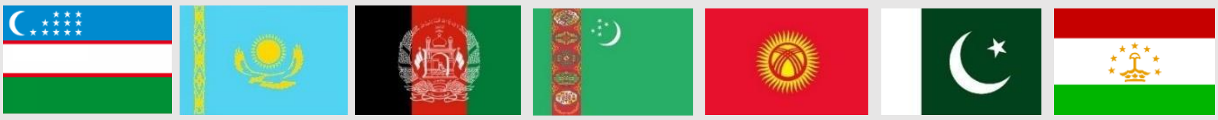
TA 9365

Regional Cooperation on Renewable Energy integration to the Grid



Final report for output 1

November 2019

Glossary

AC	Alternative Current
ADB	Asian Development Bank
AFG	Islamic State of Afghanistan
aFRR	Automatic Frequency Restoration Reserves
AGC	Automatic Generation Control
CAPS	Central Asian Power System
CAR	Central Asian Republics
CAREC	Central Asia Regional Economic Cooperation
CASA-1000	Central Asia–South Asia Electricity Transmission and Trade Project
CASAREM	Central Asia South Asia Regional Electricity Market
CCGT/CCPP	Combine Cycle Gas Turbine / Power Plant
CDC	Coordinating Dispatch Centre “Energy” of Central Asian Power System
CIS	Commonwealth of Independent States
CORESO	Coordination of Electricity System Operators
DABS	Da Afghanistan Breshna Sherkat
DC	Direct Current
DISCO	DIStribution COmpanies
DSM	Demand Side Management
DTS	Dispatcher Training Simulator
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
ESCC	Energy Sector Coordinating Committee
EWP	Energy Work Plan
FCR	Frequency Containment Reserves
FRR	Frequency Restoration Reserves
GENCO	GENeration COmpanies
GEP	Generation Expansion Plan
GMP	Generation Master Plan
GT	Gas Turbine
GW	Giga Watt
GWh	Giga Watt hour
HPP	Hydro Power Plant
HVDC	High Voltage Direct Current
IES	Intersystem Electric Networks
IGCC	International Grid Control Cooperation
IPP	Independent Power Producer
KEGOC	Kazakhstan Electricity Grid Operating Company
K-Electric	Karachi Electric
KYR	Kyrgyz Republic
KOREM	Kazakhstan Operator of Electric Power and Electric Energy
KAZ	Republic of Kazakhstan

LFC	Load Frequency Control
LOLE	Loss of Load Expectation
MEW	Ministry of Energy and Water
mFRR	Manual Frequency Restoration Reserves
MW	Mega Watt
MWh	Giga Watt hour
NDC	National Dispatch Centre
NEPRA	National Electric Power and Regulatory Authority
NEPS	North East Power System (in Afghanistan)
NLDC	National Load Dispatch Centre
NPG	National Power Grid
NTC	Net Transfer Capacity
NTDC	National Transmission and Dispatch Company
PICASSO	Platform for the International Coordination of Automated Frequency Restoration and Stable System Operation
PAK	Islamic Republic of Pakistan
PP	Power Plant
PSC	Power Supply Companies
PV	PhotoVoltaic
RCT	Remote Control and Telecommunication
RDC	Regional Dispatch Centres
RE	Renewable Energy
REC	Regional Electric Network Companies
RES	Renewable Energy Sources
RR	Replacement Reserves
RSC	Regional Security Coordinator
RSCI	Regional Security Coordination Initiative
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SO	System Operator
ST	Steam Turbine
TA	Technical Assistance
TJK	Republic of Tajikistan
TKM	Turkmenistan
ToR	Terms of reference
TPP	Thermal Power Plant
TUTAP	Turkmenistan-Uzbekistan-Tajikistan-Afghanistan-Pakistan Interconnection
UCPTE	Union for the Coordination of Production and Transmission of Electricity
UCTE	Union for the Coordination of Transmission of Electricity
UPS	Unified Power System
UZB	Republic of Uzbekistan
WAPDA	Water and Power Development Authority

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Executive Summary

0.1. Introduction

RTE International has been appointed by ADB as a Consultant for the TA-9365 REG: KSTA Regional Cooperation on Renewable Energy Integration to the Grid (51148-001).

The contract between ADB and RTE International was officially signed on December the 26th, 2017 and the works officially started on January the 3rd 2018.

The four key outputs that are to be achieved are:

- Output 1: grid reinforcement plan ready to accept intermittent renewable energy;
- Output 2: regional cooperation framework to share balancing capacity reserve;
- Output 3: dispatch operation support tool and approach analysis;
- Output 4: capacity building.

The Report for Output 1 draws the main findings of this output, and more particularly:

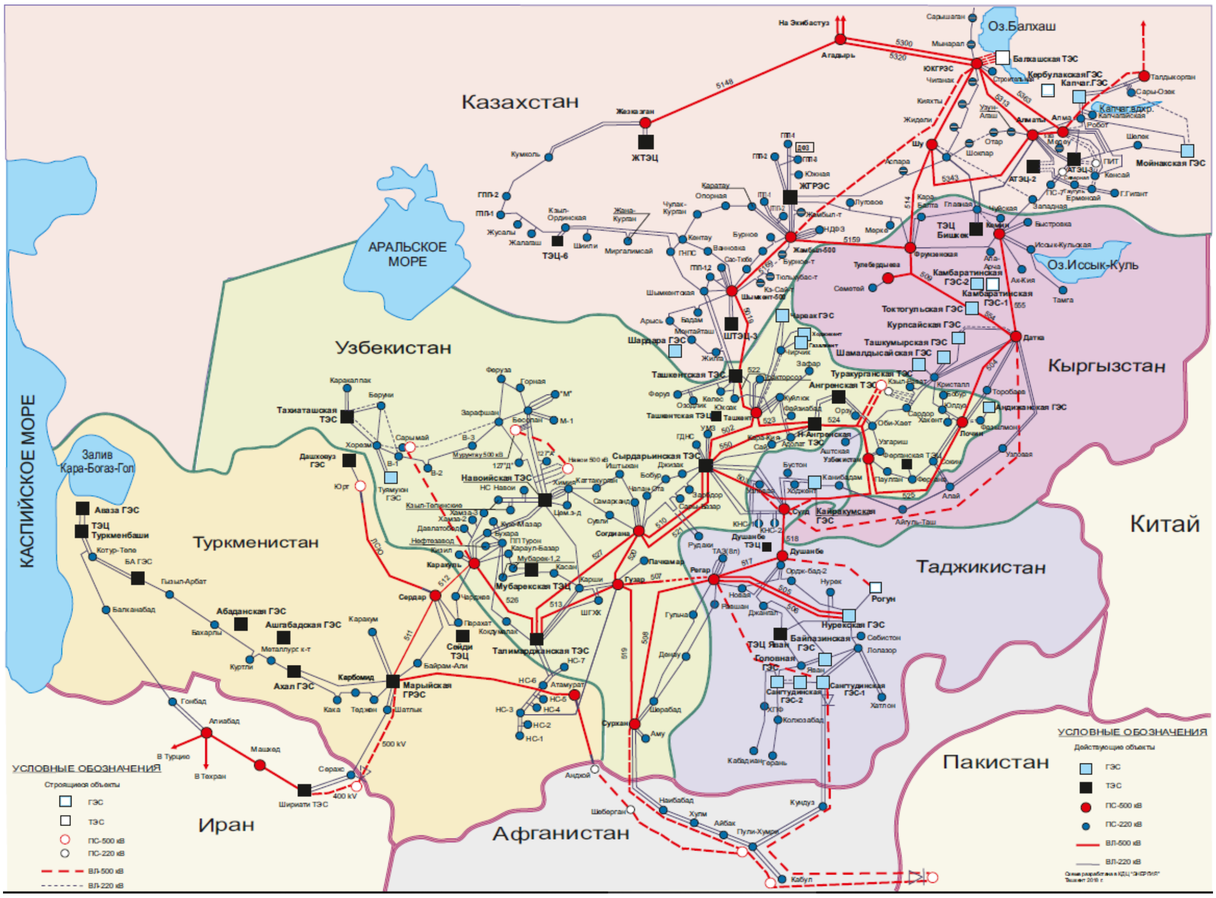
- Assesses the necessary regulation reserve in the region and the benefit of a regional cooperation (chapter 3). Main assumptions and methodology are detailed in chapter 3.1; results for 2020, 2025 and 2030 are detailed in chapters 3.2, 3.3 and 3.4); In addition detailed hypotheses and results are presented in Annex 1 – task 1/a : Hypotheses by countries and expected generation by power plant;
- Proposes a draft roadmap up to 2030 for a regional cooperation to accept intermittent renewable energy in the countries of the region. The detailed roadmap is presented in the Annex 2 – task 1/a" : Roadmap;
- Assesses the dispatching operation practices in Central Asia countries and provides recommendations. This analysis is detailed in Annex 3– task 1/b: Dispatching operation practice assessment;
- Presents the policy review that analyses the existing situation in each of the 7 countries and makes recommendations in order to create good regulatory conditions for the growth of renewable energies (Annex 4 – task 1/c : Policy Review);
- Presents the capacity building provided to the working committee members during four workshops (chapter 6).

0.2. Background

Central and South Asia countries have committed to reducing greenhouse gas emissions in the frame of the Paris agreement, relying on their important solar and wind generation potential power generation. These countries have asked the ADB to support this effort and help them develop incentives for clean power investment and invest in the consequently necessary grid adaptations. These countries are thus expected to integrate significant amounts of intermittent renewable energy sources in their systems, leading to increasing needs in reserve exchange.

Seven among these countries – namely Afghanistan, Kazakhstan, the Kyrgyz Republic, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan (the Region), have been selected by the

ADB for this Technical Assistance because of their interconnected networks and potential for increasing regional cooperation in the field of power system operation and reserve management.



As a matter of fact, these seven countries being geographically connected, it makes it easier to share backup generators or storage capacity, all the more so as those countries have historically shared electricity between each other. The existing legacy sharing protocols and mechanism can be easily utilized in the frame of this Technical Assistance. Moreover, Kazakhstan, Uzbekistan, Kyrgyz Republic and the NEPS[1] of Afghanistan are connected together with the Russian system as of today.

As experienced in other regions worldwide, notably continental Europe, regional cooperation leads to a more efficient use of the grid. There are actually many benefits to operating interconnected power systems rather than isolated, among which:

- The possibility of exchanging energy between systems, so as to benefit from cheaper energy or reduce the installed capacity, where interconnected systems have different generating fleets, or peak load occurring at different periods, depending of the level of integration agreed between systems;

[1] North East Power System

- The possibility to share the Frequency Containment Reserves (FCR – more commonly called primary reserve) among the interconnected systems and thus reducing the FCR requirements of each system;
- The possibility of exchanging Frequency Restoration Reserve (FRR – grouping the two types of reserves more commonly called secondary reserve and fast tertiary reserve) and Replacement Reserve (RR – rest of the tertiary reserve) across the borders and, in a more advanced stage of cooperation, to share them;
- The increase of the inertia of the system, reducing the gradient of the frequency deviation following a supply - demand imbalance, leaving more time for the delivery of the primary reserve and reducing the maximum transitory frequency deviation (the final frequency deviation will remain identical).

The possible drawback is that a system may be affected by an incident occurring outside its borders, however as this report shows, benefits exceed such risk.

