



CLEAN ENERGY  
ACCOUNTING  
PROJECT

# ACCOUNTING FOR UTILITY- SCALE CLEAN ENERGY STORAGE

Background Report | October 2026

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# 1. Executive Summary

Utility-scale electricity storage is expanding rapidly and is becoming integral to grid operations, renewable energy integration, and corporate decarbonization strategies. Storage enables the time-shifting of electricity supply, enhances the operational value of variable renewable generation, and supports system reliability by providing energy, capacity, and ancillary services. At the same time, the increasing deployment and diversified use of storage introduces significant challenges for clean electricity and emissions accounting. Storage decouples the timing of generation, consumption, and delivery; introduces conversion and auxiliary losses; and is frequently operated under complex, co-optimized dispatch regimes that are not fully addressed by existing attribute-tracking or emissions reporting frameworks.

Without clear and consistent accounting rules, storage can be treated in ways that unintentionally undermine the integrity of clean energy claims.

Potential risks to the integrity of accounting and retail use claims include:

- **Attribute multiplication**, in which the quantity of clean electricity claimed at discharge exceeds the quantity supported by clean inputs at charge;
- **Temporal misrepresentation**, in which clean generation at one time is implied to support use at another without defined rules for time shifting and vintage;
- **Double counting** across systems with distinct accounting logics; and
- **Conflation of claim types**, particularly when distinctions between market-based attributional accounting and consequential accounting methods are blurred.

This background report provides a baseline overview of existing and emerging methods used to account for renewable electricity and associated emissions when energy is stored and later discharged from utility-scale storage systems. Its purpose is to establish a shared factual and conceptual foundation to inform deliberations by CRS's Clean Energy Accounting Project (CEAP) Working Group on Accounting for Utility-Scale Clean Energy Storage as it considers the development of corresponding accounting guidance for stored clean energy.

Following an introduction in section 2, section 3 presents a taxonomy of approaches for accounting for stand-alone energy storage systems. This taxonomy is designed to facilitate clearer comparison among methods that differ in purpose, evidentiary basis, and treatment of attributes and emissions. It employs analogies to common grid elements—Storage-as-Generation, Storage-as-Load, Storage-as-Transmission—to highlight how each accounting approach treats attributes of renewable generation from input, through storage, to output.<sup>1</sup>

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1. These terms are meant to describe the point at which the approach generally retires, credits, or otherwise accounts for the attributes of the stored energy and not how an individual storage asset may be deployed or operated in competitive wholesale or retail markets.

**Table 1: Categorization of Accounting Approaches Using Proposed Taxonomy**

| Storage-as-Generation                                                                    | Storage-as-Transmission                                                                                                                                                                                 | Storage-as-Load                                                                                                                                                                                                                          |
|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <ul style="list-style-type: none"><li>Massachusetts Clean Peak Energy Standard</li></ul> | <ul style="list-style-type: none"><li>European Emissions Certificate System (ECS)</li><li>EnergyTag / Quintrace</li><li>Washington Clean Fuels Standard</li><li>MISO / Singularity CarbonFlow</li></ul> | <ul style="list-style-type: none"><li>GHG Protocol Scope 2 Guidance</li><li>GHG Management Institute / EPRI guidance</li><li>CAISO Accounting &amp; Reporting (A&amp;R) Framework</li><li>SPP Markets+ GHG Reporting Framework</li></ul> |

After presenting the taxonomy, Section 4 applies it to summarize the principal accounting approaches developed or applied since 2015, including both voluntary and compliance-oriented frameworks, with attention to how each addresses attribute conveyance, loss allocation, ownership and control, and risks to exclusivity.

Section 5 reviews accounting approaches for clean energy from co-located and directly connected utility-scale storage facilities, highlighting how existing compliance and disclosure regimes address storage that is physically integrated with renewable generation.

Section 6 concludes by summarizing the preceding analysis and outlining the analytical task before the Working Group. This report is intended to support informed, constructive deliberation by ensuring that members approach the development of storage accounting guidance from a common understanding of existing practices, limitations, and open questions.

## 2. Introduction

Recent technological developments making utility-scale energy storage more efficient and cost effective, combined with increased reliance on variable renewable generation resources have upended traditional power markets.<sup>2</sup> As a result, utility-scale energy storage is being deployed at a record pace. By the end of the 3<sup>rd</sup> quarter of 2025 (Q3), the U.S. had added more than 10 Gigawatts (GW) of new utility-scale energy storage capacity, more than the entire capacity installed in all of 2024. In Q3 2025 alone, the U.S. installed over 5.3 GW of storage, an

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2. International Energy Agency (IEA). 2021. *Secure Energy Transitions in the Power Sector*. Published April 12, 2021. Paris: IEA. <https://www.iea.org/reports/secure-energy-transitions-in-the-power-sector> (accessed July 22, 2026).

increase of 31% over Q3 2024.<sup>3</sup> Globally, the figures are even more impressive with projections showing 100 GW of new utility-scale capacity additions in 2025 alone, a nearly 40% increase compared to 2024.<sup>4</sup>

This rapid expansion of utility-scale storage, combined with increasing penetration of variable renewable generation, creates the operational possibility of time-shifting renewable supply and reshaping supply profiles to more closely meet demand. At the same time, storage introduces new accounting and market integrity issues; it complicates allocation of renewable attributes, creates opportunities for double counting, and can undermine the credibility of emissions inventories and emissions reduction claims, if treated inconsistently across systems.

CEAP's Accounting for Utility-scale Clean Energy Storage Working Group is tasked with helping to develop credible, stakeholder-reviewed and consensus-based accounting methods for clean energy attributes associated with utility-scale storage, while preventing double counting, accounting for losses and mixed inputs, clarifying the use of market-based instruments (e.g., Renewable Energy Certificates [RECs] / Environmental Attribute Certificates [EACs]), and enabling credible end-use claims.

While this report attempts to provide all relevant details about each discussed method in the corresponding summaries, this report is not meant to cover all existing or emerging accounting approaches. Moreover, the summaries of these complex methodologies are not meant to substitute for more comprehensive explanations. For greater detail and nuance, readers are encouraged to review the technical documents cited for each of the methods discussed.

### **3. Taxonomy of Conceptual Approaches to Utility-Scale Storage Accounting**

Existing and emerging approaches to accounting for stand-alone utility-scale energy storage differ less by jurisdiction or technology than by how storage is treated within the accounting system. Specifically, approaches can be distinguished through analogies to the functions of interconnected power systems, examining where energy attributes and emissions factors are assigned, whether attributes persist through storage, and how exclusivity is preserved. The

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3. Bonner, A. "US energy storage installations in 2025 have already surpassed last year's total: Wood Mac," *Energy Storage News*, 17 December 2025. <https://www.energy-storage.news/us-energy-storage-installations-in-2025-have-already-surpassed-last-years-total-wood-mac/#:~:text=Utility%2Dscale%20storage%20increased%20by,in%20the%20whole%20of%202024>

4. Kikuma, I. "Global Energy Storage Boom: Three Things to Know," *BloombergNEF*, 21 October 2025. <https://about.bnef.com/insights/clean-energy/global-energy-storage-boom-three-things-to-know/>

following taxonomy organizes the approaches discussed in this report according to that functional logic:<sup>5</sup>

### 3.1 Storage-as-Load

Under storage-as-load approaches, storage is treated as a load modifier: input to storage is treated as positive load, while storage output is treated as negative load. Emissions attributes attach to the energy at input, so they cannot be allocated to other end-use loads, and additional attributes are not created or transferred when energy is output.

Operational data from the storage asset is not used to characterize storage inputs. Storage losses are not specified by resource type but may reduce the total volume of output energy. Input attributes do not otherwise alter the emissions profile of output energy.

This approach generally does not support claims to specified stored energy.

### 3.2 Storage-as-Generation

Under Storage-as-Generation approaches, attributes are assigned at output and may or may not be traced to attributes at input. Instead, input energy is treated as a withdrawal from the system,<sup>6</sup> while output energy is treated like generation.

Under the Storage-as-Generation approach, output energy is characterized using program-specific credits or emissions values under a defined policy or compliance framework, such as a peak-load reduction program.<sup>7</sup> When applied in these policy-bound settings, program rules specify when and how storage output is eligible for credit under the program and credits typically are not transferable and do not support voluntary renewable energy claims.

By restricting credits within the program, emissions reductions are internalized within the program's accounting framework, but not transferable externally, protecting the inviolability of voluntary market-based energy or emissions inventories.

