SAFE WAVE

STREAMLINING THE ASSESSMENT OF ENVIRONMENTAL EFFECTS OF WAVE ENERGY

DELIVERABLE 2.7
DEVELOPMENT OF GUIDELINES FOR ENVIRONMENTAL MONITORING

This Project is co-funded by the European Climate, Infrastructure and Environment Executive Agency (CINEA)

WP 2

Deliverable 2.7 Development of guidelines for environmental monitoring

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CONTENTS

1. SafeWAVE project synopsis

The European Atlantic Ocean offers a high potential for marine renewable energy (MRE), which is targeted to be at least 32% of the EU's gross final consumption by 2030 (European Commission, 2020 (European Commission, 2020). The European Commission is supporting the development of the ocean energy sector through an array of activities and policies: the Green Deal, the Energy Union, the Strategic Energy Technology Plan (SET-Plan) and the Sustainable Blue Economy Strategy. As part of the Green Deal, the Commission adopted the EU Offshore Renewable Energy Strategy (European Commission, 2020) which estimates to have an installed capacity of at least 60 GW of offshore wind and at least 1 GW of ocean energy by 2030, reaching 300 GW and 40 GW of installed capacity, respectively, moving the EU towards climate neutrality by 2050.

Another important policy initiative is the REPowerEU plan (European Commission, 2022) which the European Commission launched in response to Russia's invasion of Ukraine. REPowerEU plan aims to reduce the European dependence amongst Member States on Russian energy sources, substituting fossil fuels by accelerating Europe's clean energy transition to a more resilient energy system and a true Energy Union. In this context, higher renewable energy targets and additional investment, as well as introducing mechanisms to shorten and simplify the consenting processes (i.e., 'go-to' areas or suitable areas designated by a Member State for renewable energy production) will enable the EU to fully meet the REPowerEU objectives.

The nascent status of the Marine Renewable Energy (MRE) sector and Wave Energy (WE) in particular, yields many unknowns about its potential environmental pressures and impacts, some of them still far from being completely understood. Wave Energy Converters' (WECs) operation in the marine environment is still perceived by regulators and stakeholders as a risky activity, particularly for some groups of species and habitats.

The complexity of MRE licensing processes is also indicated as one of the main barriers to the sector development. The lack of clarity of procedures (arising from the lack of specific laws for this type of projects), the varied number of authorities to be consulted and the early stage of Marine Spatial Planning (MSP) implementation are examples of the issues identified to delay projects' permitting.

Finally, there is also a need to provide more information on the sector not only to regulators, developers and other stakeholders but also to the general public. Information should be provided focusing on the ocean energy sector technical aspects, effects on the marine environment, role on local and regional socio-economic aspects and effects in a global scale as a sector producing clean energy and thus having a role in contributing to decarbonise human activities. Only with an informed society would be possible to carry out fruitful public debates on MRE implementation at the local level.

These non-technological barriers that could hinder the future development of WE in EU, were addressed by the WESE project funded by European Maritime and Fisheries Fund (EMFF) in 2018. The present project builds on the results of the WESE project and aims to move forward through the following specific objectives:

1. Development of an **Environmental Research Demonstration Strategy** based on the collection, processing, modelling, analysis and sharing of environmental data collected in WE sites from different European countries where WECs are currently operating (Mutriku power plant and BIMEP in Spain, Aguçadoura in Portugal and SEMREV in France); the SafeWAVE project aims to enhance the understanding of the negative, positive and negligible effects of WE projects. The SafeWAVE project will continue previous work, carried out under the WESE project, to increase the knowledge on priority research areas, enlarging the analysis to other types of sites, technologies and countries. This will increase information robustness to better inform decision-makers and managers on real environmental risks, broaden the engagement with relevant stakeholders, related sectors and the public at large and

reduce environmental uncertainties in consenting of WE deployments across Europe;

2. Development of a **Consenting and Planning Strategy** through providing guidance to ocean energy developers and to public authorities tasked with consenting and licensing of WE projects in France and Ireland; this strategy will build on country-specific licensing guidance and on the application of the MSP decision support tools (i.e. WEC-ERA[1] by Galparsoro et al., 2021[2] and VAPEM[3] tools) developed for Spain and Portugal in the framework of the WESE project; the results will complete guidance to ocean energy developers and public authorities for most of the EU countries in the Atlantic Arch.
3. Development of a **Public Education and Engagement Strategy** to work collaboratively with coastal communities in France, Ireland, Portugal and Spain, to co-develop and demonstrate a framework for education and public engagement (EPE) of MRE enhancing ocean literacy and improving the quality of public debates.