In the field of capacity reserves, on which this technical assistance (TA) focuses, the benefits of regional cooperation are twofold:

- It reduces the overall need of reserve capacity by exchanging and sharing reserve at regional scale, hence compensating local uncertainties on generation and load, and
- It reduces the overall need of reserve capacity by reducing the uncertainties linked to intermittent generation through a more accurate forecast of this type of generation.

0.3. Types of reserve considered during the technical assistance

For the sake of evaluating necessary reserves, all types of reserves that may be used for frequency control and balancing activities will be considered. They mainly include three types of reserves:

- Primary reserve, (named Frequency Containment Reserve or FCR in the European Grid Codes), whose time of activation is typically from some seconds to 30 seconds for full activation. The primary reserve is used to stabilise frequency deviation, following the tripping of a generator or a load rejection. It is may also be activated, though in a limited amount, to cover prediction error in RE generation which would incur a continuous and slow deviation;
- Frequency Restoration Reserve (FRR), for which full activation time is typically 15 minutes be it automatic (aFRR, more commonly named secondary reserve) or manual (mFRR, mainly fast acting hydro reserve). This reserve is used to restore the frequency to its nominal value (50 Hz) after stabilization by the primary control. If needed, FRR can be activated permanently, without any time limitation;
- Replacement Reserve (RR), manually activated reserves with a time of activation longer than FRR full activation time. RR can be introduced for instance to enable FRR to be ready to face new uncertainties, or to ensure that the SO can rely on enough reserve to perform intra-day unit commitment.

0.4. Hypotheses for countries' power system up to 2030

The power system considered for the assessment of the necessary regulation reserve and the benefit of a regional cooperation includes the existing system and the generation and transmission facilities planned to be commissioned or withdrawn up to 2030 in each country.

For RES growth, overall targets have been used when detailed projects are not known yet.

The 2020 situation for demand and intermittent RES installed capacity in each country is presented below:

2020	Peak load (MW)	Demand in Energy (TWh)	RES installed capacity (MW)
Afghanistan	1,800	9.09	230
Kazakhstan	15,800	105.1	2,245
Kyrgyz Republic	3,300	15.2	0
Pakistan	28,095	162.7	2,800
Tajikistan	3,300	20.4	0
Turkmenistan	3,900	21.4	0
Uzbekistan	10,400	71.4	1,000

In 2020, Tajikistan network should be operated synchronously with the Russian system (i.e. with Kazakhstan, Uzbekistan, Kyrgyz Republic and the NEPS of Afghanistan) through reconnecting the existing lines that had been disconnected for several years. Turkmenistan and Pakistan networks are not connected to the networks of the other countries of the region and are operated independently (Turkmenistan being interconnected with Iran).

2025

The 2025 situation for demand and intermittent RES installed capacity in each country is presented below:

2025	Peak load (MW)	Demand in Energy (TWh)	RES installed capacity (MW)
Afghanistan	2,360	12.4	850
Kazakhstan	16,941	110.5	3,430
Kyrgyz Republic	3,645	17.0	650
Pakistan	35,422	198.7	4,900
Tajikistan	3,695	23.0	750
Turkmenistan	4,452	23.8	1,000
Uzbekistan	12,531	85.0	2,500

In 2025, the Turkmenistan network is assumed to be operated synchronously with the Russian system (i.e. with Kazakhstan, Uzbekistan, Kyrgyz Republic and the NEPS of Afghanistan) through reconnecting the existing lines that had been disconnected for several years and with Pul e Khomri 500 kV substation (Afghanistan) synchronising the two new 500 kV lines coming one from Turkmenistan (Andkhoy) and the other from Uzbekistan (Surkhan).

In Afghanistan, a new 500 kV line between Kabul and Pul e Khomri is assumed to be in operation, tapping in and out in the future Ishpushta Coal fired TPP.

Pakistan network is connected to the networks of the other countries of the region through CASA 1000 HVDC link (750 km, 500 kV overhead DC transmission line, between Peshawar and Sangtuda HPP in Tajikistan) and a new 500 KV AC line extending this link from Sangtuda HPP to Regar.

The Turkmen system is assumed to still export power to Iran (with a future Back-to-Back substation or by supplying an islanded area in Iran).

2030

The 2030 situation for demand and intermittent RES installed capacity in each country is presented below:

2030	Peak load (MW)	Demand in Energy (TWh)	RES installed capacity (MW)
Afghanistan	3,127	16.5	1,600
Kazakhstan	17,982	117.3	4,700
Kyrgyz Republic	3,926	18.3	1,300
Pakistan	44,958	255.0	4,900
Tajikistan	4,154	25.9	1,500
Turkmenistan	5,037	26.5	2,000
Uzbekistan	15,480	105.4	4,000

A 500 kV interconnection line Datka - Sugd is assumed to be in operation before 2030 (Kambarata-1 HPP second stage development).

0.5. Assessment of necessary frequency reserve

Frequency Containment Reserve (FCR)

With regards to the Frequency Containment Reserve, it is important to point out that a Regional Cooperation is already in force among the countries operating synchronously with the Russian system, since Russia is providing FCR to the whole synchronised system.

Thus, there is no FCR necessary requirement in Kazakhstan, Uzbekistan, Kyrgyz Republic, Tajikistan and the NEPS of Afghanistan, and in Turkmenistan also after synchronisation with the Russian system (assumed by 2025).

For Turkmenistan (before synchronisation with Russia) and Pakistan, the FCR minimum requirement is the size of the largest unit connected to the grid.

Frequency Restoration Reserve (FRR)

Concerning the FRR, the necessary requirement has been calculated as the maximum value between:

- the size of the largest unit;
- the reserve requirement to face 99.9 % of the situations. This requirement corresponds to a high-quality supply.