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5. The terms "Storage-as-Load," "Storage-as-Generation," and "Storage-as-Transmission" describe alternative methods of accounting for the relationship between energy inputs, storage, and output energy. They should not be understood as mutually exclusive descriptions of the physical function of a storage asset. In particular, a storage resource may be modeled as load and generation for physical dispatch purposes while its emissions attributes are accounted for under a separate attribute-continuity framework. These categories are descriptive rather than prescriptive and are intended to characterize existing and emerging accounting approaches. This taxonomy is intended to provide a common vocabulary for comparing approaches and helps identify each approach's treatment of input energy, storage losses, and output attributes. CEAP's issued guidance may ultimately incorporate elements of multiple approaches if doing so best supports accurate and credible accounting.

6. This is sometimes referred to as "negative generation" but is treated like a loss.

7. See, for example, Massachusetts's Clean Peak Energy Standard. Massachusetts Department of Energy Resources (DOER), Renewable and Alternative Energy Division, Clean Peak Energy Standard, <https://www.mass.gov/info-details/clean-peak-energy-standard-program-details>. Accessed July 22, 2026.

Storage-as-Generation differs from Storage-as-Load by assigning value at output (either by administrative fiat, program eligibility criteria, or through contractual instruments) rather than when energy is input to storage.

### 3.3 Storage-as-Transmission

Storage-as-Transmission approaches storage as a mechanism that allows generation attributes to persist through the storage technology subject to chain-of-custody and loss-accounting rules.

This approach is conceptually analogous to spatial transmission of attributes over power lines, but functions across time rather than geography. The storage asset facilitates the time-shifting of attributes, for example, but does not itself characterize output energy.

This approach describes the more recent storage accounting methods because of its ability to support time-shifted clean energy use claims without inflating total clean energy volumes. However, when applied to attribute certificates, it typically requires precise operational data, explicit loss allocation, and registry-level controls, increasing complexity and potentially creating reconciliation challenges with monthly certificate systems.

In practice, Storage-as-Transmission accounting may be further categorized by whether or not the approach intends contractual instruments to support credible end-user claims.

For this approach, output energy from storage may be characterized as renewable or low emissions when input attributes are typically matched with operational data linking stored clean energy to storage asset charging events and concomitant state-of-charge characteristics. Moreover, operational data supporting the characterization must match the granularity of any claim that it is meant to support.

Storage losses may be incorporated conservatively by capping claimable volumes or by using metered output data to adjust for energy leaked or otherwise consumed during storage. Both loss accounting approaches link input attributes to attributes assigned to output.

Some Storage-as-Transmission approaches may not support explicit consumer claims, including some power-flow based applications designed for strict attributional accounting frameworks.

Storage-as-Transmission differs from both Storage-as-load and Storage-as-Generation accounting by allowing generation attributes to persist through storage, preserving ownership and exclusivity through strict continuity rules. Doing so permits attributes to time-shift under finer temporal granularities that better match energy dispatch intervals (hourly or sub-hourly), facilitating greater temporal matching of purchased attributes to consumed energy.

**Table 2: Explanation of Storage Accounting Taxonomy**

| Approach                       | Emissions Accounting                                 | What Happens to Attributes?                                                                                                                                              | Core Consequence                                                                  |
|--------------------------------|------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|
| <b>Storage-as-Load</b>         | Input is load; output reduces net load               | Input attributes remain with/are consumed at input; no attributes persist through storage                                                                                | Storage does not create a basis for characterizing discharge                      |
| <b>Storage-as-Generation</b>   | Output is treated as generation                      | Attributes are assigned to output under an accounting/program rule and may be independent of input attributes; In theory, unbundled certificates may characterize output | Output characterization is determined at output                                   |
| <b>Storage-as-Transmission</b> | Storage shifts energy and its attributes across time | Attributes persist through storage, subject to strict chain-of-custody and loss rules, often requiring precise operational data                                          | Output can inherit input attributes; storage cannot otherwise characterize output |

## 4. Existing and Emerging Approaches to Storage Accounting

### 4.1 Storage-as-Load Approaches

#### 4.1.1 GHG Protocol Scope 2 Guidance (2015)

The GHG Protocol *Scope 2 Guidance* was developed by the GHG Protocol Secretariat and published in 2015 to clarify how organizations should account for GHG emissions associated with purchased electricity under the Corporate Standard.<sup>8</sup>

The *Scope 2 Guidance* does not explicitly address how to account for emissions associated with stored purchased electricity. But the principles it establishes for accounting for purchased electricity, steam, heating and cooling may be characterized as a Storage-as-Load approach when applied to accounting for the emissions of stored energy. Under the Scope 2 logic, stored energy is not treated as a distinct source of clean generation. Instead, energy input to a storage device is treated as consumed at the time of input. Any emissions associated with that energy would be reported in Scope 2 by the entity that purchases and

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8. World Resources Institute, *GHG Protocol Scope 2 Guidance: An Amendment to the GHG Protocol Corporate Standard*, January 2015. <https://ghgprotocol.org/sites/default/files/2023-03/Scope%20%20Guidance.pdf>.

consumes the energy, using either the location-based or market-based method. Output does not create new clean attributes and does not independently support use claims.

In practice, a company operating or controlling a storage asset reports the Scope 2 emissions associated with purchased electricity input to the asset using both the location-based and market-based methods. The location-based method typically applies a grid-average emissions factor to calculate Scope 2 emissions. If the input energy is supported by qualifying contractual instruments (i.e. RECs), the storage asset owner may also use the market-based method that applies an emissions factor reflecting the generation represented by those instruments. However, specified storage attributes cannot be claimed and reported by end-users. Instead, generation attributes may be claimed directly by the asset owner even if the energy is only stored, but the attributes may not then characterize stored energy. Output energy is characterized using the residual mix of generation resources supplying the power grid where the asset is located and is unaffected by storage.

Under the Scope 2 logic, storage losses are treated analogously to transmission and distribution losses under the *Scope 2 Guidance*. Energy that is lost due to round-trip inefficiency, parasitic loads, or self-discharge is considered energy consumed by the storage asset.

The emissions associated with those losses are allocated to the entity that owns or controls the storage system and reported under that entity's Scope 1 inventory. This reflects the Guidance's principle of allocating emissions to the party that consumes energy within its organizational boundary.

Storage complicates this logic where ownership and operational control are not aligned. In many utility-scale configurations, storage assets are owned by one party but dispatched or economically controlled by another. The *Scope 2 Guidance* does not provide explicit rules for resolving these cases, but its underlying logic suggests that emissions be attributed to the party that controls charging decisions and, therefore, consumption. Where control is shared or ambiguous, application of the Guidance may yield inconsistent outcomes across reporters.

Compared with other approaches, applying the principles of the *Scope 2 Guidance* minimizes the risk of double counting by anchoring all renewable claims to instruments retired at input. It does not, however, recognize temporal shifting of attributes and does not attempt to model the emissions consequences of the timing of outputs.

#### **4.1.2 GHG Management Institute / EPRI Guidance (2021)**

In 2021, the Greenhouse Gas Management Institute (GHG Management Institute) and the Electric Power Research Institute (EPRI) published guidance on GHG accounting for battery

energy storage systems that was meant to align with Scope 2 reporting under the GHG Protocol.<sup>9</sup>

The EPRI guidance builds on the charging-based attribution logic of the *Scope 2 Guidance*. Storage is treated as part of the asset it supports: front-of-the-meter storage is treated as generation-adjacent, behind-the-meter storage as load, and storage embedded in the transmission or distribution network as grid infrastructure. Despite these distinctions, clean attributes and emissions are still assigned when energy is input rather than at output.

In practice, energy input to storage is treated as energy consumed by the entity that owns or controls the storage system. Unlike the Scope 2 logic applied to transmission and distribution losses, however, the GHG Management Institute/EPRI approach permits characterization of the output energy by accounting for input attributes separately from output attributes when accounting for emissions reporting purposes. This application strays from the standard Storage-as-Load approach by permitting output energy to carry an emissions factor linked to inputs but not otherwise changed through storage. However, it does not apply the same operational data and continuity rules generally adopted by the Storage-as-Transmission approach.

The EPRI guidance addresses AC-to-AC round-trip efficiency losses, parasitic consumption, and potential double counting of line losses where electricity flows through the grid multiple times. In some configurations—particularly smart-grid and end-user-owned storage—the guidance suggests applying conservative assumptions, such as double counting line losses, to avoid understating emissions.

Ownership and control are central to the EPRI framework, but the guidance acknowledges unresolved questions where storage is owned by one party and dispatched for the benefit of another.

It notes that the professional accounting community had not yet coalesced around a definitive categorization for these arrangements, particularly where storage simultaneously serves private demand and system-level grid-stability functions.<sup>10</sup>

Relative to Scope 2 logic, the EPRI approach provides more operational detail but remains aligned with charging-based attribution. It preserves exclusivity where attributes are retired at charging but does not support time-shifted clean energy claims like the Storage-as-Transmission approach.