[1] https://aztidata.es/wec-era/;
[2] Galparsoro, I., M. Korta, I. Subirana, Á. Borja, I. Menchaca, O. Solaun, I. Muxika, G. Iglesias, J. Bald, 2021. A new framework and tool for ecological risk assessment of wave energy converters projects. Renewable and Sustainable Energy Reviews, 151: 111539
[3] https://aztidata.es/vapem/

2. Glossary

AUV	Autonomous Underwater Vehicle
BiMEP	Biscay Marine Energy Platform
EMF	ElectroMagnetic Fields
ROV	Remotely Operated Vehicle
SEM-REV	Site d'Expérimentation en Mer pour la Récupération de l'Energie des Vagues (marine test site for wave energy)
SSS	Side Scan Sonar
WEC	Wave Energy Converter

3. Executive summary

Marine data are collected by different entities (institutes, governmental organizations, or private companies) using heterogeneous instruments and sensors installed in various observing platforms. However, apart from researchers' experience reported in technical reports and published papers worldwide, it seems that no specific guidelines are available concerning to the monitoring of the parameters covered by the SafeWAVE project, i.e., EMF, acoustics (noise), seafloor integrity, and fish communities around wave energy installations.

The data acquisition methodology (e.g., spatial and temporal frames, methods and equipment used) was planned to be as standardized and homogeneous as possible among devices and test sites and was developed considering recommendations from researchers and according to the specificities of the devices and their location. Details of the methodologies and results can be consulted in Deliverable 2.1 (monitoring plans for each parameter)[4], Deliverable 2.2[5] for EMF, Deliverable 2.3 for underwater noise, Deliverable 2.4[6] for seafloor integrity, and Deliverable 2.5[7] for fish communities.

In the light of the results obtained and described in the above-mentioned deliverables a better understanding of EMF, acoustics, seafloor integrity, and fish communities' data collection, processing, validation, and

[4] https://www.safewave-project.eu/wp-content/uploads/2022/06/Deliverable-2.1-Development-of-Environmental-monitoring-plans.pdf

[5] https://www.safewave-project.eu/wp-content/uploads/2023/08/SafeWAVE-D2.2-Monitoring-of-Electromagnetic-fields.pdf

[6] https://www.safewave-project.eu/wp-content/uploads/2023/02/Deliverable-2.4-Monitoring-of-the-seabed-integrity.pdf

[7] https://www.safewave-project.eu/wp-content/uploads/2023/02/Deliverable-2.5-Monitoring-fish-communities.pdf

reporting to allow comparison among sites was developed in Deliverable 2.6.

Thanks to this last exercise and the experience acquired, different lessons were learnt for each environmental parameter. In the present Deliverable 2.7 we try to translate these lessons and experience into guidelines that could be of interest when consenting processes and environmental monitoring plans will be launched for installing wave energy device arrays or farms.

According to the experience and lessons learnt during the monitoring campaigns in the SafeWAVE project, one of the main conclusions of D2.7 is the need to promote monitoring techniques based on autonomous remote sensing devices that are not dependent, or are less dependent, of sea conditions and able to cover properly the temporal and spatial resolution of the expected environmental impacts coming from wave energy harnessing devices.

4. Objectives

The main goal of the SafeWAVE work package 2 is to collect, process, analyse, and share environmental data collected in sites where Wave Energy Converters (WEC) are operating in Portuguese, Spanish, and French coastal waters. The WECs installed represent different types of technology, including: a point absorber device (HiWave, by CorPower Ocean) installed at Aguçadoura (Portugal), a direct drive WEC (Peguin II, by Wello) installed in the Biscay Marine Energy Platform (BiMEP, at Armintza, Spain) and a hybrid autonomous energy recovery platform (WAVEGEM, by GEPS Techno) installed in the marine test site for wave energy recovery of the Centrlae Nantes (SEM-REV, at Le Croisic, France).