The FRR requirements per country by 2020 are presented hereafter:

Country	FRR up requirement (MW) (1)	Largest Unit (MW)	
AFG	75	Kabul NW GT	40
KAZ	610	Ekibastuz ST	500
KYR	300 / 360	Toktogul HPP	300 / 360 (2)
PAK	660	B.Qasim port ST	660
TAJ	375	Nurek HPP	375
UZB	800	Talimarjan ST	800
TKM	395	Mary CCGT (1/2)	395

(1) FRR is assumed to be symmetrical (down requirement is equal to up requirement)

(2) Toktogul first refurbished unit (300→360 MW) is planned to return to operation in October 2020

The FRR requirements per country by 2025 are presented hereafter:

Country	FRR up requirement (MW) (1)	Largest Unit (MW)	
AFG	150	Ishpushta ST	150
KAZ	620	Ekibastuz ST	500
KYR	360	Toktogul HPP	360
PAK	1,100	KaNuPP	1,100
TAJ	375	Nurek HPP	375
UZB	800	Talimarjan ST	800
TKM	395	Mary CCGT (1/2)	395

(1) FRR is assumed to be symmetrical (down requirement is equal to up requirement)

The FRR requirements per country by 2030 are presented hereafter:

Country	FRR up requirement (MW) (1)	Largest Unit (MW)	
AFG	220	Shall HPP	200
KAZ	640	Ekibastuz ST	500
KYR	465	Kambarata1 HPP	465
PAK	1,100	KaNuPP	1,100
TAJ	466	Rogun HPP	466
UZB	1,200	Attawak NPP	1,200
TKM	395	Mary CCGT (1/2)	395

(1) FRR is assumed to be symmetrical (down requirement is equal to up requirement)

Replacement Reserves (RR)

A non-mandatory approach, similar to that of Europe is recommended for dimensioning this reserve.

In the European reserve design, RR are non-mandatory, based on the assumption that producers will balance their generation as soon as possible to meet the load of their clients.

In the Central Asia context, among the actions listed in the roadmap, countries are recommended to carry out the following actions:

- SOs perform a reliable day-ahead unit commitment, based on precise load and intermittent generation forecasts,
- SOs can access all technically available dispatchable resources.

With this prerequisite, RR is not strictlynecessary in Central Asia. However, countries can introduce RR on a voluntary basis, for instance to enable FRR to be ready to face new uncertainties, or to ensure that the SO can rely on enough reserve to perform intra-day unit commitment.

0.6. Benefits of a regional cooperation

Tajikistan and Kyrgyz Republic generation systems are mainly based on hydro power plants and can provide other interconnected countries with large amounts of FRR, which benefits all these countries during the entire period 2020 - 2030. We therefore propose that regional cooperation be introduced as soon as possible to countries where networks will be synchronized with Russia (Kazakhstan, Uzbekistan, Kyrgyz Republic, Tajikistan and Afghanistan in a first step and then Turkmenistan when it will be reconnected to the first group of countries). This regional cooperation will enable each national system operator to acquire abroad (mainly in Tajikistan and Kyrgyz Republic) a part of the FRR they need for operating their own system. Pakistan may also join the FRR regional cooperation when it will be connected to the other countries with the CASA-1000 HVDC link but with much more limited benefits.

These results have been found by comparing 3 situations:

- Without regional cooperation: each country provides its own Frequency Restoration Reserve requirement (FRR) as defined in the previous section;
- With regional cooperation based on FRR Cross Border procurement: FRR dispatch is optimised between the countries to cover the same total amount of FRR as required without regional cooperation;
- With regional cooperation based on FRR sharing. As each country will not require its full reserve at the same time, a reduction of the overall FRR requirement is accepted.

Most of the benefits of a regional cooperation are captured by Cross Border procurement. A cooperation based on FRR cross-border procurement will allow countries to reduce the annual cost of procurement from around US$~130 million in 2020 to around US$~230 million in 2030. Uzbekistan and Turkmenistan (after its reconnection to the regional transmission network) are the countries which benefit the most from this FRR regional cooperation.

Additional savings with Reserve Sharing cooperation are very limited and have not been clearly assessed since they are below the simulation model accuracy. Moreover, this solution needs the countries to agree on a stronger regional integration framework with the introduction of fair rules to allocate the FRR between them. Due to the limited benefits and its higher complexity, it is not recommended to implement it.

With regards to Replacement Reserves (RR), benefits are difficult to estimate as there is no obligation (similar in Europe). Based on this assumption, benefit of a regional cooperation on RR should be studied case by case, depending on the volume of reserves required by each country on a voluntary basis. Such benefits have not been estimated in this Technical Assistance.

In the frame of the output 2 of this TA, the Consultant recommends the countries of the region to take measures at national level to increase the flexibility of the unit commitment in intra-day and real time. Similarly, the Consultant recommends them to take measures to have flexible cross-border energy exchanges in intra-day and real time. These two sets of measures are two pre-requisites for implementing the regional cooperation on FRR. They will also pave the way to the implementation of a possible regional cooperation on RR.

2020

In 2020, Tajikistan (all year long) and Kyrgyz Republic (only during summertime) will be able to provide other neighbouring countries with FRR. A cooperation based on FRR cross-border procurement (FRR requirement of 2,160 MW from January to September / 2,220 MW from October to December[2]) will allow countries to reduce the annual cost of procurement by around US$~130 million.

Uzbekistan is the country which benefits the most from the FRR regional cooperation. To a lesser extent Afghanistan also benefits significantly from this cooperation in 2020 (with a reduction of the use of national thermal power plants which are the most expensive of the region).

A more advanced type of regional cooperation has also been investigated, based on a regional reserve sharing mechanism, which would allow a pooling of reserves between countries and

[2] After the commissioning of the first Toktogul refurbished unit (rated power increased from 300 to 360 MW)

thereby enabling the overall FRR capacity to be limited to the 2 largest national FRR requirements at regional level (1,410 MW). Compared to the regional cooperation based on cross-border procurement, the additional benefit of reserve sharing is very limited and cannot be estimated by Plexos[3] (below the model accuracy).

