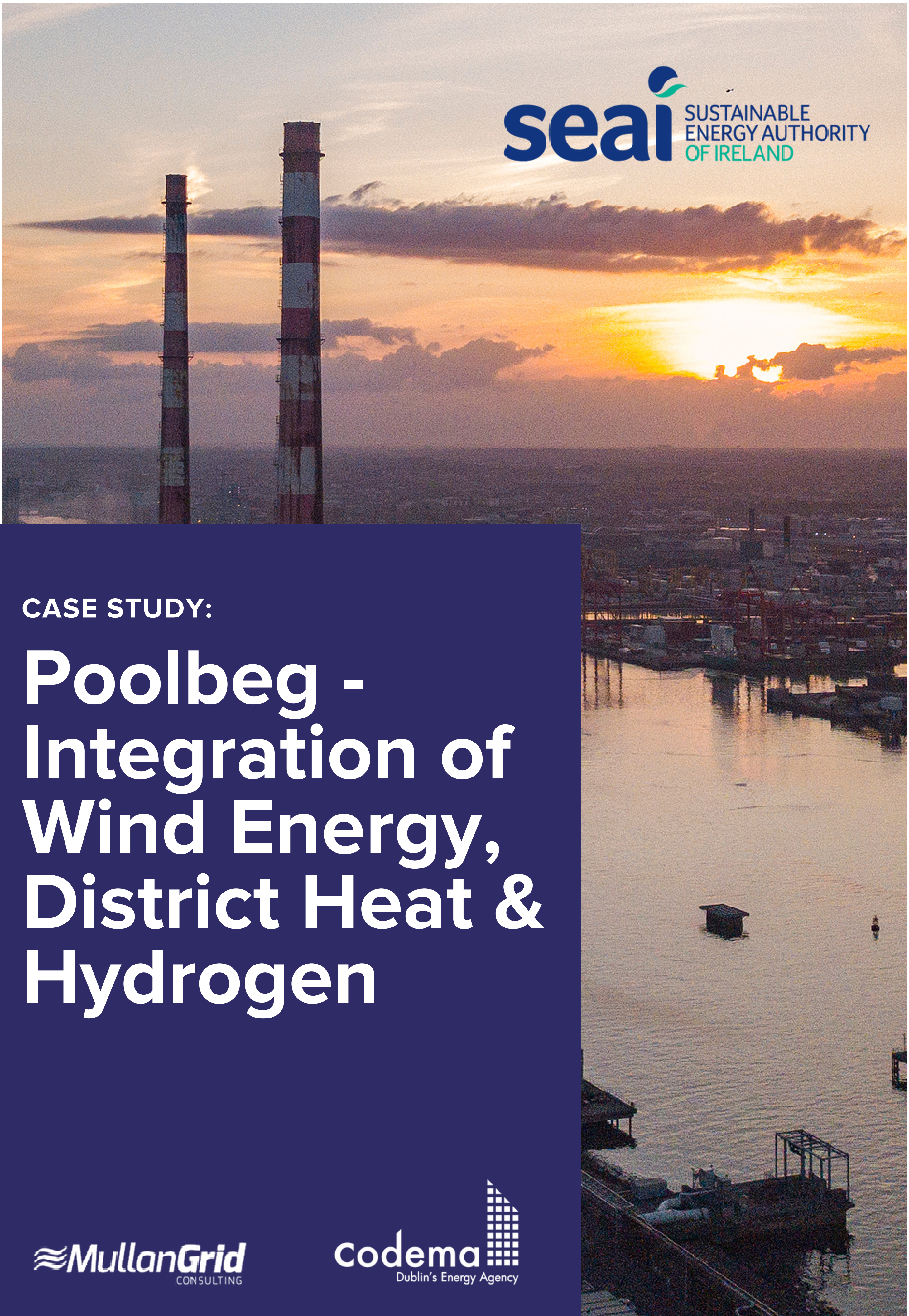

CASE STUDY:

Poolbeg - Integration of Wind Energy, District Heat & Hydrogen

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Project Goals

This report has been funded by the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2021, Grant number 21/RDD/719.

This project investigates energy system integration opportunities in Dublin, using the Poolbeg area as a case study. The project's key goal is to examine the potential for energy system benefits from linking separate energy sectors like electricity, heat and hydrogen together. Specifically, it considers how to make use of wasted (or curtailed) renewable electricity from offshore wind farms in the Poolbeg area of Dublin, while utilising existing and planned energy infrastructure in the area.

The energy sectors investigated in Poolbeg for integration opportunities are:

- Electricity Supply – there are times of surplus or wasted electricity supply, due to excess renewables. In Poolbeg, this is likely to be excess wind energy, for example on very windy days.