Such main goal was divided into seven operational objectives, with their respective tasks: (1) development of monitoring plans for acoustics (underwater noise), electromagnetic fields (EMF), seafloor integrity, and fish communities; (2) implementation of the monitoring plan for EMF; (3) implementation of the monitoring plan for acoustics; (4) implementation of the monitoring plan for seafloor integrity; (5) implementation of the monitoring plan for fish communities; (6) standardisation of data processing and reporting among test sites to allow comparison between them; and (7) translating into guidelines the **experience and lessons learnt** during the development and implementation of the common monitoring programmes.

Hence, the present report (Deliverable 2.7) aims to present the abovementioned guidelines. This information is considered relevant for consenting processes, and environmental monitoring plans to be implemented for installing WEC arrays or farms.

5. Lessons learnt

5.1 EMF monitoring

The information from EMF monitoring was limited as it was not possible to obtain data in two sites, due to delayed installation and short operational period of the HiWave-5 device in the Aguçadoura test site and the premature decommissioning of the Penguin II device in the BiMEP site early in the project.

Moreover, the WAVEGEM device at SEMREV was not connected to the grid. Nonetheless, the umbilical cable of a 2 MW floating turbine (FLOATGEN, by BW Ideol) installed in 2018 at SEM-REV, and connected to the grid, was monitored instead. The export cable was also partially monitored (Deliverable 2.2 – Imperadore *et al.*, 2023). Hence, one single 2-day survey was carried out at SEM-REV, following the monitoring plan described in Deliverable 2.1 (Vinagre *et al.*, 2021), with minor deviations. Eight transects perpendicular to the umbilical cable were carried out by RTSYS using a Comet-300 AUV, towing a Bartington GRAD-13 magnetic field gradiometer, 3 m above the seafloor.

The Comet-300 AUV can operate with rough sea states, although its deployment is limited by vessel constraints. As a result, the survey was carried out with a significant wave height lower than 1 m and the power production of FLOATGEN (37.5 kW) was far from the maximum rated power (2 MW) (Imperadore *et al.*, 2023).

In such conditions, the EMF values generated were four orders of magnitude below the geomagnetic field. However, knowing the cable geometry, phase current and frequency, and its burial depth, any condition outputting both magnetic and electric field can be modelled (Deliverable 2.6 – Le Bourhis *et al.*, 2024). The results of the modelling exercise should be validated, which could not be fully done with the data recorded at SEM-REV (Deliverable 3.1 – Imperadore *et al.*, 2024). Nevertheless, the already modelled data and the available field data are of the same order of magnitude which suggests that the EMF model is effective.

The survey undertaken in the SafeWAVE project partially considered the guidelines proposed by the WESE project (Bald *et al.*, 2021). However, the use of an AUV as a solution to overcome the limitations of the sea state conditions, aiming at acquiring EMF data in the highest range of power production, did not turn out to be totally valid, as similar restrictions applied to the deployment of the AUV. Nevertheless, the use of an AUV allowed towing the magnetic field gradiometer close enough to the umbilical cable and at a constant height above the seafloor to detect the EMF produced by the low electric current being transmitted by the cable.

In summary, the use of an AUV increases the quality of the data acquired, compared to a towed equipment, but does not fully overcome the sea state limitations, due to safety issues during the deployment. Hence, although the use of AUVs is recommended, this could be avoided in future if EMF measures are carried out on land and such measures can be used to model the EMF propagation in water. This could allow comparing the EMF measured in each case and evaluate their propagation (underwater and outside of water). This would be useful to determine if the EMF need to be measured underwater, which represents greater costs and is hampered by the lower sea states and, consequently, lower power and EMF in the subsea cables, required during the work offshore. Autonomous seafloor electromagnetic measurement stations, or AUVs with longer autonomy that could be deployed in adequate sea conditions or from land, respectively, could also be considered.

5.2 Acoustics monitoring

The acoustics monitoring surveys for SafeWAVE project were planned considering the guidelines suggested in WESE project (Bald *et al.*, 2021; Vinagre *et al.*, 2021; Madrid *et al.*, 2024).

Temporal monitoring using moored hydrophones was undertaken at all the sites (Aguçadoura, BiMEP, Mutriku, and SEM-REV). Pre-operational surveys were carried out to characterize the background sound at Aguçadoura and BiMEP, and operational surveys were carried out at all sites but not in Aguçadoura.

