Assessment of Grid Connected Hydrogen Production Impacts

Executive Summary

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ERM

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Environmental Resources Management (ERM) prepared this report for the Environmental Defense Fund (EDF). The ideas and conclusions in this document are based on the research and guidance available prior to the December 2023 release of proposed guidance on the 45V hydrogen production tax credit and thus may not be complete. EDF and ERM do not endorse every idea and conclusion listed in this report but include herein to foster discussion around the flexibility of a three-pillar framework and advance the overall discussion.

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INTRODUCTION

The Inflation Reduction Act (IRA) Section 45V ("45V") established a new clean hydrogen production tax credit (PTC) that will pay an incentive per kilogram of clean hydrogen produced over the first 10 years of a facility's production. The IRA establishes different incentive tiers dependent on a facility's lifecycle greenhouse gas (GHG) emissions rate and directs the United States (U.S.) Secretary of the Treasury ("Treasury") to issue implementing guidance for determining lifecycle GHG emissions.

Three crucial pillars for assessing the GHG emissions of electricity supply for hydrogen production and its lifecycle GHG accounting are incrementality (or additionality), temporality, and deliverability. Extensive industry discussion since the IRA's passage has focused on these three pillars due to the wide implications for electricity required in the hydrogen production process. Some stakeholders argue for stronger requirements to prevent a higher level of emissions from hydrogen production growth under the 45V PTC and to ensure these value chains continue to be robust and grow beyond the term of the tax credits. Other stakeholders assert that strict regulations may increase costs and limit hydrogen deployment and the development of a hydrogen industry.

This Executive Summary summarizes the key findings from a two-part report. Sections 1 and 2 distill key messages from Part I of the report, a literature review across approximately 30 studies and published works. Sections 3 through 5 summarize Part II, which further explores and discusses implementation guidance on hydrogen lifecycle GHG accounting.

The two-part report finds that a three-pillar framework will provide protection against emissions increases while enabling sustainable long-term industry growth. Further, it will build confidence and public support for hydrogen deployment while setting an important precedent for future policies and market harmonization efforts.

In December 2023, Treasury released its proposed guidance for the 45V Production Tax Credit; at the time of this report's publication Treasury has not released final guidance. Where appropriate, this report comments on the connections between the proposed guidance and the three-pillar framework.

Visit ERM's website to read the full two-part report: https://www.erm.com/assessment-of-grid-connected-hydrogen-production-impacts.

1. THE THREE PILLAR FRAMEWORK

Part I begins by laying out the three pillar framework and reviewing relevant literature as it pertains to each pillar.

1.1 INCREMENTALITY

Incrementality (also sometimes referred to as additionality) emphasizes that new low-carbon energy sources are needed to meet incremental new hydrogen demand to avoid a net increase in grid emissions. For example, if existing renewable generation is diverted to meet the growing hydrogen demand, fossil fuel power plants could be required to increase generation to balance the grid, increasing net grid emissions. This outcome could be avoided through additional new low-carbon generation paired with temporality.

There is consensus across the literature that incrementality or additionality requirements are essential to avoiding a net increase in emissions from the deployment of low-carbon grid-connected hydrogen production. Some even define incrementality as the bedrock principal of the three pillars, as without incrementality requirements and new low-carbon generation added to the grid, the temporality and deliverability pillars themselves alone would not avoid increased emissions.[1] The proposed guidelines define a new resource in this context as an electricity supply resource which comes online within 36 months prior to the hydrogen producer, which aligns with the European Union's (EU's) definition. However, Treasury is evaluating alternative approaches which demonstrate a reduced risk of increased grid emissions and could enable some level of existing generation to qualify. Example circumstances could include avoided plant retirements, curtailed generation, impacts of state policies, or consideration of local grid mix or intensity.

1.2 TEMPORALITY

Temporality relates to the granularity in the time periods used to determine the alignment of electricity usage and its associated emissions with that of hydrogen production. For example, it addresses whether an electrolyzer can claim zero carbon procurement by purchasing solar electricity over a year equal to its total annual load, or whether intensity should be based on the source of electricity for each hour of production. Levels of temporal granularity discussed in the literature are annual, monthly, and hourly, each with different accounting implications that may impact project development and production costs.

