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ARMENIA LEAST COST ENERGY DEVELOPMENT PLAN: 2020 - 2036

MARKET LIBERALIZATION AND
ELECTRICITY TRADE
PROGRAM

Yerevan, Armenia

November 19, 2019

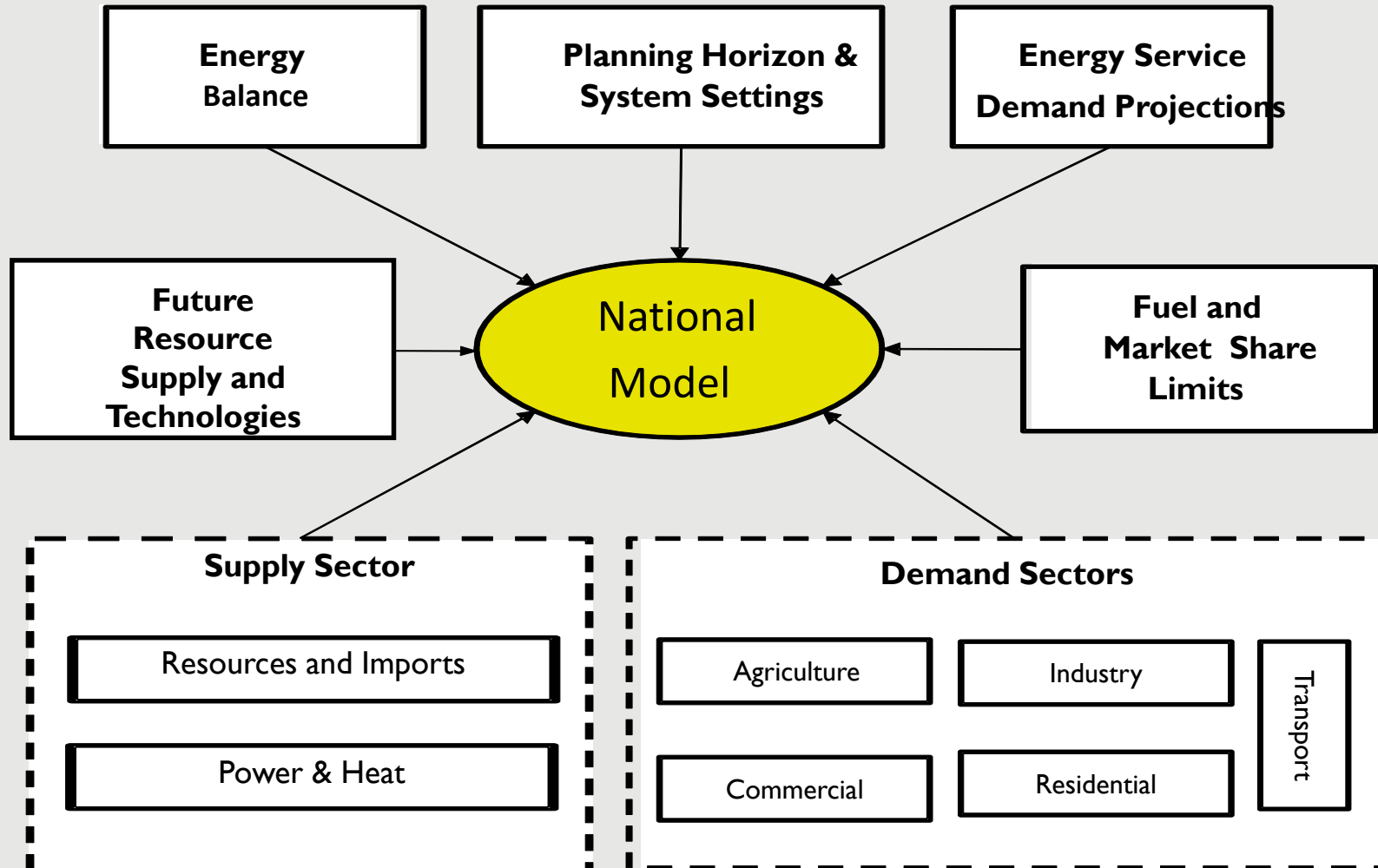
OBJECTIVES

The Least Cost Energy Development Plan (LCEDP) for Armenia was realized using The Integrated MARKAL-EFOM System (TIMES) software developed by the International Energy Agency and used in more than 70 countries.

The LCEDP for Armenia covering the period up to 2036 allows us to examine scenarios and to analyze various pathways to:

- Strengthen the energy security and independence of the country
- Bring a reliable supply of energy to meet all consumer needs at the lowest cost possible
- Realize energy efficiency and renewable energy potentials
- Assess the effectiveness of existing generation and consumption technologies available in the market

TIMES MODEL STRUCTURE



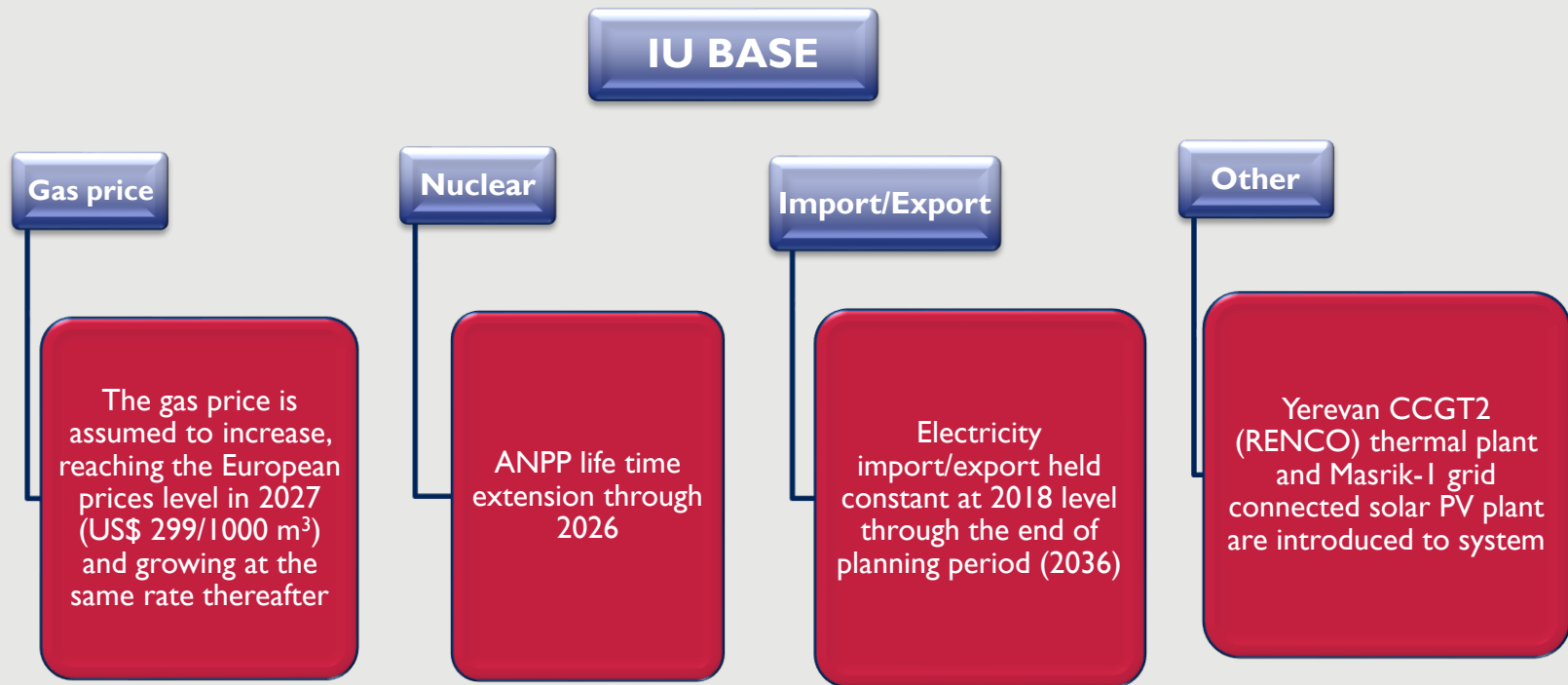
Main Assumptions for TIMES-Armenia (1 of 2)

- GDP growth was set at 6.75% in 2018, 4.65% in 2020 and held constant after 2022 at 4.5% per year
- Population has a small negative growth and will slightly decrease over the planning period, although residential demand for energy will still grow on average 1.7% per year.
- The commercial sector is the main contributor to demand for useful energy, with average annual growth of over 4.4%
- The agriculture and industrial sectors contribute less to the growth of demand for useful energy, with average annual growth rates of around 0.2% and 2.2%, respectively
- The border gas price is assumed to increase, reaching the European prices level in 2027 (US\$ 299/1000 m³) and growing at the same rate thereafter

Main Assumptions for TIMES-Armenia (2 of 2)