2025

In 2025, Tajikistan and Kyrgyz Republic will be able to provide (all year long) other countries of the region with FRR, which benefits all the interconnected countries. The regional cooperation will enable each national system operator to acquire abroad (Tajikistan and Kyrgyz Republic) a part of the Frequency Restoration Reserve they need for operating their own system. A cooperation based on FRR cross-border procurement (FRR requirement of 2,700 MW) will allow countries to reduce the annual cost of procurement by around US$~150 million.

Uzbekistan and Turkmenistan are the countries which benefit the most from this FRR regional cooperation.

Pakistan could also potentially benefit from the cooperation when CASA-1000 interconnection line is not fully loaded with import but for that, it is necessary to adopt more flexible rules for than those recommended (based on a fix monthly schedule). With the recommended rules, Pakistan cannot make benefit from the FRR cooperation. The analysis also shows that it is not economic for Pakistan to provide FRR to other countries in 2025.

As in 2020, a regional reserve sharing mechanism has also been investigated, with the same conclusions (very limited additional benefits compared to the regional cooperation based on cross-border procurement). In this sharing solution, the overall FRR capacity is reduced to the 2 largest national FRR requirements at regional level (1,420 MW).

2030

In 2030, Tajikistan (all year long) and Kyrgyz Republic (only during summertime) will be able to provide other countries of the region with FRR. The regional cooperation will enable each national system operator to acquire abroad (mainly Tajikistan and Kyrgyz Republic) a part of the Frequency Restoration Reserve they need for operating their own system. A cooperation based on FRR cross-border procurement (FRR requirement of 3,370 MW) will allow countries to reduce the annual cost of procurement by around US$~230 million.

As in 2025, Uzbekistan and Turkmenistan are the countries which benefit the most from this FRR regional cooperation.

Pakistan could also potentially benefit from the cooperation by importing FRR in summer but CASA-1000 is already fully loaded with energy import during this period of time (annual peak period in Pakistan) and in such situation no benefit can be realized with the recommended rules for FRR cross-border procurement. In wintertime, Pakistan, due to the major extension of its hydro capacity in 2030, can provide other countries with FRR. Such exchanges are technically possible but with very limited benefits.

[3] Model used by the Consultant for the simulations

As in 2020 and 2025, a regional reserve sharing mechanism has also been investigated, with the same conclusions (very limited additional benefits compared to the regional cooperation based on cross-border procurement). In this sharing solution, the overall FRR capacity is reduced to the 2 largest national FRR requirements at regional level (1,840 MW).

0.7. Main findings

0.7.1. Necessary investments for a regional cooperation

New transmission assets

One of the major conclusions of this TA is that the existing network and the network developments already scheduled to be commissioned by 2030 are ready to accommodate the RES growth in the region until 2030. They are enough to allow exchanges or sharing of reserves, as well as to transmit balancing energy resulting from reserve activation whatever the regional cooperation solution is (cross border procurement or reserve sharing).

Even if there is no need for additional investments, it should be emphasized that some of the network developments already planned are essential for a regional cooperation on FRR:

- Tajikistan reconnection to the system synchronised with Russia is a prerequisite for a regional cooperation. It shall be commissioned in time by the utility companies or state's authorities in order to enable the export of reserves and balance energy from Tajikistan to other countries in the region (see roadmap action 1);

- In the case of Afghanistan, the national generation system, the cross-border and internal transmission facilities are not enough to meet the demand at peak times in 2020. There is unserved energy during these periods and a fortiori FRR cannot be procured (with or without cooperation). Two 500 kV lines from Turkmenistan and Uzbekistan are planned to be commissioned beyond 2020 to supply Afghanistan and overcome this situation. In order to enable Afghanistan to fully benefit from the regional cooperation, it is essential to build up these lines as soon as possible.

Reserve investment plan

Except for Afghanistan in 2020 where generation is still lacking to meet the load, the existing generation system and the generation facilities scheduled to be commissioned by 2030 according to the national power development plans of the countries of the region are enough to meet the demand and to provide the reserves. The existing and planned generation system is ready to accommodate the RES growth.

Even if there is no need for additional investments, it should be emphasized that some of the generation facilities already planned are essential for a regional cooperation on FRR.

It is essential to refurbish Toktogul and Nurek hydro power plants to ensure a reliable power supply and FRR for all the region since they will be the main FRR providers for the region during the first part of the period 2020-2030 (see roadmap action 3). With the commissioning of Rogun and Kambarata-1 HPP, these last power plants will progressively take also a significant part in the FRR supply according to their development stage.

It should be noted that at short term (in 2020), the capacity of Toktogul and Nurek power plants to provide FRR will be temporarily reduced during the refurbishment program (one unit out of service for refurbishment), which therefore will limit the potential benefit of a regional cooperation. These limitations have been considered during the estimation of benefit of the regional cooperation over the studied period.

No battery storage facilities are needed with the regional cooperation[4]. The countries of the region have opportunity to buy cheap FRR provided by neighbouring hydro power plants and the possible savings expected by the installation of batteries disappear. The installation of batteries for providing FRR is not recommended in this case (see roadmap action 3).

For similar reasons, benefit of introducing Demand Side Response (DSR) is not clear if regional cooperation is developed. Abundant hydro resources in Tajikistan, Kyrgyz Republic and at the end of the period in Pakistan can provide other countries with cheap FRR during the period 2020 to 2030. In that context, the profitability of developing FRR based on DSR is not assessed and the interest of DSR could be limited to local particularities such as network congestion management (see roadmap action 3).

Similarly, the implementation of a RES curtailment tool is not deemed necessary yet. The participation of wind farms in balancing reserves and downward adjustment has little interest as long as flexible hydro resources can provide the service. However, such tool could be locally useful to manage network congestions and to enable the integration of a higher level of RES in a weak network (see roadmap action 3).

