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Energy + Water Economics

Rogun Hydroelectric Techno-Economic Assessment Study: Economic and Financial Analysis

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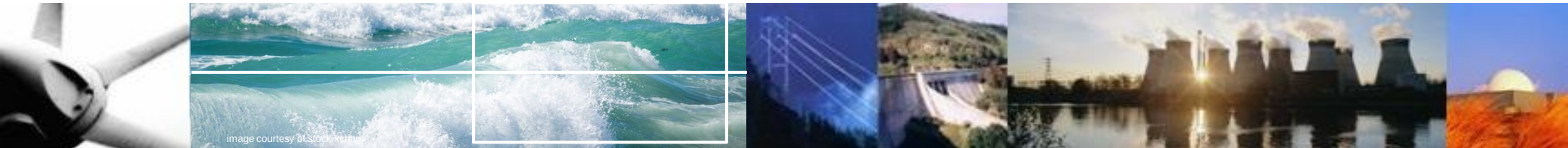

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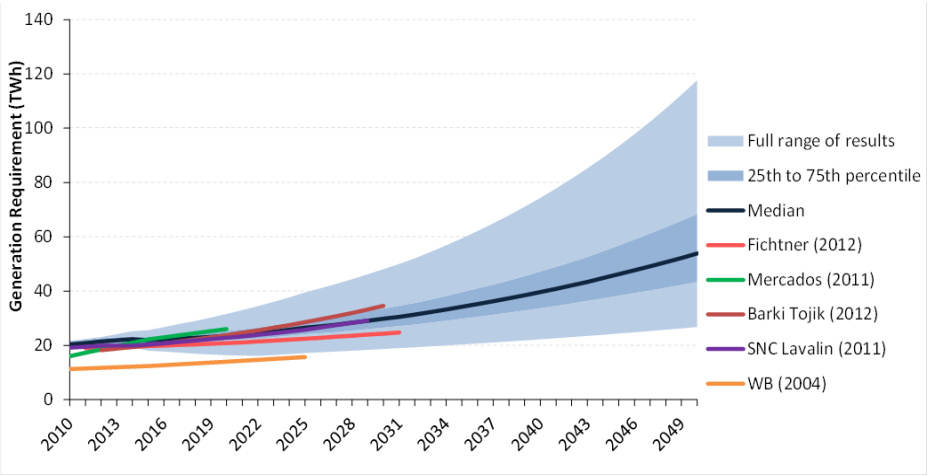
Economic Analysis: Methodology

1. **Regional least-cost generation expansion plan** to 2050 using proprietary ECLIPSE® market model considering Tajikistan, Afghanistan, Kazakhstan, Kyrgyzstan, Pakistan, Turkmenistan, Uzbekistan
   - Satisfy forecast electricity demand using known and economic new power station build and interconnector expansion
   - Nine Rogun design options assessed: three installed capacities for each of three dam heights
2. **Total System Cost savings** for Tajikistan from each Rogun design option vs No Rogun case
   - annualised capex repayments for new build
   - fixed and variable O&M costs
   - fuel and interconnector utilisation costs
   - flood protection benefits (as appropriate)
   - site decommissioning costs (No Rogun case)
3. **Economic valuation** of each Rogun design option
   - Benefits: domestic and export electricity sales, avoided flood protection costs
   - Costs: construction, equipment, resettlement, O&M, lost agricultural production

- **Probability-weighted sensitivity analysis** considering uncertainty around key inputs
  - Demand growth, fuel costs, total investment cost (TIC) of new build, interconnector capacity (NTC)
  - Reference = central forecast for each parameter; high and low single-factor sensitivities examined
  - Post-2050 value included as linear decline to end-of-life (impact of sedimentation)

Economic Analysis: Key Assumptions

- **Demand growth**
  - Forecast considered: impact of economic growth (+ve) and tariffs (-ve) on consumption, including unmet demand, plus investment to reduce T&D losses and energy efficiency measures
  - CAGR to 2050: median 2.6%, range 2.0-3.6%



- **New build options** for Tajikistan
  - Principally run-of-river (ROR) and dam hydro power plants (HPPs)
  - Limited coal, no gas or renewables
- **Interconnections**
  - CASA-1000 from 2017: 1,000 MW Kyrgyzstan ↔ Tajikistan → Pakistan + economic expansion
  - Tajikistan → Afghanistan: 110 MW existing + 300 MW from CASA-1000
  - No interconnection Tajikistan / Uzbekistan