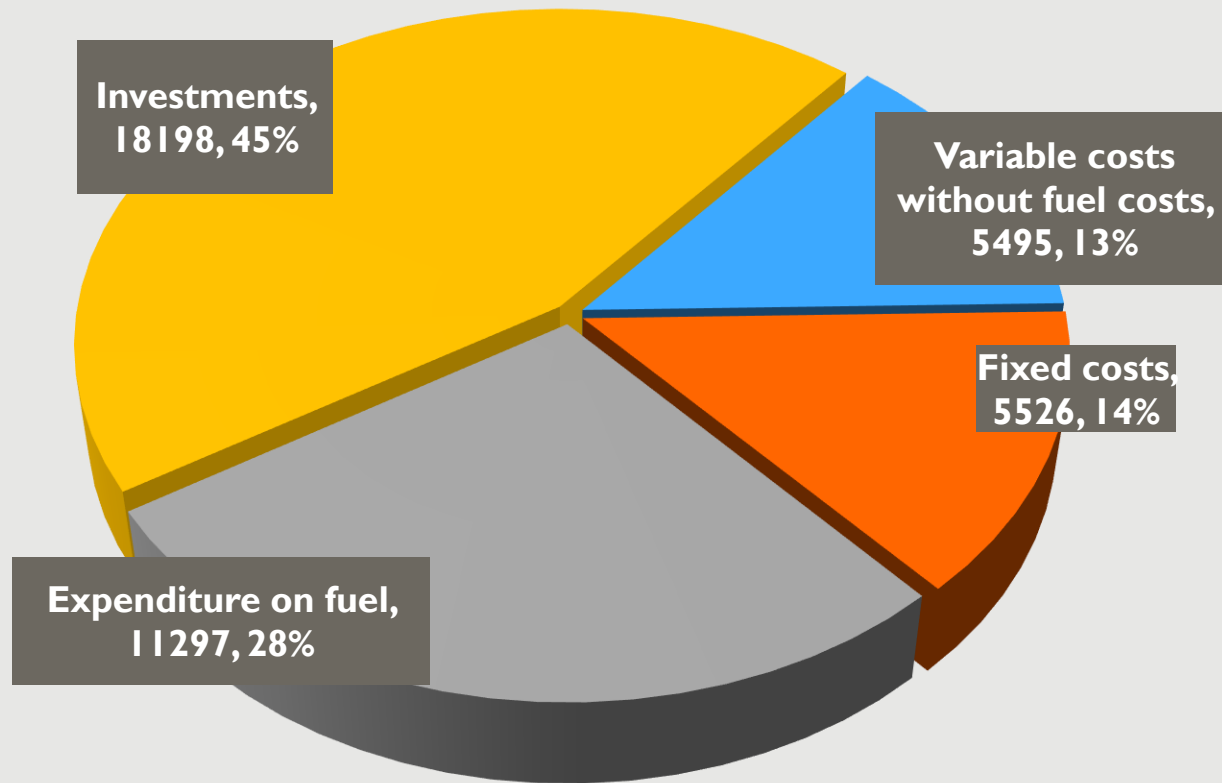
- Electricity losses decline to a total of 8.2% for the transmission and distribution systems in 2028 and remain constant thereafter.
- Net electricity imports/exports are held constant at the 2018 levels for the planning horizon: Export to the South as 1,515.2 GWh; Import from Georgia as 74.5 GWh; Import from Artsakhenergo as 17.2 GWh.
- Both Yerevan CCGT2 (RENCO) gas-fired thermal plant and Masrik-I grid-connected solar PV plant are introduced in the system at their respective Commercial Operation Dates.
- The Armenia Nuclear Power Plant is assumed decommissioned from 2027 and the old Hrazdan thermal PP from 2021.
- No other technical limitations are imposed on the introduction of new power generation candidate technologies in the system for the planning horizon.

INITIAL UNCONSTRAINED BASELINE SCENARIO



ECONOMIC PARAMETERS

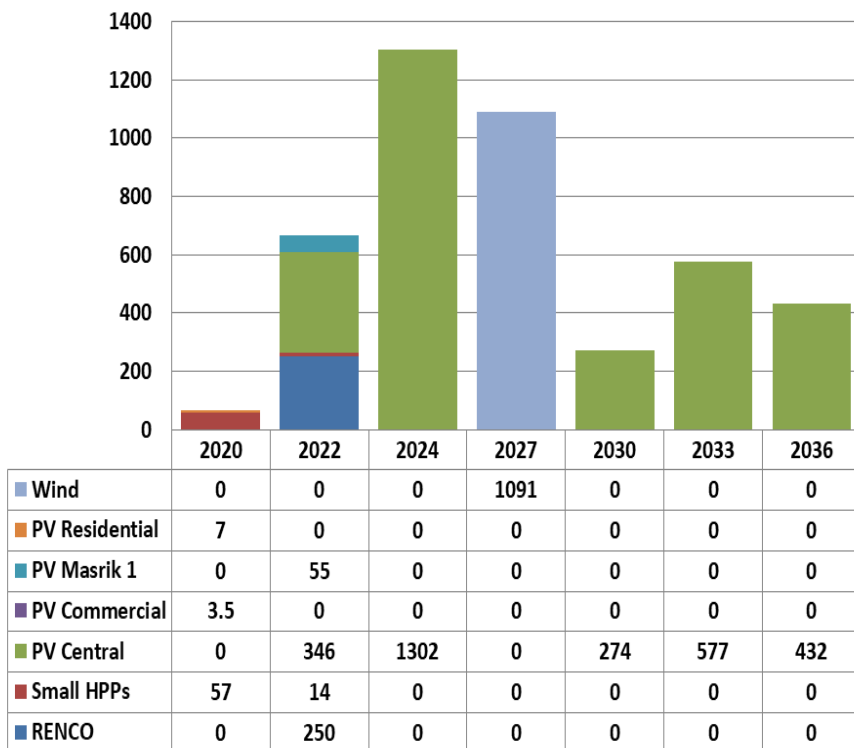
Structure of Total Discounted System Cost to 2036 (US\$ Million, %)
Total: US\$ 40.5 billion



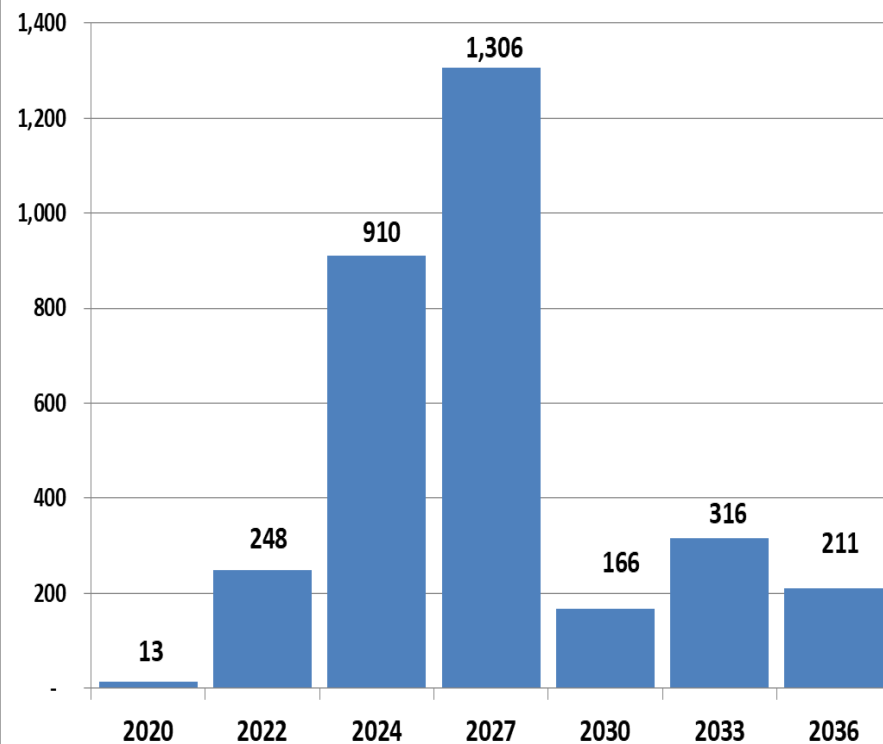
Total Discounted GDP to 2036: \$375.4 billion

NEW GENERATION ENTRY TO THE SYSTEM

Electric New Builds (by Type), MW



Lumpsum Investment in New Power Generation, MUS\$



BASELINE-REFERENCE SCENARIO

BASE-R

Further investigation of all additional scenarios formed have been done in comparison to the BASE-R scenario

Gas price

The gas price is assumed to increase, reaching the European prices level in 2027 (US\$ 299/1000 m³) and growing at the same rate thereafter

Nuclear

ANPP life time extension through 2026

Import/Export

Electricity import/export held constant at 2018 level through the end of planning period (2036)

Other

Yerevan CCGT2 (RENCO) thermal plant and Masrik-I grid connected solar PV plant are introduced to system

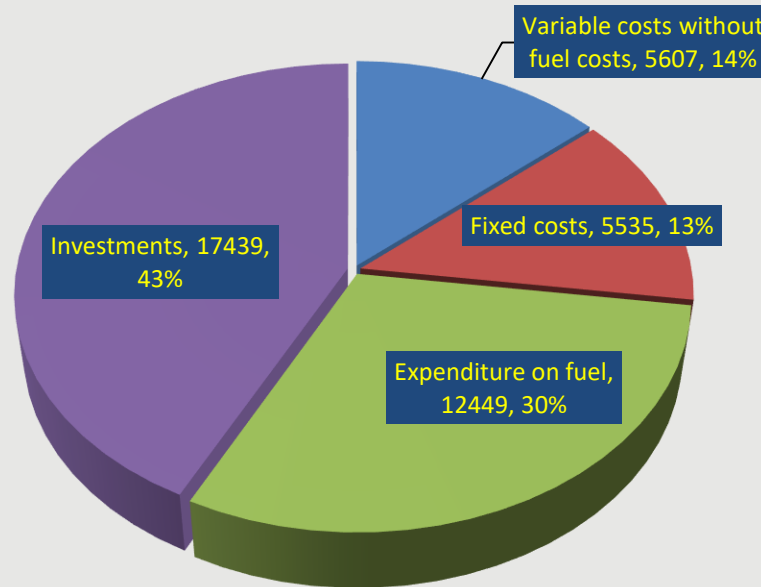
Introduction of new VRES generation capacity is limited to 1,500 MW for solar PV and 500 MW of wind

