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REPRESENTING AVISTA CORPORATION

System Planning Challenges, Technology, and Non-Wires Alternative Playbook

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1. Background and Context

Avista must adapt to industry changes driven by the decarbonization of the electricity supply. The industry's decarbonization journey is complicated by the regulatory mandate for fair electricity access, particularly to disadvantaged communities and populations. The State of Washington Clean Energy Transformation Act (CETA) provides the direction of this mandate.

Decarbonization and energy equity forces combined with load growth beyond historical patterns due to transportation electrification and replacement of other energy resources, such as natural gas and oil, are placing significant new responsibilities and constraints upon Avista's planning, engineering, and operations. Avista's ability to build infrastructure to meet these needs is also constrained by permitting processes, lack of locations, supply chains, and resources. These constraints require Avista to broaden the infrastructure options available for timely deployment that meets our customer's needs.

In addition to these impacts, customer awareness of their carbon footprint and impacts increases pressure on Avista to change its planning and operational policies, practices, and analysis of possible solutions to address capacity, reliability, resiliency, and power quality challenges. Since all grid solutions, wired or non-wired, must be operable, any solution analysis should consider operational flexibility. Operational flexibility brings additional grid benefits, such as energy storage solutions providing capacity and also offering reliability and resiliency.

Decarbonized electricity relying on weather dependent resources (WDR) brings intermittency of supply risks. Mitigating these risks forces consideration of battery energy storage systems (BESS), demand response, and new or upgraded transmission to access carbon-free and conventional generation from external sources. The mitigation strategy to select Avista's most beneficial alternatives and the appropriate volume and scale of each alternative becomes a critical decision. Further, socializing those decisions internally and externally with the appropriate supporting materials is crucial.

Avista is not alone on its journey and Avista can benefit from lesson learned and industry best practices by engaging with other utilities and industry-wide groups. The broader industry's journey is complex because electric utilities are experiencing as significant an industry transformation as our industry has since the days of Edison and Tesla. Electricity supply decarbonization brings greater generation resource distribution and diversity, reaching an energy agnostic state across electricity and sustainable gas. This transformation requires revising electric grid and gas network planning processes to address existing and emerging planning challenges. Society's awareness and focus on energy supply resources and energy consumption increases this transformation's complexity and demands more rapid improvement.

Historically utility grid planning focused on moving electricity from generation to the customer. Today, customers' deployment of renewable generation and storage behind the meter (BTM), third-party investment in supply and storage merchant power resources, and utility customers' establishment of micro/nano grids confound the planning and operations process. Further regulatory pressure to decarbonize asks utilities to enable greater participation by customers and third parties. This "ask" forces grid planning to recognize a non-utility-owned asset's value if interconnected at a specific grid location and requires that non-utility-owned asset to operate when called upon. Facilitating these non-utility assets demands the acceptance of today's two-way electricity grid must facilitate distributed energy resources (DER) and micro/nano grids.

Past planning processes focused on when and where to build new or expand substations, upgrade conductors, and route lines to address capacity and reliability issues, this practice is still fundamental to supporting load growth. Utility system planning success not only required resolving grid challenges, load growth, and addressing existing or emerging customer needs by deploying new equipment, such as conductors, structures, relays, switchgear, and transformers, but also ensuring that deploying this new equipment was accomplished efficiently and economically.

While the planning process must still deliver expanded capacity and greater reliability now, it must also fulfill the expectation of a more demanding and engaged customer and the rapidly evolving availability of DER, storage, and new electricity demand/sourcing from transportation electrification. Further, state regulators are pressuring grid planning to facilitate customer and developer investment to decarbonize more quickly and aggressively.

With a constant stream of innovative technologies and design alternatives requiring consideration, evaluation, and justification, grid planning complexity increases and opens the utility to questions regarding the solutions planning selects and implements. The solutions customers and third parties desire are becoming more ambitious, driven by society's ever-increasing reliability expectations, decarbonization, and desire to maintain low electricity costs. This complexity increases with the imposition of regulatory constraints on grid planning, including:

- Siting
  - **Land cost** – utilities compete with income-producing developments
  - **NIMBY** – adjacent residents may resist electrical installations or expansions
  - **Permitting** – permitting processes and receiving approvals from all stakeholders are increasingly slowing
  - **Space** – limitation forces expensive designs (e.g., gas-insulated substations)
- Societal
  - **Carbon-Free** – renewable electricity must replace fossil fuels
  - **Electrification** – transportation transition and gas replacement
  - **Expectations** – regulators expect a fair evaluation of all viable solutions
  - **Flexibility** – the grid must facilitate non-utility investments

- **Responsive** – society expects the utility to anticipate its needs and listen to non-utility stakeholders
- **Reliability** – society expects electricity to always be available
- **Cost** – society demands low utility cost-of-service by deferring investments
- **Equity** – customer equity for planning investment and facility siting

Uncertainty about the penetration rate of DER, micro/nano grids, and electrification stemming from transportation transition and fossil fuel replacement adds another dimension to the planning processes. As the system planning process evolves, its direction must be fashioned not only by tangible technological advances in energy storage, control capabilities, distributed supply, and electrification but also by intangibles such as the value of reliability, enabling customers DER assets, and equity among disadvantaged populations. Since 2010, the United States has seen a year-over-year residential electricity use decline driven smarter, more efficient electrical consumption and conservation programs. This decline reverses by 2030 because transportation and industrial electrification will return the industry to growth. Forecasting the timing of the growth adds additional complexity to the utility's planning process because electrification and penetration of DER and storage will not appear uniformly or consistently across the utility's service territory.

Lastly, for decades utilities were more alike than different, all having a high degree of similarity across supply and delivery assets. In the future, each region of the United States will be more different than similar because renewable energy relies on wind and the sun as fuel. Some areas have abundant and consistent wind and sun, while others do not. Those without such resources will rely more heavily on transmission to bring carbon-free energy to their customers. Further, those without sufficient local or regional carbon-free resources must deploy longer-duration storage and higher quantities of storage to maintain a reliable supply of electricity. Also, some utilities will be forced to rely on higher capacity factor resources such as sustainable gas or nuclear, augmenting those resources with wind, solar, and storage. Therefore, every utility must adopt a specific strategy to address its unique needs driven by its service territory's ability to produce carbon-free electricity from wind and solar.

2. Purpose and Intent

This document has four primary goals. First, to provide insight into the intent and justification for the system planning process. System planning faces both traditional and emerging challenges, and this document focuses more on those appearing because of electric industry changes raised in section 1.

The second goal is that any solution designed and deployed, whether wired or non-wired, must be operable and supportable by Avista. This goal requires coordination between planning, operations, and maintenance ensuring all solutions considers the impacts on operations and maintenance. That may require readiness considerations and policy changes. The Operating Model [Avista to insert link] is the visual representation of the Avista process that should achieve this goal.

The third goal is to explore how wired and non-wired alternatives address the system planning challenges mapping each challenge into a matrix of practical solutions. This document offers recommendations applicable to wired and non-wire alternatives as guidelines. The Playbook Analysis Matrix [Avista to insert link] is a planning tool to begin the application of practical solutions to identified issues.

The final goal is to identify, analyze, and evaluate emerging technologies, potentially providing new alternative solutions to the challenges of future system planning. The summary of these technologies begins on page 48 of this document. The analysis of technologies includes and is further discussed :

- Viability – what technologies are viable with sufficient detail to support a decision to pilot, deploy, or monitor
- Criteria – evaluation categories, including technology, anticipated maturity, cost expectations, market forces, supplier dynamics, and risk profiles.
- Evaluation approach – beyond the criteria, suggestions on methodology to quickly broaden the evaluation scope to build more defendable justifications for taking or not taking a path forward to address a system planning challenge.
- Evaluation thresholds – many alternatives require a go/no go threshold to enable rapidly reaching a single or set of viable options.
- Benefit streams – identify benefit streams from non-wire alternatives, their pitfalls, and mitigation strategies, including potential utility/customer partnership benefits.

Since the challenges faced by system planning are evolving based on the factors already outlined above, some parameters are required. Time is a key metric to bracket and clone continuous decision processes. This document adopts four timeframes for its analysis. The four timeframes are:

- 2022 through 2024 or "close" – this timeframe considers forecast, technologies, events, and outcomes, which are real or highly likely.

- 2025 through 2028 or "evolutionary" – this timeframe includes forecast, technologies, events, and outcomes, which have a slightly higher error probability but represent a logical evolution from those in the "close" timeframe.

- 2028 through 2035 "next generation" – this timeframe contains forecasts, technologies, events, and outcomes with higher error probability. Today, we can accept we have a reasonable understanding of the dynamics and influences of the trends but specifically analyzing them becomes much more difficult, and even as a group, they may no longer align because of possible disruption.

- Beyond 2036 or "uncertainty" – this timeframe does not consider specific events, results, technologies, or forecasts. Given utility planning horizons, preparing for what could happen remains vital. In this timeframe, only trends that may predict opportunities or threats are discussed, with some justification as to why one could appear and what impacts could result in that appearance. Discussion in this timeframe will be without adequate supporting detail since, in most cases, doing so would be purely assumptive.

A second parameter to frame this playbook is to differentiate fact, observations, and extrapolation on the author's part. The document is color-coded to separate remarks into three categories and allow the reader to exercise their judgment. NOTE: these are used very sparingly.

Each category is color-coded as follows:

- Fact – in standard text color

- Observations – these will be in blue. This category will appear sparingly throughout the document and, in each case, will have supporting reasoning associated with the conclusion drawn.

- Extrapolation – these will be in red. This category is rarely used, but it is important to alert the reader to possibilities, however unlikely they may be. In particular, the opportunities and threats that could appear beyond 2029 and the associated discussion will be color-coded in red.

3. What is and is not in this document

3.1. *What does this document contain?*

This document focuses on the following areas:

- System planning needs and concerns are referred to as "challenges." These challenges are driven by both historical grid planning requirements and the shifting landscape with distributed energy resources and micro/nano grids, evolving customer ambitions and expectations, and external pressures from regulators and the broader society.

- Available and emerging technologies could provide non-wire alternative solutions with attention to capability, economics, market penetration, and maturity.

- The confluence of the two areas above produces guidelines and recommendations of what non-wire alternatives may be viable to address which challenge in the four specific timeframes.

3.2. *What does this document not contain?*

It is essential to provide the boundaries for this document and where it cannot provide value. This document does not address the following:

- Micro/nano grids (example in Figure 1) – stand-alone micro/nano grids significantly impact the electric grid. However, since a micro/nano grid must have load as well as contain electricity supply, either in the form of renewable or fossil generation or storage, a micro/nano grid is nothing more than a combination of technological solutions and programs (e.g., demand response), which can function grid-connected and partially or wholly self-sufficient.

- The micro/nano grid's load could be greater or less than the energy the micro/nano grid can self-supply. If the supply exceeds the load, the micro/nano grid can export electricity to the grid or charge storage, if available, and the state-of-charge (SOC) allows.

  Regardless, a micro/nano grid would represent merely a combination of the technologies covered in the document. The primary consideration for the utility regarding micro/nano grids is:

  - Will the utility operate third party-owned micro/nano grids?

  - Will utility deploy utility-owned micro/name grids comprised of DER, supply, storage, or supply with storage, and, if so, where?

  - What is the utility's role in micro/nano grids' operations behind the meter – monitoring or monitoring and control?

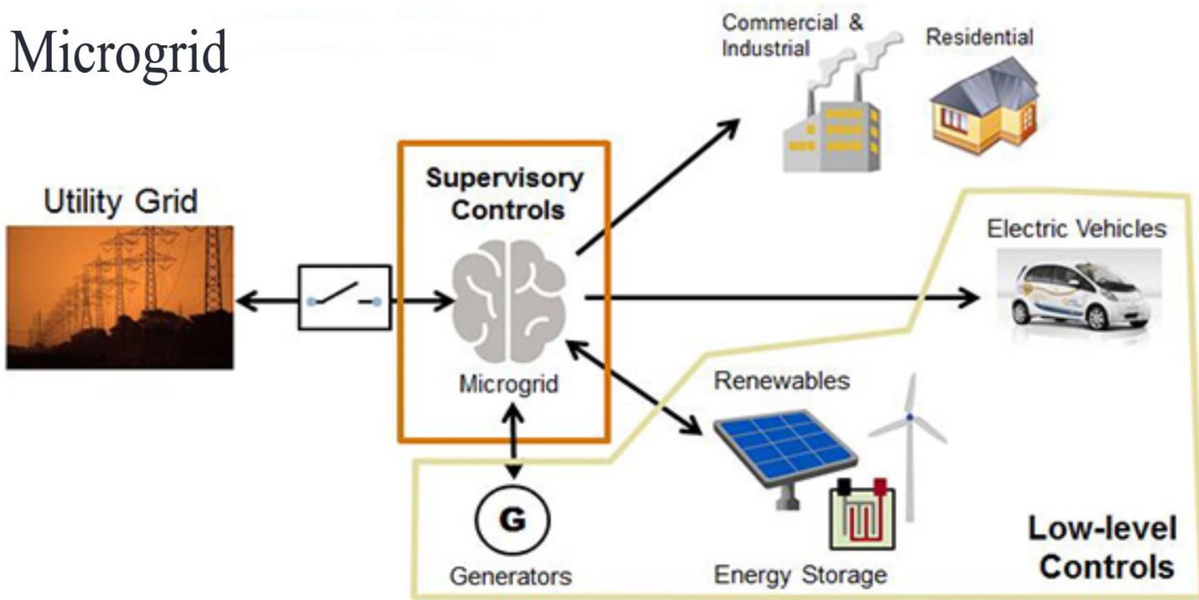

Figure 1 – Microgrid

- Specific guidance on individual planning challenges since each planning challenge is situational and location specific. Consequently, each challenge demands an analysis of the circumstance, its needs, location(s), constraints, and benefit streams to realize a justifiable outcome that solves the specific need. This document will not be mute or lacking examples of our guidelines to provide an analysis path.

- The nuances are related to the system planning project's details that will not be addressed but instead used to generalize thresholds and guidelines, enabling go/no go decisions, and providing direction to reach more precise answers.

- The business-as-usual areas (e.g., wired solutions) are well-known and do not require detailed discussion or tutorials.

- Precise and detailed cost information on emerging technologies. The focus will remain on cost trends and market drivers because detailed cost information becomes dated quickly as technology issues appear or technology scale is achieved.

- Policy guidance beyond the need for rates to specifically incent behavior such as electric vehicle charging rates.

- Discuss operational strategies such as distributed energy resource dispatch or micro/nano grid operation.

4. Standards, Protocol, and Related Documents

This document doesn't stand alone but is part of a document suite that supports the planning process. The documents referenced in this chapter contribute to improving and enabling the planning process. Central to the planning process is the operating model with the capabilities necessary to execute the planning process successfully. Those capabilities are:

- **1.1 – Evaluate Emerging Technologies** - This capability looks ahead to research, monitor, and evaluate Avista implications regarding alternative technologies (NWA, DER, OT, etc.) available in the industry. Potential technologies evaluated include automation, software systems, DER technologies and other NWA solutions to confirm their applicability (cost, performance, and suitability) to solve one or more problems identified during the planning process.

- **1.2 – Introduce and Train New Technologies** - This capability looks to introduce, test, simulate, and train within Avista new technologies and equipment. Both lab and field training environments should be utilized to build new technology confidence and core competency skills.

- **1.5 – Solution Identification** - This capability identifies and analyzes mitigation alternatives to address system needs. Alternatives will include wired, non-wired (NWA), and hybrid (wired + NWA) alternatives and include alternatives involving third-party or customer partnerships / actions (such as DR). It also specifies the implementation and operational assumptions, costs and benefits associated with each solution option.

- **1.8 – Evaluate Solution Performance** - This capability analyzes solution performance actuals versus planned performance including capital investment and associated operating and maintenance costs. Broad spectrum of performance metrics, e.g., ease of implementation and operational flexibility.

Related documents that support the planning process and tie to this playbook are:

- Performance criteria - TPL-001-WECC-CRT-3.2.pdf
- NERC standards - US Reliability Standards (nerc.com)
- Transmission standards – OASIS site - OATI OASIS

Standards Policies and Procedures

- SP-SPP-02 Facility Interconnection Requirements
- TP-SPP-00 Standards, Policy and Procedures
- TP-SPP-01 Avista Bulk Power System Planning Standa
- TP-SPP-02 Use of Uniform Identifiers
- TP-SPP-04 Data for Power System Modeling and Anal
- TP-SPP-06 Contingency Analysis
- TP-SPP-07 Loads and Resources Data Preparation
- TP-SPP-08 FERC 715 Filing
- TP-SPP-09 SOL for the Planning Horizon
- TP-SPP-10 Relay Loadability
- TP-SPP-11 Transfer Capability Assesment Metholodog
- TP-SPP-12 Generator Data Verification
- TP-SPP-13 Power Swings
- TP-SPP-14 Physical Security Assessment

Figure 2 – Standard Policies and Procedures

- Distribution standards – Avista to add a future link – documentation is being developed.

5. System Planning Needs and Concerns

This document does not treat all the areas and their components with an equal level of detail. In general, the needs drive the level of detail to those emerging areas which are less well-understood and away from the mature and well-developed ones. Those areas and their well-known accepted and understood components have less detail and supporting examples or are business-as-usual. The emergent challenge areas and their components have a higher definition and detail. This greater detail should drive consideration of pilots, pilot formation, and pilot characteristics, such as design, location, timing, partners, the definition of success, and anticipated lessons learned to evolve into business-as-usual best practices. Also, it will identify, where possible, utilities that have already put pilots in motion.

The classical system planning needs and concerns are:

- Capacity
- Reliability
- Resiliency
- Power quality

A detailed classification of the challenges enables a more thorough identification and analysis of benefit streams that deliver the most attractive project cost versus project benefit. In the future, the likelihood is a specific project's evaluated costs will shift markedly if just Avista's benefit streams or both customers and Avista benefit streams are considered. Partnership-based benefit streams increase the system planning complexity, and thoughtful classification of the challenges, their size, and a project's ability to address them ensure transparency and adequate justification.

Although system planning usually classifies a specific grid need into a single challenge category, most needs have components in multiple categories, with one or two being dominant. Of the four classical system planning challenges (needs and concerns), the two most coupled are capacity and reliability, and many times, both are significant. The other challenge categories, often capacity or reliability, will be major needs and resiliency or power quality, minor. Although this hybridization of challenges clouds consideration of a specific project's intent, it also exposes additional benefit streams if addressing the challenge resolves some or all both the major and minor groupings. Lastly, these challenges can be forward-looking based on the understanding that economic development may bring an opportunity to expand service while addressing existing needs.

The section contains two additional planning challenges, operational flexibility and alignment/ compliance with Washington State law called the Clean Energy Transformation Act.

The matrix in section 5.7 provides a more detailed breakdown of the system planning needs and concerns and includes core services, a key part of the planning process.

5.1. *Capacity*

Since a utility's IRP addresses system-wide capacity in both a general and specific on-peak context, the capacity challenge that system planning faces, and this document addresses, focuses on block loads, localized capacity shortages, and inability to deliver capacity to specific areas; historically, system planning addressed block load on an individual, as-needed basis, and in the future, it will likely remain as such. Fleet electric vehicle charging will appear as block loads more frequently, with many logistics companies already electrifying their fleets. These new block loads will be located near existing facilities the utility already serves with their existing grid infrastructure and could present significant increases in load at specific times, driven by operational needs and the utility's rate structure. Fleet operators will electrify based on locational decarbonization pressure and by the electricity costs, drivers that do not align, making forecasting the timing on Avista's service territory more challenging.

Localized capacity problems could result from the uneven penetration of private electric vehicles. A reasonable expectation is that an identical neighborhood could see load growth differentials up to five times. One neighborhood's coincident load could be vastly different, with many customers charging two electric vehicles per premise concurrently. Simultaneously, an identical neighborhood with marginal electric vehicle penetration may experience loads consistent with its historical norms.

In the future, capacity challenges will become more widespread and appear randomly until our ability to predict electric vehicle penetration improves or a consistent adoption level occurs.

5.2. *Reliability*

Today, the reliability challenge captures much of system planning's time and effort. With our industry's keen focus on reliability over the last 20 years and the introduction of standardized, quantitative measures such as SAIDI, SAIFI, and to a lesser degree, total customer minutes or CEMI, these reliability metrics provided a means of performance comparison between utilities. These comparisons are inherently flawed unless care is taken to understand the utilities' service territories. For example, a utility with a significant underground mesh network, sometimes called a spot network, will have significantly higher reliability metrics than a similar utility with an identical customer count that does not have an underground network. Lacking more representative measures for comparison, SAIDI and SAIFI remain, but as the sophistication for calculating SAIDI and SAIFI grew, other comparators, such as CEMI, appeared. CEMI is the percentage of a utility's customers experiencing multiple outages yearly. They are usually expressed as either CEMI3, the percentage of a utility's total customers experiencing three outages per year, or for lower reliability utilities as CEMI5, for the percentage experiencing five outages per year. CEMI is an essential metric for both reliability and resiliency. Grouping CEMI customers by circuit or feeder can quickly lead to an awareness of grid circuits requiring system planning's attention.

Although JD Power's ratings measure the overall utility's perception by their customers, it may not be as valuable a metric for system planning as those above. The JD Power's surveys compare regional utilities based on customer counts or size. Further, JD Power surveys residential and business customers separately. JD Power's Digital Experience rating results from studying customers' perception of a utility's digital presence and the effectiveness of their customer engagement via utilities deployed digital solutions. For this document, JD Power's Residential and Business Customer ratings and JD Power's Digital Experience ratings are not considered reasonable metrics to measure reliability because multiple factors influence these ratings. For example, since JD Power's ratings represent only the surveyed customers' perception, which may include other considerations beyond reliability, such as electricity price, environmental posture, community role, and others, it is difficult to gauge reliability accurately in the ratings.

5.3. *Resiliency*

Resiliency is the ability to withstand and recover from an outage. On a national level, resiliency became much more common as a system planning challenge in the years immediately following Super Storm Sandy. Since it is a more recently defined challenge, the industries' quantitative metrics do not accurately reflect and enable utility comparisons. One metric used to quantify resiliency is the percentage of customers experiencing extended outages or CESO. Hidden in this metric is the lack of a clear definition of an "extended outage," resulting in highly variable outcomes. For example, outages often stem from multiple causes during a single event. Some outages are embedded within or nested inside a larger group of customers experiencing an outage. Only restoring a subset of the outraged customers exposes the nested outage. The utility's treatment of nested outages, either calculating the outage length per customer based on the actual time out of service or opening another outage when the nested outage is confirmed, dramatically influences their CESO results, an interesting but less insightful mechanism for comparison between utilities. If calculation rules are consistent and followed within a utility, CESO can provide a valid and vital metric to measure resilience over time.

Resiliency initially focused on recovery or restoration, which remains essential today. More recently, however, the focus shifted sharply to outage minimization or avoidance. Simply put, utilities quickly understood not having an outage or automatically minimizing an outage's scope using technology-delivered benefits. These benefits include:

- Reduce
    - Truck rolls
    - Labor
    - Mutual Aid
    - Contractors
- Improved metrics for
    - SAIDI – System Average Interruption Duration Index (total duration of sustained interruptions in a year / total number of consumers)

- SAIFI – System Average Interruption Frequency Index (total number of sustained interruptions in a year) / (total number of consumers)
- CEMI3, CEMI4, CEMI5 – Customers experiencing more than X (3, 4, 5) non-momentary outages per period (day, week, month, quarter, year)

- Customer satisfaction
- Fewer complaints to the utility or the regulator
- External perception by
    - Regulators
    - Politicians

Technology supporting resiliency improvement continues to move forward quickly with the introduction of new field devices like low-cost, remotely controllable interrupters and system-wide solutions such as Advanced Distribution Management System's functionality, Fault Isolation, and Service Restoration FLISR, which are already delivering benefits to utilities today. While awaiting the alternative technologies' maturity, most utilities rely on improving their grid's resiliency by using traditional and widely accepted solutions such as reclosers, distance-to-fault relays, and remotely controllable sectionalizing switches.

5.4. *Power Quality*

Power quality remains a catch-all system planning challenge for most "lights-on" issues. Historically, this power quality challenge was voltage-centric. Power quality challenges usually begin with the customer experiencing:

- Low-voltage or brownouts
- High-voltage or voltage spikes result in electrical equipment damage.
- Flicker
- Harmonics

Diagnosing power quality discrepancies has always been complicated because these discrepancies are often intermittent. The intermittency can be related to the following:

- Electricity is used by the customer or by a neighboring customer.
- Electrical equipment is owned by the customer or by a nearby customer.
- Times when a circuit is heavily or lightly loaded.
- Faulty or failing equipment in the grid.

- Lack of adequate grounding

Historically, intermittent power quality challenges required longer-term monitoring with specialized equipment. With the introduction of advanced smart meters, voltage analysis became straightforward because smart meters provide instantaneous minimum non-zero and maximum voltage within each meter reading interval. With widespread smart meter deployment, diagnosing voltage-related power quality challenges became easier, while addressing non-voltage issues requires in-depth analysis.

