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ARMENIA
ENERGY STORAGE PROGRAM

Summary of Economic, Financial, and Regulatory Analyses of Energy Storage Development in Armenia

September 2023

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Rationale

Why should Armenia start thinking about battery storage now?

As Armenia works towards the Government's ambitious renewable energy targets and the share of **variable renewable generation increases**, the country might need to install **battery storage systems** to ensure the **reliable and smooth operation** of its power system

While the need for battery storage is relatively **low in the short term**, the power sector context might be **significantly different later in the decade**, also depending on the Government's **decisions on power interconnections**

In the short term, the Government of Armenia should focus on **laying the groundwork** to enable the later development of battery storage in the country, by developing a **sound legal and regulatory framework** and supporting the **first pilot storage projects**

Global context

Battery storage is gaining momentum across the world for a range of applications

Utility-scale storage in California

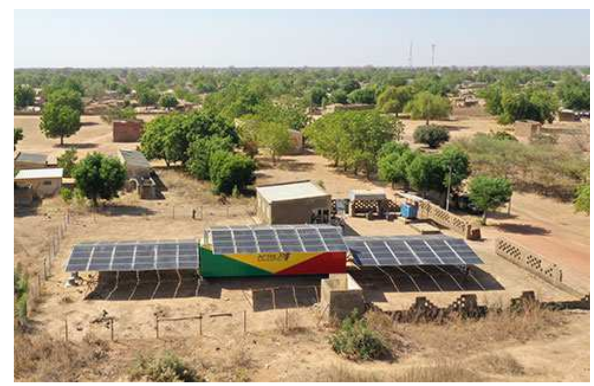
- According to the American Clean Power Association, California had only 256 MW of utility-scale batteries before 2020, but had reached **2.1 GW by the end of 2021 — an 8x increase**
- Recently, **more than 90% of utility-scale solar projects** that have applied for interconnection in California have a battery component
- California has always been a **pioneer of policies and regulations** to drive the move to renewable energy and electrification, and these policies are regularly **imitated elsewhere**
- The deployment of storage is supported by **Investment Tax Credits of up to 30%**

Behind-the-meter (BTM) storage in Germany

- **BTM batteries** are small-scale batteries (3 kW-5 MW) installed at the **residential or commercial customer level** (typically in conjunction with a solar PV system), to provide **peak shaving, self-consumption optimization, and backup power**
- **40% of recent rooftop solar PV systems** in Germany have been installed with BTM batteries
- In 2023, Germany is forecast to pass the mark of **1 million residential BTM batteries** installed, with a 59% increase vs. 2022
- A **clear regulatory framework** (with the elimination of double taxation and the exemption from certain grid access fees) is fueling this growth

Rural mini-grid storage in Africa

- It is becoming clear that building **grid-connected power plants will not be sufficient** to achieve universal access by 2030 in Africa (SDG7)
- **Solar-battery minigrids** hold great potential to boost electricity access in rural Africa, as they are a **fast and cost-effective** way to deliver electricity access to remote and rural areas
- For example, in **Mali** two solar PV installations with a capacity of **1.3 MW (each) of solar and 1.5-2 MWh battery storage** are being built to provide electricity to 24 villages, as part of a larger plan to electrify 70 villages



Summary of Analytical Approach

Two studies were carried out to support the Government of Armenia's energy storage program

A "Energy Modeling and Economic/ Financial Analyses" study	• This report analyzed the **economic and financial viability of battery storage solutions** to ensure the reliable and smooth operation of Armenia's power system in the context of an increasing share of variable renewable energy sources in the grid • **Several battery variants** (ranging from 5 MW to 100 MW, and from 1 to 4 hours of duration) were assessed under three scenarios corresponding to different **evolutions of the Armenian power sector** and two cases related to different levels of **exchanges with neighboring countries** • The financial analysis was carried out for **four possible business models** that could be used for the development of energy storage projects in Armenia
B "Legal and Regulatory Review and Roadmap for Reforms" study	• Building on the results of the earlier report that analyzed the economic and financial viability of battery storage solutions in Armenia, this report focused on assessing the **country's legal and regulatory framework** to identify **challenges to the deployment of energy storage** and recommend **options for necessary reforms** that are tailored to the various possible energy storage business models

Summary of Key Findings and Recommendations

Battery storage can provide economic benefits, but regulatory reforms are required to support its development

A "Energy Modeling and Economic/Financial Analyses" study

1. The economic analysis suggests that a **30MW/120MWh battery would be the most adequate battery size** among the ones considered and would bring **net economic benefits in the case of limited power exchanges with neighbors.**

2. In the case where battery storage is **investor-owned**, a **30MW/120MWh battery would also be financially viable** for all analyzed scenarios and cases. This battery variant could be considered also for the **TSO ownership model**, especially in especially in the case of limited power exchanges with neighbors.

3. The **economic and financial viability** of battery storage projects in Armenia **strongly depends on the level of system connection with neighboring countries**.