Annual maximum new capacity additions are capped at 100 MW for central solar PV, 4/5 MW for Residential/ Commercial rooftop PV, and 50 MW for wind

BASE-R: ECONOMIC PARAMETERS

Structure of Total Discounted System Cost to 2036 (US\$ Million, %)

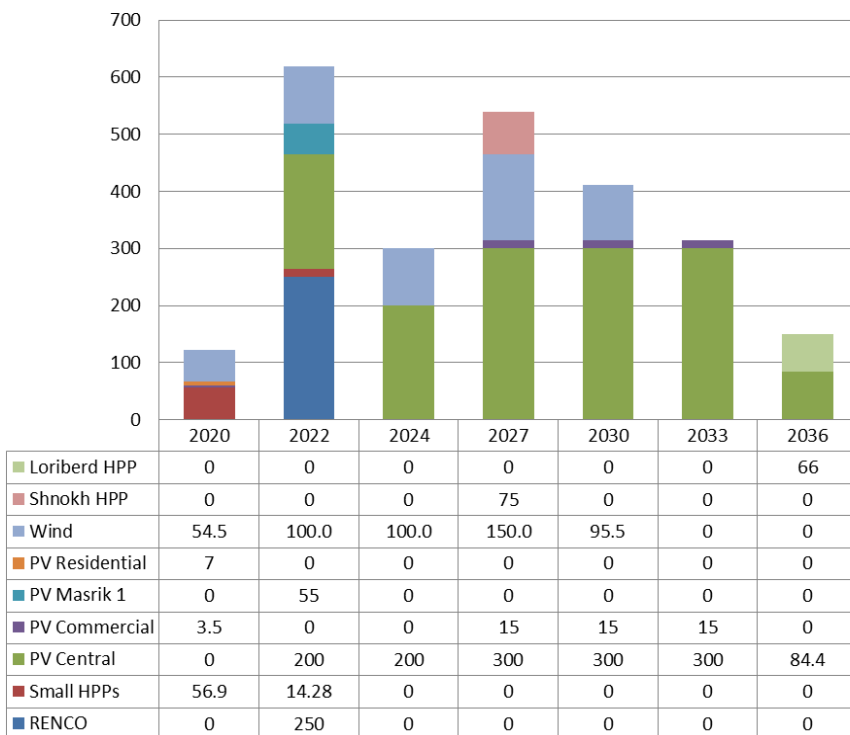
Total: US\$ 41,029 million (\$513 million higher than in IU BASE)



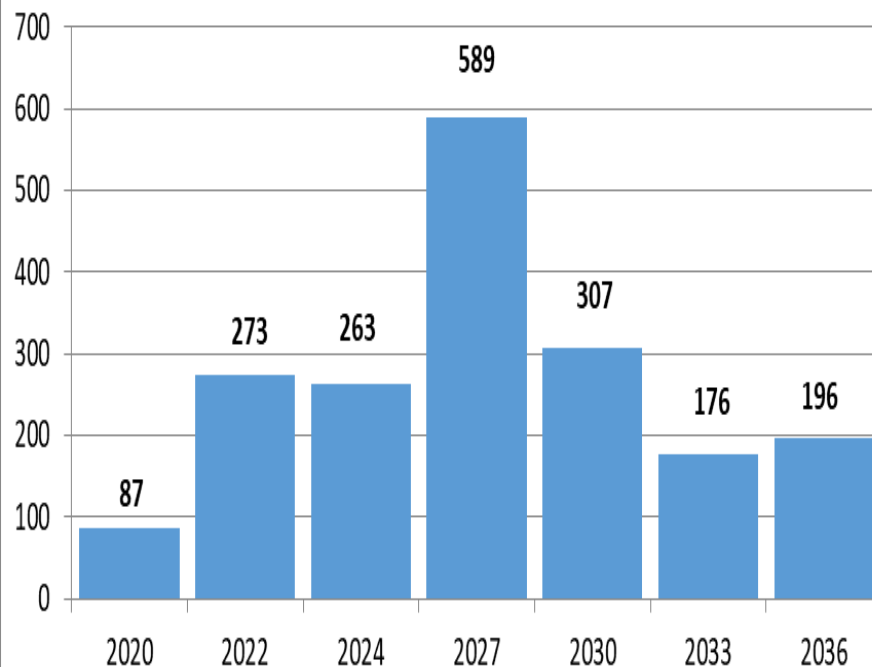
Scenario	Power Plant Builds	Power Plant Investment	Natural Gas Fuel Expenditure for Generation
	MW	M\$ ₂₀₁₅	M\$ ₂₀₁₅
Baseline Reference (BASE-R)	2,498	1,897	4,251

NEW GENERATION ENTRY TO THE SYSTEM

Electric New Builds (by Type), MW



Lumpsum Investment in New Power Generation, MU\$



The fact that the full constrained amount of solar and wind capacity is selected by the model as part of the least cost solution for new generation under this (and all) scenario(s) underscores the importance to Armenia of ensuring a policy and institutional environment that supports realization of new VRES generation to the maximum extent practicable, not only to ensure the lowest cost generation but also to minimize reliance on other imported energy sources and to strengthen Armenia's energy security and competitiveness.

BASE-R: GDP GROWTH SENSITIVITY ANALYSES

GDP

+/- 50% growth as compared to BASE-R scenario

Gas price

The border gas price is assumed to increase, reaching the European prices level in 2027 (US\$ 299/1000 m³) and growing at the same rate thereafter

Nuclear

ANPP life time extension through 2026

Import/Export

Electricity import/export held constant at 2018 level through the end of planning period (2036)

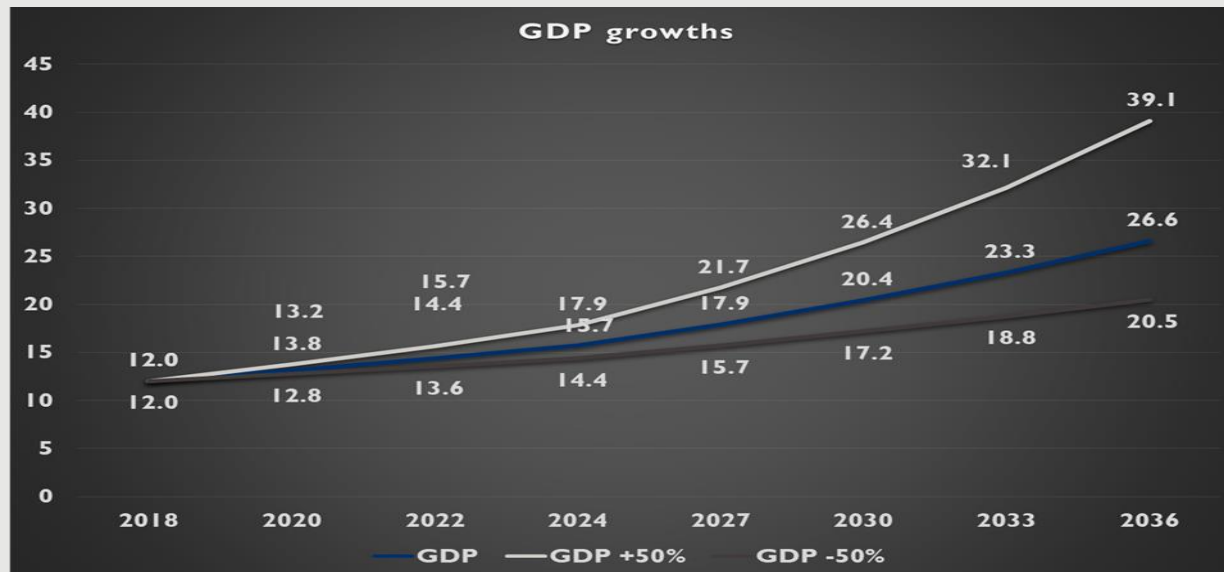
Other

Yerevan CCGT2 (RENCO) thermal plant and Masrik-1 grid connected solar PV plant are introduced to system

Hrazdan TTP decommissioned in 2021

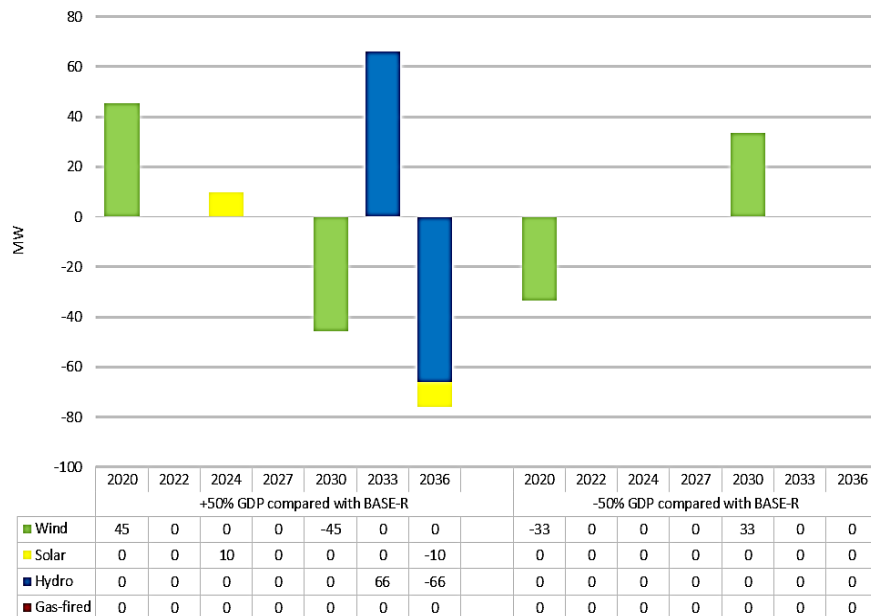
Introduction of new VRES generation capacity is limited to 1,500 MW for solar PV and 500 MW for wind