The introduction of conservation voltage reduction, CVR, and voltage/var optimization, VVO, to reduce energy demand and losses uncovered latent power quality issues not visible before. Still, modern electrical equipment is becoming more tolerant of small power quality issues than equipment from 20 years ago. Regardless, the customers' expectation of power quality continues to grow because of their increasing reliance on smart devices and awareness of power fluctuations.

The frequency of high and low voltage problems has increased with the higher penetration of distributed energy resources, specifically distributed roof-top solar installations. Those utilities with pockets of high roof-top solar penetration receive more frequent complaints about power quality. During times of significant solar production and lighter demand on the local portion of the grid, the voltage can rise to a level where sensors embedded in the inverters on the solar installations disconnect the network's installation to protect it from a voltage spike. A corresponding event occurs when the circuit cannot immediately compensate for a sudden drop in solar production, resulting in a momentary low-voltage issue.

5.5. *Grid and Operational Flexibility*

Operational flexibility represents a new system planning challenge created as the grid moves from one-way to bidirectional, complicated by rapid technological and economic changes driving customers' expectations of the grid and by the drive for a carbon-free future. This stage of the grid's evolution is typified by utility challenges caused by customers and needs resulting from customer expectations.

A former symptom manifests today as a power quality challenge, discussed under section 5.4 as a voltage issue. Treating this as a voltage issue is adequate for now, but the scope of the challenge ahead is much greater and less predictable. Operational flexibility challenges could quickly appear with surprising speed in unexpected locations in the future as more DER, storage, and load growth appear.

Although not expected to be a significant issue, the long-term impact of reverse flows on grid equipment is unknown. Thermal equipment limits could be tested with flows from distributed roof-top solar installations, as is the reality today in Southern Germany. Roof-top solar panel production drops sharply in a few seconds when panels are deprived of sunlight but recovers slowly, in minutes, when sunlight strikes the panels again. These fluctuations will have unknown impacts on both the customers' equipment and the grids. System planning will need to anticipate these impacts and plan for their eventuality.

Planning the system to address customer expectations and enable customer choice is a significant challenge because of the commercial market dynamics. Today, the cost differential between roof-top solar panel solutions is driven by installation costs. Should that change and a technology breakthrough drive cost sharply lower, or a major roof-top solar supplier come to our region, distributed solar penetration could explode. It is less likely that such a change will occur in the distributed roof-top solar space unless there is a government mandate for new construction or other financial incentives to retrofit existing structures.

The energy storage space is ripe for disruption by technological advances and external forces. This space is emergent, and the automotive sector controls the battery market. The automotive sector's dominance brings higher uncertainty to the electric utility industry because vehicle manufacturers enable unprecedented volumes and scale, shifting costs sharply lower or allowing significant competition for in-home batteries if there is a downturn in vehicle sales. A disruption enabling widespread deployment that is economically attractive and technologically feasible could rapidly demand an adjustment to the system planning process, drive more non-wire alternatives, and offer utility/customer partnership opportunities.

Higher distributed energy resource penetration will expose unexpected weaknesses in the grid, forcing system planning to address specific issues and adopt new best practices to accommodate customers' BTM investments. At stages of roof-top solar penetration, grid reinforcement will be required to ensure additional roof-top solar deployments can be supported. This cycle will repeat itself during several levels of penetration.

System planning needs to enable customers and provide for system flexibility, accommodating rapid change while ensuring an adequate electricity supply.

5.6. *Clean Energy Transformation ACT*

On May 7th, 2019, Washington State's Clean Energy Transformation Act was signed into law. CETA addresses the following:

- Electric Utility Generation (impacts sixty utilities in the state)
    - 80% carbon-free by 2030.
    - 100% carbon-free by 2045
    - Fail to comply by 1/1/2030 results in a penalty of $100/MWH
- Utility Gas Supply
    - Pursue electrification
    - Heat pumps
    - State zoning changes (Washington State 1257)

  - All new large commercial buildings cannot utilize natural gas w/o a waiver
  - Likely a similar standard will apply to smaller commercial buildings by the end of 2024 (>20,000 square feet)
  - Possibly extended to all new construction and eventually retrofit subject to the possible conflict with local zoning ordinances
- Energy Equity
  - Vulnerable populations – mean communities that experience a disproportionate cumulative risk from environmental burdens due to:

    o Adverse socioeconomic factors, including unemployment, high housing and transportation costs relative to income, access to food and health care, and linguistic isolation; and

    o Sensitivity factors, such as low birth weight and higher rates of hospitalization.
  - Highly impacted communities – means a community designated by the Washington Department of Health based on cumulative impact analyses in section 24 of this act or a community located in census tracts that are fully or partially on "Indian country" as defined in 18 U.S.C. Sec. 1151.12.

    Identification of geographic communities impacted by fossil fuels and climate change can be found by using the Washington Environmental Health Disparities Map.
  - Named Communities – both vulnerable populations and highly impacted communities together are Named Communities; this term is more commonly used

Non-wire alternative consideration by utility system planning must be considered because of CETA. Further, utilities must consider energy equity as part of the assessment of any solution to address planning challenges and other evaluation criteria. The consideration must be documented as part of the justification.

Each utilities implementation of CETA is documented in their Clean Energy Implementation Plan (CEIP). Avista's most recent CEIP describes the Company's the specific targets, customer benefit indicators (metrics), specific actions, and incremental costs to be compliant with State of Washington law.

5.7. *Applicability Matrix*

The planning process is both diverse and complex. This document offers guidance to those executing the planning process in its use of technology solutions. The following matrix provides the planner with general direction and guidance on the applicability of solutions to planning needs and concerns.

The columns break down the planning needs and concerns in more granular detail. The rows depict the planning solutions. The intersection shows the applicability as a Harvey Ball, and the color indicates the solutions' maturity.

Matrix Legend

Not an Applicable Solution = 0
Very Limited Applicability = 1
Possibly an Applicability Solution = 2
Applicability Solution = 3
Highly Applicability Solution = 4

Green = available for production (cost & risk acceptable)

Blue = available for pilot (cost and/or risk remain high)

Red = too early to deploy (cost and risk unacceptable)

	Reliability					Safety		Capacity					Power Quality	
	Outages							Load Growth		Peak Support				
	Prevent (SAIFI)	Shorten (SAIDI)	Shorten (CAIDI)	Reduce (CEMI3)	Vulnerable Customer Resiliency	Mitigate Wildfire	Short Circuit	Transportation Electronification	Electrification (replace gas)	Summer	Winter	8,760 Hours	Voltage	Flicker & Harmonics
Wired Alternatives														
Asset maintenance	●	●	●	●										
Asset replacement	●	◕	◕	●				●	●					
Addition of reclosers	●	◑	◑	●										
Addition of fault indicators		◕	◕											
Addition of fuses	●	◑	◑	●										
Addition of regulator/capacitor								◑	◑				●	◕
Spacer cable	◑			◔		◑								
Fuse replacement/interrupters	◕	◑	◑	◕		◑	◕							
Sectionalizing switches (load-break)		●	●											
Feeder tie or lateral Tie		●	●					◔	◔	◑	◑			
Enhanced vegetation management	●	●	●	●		●								
Tree wire	◑			◑		◑								
Grid hardening (wildfire resiliency)														
Crossarm replacement	◕	◔	◔	◑		◕								
Conductor replacement (#4 ACSR)	◑	◑	◑	◔		◕	◕						◑	
Convert open wire districts	◑	◕	◕	◑		◑								
Add ampact/bail to hot tap connections	◑	◑	◑	◑		◕								
Replace high-value wood structures with steel	◑	◔	◔	◔		◕								
Install animal guards	●	◑	◑	●		●								
Load shifting (circuit reconfiguration)								◑	◑	◑	◑		◑	◑
New infrastructure (re-route or extension)						◑		◑	◑	◑	◑		◑	◑
Reconductor (conductor upgrade/upsize)						◑	◑	◕	◕	◕	◕	◕	◑	◑
Underground conversion	◕	◕	◕	◕		●								
New feeder							◑	◕	◕	◕	◕	◕	◑	◑
Upsized/add substation transformer							◑	◕	◕	◕	◕	○	◑	◑
New substation							◑	◕	◕	◕	◕	◕	◑	◑
Addition of phase(s)								◕	◕	◑	◑	◑	◕	◕
Increased SCADA telemetry		◑	◑			◕							◑	◑
Digital substation		◑	◑					◕	◕	◕	◕	◕	◑	◑
Mobile (temporary) generation		◕	◕		◕					◑	◑			

Figure 3 – Matrix - Wired Alternatives (1 of 2)

	Operational Flexibility	Core Services						CETA Compliance		
		New Connections				Field Work				
	Microgrids	Traditional	Supply Interconnections	Supply & Storage Interconnections	Block Loads	Scheduled Work	Emergency Repair	Energy Equity	Economic Development	Decarbonization
Wired Alternatives										
Asset maintenance										
Asset replacement					●					
Addition of reclosers			◑	◑						
Addition of fault indicators										
Addition of fuses										
Addition of regulator/capacitor					◑					
Spacer cable										
Fuse replacement/interrupters										
Sectionalizing switches (load-break)	◑									
Feeder tie or lateral Tie	◑				◔	◕	◕			
Enhanced vegetation management										
Tree wire										
Grid hardening (wildfire resiliency)										
Crossarm replacement										
Conductor replacement (#4 ACSR)										
Convert open wire districts										
Add ampact/bail to hot tap connections										
Replace high-value wood structures with steel										
Install animal guards										
Load shifting (circuit reconfiguration)	◑					◕	◕			
New infrastructure (re-route or extension)	◑	●	◕	◕	●					
Reconductor (conductor upgrade/upsize)		◕	◕	◑	◕					
Underground conversion										
New feeder	◑	◕	◕	◕	◕				◑	
Upsized/add substation transformer		◕	◕	◕	◕	◕	◑			
New substation		◕	◕	◕	◕	◕	◑		◑	
Addition of phase(s)		◑	◑	◑	◑					
Increased SCADA telemetry			◑	◑						
Digital substation		◕	◕	◕	◕				◑	
Mobile (temporary) generation						◕	◕	◑		

Figure 3 – Matrix - Wired Alternatives (2 of 2)

	Reliability					Safety		Capacity					Power Quality	
	Outages							Load Growth		Peak Support				
	Prevent (SAIFI)	Shorten (SAIDI)	Shorten (CAIDI)	Reduce (CEMI3)	Vulnerable Customer	Mitigate Wildfire	Short Circuit	Transportation Electronification	Electrification (replace gas)	Summer	Winter	8,760 Hours	Voltage	Flicker & Harmonics
Non-Wires Alternatives														
Transmission Connected														
Remedial action schemes												◑		
Dynamic line rating										◑	◑	◑		
Series compensation										◑	◑			
Hydrogen fuel-cell														
Storage														
Short-duration (<=8hrs.) - lithium (NMC, LFP, LTO)														
Medium-duration (>8hrs.& <=72hrs.)								◑	◑	◑	◑			
Long-duration (>72hrs.)								◑	◑	◑	◑			
Distribution Connected														
Natural gas generation		◑	◑		◕					◑	◑			
Distribution automation FDIB (FLISB)	●		●											
Resource aggregation - virtual power plant										◕	◕	◔		
Automatic feeder reconfiguration (load shifting)										◑	◑			
Load balancing										◕	◕		●	◕
Demand response								◕	◕	◕	◕			
Energy efficiency												◕		
Remedial action schemes							◑							
Wind													◑	
Solar										◕		◔	◕	
Hydrogen fuel-cell					◕			◑	◑	◑	◑	◑		
Storage														
Short-duration (<=8hrs.) - lithium (NMC, LFP, LTO)		◑	◑		◕			◕	◑	●	●		◕	
Medium-duration (>8hrs.& <=72hrs.)		◑	◑		◕									
Long-duration (>72hrs.)		◑	◑		◕									
Portable storage					◑					◑	◑			
Immediate response storage (e.g., fly-wheel)					◑								◕	◑
Behind the Meter														
Wind													◑	
Solar										◑		◕	◕	
Natural gas generator					●	◑		◑		◑	◑			
Demand response								◕						
Hydrogen fuel-cell					◕			◑	◑	◑	◑			
Storage														
Short-duration (<=8hrs.) - lithium (NMC, LFP, LTO)		◑	◑		◕			◕		◕	◕		◕	
Medium-duration (>8hrs.& <=72hrs.)		◑	◑							◔	◔			
Long-duration (>72hrs.)		◑	◑											
Microgrid														
Eco-district								◕	●	◕	◕	◕		
Fossil generation					●	◕				◑	◑			
Renewable generation										◑			◑	
Stand-alone Storage					◕					◕	◕		◕	
Fossil generation w/ storage	◑	◑	◑	◑	●	◕				◕	◕		◕	
Renewable generation w/ storage	◑	◑	◑	◑	●	◕		◕	◕	◕	◕	◕	◕	

Figure 4 – Matrix-Non-Wires Alternatives (1 of 2)

	Operational Flexibility	Core Services						CETA Compliance		
		New Connections				Field Work				
	Microgrids	Traditional	Supply Interconnections	Supply & Storage Interconnections	Block Loads	Scheduled Work	Emergency Repair	Energy Equity	Economic Development	Decarbonization
Non-Wires Alternatives										
Transmission Connected										
Remedial action schemes			◑	◑						
Dynamic line rating			◑	◑						
Series compensation			◑	◑						
Hydrogen fuel-cell										
Storage										
Short-duration (<=8hrs.) - lithium (NMC, LFP, LTO)					◑					◕
Medium-duration (>8hrs.& <=72hrs.)										◕
Long-duration (>72hrs.)										●
Distribution Connected										
Natural gas generation						◑	◑			
Distribution automation FDIB (FLISB)	◑									
Besource aggregation - virtual power plant	◕									◑
Automatic feeder reconfiguration (load shifting)	◑					◕	◕			
Load balancing										
Demand response					◕			◑		◕
Energy efficiency		◑	○	○	◑			◕		◕
Remedial Action Schemes	◑	○	◑	◑						◕
Wind								◑	◑	●
Solar								◑	◑	●
Hydrogen Fuel-cell					◑					◕
Storage										
Short-duration (<=8hrs.) - lithium (NMC, LFP, LTO)					◑			◑	◔	◕
Medium-duration (>8hrs.& <=72hrs.)									◑	●
Long-duration (>72hrs.)								◑	◑	●
Portable Storage						◕	◕	◑	◑	
Immediate response storage (e.g., fly-wheel)										
Behind the Meter										
Wind									◑	◕
Solar								◑	◑	●
Natural gas generator										
Demand response								◑	◑	◑
Hydrogen fuel-cell									◔	◕
Storage										
Short-duration (<=8hrs.) - lithium (NMC, LFP, LTO)					◑			◑	◔	◕
Medium-duration (>8hrs.& <=72hrs.)								◑	◑	●
Long-duration (>72hrs.)								◑	◑	●
Microgrid										
Eco-district	◕				◑			◑	◕	●
Fossil generation	◑				◑					
Renewable generation	◑				◑			◑	◑	●
Stand-alone Storage	◑				◑				◔	◕
Fossil generation w/ storage	◕				◑					
Renewable generation w/ storage	◕				◑			◑	◑	●

Figure 5 – Matrix-Non-Wires Alternatives (2 of 2)

5.8. *Summary and Direction*

Each system planning challenge is evolving, and some specific direction is uncertain. With that understanding, some predictions are possible, but the areas with the least clarity are:

- Capacity will become a localized issue in the face of declining load per premise, increasing premise count, early-stage distributed roof-top solar deployment, and uncertain transportation electrification.
- Reliability will continue to be the number one challenge that system planning must face, although its nature may change as more distributed energy resource deployment and transportation electrification occur.
- Resiliency becomes the fastest growing challenge because of pressure for fewer and short outages.
- Power quality challenges can become more frequent; however, their impact will remain low.

6. Programs That are or Will Impact Utility Planning

Controllable load is a critical component of a decarbonized future because DR can reduce load when the electricity supply from non-emitting resources cannot meet load and storage is depleted. With the rise of DERs bringing distributed and centralized non-emitting supply and storage into the grid, standard programs, such as demand response (DR), will have to evolve.

In the future, DR programs will have a key role, but much DR will be embedded in micro/nano grids, each with supply/storage and load. A micro/nano grid can reduce its reliance on grid power by completely or partially self-suppling, reducing storage charging, or simply reducing load like a traditional DR resource. The future of DR will be ensuring the load is controllable, will respond when needed, and certainty of economic compensation to load reduction providers.

6.1. *Demand Response*

Demand response targeted peak shaving or peak shift. Several RTO/ISO have demand response market categories, which usually pay for the obligation or participation, with some paying for both. It provides additional compensation for the volume of the reduction if the market calls for it. Demand response programs have been successful primarily with commercial and industrial customers, although a significant effort is underway to capture residential customers. Initially driven by a few public utilities and third-party aggregators, such as Comverge (now Itron) and EnerNOC, traditional utilities, today both IOUs and Publics offer demand response programs subject to their needs. These programs offer economic incentives for load reduction. Demand response agreements frequently are limited by the following:

- The duration of the load reduction
- Size of the reduction
- The frequency of the reduction
- When reductions can occur (season, week, day, hour, and so on)

There are many approaches to demand response, but the following are the most common:

- Direct load control – the electricity user contracts with a third party or utility to reduce load. The user cedes control to the third party or utility, allowing them to reduce the load within the contractual terms.
- User-managed load control – the electricity user contracts with a third party or utility to reduce load. The utility or third party notifies the user when a reduction is required and actively takes the necessary action to reduce the load within the contractual terms.
- Appeal-based load control – the electricity user contracts with a third-party or utility to reduce load, and a third party or utility notifies the user that a reduction is required, and the user

decides if they will comply with the request. The contractual terms specify the user's options, including a commitment of a certain number of hours or energy-reduced per year.

Demand response requires the customer to participate, either actively or passively, as indirect load control. Regardless the customer reduces electricity consumption and must adjust their behavior and activity to accommodate that reduction. Ensuring the customer is fulfilling their commitment requires the utility to measure and validate the customer reduction. Customers may not respond as anticipated leaving the utility seeking reductions elsewhere, purchasing additional electricity, or generating more expensive and higher emission resources.

DER and micro/nano grids will replace some or all the demand response programs in the coming years. DER, in the form of storage, provides an exciting alternative to manage the load by storing electricity when it is abundant and delivering it to reduce the Peak. Further, this approach has the attraction of continuing to serve the load and not shifting or prolonging the Peak.

Micro/nano grids provide an attractive alternative to demand response. Moving specific commercial and industrial customers into a utility-owned or privately owned micro/nano grid could reduce load and only operate when incentives are available to the electricity user. Utility-owned micro/nano grids could alleviate customers' need to reduce consumption, reduce demand response incentives, and protect revenue while providing the utility with increased operational flexibility and customer resiliency. Such an approach could be particularly attractive to combined electricity and gas utilities if fuel cell cost-competitiveness improves.

6.2. *Critical Peak Pricing*

In California and a few other areas, Critical Peak Pricing (CPP) was implemented to reduce energy demand at times of the day. CPP uses a customer-specific or customer class baseline of electricity consumption, below which electricity cost is modest. High wholesale market prices or a power system emergency occur, resulting in a CPP announcement, which raises electricity costs for a specified duration. If the regulatory body, the wholesale market operator (RTO/ISO), or utility announces a CPP event, all consumption above the customer's baseline incurs a significantly higher cost. CPP's rules require notification to its participants before the beginning of a CPP price going into effect, usually one day in advance.

For example, in some parts of California's East Bay, the residential baseline is set based on the December 1997 consumption. Energy consumed below the baseline is priced at approximately 14 cents per kWh, while electricity consumed above the baseline costs 38.9 cents per kWh.

There are two versions in California and New Jersey, where CPP rates exist. When the controlling entity, such as a utility or the RTO/ISO, anticipates a wholesale price excursion, a CPP is called for a predefined rate and enforced for a specific duration. The second is an emergency or unexpected event. For an unforeseen event, such as a weather or transmission failure, which requires a load reduction, a CPP event provides an economic penalty to reduce load.

CPP is independent of all other rates and contractual terms. CPP has limited usage in the United States, primarily in California and New Jersey. CPP is challenging to manage because the evaluation of its necessity is resource-intensive to be fairly instituted across customers. It is also billing intensive, requiring significant investment to charge customers accurately and address customer disputes.

With regards to CPP, according to the California Statewide Pricing Pilot, California utilities averaged 5 to 15 CPP events per year, which varied by date and duration among utilities. Residential households with sophisticated end-use controls dropped 41% of baseline load over the 2-hour hot-weather CPP events. Homes that did not have those end-use controls only dropped an average of 13% of baseline load over 5-hour hot-weather CPP events.

In practice, CPP suffers from a practicality issue. Targeting customers most likely to use and benefit from a CPP rate would offset the resource-intensive aspect of its adoption. However, providing benefits to only specific segments of a utility customer base creates equity concerns. This inequality was particularly evident when considering California roof-top solar adoption was most prevalent for upper middle income and wealthier homeowners, shifting the cost burden to those with less income renting or leasing their residence.

California began phasing out CPP in January 2020, when the state moved to mandatory Time-of-Use pricing. CPP's rates end as soon as TOU rates are put in place and tested area by area across California. New Jersey also plans to end CPP rates over the next two years, although New Jersey has rarely exercised the CPP.

6.3. *Time of Use Rates (TOU)*

TOU rates provide customers with lower-cost electricity during off-peak hours. TOU plans vary widely based on the utility's desired outcome to incentivize or penalize. Some TOU rates are seasonal. Additionally, cost tiers range from two price brackets, on- and off-peak, to as many as four. Lastly, some utilities have multiple TOU plans to drive specific consumer behavior. Regardless of the plan's rate structure, prices are preset and do not vary based on external factors such as wholesale market prices.

Most TOUs have been instituted and evaluated through pilot programs, allowing utilities to assess strengths and weaknesses before full-scale implementation. Alternatively, as was the case in Massachusetts, ending the implementation of a TOU rate plan for Eversource utility customers and replacing it with demand charges for net metering.

Many TOU pilots were terminated earlier than anticipated because they were not achieving the desired effect. Many other TOU programs were terminated or modified after failing to prove effective. The other extreme was the residential TOU program at Arizona Public Service, APS. By year three of their TOU program, their residential Peak moved from early evening to after midnight because the residential customers moved discretionary electric use to the period when APS's 2.2 cent rate was in force.

Several factors impact the success of a TOU program. One such factor is choosing Opt-in vs. Opt-out and how the utility presents the customer's choice. Program implementation at various utilities has shown us that the method used for shifting customers to a TOU impacts the penetration and effectiveness of the program.

- Opt-in: Customers have been allowed to switch to a TOU rate plan – giving them the perception that they control their destiny.
- Out-out: Customers automatically switch to the TOU rate plan with the option to switch back to either their original flat rate or an alternate TOU.

Higher acceptance and TOU program participation result when customers are offered the opportunity to opt-out of a default plan over opting in. Fewer customers opt-out of the TOU than will opt-in to the same program, but this does not imply that the opt-out approach will reduce energy use on the Peak. Customers who opt-in will have a higher energy use reduction because opting-in coincides with awareness and desire to lower electricity usage. While the opt-in numbers will foster lower program participation, the participation yields a more significant decrease in energy usage per customer. The opt-out participants who do not actively participate incur a higher cost and decrease energy usage at a significantly lower rate resulting in dissatisfaction with the utility, increased disputed bills, and a higher volume of customers opting out across the program's duration. The choice of opt-in versus opt-out is not simple, and the program's energy reduction target must be well understood before making this choice, or the result may not match expectations.

Regardless of opt-in or opt-out, customer education and marketing are other factors to a TOU program's success. Marketing is not identical to opt-in or opt-out. For opt-in, marketing to recruit participants remains the most critical investment. For opt-out customers, marketing to encourage changes in behavior is paramount to reaching the program's goals.

Marketing TOU is complicated and expensive. For example, Sacramento Municipal Utility District, SMUD, found their marketing costs were one of the highest costs of implementing their pilot program and significantly increased their opt-in rates.

The final and principal factor in a TOU program's success is the cost differential between the on-peak and off-peak rates. A minimal cost differential does not provide a sufficient incentive for customers to change their lifestyles or modify their energy usage.

California utilities, for example, instituted a much higher differential resulting in roughly 15% in the shift from on-peak to off-peak. Southern California Edison charges 12 cents for off-peak hours and 47 cents for the most expensive peak hours, a differential of 35 cents, representing a more than 290% increase over the base rate. Other examples follow:

- Con Edison in New York (Orange & Rockland) rates:
  - June through September, the off-peak rate is 1.9 cents, and the on-peak rate is 29.66 for a differential of 27.76 cents.