In 2025, EPRI expanded but did not fundamentally alter the approach outlined in the 2021 guidance with a technical update that raised several challenges associated with time-shifting

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9. Colbert-Sangree, T., Gillenwater, M., Diamant, A., Fischer, L., 2021, Greenhouse Gas Emissions Accounting for Battery Energy Storage Systems (BESS), EPRI Report 3002022395, September 9, 2021. <https://www.epri.com/research/products/000000003002022395>

10. Colbert-Sangree, *et.al.* (2021), *supra* note 9, at 10.

attributes through energy storage.<sup>11</sup> The update specifically evaluated EnergyTag's Granular Certificate (GC) scheme as applied to stored energy and raised several technical hurdles facing accurate hourly or sub-hourly attribute tracking and accounting. It noted that charging and discharging losses of battery energy storage systems are governed by complex and rapidly changing state-dependent variables, including charge/discharge rate, state of charge (SOC), and ambient temperature. The update refers to inaccuracies associated with current methods of measuring storage losses, which may not account for variable AC output depending on a batteries age and SOC. The update notes that discharging a battery from 20% SOC to 10% SOC, for example, might produce less energy than discharging the same battery from 90% SOC to 80% SOC.<sup>12</sup>

The 2025 guidance also raises concerns about the precision of operating data at more granular time intervals. Identifying the net charging or discharging over each hour, for example, will not accurately capture storage providing frequency regulation, which requires switching several times between charging and discharging within the same time interval.<sup>13</sup> Ultimately, EPRI concludes that the complexity and uncertainty involved in estimating and allocating stored energy losses at hourly temporal granularities may produce reported output totals that do not accurately reflect the storage asset's impact on decarbonizing the power system.<sup>14</sup> Rather than resolving issues that arise when applying stored energy to granular clean energy claims, however, the update raises challenges that granular storage accounting must overcome if it is to accurately report the emissions from output energy.

### **4.1.3 CAISO Accounting & Reporting (A&R) Framework (in Development)**

CAISO's GHG Accounting and Reporting (A&R) Framework is an allocational, post-market reporting system that overlays ownership and contract information onto CAISO market dispatch outcomes to produce hourly, entity-specific emissions information and a market-wide residual emissions dataset.<sup>15</sup> Under this framework, stored renewable electricity is not treated as a distinct category of generation with independently transferable clean attributes.

Under the final proposed Accounting & Reporting (A&R) Framework, CAISO distinguished between stand-alone energy storage resources operated by reporting entities that serve load

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11. Electric Power Research Institute (EPRI), *Tracking Energy Through Electric Energy Storage Systems: Conceptual Challenges and Empirical Results for Emissions Tracking Applications*, Technical Update, June 2025. <https://www.epri.com/research/products/000000003002033318>.

12. EPRI (2025), *supra* note 11, at 4.

13. EPRI (2025), *supra* note 11 at 5.

14. EPRI (2025), *supra* note 11, at 17.

15. California ISO. *Briefing on Greenhouse Gas Accounting and Reporting Approach*, October 2025. <https://www.caiso.com/documents/briefing-on-greenhouse-gas-accounting-and-reporting-oct-2025.pdf>

and those operated by entities that do not serve load.<sup>16</sup> This distinction determines whether storage is treated as modifying the entity's reported electricity consumption or as an independent source of emissions responsibility.

For reporting entities that serve load, CAISO treats stand-alone energy storage as a **load modification** rather than as an independent emitting or non-emitting resource. Storage adjusts the timing of when the entity is deemed to consume electricity, but it does not create a separate emissions profile for storage itself.

In practice, when energy is input to a stand-alone storage resource operated by a load-serving entity, the energy consumed by the storage system is added to the entity's reported load for that hour. When energy is output from the storage resource, the output is subtracted from the entity's reported load in the hour it is output. The emissions associated with energy input are therefore carried forward and reflected in the hour when the electricity is effectively used to serve load, rather than in the hour when the storage system physically input the energy.

CAISO's view is that where an entity has load, storage is functionally part of how that entity manages and serves that load, rather than a distinct source of supply.

For stand-alone storage assets from entities that do not serve load, CAISO assigns an emissions characteristic based on the **residual mix**. In this case, storage is treated as a supply-side resource for accounting purposes, because there is no load against which charging and discharging can be netted.<sup>17</sup>

This approach ensures that all electricity injected into the system by non-load-serving storage operators is assigned an emissions profile for reporting purposes, even though the operator is not a consumer of electricity in the A&R framework.

The distinction between load-serving and non-load-serving entities means that the same physical storage asset can be treated very differently under A&R depending on the reporting entity's role in the market. Where storage is owned or operated by an entity with load, it functions as a temporal reallocation mechanism for that entity's electricity consumption and emissions. Where storage is operated by an entity without load, it is treated as injecting electricity with an emissions profile defined by the residual mix.

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16. California ISO, *Greenhouse Gas: Accounting and Reporting: Final Proposal*, 15 October 2025. <https://stakeholdercenter.caiso.com/InitiativeDocuments/Accounting-and-Reporting-Final-Proposal-Greenhouse-Gas-Coordination-Working-Group-Oct-15-2025.pdf>

17. The effect essentially is to treat storage discharge as unspecified power and assign it an emissions factor derived from a residual mix calculation since its emissions reflect those of the grid where the storage asset resides rather than specified and claimed power with clean attributes.

In both cases, the A&R framework is designed to allocate emissions responsibility for reporting purposes rather than to determine ownership of clean energy attributes.<sup>18</sup> As a result, the emissions outcomes produced by A&R may differ from those reflected in certificate tracking systems or voluntary market-based emissions inventories, particularly where storage is charged with electricity associated with specified renewable procurement.

#### 4.1.4 SPP Markets+ GHG Tracking and Reporting Protocol

Under the proposed SPP Markets+ GHG Tracking and Reporting Protocol, energy storage is incorporated into emissions accounting using an administrative allocation model similar to CAISO's A&R framework in structure but which diverges in implementation detail and governance.<sup>19</sup> Markets+ is designed to support jurisdictional emissions reporting and policy coordination across states with different GHG emissions mitigation policies.

For reporting entities that serve load, SPP Markets+ treats stand-alone energy storage as a **load-modifying resource**. Energy input to storage increases the reporting entity's load in the input interval, while output energy reduces load in the output interval. Storage does not receive a standalone emissions profile, nor is it treated as an independent source of generation for reporting purposes.

For reporting entities that do not serve load, or for the portion of storage output that exceeds the reporting entity's total load, Markets+ uses **system-level average or residual emissions characteristics** broadly like A&R's use of residual emissions rates to assign emissions to stand-alone storage. In both frameworks, storage discharge is treated as unspecified

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18. Indeed, CAISO staff maintain that, "*the ISO market does not create a claim on a REC,*" and stakeholders in the voluntary market should pursue their own solutions to reporting requirements. California ISO, *Greenhouse Gas: Accounting and Reporting*, Issue Paper, December 20, 2024, p.21. <https://share.google/XSAA4wE7QZPuTiANz>. See also Breidenich, C. (Western Power Trading Forum). Energy and GHG Accounting Framework Illustration, 14 April 2024, (slide materials summarizing storage treatment in the accounting framework). <https://stakeholdercenter.caiso.com/initiatedocuments/wptfpresentation-ghgattributionsframework-ghgcoordination-apr17-2024>.

19. Southwest Power Pool (SPP), Market Protocols for SPP Markets+, Section 5. Greenhouse Gas (GHG) Pricing Programs & GHG Tracking and Reporting, 23 April 2025. <https://www.spp.org/documents/73715/marketsplus%20protocols%20-%20combined%20-%20mpec%20approved%20as%20of%2020250423.pdf>

electricity for emissions reporting purposes, reflecting the absence of a load against which emissions can be netted.<sup>20</sup>

Whereas A&R frames residual emissions primarily as a balancing mechanism within entity-level accounting outputs, Markets+ explicitly incorporates the concept of “Residual Energy,” derived from unmapped generation and excess attributed generation, and publishes residual emissions information as part of its public GHG reporting. This residual construct is central to Markets+ and is designed to support transparency across participating states.

## 4.2 Storage-as-Generation Approaches

### 4.2.1 Massachusetts Clean Peak Energy Standard (CPS) (2018)

The Massachusetts Clean Peak Energy Standard (CPS) is a state compliance program established in 2018 to **reduce greenhouse gas emissions during periods of peak electricity demand**.<sup>21</sup> Adopted as part of Massachusetts’ broader clean energy and climate policy framework, the CPS incentivizes resources that can demonstrably deliver cleaner electricity during defined peak demand windows, rather than increasing total renewable generation on an annual basis.