B "Legal and Regulatory Review and Roadmap for Reforms" study

1. Armenia's energy sector **institutional framework** consists of state bodies responsible for **policymaking and regulation**; state-owned enterprises responsible for **power generation, and system, market, and transmission network operation**; and a state-owned fund responsible for **facilitating investments.**

2. Regulatory gaps in the areas of **storage definitions in laws, permitting, safety and security standards, wholesale electricity market barriers, and capacity mechanisms** need to be addressed to support development of the battery storage.

3. The **widest gaps** are related to the **investor-owned business model**, while **only a few regulations** need to be developed in the **TSO-owned business model** and the **hybrid business model** in which storage is attached to a VRE plant.

Recommendations

- The economic/financial analyses study should be complemented with **project-specific analyses** with additional granularity on the RE development scenarios, when an **actual battery storage project is proposed** and when decisions are made on **interconnections with neighboring countries** (as the potential for regional power trade to balance variable RE should be considering together with domestic storage).
- To facilitate investments into the battery storage sector, **amendments to relevant laws should be made** over the **first ~1.5 years of the regulatory reform process**, followed by amendments to a range of **relevant PSRC decisions** during the **following six months**.
- Instead of just seeking financing, the Government should **engage the private sector early on** in business model design to get feedback on **revenue scenarios, risk allocation, and policy incentives** that make projects bankable

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- **Energy Modeling and Economic/Financial Analyses**
- Legal and Regulatory Review and Roadmap for Reforms
- Annexes

Key Findings and Recommendations

Armenia Energy Storage Program: Energy Modeling and Economic/Financial Analyses

Objective

The objective of this study is to **analyze the economic and financial viability of several battery storage options** under different scenarios of the Armenian power system and different levels of interconnection with neighboring countries, in order to ensure the **reliable and smooth operation** of the power system in the context of an **increasing share of variable renewable energy sources** in the grid

Summary of key findings

1. The economic analysis suggests that a **30MW/120MWh battery would be the most adequate battery size** among the ones considered and would bring **net economic benefits in the case of limited power exchanges with neighbors,** where additional flexibility would be needed to support the integration of wind and solar capacities.

2. In the case where battery storage is **investor-owned**, a **30MW/120MWh battery would also be financially viable** for all analyzed scenarios and cases, which makes it an attractive options for the private sector. This battery variant could be considered also for the **TSO ownership model**, especially in especially in the case of limited power exchanges with neighbors.

3. The **economic and financial viability** of battery storage projects in Armenia **strongly depends on the level of system connection with neighboring countries**: in more isolated and less flexible operating circumstances of the Armenian power system, batteries could play a more important role and be a more viable option.

Recommendations and Next Steps

- This study should be complemented with **project-specific analyses** when an **actual battery storage project is proposed** (given that the benefits are site-specific) and when decisions are made on **interconnections with neighboring countries**
- Subsequent analyses should consider **different types and sizes** of battery storage solutions, **potential future evolutions of energy storage** (e.g., technological advances, changes in regulations), **and other effects** (e.g., availability of balancing services from neighboring countries)

Research considerations

The study analyzed the viability of four battery storage variants under three scenarios and two operating cases

Battery Storage Variants

5 MW / 5 MWh	
Power capacity:	5 MW
Storage duration:	1 hour

15 MW / 15 MWh	
Power capacity:	15 MW
Storage duration:	1 hour

30 MW / 120 MWh	
Power capacity:	30 MW
Storage duration:	4 hours

100 MW / 400 MWh	
Power capacity:	100 MW
Storage duration:	4 hours

X

Power System Scenarios

Reference Scenario	Scenario based on the expected development of the Armenian power system till 2040 determined in the latest least-cost development plan
High VRES Scenario	Scenario based on Reference with assumed faster VRES (solar and wind capacity) development
High VRES Scenario without new nuclear unit	Scenario based on the High VRES Scenario, but without a new nuclear unit in 2040

X

Operating Cases

Case A (flexible exchanges)

Exchanges with Georgia with the realization of only **one phase of the Armenia-Georgia back-to-back project (350 MW)** and **hourly optimized export to Iran with a predetermined annual total of 1.2 TWh** based on the "Electricity for gas" program with Iran

Case B (exchanges as today)

No interconnection with Georgia (based on considerations given in the latest least-cost development plan) and **export to Iran simulated with fixed and predetermined hourly profiles**

Economic analysis results

Market simulations indicate that a 30MW / 120MWh battery storage variant is best suited for Armenia

Results from Economic Analysis

Net Present Value

The value of all future cash flows over the entire life of an investment discounted to the present.

NPVe		Battery 30MW / 120MWh	Battery 100MW / 400MWh
REFERENCE Scenario	Case A - flexible exchanges with neighbours	-0.02 M$	-74 M$
	Case B - exchanges with neighbours as today	16 M$	2 M$
HIGH RES Scenario	Case A - flexible exchanges with neighbours	-9 M$	-54 M$
	Case B - exchanges with neighbours as today	11 M$	10 M$
HIGH RES Scenario, NO new nuclear unit in 2040	Case A - flexible exchanges with neighbours	-0.4 M$	-38 M$
	Case B - exchanges with neighbours as today	60 M$ (See note *)	91 M$

Internal Rate of Return

A discount rate that makes the NPV of all cash flows equal to zero in a discounted cash flow analysis.