Annual maximum new capacity additions are capped at 100 MW for central solar PV, 4/5 MW for Residential/ Commercial rooftop PV, and 50 MW for wind



BASE-R GROWTH SENSITIVITIES: MAIN RESULTS

Electric New Builds (by Type) - Difference from BASE-R



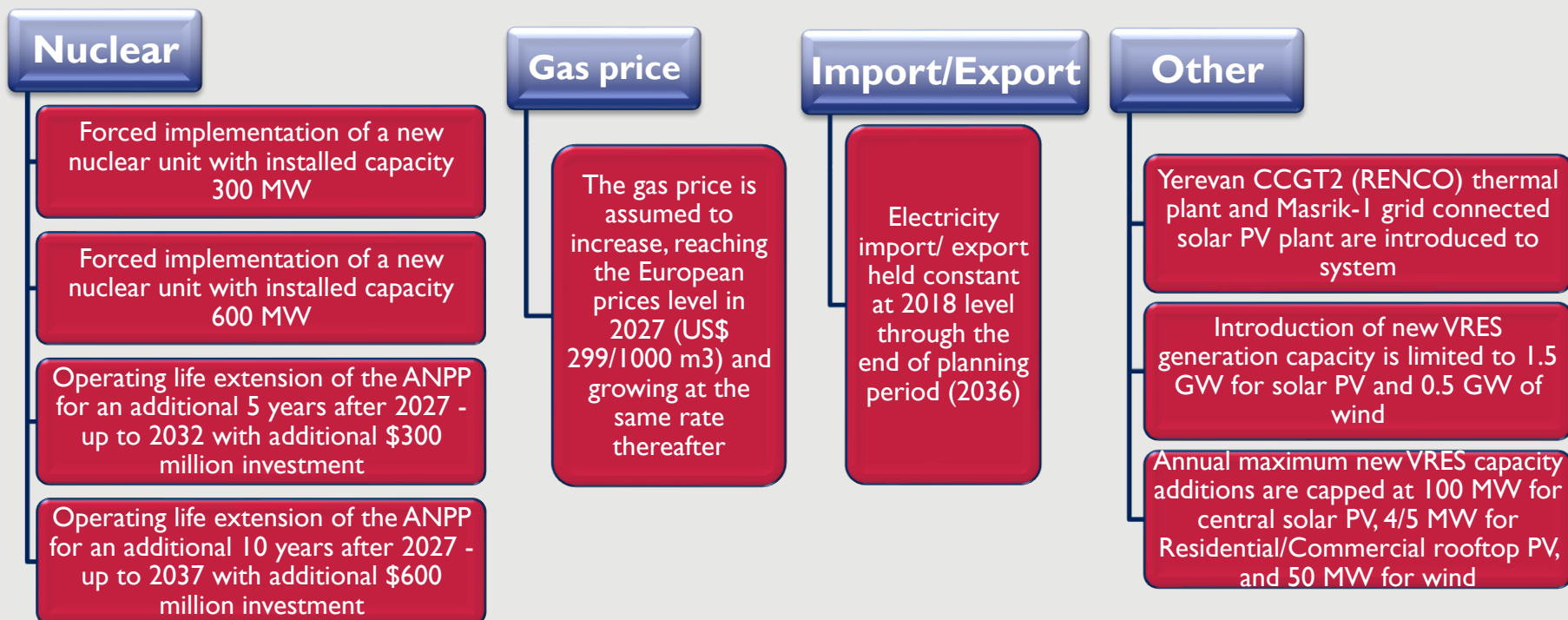
Lumpsum Investment in PP - Difference from BASE-R



Scenario	System Cost		Power Plant Builds		Power Plant Investment		Natural Gas Fuel Expenditure for Generation		GHG Emissions (CO2eq)	
	M\$ ₂₀₁₅	%	MW	%	M\$ ₂₀₁₅	%	M\$ ₂₀₁₅	%	Mt	%
Baseline Reference (BASE-R)	41,029	-	2,498	-	1,897	-	4,251	-	137	-
+ 50% GDP compared to BASE-R	46,017	12.2	2,498	0.0	1,910	0.7	4,676	10.0%	148	7.9
- 50% GDP compared to BASE-R	38,153	-7.0	2,498	0.0	1,891	-0.3	3,997	-6.0%	131	-4.7

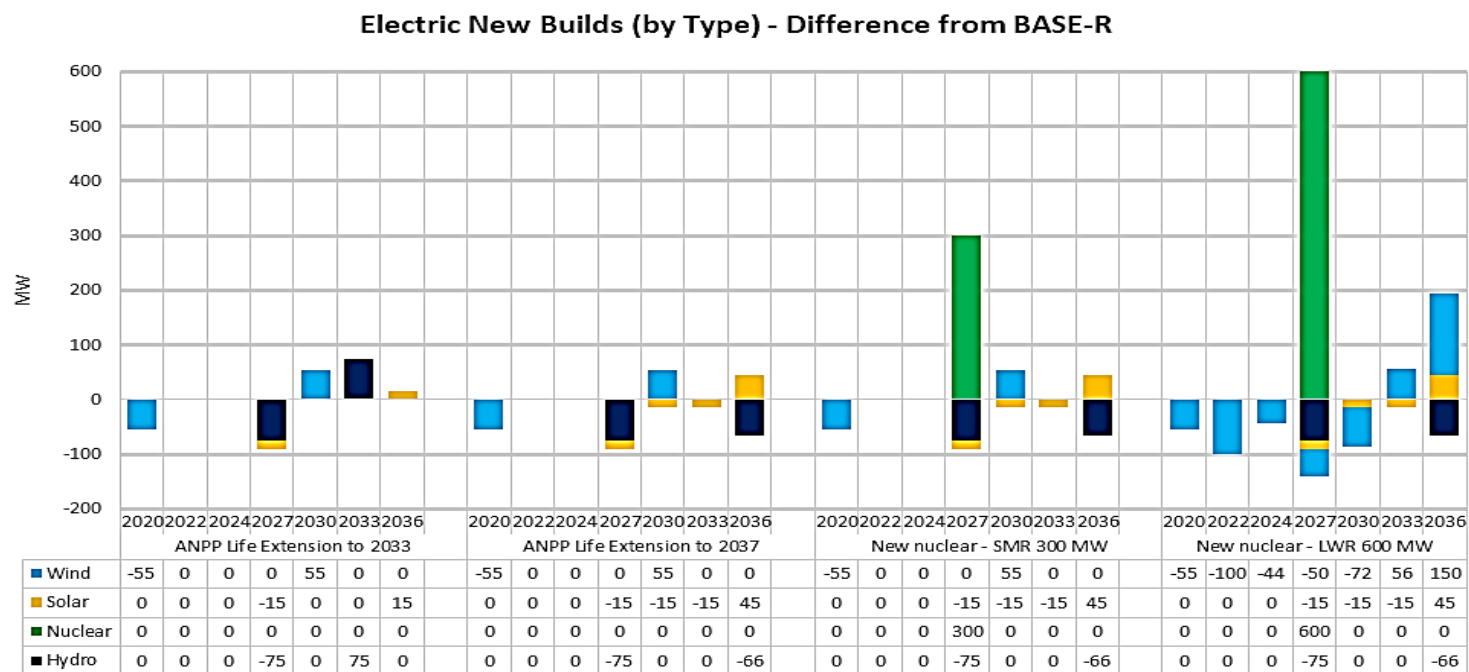
**ADDITIONAL SCENARIOS
IDENTIFIED BY
STAKEHOLDERS**

NUCLEAR DEVELOPMENT SCENARIOS



Scenario	System Cost		Power Plant Builds		Power Plant Investment	
	M\$ ₂₀₁₅	%	MW	%	M\$ ₂₀₁₅	%
Baseline Reference (BASE-R)	41,029	-	2,498	-	1,897	-
ANPP Life Extension to 2032	40,711	-0.8	2,498	0.0	2,184	15.1
ANPP Life Extension to 2037	40,553	-1.2	2,357	-5.6	2,133	12.5
New nuclear - SMR 300 MW	41,857	2.0	2,657	6.4	4,097	116.0
New nuclear - LWR 600 MW	41,825	1.9	2,843	13.8	5,013	164.3

NUCLEAR SCENARIOS: FURTHER RESULTS



	Natural Gas Fuel Expenditure for Generation		GHG Emissions (CO ₂ eq)	
	M\$ ₂₀₁₅	%	Mt	%
Baseline Reference (BASE-R)	4,251	-	137	-
ANPP Life Extension to 2032	3,945	- 7.2%	131	- 4.5
ANPP Life Extension to 2037	3,591	- 15.5%	124	- 9.3
New nuclear - SMR 300 MW	3,751	- 11.8%	127	- 7.1
New nuclear - LWR 600 MW	3,384	- 20.4%	120	- 12.2

DIFFERENT TRENDS IN IMPORTED GAS PRICES

Gas price

The gas price applies the EU trend growth rate over the entire period to 2036

The gas price is assumed to grow to US\$ 180 per 1000 m3 by 2027, and then to remain fixed at that level until the end of the planning period

Nuclear

ANPP life time extension through 2026

Import/Export

Electricity import/export held constant at 2018 level through the end of planning period (2036)