- Heat – the planned Dublin District Heating Scheme in the Poolbeg area will supply heating to buildings in the surrounding area and will have associated heat storage (large insulated hot water tanks). Excess electricity can be converted and stored as heat for use in the district heating scheme.

- Hydrogen – hydrogen is a key element of the EU's decarbonisation strategy, and will also be a part of Ireland's decarbonisation approach. Hydrogen is likely to be used in hard-to-decarbonise sectors such as dispatchable power generation, certain types of industry and heavier modes of transport. Poolbeg, as a likely location of available excess or wasted wind energy, offers potential for green (or renewable) hydrogen production using wind energy. This hydrogen could be used in the Dublin area for industry or transport needs.

The Poolbeg Peninsula is home to several large energy users, a national oil reserve, and major utility infrastructure including wastewater treatment, waste-to-energy electricity generation and fossil fuel electricity generation. There are plans for large, new offshore wind farms to connect into the electricity system in Poolbeg. Additionally, the area has also been proposed as a potential location for a hydrogen valley.

Energy system integration is a key EU and Irish strategy to support European and Irish trajectories towards net-zero greenhouse gas emissions by 2050.

Background

- Ireland's Climate Action Plan 2023 sets a roadmap to cut emissions by 51% by 2030 and reach net-zero by at least 2050 in Ireland.
- The electricity sector will continue to provide a leading role in the decarbonisation of Ireland's energy system. The Climate Action Plan 2023 aims to accelerate the build out of renewable generation with a target for 5 GW of offshore wind, plus 2 GW of offshore wind capacity for green hydrogen production, 8 GW of solar PV capacity and 9 GW of onshore wind capacity, to deliver an 80% share of renewable electricity by 2030.
- The built environment sector in Ireland is required to reduce emissions by 45 – 55% by 2030, with approximately 10% of heat demand in buildings targeted for conversion to district heating by 2030 (2.7 TWh). Ireland's transport sector has targets for 845,000 electric passenger cars, 95,000 commercial electric vehicles, 3,500 low-emission trucks and an expanded electrified rail network.

Research Approach

The key elements of the research approach used in this project are:

1. Literature review of electricity and curtailment, district heating and hydrogen in an Irish and European context.
2. Engagement with key stakeholders in the Poolbeg area.
3. Development of an integrated energy system model of the Poolbeg area with the following core elements:
   - Electricity system curtailment model
   - District heating and heat storage model
   - Green hydrogen production model
4. Future scenario analysis using this integrated energy system model and development of project insights.

Key Findings

1 Electricity

1. Ireland's electricity system is inefficient at times of high wind speeds and low electricity demand – excess wind energy can be wasted in these scenarios. Key factors that influence the levels of excess or wasted wind energy are:

- Amount of wind farms connected to the electricity grid (wind farm capacity).
- Electricity demand.
- International electricity export levels (interconnector capacity).
- Key electricity system operational constraints: 'min. gen' (footnote 1) and 'system non-synchronous penetration' (footnote 2).

2. The Dublin area is facing significant challenges to deliver the electricity network infrastructure. The electricity network operators in Ireland – ESB Networks and Eirgrid - are critical enablers of a net-zero pathway for Ireland. MaREI and SEAI have projected increases in electricity demand of 187-198%, compared to 2019, for a net-zero energy system. We will need to reach net-zero emissions, accounting for electricity demand growth, connection of offshore renewable generation and electrification in the heat and transport sectors.

3. Currently, the necessary infrastructure upgrades to accommodate the future electricity demand, additional renewable and flexible generation capacity are not yet understood for a net-zero emissions energy system. Further work is recommended for the wider energy sector to understand the scale and type of infrastructure required to achieve net-zero emissions.

4. MullanGrid modelling results project average wind and solar wasted energy (or curtailment) levels to be 6-23% for 2030-2035, and 14-16% for 2040.

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1. **Minimum generation requirements from conventional or traditional electricity generation plants such as fossil fuel plants, to maintain electricity system security of supply.**
2. **System Non-Synchronous Penetration – a measure of the maximum permitted real-time electricity generation that the electricity system can safely accommodate from variable renewables such as wind and solar at any one time while maintaining system security.**

Key Findings

5. There are no clear policy measures to address excess or wasted renewables on the electricity system for the key 2040 energy system planning time checkpoint. Limited modelling has taken place in Ireland to date for this time checkpoint.

6. The priority order of measures to reduce excess or wasted renewables has not yet been defined – this will be a key step in future planning. District heating with large-scale storage represents a highly cost-effective measure to reduce curtailment and should form part of this priority order of measures.

7. Long-term energy storage capacity is a key element of Ireland's future energy system to ensure energy security and resilience. For prolonged times of low wind or solar (variable renewable) output, there will be the need for back up (dispatchable) electricity generation fuelled by renewable energy.