  - October through May, the off-peak rate is 1.9 cents off-peak, and the on-peak rate is 10.6 cents, a differential of 8.7 cents.
- Portland General Electric rates:
  - On-Peak: 19.978, Mid-Peak: 14.587, Off-Peak: 4.209, a differential of 15.769 cents on a base price of 6.510 cents up to 1000kwh and 7.232 over 1000kwh.
- Oncor rates:
  - Summer: Super Economy - 3.9 cents, Economy - 4.36 cents, Normal – 5.36 cents, Peak – 6.98 cents, Super Peak – 10.26 cents
  - Winter: Super Economy - 3.76 cents, Economy: 4.26 cents, Normal - 05.86 cents, Peak - 6.77
    - Differentials: Summer: 6.36 cents, Winter: 3.01 cents – a flat rate is 6.05 cents
- Tucson Electric Power uses the current electric rate plus a TOU adder.
  - Summer for all usage rates, the differential is 4.02 cents.
  - Winter for all usage rates, the differential is 0.69 cents
- Southern Cal Edison uses six individual TOU rates based on usage, time, and day:
  - TOU-D-A: 12 cents to 47 cents. Differential: 35 cents
  - TOU-D-B: 12 cents to 36 cents: Differential 24 cents
  - TOU-D-T: 19 cents to 41 cents: Differential 22 cents
  - TOU-EV-1: 13 cents to 37 cents: Differential 24 cents (EVs charging > 9 PM & < 6 AM)
  - TOU-D-4-9 PM: 22 to 41 cents: Differential 19 cents
  - TOU-D-5-8 PM: 23 to 49 cents: Differential 26 cents
- SDG&E
  - Winter
    - Normal - 23 cents, at 130% of baseline - 40 cents, at 400% of baseline - 47 cents – differential - 24 cents
    - TOU-DR1 - On-peak - 24 cents, after 130% of baseline - 41 cents, Off-Peak 23 cents, after 130% of baseline - 40 cents, Super-off-peak - 22 cents, after 130% of baseline - 39 cents - differential (usage + peak) - 19 cents

- TOU-DR2 - On-peak - 24 cents, after 130% of baseline - 41 cents, Off-peak 23 cents, after 130% of baseline - 40 cents - differential (usage + peak) - 18 cents

- Summer
  - Normal - 27 cents, at 130% of baseline - 48 cents, at 400% of baseline – 55 cents – differential - 28 cents
  - TOU-DR1- On-peak - 47 cents, after 130% of baseline - 67 cents, Off-Peak 22 cents, after 130% of baseline - 42 cents Super-off-peak - 16 cents, after 130% of baseline - 36 cents - differential (usage + peak) - 51 cents
  - TOU-DR2 - On-peak - 43 cents, after 130% of baseline - 64 cents, Off-peak 21 cents, after 130% of baseline - 41 cents - differential (usage + peak) - 43 cents

Programs around the United States have enjoyed varying success in implementing TOUs. As of 2017, an estimated 69,474,626 residential customers, approximately half of the 150 million US residential electricity customers, have smart meters, which is a requirement for real-time or variable rate plans.

Rate fatigue is a common issue with instituting a TOU resulting from presenting too many complicated options with minimal cost differentials, which discourages customer participation. Tucson and Southern Cal Edison are examples of rate plans with a high probability of rate fatigue. Programs with a higher cost differential and shorter peak times appear to have the most success in driving changes in customer behavior. Further marketing costs, marketing communications, and fairness also threaten the success of TOU programs.

6.4. *Conclusions*

All forms of utility programs providing incentives for altering customer behavior may face severe challenges as DER, and micro/nano grids' impacts become more prevalent. In facing falling costs for DER solutions, punitive programs will lower participation as customers opt-out and deploy their resources.

Demand Response will become a principal component of micro/nano grid solutions. Micro/nano grids will have both supplies in the form of generation (likely non-emitting) or storage BTM that can supply.

7. Technologies That are or Will Impact Utility Planning

7.1. *Renewable, Non-Emitting Resources, & Weather Variable Supply*

7.1.1. Solar

Solar electricity generation technology is both very mature and quite immature. This bifurcation results because solar panel manufacturing uses mature technology, which has achieved production at scale, benefiting from modest and ongoing efficiency improvements. In parallel, solar shingles, windows, and coatings imply solar generation from every roof, window, and exterior wall. Despite publicity and promises, this emerging technology has not yet successfully transitioned from concept and laboratory into production and scale.

7.1.1.1. Panels

Panel solutions range from twelve to twenty-five percent efficiency in converting solar energy into electricity. Watts per panel ranges from 145 to 435 based on the design and materials used in the manufacturing.

Once deployed, panel electrical output varies based on the following:

- Location of the panel on the planet – higher latitudes have a lower sun angle

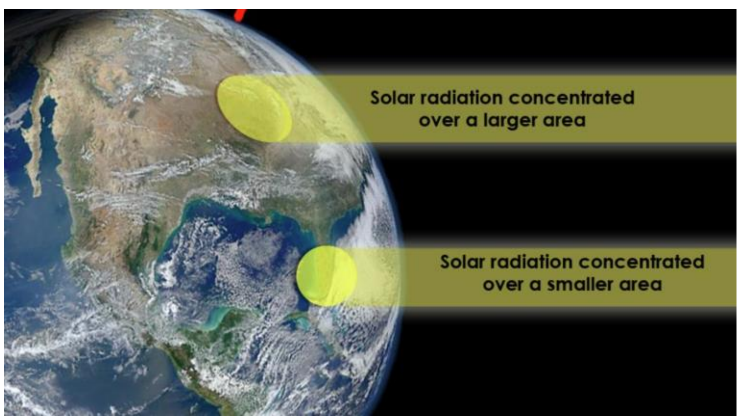

Figure 6 – Solar Radiation by Location on the Planet

- Time of the year – the sun is lower in the winter sky and higher in the summer
- Local terrain, weather, and air quality

Single- and double-axis trackers increase the electrical output by:

- Single axis tracks the sun from east to west from sunrise to sunset
- Double axis tracks the sun from east to west and tracks the seasonal sun angle

7.1.1.2. Shingles, Windows, and Coatings

Solar electricity-producing shingles, windows, and coatings rely on various capabilities incorporating existing or emerging technologies into new forms. Stick-on solar panels are common for mobile applications, such as RVs and bucket trucks. Most solar shingle solutions incorporate existing solar cells into the shingle. The challenge shingles faces are interconnecting all the shingles to extract the DC voltage and deliver it to the inverter.

Coatings are another approach that can be used, like paint or film on surfaces such as roads, windows, and walls. Although several companies' concepts have transitioned from concept into labs, none have become commercially viable so far.

The challenges these approaches face are two-fold. First, at this point in the maturity curve for these technologies, energy efficiency and conversion from sunlight to electricity are extremely low, well below 5%. Some believe these technologies become competitive at 3%+ efficiency. Deployed at scale on surfaces and roofs yields lower efficiency than panels may be acceptable if the deployment cost is also substantially lower than deploying panels. Secondly, solar roof deployment approaches are changing to reduce the cost of using conventional panels. Per-built roof sections with panels embedded applicable to new construction are commercially available in the southwest. A few companies also offer structure-less deployment of panels for retrofit applications that are easily attached to existing roofs. Lastly, grid-scale deployment on flat surfaces using new panel structures can reduce cost by almost 40% over traditional approaches.

Cautions aside, these emerging technologies will be disruptive if any reach commercial viability.

7.1.1.3. Inverters

Since all solar cells convert the energy in sunlight to direct current (DC) electricity, conversion from (DC) into alternating current (AC) for use in the electric system inversion. Inverter design and efficiency impact overall electrical output. Some panels contain micro-inverters in each panel, allowing flexibility in deployment.

IEEE 1547 standard for smart inverters has undergone multiple revisions, beginning with the Energy Act of 2005. The currently accepted revision aligned with the most available inverters is IEEE 1547-2018, but IEEE 1547-2020 and IEEE 1547-2020b are the most current standards, and some inverters already in the marketplace are compliant.

IEEE 1547 matters because smart inverters do much more than converting DC to AC.

They can:

- Ride-through AC voltage and frequency fluctuations (through leading and lagging power factor settings)
- Supports a default schedule for real and reactive AC power output
- Supports receiving external schedules for real and reactive AC power output

- Supports multiple modes of operation (not every inverter supports the last two)
- Constant power factor
    - Constant reactive power factor
    - Voltage reactive power
    - Active power-reactive power mode
    - Voltage-active power most

7.1.1.4. Summary

As with all renewable, success results from thoughtful site selection. Grid-scale solar has a levelized-cost in mid-2022 of <$45/MWH according to the DoE projections if the location has a 3.5 rating or higher based on Figure 7.

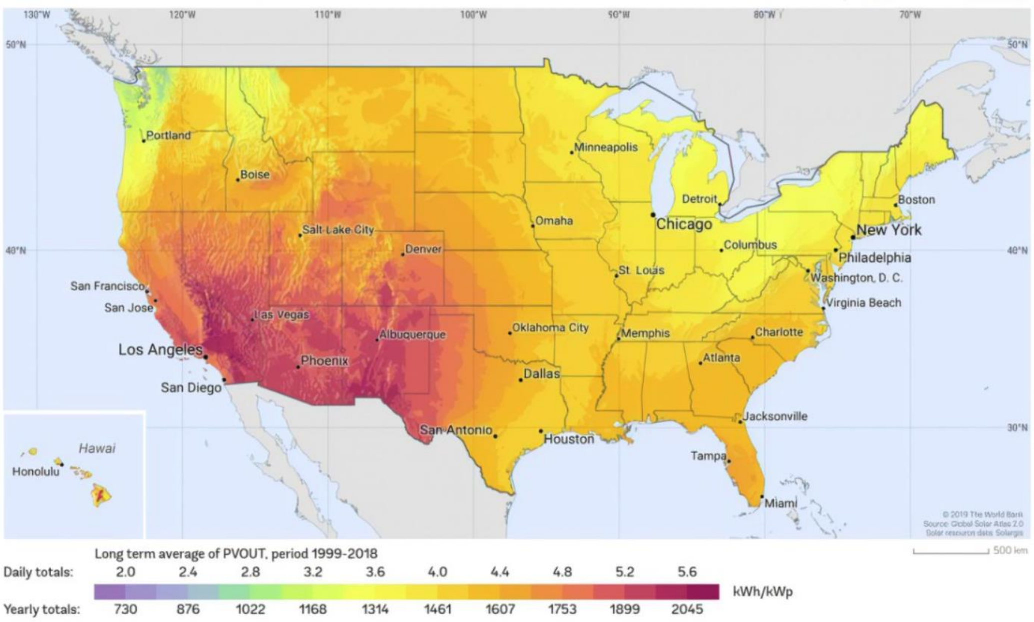

Figure 7 – Solar Production by Location

Emerging solar technologies, such as coatings and shingles, may allow solar generation deployment as part of standard construction processes and materials if the costs are competitive regardless of the solar efficiency. If costs fall to enable solar capabilities in more building materials, it represents a disruptive change to the energy landscape.

7.1.2. Wind

Wind-generated electricity has moved from a concept to a mainstream supply source over the last three decades. The author considers all wind generation as grid-scale. The on-shore grid-scale wind has a levelized-cost in mid-2022 of <$40/MWH and offshore grid-scale ≈$84/MWH according to the DoE projections if sited thoughtfully.

Production per turbine has increased steadily, as shown in Figure 8.

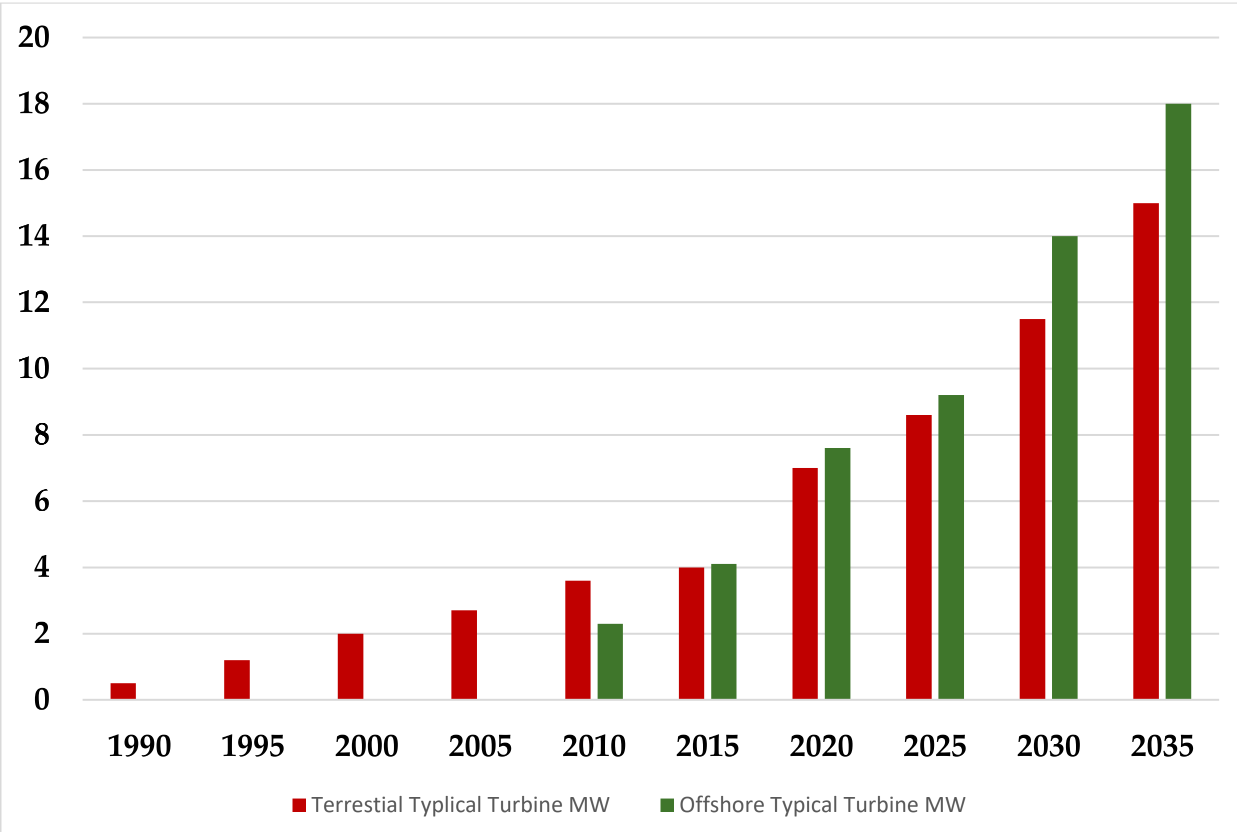

Figure 8 – MW production per turbine over time

Contributing to the increased output per turbine are not only taller towers with more efficient blades but increased efficiency by switching from gears to direct drive. Most turbines use gears to increase the turbine shaft's speed from less than 100 rpm to greater than 1,000 rpm the generator requires. Direct drive, available on only larger turbines, turns a much larger generator at the speed of the turbine shaft, eliminating the need for a gearbox.

Production per turbine will continue to grow, as will typical turbine height. Tall towers can utilize a steadier and more powerful wind stream in many locations. Some existing wind farms will retire their existing turbines and replace them with fewer but taller and more powerful turbines as the existing turbines age.

7.1.3. Small Modular Reactors

There is widely believed that decarbonization must embrace nuclear power as part of the solution to mitigate both the intermittency of solar- and wind-produced electricity and the finite nature of storage. According to the International Atomic Energy Agency (IAEA), there are more than a hundred candidate technologies across more than fifteen countries for advanced reactor designs, and all fall into one of the following categories:

- Pressurized water reactors (PWR)
- Boiling water reactors (BWR)
- Pressurized water reactors (PHR)
- Super-critical water reactors (SCWR)
- Integrated Pressurized water reactors (iPWR)
- Gas Cooled Reactors (GCR)
- Gas Cooled Fast Reactors (GFR)
- Sodium Cooled Fast Reactors (SFR)
- Lead Cooled Fast Reactors (LFR)
- Molten Salt Cooled Reactors (MSR)
- Fast Reactors (FR)
- Modular Small Fast Reactors (MSFR)

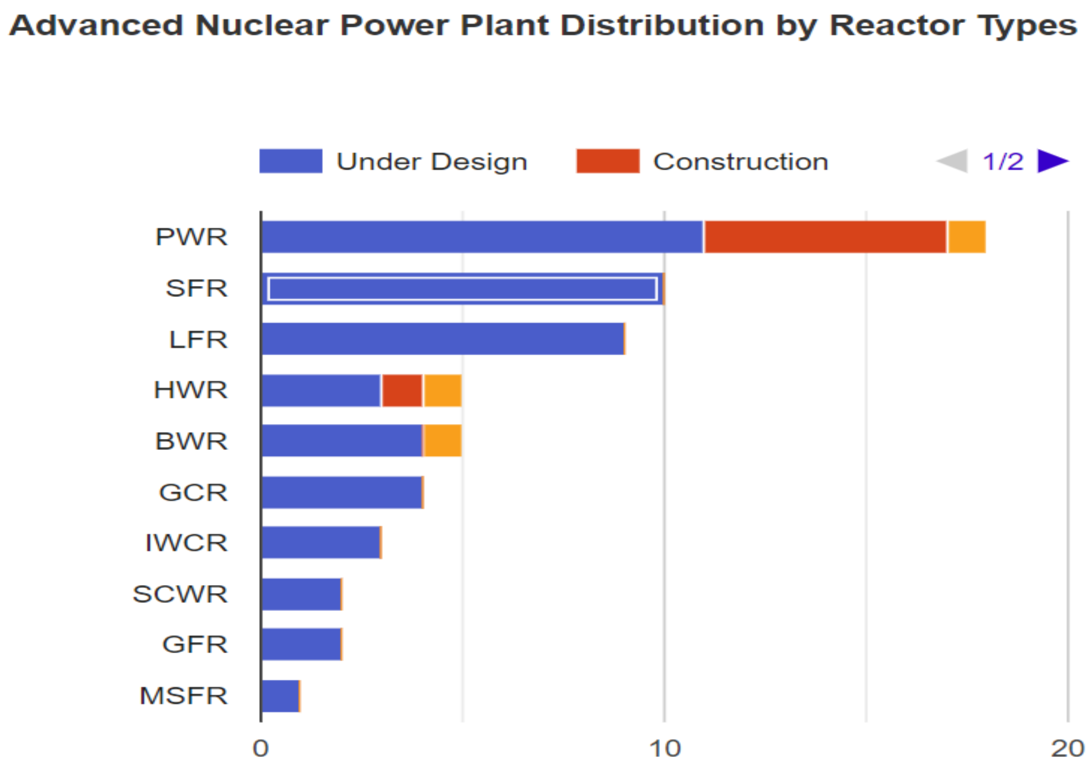

Figure 9 – Advanced Nuclear Power Plant Reactor Types

A commonality remains the steam temperature as all are below 600 °c ranging from 270°c to 585°c. Another broad similarity is they fall into traditional versus fast reactors. Both designs consume nuclear material, but fast reactors create additional nuclear material reprocessable into fuel, thereby reducing waste. Lastly, most are fueled with Uranium Oxide (UO2), but some use more advanced fuels or forms of fuel, such as spherical "pebbles" called TRi-structural ISOtropic (TRISO).

Beyond those similarities, the differences between the designs are substantial, with the greatest being the coolant for controlling temperature and a moderator to slow down the high-velocity neutrons. Many use the same solution for both (e.g., light water, heavy water, or graphite), but some newer designs do not require a moderator and use Sodium, Lead, Helium, Carbon Dioxide, or salts for cooling, which may be active (pumped) or passive (gravity). Some are refueled continuously, some periodically. Lastly, operationally, some designs enable load-following performance with the ability to move from 100% output to 40% in 20 minutes. Also, operational flexibility is supported by the modular designs as most have smaller output per unit (>10 to 300MW) and deploy two, four, six, or eight units in a cluster. In the United States, there are eighteen competing AF technologies from ten separate companies. Those companies are:

- Flibe
- Framatome
- GE-Hitachi

- Gen4 Energy
- General Atomics
- NuScale Power
- TerraPower
- ThorCon
- Westinghouse
- X-energy

Analysis of the commitments to specific vendors and technologies is complex because none are in production and some of the technology has yet to be proven at scale. Considering that, a precise economic analysis also remains elusive. Several utilities, IOUs, and Publics have engaged one or more companies to hedge their future needs because they perceived intermittent solar and wind coupled with a finite storage capacity might not provide sufficient electricity supply.

7.2. *Storage*

Each storage technology analysis begins with a description of the technology and, where possible, a link to one of the leading vendors.

A radar chart follows the description and summarizes each technologies current characteristics across ten measures, each rated from 0 (least favorable) to 9 (most favorable).

The measures for this analysis are:

- **Energy** storage application suitability – suitability for storing energy for a duration expressed in hours
- Storage **duration** – although many technologies can and do store energy for widely varying durations, each technology has a duration(s) where it is most competitive. Storage competitiveness combines two factors, anticipated charge/discharge cycles over the asset's life and overall cost (CAPX & OPX shown this list of measures). The storage asset's cost must be recovered through charge/discharge cycles and its suitability for power applications (also shown in this list of measures). The ratings are:
    - 0 = less than or equal to 2 hours (short-duration storage)
    - 1 = greater than 2 hours but less than or equal to 4 hours (short-duration storage)
    - 2 = greater than 4 hours but less than or equal to 6 hours (short-duration storage)
    - 3 = greater than 6 hours but less than or equal to 8 hours (short-duration storage)
    - 4 = greater than 8 hours but less than or equal to 12 hours (medium-duration storage)
    - 5 = greater than 12 hours but less than or equal to 16 hours (medium-duration storage)
    - 6 = greater than 16 hours but less than or equal to 24 hours (medium-duration storage)
    - 7 = greater than 24 hours but less than or equal to 72 hours (medium-duration storage)
    - 8 = greater than 72 hours but less than or equal to 168 hours (long-duration storage)
    - 9 = greater than 168 hours (long-duration storage)
- **Power** application suitability – e.g., regulation, load following, voltage support, and power quality. Those technologies that can charge/discharge at high power (KW) levels without shortening the assets life, such as lithium-ion or fly-wheel kinetic rates high for power suitability, while those technologies having prescriptive or bounded charging levels, such as flow rates, are lower.
- **Scalability** – The storage asset's scalability is rated based on whether it requires a certain scale, such as some gravity-based kinetic storage technology, or if it can scale from small to large based on linear replication. The ratings are:

- 0 to 3 = requires a fixed scale 0 = small, 1 = medium, 2 = large, 3 = massive
- 4 to 6 = 4 scales small to medium, 5 scales medium to large, 6 scales large to massive
- 7 to 9 = 7 scales small to large, 8 = scales medium to massive, 9 = scales small to massive

- **Longevity** – The anticipated number of charge/discharge cycles that the storage asset survives without refurbishment. NOTE: because suppliers are highly protective of providing realistic charge/discharge cycle expectations, they provide plan refurbishment allowing them to offer 15 years of greater lifetimes (assuming ≈250 charge/discharge cycles per year). Also, in their assumptions, the cost of refurbishment components will become less expensive over time; facing the uncertainty of lithium prices, this may not be valid. The rating is based on ≈250 charge/discharge cycles per year:
    - 0 = less than or equal to 2 years (e.g., recycled EV batteries)
    - 1 = greater than two years but less than or equal to 5 years (e.g., EV batteries)
    - 2 = greater than five years but less than or equal to 7 years (e.g., low-quality Li)
    - 3 = greater than seven years but less than or equal to 10 years (e.g., mid-quality Li)
    - 4 = greater than ten years but less than or equal to 15 years (e.g., high-quality Li)
    - 5 = greater than 15 years but less than or equal to 20 years (e.g., kinetic, thermal)
    - 6 = greater than 20 years but less than or equal to 25 years (e.g., kinetic, thermal)
    - 7 = greater than 25 years but less than or equal to 30 years (e.g., kinetic, thermal)
    - 8 = greater than 30 years but less than or equal to 40 years (e.g., kinetic)
    - 9 = greater than 40 years (e.g., kinetic)
- **Efficiency** – round-trip efficiency – for every kWh charged, the percentage is delivered at discharge.
    - 0 = less than or equal to 20%
    - 1 = greater than 20% but less than or equal to 40%
    - 2 = greater than 40% but less than or equal to 50%
    - 3 = greater than 50% but less than or equal to 60%
    - 4 = greater than 60% but less than or equal to 70%
    - 5 = greater than 70% but less than or equal to 80%
    - 6 = greater than 80% but less than or equal to 85%

- 7 = greater than 85% but less than or equal to 90%
- 8 = greater than 90% but less than or equal to 95%
- 9 = greater than 95%

- **Cost** – this cost reflects the CAPX, capital cost per kWh stored at optimum scale (higher rating = less expensive), plus OPX – O&M cost per kWh stored at optimum scale (higher rating = less expensive) and considers efficiency (losses) but does not factor the cost of the energy to charge the storage
- **Environmental** – Siting flexibility (e.g., easily sited), resource use (land, water, electricity for HVAC), decommissioning & recycling issues (e.g., toxicity) - a higher number is more environmentally friendly
- **Maturity** – Technology maturity & risk
  - 0 = greater than ten years from production with significant technological risk
  - 1 = greater than five years from production with significant technological risk
  - 2 = greater than five years from production without significant technological risk
  - 3 = greater than three years but less than or equal to 5 years from production
  - 4 = greater than one year but less than or equal to 3 years from production
  - 5 = pilotable with uncertain technological risk
  - 6 = pilotable with manageable technological risk
  - 7 = pilotable without technological risk
  - 8 = in production but not widely deployed
  - 9 = field deployed in multiple grid-scale implementations
- **Avista Applicability** – Avista's ability and readiness to deploy this technology
  - 0 = Avista not ready to pilot within the next ten years
  - 1 = Avista is not ready to pilot within the next five years
  - 2 = Avista is not ready to pilot within the next three years
  - 3 = Avista ready to pilot deployment timeframe is uncertain
  - 4 = Avista is ready to pilot but won't deploy within the next 10 years
  - 5 = Avista is ready to pilot but won't deploy within the next 5 years

- 6 = Avista is ready to pilot but won't deploy within the next 3 years
- 7 = Avista ready to pilot and deploy within the next 3 years
- 8 = Avista has piloted and is ready to deploy within the next 1 to 2 years
- 9 = Avista ready to deploy now

Below is an example of a radar chart using these measures.