Other

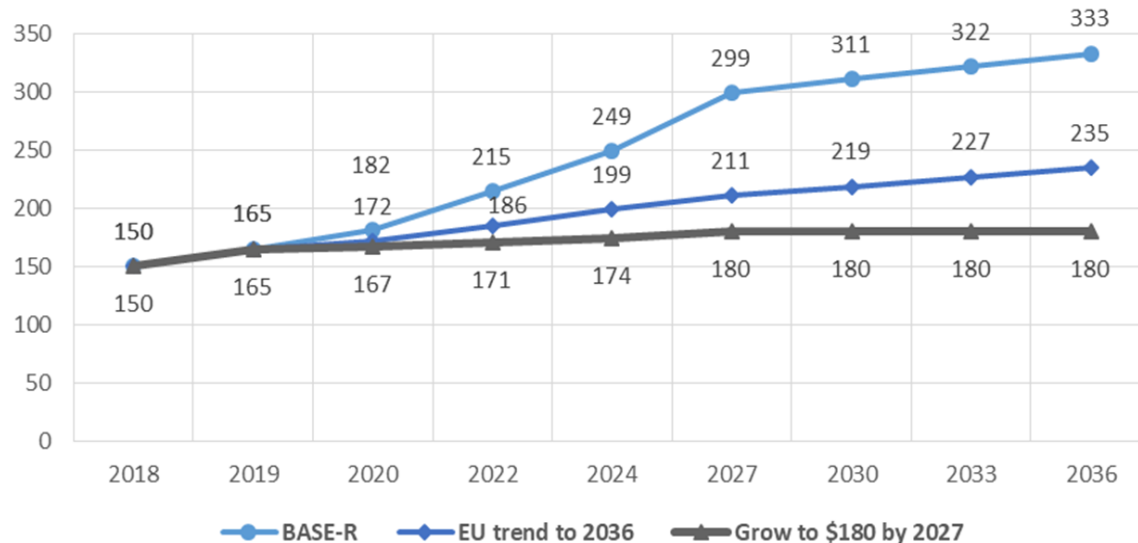
Yerevan CCGT2 (RENCO) thermal plant and Masrik-I grid connected solar PV plant are introduced to system

Introduction of new VRES generation capacity is limited to 1.5 GW for solar PV and 0.5 GW of wind

Annual maximum new capacity additions are capped at 100 MW for central solar PV, 4/5 MW for Residential/Commercial rooftop PV, and 50 MW for wind

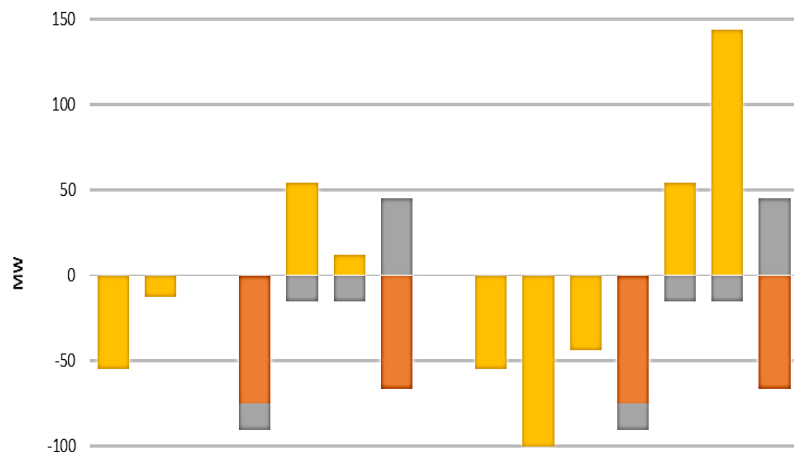
=> 1,500 MW solar
500 MW wind

Natural gas prices at the border



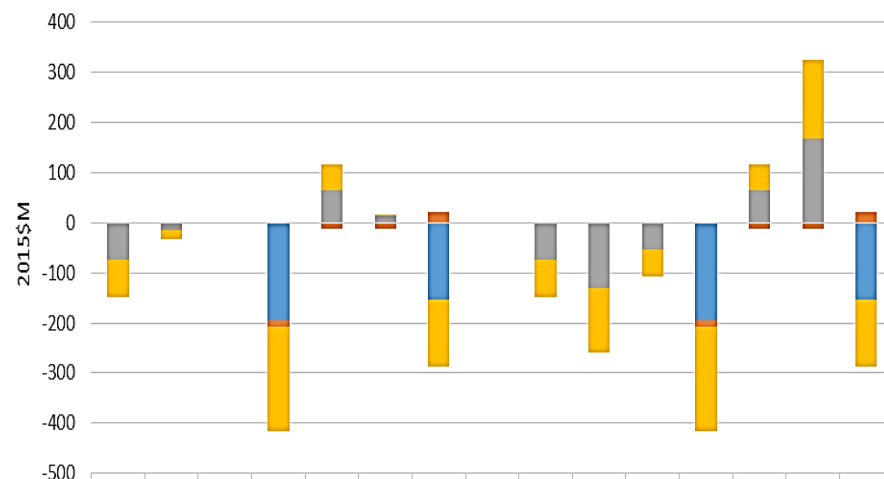
GAS PRICE SCENARIOS: MAIN RESULTS

Electric New Builds (by Type) - Difference from BASE-R



	2020	2022	2024	2027	2030	2033	2036		2020	2022	2024	2027	2030	2033	2036
EU trend to 2036								Grow to \$180 by 2027							
Wind	-55	-12	0	0	55	12	0	-55	-100	-44	0	55	144	0	0
Solar	0	0	0	-15	-15	-15	45	0	0	0	-15	-15	-15	45	0
Hydro	0	0	0	-75	0	0	-66	0	0	0	-75	0	0	0	-66
Gas-fired	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

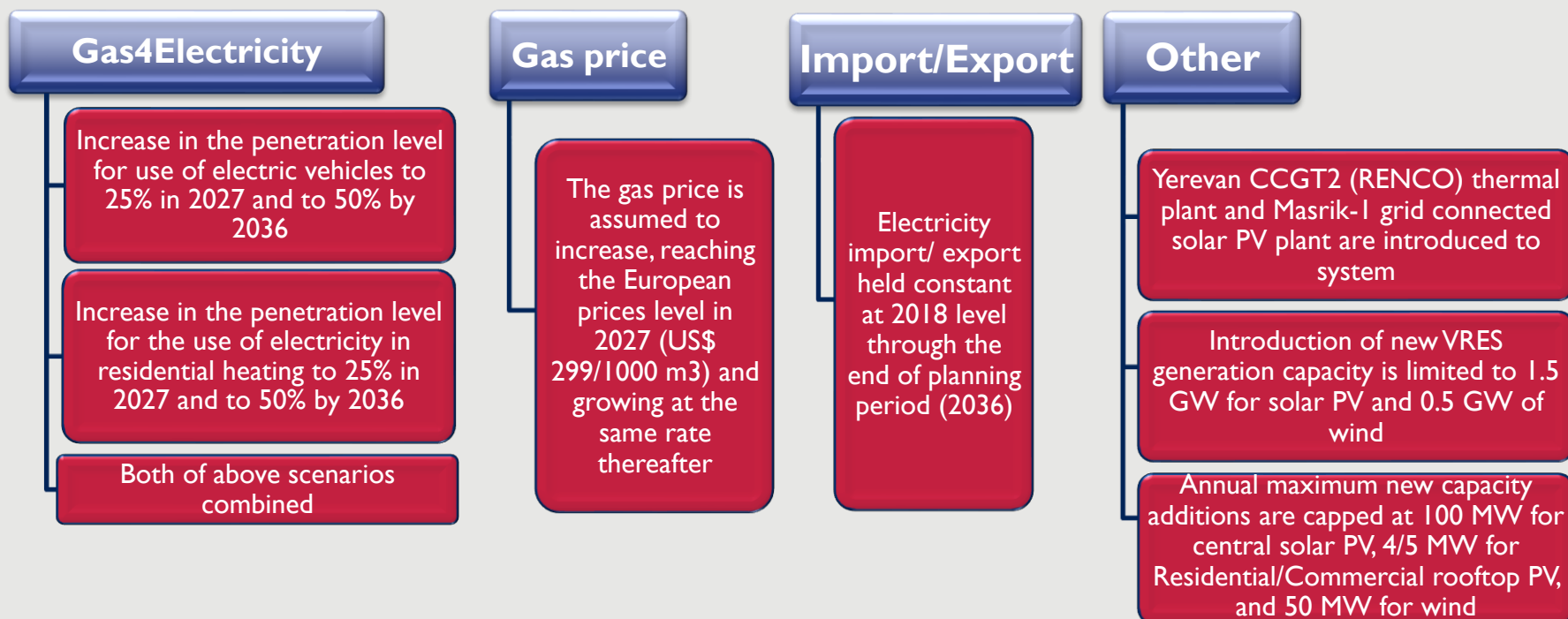
Lumpsum Investment in PP - Difference from BASE-R



	2020	2022	2024	2027	2030	2033	2036		2020	2022	2024	2027	2030	2033	2036
EU trend to 2036								Grow to \$180 by 2027							
Total	-74	-16	0	-209	51	3	-133	-74	-130	-54	-209	51	157	-133	0
Wind	-74	-16	0	0	64	14	0	-74	-130	-54	0	64	168	0	0
Solar	0	0	0	-14	-13	-12	22	0	0	0	-14	-13	-12	22	0
Hydro	0	0	0	-194	0	0	-155	0	0	0	-194	0	0	0	-155