8. The development of long-term storage capacity for renewable electricity could also help to reduce the reliance on imported fuel and in turn reduce energy price volatility, experienced in recent times in Ireland and most notably in 2022.

2 District Heat

1. District heat systems have the ability to reduce wasted renewable energy using heat storage. Different forms of heat storage can cover different storage durations from seconds to months. Large insulated hot water tank storage is the most common and covers response times from seconds to days.

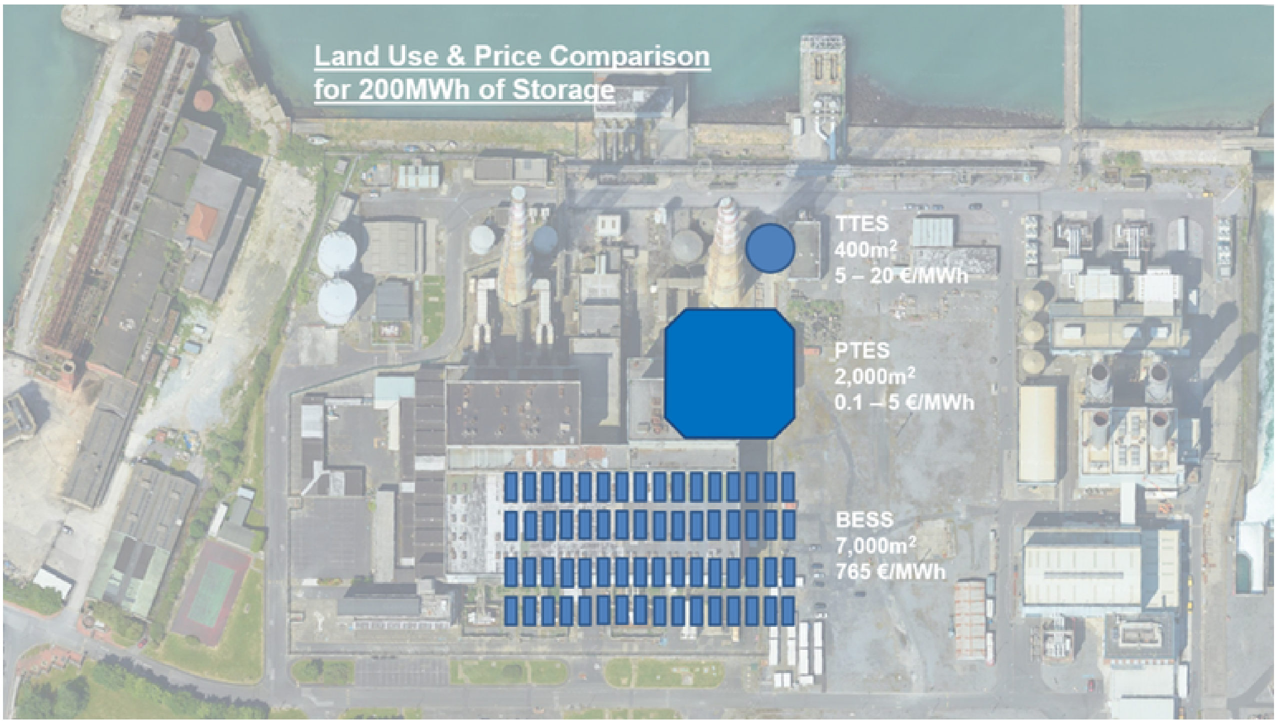
2. District heat (with heat storage) can potentially reduce wasted wind energy (curtailment) by up to 70-86% in 2030 if the national district heat target of 2.7 TWh was achieved.

3. Heat storage is significantly more cost and space efficient than battery energy storage. Analysis for the Dublin District Heating System shows that:

- Heat storage for the Dublin District Heating System is approximately 1% of the cost and uses less than 10% of the land area compared with battery storage of the same energy capacity.
- Heat storage has a lifespan which far exceeds battery storage with comparatively little degradation (heat storage greater than 50 years vs. battery storage 5 - 15 years).
- Electric boilers with heat storage represent the best option for the Dublin District Heating System assuming access to free or low-cost curtailed electricity.

Key Findings

Space requirement comparison between heat storage and battery energy storage



4. The Dublin District Heating System (DDHS) can offer important energy system integration benefits:
- Wasted (curtailed) electricity could supply 53.2% and 58% of heat demand in the DDHS by 2030 and 2040, respectively.
- The Dublin District Heating System could reduce national curtailment by 2.1% and 8.6% in 2030 and 2040, respectively.

5. District heating represents a more advanced curtailment mitigation option compared with hydrogen in the Poolbeg area. The Dublin District Heating System has begun the procurement process, with certain sections of the network already installed. Additionally, in a wider Dublin context, networks which are fully electric such as the Tallaght District Heating Scheme are already developed and operating.