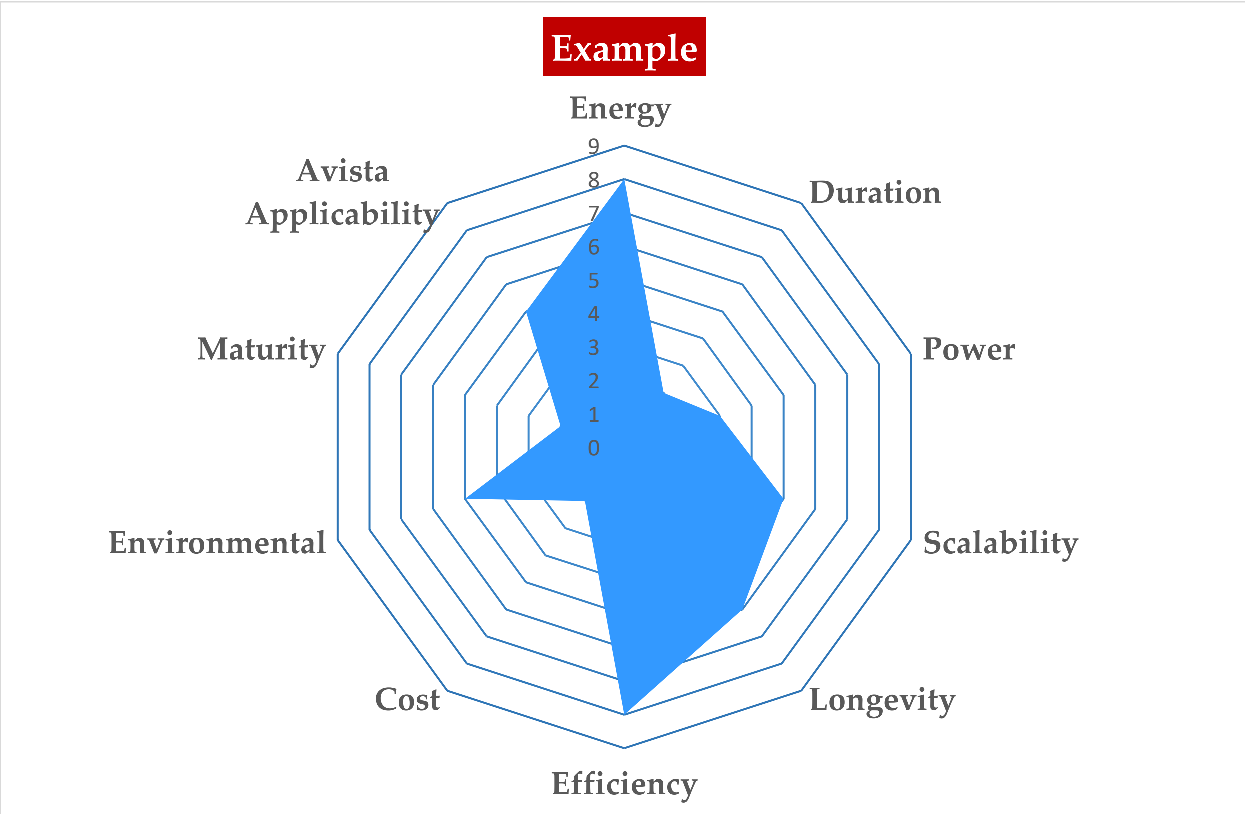

Figure 10 – Example Storage Analysis Chart

Legend – a higher value is better for all measures

The radar chart is followed by a high-level analysis of the advantages and limitations of the technology, addressing all aspects of a deployment, including technology, commercial, siting, and risk. If possible, the last section identifies utilities committed to pilots, the vendor chosen, and the deployment schedule and status.

7.2.1. Electrochemical

Solid electrochemical batteries dominate today's energy storage landscape because they are critical to transportation electrification, specifically for passenger and light-duty electric vehicles (EV). Bloomberg estimates that EVs in this class will consume over 85% of the battery production between 2020 and 2030. Solid electrochemical batteries are assembled from individual battery components; all are lithium-ion-based today. Currently, 119 domestic battery component factories are in production, construction, or planned, including 13 Giga factories, all of which will be in operation before 2026, and all are owned the auto manufacturers. Still, today, three counties dominate battery components manufacturing, China, South Korea, and Japan.

Although all electrochemical battery chemistries store electricity as DC, the individual chemistry matters because each chemistry brings unique characteristics, these characteristics provide both opportunities and constraints, making the control of the battery a critical consideration that dictates how the battery may be used.

Some lithium-ion chemistries tolerate vibration better and therefore are better suited to mobile applications, while other chemistries are not. Lithium nickel manganese cobalt oxides (Li-NMC) is the most common chemistry for EV batteries, but some EVs adopted Lithium iron phosphate (Li-FP) as well because they are less costly.

Many lithium chemistries for stationary applications, such as grid-scale battery energy storage systems (BESS), are suitable subject to the specific BESS requirements and cost considerations. Li-NMC and Li-FP are commonly BESS chemistries and for higher-performance stationary applications, Lithium titanate oxide (Li-TO), although more expensive, is frequently the chemistry of choice. Today, for BESS solutions, these three chemistries dominate.

Other solid battery chemistries threaten lithium-ion's dominance because of lithium scarcity, cost, toxicity, source countries, and extraction approach. More abundant metallic elements such as zinc, 24th most abundant, sodium, the 6th most element, and iron, the most abundant, may become battery chemistries offering significantly lower cost and less toxicity. Several companies already produce prototypes, and a few companies are in the production of batteries using these more abundant metallic chemistries.

Flow batteries are another variant of electrochemical energy storage. While most electrochemical batteries are solid, flow batteries use a liquid to store energy. They charge by pumping a liquid through a charging chamber that adds electrons to the liquid and discharges by striping those electrons off by reversing the process.

Flow batteries are less costly to produce and scale simply by adding more liquid, bigger liquid storage, and more powerful pumps. Despite these advantages, flow batteries' initial deployments have been less than successful because the liquids are highly corrosive, damaging pipes, tanks, and pumps. These issues have damaged their reliability and availability for the pilot projects deploy, leading to concerns that the technology remains immature.

Also, flow batteries are best suited for energy applications because their performance for power applications is dictated by how much fluid can be pumped through the discharging process, whereas solid electrochemical batteries can discharge all their components quickly, only limited by thermal constraints.

While solid metal electrochemical battery technologies have matured over the last five years, flow batteries have not shown the same progress.

The packaging of BESS solutions has seen significant innovation. Many BESS suppliers are now agnostic chemistry (NMC, LFP, or LTO), tailoring their solution to the clients' needs and the batteries' chemistry with the control software supplied. Finally, innovation in safety, fire suppression, and access enable vertical packaging reducing the footprint by as much as 75 to 80% s required.

7.2.1.1. *Electrochemical Lithium-NMC*

Description

Lithium NMC batteries are the leading lithium-based electrochemical battery technology. Its components are less brittle than other lithium-based chemistries; therefore, it is preferred for mobile (EV) applications.

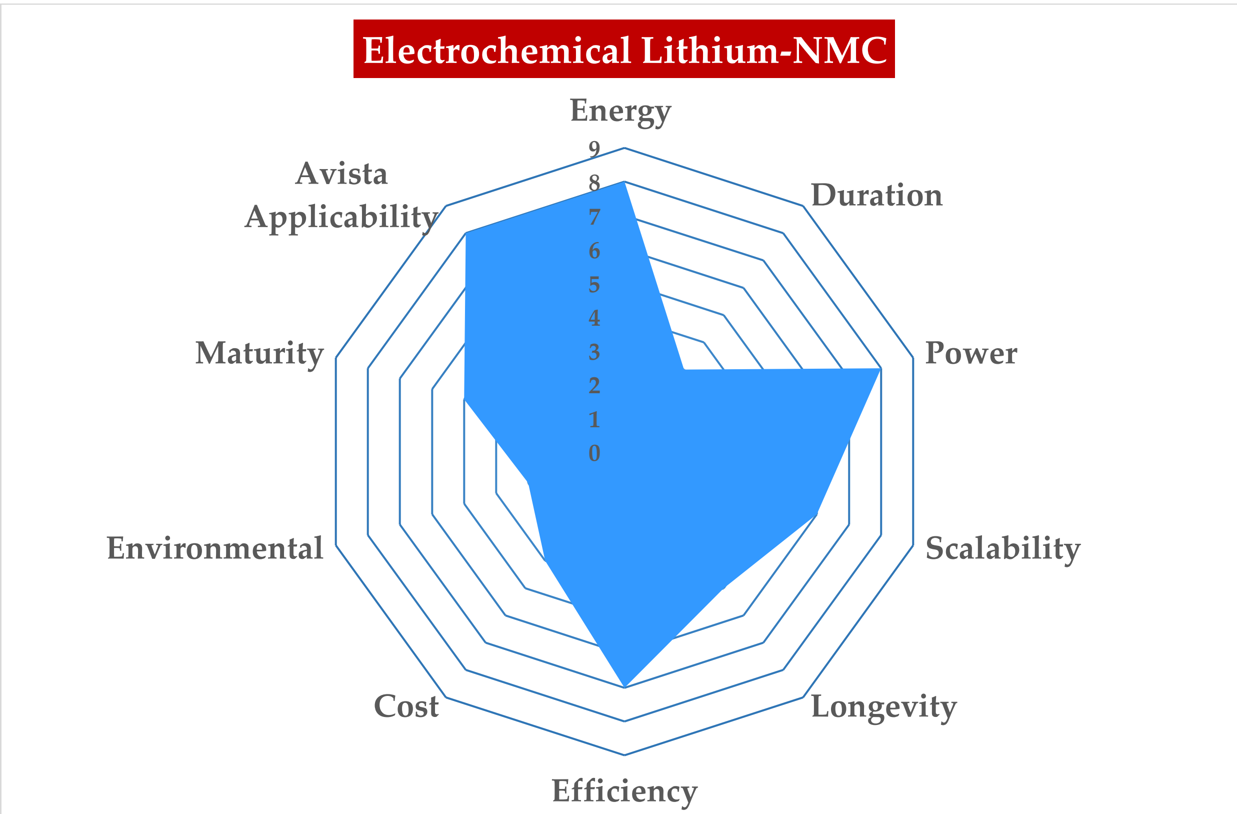

Figure 11 – Electrochemical Lithium-NMC

Advantages & Limitations

Lithium NMC batteries as energy storage have the following advantages:

- Suitable for both energy and power applications.
- Massive production facilities exist, and many more are being built.
- Solution moved from project to product, driving BESS costs down.

Lithium NMC batteries as storage have the following disadvantages:

- Lithium prices continue to rise based on the demand
- BESS solutions compete with EV demand.
- Lithium's scarcity, sources, toxicity, and extraction methods remain a concern

Commitments & Deployments

The US already has > 8GW of BESS capacity in operation, and another 30+GW have requested grid interconnections, with roughly 70% in Texas and California. Most utilities have BESS pilots in operation or planned. Of these,>90% are Lithium NMC batteries.

7.2.1.2. Electrochemical Lithium-LFP

Description

Lithium LFP batteries have closed the gap against the dominant chemistry, NMC, because of their lower cost based on materials and production processes. Further, their reliability for mobile applications has improved greatly through innovative packaging. Their longevity as measured by charge cycle is different from NMC, losing significant capacity in the first months, for some as high as 25%, but stabilizing and delivering more charge/discharge cycles of their life.

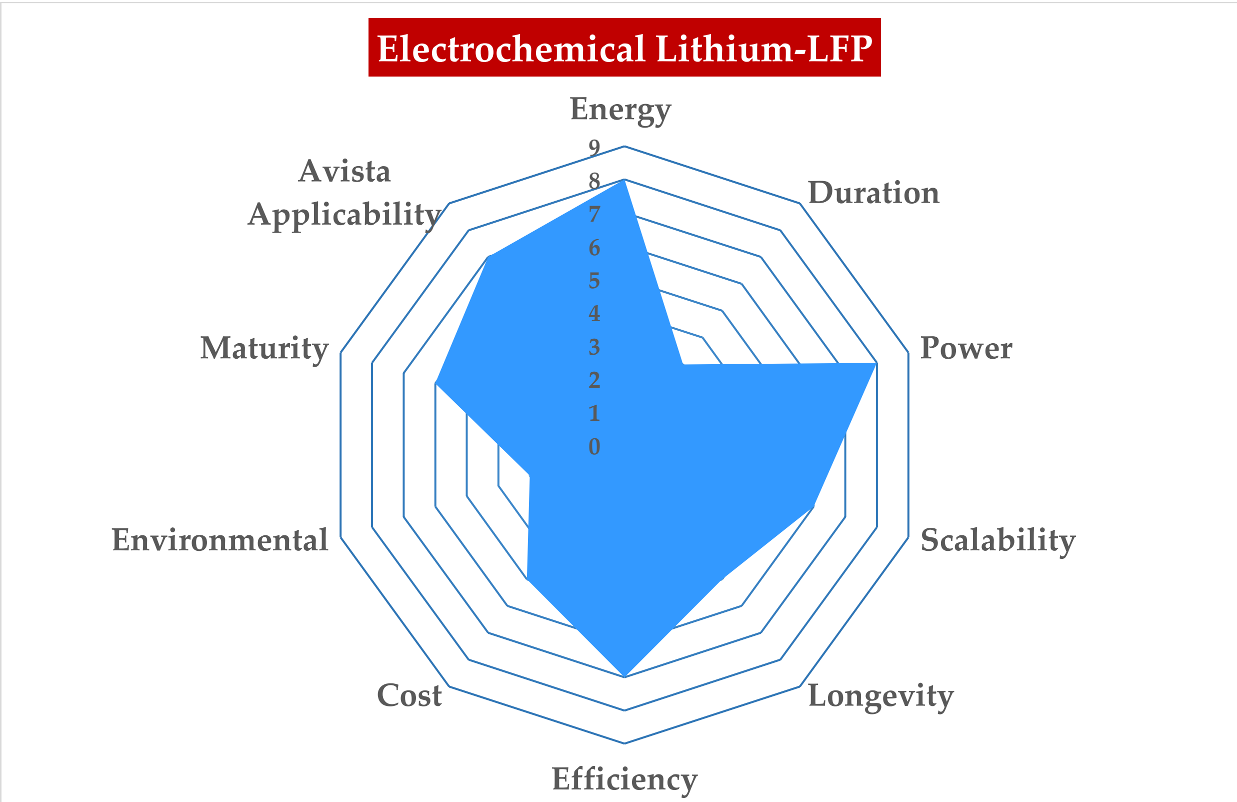

Figure 12 – Electrochemical Lithium-LFP

Advantages & Limitations

Lithium LFP batteries as energy storage have the following advantages:

- Suitable for both energy and power applications.
- Chinese production facilities exist, and more are being built there and elsewhere.
- Many BESS solutions now offer flexibility between NMC, LFP, and LTO.

Lithium LFP batteries as storage have the following disadvantages:

- Lithium prices continue to rise based on demand, but LFP uses less.
- LFP BESS solutions compete with EV demand.

- Lithium's scarcity, sources, toxicity, and extraction methods remain a concern

Commitments & Deployments

The first wave of US BESS production solutions based on Lithium LFP components are already in production with results competitive with Lithium NMC-based BESS.

7.2.1.3. Electrochemical Lithium-LTO

Description

Lithium LTO batteries offer performance advantages for power applications, but that performance comes with a slightly higher cost. The cost disadvantage LTO brings diminished diminishes as more factory capacity is online. Further, LTO offers a longer life than NMC or LFP, with expected charge/discharge cycles 30% higher. The Japanese dominate Lithium LTO battery component production.

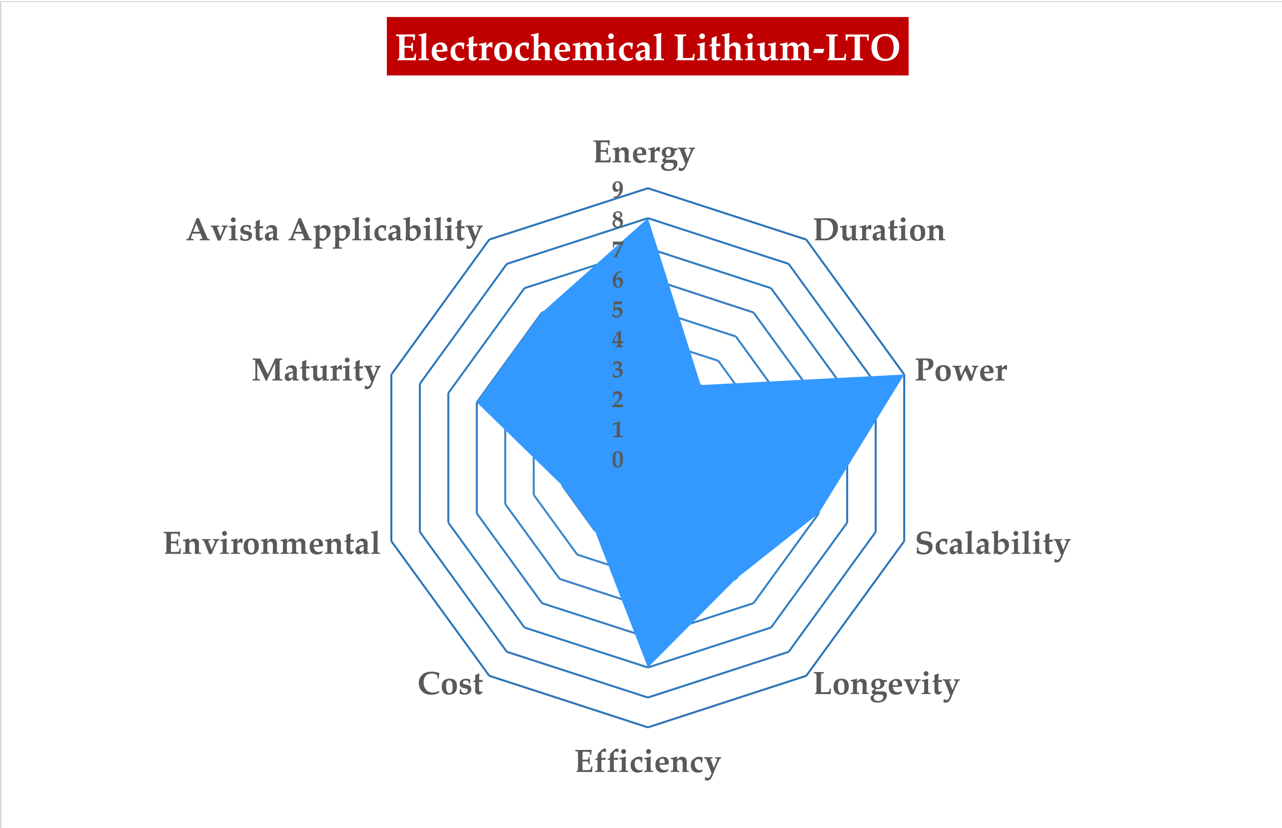

Figure 13 – Electrochemical Lithium-LTO

Advantages & Limitations

Lithium LTO batteries as energy storage have the following advantages:

- Suitable for energy but more attractive for power applications.
- Japanese production facilities exist, and more are being built in the US.
- The EV market does not use Lithium LTO.

Lithium LTO batteries as storage have the following disadvantages:

- Lithium prices continue to rise based on demand, but LTO uses less.
- LFP BESS solutions compete with EV demand.

- Lithium's scarcity, sources, toxicity, and extraction methods remain a concern

Commitments & Deployments

The first Lithium LTO BESS is in production, but the deployment has been limited to ancillary service market applications. As the price differential disappears between LTO and LFP/NMC, chemistry agnostic BESS solutions will become more common, and LTO's performance and longevity advantages will drive greater adoption.

7.2.1.4. Electrochemical Zinc-Air

Description

After some initial challenges and marketplace failures, Zinc-air batteries appear to have resolved most of their challenges. The chemistry is more stable, and production is repeatable. Zinc-air is poised significantly disrupt the traditional dry-cell marketplace because of its lower cost and recyclability. Propelled by the volume from that scale, Zinc-air-based BESS solutions cost will fall sharply, creating a further advantage for zinc over lithium.

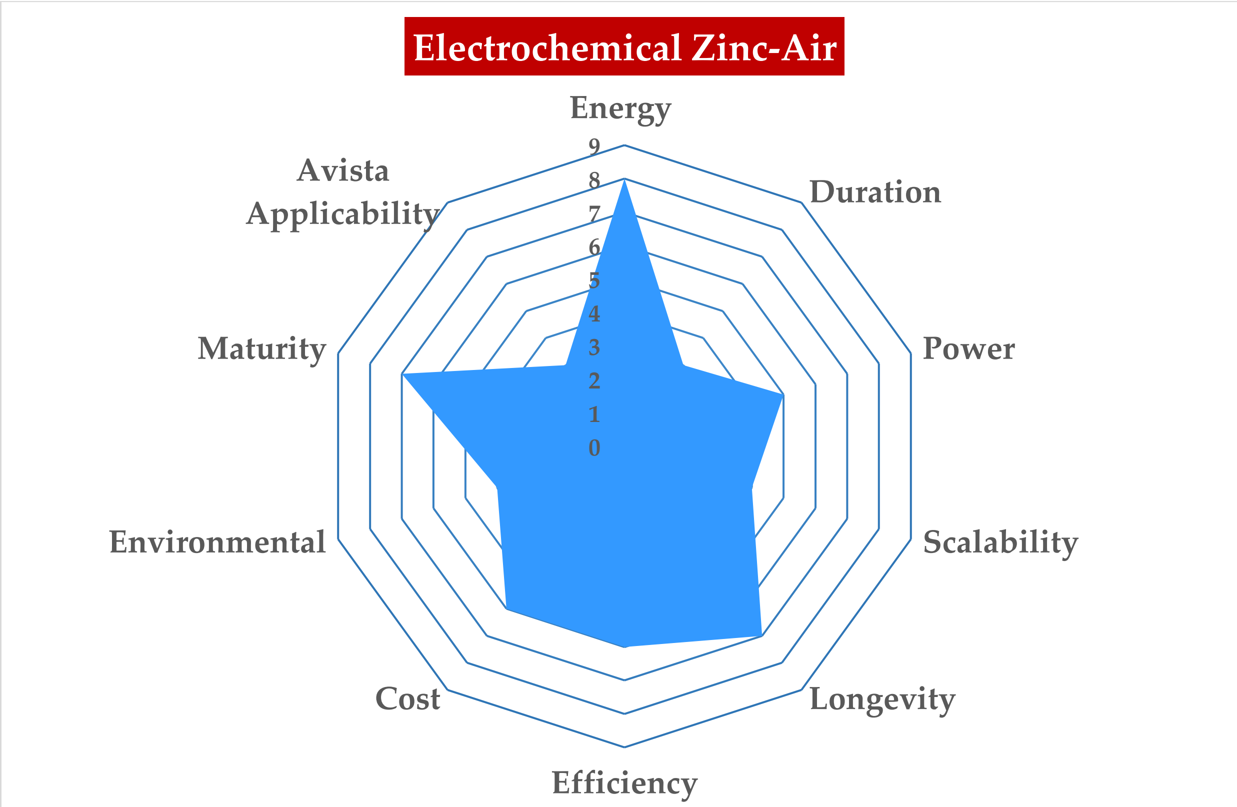

Figure 14 – Electrochemical Zinc-Air

Advantages & Limitations

Zinc-air batteries as energy storage have the following advantages:

- Suitable for energy and power applications.
- US production is rising rapidly.
- The batteries are fully recyclable.
- Zinc-air batteries are significantly less expensive than lithium-based batteries.