Scenario	System Cost		Power Plant Builds		Power Plant Investment		Natural Gas Fuel Expenditure for Generation		GHG Emissions (CO2eq)	
	M\$ ₂₀₁₅	%	MW	%	M\$ ₂₀₁₅	%	M\$ ₂₀₁₅	%	Mt	%
Baseline Reference (BASE-R)	41,029	-	2,498	-	1,897	-	4,251	-	137	-
Gas price EU trend to 2036	39,481	-3.8	2,357	-5.6	1,519	-19.9	3,302	-22.3%	140	2.2
Gas price grow to \$180 by 2027	38,741	-5.6	2,357	-5.6	1,505	-20.6	2,833	-33.4%	141	3.5

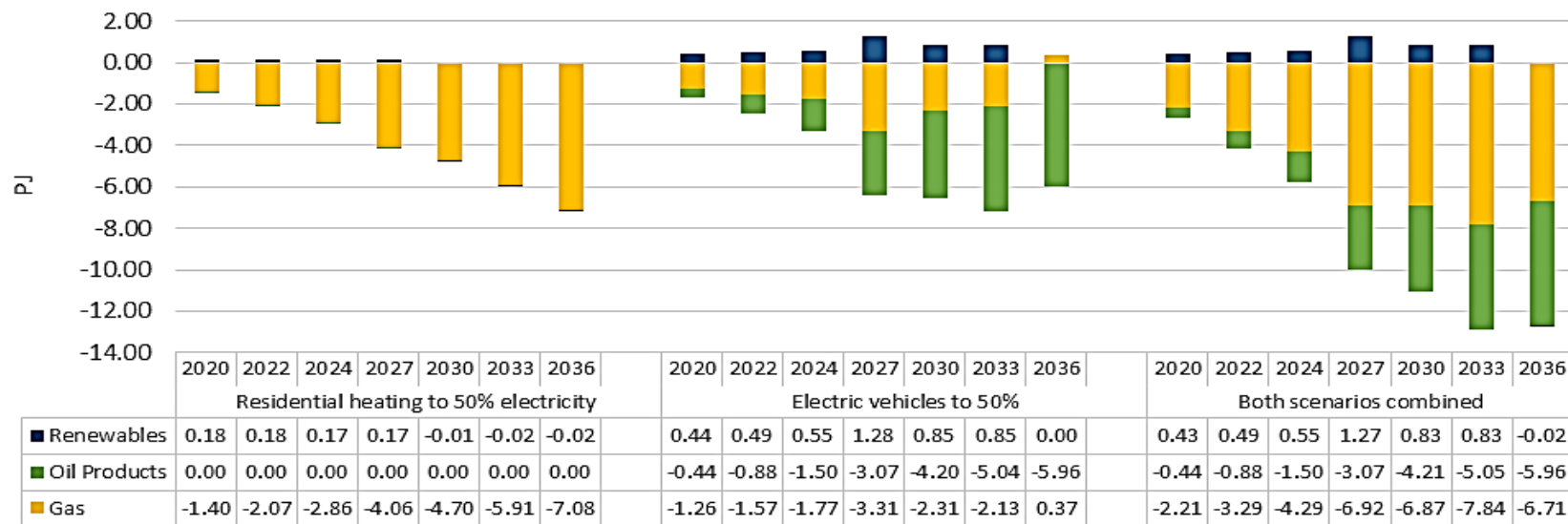
FUEL SWITCHING FROM GAS TO ELECTRICITY



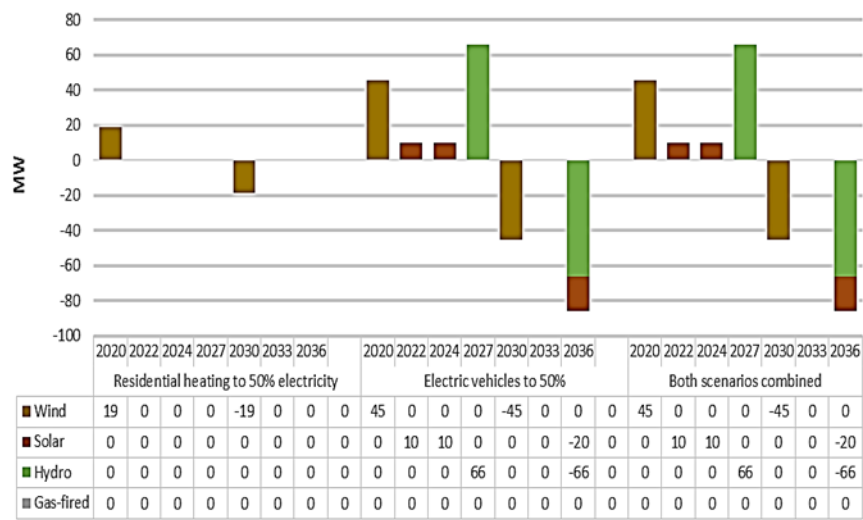
Scenario	System Cost		Power Plant Builds		Power Plant Investment		Natural Gas Fuel Expenditure for Generation		GHG Emissions (CO2eq)	
	M\$ ₂₀₁₅	%	MW	%	M\$ ₂₀₁₅	%	M\$ ₂₀₁₅	%	Mt	%
Baseline Reference (BASE-R)	41,029	-	2,498	-	1,897	-	4,251	-	137	-
Residential heating to 50% elec.	40,551	-1.2	2,498	0.0	1,900	0.2	4,011	-5.6%	132	-3.3
Electric vehicles to 50%	40,285	-1.8	2,498	0.0	1,915	1.0	4,156	-2.2%	131	-4.6
Both above scenarios combined	39,813	-3.0	2,498	0.0	1,915	1.0	3,930	-7.6%	126	-7.7

GAS TO ELECTRICITY: MAIN RESULTS

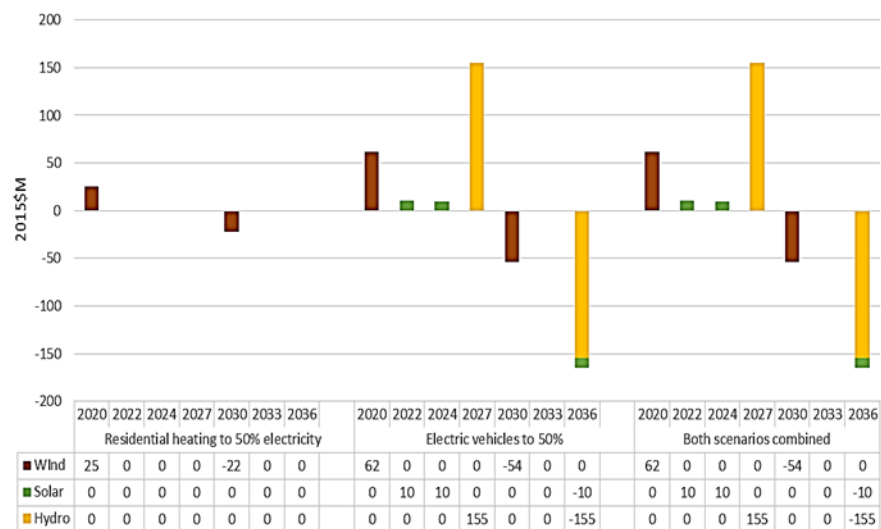
Supply - Total Primary Difference from Baseline



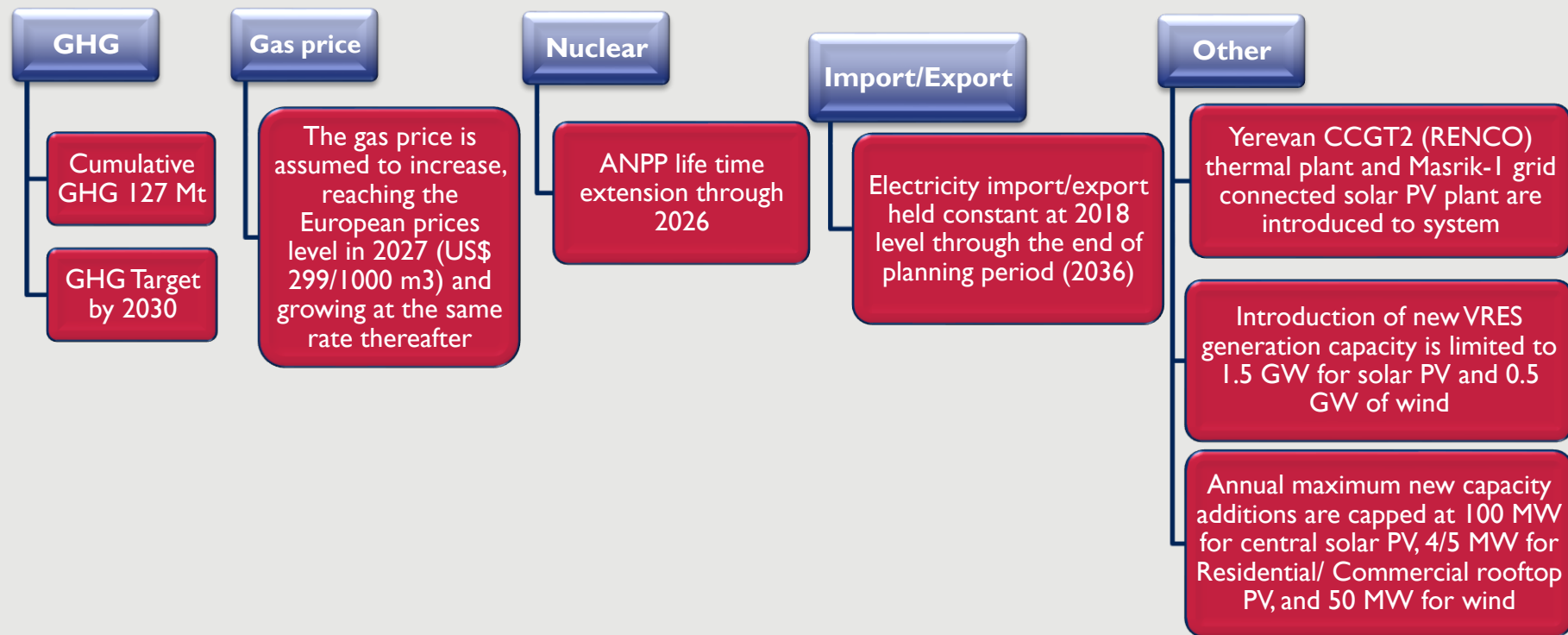
Electric New Builds (by Type) - Difference from BASE-R