IRRe		Battery 30MW / 120MWh	Battery 100MW / 400MWh
REFERENCE Scenario	Case A - flexible exchanges with neighbours	-2.1%	-7.2%
	Case B - exchanges with neighbours as today	12.1%	6.3%
HIGH RES Scenario	Case A - flexible exchanges with neighbours	0.92%	-2.4%
	Case B - exchanges with neighbours as today	10.8%	7.2%
HIGH RES Scenario, NO new nuclear unit in 2040	Case A - flexible exchanges with neighbours	5.8%	0.9%
	Case B - exchanges with neighbours as today	20.0% (See note *)	13.9%

Key messages

1. Results of the economic analysis suggest that the realization of a **30MW/120MWh battery would bring sufficient economic benefits** in the case with **more limited power exchanges** with neighbors (case B)

2. Results for **case A** are less positive, but the battery could still **support exchanges with neighbors** (e.g., by improving the net transfer capacity of transmission lines) and provide additional benefits that are **not quantified in this study**

3. A **100MW/400MWh battery** seems to be **oversized for the current Armenian power system** and this battery solution would not be able to release its full potential, at least not before 2040. In the Reference and the High RES scenarios, results are barely above the breakeven point of 6%

4. The economic analysis was **not carried out for the smaller battery variants (1 hour)**, as they are too small to be modeled from the point of view of the whole power system and their **overall contribution to the system is negligible**

** Note: In this scenario, the power system adequacy risks are found to be unrealistically high. This suggests that additional generation capacity or stronger interconnections would need to be implemented, and this might alter the economic benefits of battery storage*

Financial analysis results

A 30MW/120 MWh battery would be the most profitable variant for private players to invest in

	Business model description	Financial analysis results	Key takeaways
Investor-owned storage with pure market remuneration (IOPMR)	Battery storage considered as a **commercial asset,** owned and operated by an **investor who aims maximize revenues** from the wholesale, ancillary services, and balancing energy markets	• The **financial viability of battery storage in case B** (limited exchanges) **is much better** than in case A (flexible exchanges), especially for larger batteries • The **30MW/120MWh battery shows positive NPV and IRR in all scenarios and all cases**, suggesting that this would be the most profitable variant for private investors	• **30MW/120MWh battery** is a **viable option** regardless of the scenario/case
Investor-owned storage with support scheme based on capacity payments (IOCM)	Similar to the previous business model, but with battery storage receiving an **additional revenue stream in the form of capacity payment,** which contributes to solving system adequacy issues or shortage of balancing reserves	• The use of this business model **does not seem justified for battery storage in Armenia**, since: – In **case A** (flexible exchanges), **adequacy risks are limited** and storage does not play a significant role in mitigating them – In **case B** (limited exchanges), larger battery storage variants show **good financial results** and would not need public support anyway	• **Capacity mechanism** is unnecessary based on results of the analyses
TSO ownership (TSO)	Battery storage treated as a **network asset** and owned and operated by a **network operator,** which recovers the cost through **tariffs set by the regulator**	• Financial analysis indicates that this model would make **most sense for case B** (limited exchanges) **and for the 30MW/120MWh battery variant**, which shows the best results • For this battery and case, the **NPV would be US$7 million, with an IRR is 34%,** which is far above the discount rate • **Tariff increase would be limited,** between 0.09 and 0.75 $/MWh	• TSO investment **viable only in case B**
Investor-owned hybrid solution of energy storage and VRE plant (IOHS)	Battery storage used by the **owner of a VRE plant** as an option to maximize revenues by **minimizing VRE curtailment** and **shifting power dispatch** to hours with higher prices	• Assuming that a **200MW investor-owned solar PV plant** is combined with battery storage, **neither of the 4-hour battery variants analyzed** (30MW and 100MW) **is financially viable**, with with NPV and IRR being negative in all cases • As a result, it would be **unprofitable** for the owner of a solar PV plant to **combine it with battery storage**	• **Unviable** business model

Detailed results presented in the Annex

Impact of exchanges with neighboring countries

The level of system connection with neighboring countries significantly impacts the viability of battery storage

More limited interconnections drive higher levels of curtailment…

- The level of Armenian system connection with neighboring countries has a **strong impact on generation adequacy and the utilization of the increased levels of VRES generation**.
- Both VRES curtailment and adequacy issues are **significantly higher in the case of limited exchanges** with neighbors and the operations of an almost isolated system

Power system and market indicators

High RES Scenario, no NUCLEAR unit	Case A – flexible exchanges with neighbors	Case B – exchanges with neighbors as today
	2040	2040
Total VRES generation (GWh)	4,371	4,371
VRES curtailment (GWh)	148	617
Level of curtailment (%)	**3.4%**	**14.1%**
Energy Not Served (GWh)	**17**	**196**

… which makes the case for battery storage stronger

- In **more isolated and less flexible operating circumstances** of the Armenian power system (case B), batteries offer positive NPVs through **both economic and financial analysis**.
- Under each of the different scenarios considered (Reference, high RES, and high RES with no nuclear unit), **battery storage consistently offers positive economic NPV under case B**.