Operation tools necessary investment

Beyond the construction of new transmission infrastructures, the operation of a power system integrating large amount of intermittent RES requires the implementation of new innovative tools.

The variability of weather conditions makes the solar and wind generation output less predictable than conventional generating units; thus, each national load dispatch centre must be able to ensure forecasting, real-time monitoring, and controllability of the RES. This implies:

- forecasting the RES with an adapted forecasting tool or forecasting service (typically to forecast RES generation from 2 days to 4 hours ahead);
- adapting the SCADA system so as to make it ready to accept all the telemeasurements and remote control (if needed) of the RES.

It is recommended to implement a forecasting service in National load dispatch centres (NLDC) when the installed capacity of RES reaches 5% of the peak load of the country; Thus Pakistan, Uzbekistan, Kazakhstan and Afghanistan shall implement a forecasting service by 2020 (see roadmap action 4.1).

[4] The CDC disagrees with this conclusion. The Consultant maintains the conclusion based on the result of the study in Output 1, which shows that with regional cooperation, Uzbekistan has the opportunity to buy cheap FRR provided by neighboring hydro power plants. However, without regional cooperation, the result of the study in Output 3 shows that an investment of 100 MW of battery to provide FRR in Uzbekistan in 2020 almost achieves the break-even point, which is close to the CDC concerns.

Among these countries receiving significant amount of RES, Pakistan, Kazakhstan and Afghanistan are equipped with modern SCADA systems which are ready to receive all the telemeasurements coming from the RES plants. No additional specific action needs to be taken in these countries. However, the Uzbek's SCADA/EMS is very old and has limited processing capability, making NDC Uzbekenergo's SCADA/EMS system upgrade paramount: it shall be launched as soon as possible in order to make it able to monitor the 1,000 MW of RES planned to be connected by 2020. Considering the time of implementation of such a large-scale project, the new SCADA/EMS will not be commissioned before 2021. The decision of renovation shall be included as an urgent measure in the roadmap to 2020 (see roadmap action 4.2).

CDC's SCADA/EMS is also very old and with limited processing capability. An in-depth renovation of the SCADA/EMS is needed to enable CDC to change its mission to that of a Regional Security Coordinator. As for Uzbek's SCADA/EMS, the new SCADA/EMS cannot be commissioned before 2021.

FRR can be activated manually by the dispatcher (with a remote device or by phone), which is the most current mode of activating the reserve in the countries of the region. It can also be activated with an AGC system: Pakistan already operates this automatic system and under implementation phase in Tajikistan.

In the countries which will join the regional cooperation, FRR will be provided by a limited number of generating units and manual activation is not a barrier for performing a rapid activation of FRR. In that context, the installation and generalization of AGC does not seem urgent and crucial, in so far as the controllability can remain performed manually in a safe way by the SO. AGC can be introduced by the countries on a voluntary basis (see roadmap action 5).

0.7.2. Operation improvement: target conditions for exchanging FRR

The establishment of regional cooperation on FRR, based on a cross-border procurement mechanism, implies several prerequisites in terms of system operation:

- Introduction of harmonised rules for FRR dimensioning (see roadmap action 6);
- Definition of scheduling, balancing and accounting rules for cross-border exchanges of energy (see roadmap action 7);
- Definition of common rules for coordinated operation planning: outage planning and cross-border capacity calculation[5] (see roadmap action 8);
- Implementation of harmonised training program for dispatchers (see roadmap action 10);
- Implementation of a trade model for cross-border procurement of FRR (see roadmap action 11).

Concerning FRR dimensioning, it is recommended to introduce an obligation for the minimum FRR required in each country. The recommended rule consists in having FRR at least equal to the size of the largest unit of the country, and having it activated in 15 minutes.

[5] The CDC and countries commented that this process already exists. It must be extended to the new members of the cooperation.

The dimensioning rule used for the assessment of necessary frequency reserve and described above in section 0.5 is more complex and precise. The loss of the largest unit is compared to the reserve required to face 99,9% of the situations and the final requirement is the maximum value between these two criteria. For an operational rule, the probabilistic approach seems too complex to be used in daily operation and the adoption of a more simple and robust approach based only on the loss of the largest unit is recommended. However, each SO remains free to use the complex criterion if it considers that this approach can lead to a better level of security for the operation of the system.

The interconnected countries shall adopt and apply harmonized rules for:

- developing a common outage coordination process (coordination of the maintenance periods between generating units and transmission facilities) and
- determining the cross-border transfer capacity which includes two components, the maximum transfer capacity of each cross-border line (Permanent Admissible Transmission Loading) and the overall transfer capacity available for commercial exchanges at each border (Net Transfer Capacity); the latter could be in a first step a fixed value for a week calculated on a weekly basis (one value for export and another one for import).

Considering the capacity on the interconnection lines between the countries, each System Operator should ensure that an activation of a cross border procured reserves is always possible without congestion, considering the commercial energy exchanges scheduled on the cross-border transmission lines. It is recommended that a part of the NTC would be reserved for the activation of cross-border FRR.

The interconnected countries shall also adopt a common trade model for the procurement and activation of cross-border FRR. This model shall include two steps:

- a model for the procurement of cross-border FRR in advance (capacity reservation to ensure that FRR will be available at any time). It is recommended in the long term to adopt a centralised process performed month ahead or week ahead (with a possible first step based on bilateral contracts);
- a centralised process for activating the cross-border FRR in real time (upon SO's requests). The trading solution for this process will be a System Operator – System Operator « SO-SO » model:
    - Each unit qualified to the FRR process has a contract with its connected SO for the procurement of reserve;
    - SOs have bilateral agreement.

It is recommended to entrust CDC with the operation of the centralised processes for cross-border FRR procurement and activation.