The hydrophones were deployed for a minimum of 40 days (except for the preoperational survey at Aguçadoura, which consisted of two 3-and 4-days surveys, due to an extreme wave event with waves reaching 16-18 m high), which meets the minimum resolution of 1-2 months suggested by Bald *et al.* (2021). With such a time scope, different sea states were covered (in terms of significant wave height).

The hydrophones were installed with the aim of monitoring the noise produced by the devices. However, noise coming from the moorings was also detected (Madrid *et al.*, 2024). Bald *et al.* (2021) concluded that hydrophones should be moored at less than 200 m from the noise source, but moorings should also be considered, and their effect should also be monitored and modelled since they are part of the WEC system.

For the preoperational phase, three hydrophones were deployed at Aguçadoura, whereas a single hydrophone was deployed at BiMEP. However, the background noise was adequately characterized at both sites, which permitted the comparison of the sound produced by the device and the mooring lines (which produced a detectable noise at least at BiMEP) to the background sound. On the contrary, the deployment of three hydrophones in the operational phase is recommended to consider the directivity of the device. Moreover, the deployment of several hydrophones is useful to assess the uncertainty of the measurements too.

Regarding the modelling of the noise propagation, it was found that the sampling period was not long enough to conclude about the potential impacts of the devices in terms of noise at Aguçadoura, and neither at Mutriku and SEM-REV, where even the hydrophones were deployed long enough, one of the hydrophones experienced a malfunctioning. To undertake a complete modelling, the sampling period must be long enough to capture information with the device operating at different sea states, and with the device both in operation and in stand-by. Therefore, the use of more hydrophones than the strictly needed should be considered to reduce the risk of obtaining an insufficient amount of data after such a long campaign.

With the data available, significant sound levels increases were identified only for the Penguin II device at BiMEP. Moreover, such increases were related to the presence of the devices disregarding its operational state (Madrid *et al.*, 2024).

Finally, although not considered for this project, mobile autonomous surveys could be considered for acoustic monitoring as a complement. This kind of surveys, which permit to take data at different sampling points and times, if adequately designed, could be useful to validate the underwater noise propagation maps modelled. The problem with this type of monitoring is that it requires very good sea conditions, conditions in which the WEC will be at its minimum activity and therefore noise emission.

5.3 Seafloor integrity monitoring

As it was explained in Deliverable 2.4 (Muxika et al., 2022) the seafloor integrity surveys were undertaken using two different techniques: (i) a side-scan sonar (SSS) mounted on an AUV and (ii) a visual inspection with ROVs.

Both techniques were applied at BiMEP and SEM-REV. However, as Penguin II was prematurely decommissioned, operational surveys could not be performed at BiMEP. Instead, post-operational surveys with SSS and ROV were conducted approximately 7-8 months after the device was removed from the area (the mooring lines remained). Similarly, at Aguçadoura, a ROV survey was carried out without the device, but with the export cable and the foundation still at the site, although problems with the tracking system prevented from finding them. At SEM-REV, operational surveys were carried out with both SSS and ROV, and post-operational surveys were conducted 6 months after partial decommissioning of WAVEGEM (the moorings remained until 4 months before the surveys; then, only anchors and bottom chains were left).

In contrast to WESE project, where the SSS was towed by a vessel and which derived in limited usefulness of the results due to the low quality of the data acquired (because of the 'less-than-ideal oceanographic conditions') (Bald *et al.*, 2021), the use of an AUV in SafeWAVE allowed a certain degree of independence from the sea state. Hence, the SSS survey allowed for a quantitative overview of the mooring lines and the footprints caused by their movements on the seafloor (in the operational survey performed at SEM-REV).

The ROV surveys completed the information provided by the SSS with an interpretation of the footprints being caused by the movement of the mooring lines and the local changes in sedimentation, which derived into sediment accumulation next to the mooring lines and the anchors. Moreover, the images allowed to observe marine organisms and to identify some degree of artificial reef effect.

However, one of the main limitations of the technique arose at SEM-REV: the high turbidity in the area during the surveys difficulted the operations, and the surveys could not be completed (Muxika *et al.*, 2022). Moreover, the positioning system failed at both Aguçadoura and BiMEP. Nevertheless, the objective of the survey was to monitor the physical impact of the moorings and since the SSS monitoring provided quantitative information, such failure during the ROV monitoring was not critical at BiMEP, where video recordings of the moorings were also available.