Example: economic (NPVe) and financial (NPVf) NPVs for the High RES Scenario with no NUCLEAR unit

		30MW / 120MWh	100MW / 400MWh
NPVf (M$)	Case A – flexible exchanges with neighbors	8	-16
	Case B – exchanges with neighbors as today	34	60
NPVe (M$)	Case A – flexible exchanges with neighbors	-0.4	-38
	Case B – exchanges with neighbors as today	60	91

Additional analyses of the economic viability of battery storage *would be needed once decisions concerning the realization of the* ***interconnection projects with neighboring countries*** *will* ***become clearer***

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Key Findings and Recommendations

Armenia Energy Storage Program: Legal and Regulatory Review and Roadmap of Reforms

Objective

The objective of this report is to assess **Armenia's legal and regulatory framework for energy storage** and **provide recommendations for reforms** that would be needed to successfully implement energy storage projects in Armenia.

The report also provides recommendations on **amendments to key pieces of energy legislation**

Summary of key findings

1. Armenia's **institutional framework** in the energy sector consists of key state bodies responsible for **developing policies for and regulating the sector**; state-owned enterprises responsible for **power generation, system operation, market operation, and transmission network operation**; and a state-owned fund responsible for **facilitating investments.**

2. Regulatory gaps in the areas of **storage definitions in laws, permitting, safety and security standards, wholesale electricity market barriers, and capacity mechanisms** exist and need to be addressed to support development of and investment in Armenia's battery storage sector.

3. The **widest gaps** are related to the **investor-owned business model**, while **only a few regulations** need to be developed in the **TSO-owned business model** and the **hybrid business model** in which storage is attached to a VRE plant.

Recommendations and Next Steps

To facilitate investments into the battery storage sector, **amendments** will need to be made to **RA laws** over the **first ~1.5 years of the regulatory reform process**, followed by amendments to a range of **relevant PSRC decisions** during the **following six months**.

The Government should prioritize **no-regret policy and regulatory reforms** that do no need to be tied to specific projects.

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Institutional Framework

Armenia's energy sector is governed by state bodies, state-owned enterprises, and a state-owned fund

Institution	Description	Selected batter storage-related functions	
Ministry of Territorial Administration and Infrastructures (MTAI)	The authorized body of the government in the energy sector	• Implements the state policy in the field of energy within its mandate. • Supports the state regulation in the field of energy	• Develops investment plans for state-owned enterprises
Public Services Regulatory Commission (PSRC)	Independent body regulating electricity, natural gas, water, and telecommunications industries	• Defines electric energy tariffs. • Provides licenses in the field of energy. • Approves the rules of the electricity market;	• Defines the mandatory conditions or samples of contracts concluded between energy licensees.
"Power System Operator" CJSC	A 100% state-owned TSO, responsible for the operational management of the power system.	• Short-term planning and regulation in the power system • Operational management of the electric power system	• Planning of electricity transmission network development.
"Settlement Center" CJSC	A 100% state-owned company, responsible to make power and energy calculations in wholesale electricity market.	• Recordkeeping of contracts concluded between participants of the wholesale electricity market and for the import or export of electric energy (capacity).	• Organization of electricity market activity. • Registration of electricity market participants.
"High Voltage Electric Networks" CJSC	A 100% state-owned company. Owns and operates the transmission network	• RA electrical energy (power) transmission. • Transmission network maintenance and operation.	• Expansion and development of transmission network.
"Armenian Nuclear Power Plant" CJSC	A 100% state-owned company that generate electricity under a generation license.	• Electricity /power/ production.	• Export of produced electricity/capacity belonging to the company.
"Yerevan TPP» CJSC	A 100% state-owned company and sole balancing service provider of WEM.	• Production, delivery, and sale of electric energy. • Production, transportation, and sale of thermal energy	• Provides the service of BSP in the WEM
Armenia Renewable Resources and Energy Efficiency Fund (R2E2)	A state-linked autonomous legal entity that facilitates investments in energy efficiency and renewable energy in Armenia.	• Support for the creation of new productions and the organization of services promoting the development of renewable energy; • Organization of implementation of credit and grant programs in the field of renewable energy;	• Implementation of other measures to increase national energy security; • Responsible for the legal and regulatory review for the Armenia Energy Storage Program.