Least-Cost Generation Expansion Results

- All economic cases – Reference case and sensitivities – indicate need for at least one large dam, Rogun or Dashtijum, plus several ROR HPPs
  - Except for short period after large dam construction, imports from Kyrgyzstan needed to fully meet winter demand
- Location of Rogun upstream of existing hydro plants increases total output from Vakhsh cascade and allows wide range of control for load-following purposes
  - Still abiding by existing agreements and practices on summer water release
  - Without Rogun, much greater capacity of ROR plants needed – higher investment cost and greater summer energy surplus, requiring more interconnector capacity to utilise
- Tajikistan expected to become net exporter in all cases
  - Summer exports to Pakistan and Afghanistan (including wheeling of energy from Kyrgyzstan)
  - Winter imports from Kyrgyzstan (some of which may be wheeled from Uzbekistan) for most of forecast period

Total System Cost Savings

- All Rogun design options provide significant system cost savings to meet forecast Tajik power demand compared to No Rogun because of large amount of alternative ROR build required in latter case
  - Rogun beneficial across all design options and sensitivities

- Highest dam **1,290 masl** generally provides greatest savings
  - Lowest only slightly better in low demand growth case, without delaying construction of Rogun

Present Value of Total System Cost Savings @ 10%

USD million (real 2013)	Reference 20%	High Demand 10%	Low Demand 10%	High Fuel Costs 10%	Low Fuel Costs 10%	High TIC 10%	Low TIC 10%	High NTC 10%	Low NTC 10%	Probability-weighted Average
1290 masl, 3,600 MW	1,678	1,854	628	1,881	1,215	2,509	554	1,051	1,485	**1,453**
1290 masl, 3,200 MW	1,707	1,825	679	1,929	1,238	2,531	560	1,072	1,542	**1,479**
1290 masl, 2,800 MW	1,701	1,452	688	1,897	1,248	2,522	538	1,071	1,552	**1,437**
1255 masl, 3,200 MW	1,495	1,687	621	1,729	1,103	2,399	580	948	1,353	**1,341**
1255 masl, 2,800 MW	1,497	1,344	648	1,739	1,099	2,410	529	944	1,436	**1,314**
1255 masl, 2,400 MW	1,524	468	635	1,672	1,106	2,395	541	937	1,380	**1,218**
1220 masl, 2,800 MW	1,389	1,432	723	1,381	983	2,047	356	936	1,111	**1,174**
1220 masl, 2,400 MW	1,387	728	734	1,315	980	2,034	348	927	1,155	**1,100**
1220 masl, 2,000 MW	1,342	69	710	1,329	933	1,980	424	866	1,228	**1,022**

The colour coding is used to highlight relative cost savings **within each scenario (column)** not across all cases:
red = lowest, orange/yellow = middle, green = highest.

Economic Valuation

- All Rogun design options demonstrate positive economic NPV at 10% discount rate across all scenarios

- Highest dam **1,290 masl** again shows greatest value
  - Higher initial costs outweighed by greater revenues over longer lifetime and flood protection benefits