Following the guidelines suggested by Bald *et al.* (2021) a common monitoring protocol could be applied to the surveys at BiMEP and SEM-REV, as the devices installed at both sites were floating WECs with their respective mooring lines, contrary to the devices monitored in Portugal, where (i) in the WESE project it consisted of an oscillating bottom hinged WEC, mounted on a large concrete foundation, and (ii) in SafeWAVE it is of point-absorber type, with a heaving buoy on the surface and a foundation micropiled onto the seafloor. Hence, despite the differences in environmental conditions, the deviations from the initial plan were caused by: changes in the scheduling of the WECs (HiWave was installed before August 2023, and the unexpected decommissioning of Penguin II at BiMEP); and the high turbidity at SEM-REV, which derived in an incomplete survey.

Therefore, as visibility is a critical issue to image-based techniques (including sampling and samples processing and analysis), together with surface sea states (mainly wind and waves), the bottom sea conditions (bottom currents, turbidity, etc.) must be considered when performing a ROV survey. Image enhancement techniques are available, from simple processing techniques (e.g., histogram equalization or Retinex algorithm) to image formation model, which could improve the image quality. However, their usefulness is limited to clear waters (Shen *et al.*, 2021). Instead, although they have their own limitations, technologies based on signal light enhancement, such as range-gated imaging, laser synchronous scanning, streak tube imaging, polarization imaging, spectral imaging or ghost imaging (Shen *et al*., 2021), could be considered. As an example, range-gated imaging works emitting intermittent lasers and recording the reflected light after the time required by the laser to reach the focus distance, which can be set as a range of distances, and the reflected light to reach the sensor (Risholm *et al.*, 2018). This allows recording the objects located at the focus distance, ignoring the suspended particles found between the recording device and the objects of interest.

Finally, the results showed a negligible impact on seafloor morphology, as it was limited to less than 1% of the area devoted to the installation of the WECs. Although the impacts caused by arrays could not be assessed, it is presumed to be also negligible. Moreover, such impacts would probably be reverted in the short to medium term, depending on the local hydrodynamics. Regarding the biological effects, some degree of artificial reef effect was observed. However, that should be more thoroughly evaluated and quantified; thus, the monitoring plan should take that into consideration and include an adequate sampling design foreseeing control areas and, whenever possible, baseline surveys.

5.4 Fish communities monitoring

Fish communities were monitored at BiMEP to explore the association between WECs and fishing aggregations (Uriarte *et al.*, 2022). The monitoring was performed by a Wideband Autonomous Transceiver Mini echo-sounder integrated in an autonomous marine surface drone. This drone was a prototype still in development, thus limited by the need of good sea conditions and the need of a crew for the operation in a mid-autonomous way, but not fully autonomous.

As Penguin II was removed prior to the monitoring survey, the Harshlab 2.0 floating laboratory device (by Tecnalia) and DemoSATH floating wind turbine (by Saitec Offshore Technologies) installed also in BiMEP were inspected instead (dimensions similar to those of a WEC, similar mooring lines and anchors, etc.).

The surveys didn't show a significant aggregation effect over the fish communities. However, several issues should be pointed out:

- Even though the Harshlab 2.0 was similar to a WEC in terms of dimensions and anchoring system, it does not produce the underwater noise a WEC would produce, it does not generate the EMF that the umbilical cable of a WEC would produce, etc.;
- The surface drone was limited by the sea status requiring good sea conditions and be operated during daylight due to its prototype status;
- The artificial reef effect of the moorings was not considered, and the areas where the anchors lay were not inspected.
- The behaviour of ichthyofauna varies according to environmental factors that were not considered in the sampling strategy, such as: the time of day, the seasonality or the sea state. Only two surveys were carried out, at daylight and good metocean conditions.

In this regard, the use of fully autonomous surface vehicles may contribute to undertake surveys that last several hours without the need of a vessel and a crew with the capacity to work for 24 hours, being more cost-effective.

Also the installation of acoustic sensors similar to those of the autonomous surface vehicles and able to monitor during long time periods could be a promising methodology to overcome the above described limitations. These sensors could be installed in the WEC itself, such as the Simrad WBAT or Wideband Autonomous Transceiver sensor installed in the Harshlab, or be included in moored buoys near the devices.