Regulatory gap and recommended actions (1/3)

Define storage in laws, optimize the permitting process, and establish safety and security standards

	Importance	Armenia context	Actions
Storage definitions in laws	**Defining storage** as a unique entity in the electricity sector is **essential to prevent regulatory discrimination**. **Market access rules**, initially designed for other actors, **could unintentionally disadvantage storage**. Clear legal definitions for storage within national laws can **boost investment security**, supporting energy system deployment.	Most key pieces of energy legislation do not make specific references to electricity storage and do not provide any status to entities engaged in electricity storage, and particularly battery energy storage.	➢ **Define the activity of electricity storage as a type of activity subject to licensing (or notification) in the field of energy.** *Germany gave energy storage its legal definition in 2022, defining it as an asset where "the final use of electrical energy is postponed to a later point in time than when it was generated"*
Permits	Permitting regulations for storage facilities should account for their **technical features and potential environmental, safety, fire, public health, and landscape impacts**. While the absence of tailored rules isn't necessarily a primary obstacle to storage development, it can **impede the permitting process**. Challenges may arise from the inappropriateness of the standard legal framework for storage projects and the absence of specific provisions.	Legal acts establishing permits in Armenia do not address the activity of electricity storage. Organizations operating in the field of energy must also obtain the following permits, among others. • License for relevant activities in the field of energy • Positive conclusion of the environmental impact assessment of the project detailed design • Positive conclusion of the technical examination of the project detailed design and construction permit Legislation governing these permits do not make any reference to electricity storage, and particularly BESS.	➢ **Review and optimize the permitting process** ➢ **Promote efficient coordination among all relevant administrative bodies.** ➢ **Establish reasonable timeframes for the permitting process process, while facilitating timely and meaningful public input.**
Safety and security standards	Adherence to safety and security standards, can **impact the economic and technical feasibility of battery storage**. It's essential to establish safety and security standards for storage installation companies that **accurately assess risks without impeding the adoption of storage solutions.**	Mandatory rules for the design, implementation, and operation of urban planning objects, buildings, and constructions in Armenia are defined by the system of urban planning normative-technical documents. In Armenia, no normative-technical document regulates BESS's design, installation, operation, and maintenance.	➢ **Develop safety and security normative-technical documents regulating the design, installation, operation and maintenance of BESS.**

Regulatory gap and recommended actions (2/3)

Address key barriers in the wholesale electricity market and gaps related to capacity mechanisms

	Importance	Armenia context	Actions
Wholesale electricity market (WEM) barriers	Market barriers for storage can be categorized as entry barriers and participation barriers. Entry barriers include **issues like undefined storage market rules or excessive pre-qualification requirements**, while participation barriers involve **inappropriate market design parameters, such as minimum bid sizes**. Specific market designs may feature only one type of barrier, but they ultimately **hinder storage deployment**.	The WEM rules do not in any way regard the entities engaged in the activity of electricity storage and do not give them any status (WEM participant, trade participant or service provider). Under the current market model, a storage plant (Investor-owned storage) can receive the status of BPP, being included in the balancing group of the BSP, and provide only a secondary reserve; or receive the status of market trade participant (as producer and supplier) and carry out electricity trading in the direct contract market and day-ahead market components of the wholesale electricity market.	➢ **Define the status of companies engaged in electricity storage as participants in WEM** ➢ **Define the rights and responsibilities of the companies engaged in the activity of electricity storage as participants of the wholesale market.** ➢ **Make any other amendments to bring the PSRC decisions into compliance with the requirements of the amended laws and adopt new normative legal acts necessary for the implementation of the amended laws** *California developed regulations to allow utility-scale batteries to participate in the wholesale electricity market. Today, batteries provide over half of the California ISO's regulation up and regulation down requirements*
Capacity mechanism	Capacity mechanisms are measures taken in support of medium- and long-term **electricity supply security.** They enable power plants to be available for generating electricity when needed **in exchange for payments.**	RA legislation on electric energy does not contain provisions on Capacity Mechanism. As a result, the use of Capacity Mechanism is not regulated in RA.	➢ **Define capacity payments** ➢ **Define the transparent and non-discriminatory access of the capacity mechanism for those participants of the wholesale market whose technical capabilities allow to provide such a service in accordance with the network rules.** ➢ **Make associated amendments to the secondary legislation.** *California's ISO and other ISOs around the world allow the participation of storage units in their Capacity Remuneration Mechanisms (CRMs), although their participation can be more or less economically viable depending on the concrete rules*

Regulatory gap and recommended actions (3/3)

Existing rules in Armenia already address the issues of double tariffs and double taxation for storage