Zinc-air batteries as storage have the following disadvantages:

- Initial failures still raise concerns.

- The dry-cell marketplace is driving this chemistry.
- Existing production facilities lack a history of performance.

Commitments & Deployments

The first Zinc-air BESS deployment failed to deliver as expected and soured the marketplace. Recent pilots (NYSERDA) show these initial shortcomings are resolved, but this chemistry, although attractive because of its cost and recyclability, may still be immature for BESS solutions.

7.2.1.5. Electrochemical Nickle-Hydrogen

Description

A spin-off of batteries in orbital space craft, Nickle-hydrogen batteries began to emerge in 2020 as a threat to lithium-based batteries. The technology shows promise (30,000 charge/discharge cycles and wide operating temperature regime) but is immature. Thus far only on company is producing batteries domestically. Their approach is modular and scalable batteries.

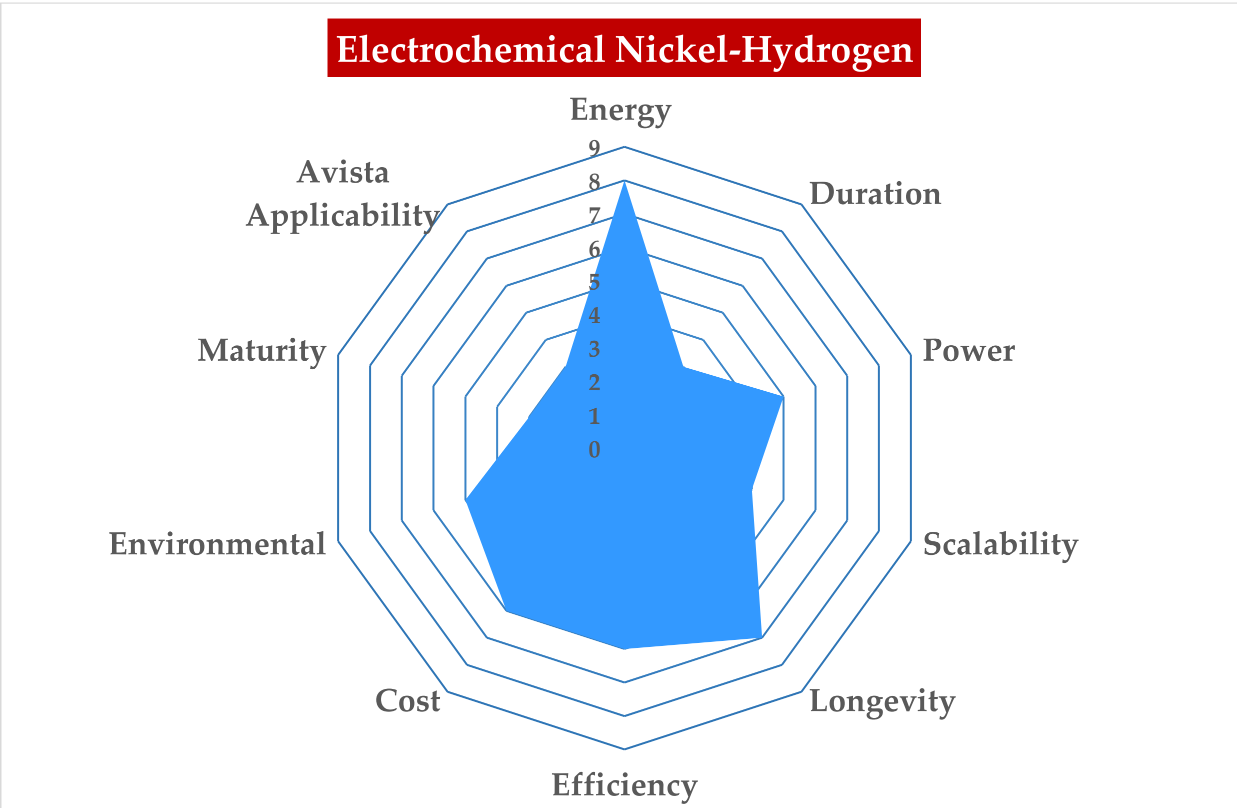

Figure 15 – Electrochemical Nickel-Hydrogen

Advantages & Limitations

Nickel-hydrogen batteries as energy storage have the following advantages:

- More suitable for energy applications.
- US production is rising rapidly.
- Long-duration and great longevity.
- Low cost.

Nickel-hydrogen batteries as storage have the following disadvantages:

- Limited production.
- Technology is only at the initial pilot stage.

- New.

Commitments & Deployments

The only domestic supplier is Enervenue, a California based manufacturer. Their initial pilot projects have started in the last two year, all offshore and small BESS installations thus far.

7.2.1.6. Electrochemical Iron-Air

Description

Iron-air batteries offer low cost, significant storage duration, and at least an order of magnitude more charge/discharge cycles, but no pilots exist at the grid scale. The chemistry is stable and less demanding for production at scale.

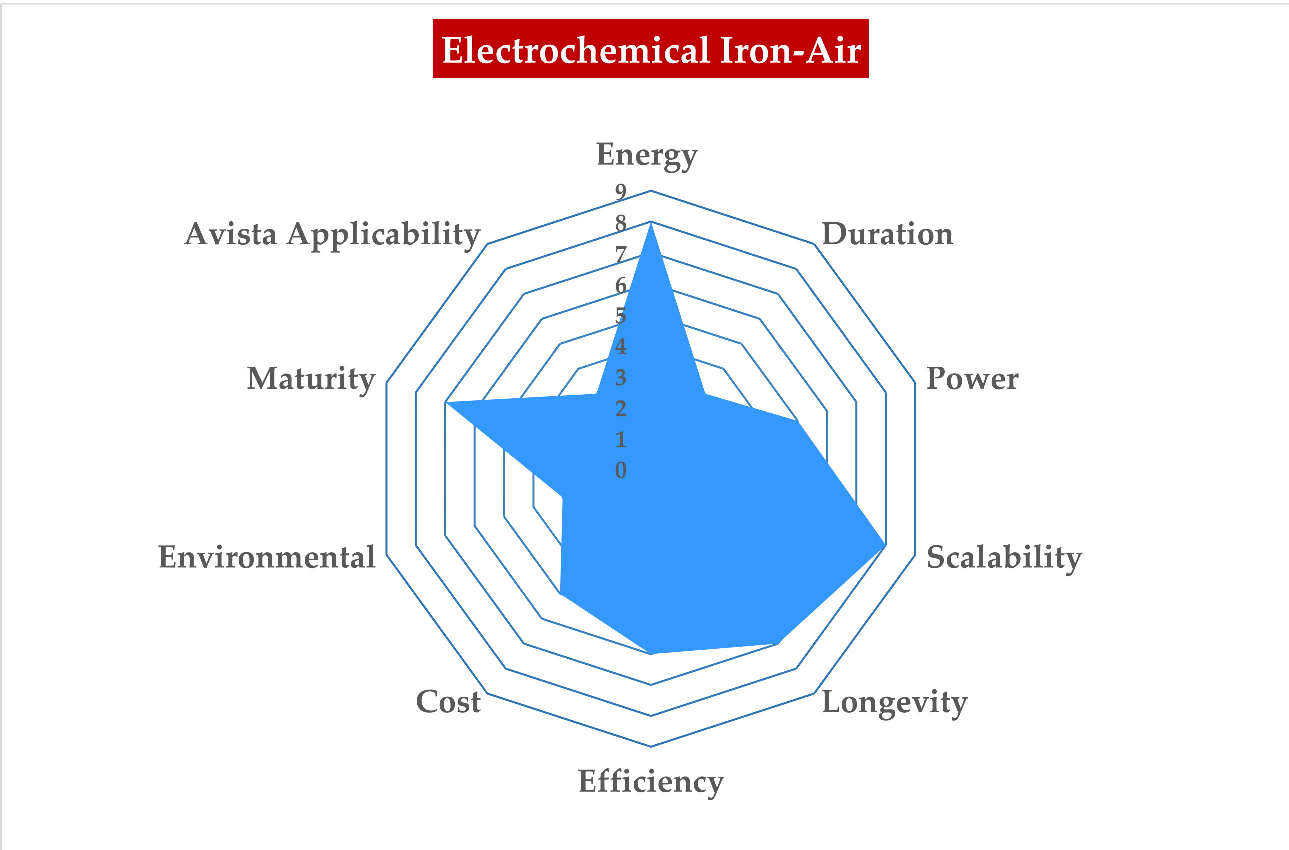

Figure 16 – Electrochemical Iron-Air

Advantages & Limitations

Iron-air batteries as energy storage have the following advantages:

- Greater suitability for energy than power applications.
- The batteries are fully recyclable.
- Iron-air batteries are significantly less expensive than lithium-based batteries.

Iron-air batteries as storage have the following disadvantages:

- No production scale BESS deployed.
- Limited suppliers and production capacity.
- Technology risks remain.

Commitments & Deployments

Southern Company has made a major commitment to the leading supplier, Form Energy, for a 120MWH battery pilot.

7.2.1.7. Electrochemical NiCAD

Description

Electronics have used NiCd batteries for decades and compete against traditional dry-cell batteries for small applications but deliver more energy. Today, adaptation is underway to test NiCd batteries for BESS applications, but thus far, none have reached a pilot deployment at scale.

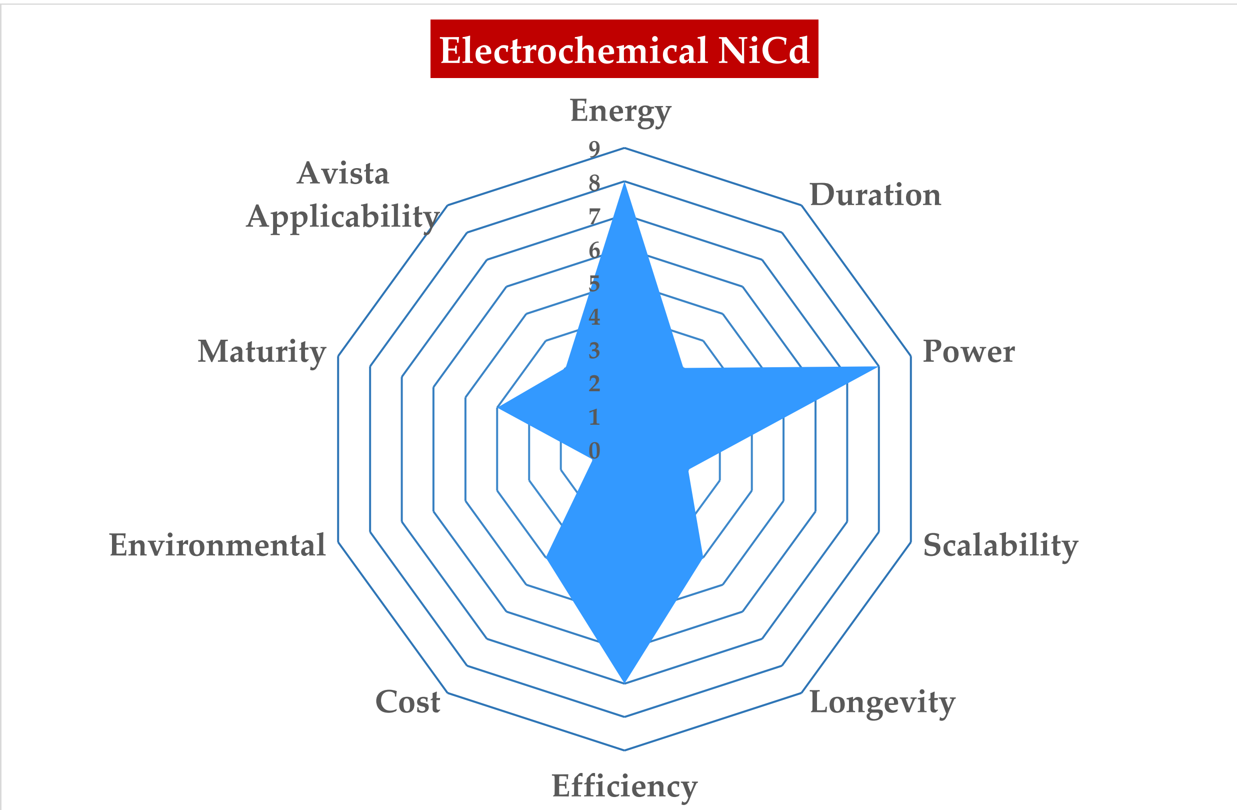

Figure 17 – Electrochemical NiCD

Advantages & Limitations

NiCd batteries as energy storage have the following advantages:

- Suitability for energy and power applications.
- Production is well understood for the components.
- Existing factories could supply BESS demand.

NiCd batteries as storage have the following disadvantages:

- No production scale BESS deployed.
- Supply chain risks exist for base material, Cadmium.
- Limited suppliers of grid-scale BESS pursuing NiCd solutions.

Commitments & Deployments

No commitments or planned deployments currently.

7.2.1.8. Electrochemical Liquid Metal

Description

Electronics have used Liquid Metal batteries for decades and compete against traditional dry-cell batteries for small applications but deliver more energy. Today, adaptation is underway to test Liquid Metal batteries for BESS applications, but thus far, none have reached a pilot deployment at scale.

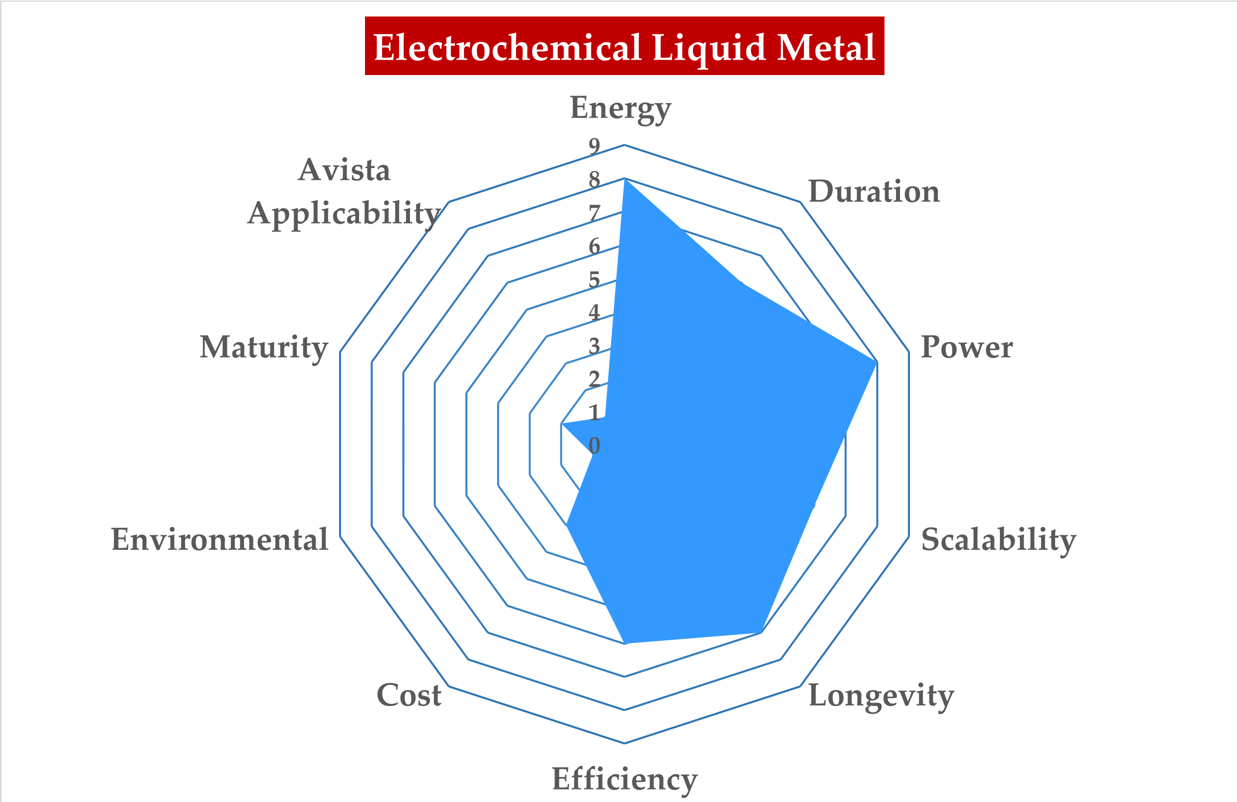

Figure 18 – Electrochemical Liquid Metal

Advantages & Limitations

Liquid Metal batteries as energy storage have the following advantages:

- Suitability for energy and power applications.
- Production is well understood for the components.
- Existing factories could supply BESS demand.

Liquid Metal batteries as storage have the following disadvantages:

- No production scale BESS deployed.
- Supply chain risks exist for base material, Cadmium.
- Limited suppliers of grid-scale BESS pursuing Liquid Metal solutions.

Commitments & Deployments

No commitments or planned deployments currently.

7.2.1.9. Electrochemical NaS

Description

NaS batteries were the initial wave of grid-scale BESS solutions but have been supplanted by lithium-based batteries. Recent innovation revitalized NaS-based battery prospects leading to several commitments for next-generation NaS-based BESS deployments.

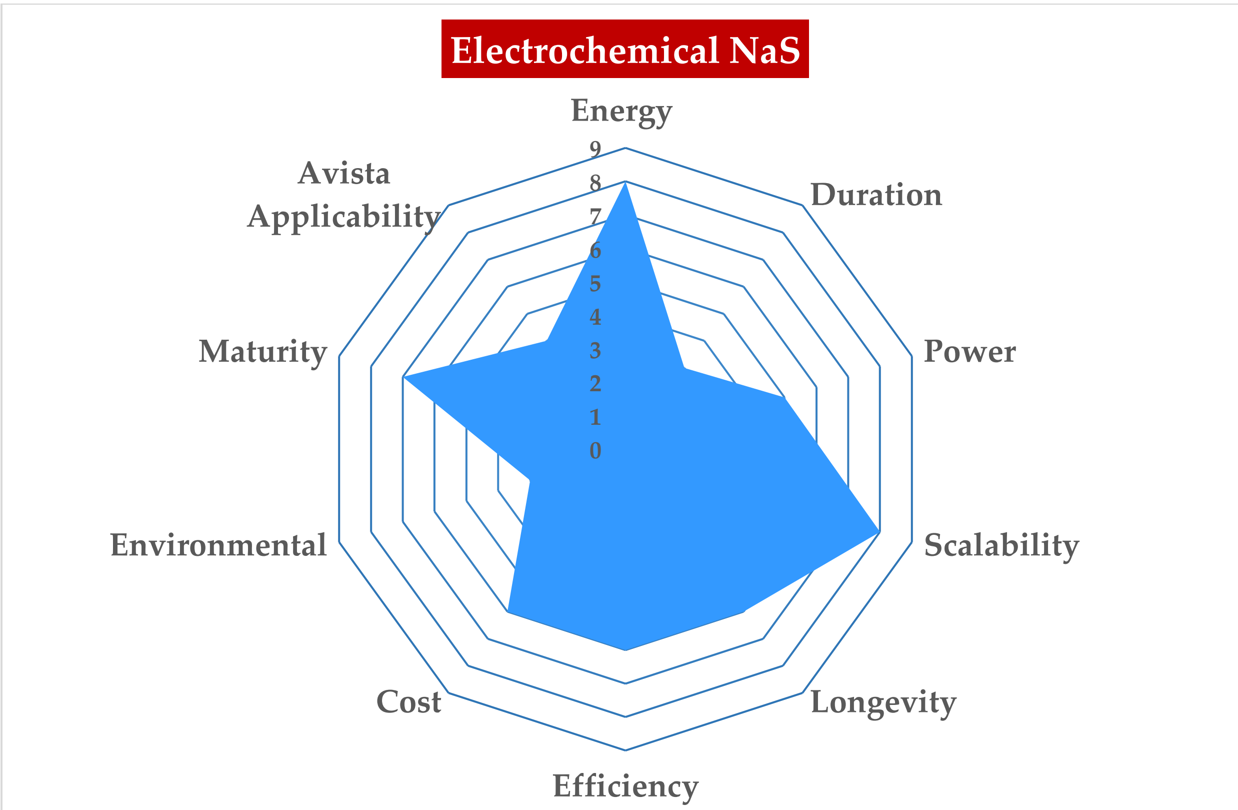

Figure 19 – Electrochemical NAS

Advantages & Limitations

NaS batteries as energy storage have the following advantages:

- Historical successful deployment at scale.
- Costs are falling based on innovation.
- Fully recyclable and no supply chain challenges.

NaS batteries as storage have the following disadvantages:

- Faces difficulty competing with other chemistries
- The latest innovations are not field-proven.
- Limited suppliers of grid-scale BESS pursuing NaS solutions.

Commitments & Deployments

Dubai, Indonesia, and some North America Public Utilities (e.g., Glendale, CA) have committed to additional NaS-based solutions.

7.2.1.10. Electrochemical Advanced Lead-Acid

Description

No discussion of batteries would be complete without considering Lead-acid-based batteries. Lead-acid batteries have been common for a century but have not been deployed as grid-scale BESS solutions. Advanced lead-acid batteries relying on innovation may force a reconsideration of this chemistry for grid-scale BESS solutions, but thus far, none have been deployed in production, and only a few pilots are underway. Industrial and commercial use is driving the innovation of this technology.

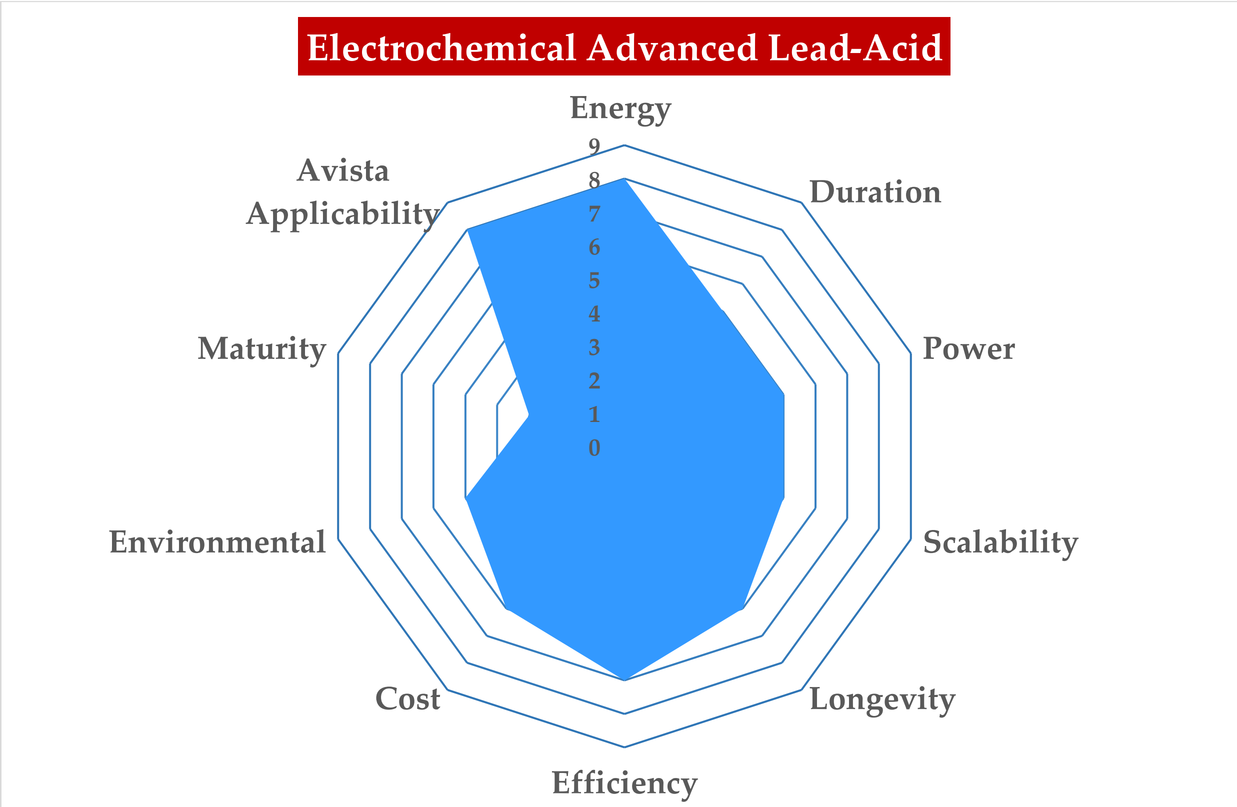

Figure 20 – Electrochemical Advanced Lead-Acid

Advantages & Limitations

Lead-acid batteries as energy storage have the following advantages:

- Long history and success with the technology.
- Improvements in basic chemistry continue.
- No supply chain challenges.

Lead-acid batteries as storage have the following disadvantages:

- Lead is toxic.
- The latest innovations are not field-proven at scale.