Expenditure - Lumpsum New PP Builds (by fuel)



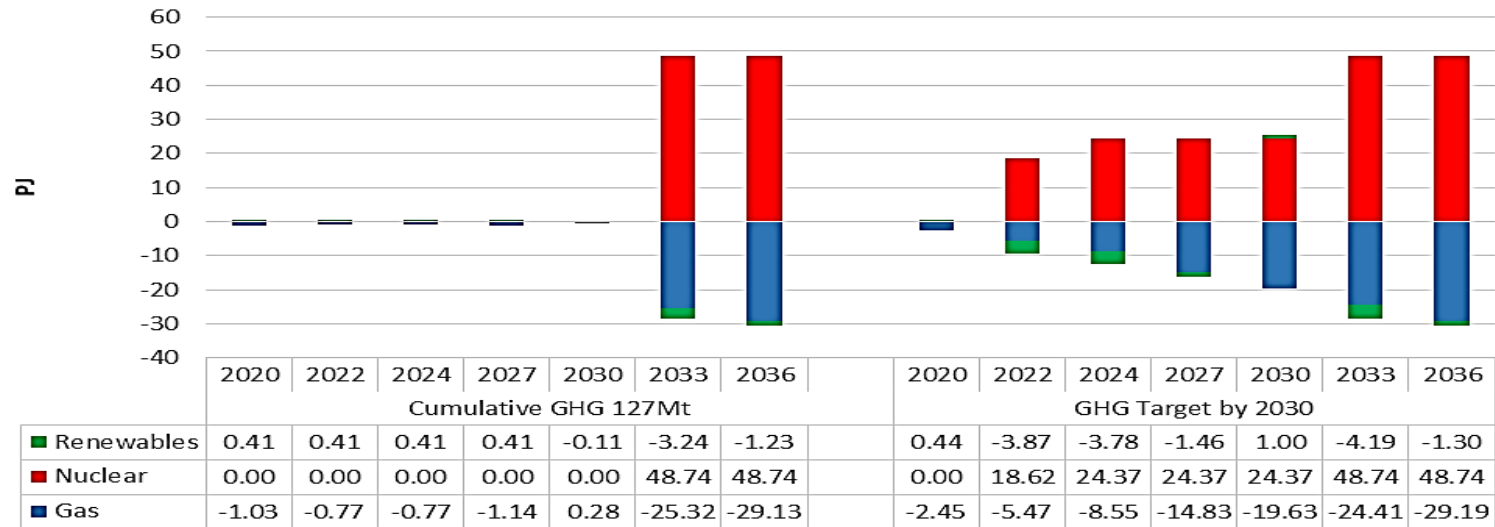
REDUCED GHG EMISSIONS SCENARIOS



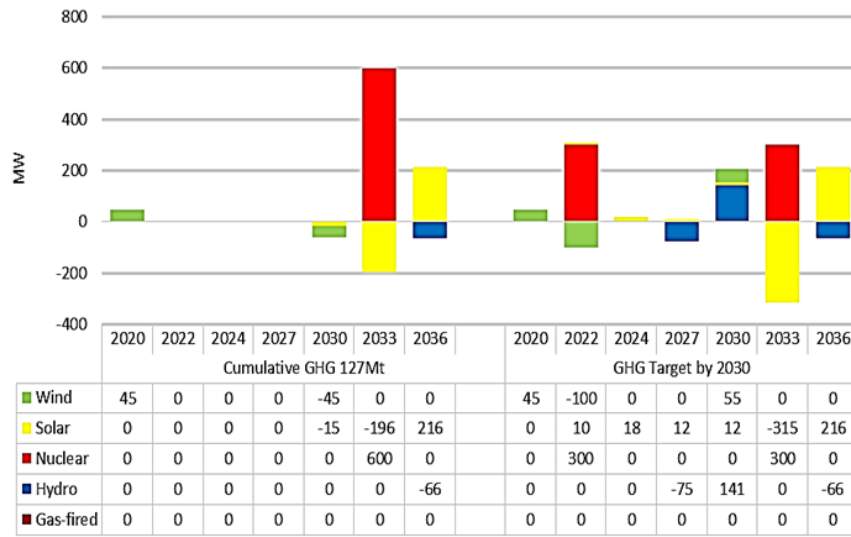
Scenario	System Cost		Power Plant Builds		Power Plant Investment		Natural Gas Fuel Expenditure for Generation		GHG Emissions (CO2eq)	
	M\$ ₂₀₁₅	%	MW	%	M\$ ₂₀₁₅	%	M\$ ₂₀₁₅	%	Mt	%
Baseline Reference (BASE-R)	41,029	-	2,498	-	1,897	-	4,251	-	137	-
Cumulative GHG 127Mt	41,392	0.9	3,046	21.9	5,369	183.1	3,717	-12.6%	127	-7.3
GHG Target by 2030	42,676	4.0	3,030	21.3	7,027	270.4	3,337	-21.5%	120	-12.7

REDUCED GHG EMISSIONS: MAIN RESULTS

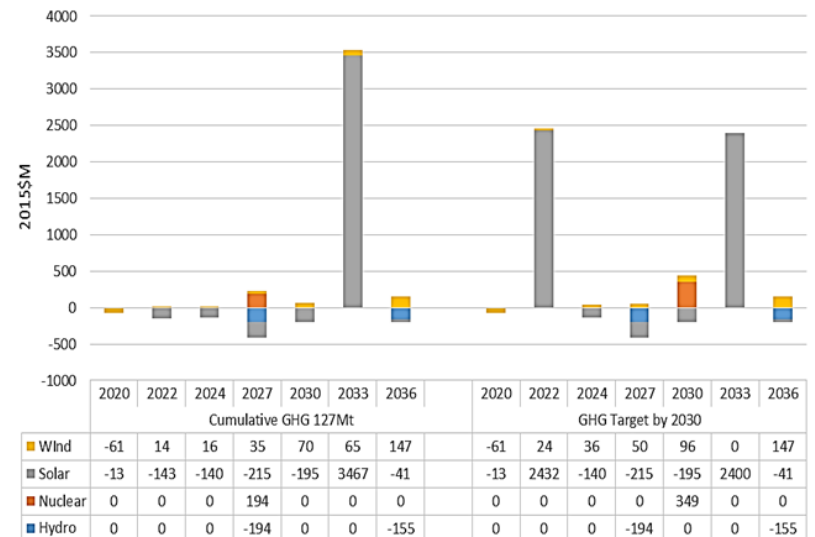
Supply - Total Primary Difference from BASE-R