0.7.3. National regulations improvement

With various energy challenges to face, most of the seven countries of the region have set themselves target levels of renewable energy use; they have, however, made uneven progress in creating the necessary regulatory frameworks and adopting specific policies and regulations.

Along necessary grid development or adaptation, in order to build sustainable and resilient energy systems offering reliable energy, it remains an important challenge to set a regulatory framework that will be both attractive for foreign investment and practicable for future grid users, whether private or public, while guaranteeing energy security and power system flexibility.

Preparing the countries of the region to meet their green energy targets requires consideration in many fields of governmental intervention: energy of course, but also industry, economy and finance, construction and agriculture for example. Each considered Ministry needs to set up policies that must be coordinated to be efficient.

Based on international best practices, the target regulatory conditions to accept a significant raise in intermittent renewable energies should be:

- A largely open market structure, with conditions favouring the participation of private sector in generation (IPP). In order to make renewable energy policies efficient, States need to create a broad business friendly framework for private investors;

- The enactment of more practical, technical grid codes detailing homogenous technical requirements for the connection to the grid and operation of generators, connection procedures, including specific rules for renewable energies;

- The enactment of a set of non-discriminatory and publicly available contractual templates, ideally concerted with stakeholders;

- Rules for balancing activities and procurement of ancillary services in each country, allowing each system to reach adequacy;

- On the long term, rules facilitating demand side response, as well as storage.

It is recommended to set up in all the countries of the region a transparent and no discriminatory framework for private companies investing in RES (see roadmap action 14).

Establishing and making publicly available a connection code with high level requirements for RES is a prerequisite to accommodate RES growth. Now, Pakistan only has a public connection code, but it needs to be completed in various fields to ensure a coherent set of rules. A grid code including connection requirements is under development in Afghanistan.

It is recommended to set up in all the countries of the region grid codes including a connection code with high level requirements for RES (see roadmap action 13).

In order to effectively realise the potential benefits of the regional cooperation, it is of the utmost importance that national SO or utilities have flexible access to all the potential source of FRR, in the country or abroad. For this purpose, it is recommended to introduce obligation in the regulatory framework or to develop incentive solutions such as national FRR market (see roadmap action 12).

0.7.4. Regional cooperation framework

Technical rules: the "Central Asia South Asia Operation Handbook"

Common technical rules need to be established to ensure a reliable operation of the interconnected system in the framework of the regional cooperation. These rules will be included in a document that we propose to call "Central Asia South Asia Operation Handbook" by reference to the "Operation Handbook" in force in Continental Europe. These rules shall include all the rules that have been identified as prerequisites for implementing cross-border exchange of FRR in the chapter "0.7.2 - Operation improvement: target conditions for exchanging FRR" of this executive summary. There are reminded here below:

- harmonised rules for FRR dimensioning (see roadmap action 6);
- scheduling, balancing and accounting rules for cross-border exchanges of energy (see roadmap action 7);
- common rules for coordinated operation planning: outage planning and cross-border capacity calculation (see roadmap action 8);
- harmonised training program for dispatchers (see roadmap action 10);
- trade model for cross-border procurement of FRR (see roadmap action 11).

National rules shall be harmonized with the Central Asia South Asia Operation Handbook (see roadmap action 15).

Regional multilateral agreement

A regional multilateral agreement needs to be signed between the countries involved in the regional cooperation (see roadmap action 17). For 2020 regional cooperation, it involves Kazakhstan, Uzbekistan, Kyrgyz Republic, Tajikistan and Afghanistan. Turkmenistan and Pakistan may join this regional cooperation when they are physically interconnected with the previous group of countries.

The regional multilateral agreement:

- sets the principles of the frequency control in the region: FCR provided by Russia, obligation for the member countries to balance their generation and load in a time of 15 minutes after the occurrence of an imbalance (by activation of the FRR), trade model for cross-border procurement of FRR;
- makes the "Central Asia South Asia Operation Handbook" mandatory for the countries signing the agreement;
- define the new missions and role of CDC in order to change its role to that of a regional security coordinator and to be the entity in charge of processing the cross-border FRR procurement and activation (see roadmap action 19).

Other existing multilateral agreements concerning FRR and other reserves in the region

Existing multilateral agreements concerning FRR and other reserves in the region will need to be adjusted (see roadmap action 18).

0.8. Significant changes in the conditions of operation in the near future

According to the CDC's experience, some countries such as Uzbekistan, and at a lesser extent Kazakhstan, are currently facing difficulties in load following and reserve procurement and the CDC fears that these difficulties will be a barrier to future integration of a significant volume of intermittent renewable energy sources into the grid.

From the consultant's understanding of this situation, these difficulties in Uzbekistan arise from a considerable need for generation adjustments in real time operation due to a day ahead unit commitment done in a very much simplistic way (without a fine balancing of load with supply) and from real time limitations or inflexibility in gas procurement which prevents generating units technically capable of regulating from varying their output. Producers also seem reluctant to reduce the output of their generating units for economic reasons (less efficient operation when the unit output is lower than its rated power). Due to these inflexibilities, imbalances between generation and load occur frequently in the Uzbek power system. According to the CDC, the other countries face similar difficulties to balance their national systems, and the Russian system needs to compensate for the resulting imbalance in the three countries (Kazakhstan, Uzbekistan and Kyrgyz Republic).

Concerning intermittent renewable energy integration into the grid in Uzbekistan, the consultant's conclusions are much more favourable than those drawn by the CDC for two reasons.

The first reason is that even isolated, the Uzbek power system is technically capable of load following as soon as the legal and contractual barriers preventing the system from being flexible are to overcome. Based on this assumption, simulations done by the consultant for 2020 show that the existing Uzbek power system into which 1,000 MW of RES is integrated can be operated safely even when fully isolated from the other countries. Obviously, operation costs are high in this isolated situation due to the use of old inefficient units to ensure load following and to provide the reserve. That's why in this context, installation of batteries is close to the breakeven point.