Electricity storage is treated as an **eligible clean peak resource whose discharge can be credited as clean electricity output**, subject to specific statutory and regulatory conditions. Storage is therefore treated functionally as **generation at the point of discharge**, not merely as load or as a neutral intermediary, but only for the purpose of CPS compliance.

Under CPS rules, storage units may earn **Clean Peak Energy Certificates (CPECs)** for electricity discharged during designated peak periods. Eligibility is determined by the storage resource’s demonstrated ability to contribute to peak-period emissions reductions, which is demonstrated by meeting one of several criteria:<sup>22</sup>

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20. One notable divergence from CAISO is SPP’S explicit treatment of “null power”—electricity from renewable or non-emitting generation for which the associated certificates or other claimable attributes have been retained, transferred, or sold separately—in Markets+. The designation prevents Markets+ from allocating the same zero-emission attributes to a market purchaser after they have already been conveyed to another purchaser. SPP’s approach may therefore improve the consistency of specified-source allocations and residual-mix calculations. However, null status cannot be established from dispatch and settlement data alone. It requires SPP to receive or verify information from certificate tracking systems, reconcile differences in timing and granularity, allocate partially stripped generation, and revise reports when attribute transactions occur after market settlement. CAISO faces the same underlying risk of duplicate attribution, but where SPP explicitly reports quarterly aggregated null power volumes by fuel type, CAISO’s A&R approach avoids publishing fuel-specific null power information at all. Markets+ consequently addresses the issue more explicitly but also generates a more complex interface between wholesale-market reporting and certificate administration.

21. Massachusetts Department of Energy Resources. 225 CMR 21.00: Clean Peak Energy Standard. <https://www.mass.gov/regulations/225-CMR-2100-clean-peak-energy-standard>

22. Massachusetts Department of Energy Resources. Clean Peak Energy Standard Guideline Statements. <https://www.mass.gov/doc/clean-peak-energy-standard-guideline-statements/download>

- The energy storage system is co-located with a qualified renewable resource or is contractually paired with a qualified RPS renewable generator
- The associated renewable generator has a capacity at least **75 % of the storage system's nameplate capacity**
- Storage is shown to charge coincident with periods of high output from renewable generators

Massachusetts' approach can be characterized as Storage-as-Generation and not Storage-as-Transmission because the energy output at certain critical times (during peak periods) is assumed clean based on a proxy for clean inputs (charging during high renewable generation periods) rather than based on input attributes or operational input data.

Because only **output energy during defined peak windows** is eligible for CPEC issuance, and because input energy must satisfy program rules, inefficient storage systems must charge more energy to earn the same number of peak credits. The program therefore **internalizes losses economically**, rather than accounting for them metrically. The result is that inefficiencies reduce the quantity of creditable output without requiring a formal loss calculation.

It is important to note that CPECs are **compliance instruments created solely for the CPS**. They avoid double-counting by being limited in scope to the state program. They are not interchangeable with RECs used in voluntary markets and do not convey transferable ownership of clean energy attributes beyond the statutory scope of the program.

## 4.3 Storage-as-Transmission Approaches

### 4.3.1 European Emissions Certificate System (EECS)

The European Energy Certificate System (EECS), administered by the Association of Issuing Bodies (AIB), has governed the issuance and tracking of Guarantees of Origin (GOs) since the early 2000s.

Under EECS rules, electricity discharged from storage is not treated as renewable generation by default. Instead, attributes associated with electricity charged into storage may persist through storage and be re-associated with discharged electricity under narrowly defined conditions preventing double issuance.<sup>23</sup> These conditions generally require that the attributes of the charging electricity be clearly established, that upstream certificates not be claimed elsewhere, and that issuance volumes at discharge not exceed charging volumes net of losses.

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23. Association of Issuing Bodies (AIB), *EECS Rules*, release 8, v1.10, 22 May, 2025. <https://www.aib-net.org/sites/default/files/assets/eecs/EECS%20Rules%20Release%208%20v1.10%20Final.pdf>

This often requires cancellation of upstream certificates before issuance of post-storage certificates, or other registry-level controls on double claiming. Storage is treated as an intermediate process through which attributes may pass, rather than a source of new attributes.

Losses are explicitly recognized. Certificates issued for discharged electricity must be reduced to reflect round-trip efficiency losses, and allocation is typically performed on a proportional, mass-balance basis.

The EECS has issued subsidiary guidance, EECS Rules Fact Sheet 23: Storage and Conversion Tracking, that provides principles guiding the robust tracking of stored attributes, but leaves operational handling of stored energy to national domains.<sup>24</sup> While the EECS provides a framework, national registries implement these rules differently. For instance, some nations limit issuance of GOs for the output of pumped hydro storage units to net production from natural inflow, while others do not adopt such restrictions.

The following national domains have enabled storage tracking consistent with the EECS framework through their national registries:

#### **4.3.1.1 Austria (E-Control)**

Austria's Domain Protocol describes a registry process where certificates are **moved into a storage account** after charging, **losses are cancelled** based on declared (or default) efficiency, and attributes are carried through to the post-storage certificates (with changes only to things like certificate ID/production period/country/dissemination level).<sup>25</sup>

#### **4.3.1.2 Ireland**

The Irish registry permits issuing GOs associated with storage only where the attributes of the electricity charged into storage can be **clearly identified** and where **no GOs have been issued** for that electricity at the time of generation. Where renewable electricity has already been certified upstream, the protocol does not allow a second issuance following storage discharge. Issuance volumes must also be constrained by mass-balance principles, such that certificates issued after discharge cannot exceed eligible charging volumes, net of losses.<sup>26</sup>

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24. Association of Issuing Bodies (AIB), *EECS Rules Fact Sheet 23: Storage and Conversion Tracking*, version 2.1, Document # AIB-EECS-FS23, 28 August 2025. <https://www.aib-net.org/sites/default/files/assets/eecs/facts-sheets/AIB-2024-EECSFS-23%20EECS%20Rules%20Fact%20Sheet%2023%20-%20Storage%20and%20Conversion%20Tracking%20-%20Release%202.1.pdf>

25. Association of Issuing Bodies (AIB), *EECS Domain Protocol for E-Control – Austria*, AIB-2023-DPAT- E-Control Austria, 25 September 2024. [https://www.aib-net.org/sites/default/files/assets/facts/domain-protocols/AIB-2024-DPAT-E-Control%20Austria%20Domain%20Protocol%2025052023\\_Correction%20200092024\\_clean%20version\\_.pdf](https://www.aib-net.org/sites/default/files/assets/facts/domain-protocols/AIB-2024-DPAT-E-Control%20Austria%20Domain%20Protocol%2025052023_Correction%20200092024_clean%20version_.pdf)

26. Association of Issuing Bodies (AIB), *EECS Domain Protocol for Ireland*, SEMO, 20243. <https://www.aib-net.org/sites/default/files/assets/facts/domain-protocols/AIB-2023-DPIE-SEMO%20Ireland%20Domain%20Protocol%2025052023.pdf>

Rather than transferring certificates to a storage account and canceling them upon consumption of output, the Irish approach relies on **issuance gating**: the registry blocks issuance in cases where prior certification would create duplication.

#### 4.3.1.3 National Domains with Rules for Pumped Hydro Storage Only

##### 4.3.1.3.1 France (EEX Registry)

France's Domain Protocol contains a pumped-storage calculation approach (including a normative yield assumption) that determines the eligible renewable output by adjusting for pumping consumption/efficiency.<sup>27</sup>

##### 4.3.1.3.2 Norway (Statnett)

Norway issues instruments for production devices "with energy storage capacity" based on **net production**, with pumping consumption tracked via specific metering identifiers and then deducted from production.<sup>28</sup>

##### 4.3.1.3.3 Switzerland (Pronovo)

Switzerland's Domain Protocol states that EECS-GOs are issued for pumped-storage hydro only on **natural inflow**, with pumping electricity multiplied by an efficiency factor and then deducted, with GOs cancelled to account for losses due to inefficiency.<sup>29</sup>

##### 4.3.1.3.4 Sweden (SEA)

Sweden requires the plant owner to declare pumping, and states that GOs can only be issued for electricity produced by the **natural inflow of water** (i.e., pumped hydro storage is explicitly excluded to prevent the risk that re-certification double-counts renewable attributes).<sup>30</sup>

##### 4.3.1.3.5 Spain (CNMC)

Spain's Domain Protocol says pumped water "should not be considered renewable," but that GOs may be issued for pumped storage devices **if the energy consumed by the pump is**

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27. Association of Issuing Bodies (AIB), *EECS Domain Protocol for EEX – France*, AIB-2024 -DPFR - EEX – FRANCE, 23 January 2024. [https://www.eex.com/fileadmin/EEX/Downloads/Registry\\_Services/Guarantees\\_of\\_Origin\\_Documentation/20250310\\_AIB-2024-DPFR-v8-Domain\\_Protocol\\_vf.pdf](https://www.eex.com/fileadmin/EEX/Downloads/Registry_Services/Guarantees_of_Origin_Documentation/20250310_AIB-2024-DPFR-v8-Domain_Protocol_vf.pdf).