	Importance	Armenia context	Actions
Double application of grid tariffs for storage units	End-users pay grid charges based on the amount of electricity taken off from the grid and/or based on their connection capacity or peak capacity taken off from the grid. **Energy storage can physically be considered as both producer and consumer**, and therefore both type of grid charges could apply. **This distortion can be a major barrier to the development of storage.**	In Armenia, end-users pay grid charges on the bases of the amount of electricity taken off from the grid (AMD/MWh). Armenia does not apply injection charges for generators and thus the problem of double application of grid tariffs does not exist in RA.	NA
Double application of taxes	Storage plants that are directly connected to the grid, **may be considered as both producer (injection) and consumer (offtake)**. If storage is considered an energy consumer for taxation purposes, energy offtake by storage will constitute a taxable event. Subsequently, the discharge energy will be taxed once again when finally consumed by the end-user. This can have a **negative impact on investment and use of storage**.	The end-user pays VAT on the bases of the amount of electricity taken off from the grid (AMD/MWh) when it comes to VAT. As a result, discharged energy will be taxed at two points (once when energy is off taken by storage and once again when finally consumed by the end-user). However, the problem of double taxation does not arise, because energy storage company will reduce the VAT to be paid to the state budget by the amount of VAT already paid when energy was off taken. Hence the issue of double taxation will not arise.	NA

The elimination of the double application of grid tariffs and taxes was a crucial action to enable the development of energy storage in Germany and California

Reform roadmap (1/2)

Key primary legislation amendments should be the focus during 2024 and first half of 2025

Area	Milestones	Business model*	Timeline																							
			Number of Months																							Year
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
	Primary Legislation																										
Storage definitions in laws	Law on Energy (N148 of 07.03.2001)	IOPMR; IOCM; TSO																								2024-2025
	Law on Renewable Energy and Energy Efficiency (N122 of 09.11.2004)	IOPMR; IOCM																								
	The draft law on Electricity produced by USAID (May 16, 2023)	IOPMR; IOCM																								
WEM barriers	The draft law on Renewable Energy and Energy Efficiency produced by USAID (May 31, 2023)	IOPMR; IOCM																								
Permits	Law on Licensing (N193 of 30.05.2001)	IOPMR; IOCM																								
	Law on Environmental Impact Assessment (N110 of 21.06.2014)	IOPMR; IOCM; TSO; IOHS																								

Note: The 4 business model options include: (i) investor-owned storage with pure market remuneration (IOPMR), (ii) investor-owned storage with support scheme based on capacity payments (IOCM), (iii) TSO ownership (TSO), and (iv) investor-owned hybrid solution of energy storage and VRE plant (IOHS)

Reform roadmap (2/2)

Amendments to relevant PSRC decisions should be made in the second half of 2025

Area	Milestones	Business Model*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Year
	Secondary Legislation																										
Permits	PSRC Decision on approving the procedure for licensing activities in the field of energy and revoking a number of decisions (N 374 of 01.11.2013)	IOPMR; IOCM																									2025
WEM barriers	PSRC Decision on approving the trading rules of the RA electricity wholesale market and revoking RA PSRC decision N 344 of August 9, 2017 (N 516 of 25.12.2019)	IOPMR; IOCM																									
	PSRC Decision on approving the RA electricity market transmission network rules and revoking RA PSRC decision No. 161 of May 17, 2017 (N 522 of 25.12.2019)	IOPMR; IOCM																									
	PSRC Decision on approving the RA electricity market distribution network rules and revoking a number of decisions of the RA PSRC (N 523 of 25.12.2019)	IOPMR; IOCM																									
Safety and security standards	Safety and Security Standards /Development of normative-technical documents regulating BESS design, installation, operation and maintenance	IOPMR; IOCM; TSO; IOHS																									

Note: The 4 business model options include: (i) investor-owned storage with pure market remuneration (IOPMR), (ii) investor-owned storage with support scheme based on capacity payments (IOCM), (iii) TSO ownership (TSO), and (iv) investor-owned hybrid solution of energy storage and VRE plant (IOHS)

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Economic analysis: methodology and assumptions

Key economic benefits and costs were considered to evaluate net economic benefits

Benefits

Social Economic Welfare	Calculated as the sum of the changes in Consumer and Producer Surpluses and Congestion Rents for different energy storage variants.
Monetization of Energy Not Served (ENS)	The monetized value of the improvement in security of supply. Calculated by multiplying ENS (amount of energy demand not supplied due to insufficient resources) by Value of Lost Load (sum of costs associated with unserved energy)
Societal benefit from reduction in CO2 emissions	the change in CO2 emission due to a new project. The indicator consists of two components: the pure CO2 emission in tons and corresponding costs in $/year.

Costs

Capital expenditure	
Battery storage variant	**CAPEX (M$)**
30 / 120	29.220
100 / 400	97.400

Operating expenditure	
Battery storage variant	**OPEX (M$/year)**
30 / 120	0.731
100 / 400	2.435

Assumptions

Discount rate:	**6%**
Economic lifetime:	**15 years**

Financial analysis: methodology and assumptions

Financial analysis was conducted for four business models taking into account four revenue sources

Business Models

Investor-owned storage with pure market remuneration	Battery storage is considered as a commercial asset, owned and operated by the investor who aims to operate the storage in a manner to maximize the revenues from the wholesale, ancillary services and balancing energy markets. In this business model, the battery storage is competing with other portfolios like power plants and export/imports.
Investor-owned storage with support scheme based on capacity payments	This model is assessed in the case that adequacy issues are detected in Armenia without new storage projects. In addition to the above-described model, here the energy storage obtains an additional revenue stream in the form of capacity payment based on the available capacity which contributes to solving adequacy issue or shortage of balancing reserve.
TSO ownership	The storage project in this model is treated as a part of network asset, which is constructed, owned and operated by a network operator. Energy storage is used outside the wholesale market and could be used for network services only.
Investor-owned hybrid solution of energy storage and VRE plant	In this case battery energy storage provides an option for the owner to maximize revenues by minimizing VRE curtailment. Through energy storage charging, revenue can be maximized by shifting power dispatch to hours with higher prices and reducing balancing costs.