- Limited suppliers of grid-scale BESS pursuing Lead-acid solutions.

Commitments & Deployments

Several Indian and European suppliers are pursuing gird-scale BESS solutions. Thus far, they have found unique industrial applications for their solutions and none in the US.

7.2.1.11. *Electrochemical VRB-Flow*

Vanadium-Redox (VRB) flow batteries were the first flow batteries deployed in BESS solutions. Some were megawatt scale, with the largest exceeding 200MWH. These initial at-scale deployments suffer from reliability and availability challenges. These challenges resulted from contamination, corrosion-driven leakage, and pump failures. Many of these issues have been resolved in the latest deployments bringing the possibility that flow batteries cost and scalability advantages may result in wider utilization of this technology.

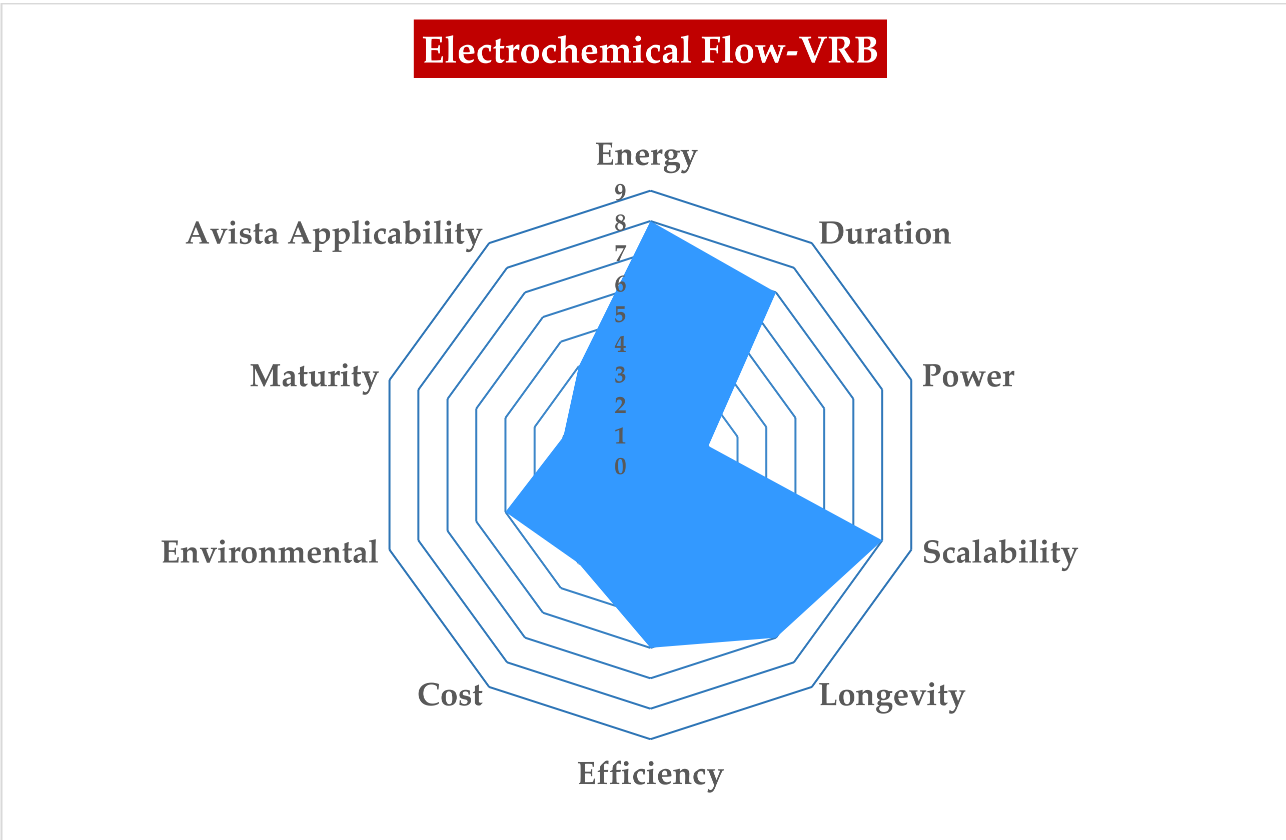

Figure 21 – Electrochemical Flow-VRB

Advantages & Limitations

VRB-flow batteries as energy storage have the following advantages:

- With maintenance, virtually limitless charge/discharge cycles.
- Scalable by adding larger tanks and more powerful pumps.
- Storage duration of hours to weeks.
- Significantly less expensive than any solid electrochemical batteries.

VRB-flow batteries as energy storage have the following disadvantages:

- Vanadium is toxic and has supply chain challenges.

- Unclear if all the initial issues causing low reliability have been resolved.
- Initial suppliers of grid-scale BESS VRB-flow solutions disappeared.

Commitments & Deployments

The largest deployment is underway in Australia (>200MWH), but few pilots. Several Indian and European suppliers are pursuing gird-scale BESS solutions. Thus far, they have found unique industrial applications for their solutions, and none in the US.

7.2.1.12. Electrochemical Flow PSB & ZRB

Description

Polysulfide Bromide (PSB) and Zinc Bromide (ZRB) are alternative flow battery electrolytes to VRB, each bringing advantages and disadvantages. The largest BESS deployment for PSB was not put into service (UK) because technology proved challenging at scale, and PSB's costs made it infeasible for further pilots. Further, both PSB and ZRB have charge/discharge cycles below competitive solid metal electrochemical batteries making these electrolytes uncompetitive.

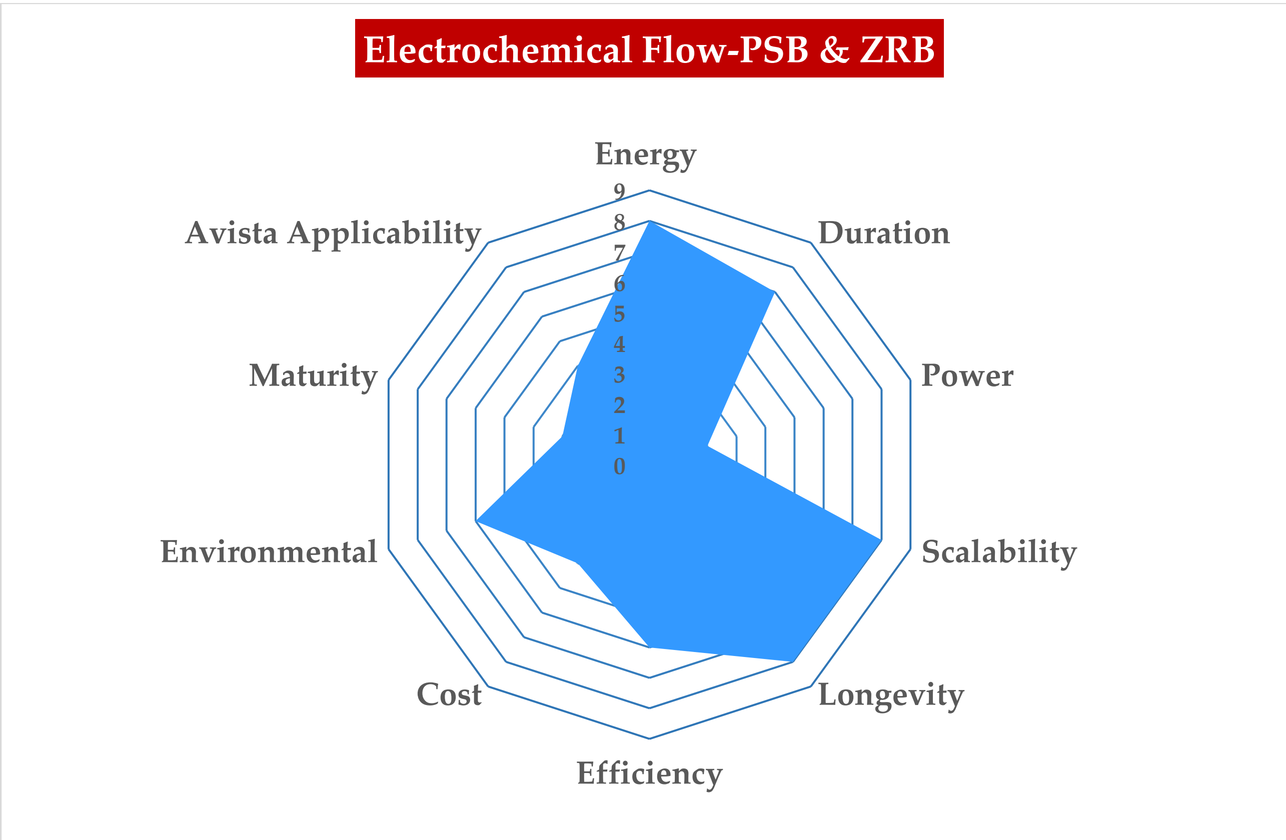

Figure 22 – Electrochemical Flow-PSB & ZRB

Advantages & Limitations

PSB & ZRB-flow batteries as energy storage have the following advantages:

- Low safety and fire risk.
- Reclaimable and very low-cost electrolytes.
- Much less corrosive than VBR.
- Storage duration hours to months

PSB & ZRB-flow batteries as energy storage have the following disadvantages:

- No grid-scale suppliers exist. Today's supplies are focused on <1MWH.
- Research and innovation have slowed significantly following VBR's issues.
- <3000 charge/discharge cycles in the electrolyte's lifetime.

Commitments & Deployments

No grid-scale BESS deployment using PSB and ZRB is in operation or planned.

7.2.1.13. Hydrogen Production (Conversion)

Hydrogen as energy storage brings greater complexities compared to other energy storage technologies. First, hydrogen's role in the energy landscape is multi-dimensional. Hydrogen is not only an energy storage technology but also a stepping stone in a sustainable gas journey and a potential natural gas replacement or a transportation fuel. This multi-dimensional nature makes evaluating hydrogen energy storage much more difficult.

Hydrogen has an energy density per kilogram at least two orders of magnitude higher than other electrochemical storage. The conversion of pure hydrogen produces decarbonized electricity. Its production also can be carbon-free or not, subject to the method of production and the source of the electricity used in that production, as shown in Figure 24 (below)

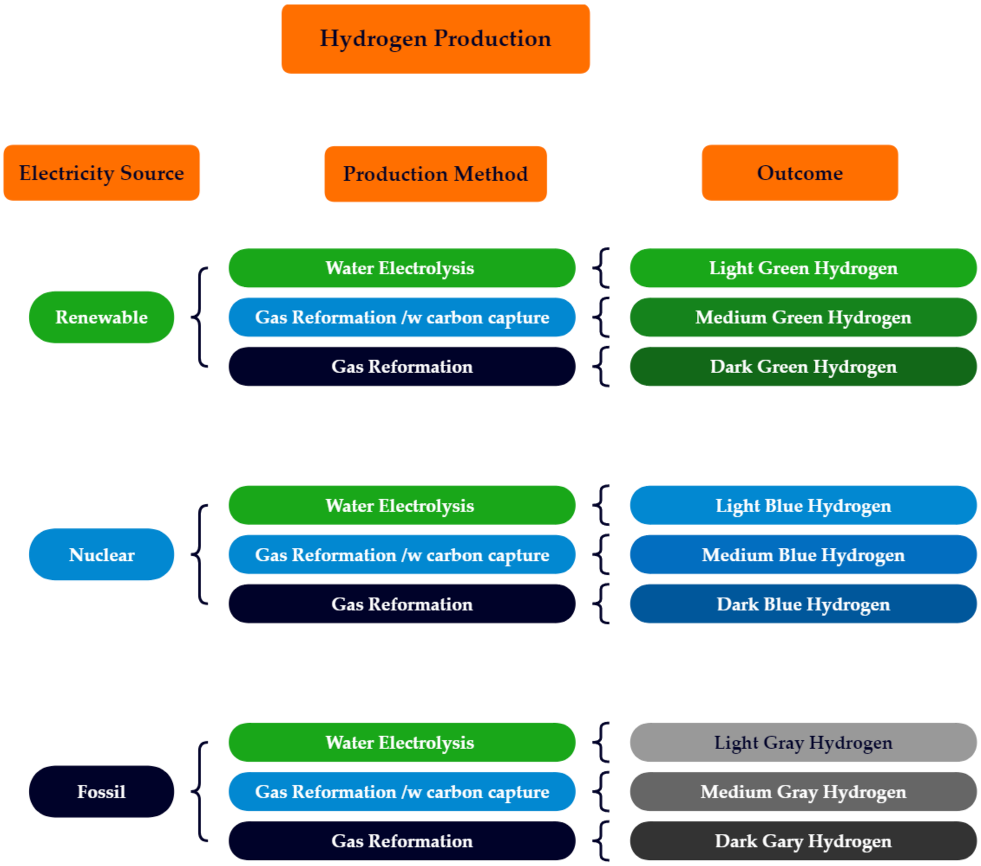

Figure 23 – Hydrogen Production

Hydrogen also brings technological and logistic challenges. First, hydrogen atoms are much smaller than natural gas molecules making utilization of existing natural gas pipelines and distribution networks prone to leakage. Also, hydrogen is more corrosive than natural gas because it is chemically active. So, although the US has a mature natural gas infrastructure, it is uncertain if that infrastructure can be converted to support hydrogen, presenting a logistical challenge. However, hydrogen can preserve other infrastructure if blended with natural gas or renewable natural gas that can be converted to electricity in existing power plants.

Finally, conversion from electricity to hydrogen and back has lower round-trip efficiency than other forms of energy storage, so although it has a huge energy density advantage, its efficiency lowers its attractiveness.

7.2.1.14. Electrochemical Hydrogen Fuel-Cell (Conversion)

Description

Fuel cell directly converts hydrogen to electricity, quietly producing only heat and water, and some water vapor. The electricity produced is more expensive than natural gas because hydrogen remains at least five times more expensive than natural gas, and the fuel cell technology itself is not as mature and, therefore, more expensive.

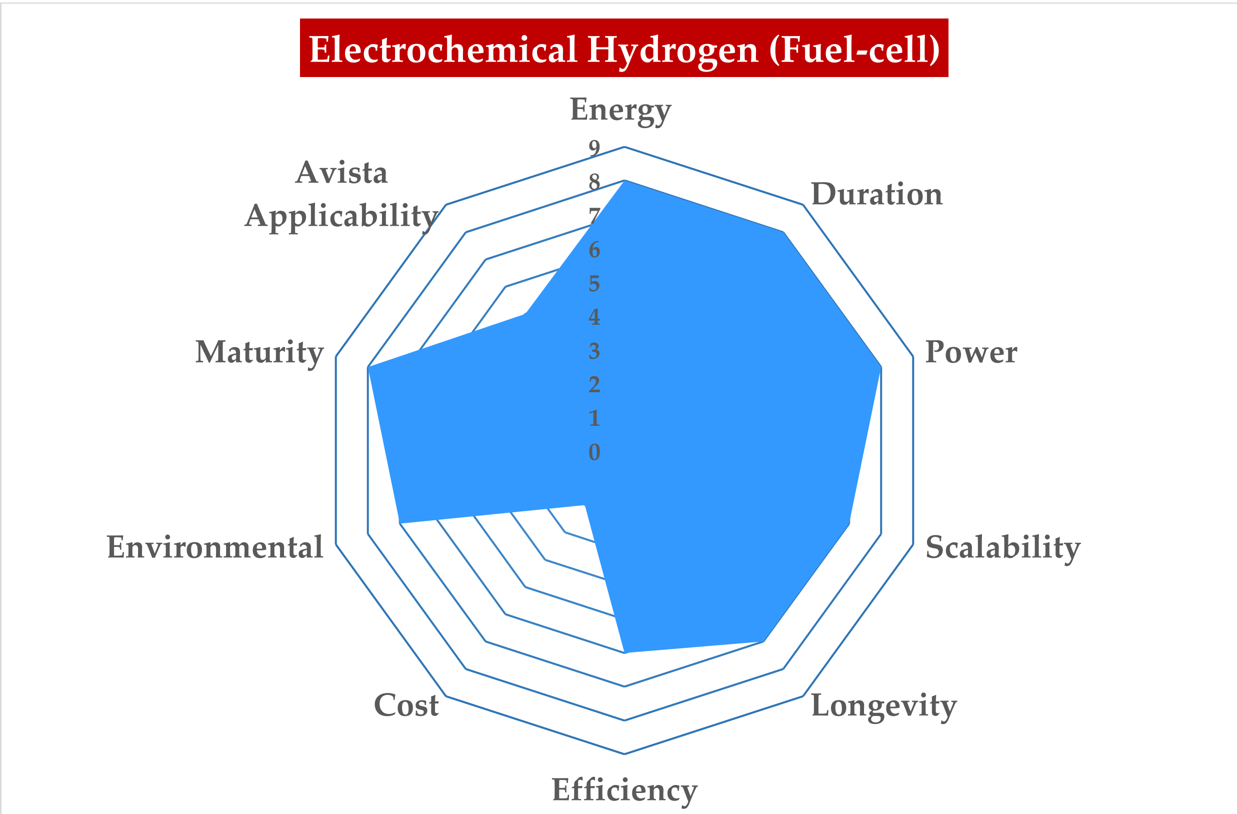

Figure 24 – Electrochemical Hydrogen (Fuel-Cell)

Advantages & Limitations

Fuel cell hydrogen conversion as energy storage has the following advantages:

- Fuel cells serve both energy and power applications (fast-start)
- Fuel cells scale from small to large simply by increasing the cell count
- Energy stored as hydrogen can become electricity or a fuel

Fuel cell hydrogen conversion as storage has the following disadvantages:

- Round trip efficiency remains low.
- Hydrogen storage is expensive and not easily deployed for safety reasons.

- Not all hydrogen is produced via carbon-free electricity

Commitments & Deployments

The US Department of Energy has proposed eight domestic hydrogen hubs to foster production, improve distribution, and innovate in its use. Natural gas utilities and the petrochemical supply chain are actively pursuing hydrogen solutions. Many technology companies are aggressively innovating in the hydrogen landscape.

7.2.1.15. Electrochemical Hydrogen (Combustion)

Description

Hydrogen can be burned as a replacement for natural gas in a single cycle, combined cycle powerplants, or reciprocating engines; however, the greater the percentage of hydrogen in the fuel, the greater the equipment modifications. Natural gas blended with a small percentage of hydrogen (<30%) can be used in some existing power plants. Some existing natural gas-fired reciprocating engines that produce electricity can be converted to blended or pure hydrogen more easily than single and combined-cycle steam-turbine powerplants. eFuels, corn-based ethanol blended with hydrogen, can be used directly in existing reciprocating engines with minimal modification.

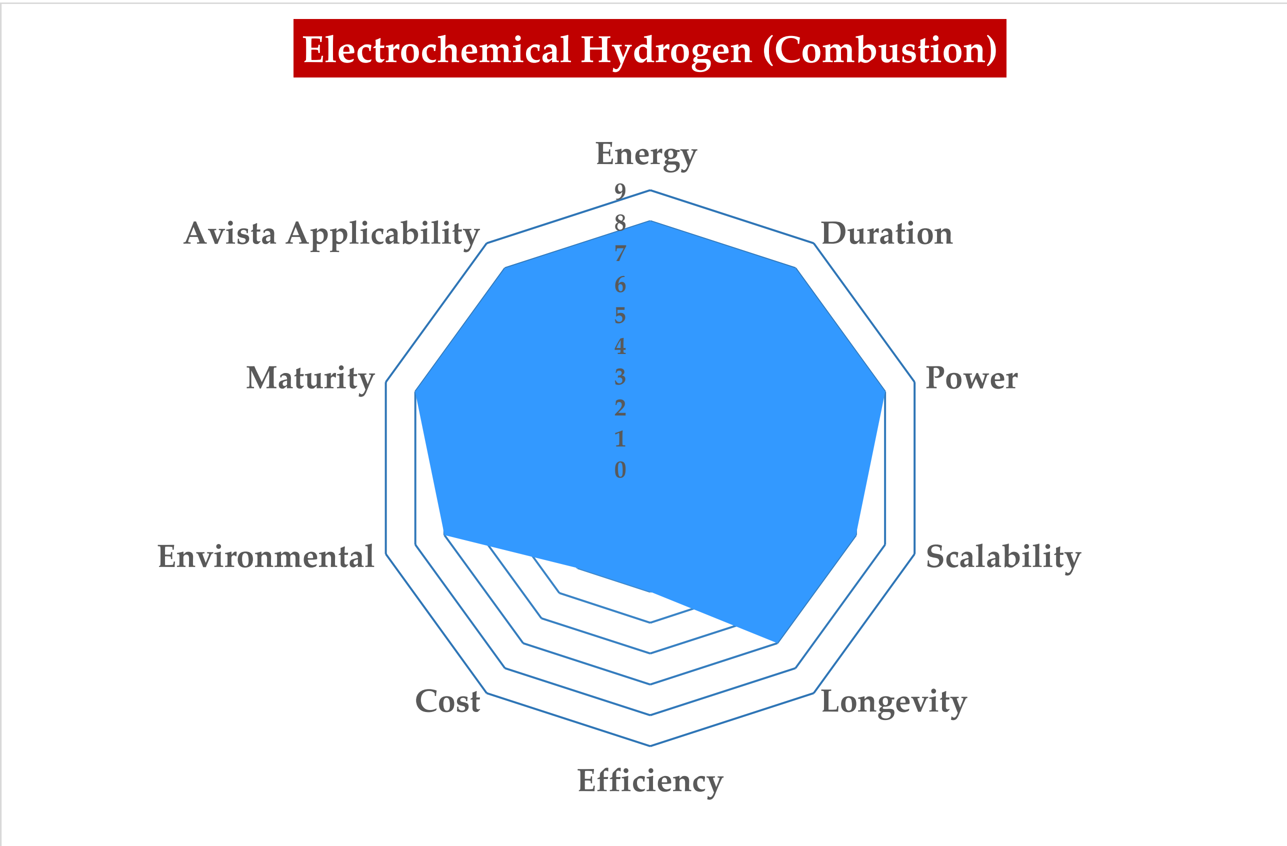

Figure 25 – Electrochemical Hydrogen (Combustion)

Advantages & Limitations

Hydrogen combustion as energy storage has the following advantages:

- Preserves significant infrastructure
- Provides a transition path from fossil fuel – blend then replace
- Energy stored as hydrogen can become electricity or a fuel

Hydrogen combustion as storage has the following disadvantages:

- Round trip efficiency remains low.
- Hydrogen storage is expensive and not easily deployed for safety reasons.
- Not all hydrogen is produced via carbon-free electricity

Commitments & Deployments

The US Department of Energy has a demonstration project in Utah to convert an existing combined cycle plant to blended hydrogen. The single and combined cycle powerplant technology suppliers already have demonstration facilities at the pilot stage. eFuel facilities are in production.

7.2.2. Electronic

7.2.2.1. Electronic SMES

Description

Superconducting magnetic energy storage (SMES) stores energy by creating a flow of direct current into a superconducting coil. Superconducting requires cryogenically cooling the coil below its superconducting critical temperature. Further, electronic semiconductors' power conditioning enables the SMES to provide stable DC power to an inverter. SMES technology, developed in the 1990s, continues to evolve with pilot projects but has failed to reach widespread deployments with standardized products.