28. Association of Issuing Bodies (AIB), *EECS Domain Protocol for Norway*, Statnett, 2023. <https://www.aib-net.org/sites/default/files/assets/facts/domain-protocols/AIB-2023-DPNO-Statnett%20Norway%20-%20Domain%20Protocol%20-%2016032023.pdf>.

29. Association of Issuing Bodies (AIB), *EECS Domain Protocol for Pronovo – Switzerland*, AIB-2025-DPCH Switzerland, 25 June 2025. <https://www.aib-net.org/sites/default/files/assets/facts/domain-protocols/AIB-2025-DPCH-Pronovo%20Clean%20v2.pdf>.

30. Association of Issuing Bodies (AIB), *EECS Domain Protocol for the Swedish Energy Agency – Sweden*, AIB-2024-DPSE- Swedish, 09 December 2024. <https://www.aib-net.org/sites/default/files/assets/facts/domain-protocols/AIB-2024-DPSE-Swedish%20DP%202024-12-09%20%28clean%29.pdf>.

**fully deducted from the output**, and consumption of energy by pumping is declared/verified.<sup>31</sup>

### 4.3.2 EnergyTag / Quintrace

EnergyTag is a nonprofit organization that promotes granular energy attribute certificates. Quintrace is an operational platform that implements EnergyTag's storage provisions and is deployed commercially to track attributes through utility-scale storage assets.<sup>32</sup>

Quintrace's approach is designed primarily for voluntary procurement and granular hourly matching under the Granular Registry, the technical registry infrastructure that issues and tracks certificates in accordance with EnergyTag's Granular Certificate Scheme Standard.<sup>33</sup> It applies to utility-scale storage and assumes access to high-resolution operational data.

Under the Granular Registry, temporal conveyance of attributes is not presumed but demonstrated through a defined sequence of recorded events establishing continuity, mass balance, and exclusivity. Attributes associated with energy at input may persist through storage only if registry-level records explicitly link input and output events. Input events create time-stamped storage charge records; output events create corresponding discharge records. Upstream granular certificates must be allocated and cancelled, and new storage output certificates are issued net of losses.

The process begins when energy is input to storage. Each input interval creates a Storage Charge Record (SCR), which records, at minimum, the storage asset identifier, the charging timestamp, the quantity of electricity charged, and the declared charging source category (which distinguished charging backed by granular certificates from unspecified charging from the grid).

Each SCR also includes an efficiency placeholder that is later used to account for storage losses when charging is reconciled with output. At this stage, SCRs function as a pending inventory of energy entering storage and do not yet support any time-shifted attribute claim.

When electricity is subsequently released from storage, a Storage Discharge Record (SDR) is created for each output interval. The SDR records the storage asset identifier, the discharge timestamp, the quantity of electricity discharged, and the destination of the discharged electricity (*i.e.* injection to the grid or behind-the-meter).

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31. Association of Issuing Bodies (AIB), EECS Domain Protocol for Spain, 2023. <https://www.aib-net.org/sites/default/files/assets/facts/domain-protocols/AIB-2023-DPES-CNMC%20Spain%20Domain%20Protocol%2026012023.pdf>.

32. Quinbrook Infrastructure Partners, "Quintrace: Hourly Energy Matching for Utility-scale Batteries," Quintrace.com, Home > Case Studies, February 2024. <https://www.quintrace.com/case-studies/988535b8-7c7b-42f3-9a70-481d12555b29>.

33. EnergyTag, Granular Certificate Scheme Standard, Version 2, March, 2024. [https://energytag.org/wp-content/uploads/2024/12/EnergyTag\\_Granular-Certificate-Scheme-Standard-V2.pdf](https://energytag.org/wp-content/uploads/2024/12/EnergyTag_Granular-Certificate-Scheme-Standard-V2.pdf).

The SDR also incorporates a storage efficiency factor used to adjust the discharged quantity for round-trip losses. Like SCRs, SDRs initially remain pending and do not independently carry clean energy attributes.

Notably, Quintrace calculates losses dynamically at hourly resolution rather than applying a static round-trip efficiency factor. At hourly granularity, assuming a static round-trip efficiency can overstate or understate losses depending on battery state of charge, particularly near full or near empty conditions, when, applying a static factor can make it appear that the accounting system creates or destroys energy. While these artifacts only appear at hourly or sub-hourly granularities, dynamic, metered loss calculation resolves them by more accurately modeling operational conditions.

Quintrace uses two pre-defined allocation methodologies—first-in, first-out (FIFO) and last-in, last-out (LIFO)—as well as a user-prescribed allocation to link one or more SCRs to one or more SDRs. The user-prescribed option is not a single methodology but a configurable category potentially encompassing any allocation rule specified. Every methodology, however, is governed by the same mass balance and exclusivity controls and each is employed to prevent selective matching of input intervals to output intervals and to preserve chronological integrity.<sup>34</sup>

The Storage Allocation Record (SAR) represents an auditable, time-ordered slice of storage operation and specifies the relevant energy input and energy output time intervals, the storage asset details, the applicable efficiency factor, and the volume of electricity available for allocation after losses are applied.

The output volume recorded in the SAR is constrained by the quantity of energy previously input into storage and adjusted for round-trip efficiency. This is the point at which the registry operationalizes mass balance over time: energy output eligible to carry attributes cannot exceed energy input to storage, net of losses, and must be chronologically linked to the underlying input events.

Granular certificates are not assumed to pass through storage automatically. To substantiate a time-shifted claim, a certificate holder must actively allocate valid, unallocated granular certificates to a SAR. The registry verifies a set of integrity constraints before allowing allocation, including that the certificates are valid and unallocated, that their generation timestamps precede the SAR's charging interval, and that the certificate volumes do not exceed the SAR's available capacity. Where necessary, proportional allocation may be used.

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34. EnergyTag identifies FIFO and weighted-average allocation as the two pre-defined methodologies and permits a "Storage Operator Decides" approach, under which the operator selects the SCRs allocated to each SDR. EnergyTag recognizes LIFO as another possible methodology but cautions that it may create unused attribute layers that persist throughout the project's life. EnergyTag also requires operators to publish their allocation logic transparently and acknowledges that operator-directed allocation requires clear rules to remain credible. See EnergyTag, Granular Certificate Scheme Standard, Version 2 (March 2024), Annex 3, pp. 51–52. [https://energytag.org/wp-content/uploads/2024/12/EnergyTag\\_Granular-Certificate-Scheme-Standard-V2.pdf#page=51](https://energytag.org/wp-content/uploads/2024/12/EnergyTag_Granular-Certificate-Scheme-Standard-V2.pdf#page=51).

Once these checks are satisfied, the registry cancels the allocated granular certificates, thereby preventing their use for any other claim.

Only after certificate allocation and cancellation does the registry issue a Storage Discharge Granular Certificate (SD-GC). The SD-GC preserves the environmental attributes of the cancelled input certificates, while adding storage-specific metadata. The resulting certificate represents the same attributes conveyed forward in time at a reduced volume, with exclusivity enforced through upstream certificate cancellation.

Within the Granular Registry, ownership and control of clean energy attributes are determined by control over certificates and registry actions rather than by physical ownership of the storage asset. Exclusivity is preserved within the granular system itself, but reconciliation is required when time-shifted granular certificates interact with annual or monthly certificate regimes or with administrative energy and emissions allocation frameworks.<sup>35</sup>

### 4.3.3 MISO / Singularity CarbonFlow

CarbonFlow was developed by Singularity Energy in collaboration with the Midcontinent Independent System Operator (MISO) to estimate consumed emissions using power-flow tracing. It is designed to provide **transparent, attributional estimates of greenhouse gas emissions associated with electricity consumption** across the MISO footprint.<sup>36</sup> It is intended for analyzing and reporting emissions under an attributional accounting framework using a location-based method rather than supporting specified power claims under a market-based approach.