The literature reaches varying conclusions on the emissions impact of annual versus monthly versus hourly time matching based on the different regions, scenarios, and methodologies used in the assessments. Some reports suggest there is a connection between incrementality and temporality when considering the emissions impact of time matching requirements. For example, in regions analyzed in some of the literature reviewed, when there are lax or no incrementality requirements, annual matching is found to significantly increase net grid emissions. A key consideration across the reviewed literature is the methodologies used for analysis, including whether the emissions are calculated on a marginal or absolute basis. The latter serves as a more

[1] Energy Innovation Policy & Technology LLC. 2023. "Smart Design of 45V Hydrogen Production Tax Credit Will Reduce Emissions and Grow the Industry." April 2023. https://energyinnovation.org/publication/smart-design-of-45v-hydrogen-production-tax-credit-will-reduce-emissions-and-grow-the-industry/.

direct application of book-and-claim or market-based emissions accounting similar to the methodologies used in GHG Protocol Scope 2 accounting.

While there are regions and supply combinations which may be advantageous for hourly matching due to the economic value of excess generation, several studies suggest that hourly matching will place upward pressure on costs. Cost estimates range considerably due to differences in model methodologies and assumptions, such as the ability to optimize utilization rates by oversizing renewables and incorporating sales of excess renewable electricity, as well as assumptions around renewable generation profiles and capital costs. The impact of phasing in hourly matching on project viability will likely depend on reductions in hydrogen capital costs.

A key question around the adoption of strict temporality requirements (e.g., hourly time matching) is data availability. In documentation surrounding the draft 45V rule, the U.S. Department of Energy (DOE) indicated that hourly matching is necessary to address indirect emissions from electricity use and notes proper tracking systems and hourly contracts will take time to develop.[2] There is currently no national platform for hourly tracking of energy attribute certificates (EACs) in the U.S; however, entities working to enable and expand hourly tracking, such as the Midwest Renewable Energy Tracking System (M-RETS) and EnergyTag, estimate that building a national system is feasible within about 12 to 18 months.[3] They also note that scaling the tracking system will be far less complex and lengthy than the process of building out large-scale electrolyzers, particularly since the source data for issuing certificates is hourly generation. The draft rule’s proposed timeline for moving from annual to hourly matching is 1 January 2028.

1.3 DELIVERABILITY

Deliverability refers to which geographic boundaries should be used to ensure low-carbon energy is generated in a location that is connected to hydrogen production through the electrical grid. Deliverability of low-carbon electricity to the electrolyzer is another consideration where the literature suggests varying recommendations. Where geographic boundaries are large, there are potential transmission connectivity issues to enabling delivery of low-carbon electricity to hydrogen production facilities; conversely, if geographic boundaries are small, this electricity delivery can be inefficient or infeasible. The challenge is in finding a compromise that can accommodate the diversity of U.S. grid boundaries.

Grid boundaries within the U.S. are not clearly or uniformly defined, particularly in the context of energy attributes. While there was consensus in the literature that low-carbon electricity sources and hydrogen production facilities should be connected to the same grid, different options were posited to define the boundaries of a contiguous grid region. Potential boundaries already leveraged by industry include the North American Electric Reliability (NERC) subregions, NERC assessment areas, eGRID subregions, and balancing authorities. Specific to Independent System Operators (ISOs), these options can also expand or be defined as the entire ISO, an ISO

[2] DOE (U.S. Department of Energy). 2023. “Assessing Lifecycle Greenhouse Gas Emissions Associated with Electricity Use for the Section 45V Clean Hydrogen Production Tax Credit.” December 2023. https://www.energy.gov/sites/default/files/2023-12/Assessing_Lifecycle_Greenhouse_Gas_Emissions_Associated_with_Electricity_Use_for_the_Section_45V_Clean_Hydrogen_Production_Tax_Credit.pdf.