Revenue Sources

Energy arbitrage revenues	Represents the revenues which can be generated by energy storage operation on the wholesale market.
Balancing reserve provision revenues	Represents the revenues gained from provision of the reserve related ancillary services.
Revenues from balancing energy provision	Represents the difference between revenues obtained from balancing energy provision and costs from balancing energy provision.
Capacity payment	Represents the state aid provided for the rights to utilize the battery storage plant's available capacity.

Financial analysis results

Investor-owned storage model: 30MW/120MWh battery is the only one that is profitable across all scenarios/cases

Results from Financial Analysis

Net Present Value

The value of all future cash flows over the entire life of an investment discounted to the present.

NPVf		Battery 5MW / 5MWh	Battery 15MW / 15MWh	Battery 30MW / 120MWh	Battery 100MW / 400MWh
REFERENCE Scenario	Case A - flexible exchanges with neighbours	-0.4 M$	-1.3 M$	0.6 M$	-34 M$
	Case B - exchanges with neighbours as today	-0.1 M$	-0.3 M$	14 M$	6 M$
HIGH RES Scenario	Case A - flexible exchanges with neighbours	-0.04 M$	-0.2 M$	8 M$	-13 M$
	Case B - exchanges with neighbours as today	0.1 M$	0.2 M$	19 M$	25 M$
HIGH RES Scenario, NO new nuclear unit in 2040	Case A - flexible exchanges with neighbours	-0.04 M$	-0.2 M$	8 M$	-16 M$
	Case B - exchanges with neighbours as today	0.1 M$	0.2 M$	34 M$	60 M$

See note *

Internal Rate of Return

A discount rate that makes the NPV of all cash flows equal to zero in a discounted cash flow analysis.

IRRf		Battery 5MW / 5MWh	Battery 15MW / 15MWh	Battery 30MW / 120MWh	Battery 100MW / 400MWh
REFERENCE Scenario	Case A - flexible exchanges with neighbours	-11.6%	-12.2%	10.4%	-12.1%
	Case B - exchanges with neighbours as today	6,0%	5.5%	34.5%	12.2%
HIGH RES Scenario	Case A - flexible exchanges with neighbours	8,0%	7.3%	21.8%	3.7%
	Case B - exchanges with neighbours as today	12.4%	11.7%	40.8%	20.3%
HIGH RES Scenario, NO new nuclear unit in 2040	Case A - flexible exchanges with neighbours	8,0%	7.3%	22.0%	2.1%
	Case B - exchanges with neighbours as today	12.4%	11.7%	45.3%	26.7%

See note *

Key messages

1. The financial viability of battery storage in case B (limited exchanges) is much better than in case A (flexible exchanges), especially for larger batteries

2. The 30MW/120MWh battery shows positive NPV and IRR in all scenarios and all cases (ranging from US$0.6 million to US$19 million, and from 10% to 41% respectively), suggesting that this would be the most profitable variant for private investors

3. The two 1-hour batteries show positive results only in case B in the High RES scenario, but even in this case the benefits are low, due to the fact that they can only provide balancing services (and not arbitrage)

** Note: In this scenario, the power system adequacy risks are found to be unrealistically high. This suggests that additional generation capacity or stronger interconnections would need to be implemented, and this might alter the economic benefits of battery storage*

Financial analysis results

Comparison of revenues of different battery storage variants in the investor-owned storage model

Range of monetized market indicators of analyzed battery storages across all scenarios and cases between 2025 and 2040

	Battery 5MW / 5MWh		Battery 15MW / 15MWh		Battery 30MW / 120MWh		Battery 100MW / 400MWh	
	Min	Max	Min	Max	Min	Max	Min	Max
Financial revenue from arbitrage (M$)	n.a.	n.a.	n.a.	n.a.	0.1	3.6	0.2	11.2
Reserve provision revenue (M$)	0.07	0.28	0.21	0.83	1.0	3.3	1.7	9.7
Balancing energy revenue (M$)	0.03	0.07	0.08	0.15	0.3	1.7	0.5	3.1
Total financial revenue (M$)	**0.10**	**0.31**	**0.29**	**0.93**	**1.7**	**7.8**	**2.5**	**22.9**

Revenues from arbitrage

- For the two 1-hour battery storage variants, revenues from arbitrage are negligible and have not been considered due to their limited energy capacity.
- Limited energy storage capacity of just one hour does not provide enough time for any significant activity in the wholesale market. As a result, only the larger 4-hour battery variants generate financial revenue from arbitrage.