Stored clean power is incorporated implicitly:

- Energy input to storage is treated as **consumption** and inherits the emissions characteristics of the transmission grid at the time it is input.
- Energy output from storage is treated as part of system flows at the time of output but **does not carry independently defined emissions or clean attributes**.
- In current public reporting, storage output may appear as having **zero direct emissions**, but this reflects the absence of on-site combustion rather than a claim about how the electricity was generated.

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35. This issue is a known boundary condition of the Quintrace approach and is being actively addressed by a separate CEAP stakeholder working group under its initiative on Credible Transactions of Hourly Clean Energy: Principles and Transaction Types for Emerging Markets. CEAP guidance on proper reconciliation of granular certificates with monthly or annual regimes is forthcoming.

36. Midcontinent Independent System Operator (MISO), Consumed Emissions Estimates Technical Documentation, March 2025. [https://miso.singularity.energy/CarbonFlow\\_documentation.954093.pdf](https://miso.singularity.energy/CarbonFlow_documentation.954093.pdf)

Importantly, CarbonFlow does **not** track the temporal transfer of attributes through storage, preserve or extinguish clean energy claims at storage input or output, nor track ownership or retirement of stored attributes

Nevertheless, CarbonFlow is capable of providing granular data to facilitate hourly matching. It can also facilitate the calculation of locational marginal emissions (LME), by providing temporally and spatially granular data on generator emissions, network topology, load, and actual power flow.

CarbonFlow's outputs are designed to be consistent with Scope 2 location-based emissions reporting, which characterizes emissions based on the resource mix of the distribution grid where the energy is output.

CarbonFlow can facilitate hourly granularity for location-based Scope 2 reporting because the node-level emissions estimates are calculated every five minutes. Generally, 12 five-minute intervals can be aggregated and spatially averaged to produce an hourly marginal emissions estimate.

CarbonFlow's spatial data for emissions estimates is also flexible and can either aggregate MISO regional node-level data, geospatial boundaries based on commercial relationships, or even node-level data across assets to develop a facility-level emissions estimate.

Because it is intended to be used for location-based Scope 2 reporting, all specified power claims are embedded in the emissions characteristics of the grid where the energy is consumed. It is impossible, therefore, for a reporting entity to claim 100% clean consumption until the local grid delivers 100% clean energy.

#### **4.3.4 Washington Clean Fuels Standard (CFS) Model**

The Washington Clean Fuels Standard (CFS) differs from all other approaches presented in that it is not a program that accounts for clean energy storage, but it is included here as a model that can be applied to storage accounting, particularly where instruments substantiate clean energy use claims in a fully commingled power grid.

Under the Washington CFS, regulated entities that claim low-carbon-intensity electricity are required to substantiate those claims through RECs retired in a designated tracking system.<sup>37</sup> Program guidance specifies eligibility criteria for RECs, including vintage requirements (2023 or later) and a defined retirement window (within three calendar quarters of generation). The program also provides detailed procedural guidance for REC retirement through the Western Renewable Energy Generation Information System (WREGIS,) including documentation

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<sup>37</sup> See *Transportation Fuel – Clean Fuels Program*, Revised Code of Washington, Title 70A, Chapter 70A.535. <https://app.leg.wa.gov/RCW/default.aspx?cite=70A.535>.

requirements and verification steps. In this way, it operationalizes certificate retirement as affirmative evidence supporting a discrete emissions-related claim.

Unlike many state Renewable Portfolio Standard (RPS) programs, which use RECs to demonstrate system-level compliance by load-serving entities, the focus of the Washington CFS is on whether a particular entity can credibly assert that a defined quantity of electricity use is associated with a lower carbon intensity. The Washington CFS model can be translated into a structured and auditable method for substantiating stored renewable electricity use claims without requiring proof of the physical provenance of charging electricity. Under this approach, electricity discharged from storage may be characterized as renewable only to the extent that the claimant retires eligible RECs in the approved tracking system, subject to defined temporal and geographic constraints.

A conservative implementation would further limit claimable discharge to volumes no greater than the volume covered by eligible retired RECs, optionally adjusted for round-trip efficiency to ensure that storage does not increase the quantity of claimable attributes. Responsibility for securing, retiring, and documenting the supporting instruments rests with the reporting entity, rather than with the market operator or a system-level allocation framework.

Several elements are central to the integrity of this model:

First, it depends on a standardized certificate tracking system (WREGIS) with consistent fields, controls, and public rules.

Second, it relies on explicit time discipline (the three-quarter retirement window) that offers more precision than annual matching but remains administrable and verifiable.

Third, retirement of certificates is the mechanism by which double counting is prevented; a REC retired for one claim cannot be reused to support another.

Fourth, the program produces transparent records that can be reviewed, audited, and, where necessary, used to correct or disallow unsupported claims.

The Washington CFS model aligns closely with how organizations operationalize market-based Scope 2 accounting under the Greenhouse Gas Protocol. Emissions factors are applied to electricity consumption based on qualifying contractual instruments, subject to quality criteria intended to ensure claims are exclusive, credible, and appropriately bounded.

In the context of storage, this Storage-as-Transmission approach treats renewable-backed discharge as an accounting construct supported by REC retirement, rather than as a statement about the physical characteristics of electricity delivered at the time of discharge. The retirement record in a recognized tracking system functions as the primary evidence that the reporting entity has acquired exclusive rights to the relevant renewable attributes, including their associated emissions profile.

The Washington CFS model differs from the EnergyTag/Quintrace approach because it is entirely contractual. Input attributes are characterized entirely by contractual instruments and are passed through to output energy without regard to storage operations relative to the time and location of operating generation on the grid. The EnergyTag/Quintrace approach on the other hand combines contractual and physical operating data of inputs to substantiate attributes associated with output energy.

The Washington CFS certificate-based approach provides an enforceable basis for avoiding double counting and supporting emissions inventories in settings where physical tracing or system-wide attribute tracking is not feasible.

**Table 3. Characterization of Accounting Approaches for Stored Electricity**

| <b>Effort / Scheme</b>                | <b>Defining Feature</b>                                                                          | <b>Point of Attribute Attachment</b>                                                             | <b>Treatment of Storage Losses</b>                                            | <b>Responsible for Loss Emissions</b>                                     | <b>Claims supported</b>                                            | <b>Risk of double counting</b>                                          |
|---------------------------------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------|-------------------------------------------------------------------------|
| <b>GHG Protocol Scope 2</b>           | Attributional accounting of purchased electricity                                                | Attributes characterize inputs, carried through via contractual instrument or other verification | Losses are not allocated by attribute class; ambiguous about characterization | Entity that owns or has operational control of the storage asset          | Claims to specified storage inputs; Scope 1 storage asset claims   | Low – assuming attributes are fully accounted                           |
| <b>GHGI / EPRI Guidance</b>           | Inventory reporting under the GHG Protocol; accounting follows physical and functional placement | At charging (attributes of electricity consumed)                                                 | Explicit; specified procedures based on operational configuration             | Assigned to the entity owning or operating the storage asset              | Scope 2 emissions inventories; no independent renewable use claims | Low — if charging attributes are retired and losses fully accounted for |
| <b>CAISO A&amp;R</b>                  | Market GHG reporting; post-dispatch administrative allocation                                    | stored energy treated like load modification for load-serving entities                           | Explicit in accounting logic, not instrument-based                            | Assigned to reporting entities per A&R allocation rules                   | Regulatory and market GHG reporting                                | High — parallel allocation ledger may conflict with certificates        |
| <b>SPP Markets+</b>                   | Post-dispatch GHG reporting                                                                      | Storage = load adjustment or characterized with residual mix                                     | Implicit; embedded in load and residual mix calculations                      | Assigned to reporting entities (load) per administrative process          | Jurisdictional and entity-level GHG reporting                      | High — residual mix and null power treatment may duplicate attributes   |
| <b>MA Clean Peak Energy Standard</b>  | Peak-period emissions                                                                            | Output eligible only within bounded compliance regime                                            | Implicit; inefficiencies reduce volumes eligible for credit                   | Internalized within program design                                        | Program-specific compliance claims                                 | Low – credits are non-transferable and confined to the CPS              |
| <b>EECS / EU Guarantees of Origin</b> | GO issuance and disclosure; chain-of-custody controls and mass-balance constraints               | Explicit; losses deducted prior to issuance                                                      | Implicit; embedded in issuance rules rather than entity-level inventories     | Allocated across market since losses reduce volume of certificates issued | Disclosure and compliance claims; limited voluntary claims         | Low — issuance rules prevent duplication                                |
| <b>EnergyTag / Quintrace</b>          | Hourly / granular clean energy claims                                                            | Temporal transfer mechanism governed by registry-level mass balance                              | Explicit and proportional at granular (hourly) resolution                     | Enforced through certificate volume constraints                           | Time-shifted renewable electricity use claims                      | Low —though difficult to reconcile with annual regimes                  |

| Effort / Scheme                      | Defining Feature                      | Point of Attribute Attachment                                                         | Treatment of Storage Losses                             | Responsible for Loss Emissions                            | Claims supported                                                  | Risk of double counting                                              |
|--------------------------------------|---------------------------------------|---------------------------------------------------------------------------------------|---------------------------------------------------------|-----------------------------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------------------|
| <b>MISO / Singularity CarbonFlow</b> | Consumed-emissions estimation         | Power-flow tracing to infer emissions w/o adjudicating ownership                      | Implicit; reflected in modeled dispatch and power flows | Assigned analytically to consuming load                   | Location-based, consumption-based emissions estimates             | Medium — risk outputs are misconstrued as evidence of ownership      |
| <b>WA CFS Model</b>                  | Certificate-based attribute ownership | Attributes attached to instruments, which can be applied at any point prior to output | Prescriptive retirement of eligible instruments         | Assigned to the reporting entity retiring the instruments | Market-based Scope 2 emissions claims, including reduction claims | Low — retirement in a recognized tracking system secures exclusivity |