[3] RMI (Rocky Mountain Institute). 2022. “RE: Notice 2022-58 Request for Comments on Credits for Clean Hydrogen and Clean Fuel Production.” December 2022. https://www.regulations.gov/comment/IRS-2022-0029-0111.

subregion determined by notable transmission constraints, or wholesale pricing zones. The deliverability requirement outlined in the proposed guidance references the boundaries defined by the DOE's National Transmission Needs Study[4] but also specify that a facility's deliverability region, defined as the location of both its hydrogen production and electricity generation, is based on the balancing authority to which it is connected.[5] The Transmission Needs Study regions leverage the market boundaries defined by the ISOs while acknowledging transmission constraints. The U.S. Environmental Protection Agency's (EPA's) eGrid sub-regions are a notable viable alternative to ISOs, as they are designed to reflect limitations on transmission exchanges between regions. Proposed guidance is not specific about whether and how transfers between neighboring grids might be allowable. Treasury could consult with Green-e®, as their approach to evaluating transfers between regions could be provide flexibility in demonstrating deliverability between eGRID or Transmission Needs Study regions.

2. CROSS-PILLAR IMPLEMENTATION CONSIDERATIONS

Part I concludes by identifying implementation elements emerging from the literature that will likely impact multiple pillars and are assessed further in the second part of this report. These include:

- Recognition of the differences and therefore inequities in market structures, operations, and generation resources between ISO and non-ISO regions which could impact ease of accessing and verifying sufficient cost-effective electricity supply;
- Transmission constraints that could create a time lag for access to new renewable energy;
- Data availability and management capabilities for electricity supply to ensure electricity for hydrogen production is low-carbon; and
- Broader impacts to incentivizing optimal system solutions and the long-term economic viability of established value chains post the hydrogen tax credit subsidy period.

Treasury should consider how these additional elements could require agency support, impact phasing considerations, or justify proposed alternatives to ensure implementation and sufficient access to the 45V credits to enable clean hydrogen development while maintaining the IRA's integrity.

3. REGIONAL FACTORS INFLUENCING HYDROGEN DEVELOPMENT

Part II begins by exploring how regions within the U.S. have varying resource quality and opportunity to develop low- and zero-carbon power generation to support electrolysis production. Regions with high-quality wind and solar, particularly those which can leverage the effect of combining those resources to better align clean electricity supply to hydrogen production demand, are likely primary candidates for early development of electrolysis. Regional demand strength will also determine early uptake regions for establishing electrolytic hydrogen markets. While these

[4] DOE (U.S. Department of Energy). 2023. "National Transmission Needs Study." October 2023. https://www.energy.gov/sites/default/files/2023-12/National%20Transmission%20Needs%20Study%20-%20Final_2023.12.1.pdf.

[5] Treasury proposed guidance makes one exception for the Midcontinent Independent System Operator balancing authority given that it is split into two regions.

regional differences in resources, market structures, and demand present challenges to uniform development of hydrogen value chains, effective well-designed hydrogen tax credit guidance from Treasury can enable optimal regional solutions across all hydrogen pathways. Appropriate incentives promote robust regional value chains that are more likely to endure past the expiration of the 45V tax credit. Although certain regions may not be conducive environments for early adoption of electrolysis, these regions may leverage alternative resources for low-carbon hydrogen production through other pathways, and electrolysis may become more feasible in the future once capital costs decline and the market is further established.

4. IMPLEMENTATION CONSIDERATIONS

Part II continues by exploring how regional context and three pillars considerations introduced in Part I impact implementation of the 45V tax credit. Some implementation considerations directly impact specific pillars, others impact multiple pillars, and still others are unrelated to the pillars but will require additional guidance or clarity from Treasury. The primary pillar or pillars impacted by the implementation considerations are indicated in parentheses below.

4.1 GLOBAL VALUE CHAINS (ALL PILLARS)

Global value chains will require sufficient alignment on classification and eligibility requirements across national and regional standards for hydrogen produced from zero- and low-emission technologies. Near-term export demand is an additional opportunity to support hydrogen production while domestic value chains are still in the early stages of development. A strong three pillars framework would be more conducive to international hydrogen trade.

4.2 CERTIFICATES (DELIVERABILITY, OTHER NON-PILLAR CONSIDERATIONS)

Demonstrating compliance with the three pillars (or any other form of book-and-claim emissions accounting) will require the use of certificates. Proposed guidance from Treasury affirms the importance of certificates and requires the use and retirement of certificates to represent generation that meets incrementality, temporality, and deliverability requirements, whether they be bundled or unbundled. This report focuses on two main considerations: *sustainability criteria* and mechanisms to avoid *double counting*.