Reserve provision and balancing energy revenues

- The key benefits provided by the smaller 1-hour battery storage variants are revenues from reserve provisions and balancing energy; however, the limited size of these battery storage variants (5MW and 15MW) act as constraints to these revenue sources compared to the larger 4-hour battery storage variants (30MW and 100MW).

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Detailed recommendations for regulatory reform (1/3)

Milestones	Action items/Recommendations
Law on Energy **(N148 of 07.03.2001)** **Law on Renewable Energy and Energy Efficiency** **(N122 of 09.11.2004)**	Define the activity of electricity storage as a type of activity subject to licensing (or notification) in the field of energy. Define the rights and responsibilities of entities engaged in energy storage activity. Grant the non-discriminatory electricity market participant status to entities engaged in energy storage activity. To ensure non-discriminatory and transparent dispatching, access to balancing services, and to the grid. To ensure that storage can be dispatched and can set the wholesale market clearing price as both a seller and buyer consistent with existing market rules; To ensure storage is eligible to provide all capacity, energy, and ancillary services that it is technically capable of providing in the WEM.
	It is proposed to make the following additions in the paragraph 1 of the law: "The Transmitter has the right to own, develop, manage or operate energy storage facilities, where they are fully integrated network components and are used exclusively to ensure the reliability and security of the transmission network."
The draft law on Electricity produced by USAID (May 16, 2023)	It is proposed to make the following additions in the draft law: - To define in the draft law all types of activities in the field of electricity presented in part 1 of Article 18, so that it is clear what is meant by electricity production, supply, etc. - In the draft law, define the term "Electricity storage" as follows: "means, in the electricity system, deferring the final use of electricity to a moment later than when it was generated, or the conversion of electrical energy into a form of energy which can be stored, the storing of such energy, and the subsequent reconversion of such energy into electrical energy or use as another energy carrier." - Define the term "Renewable energy generation" in the draft law as follows: "means energy generation from renewable, non-fossil sources (wind, solar hydro, geothermal, biomass, biogas and other) applicable for the generation of electric and/or thermal energy and energy storage." - In the Article 35 of the draft law it is proposed to make the following additions: "Those participants of the wholesale market whose technical capabilities meet the requirements set by the transmission network rules have the opportunity to provide balancing service."

Detailed recommendations for regulatory reform (2/3)

Milestones	Action items/Recommendations
The draft law on Renewable Energy and Energy Efficiency produced by USAID (May 31, 2023)	In the Article 41 of the draft law it is proposed to make the following additions: - “In addition to the rights reserved to the producer under Article 26 of the law on Electricity, the storage plant also has the right to purchase electricity in the wholesale electricity market.” - “Transmission System Operator shall ensure that storage plant is eligible to provide all capacity, energy, and ancillary services that it is technically capable of providing in the wholesale market.”
Law on Licensing **(N193 of 30.05.2001)**	Define the activity of electricity storage as an activity subject to licensing in the field of energy in compliance with the requirements of the amended laws (as provided above).
PSRC Decision on approving the procedure for licensing activities in the field of energy and revoking a number of decisions **(N 374 of 01.11.2013)**	Make amendments to bring the PSRC decisions into compliance with the requirements of the amended laws (as provided above).
Law on Environmental Impact Assessment **(N110 of 21.06.2014)**	Classify the activity according to the appropriate category, taking into account the impact of the activity on the environment. When classifying, it is necessary to take into account the technology, power, and the area occupied by the plant.

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Detailed recommendations for regulatory reform (3/3)

Milestones	Action items/Recommendations
Safety and Security Standards /Development of normative-technical documents regulating BESS design, installation, operation and maintenance	Develop safety and security normative-technical documents regulating the design, installation, operation and maintenance of BESS. Standards should be based on the real risks and avoid jeopardizing the uptake of storage.
PSRC Decision on approving the trading rules of the RA electricity wholesale market and revoking RA PSRC decision N 344 of August 9, 2017 **(N 516 of 25.12.2019)**	Define the status of companies engaged in electricity storage as participants in the wholesale electricity market. Define the rights and responsibilities of the companies engaged in the activity of electricity storage as a participant of the wholesale electricity market that will enable the operation of energy storage battery systems as a wholesale trade participant in the electricity market and balancing service provider (including secondary reserve). Make any other amendments to bring the PSRC decisions into compliance with the requirements of the amended laws (as provided above), as well as to adopt new normative legal acts necessary for the implementation of the amended laws.
PSRC Decision on approving the RA electricity market transmission network rules and revoking RA PSRC decision No. 161 of May 17, 2017 **(N 522 of 25.12.2019)**	
PSRC Decision on approving the RA electricity market distribution network rules and revoking a number of decisions of the RA PSRC **(N 523 of 25.12.2019)**	