## 5. Accounting for Co-located and Directly Connected Storage

In co-located and directly connected storage configurations, storage is paired with a generating resource—often a renewable facility—behind a shared point of interconnection or through a dedicated connection. These configurations present a distinct set of accounting considerations and fall outside of the taxonomy of approaches that we have applied to accounting approaches for grid-connected clean energy storage in the previous section.

### 5.1 Co-Located Power Storage in California’s RPS Program

California’s Renewable Portfolio Standard (RPS) incorporates co-located storage with rules intended to prevent the inflation of renewable generation claims. The California Energy Commission’s *RPS Eligibility Guidebook (Tenth Edition)* makes explicit that storage does not create additional renewable generation for compliance purposes.<sup>38</sup> Electricity output from storage may be counted toward compliance with the RPS only to the extent that it is demonstrably attributable to eligible renewable generation and does not exceed the renewable output that would otherwise have been counted absent storage.

The Guidebook reflects an evolution in regulatory treatment. Earlier categorical distinctions between “integrated” and “directly connected” storage have been removed in favor of an approach centered on energy flow reconciliation. Under the current framework, the accounting treatment hinges on metered measurements at defined points. These

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38. California Energy Commission (CEC). *Renewable Portfolio Standard Eligibility Guidebook, 10th ed.* Sacramento, CA: California Energy Commission, adopted April 2024 (as amended). <https://www.energy.ca.gov/programs-and-topics/programs/renewables-portfolio-standard/renewables-portfolio-standard>.

measurements are then reconciled through netting rules that ensure only the portion of discharged electricity attributable to eligible renewable generation, net of losses, remains RPS-eligible.

In effect, the accounting approach treats storage co-located with renewable generation as a single renewable facility, the post-storage output of which is eligible for the RPS. Round-trip efficiency losses, auxiliary consumption, and other conversion losses incurred during charging, storage, and discharging are deducted from the quantity of electricity eligible for RPS certification. This netting approach enforces a mass-balance constraint where credited output cannot exceed eligible input, and storage cannot be used to re-certify energy that has already been counted.

Metering configuration and accuracy are integral to this loss accounting framework. The Guidebook includes requirements for meter placement and performance sufficient to distinguish between electricity delivered directly from the renewable generator and electricity delivered after passing through storage. Accurate metering is necessary not only to quantify losses, but also to prevent inadvertent double counting where the same unit of renewable generation could otherwise be credited once at generation and again after discharge. By embedding metering and reconciliation requirements into eligibility determinations, California treats measurement infrastructure as a governance mechanism rather than a technical afterthought.

For the purposes of developing a comprehensive accounting protocol for utility-scale clean energy storage, California's approach illustrates how loss calculation and netting rules can be operationalized without relying on physical traceability beyond the facility boundary. This approach demonstrates that co-located and directly connected storage can be accommodated within a rigorous accounting regime only when loss treatment, netting formulas, and metering requirements are specified with sufficient precision to prevent storage from increasing the quantity of claimable renewable electricity.

## 5.2 Dedicated Pumped Hydro in the EECS

Similar accounting challenges arise for other storage technologies that are directly connected to specific energy-producing assets. For pumped hydropower with natural inflow, the central accounting question is not whether the input energy is renewable, but how to ensure that storage does not increase the quantity of claimable renewable output once conversion losses and operational constraints are considered.

At least some European jurisdictions distinguish renewable generation attributable to natural inflows from generation attributable to pumped water. Germany, for example, issues GOs from pumped-storage facilities with natural inflows only for the volume generated from

those inflows.<sup>39</sup> Electricity consumed for pumping is explicitly excluded or deducted from the calculation of eligible renewable output. This approach enforces a mass-balance constraint at the facility level: storage may reshape the timing of delivery but may not convert previously generated electricity into additional renewable megawatt-hours.

Losses incurred through pumping and generation therefore directly reduce the volume of electricity that may be certified as “clean,” rather than being absorbed into the grid or ignored for accounting purposes.<sup>40</sup>

### 5.3 Power-to-X & Green Hydrogen in Europe’s RFNBO Rules

A comparable logic appears in emerging accounting frameworks for power-to-X and renewable hydrogen facilities, particularly under the European Union’s Renewable Fuels of Non-Biological Origin (RFNBO) rules. Although these regimes address fuel production rather than electricity storage, they provide a useful analogue for directly connected energy conversion.<sup>41</sup> Renewable eligibility is tied to electricity sourced from specific renewable generators through direct connections or tightly defined temporal correlation rules. Conversion losses at each stage are explicitly accounted for, and only net output qualifies for renewable recognition. As with pumped hydro, eligibility depends on documented energy flows and reconciliation at the facility boundary, not on assumptions about grid composition at the time of delivery.

### 5.4 Thermal Energy Storage Systems

Thermal energy storage systems, including molten salt storage at solar thermal plants and hot- or cold-water storage in district energy systems, further illustrate how co-located storage is treated across energy sectors. In these systems, renewable attribution is typically anchored to the primary heat source rather than to the storage medium itself. Storage losses are commonly incorporated through standardized efficiency assumptions or performance factors that limit the quantity of energy deemed renewable at delivery.<sup>42</sup> These approaches

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39. German Environment Agency, Guarantees of Origin and Guarantees of Regional Origin Implementing Ordinance (HKRNDV), § 13(1)–(3) (unofficial English trans.). [https://www.umweltbundesamt.de/system/files/document/non-binding\\_translation\\_HKRNDV.pdf](https://www.umweltbundesamt.de/system/files/document/non-binding_translation_HKRNDV.pdf).

40. It may be legitimate to issue a Guarantee of Origin (GO) for “new” renewable generation where there is natural in-flow. Most pumped hydro in the U.S., however, relies on pumping water to a higher reservoir. Consequently, while all pumped hydro is a net consumer of renewable energy, there is little basis for issuing instruments conveying new renewable attributes where there is no natural in-flow.

41. See Commission Delegated Regulation (EU) 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 on detailed rules for renewable fuels of non-biological origin, Official Journal of the European Union L 157/11, 20 June 2023. [https://eur-lex.europa.eu/eli/reg\\_del/2023/1184/oj/eng](https://eur-lex.europa.eu/eli/reg_del/2023/1184/oj/eng).

42. See McMillan, C. et. al. Renewable Thermal Energy Systems: Systemic Challenges and Transformational Policies. National Laboratory of the Rockies Technical Report NREL/TP-7A40-83020, February 2023. Golden, CO: National Renewable Energy Laboratory, U.S. Department of Energy. <https://www.nrel.gov/docs/fy23osti/83020.pdf>

reinforce the same core principle: storage alters delivery profiles but does not generate additional renewable attributes.

By contrast, other utility-scale storage technologies (like compressed air storage and flywheels) lack dedicated accounting frameworks when co-located with renewable generation. In the absence of explicit rules governing direct connection and loss reconciliation, these technologies are typically accounted for using charging-based attribution frameworks that treat storage as a form of load.<sup>43</sup> The absence of tailored treatment in these cases underscores the importance of explicit governance choices: without clearly defined netting and loss rules, co-location alone is insufficient to support differentiated accounting outcomes.

Taken together, these examples suggest that credible accounting for co-located and directly connected storage across technologies relies on a consistent set of principles, including that renewable attributes derive from the underlying energy-producing resource; storage must not increase the quantity of claimable attributes at output (unless accompanied by corresponding retired instruments); losses must be explicitly deducted rather than implicitly absorbed; and netting and loss accounting rules must be clearly defined, incorporating metering data and reconciled at the facility boundary with sufficient specificity to support verification.