- **Sustainability criteria**. In the U.S., certificate issuance and tracking are driven by state compliance programs and requirements, including generation eligibility criteria such as sustainability requirements for biomass and hydro. This structure extends to the voluntary market. While the core mechanics are consistent, efforts will need to be made to establish overarching guidelines and/or a unified registry system, including ways to address attributes associated with fossil-based generation with carbon capture and storage, biogenic pathways, and fugitive methane.
- **Double counting**. The risk of two entities making a claim on the same volume arises due to various state-specific compliance programs and regulations, including renewable portfolio standards (RPS). Three primary risk areas are disaggregation of attributes, allocation of emission reduction benefits, and application or designation of generation towards RPS, which will be dependent upon the specific language of each standard. Treasury should provide additional clarity to address if and how the requirements may deviate from the GHG Protocol

approach to double counting claim rights in the context of compliance programs such as RPS or carbon programs.

4.3 MARKET STRUCTURE AND SUPPLY OPTIONS (ALL PILLARS)

Market regulatory structures greatly impact the commercial electricity supply options available for end-users which can meet both volume and framework requirements. The stronger the requirements in the 45V framework, the more impactful the regulatory and electricity market structures will be on the availability and ease of transacting supply options which meet the criteria.

- The primary consideration is the existence of a competitive wholesale market that can enable financial power purchase agreements (PPAs). An even wider range of commercial options, including physical PPAs, are available in regions with fully competitive retail markets. Additionally, wholesale market regions tend to have existing systems for certificate tracking and curtailment data collection. Finally, compared to vertically integrated regions, market environments affect power plant economics and retirement decisions differently in ways that may impact tax credit eligibility.
- In regions with neither competitive wholesale nor retail markets, electricity supply options and power plant additions and retirements are determined more by local utility offerings. While many utilities are increasing options for customers to secure access to renewable electricity supplies, such as voluntary tariff programs, these vary in quantity, access, and structure, and currently may or may not be sufficient to meet the needs of hydrogen producers. This will likely evolve as utilities strive to participate in the hydrogen value chain, including as potential fuel buyers. Treasury guidance can help advance continued progress on structured customer offerings to meet evolving needs.

4.4 EMISSIONS CALCULATIONS AND APPLICATION OF TAX CREDIT TIERS (TEMPORALITY)

Emissions calculations are directly dependent upon the temporality of the data sources used to determine alignment of electricity usage and associated emissions with that of hydrogen production. The proposed guidance is not definitive on the methodology for determining the weighted average emissions intensity of electricity (e.g., where and when marginal emissions may be used). Several key issues warrant consideration:

- A Scope 2 attribute-based approach (i.e., one based on absolute emissions) is more consistent with specific end-user accountability for electricity procurement and more manageable regarding data management and validation than a marginal emissions approach. Treasury should consider ensuring that the GREET 45VH2 model allows for user inputs that reflect a Scope 2 attribute-based approach.
- There are options for retaining the integrity of a strong temporality requirement while providing a degree of operational flexibility, such as allowing a small buffer volume which could be met with unbundled attribute credits that do not meet the three pillars.
- Providing special allowances to legacy facilities (a.k.a., “grandfathering”) would prolong the emissions impact introduced from a temporarily lax temporality requirement, as generation from such facilities would lock in higher emissions impacts from early hydrogen producers for a longer duration.

4.5 EXPANDED OPTIONS FOR INCREMENTALITY ELIGIBILITY

The incrementality pillar – the expectation that new low-carbon energy satisfies new hydrogen demand – has various interpretations depending on the context. In the case of 45V framework guidance, and in this report, it is defined more broadly than in other contexts such as RPS. Here incrementality is defined as new generation proximate in time to the hydrogen production (e.g., operational start date within 36 months), as well as generation which would otherwise not have existed but was enabled by demand from hydrogen production, such as capacity under threat of retirement or curtailed generation. This latter category has the same net impact as adding new generation to meet incremental new hydrogen demand and avoid increased grid emissions. However, any such provisions must be narrow, targeted and/or beneficial from a net emissions perspective. Several key implementation considerations warrant consideration:

- Nearly half of existing U.S. nuclear capacity is scheduled for license expiration by 2030. Access to hydrogen-based demand could open access to new markets to provide financial support and justification to avoid early retirements and/or extend operations for those at risk. Existing programs can provide frameworks for demonstration of need.
- The incrementality impact of additional new clean generating resources stands to diminish once the grid reaches sufficiently high levels of decarbonization, which is why the European Union (EU) has included exceptions for areas with high renewable penetration rates (e.g., >90 percent). Given the range of resource quality, few regions in the U.S. are likely to achieve the same levels of renewable penetration in the near future; however, emissions intensity thresholds that also account for the impact of nuclear generation have greater potential to be reached.
- Well-designed state or regional emission cap programs can limit potential consequential emissions growth from hydrogen production, but this is dependent upon the integrity of program design, including how potential leakage concerns are addressed.
- Curtailment volumes in the U.S. are more likely to be meaningful in the long term when electrolyzer costs decrease sufficiently to become economic operating at lower utilization factors, and therefore have spare capacity to take advantage of hours with surplus generation. Validation of these volumes will be challenging outside of grid-mandated hourly signals. Due to the real-time nature of curtailment, it is also best suited to be paired with hourly temporal matching, which also becomes a market signal on which type of supply and grid solutions are most beneficial to optimize the system and investments.

4.6 DEMONSTRATION OF DELIVERABILITY

The deliverability pillar is important to ensuring electricity supply and hydrogen production demand are physically connected via the electrical grid. Transmission constraints limit generation flow. This has a compounding effect on the ability for clean generation to supply hydrogen production the farther the designated electricity supply is physically on the grid from the hydrogen production. Constraints are the primary justification for a deliverability requirement and how the deliverability boundaries are defined to meet the objective of the pillar. Perhaps in light of this fact, Treasury’s proposed guidance adopts the geographic regions used in the U.S. Department of Energy’s (DOE's) *National Transmission Needs Study*. In this area, several implementation considerations warrant consideration:

- Investment in grid infrastructure (including transmission build out) is required to address existing constraints and support renewables growth to meet increased demand from decarbonization efforts including hydrogen production as highlighted by the National Transmission Needs Study. As transmission builds out and constraints are sufficiently resolved, deliverability regions should be periodically assessed to determine if these regions can be expanded.

- Electricity may be transmitted or "wheeled" between different regions. One example of satisfying the deliverability requirement is to permit wheeling of electricity along with attributes between regions, which could be demonstrated through transmission capacity rights. The relationship between the grid market prices at the generation source and hydrogen production could be considered as a modeling methodology or proxy.

5. ASSESSMENT OF A STRONG PILLARS-BASED FRAMEWORK

Part II of the report concludes with an example design of a strong pillars-based framework (many of which are reflected in the proposed guidance from Treasury), and assesses it against the key principles enumerated in Part II.

In this assessment, what emerges is how the various elements reinforce and enhance the efficacy of each other. Most notably, incrementality underpins temporality and deliverability. Without incrementality measures, temporality and deliverability measures alone would be challenged to safeguard against emission increases. In the case of no incrementality combined with lax temporality or deliverability requirements, electrolysis production would likely lead to notable net increases in grid emissions, contravening the spirit of the IRA. This speaks to synergy within the framework and the necessity of all three pillars supporting each other.

Example Strong Pillars-Based Framework (underlined elements represent new ideas presented in this report while the rest represent elements in Treasury proposed guidance)

1. **Incrementality:** Clean energy source placed in service no more than 36 months before the electrolyzer claiming the generated clean electricity
   - Can include direct connection, PPAs or equivalent utility program, or hourly matched energy attribute certificates (EACs) from generators that meet the same requirements
   - Can apply the 80/20 rule for renewable facility repowering
   - Can include uprates and resources that would otherwise be curtailed
   - Consider including resources that would otherwise be retired (e.g., nuclear) subject to demonstrated need beyond existing subsidies
   - Consider exceptions for deliverability regions with high renewables penetration (e.g., >90 percent), low grid carbon intensity, and/or states with emissions caps
2. **Temporality**: Clean electricity supply matched on an hourly basis by 2028
   - No legacy (a.k.a. grandfathering) of facilities
   - Consider potential buffer approaches to provide reasonable operational flexibility (e.g., small buffer volume for non-hourly-aligned, unbundled certificates)
3. **Deliverability**: Clean energy source procured from same region as defined by either eGRID boundaries or the *National Transmission Needs Study*
   - Ability to wheel from adjacent regions (e.g., based on transmission capacity rights or LMP differential)
   - Consider periodic updates to boundaries to reflect changing transmission constraints
4. **Calculation Methodology:** The calculation methodology should be Scope 2 attribute-based with electricity supply volumes accounting for transmission / distribution system losses