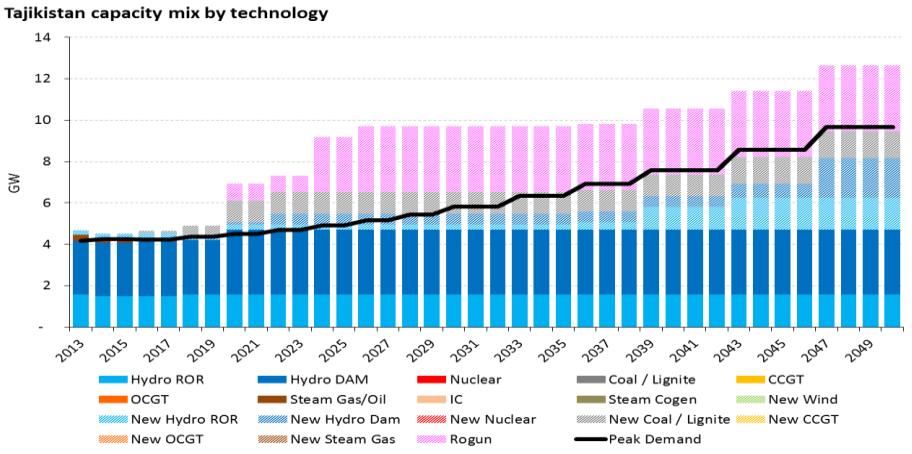
Economic Net Present Value @ 10%

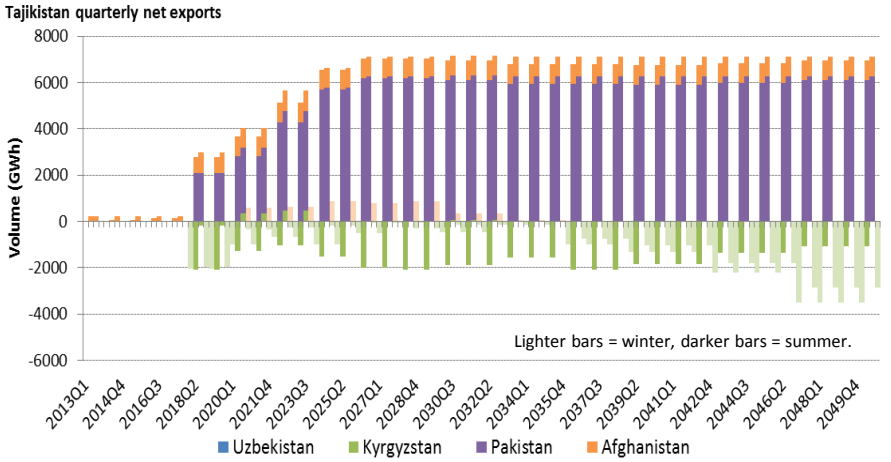
USD million (real 2013)	Reference 20%	High Demand 10%	Low Demand 10%	High Fuel Costs 10%	Low Fuel Costs 10%	High TIC 10%	Low TIC 10%	High NTC 10%	Low NTC 10%	Probability-weighted Average
1290 masl, 3,600 MW	819	852	720	1,080	523	1,222	366	766	780	**795**
1290 masl, 3,200 MW	863	887	765	1,121	559	1,244	420	808	819	**835**
1290 masl, 2,800 MW	878	792	769	1,132	561	1,251	405	820	767	**825**
1255 masl, 3,200 MW	729	768	648	951	460	1,074	302	663	667	**699**
1255 masl, 2,800 MW	758	715	678	973	471	1,102	331	690	747	**722**
1255 masl, 2,400 MW	748	578	699	982	495	1,087	332	704	641	**701**
1220 masl, 2,800 MW	656	656	640	887	402	943	312	629	398	**618**
1220 masl, 2,400 MW	667	534	650	889	404	919	326	637	435	**613**
1220 masl, 2,000 MW	635	431	614	848	389	874	286	601	435	**575**

The colour coding is used to highlight relative cost savings **within each scenario (column)** not across all cases:
red = lowest, orange/yellow = middle, green = highest.

Recommended Rogun Design Option

- Highest dam **1,290 masl** generally exhibits greatest cost savings and NPV
  - Choice of capacity should be examined in more detail considering optionality and flexibility of additional units
  - Further analysis on **3,200 MW** option as best at this stage
- Least-cost capacity expansion relies on Rogun in early years
  - Additional new run-of-river and dam hydro needed once demand exceeds > ~7 GW
  - Further interconnector expansion to Pakistan from 2020 when Rogun starts generating – significant summer exports to Pakistan/Afghanistan
  - Rogun initially removes need for net winter imports – until demand grows further





Recommended Option Sensitivities: System Cost Savings

- Economic interconnection ("Modified Reference")
  - Interconnector expansion only required later than firm CASA-1000 in 2017
- Imported gas supply to Tajikistan
  - Rogun still least-cost option, especially considering increased CO_2 emissions
- Delay in Rogun construction
  - 2-year deferral slightly benefits system from reduction in PV of costs – longer deferral increases costs due to delay in generation
- Share reimbursement costs
  - To be paid if Rogun does not proceed
- Demand growth
  - Would need to be 55% lower than median forecast for savings to approach zero

USD million (real 2013)	$PV_{10\%}$ of TSC savings	Variation to Reference	
Reference	1,707	-	-
High Demand	1,825	+118	+6.9%
Low Demand	679	-1,028	-60.2%
High Fuel	1,929	+222	+13.0%
Low Fuel	1,238	-469	-27.5%
High TIC	2,531	+824	+48.3%
Low TIC	560	-1,147	-67.2%
High NTC	1,072	-635	-37.2%
Low NTC	1,542	-165	-9.7%
Modified Reference	1,508	-199	-11.6%
Gas generation	775	-933	-54.6%
Gas generation + heating	684	-1,023	-59.9%
Rogun delay:			
2 years	1,770	+63	+3.7%
4 years	1,658	-49	-2.9%
6 years	1,301	-406	-23.8%
Share reimbursement	1,747	+40	+2.3%
Demand growth -55%:			
full savings	389	-1,318	-77.2%
excluding externalities	56	-1,651	-96.7%

Recommended Option Sensitivities: Economic Valuation

- Delay or Extension in Rogun construction
  - 2-year delay in benefits outweighs deferral of costs, reducing NPV
- Rogun capital costs (TIC)
  - Need to increase by >30% for NPV to be zero – but major part of works already done
- Achieved Rogun sale prices
  - Domestic tariffs and negotiated compromise for exports halves NPV
- CO_2 abatement benefit
  - Central Asian emissions slightly higher than in No Rogun case with more HPPs
- Delay in export revenues
  - Would need to not be realised until 2032 for value to be fully eroded