6. Energy system integration opportunities exist between green hydrogen and district heating. Green hydrogen production can be a future heat source for district heat networks (using waste heat from the hydrogen production process). This can increase the overall efficiency of green hydrogen production (using electrolysers) from 60%-70% to up to 95% and potentially help reduce the cost of green hydrogen production.

Key Findings

3 Hydrogen

1. Hydrogen production configurations that qualify as 'green hydrogen' under the 'European Union Hydrogen Additionality Delegated Act' include:
   - 'Direct line' configuration – an electrolyser connection directly to a renewable electricity generator.
   - Electricity grid connected electrolyser for consumption of only wasted (curtailed) electricity – connected to the electricity network, not directly connected to a renewable generator.
   - Electricity grid connected electrolyser in a system with more than a 90% share of renewable electricity – connected to the electricity network, not directly connected to a renewable generator.
   - Electricity grid connected electrolyser with renewable electricity supplied under a power purchasing agreement with a renewable electricity generator subject to meeting 'temporal' and 'spatial' criteria - connected to the electricity network, not directly connected to a renewable generator.

2. There is currently a very small existing requirement for hydrogen in Ireland and a high degree of uncertainty on the future market for hydrogen in Ireland.

3. Additionally, end uses for hydrogen in Ireland are not yet fully understood or defined. Assessing the challenges to electrification will help inform the sectors where green hydrogen could be used. There may be additional potential applications for hydrogen in sectors that cannot be fully electrified.

4. Dublin could be a potential demand hub for green hydrogen in Ireland. Potential demands include back-up (dispatchable) electricity generation in times of low wind or solar energy, and the transport sector including heavy goods vehicles, and also in aviation and maritime sectors.

5. Ireland's National Hydrogen Strategy published in July 2023 sets out a number of actions to enable hydrogen to develop across the entire value chain and the end use sectors that hydrogen may be targeted towards.

Key Findings

6. Large scale hydrogen storage capacity will be critical to supporting future green hydrogen deployment in Ireland. Projects exploring this area are largely at a research stage, and the safety aspects, development costs and timelines are not yet fully understood.

7. The cost of electricity from offshore wind in Ireland needs to reduce in future for green hydrogen production in Ireland to be competitive with other countries.

8. Green hydrogen can substantially reduce wasted wind energy (curtailment) and simultaneously increase renewable energy levels in Ireland. However, the business model for hydrogen production using solely wasted (curtailed) wind energy appears to be expensive compared to other operating models that carry a high risk for developers, and is sensitive to a range of factors, including:

- Future electricity demand, future capacity of renewable electricity generation, electricity system technical limits, international export of electricity (interconnector capacity), and the rate at which new electricity network infrastructure is built.

9. There are also competing technologies for wasted electricity that can affect the business model including flexible electricity demands and district heat, among others.

10. Ultimately, a viable business model for green hydrogen production from wasted electricity depends on the electricity system being very inefficient in using future renewable electricity.

11. Modelling of various hydrogen production configurations for a 400 MW capacity electrolyser located at Poolbeg in a 2030-2040 timeline indicate a levelised cost of hydrogen production in the range of €3.8-7.1/kg.

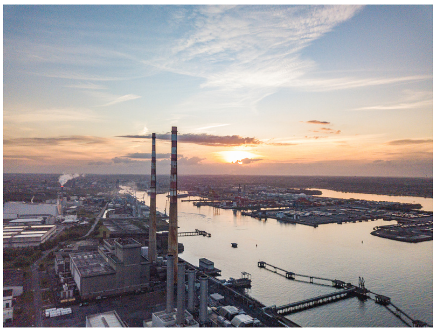
12. This analysis shows that Dublin-adjacent areas other than Poolbeg may be more favourable for locating hydrogen production. Locating hydrogen production facilities is complex, with many interplaying factors, including those outlined below:

- Hydrogen demand
- Land availability / land-use competition
- Availability of renewable energy
- Competing uses for renewable energy (growing electricity demand and competing uses for wasted / curtailed energy)
- Local electricity grid network constraints
- Hydrogen safety standards (currently in development from the National Standards Authority of Ireland).

Recommendations and Next Steps

1. A detailed, net-zero roadmap should be carried out by national government or its agencies, to understand the scale of energy system infrastructure and investment required to meet net-zero.

2. Establish a hierarchy of uses for excess / wasted renewable electricity and how this applies across different geographical areas of Ireland.



3. Further research into the opportunities for heat storage to reduce wasted renewable electricity. For example, analysis of the viable distance between heat sources using curtailed/waste electricity or waste heat from green hydrogen production and heat demand in a district heat network. This could provide further opportunities for district heating where offshore wind power comes ashore adjacent to urban settlements or towns.

4. Investigate the feasibility of developing large-scale hydrogen storage technologies both onshore and offshore in Ireland, including the East Coast of Ireland.

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