5.1 INCREMENTALITY ASSESSMENT

Strong incrementality requirements carry the opportunity for increased and efficient development and deployment of renewables within the grid and support continued grid decarbonization, including incentives for transmission solutions. This is a strong positive externality which connects the development of resource capacity and deployment of low-carbon generation sources with the deployment of low-carbon hydrogen, tying together establishment of the low-carbon hydrogen economy with the increased penetration of renewables in the grid.

5.2 TEMPORALITY ASSESSMENT

Strong temporality requirements in the form of hourly matching, paired with incrementality, create demand support for optimal grid solutions and system-wide investments, including efficient deployment of energy generation tax credits and further development of flexible electrolysis technologies. This includes other forms of grid management solutions by highlighting periods of low renewable generation as well as periods of high renewable generation, which can encourage more efficient use of curtailment volumes.

There has been much discussion on the potential cost impacts of a strong temporality requirement, specifically hourly matching, with varying views on the magnitude of this impact. The actual net cost effect will be dependent upon a variety of factors which become very location-specific and even project-specific, but which may be balanced by reduced market exposure through higher alignment of supply and demand. While commercial options for procuring high hourly matched electricity supply may be more prevalent for those located in competitive markets versus regulated markets, utilities are continually expanding their green tariff offerings. Temporality may be an opportunity to structure supply options which better meet the emissions tracking and reporting needs of end-users beyond hydrogen. This demand signal will indirectly support the continued evolution of the use and application of market-based mechanisms in the electricity market and robust emissions accounting through improved data management, including development of centralized certificate tracking and residual emissions reference resources.

5.3 DELIVERABILITY ASSESSMENT

By requiring low-carbon electricity for electrolysis production be both local and matched, deliverability and temporality drive the focus on leveraging local resources for the establishment of regional low-carbon hydrogen economies. This supports the DOE's goals for a hydrogen strategy, which underscores the development of regional networks of low-carbon hydrogen production. It also presents the opportunity to advance a diverse set of decarbonization solutions, as each region will develop and deploy a specialized toolkit tailored to the region’s specific available resource, whether that be high-quality low-carbon generation or abundant gas and sequestration.

5.4 VALUE CHAIN IMPACT ASSESSMENT

With strong requirements for all three pillars, there will be no need to transition from an initial state of non-optimized emissions reductions to a truly low-carbon hydrogen economy. Some of the challenges that come with a strong three pillar framework can be mitigated or managed in the short term with expanded eligibility and flexibility options, while others present the opportunity and incentive to support longer term goals. This diversity can be an opportunity to drive efficiency through leveraging local resources to enable and support the development of a range of hydrogen pathways, while setting precedent which enables broader progress across the energy sector and promotes efficient investment. By taking advantage of regional factors, the framework could facilitate the foundation of robust value chains which endure past the expiration of the tax credit.

Strong requirements will also support global value chains. The Group of 20 (G20) New Delhi Leaders' Declaration from September 2023 laid out voluntary principles for sustainable hydrogen value chains. In particular, the declaration clarified the mutual ambition for a globally harmonized approach to classification requirements for hydrogen produced from zero and low-emission technologies. This ambition is most relevant as it pertains to aligning with or exceeding international market requirements such as those in the EU. Strong 45V framework guidance will fulfill this ambition for a transparent global approach, mitigate the perception of green-washing, and position U.S. hydrogen producers and end-users for success in global value chains.

Furthermore, the guidelines for 45V will provide guidance and a precedent which future tax credits, policies, or regulations may reference. In this manner, the 45V production tax credit (PTC) could be expected to continue to influence future hydrogen-related decarbonization initiatives, as well as other regulations relating to low-carbon grid-connect production, even after the expiry of the tax credit itself. 45V guidance represents an opportunity to set a strong precedent and establish principles that will influence future measures.

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