USD million (real 2013)	Economic $NPV_{10\%}$	Variation to Reference	
Reference	863	-	-
High Demand	887	+23	+2.7%
Low Demand	765	-98	-11.4%
High Fuel	1,121	+258	+29.8%
Low Fuel	559	-304	-35.2%
High TIC	1,244	+380	+44.0%
Low TIC	420	-444	-51.4%
High NTC	808	-55	-6.4%
Low NTC	819	-45	-5.2%
Rogun delay 2 years	732	-132	-15.2%
Construction extension	657	-207	-24.0%
Rogun TIC:			
-20%	1,417	+553	+64.1%
+20%	310	-553	-64.1%
+31.2%	0	-863	-100.0%
Rogun sale prices:			
domestic tariffs + exports -50%	410	-454	-52.5%
only domestic -38.4%	0	-863	-100.0%
only exports -62.5%	0	-863	-100.0%
CO_2 abatement costs	801	-63	-7.3%
No export revenues until Q3 2032	-15	-879	-101.8%

Economic Analysis: Conclusions

- Analysis demonstrates economic viability of all Rogun design options under wide range of assumptions
  - Project is least-cost generation option for Tajikistan, saving 1.0-1.5 USD billion in present value terms compared to alternatives, due to high degree of controllability to match generation to demand domestically and for exports
  - Economic value of 575-835 USD million depending on dam height and installed capacity option

- Highest dam alternative **1290 masl** recommended to be taken forward for detailed consideration
  - Intermediate installed capacity option (3,200 MW) has greatest system cost savings and economic NPV, and economics are robust to wide range of future outcomes
  - Additional analysis required to optimise installed generation capacity, considering potential benefits vs costs of maintaining extra unit for e.g. higher demand growth or maintenance outages

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Financial Analysis: Project Assumptions

- Initial analysis to identify high-level range of funding possibilities for recommended Rogun design option **1290 masl, 3,200 MW**

- **Costs** as used in economic analysis

- Capex considered in three categories
  - **Safety critical** to be fully funded before construction starts: civil works from start of river diversion, hydro-mechanical and related equipment
  - **Electromechanical** equipment
  - **Other**: pre-2016 civil works, administration and engineering, infrastructure replacement and resettlement

- **Revenues** determined from electricity sales domestically and for export

- Volume split between countries assumed *pro rata* with total Tajikistan generation mix calculated from least-cost expansion plan
  - Long-term share ~ 70:30 domestic/export
- Electricity sale prices based on tariffs (same as economic analysis "Achieved sale prices" sensitivity)
  - Domestic: tariffs increase to ¢9/kWh by 2023 with ¢1.5/kWh T&D costs (real 2012)
  - Export: 50% of calculated prices

Financing Assumptions

- Four potential structures examined
  1. **Full Self-Financing**: Government of Tajikistan equity only
  2. **Preferential Loan**: equity plus up to 90% debt from friendly partner
  3. **Multilateral and Commercial Loan**: equity plus up to 90% debt
  4. **Bond**: dedicated cash fund retained as security for repayment
- Net operating revenues from early generation during construction period used to supplement external sources
  - Exports in 2020-27 will help provide foreign currency for capex
- Indicative costs assumed for various external sources of funds
  - Constraint to maintain positive cash flow and minimum 1.25× debt service coverage ratio (DSCR)

(nominal)	Bond	Preferential loan	Multilateral loan	Commercial loan
Cost of funding				
LIBOR	-	3.30%	3.30%	3.30%
+ Premium	-	1.70%	1.30%	9.00%
Interest rate	10%	5.00%	4.60%	12.30%
Upfront fee	-	0.50%	0.25%	1.50%
Commitment fee	-	0.50%	0.25%	1.50%
Drawdown and repayment schedule				
Available from	2020	2015	2015	2020
Duration/Tenor	25	25	20	15
Repayment from	2020	2025	2025	2025
Maturity	2044	2039	2034	2034

Financial Analysis Results

- Range of Government of Tajikistan equity requirements and financial internal rates of return (FIRR) calculated
  - External gearing of close to 90% can be supported based on revenue and cost assumptions
  - Project **FIRR ~12% post-tax nominal** > indicative 10% WACC
  - Equity FIRR increase as amount of debt rises
  - High capex sensitivity (+20%) increases equity and reduces returns – below 10% for full self-financing and bond

(post-tax, nominal)	Full Self-Financing	Preferential Loan	Multilateral and Commercial Loan	Bond
Project				
FIRR	11.88%	12.07%	12.05%	12.17%
Payback (years)				
Nominal	18	18	18	18
Discounted	30	29	29	28
Equity				
FIRR	10.97%	22.25%	22.52%	11.18%
Payback (years)				
Nominal	19	16	16	19
Discounted	36	17	18	36

Financial Analysis: Conclusions

- Initial analysis suggests project could achieve reasonable rates of return for a range of funding structures and sources

- Specific discussions with potential funders required at next stage to ascertain exact level of external financing likely to be available and costs thereof

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