6. Guidelines

Based on the lessons learnt, which have been described above, some guidelines will be presented in this section, which could be useful to develop environmental monitoring plans to be implemented for installing WEC arrays or farms. This information is considered relevant for consenting processes, and environmental monitoring plans to be implemented for installing WEC arrays or farms.

According to the experience and lessons learnt during the monitoring campaigns in the SafeWAVE project, one of the main conclusions is the need to promote monitoring techniques based on autonomous remote sensing devices that are not dependent, or are less dependent, of sea conditions and able to cover properly the temporal and spatial resolution of the expected environmental impacts coming from wave energy harnessing devices.

6.1 EMF

Regarding the EMF monitoring, as it can be modelled from the cable architecture, the characteristics of the cable current and the cable burial depth, the monitoring could be done on land, with regular surveys along the cable to check the burial depth and its effect on the EMF. These regular surveys would be carried out with the WECs producing, although at low production rates, due to the security and operational limitations of the sampling method. Additionally, offshore measurements can also be done using fixed stations. However, the effect of the EMF on marine organisms is still limited, and a precautionary stance should be taken.

6.2 Underwater acoustics

Regarding underwater acoustics, a baseline survey should be performed for the characterization of the submarine acoustic environment in the study area before the installation of the WEC or the array of WECs. Then, for the operational monitoring both the WECs and the mooring lines should be taken as sources of noise and that should be considered when defining the monitoring design. The hydrophones should be installed for a minimum of one month to gather information relative to the effect of different sea states, and to the effect of the device(s) both in operation and in stand-by. As there is no chance of knowing whether the data acquisition is correctly done until the hydrophones are recovered, it is recommended to install several hydrophones at each time. This will also allow to model the sound propagation, considering the hydrophones are installed at increasing distances from the sources. Additionally, the use of several hydrophones reduces the uncertainty of the simulations. On the other hand, the collection of additional data should be considered to validate the results provided by the models. Finally, the Marine Strategy Framework Directive considers some standards to assess the impact of noise, but such standards may be not enough at least to some cases. Hence, they should be complemented with other standards that consider metrics to assess the impact to different marine organisms. In this respect, models that are optimal for high frequencies should be considered.

6.3 Seafloor integrity

Monitoring of seafloor integrity can be undertaken using different methods. The combination of SSS and video techniques has been proven suitable. An extensive SSS monitoring should be performed, using an AUV if possible (to avoid undesirable artefacts of towing systems), to identify and locate the mooring elements. Then, if necessary, higher-resolution surveys could be carried out for a closer view of the elements identified and their footprints. Finally, a video survey should be undertaken to characterize the footprints of the mooring elements. Moreover, images could be used to assess the artificial reef effect, which could be done by comparing the presence and abundance of organisms between the moorings and control areas, applying appropriate methods. The use of ROVs is appropriate for video monitoring, as it is safe for operators (scuba diving is avoided) and suitable for high depths and longer surveys. However, the effect of bottom turbidity must be considered because of its effect over the quality of the images. Increased turbidity in the study area can be caused by high currents. Hence, knowing the time frames when high currents are expected is important to avoid conducting the monitoring surveys then. The use of technologies based on signal light enhancement could also be an option in areas where the high turbidity episodes are not temporary.

6.4 Fish communities

In general, the placement of any artefact in the sea can result in an attracting effect on fish communities, especially if it is floating. The diversity of techniques and methodologies used in the study of fish communities is wide so, sampling could be performed using traditional techniques (visual censuses, trawling, purse seine fishing, etc.), methods that include advanced technological developments (ROVs, UAVs, etc.) or a combination of both. The use of fully autonomous marine surface drones and/or sensors installed directly on the WECs of moored near the devise in moored buoys could be an excellent monitoring technique due to its capacity to work remotely and in near shore areas, to carry out trials continuously, both day and night, as well as different sea states. Thus, more objective assessment could be obtained, with a completer and more realistic outcome. This non-invasive fish monitoring method it is also safe for operators. Another advantage of marine drones is the capacity of these devices to interchange sensors or to house more than one sensor. These can be adapted and weighted according to the researcher's approach to the proposed study.

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