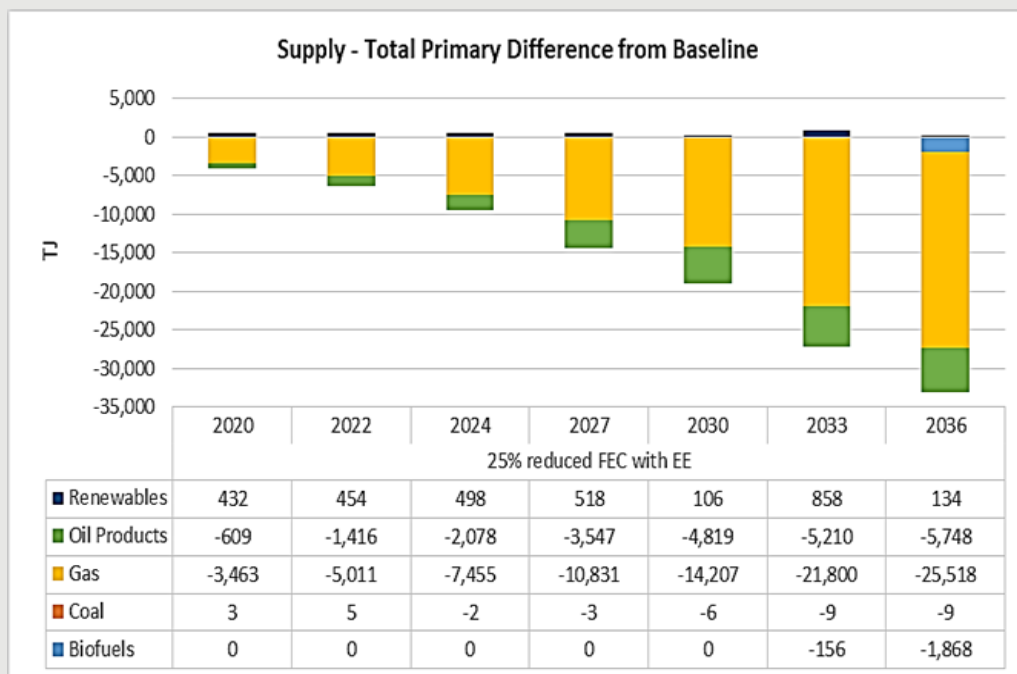
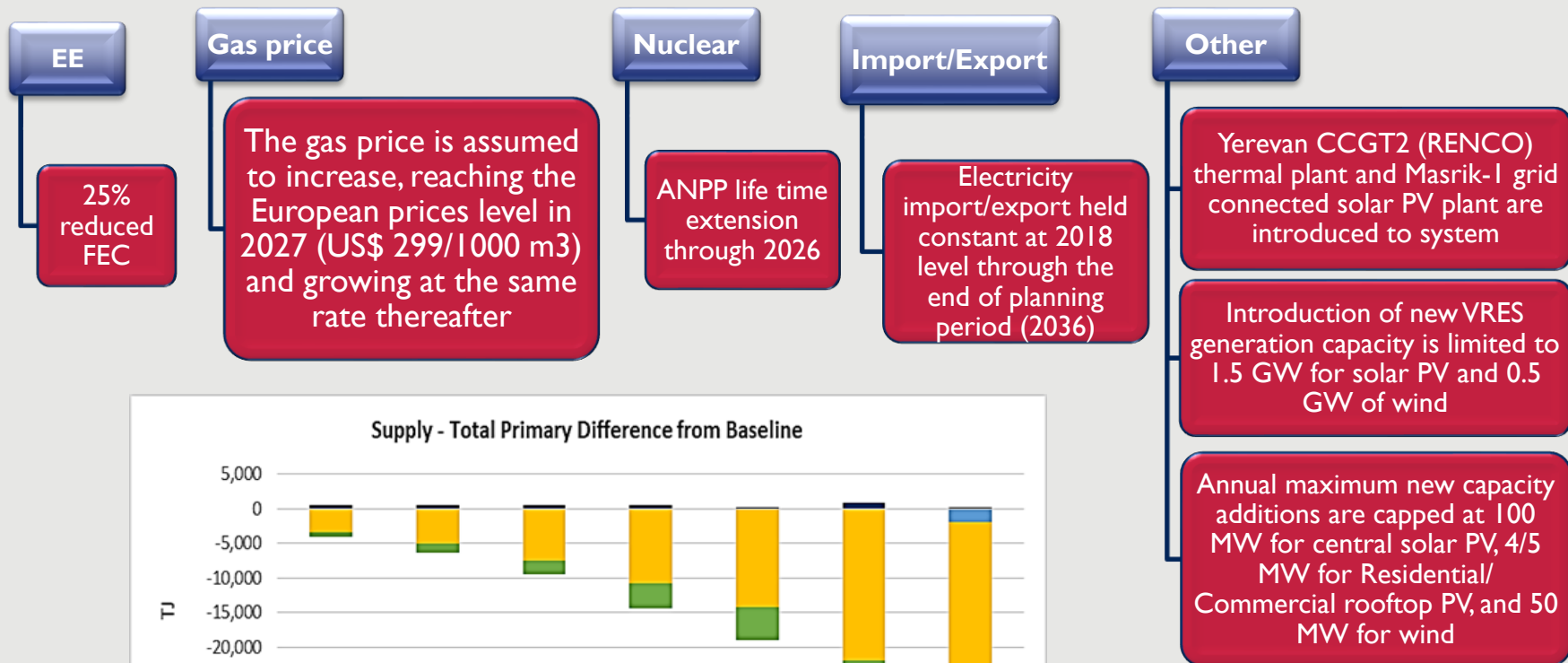
Electric New Builds (by Type) - Difference from BASE-R



Expenditure - Lumpsum New PP Builds (by fuel)

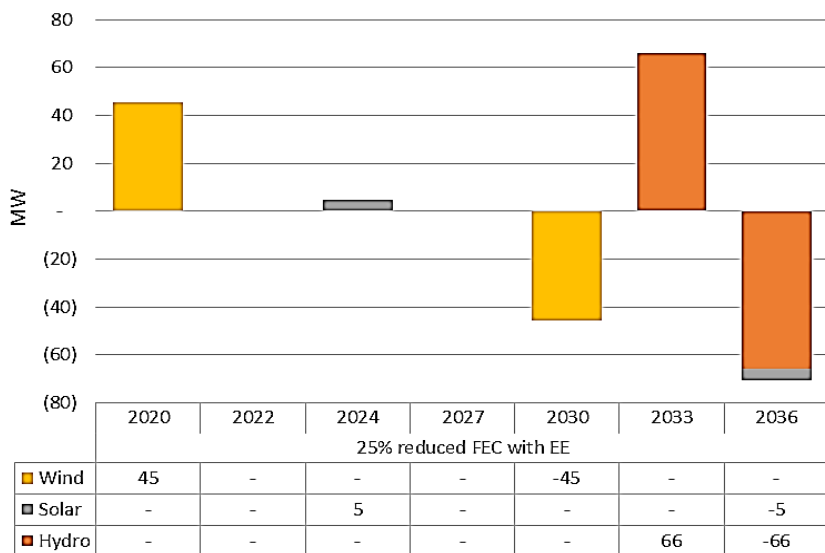


FORCED IMPLEMENTATION OF ENERGY EFFICIENCY TARGETS SCENARIOS

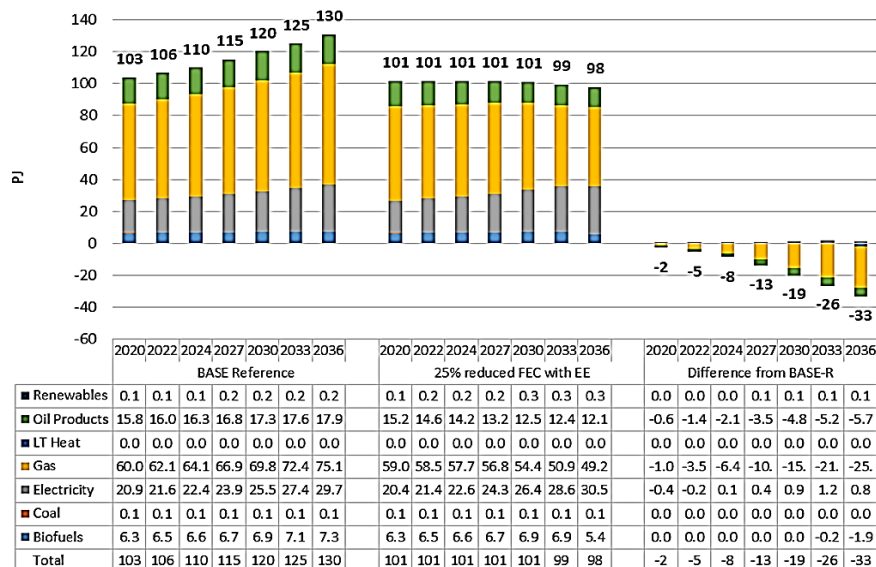


ENERGY EFFICIENCY: MAIN RESULTS

Electric New Builds (by Type) - Difference from BASE-R



Final Energy Consumption (by Fuel)



Scenario	System Cost		Power Plant Builds		Power Plant Investment		Natural Gas Fuel Expenditure for Generation		GHG Emissions (CO ₂ eq)	
	M\$ ₂₀₁₅	%	MW	%	M\$ ₂₀₁₅	%	M\$ ₂₀₁₅	%	Mt	%
Baseline Reference (BASE-R)	41,029	-	2,498	-	1,897	-	4,251	-	137	-
25% reduced FEC with EE	39,261	-4.3	2,498	0.0	1,907	0.6	3,483	-18.1%	118	-14.0

Economic Sector	GHG, kt CO ₂ eq	Share in total
Transport	- 9,486	53%
Residential	- 5,299	30%
Commercial	- 3,322	19%
Industry	- 100	1%
Agriculture	0	0%
Power Sector	467	-3%

SUMMARY AND CONCLUSIONS (1/3)

- **The LCEDP results emphasize the importance to Armenia of ensuring a policy and institutional environment to support realization of new VRES generation to the maximum extent practicable.**
- This will not only ensure the lowest cost generation but also minimize reliance on other energy sources and strengthen Armenia's energy security and competitiveness
- Evaluating higher levels of economic growth introduced no differences in new power plant capacities in level or by type required to cover electricity demand through 2036 compared to the baseline.
- The only effect of higher income growth was in increased use of existing installed capacity of both VRES and gas-fired thermal power plants, with a concomitant increase in expenditures on natural gas fuel.

SUMMARY AND CONCLUSIONS (2/3)

- Scenarios for life extension of the ANPP decrease total system cost and reduce GHG emissions and imports of natural gas for electricity generation, while they increase total investment costs for new generation capacity by around 12 - 15% compared to BASE-R.
- Scenarios with new nuclear units to replace the ANPP from 2027 increase total system cost and reduce GHG emissions and imports of natural gas for electricity generation, while they ***significantly increase*** the required total investment costs for new power generation by 116 - 164%, compared to BASE-R.
- **While life extension of the ANPP represents a least-cost policy choice for continuing to maintain nuclear capacity in Armenia' energy mix, such life extensions must first and foremost always ensure that all measures required for the continued safe and reliable operation of this older plant are fulfilled.**

SUMMARY AND CONCLUSIONS (3/3)

- **While low gas prices reduce total energy costs, the increased use of cheaper gas maintains and deepens Armenia's dependence on imported energy.**
- Scenarios which imposed GHG emissions reduction targets to meet the level defined in Armenia's NDC largely mirror the “new nuclear” scenarios, increasing total system cost and reducing in GHG emissions and imports of natural gas for electricity generation, while leading to even larger total investment costs for new power generation capacity than the nuclear scenarios.
- ***Policies that would promote increased deployment of electric vehicles and electricity for heating increase the utilization of expanded domestic VRES, reduce reliance on imported gas and strengthen Armenia's energy security.***

Thank You for Your Attention

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