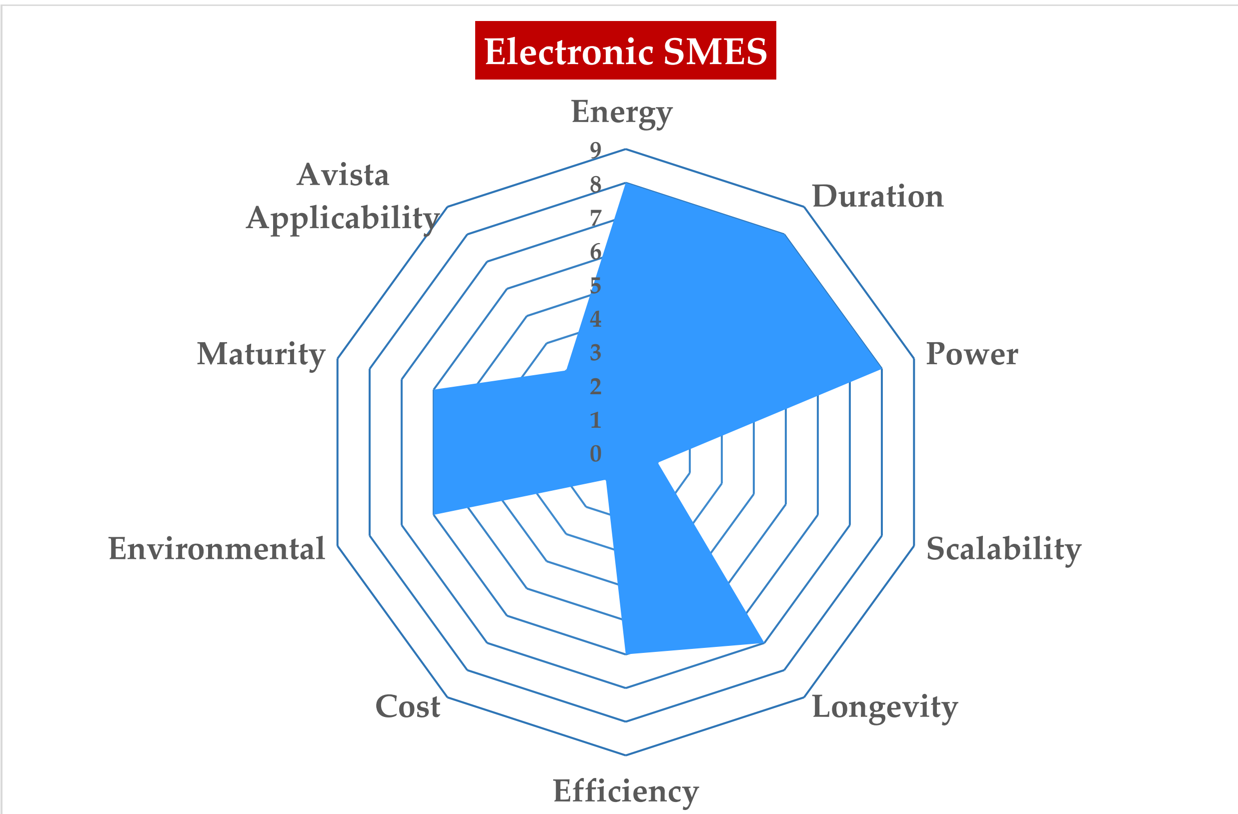

Figure 26 – Electronic SMES

Advantages & Limitations

SMES storage has the following advantages:

- ≈95% round-trip efficiency
- Attractive for power and energy applications.
- Scalable from small to very large applications.

SMES storage has the following disadvantages:

- Short-duration storage (minutes to perhaps a few hours).
- Cost per kWh stored is high.
- Technical risk and complicity.

Commitments & Deployments

Although testbed deployments continue from a few to several hundred MWH, the SMES technology's widespread deployment has been hampered by its supercooling requirement. This supercooling requirement has limited SMES technology to power quality, high-voltage breakers and current limiters, and flexible AC transmission (FACT) devices.

7.2.2.2. Electronic Capacitor

Description

Capacitors-based energy storage devices focus on power, not energy applications. Although capacitors can support energy applications, their costs make them unattractive solutions for most grid-scale energy storage applications. Development is underway on scaling up component-based capacitor solutions but non-have been deployed.

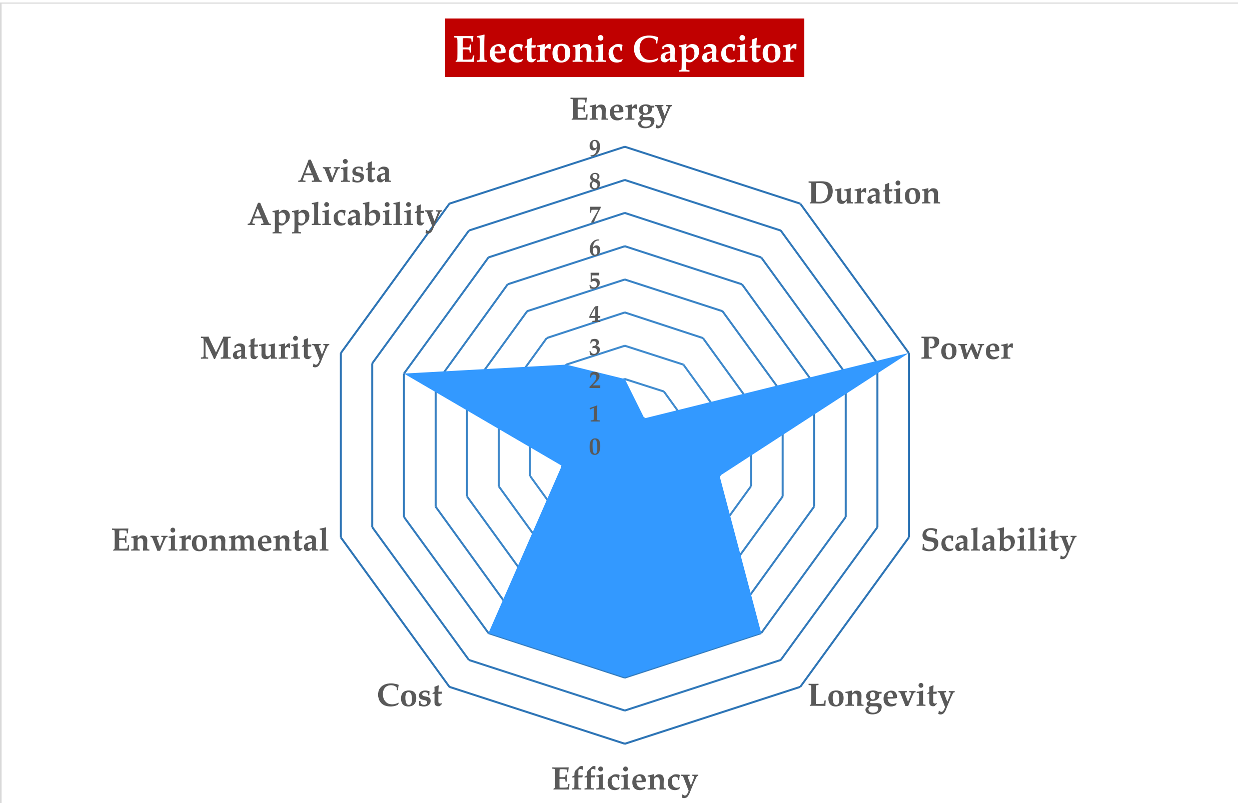

Figure 27 – Electronic Capacitor

Advantages & Limitations

Capacitor-based storage has the following advantages:

- Attractive for power (e.g., regulation) applications.
- Applicable to some highly variable industrial (non-conforming) loads.
- Inertia supply solution for grids with high renewable penetration.

Capacitor-based storage has the following disadvantages:

- Short-duration storage (minutes to perhaps a few hours).
- Less attractive for energy storage.
- It does not scale well to fulfill large requirements.

Commitments & Deployments

Reactive Technologies is building a 5MW ultracapacitor for National Grid (UK) as an inertia solution. When combined with power electronics, ultracapacitors may offer the capability to stabilize the grid automatically based on research underway, but no pilots have been deployed to date.

7.2.3. Thermal

7.2.3.1. Electro-Thermal Energy Storage

Description

Charging storage by heating an inert material, such as sand, and discharging but using the heated air's expansion through a turbine provides a low-tech, low-cost mechanism for electricity storage. The technology is rapidly deployed because it is straightforward, well understood, faces no technological or mechanical challenges, and appears easily productized yet lacks standardization. Charging is accomplished by heating a material stored in a heavily insulated container. Discharging uses heat to heat air that runs through a turbine. Some emerging solutions use the sun to preheat the sand as a combined solar PV and heat facility.

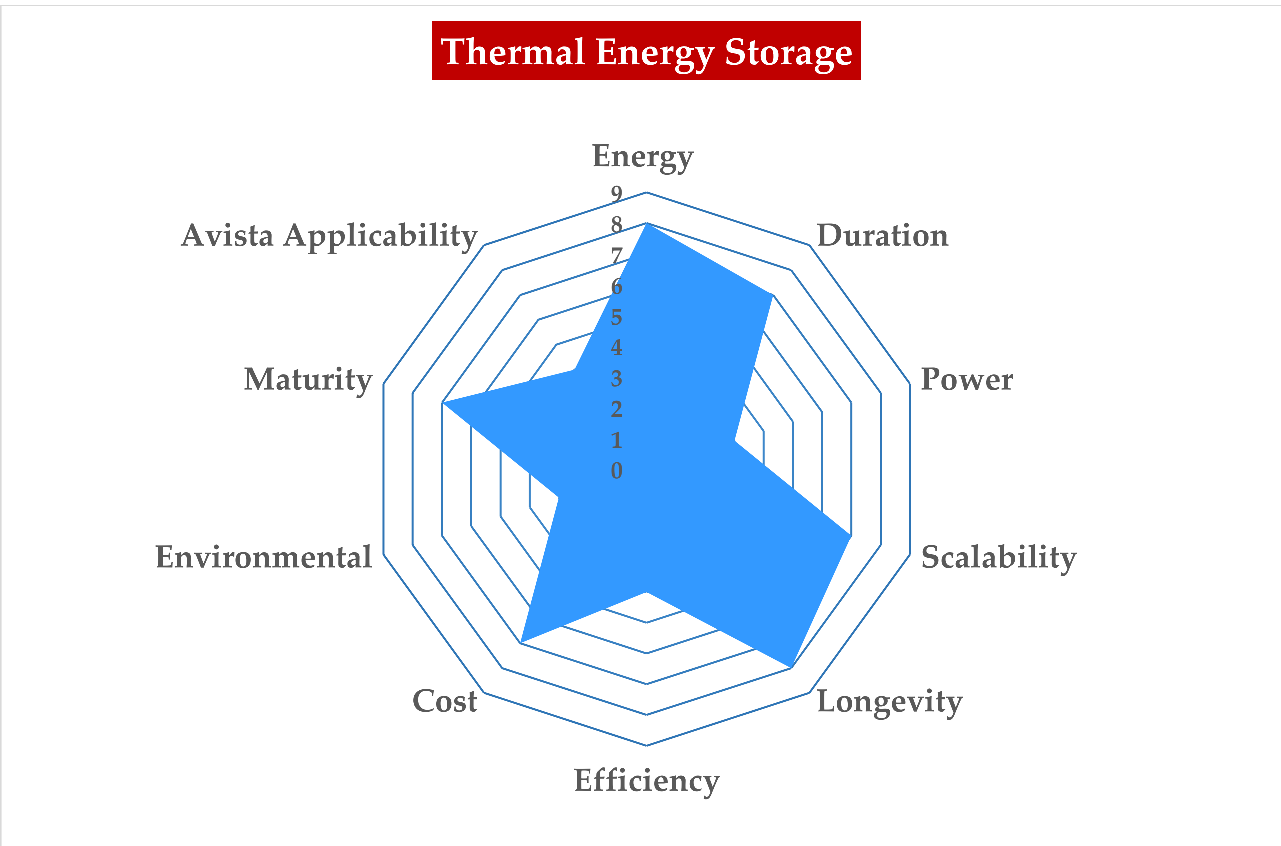

Figure 28 – Thermal Energy Storage

Advantages & Limitations

Heated air storage has the following advantages:

- Attractive for power and energy applications.
- Enables repurposing of existing turbines and power plant sites.
- Low costs per kWh stored at scale.

- Short- to long-duration energy storage (hours to months duration)
- Offers possible combined heat & power industrial applications.

Heated air storage has the following disadvantages:

- Lower round-trip efficiency than lithium-ion batteries.
- Scalability appears attractive but is yet to be demonstrated.
- Lower energy density for the footprint required.

Commitments & Deployments

Deployments in Finland (100 kWh), Australia (5MWH), and Italy (25MWH) are in production using solar- or wind-produced electricity to charge the storage. Thus far, there are no domestic deployments, but NextEra has committed to a pilot project. In North America, Echogen Power Systems is emerging as one of the key suppliers of Electro-Thermal Energy Storage.

7.2.3.2. Thermal Heated Salt

Description

The concept of using a heated chemical in the form of salts or liquids is a derivative of the space program. The technology evolved in conjunction with concentrated solar facilities, where the heat from the concentrator was stored and later converted to electricity to extend the electricity supply after sundown. Today's energy storage approach storage electricity in the form of heat captured in the salts or liquids and discharges by converting the heat to steam and running it through a traditional turbine to produce electricity.

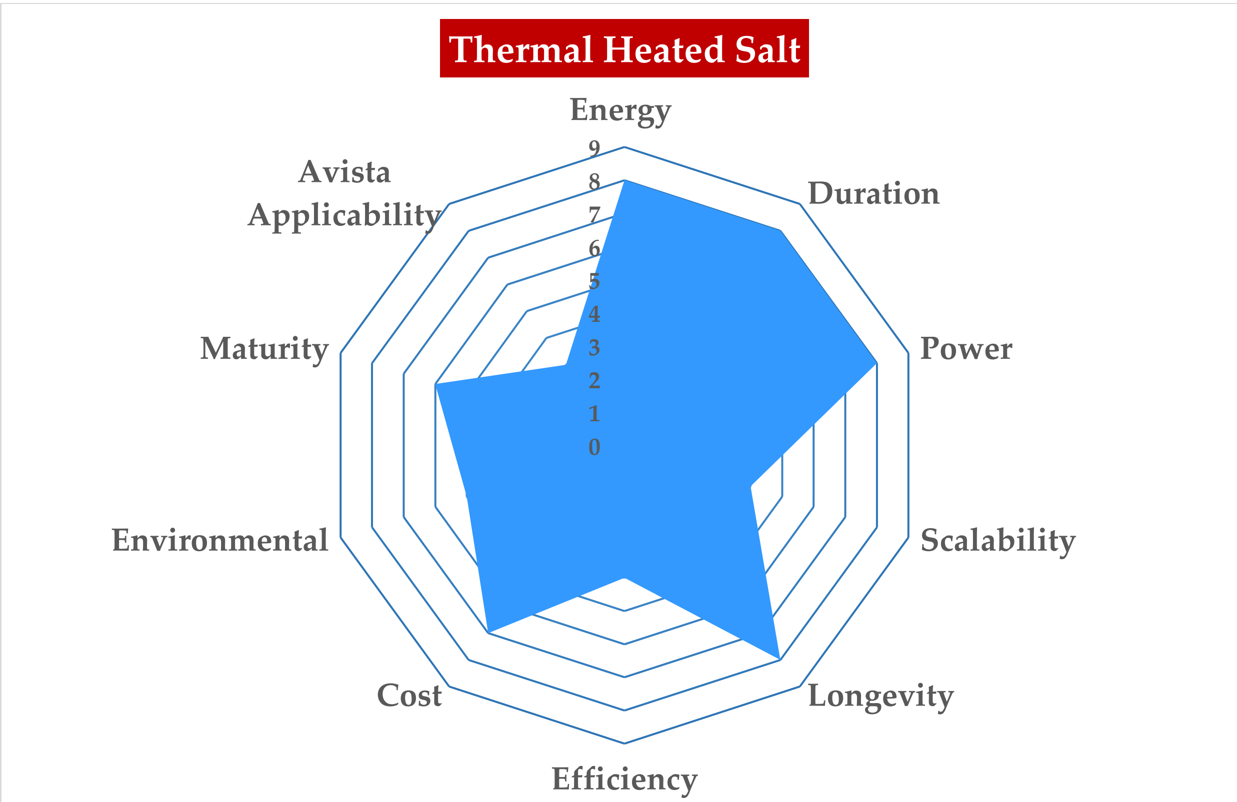

Figure 29 – Thermal Heated Salt

Advantages & Limitations

Heated salts or liquids storage has the following advantages:

- Medium technical risk because most technology is field-proven.
- Support both energy and power applications.
- Repurposes retired coal and gas turbines and sites.
- It has an anticipated life of 30-40 years.

Heated salts or liquids storage has the following disadvantages:

- Requires substantial scale to reach low cost per kWh stored.
- Short to medium (hours to days) storage duration.
- Salts or liquids employed raised environmental concerns.

Commitments & Deployments

Traditional heating and cooling integration and product vendors dominate the space, but the solutions deployed are project specific. Some examples are:

- The University of Arizona deployed an underground chilled water storage facility (>800,000 gallons). The water is chilled when electricity costs are low, and the water is used to air condition >50 campus buildings. It also provides up to five days of HVAC capability before needed to be recharged.
- A major Seattle City Light seafood processing customer deployed an oversized (50 ton/hour) ice production facility and provided ice to other food processors as a service shifting all the electrical load off-peak.

7.2.3.3. Thermal Water/Ice

Description

Although effective for specific applications, such as HVAC applications, chilled or heated water or ice thermal energy storage has not found success for electricity storage. For HVAC and some industrial applications, particularly in food processing, chilling, heating, or freezing water to provide cooling or heating later allows the shifting of the electrical load and, as such, resembles energy storage but only for applications requiring heating or cooling. Cooling applications a much more common than heating.

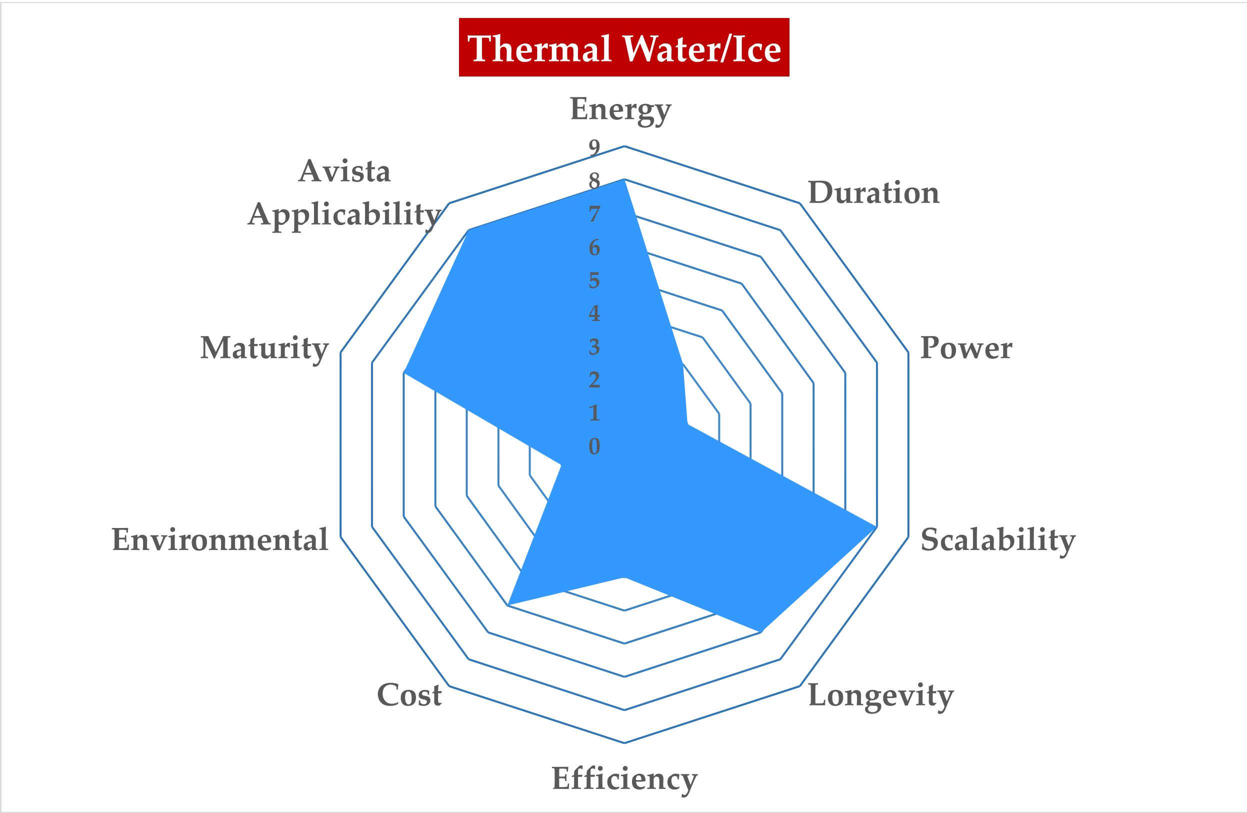

Figure 30 – Thermal Water/Ice

Advantages & Limitations

Chilled or heated water/ice storage has the following advantages:

- Low technical risk because it uses all field-proven off-the-shelf technology.
- Effective at shifting electrical usage across time.
- Provides flexibility - demand response, weather variable wind, and solar.
- Scalable but subject to the specific application and need.

Chilled water/ice storage has the following disadvantages:

- Requires specific applications to provide storage.

- Short to medium (hours to days) duration.
- Scalability is an application that needs specific.

Commitments & Deployments

Traditional heating and cooling integration and product vendors dominate the space, but the solutions deployed are project specific. Some examples are:

- The University of Arizona deployed an underground chilled water storage facility (>800,000 gallons). The water is chilled when electricity costs are low, and the water is used to air condition >50 campus buildings. It also provides up to five days of HVAC capability before needed to be recharged.
- A major Seattle City Light seafood processing customer deployed an oversized (50 ton/hour) ice production facility and provides ice to other food processors as a service shifting all the electrical load off-peak.

7.2.4. Kinetic

7.2.4.1. *Compressed Air*

Description

Although decades-old technology, compressed air energy storage (CAES) is seeing innovation through new siting technologies. The concept requires a sealed, pressurized underground cavern. The technology is quite similar to underground natural gas storage. The cavern is charged with compressed air and discharged as that air is run through a turbine turning a generator. Although some caverns are available, most have been exploited for gas or oil storage. Fracking technological advances now allow cavern creation in just a few years by pumping fluids into an underground formation, dissolving the material, and pumping it to the surface where it is dried and used in concrete or fill material. The resulting cavern is sealed and pressurizable.

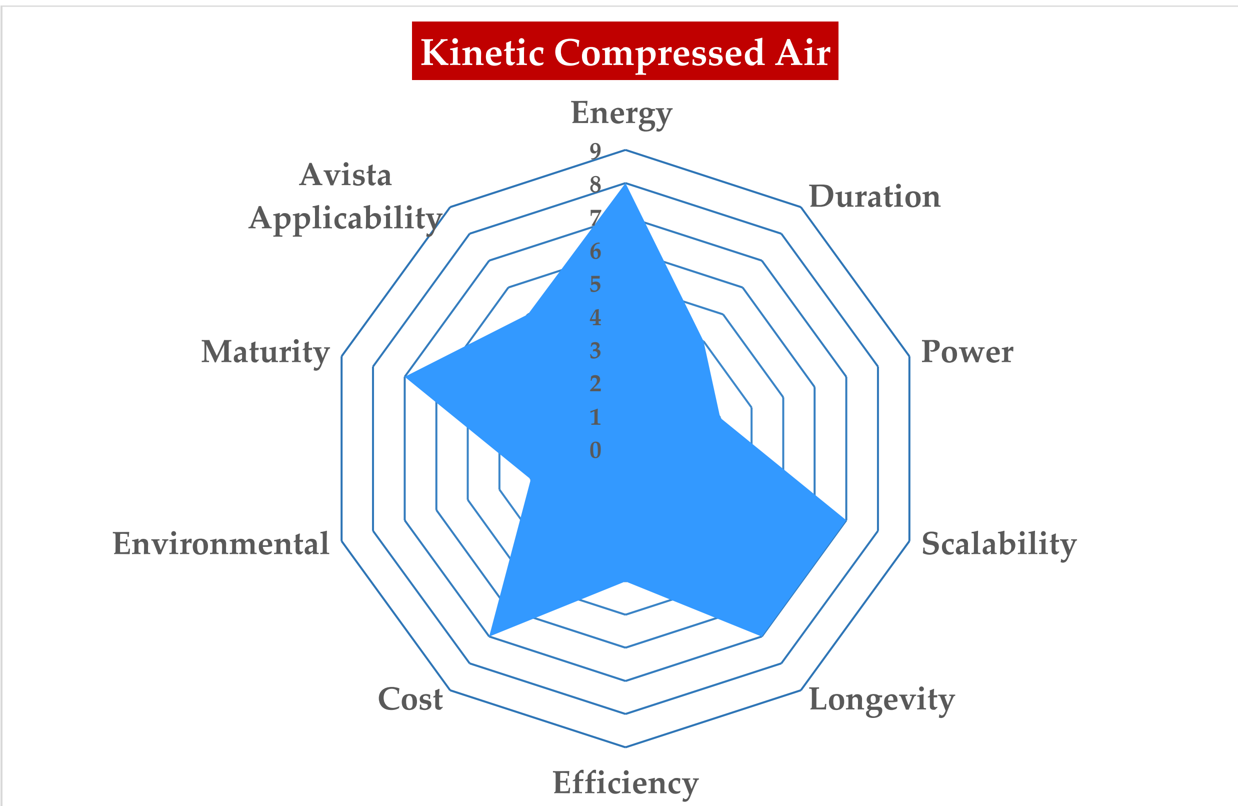

Figure 31 – Kinetic Compressed Air

Advantages & Limitations

Compressed-air storage has the following advantages:

- Low technical risk because it uses all field-proven off-the-shelf technology.
- Predictable operational cost
- Can support both power and energy storage applications

- Attractive for short, medium, and long storage durations (minutes to months)
- It has an anticipated life of 40-50 years.

Compressed-air storage has the following disadvantages:

- High capital cost.
- Massive scale required to reach low cost per kWh stored.
- Requires specific landforms for siting.

