated results across the ESM ensemble. For this purpose monthly

mean averages and the global chemical budget terms will be used to determine the impact on oxidative capacity and derive a global H_2 budget from the model ensemble.
A set of time-slices for 2050 will then be performed in 2027 both with and without a transition to the H_2 economy to investigate future impacts of the energy transition on future air quality and climate. The soil sink for H_2 depends on soil moisture, therefore excessive dry and wet periods will impact the sink term potentially decreasing or increasing simulated effects. Finally a set of sensitivity experiments will be performed to determine which of the sectors (transport, energy, industry) has the largest climate impact and potential feedback. Depending on the progress of the project and the expense of running EC-EARTH-v3 (with 3D global output) further resources may be requested for this final year of the project in case of unforeseen delays or model issues.
In that this special project will support a much wider international research effort means that results will lead to numerous conference proceedings and high-quality research papers and support the EU and national partners with respect to policy making with respect to the proposed Green Deal.