**Table 4. Characterization of Accounting Approaches for Co-Located and Directly Connected Energy Storage**

| Framework / Example | Defining Feature                            | Source of Attributes                                                                  | Treatment of Losses                                                                       | Governance Mechanism                                                                                                      | Claims Supported                                    |
|---------------------|---------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|
| California RPS      | Facility reconciliation under netting rules | Attributes originate with the co-located renewable generator and pass-through storage | Round-trip losses, auxiliary load, and other losses are deducted before RPS certification | Revenue-grade metering and reconciliation at defined meter points ensure mass balance and prevent duplicate certification | RPS compliance; renewable electricity certification |

43. See National Laboratory of the Rockies (NLR). Energy Storage: Technologies, Opportunities, and Challenges. Golden, CO: NREL, April 2024. NREL/TP-5R00-89172. <https://www.nlr.gov/docs/fy24-osti/89172.pdf>. The report surveys major electricity storage technologies, including compressed air energy storage and flywheels, but does not describe technology-specific accounting or attribute-tracking frameworks for co-located renewable generation, reflecting the absence of formalized approaches in this area.

| Framework / Example                          | Defining Feature                                                             | Source of Attributes                                                                               | Treatment of Losses                                                                 | Governance Mechanism                                                             | Claims Supported                                |
|----------------------------------------------|------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------|
| <b>EECS / Germany Dedicated Pumped Hydro</b> | Only generation from natural inflows is renewable; pumped energy is excluded | Attributes derive only from natural renewable inflows, pumped power is subtracted                  | Pumping and generation losses reduce output eligible for Guarantees of Origin (GOs) | Accounting reconciles natural inflows, power for pumping, and certified output   | GOs; renewable disclosure and compliance claims |
| <b>EU RFNBO Power-to-X</b>                   | Qualifying dedicated generators directly connected                           | Attributes originate with qualifying generators either directly connected or temporally correlated | Each conversion loss reduces eligible renewable-fuel output                         | Direct-connection rules, temporal correlation, and auditable energy-flow records | Renewable hydrogen and fuel compliance claims   |
| <b>Thermal Energy Storage Systems</b>        | Renewability follows the primary heat source, not the storage medium         | Attributes remain with the underlying renewable heat source                                        | Standard efficiency assumptions or performance factors account for storage losses   | Facility performance accounting and engineering efficiency methods               | Renewable heat and district energy claims       |

## 6. Conclusion

Utility-scale electricity storage is rapidly becoming a foundational component of modern power systems. As deployment accelerates, storage will increasingly shape how renewable electricity is integrated, delivered, and valued across both compliance and voluntary markets. At the same time, storage challenges many of the implicit assumptions embedded in existing electricity and emissions accounting frameworks. By separating the timing of generation, delivery, and consumption, storage introduces new risks to claims integrity—particularly where accounting systems are not designed to reconcile attributes, losses, and ownership consistently across time and across institutional frameworks.

This background report demonstrates that existing approaches to storage accounting fall into several distinct conceptual categories. Some approaches treat storage as load and anchor emissions and attributes to the charging event, prioritizing simplicity and minimizing the risk of double counting, but limiting the ability to characterize outputs in terms of specified power. Others treat storage output as generation within bounded compliance

programs designed to achieve system-level impacts or specific state policy outcomes but have limited applications for consumer-level attributional accounting and claims based on retail clean energy delivery and use.

A third category treats storage as a temporal conveyance mechanism through which attributes may persist across time, subject to mass-balance, chain-of-custody, and instrument retirement requirements. Each of these approaches serves a different purpose and is embedded in different governance contexts. None alone resolves all the accounting challenges introduced when storing clean energy.

Across these frameworks, several consistent principles emerge.

- Renewable attributes originate with the underlying energy-producing resource
- Storage may shift the timing of delivery, but must not increase the quantity of claimable renewable attributes
- Storage and conversion losses must be explicitly accounted through netting or other appropriate reconciliation
- Facility-level operational and metering data are required to demonstrate compliance with mass-balance principles

The survey of co-located and directly connected storage systems further reinforces these principles. Where storage is paired with a specific generation asset, credible accounting frameworks consistently enforce mass-balance constraints and deduct storage losses before recognizing renewable output. These approaches confirm a common policy logic across jurisdictions and technologies: storage can reshape the timing of delivery but should not increase the quantity of claimable renewable attributes unless supported by additional contractual instruments and operational data.

The task before the CEAP Accounting for Utility-scale Clean Energy Storage Working Group is not to choose a single universal accounting model, but to develop guidance that borrows from each of these approaches components required to accurately account for attributes under different use cases while integrating utility-level clean energy storage accounting with existing and emerging attribute markets. In particular, the Working Group must resolve how certificate-based systems, emissions attribution frameworks, and emerging granular accounting regimes can coexist without undermining claims integrity. Clear rules governing attribute attachment, instrument retirement, loss allocation, and temporal matching will be essential to ensure that storage supports the credibility of clean electricity claims and emissions inventories.

Developing useful guidance will become increasingly important as storage continues to scale and as electricity markets integrate more variable renewable generation. By grounding storage accounting in transparent, verifiable principles that preserve exclusivity and credibility, the Working Group can help ensure that storage enhances the reliability and flexibility of the power system while maintaining the integrity of clean energy and emissions reporting frameworks.

## Appendix A – Glossary of Relevant Terms

**Attributes (energy attributes):** Non-power characteristics of produced energy that may be unbundled, quantified, and transferred through contractual instruments, commonly evidenced through Energy Attribute Certificates (EACs), such as Renewable Energy Credits (RECs) (North America) and Guarantees of Origin (GOs) (Europe), but also transacted through other contractual instruments.

**Contractual instruments:** Legal instruments that convey or substantiate the transfer of electricity attributes separately from physical electricity delivery (e.g., EACs, Power Purchase Agreements (PPAs) with attribute conveyance provisions).

**Consumed emissions:** Generation emissions attributed to the final consumer of goods and services rather than to the generator, typically calculated in location-based methodologies as *generation-based emissions - exports + imports*.

**Duration:** How long a storage system can supply power at its rated capacity, calculated as Energy (MWh) divided by Power (MW) ( $\text{Energy} = \text{Power} \times \text{Time}$ ).

**Energy arbitrage:** Inputting energy to storage when prices are low and outputting energy when prices are high to profit from the difference.

**Energy input (charging):** Energy withdrawn from the grid and converted into a form to be stored in a storage asset.

**Energy output (discharging):** Energy output converts stored energy back to a form that can contribute to transmission grid charging or otherwise serve a specific load; System operators typically treat output like energy generation.

**Losses:** All reductions in usable electricity due to conversion inefficiencies and auxiliary consumption, including round-trip efficiency losses, parasitic loads (cooling, controls, plant balancing), and standby losses (thermal leakage, power draining).

**Loss allocation:** The method by which losses accrued by the act of storing energy are characterized based on the generation mix of the energy input to the storage asset. Examples include proportional allocation (based on the percent a particular attribute class represents within the entire input volume), Input gross-up (requiring input volumes to account for estimated round-trip efficiency losses when output), and Attribute-first allocation (assigning losses first to specified input attributes before attributing losses to unspecified input).

**Market-optimized dispatch:** Generally, market dispatch that where storage is employed dynamically to serve both energy supply and grid stability functions.

**Mass balance (within a defined boundary):** The principle that claimable outputs (net of losses) must not exceed eligible inputs over the accounting boundary.

**Parasitic losses (auxiliary losses):** Energy consumed by storage systems for cooling, controls, or balance-of-plant functions.

**Power capacity:** The maximum rate at which a storage asset can input energy at any moment, typically measured in watts (which are equivalent to 1 joule/1 sec), distinct from energy capacity, which is a measure of maximum volume of energy that can be stored in the asset.

**Round-trip efficiency (RTE):** The ratio of electricity discharged from storage to electricity charged, accounting for conversion and auxiliary losses.

**Stand-alone energy storage:** A storage asset that is not co-located or directly integrated (physically or contractually) with a particular energy generating facility and whose stored energy is input from and output to a shared distribution system.

**State of Charge:** The amount of energy stored in a storage system at any given point in time.

**Temporal granularity:** The time interval over which generation attributes are aligned with use or claims (e.g., annual, monthly, hourly).

**Utility-scale storage:** Generally, grid-connected storage owned or operated by utilities, independent power producers, or other market participants, capable of providing system-level services (energy shifting, capacity, ancillary services) and typically sized at approximately 1 MW or larger.



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