Commitments & Deployments

Apex CAES developed the Bethel Energy Center in Anderson County, Texas. Siemens Energy implemented a similar facility in Macintosh, Alabama that can store up to 110MWHs, and larger facilities are proposed for New York, Arizona, and Oregon.

7.2.4.2. Compressed Gas (CO_2)

Description

Charging storage by compressing carbon dioxide into a liquid, capturing the heat produced in a liquid (vegetable oil), and discharging using the stored heat to gasify the carbon dioxide through a turbine into a large storage tank may appear complex, but it is an emerging technology. The energy density of CO_2 is at least an order of magnitude higher than air (ten to thirty times subject to humidity). This closed thermodynamic process has surprising round-trip efficiencies, claimed to be >70%. This European technology has yet to find domestic clients but has several European commitments.

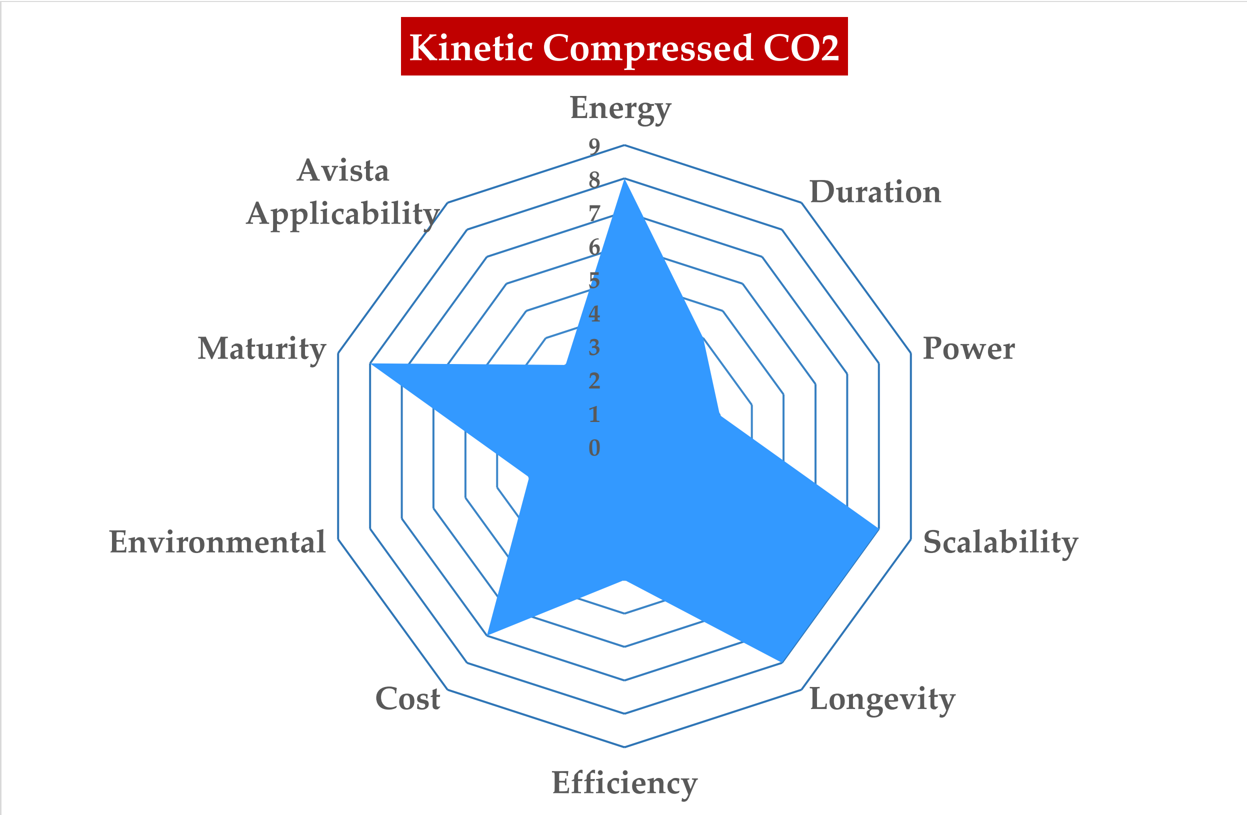

Figure 32 – Kinetic Compressed CO_2

Advantages & Limitations

- Compressed CO_2 storage has the following advantages:
- Adapts well to large-scale deployments.
- Provides a means to sequester CO_2 from existing power plants.
- At scale has a high energy density.
- Provides flexibility – switching from charging to discharging in minutes.
- Can repurpose existing turbines from retired coal and natural gas power plants.

Compressed CO_2 storage has the following disadvantages:

- Requires significant scale to reach efficient cost per kWh stored.
- Short to medium duration storage (minutes to days) because of heat loss.
- High capital cost with modest operational cost.

Commitments & Deployments

EnergyDome, a heavily funded start-up, is the leading vendor. Several European customers have substantial investments and project commitments to technology. Enel (Italy) has made a commitment to four 250MWH units and an option on sixteen additional units.

7.2.4.3. Pumped Storage Hydro

Description

Pumped storage hydro solutions, used for decades and based on mature technology, are undergoing innovation. The innovation enables greater flexibility in siting by removing some landform constraints (e.g., surface reservoirs separated by an elevation change). Subsurface pumped storage solutions with one or both reservoirs underground, perhaps utilizing abandoned mines or shafts, provides unique opportunities for large-scale energy storage. Further, the site can be engineered because the elevation between the upper and lower reservoirs can be created to achieve the desired storage capacity and operational flexibility.

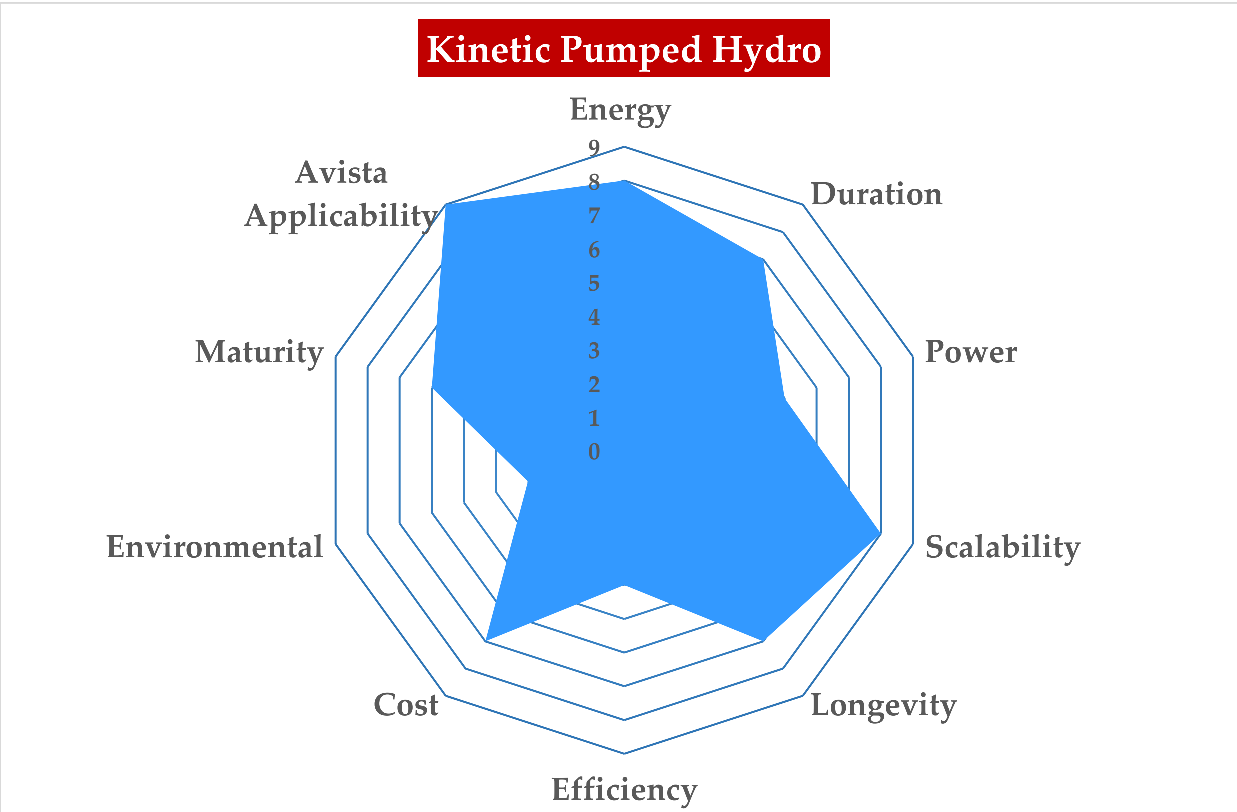

Figure 33 – Kinetic Pumped Hydro

Advantages & Limitations

Pumped-storage hydro has the following advantages:

- Low technical risk because it uses all field-proven off-the-shelf technology
- Underground reservoirs(s) allow greater siting flexibility.
- Modest capital and operational costs if existing mines and shafts are used.
- Flexible storage duration from minutes to months.

Pumped-storage hydro storage has the following disadvantages:

- It does not scale down well.
- Requires scale to reach low cost per kWh stored targets.
- Siting is still limited without drilling new shafts.

Commitments & Deployments

Multiple deployments domestically:

- The Elmhurst Quarry Pumped Storage Project (EQPS - Illinois) was initially designed for 50MW going to 250 MW with >700 GWH storage.
- Riverbank Wisacasset Energy Center (RWEC - Maine) proposed a 1GW facility with a head height of 2,220 feet.
- Gravity Power LLC. and Cavern Energy Storage, with oil/gas industry backgrounds, have proposed massive facilities (>500GWH) in New York, Texas, Louisiana, and Mississippi.

7.2.4.4. Gravity Tower Storage

Description

Lifting large weights with conventional AC electric motors charges the gravity tower/building storage. Lowering those weights down discharges the storage, with the motor becoming a generator. The technology brings scalability by mass producing standard components and siting ease, requiring no unique geographic features. Further, the new commercial buildings can embed the technology in their design.

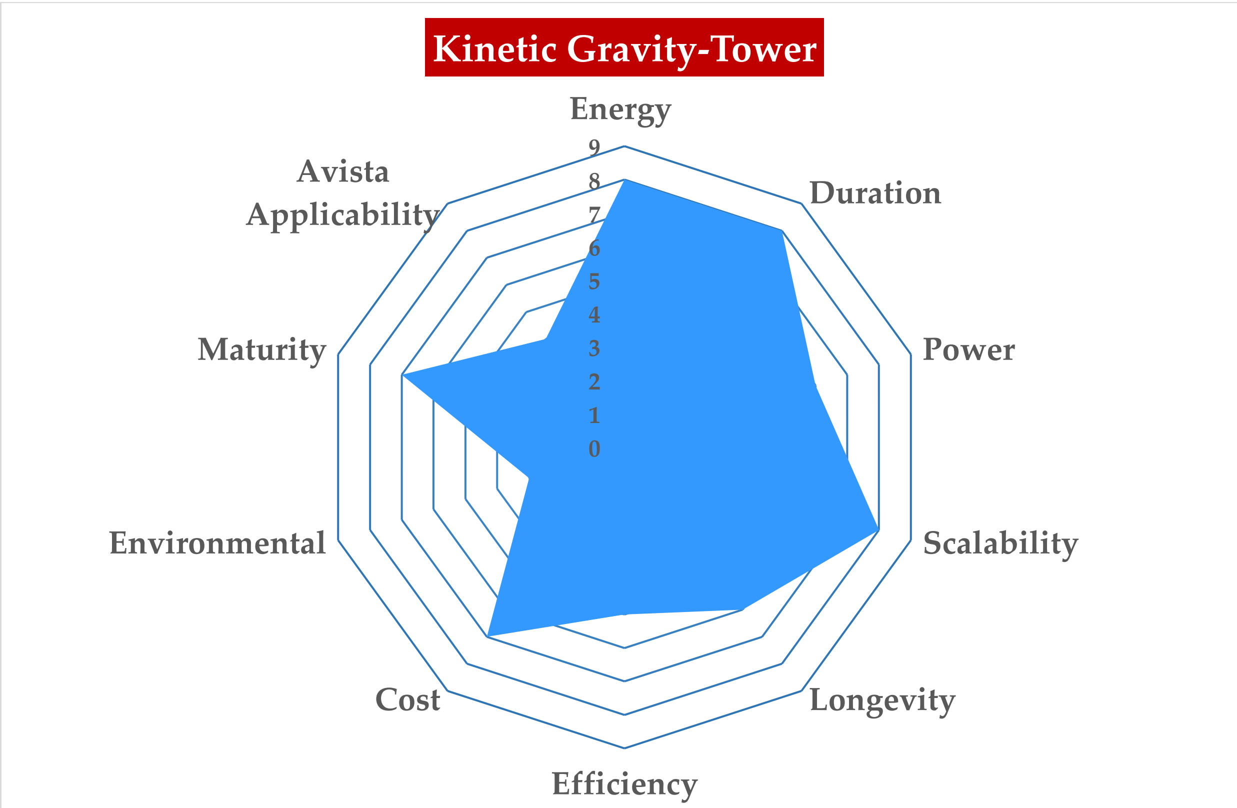

Figure 34 – Kinetic Gravity-Tower

Advantages & Limitations

Gravity tower/building storage has the following advantages:

- Low technical risk because it uses all field-proven off-the-shelf technology.
- Siting requires a location of size and the height adjusted to reduce the footprint.
- Modular components enable simple scalability from kWh to GWH.
- Flexible storage duration from minutes to months.

Gravity tower/building storage has the following disadvantages:

- Lower energy density footprint without very tall structures.

- Modest capital and operational costs.

Commitments & Deployments

Several deployments are underway in Europe. Energy Vault, the leading supplier, claims 1.6GWH of commitments in North America with 220MWH in design in California and Texas.

7.2.4.5. Gravity Rail Storage

Description

Gravity rail storage uses 330+ ton railcars pulled up an incline using AC electric motors that become generators, discharging the electricity as the car moves back down. With multiple tracks, each with multiple cars in motion, the amount of energy available can be tailored to the storage need. Further, the space to store cars at the top of the incline allows significant energy storage.

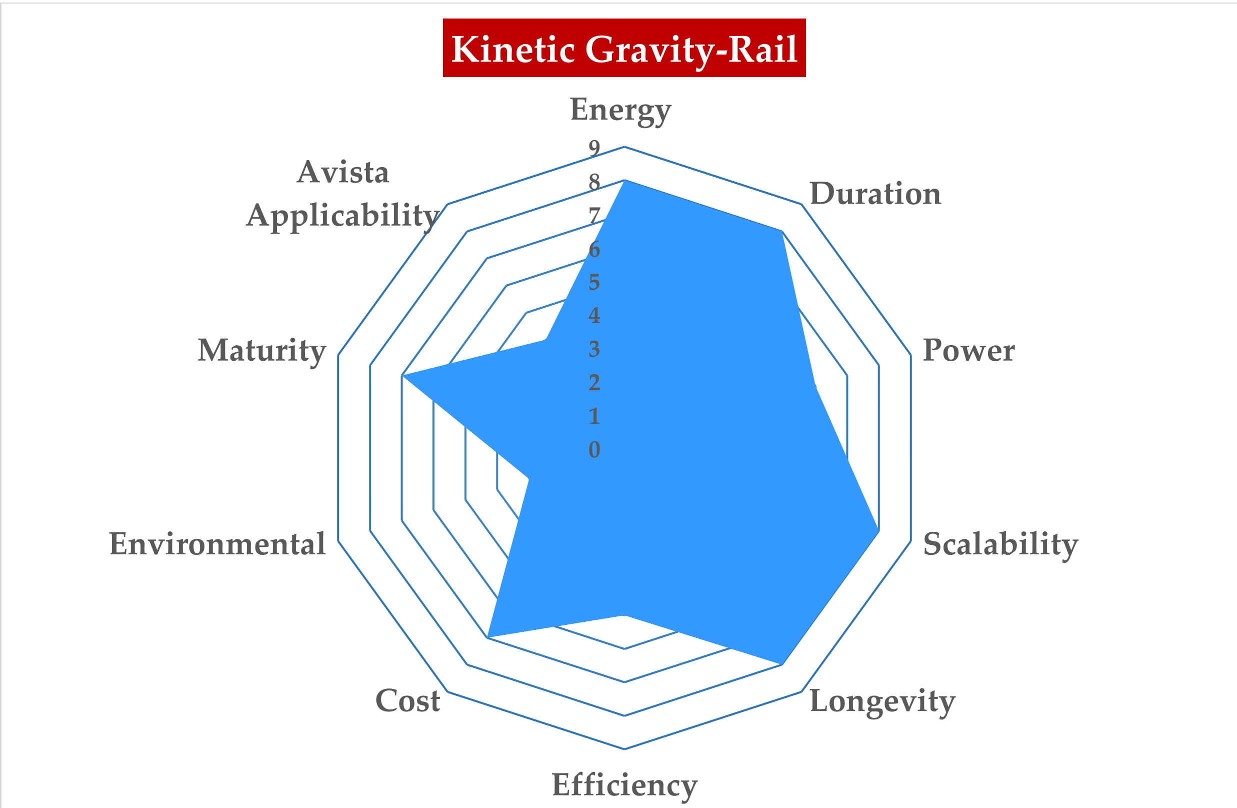

Figure 35 – Kinetic Gravity-Rail

Advantages & Limitations

Energy rail storage has the following advantages:

- Low technical risk because it uses all field-proven off-the-shelf technology.
- Efficient as rail systems have low frictional losses and no inverter losses.
- Inexpensive cost per kWh storage.
- Flexible storage duration from minutes to months.
- It has an anticipated life of 40-50 years.

Energy rail storage has the following disadvantages:

- Requires specific landforms with elevation change and acceptable inclines.
- Relatively low energy density for the footprint required.
- A high initial capital cost but low operating cost.
- Does not scale to small installations – requires significant scale to reach its low storage per kWh projects (forecast at <2 cents/kWh stored).

Commitments & Deployments

Two facilities are planned for Nevada, one by Berkshire Hathaway Energy, the owner of NV Energy, and the other by a developer. Both deployments target retired open pit mine sites to provide the necessary incline and elevation change, and each will begin with a 50MWH single-track system. Each site can support significant expansion, one to possible 20GWH. The technology supplier in both cases is ARES North America.

7.2.4.6. FlyWheel

Description

FlyWheel storage relies on a rotating mass on a vertical shaft connected to a motor/generator. The motor increases the rotation speed to charge, and the generator slows the rotation to discharge. The mass is usually in a vacuum to reduce losses from air friction. Much innovation is needed to manage "wobble" and vibration at speeds up to 300,000 RPMs. The housing, such as Kevlar, around the rotating mass, protects anything outside the energy storage unit from damage should the fly-wheel rotor experience a mechanical failure.

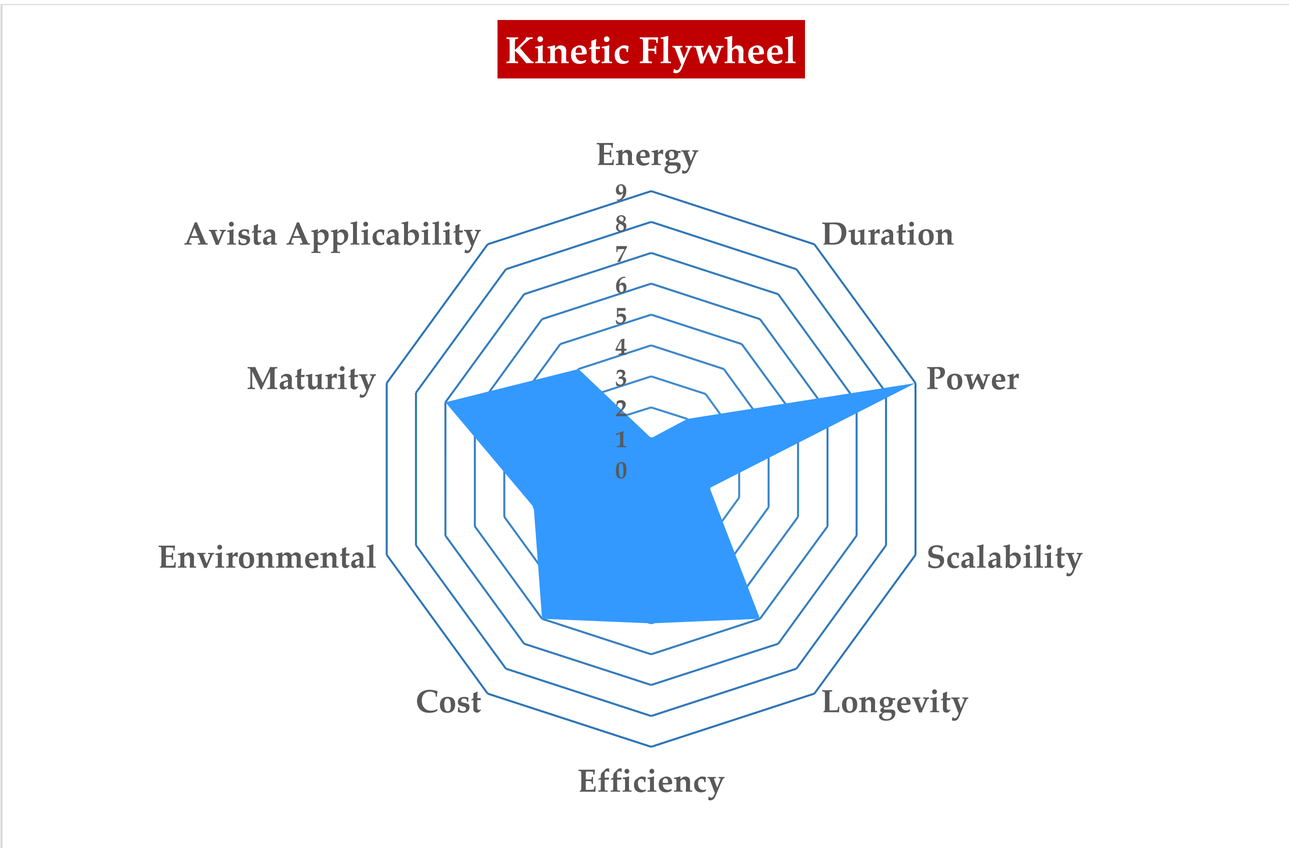

Figure 36 – Kinetic Flywheel

Advantages & Limitations

Fly-wheel storage has the following advantages:

- Low technical risk because it uses all field-proven off-the-shelf technology.
- Attractive for power (e.g., regulation) applications.
- Applicable to highly variable industrial (non-conforming) loads.
- Scales by replication of small units providing granular solutions.

Fly-wheel storage has the following disadvantages:

- Short-duration storage (minutes to perhaps a few hours).
- Less attractive for energy storage.
- Low capital cost but higher operational cost due to its mechanical nature.
- It does not scale well to fulfill large requirements.

Commitments & Deployments

Vendors such as Omnes and Velkess deliver up to 25 kWh per unit production solutions. These units are in operation in North America, some targeting ancillary services arbitrage in wholesale markets and others in industrial applications to reduce demand charges.

8. Summary & Conclusion

Identifying, selecting, evaluating, and deploying non-wire alternatives to address system planning needs and concerns requires tracking the technological innovations, the customer's ambitions, choices, and emerging technology's market conditions compared to traditional solutions to justify projects. This playbook provides a framework and guidelines to assist in that process and requires periodic updates on technology innovations and breakthroughs to remain viable. Implementing non-wire alternative solutions will initially be more difficult because of the lack of familiarity with the approach and technology, but over time, the non-wire alternatives will address a growing portion of system planning's challenges and provide better outcomes to customers and Avista.

Non-wire alternatives can address system planning's challenge of providing adequate capacity for block loads at known locations and specific circuits. Today, block load capacity challenges are tied to a new or significant expansion of commercial customers or residential developments, which can be anticipated and addressed while construction is underway. Even this traditional load growth is proving more challenging to address as property acquisition, permitting, environmental, and zoning requirements increasingly slow the process. The deployment of electric vehicle fleets, data centers, or hydrogen production could introduce new block loads in short timeframes that require more agile and timely solutions

For example, the local delivery service depot or service station could become a capacity challenge without significant construction activity, requiring system planning to have designed and proven solutions available, from storage or additional end-point capacity, such as fuel cells. With the uncertainty of hydrogen as a feedstock, fuel cells reforming natural or renewable gas may provide an interim solution until storage or hydrogen technologies replace them.

What technologies have the most potential to address system planning needs and concerns, then? Storage appears to be the game-changer, but penetration will remain slow, per S&P global <50GWH in the US by 2040. With significant progress in cost, longevity, and disposal/recycling, storage deployments will increase, and a breakthrough in any of these areas will rapidly accelerate storage penetration. In contrast, substantial improvement in multiple areas could increase the demand for storage beyond the market's ability to deliver and deploy.

What technology will experience a breakthrough and profoundly impact the electric grid? In the author's opinion, hydrogen, gravity, or thermal storage could be that technology, bringing short-term, intra-day storage to months to the market at an extremely low cost.