The second reason is that operation conditions in Uzbekistan will drastically change in the near future with the reconnection of Tajikistan, which enables Uzbekistan to procure a cheap reserve from abroad and balance energy provided by neighbouring hydro power plants. With regional cooperation on FRR, operation costs in Uzbekistan will be significantly reduced and the investment in batteries is no longer profitable.

In conclusion it is of the utmost importance for Uzbekistan, and also for all the interconnected countries, to overcome without delay operational difficulties currently encountered at national level. Two measures are recommended by the Consultant:

1. each NLDC needs to perform day ahead adequacy studies based on precise load and intermittent generation forecasts and needs to ensure fine load following through the day-ahead unit commitment;
2. Contractual barriers need to be overcome to enable the system operator to access the full technical flexibility of the generating units. More particularly, gas availability for FRR activation shall be entrusted to the producers providing FRR. This obligation prevails over gas export considerations.

0.9. Roadmap

The Consultant has identified 19 actions to be achieved for enabling countries of the region to accommodate large scale intermittent renewable energy in the grid and for implementing a regional cooperation enabling them to acquire abroad a part of the FRR they need for operating their own power system.

This roadmap mainly includes the necessary actions to be achieved for implementing a regional cooperation as soon as possible. These actions are scheduled for an implementation of the regional cooperation in the second half of 2020 even if it is not clear whether Tajikistan reconnection will be fully achieved at this date.

Some actions starting beyond 2020 are also included, more particularly to prepare a future extension of the regional cooperation to Pakistan and Turkmenistan:

- A specific action about new investment in HVDC systems has been added to the section of the roadmap dealing with necessary investments for a regional cooperation (see roadmap action 2);
- Special operational rules for countries connected through DC systems shall be established (see roadmap action 9).

The 19 actions are listed in the attached table with a tentative schedule of implementation. They are grouped in five areas:

- Necessary investments for a regional cooperation;
- Operation tools necessary investment;
- Operation improvement: target conditions for exchanging FRR;
- National regulations improvement;
- Regional cooperation framework.

Roadmap for Regional Cooperation on Renewable Energy Integration to the Grid

Working group Light mobilization
Internal consultation - Decisions on external consultation

Final approval

05/09/2019

Action	Action n°	Activity	Sub action	Sub-activity	Responsible	Countries concerned	2020 T1	2020 T2	2020 T3	2020 T4	2021 - 2025 21	22	23	24	25	2026-2030 26	27	28	29	30	Antecedent
Necessary investments for a regional cooperation	Action 01	New transmission assets			Ministry of Energy		Tajikistan reconnected to operate synchronously					Turkmenistan synchronuously connected to Uzbekistan and Afghanistan				Commissionning of the decided interconnections between Kyrgyz rep. and Tajikistan					/
	Action 02	HVDC systems			Ministry of Energy	All the countries involved in these projects	CASA-1000 project enables participation of Pakistan in the regional cooperation							Back to back solutions for Turkmenistan							/
	Action 03	Reserve investment plan	3.1	Toktogul & Nurek refurbishment	Ministry of Energy		Toktogul & Nurek Generation refurbishment schedule														/
			3.2	Rogun & Kambarata FRR contribution	Ministry of Energy				Commissionning of Rogun & Kambarata 1 and of HPP reservoirs in Uzbekistan, Pakistan and Afghanistan												/
			3.3	Pakistanis and Afghan contribution increase	Ministry of Energy											Higher contribution of Pakistan and Afghanistan dur to HPP investment program					/
Operation tools necessary investments	Action 04	SCADA/EMS adaptation	4.1	Forecast RES according to RES penetration	TSO																/
			4.2	SCADA renovation	TSO	CDC and Uzbekenergo															/
			4.3	Forecast of RES in all countries	TSO	All the countries						in Tajikistan. Kyrgyz Republic and Turkmenistan									/
	Action 05	Introduction of an AGC			TSO	Voluntary basis															/
Operation improvement: target conditions for exchanging FRR	Action 06	Harmonized rules for FRR	6.1	Dimensionning rules for FRR	Multilateral coordination	All the countries part of the cooperation															11.2 17
			6.2	Compliance monitoring	SO / utilities	All the countries part of the cooperation															6.1
	Action 07	Scheduling and accounting rules for cross border commercial exchange	7.1	Harmonise time step for buying and selling energy cross border	SO / utilities and Ministry of energy	All the countries part of the cooperation															/
			7.2	Centralized scheduling verification process	Multilateral coordination	CDC															17 19
			7.3	Metering process	SO / utilities	All the countries part of the cooperation															/
			7.4	Settlement rules for FRR exchanges and unintended exchanges	Multilateral coordination	All the countries part of the cooperation						Imrpovement premanent process									17
	Action 08	Coordinated operation planning: outage planning and cross-border capacity calculation	8.1	Reinforce the common outage planning process	Multilateral coordination	All the countries part of the cooperation															17
			8.2	Determine FCR and TRM methodology	Multilateral coordination	All the countries part of the cooperation															17
			8.3	Capacity calculation in weekly process	Multilateral coordination	CDC															8.1 8.2 19
			8.4	Capacity calculation in D-2 process	Multilateral coordination	CDC															8.3
	Action 09	Common operational rules for countries connected by DC systems			Multilateral coordination	Countries connected with DC systems															/
	Action 10	Reinforcement of operators training	10.1	Design a common training curriculum for the operators	Multilateral coordination	All the countries part of the cooperation						Imrpovement premanent process									/
			10.2	Use of a DTS	Multilateral coordination	All the countries part of the cooperation															/

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Action	Action n°	Activity	Sub action	Sub-activity	Responsible	Countries concerned	2020				2021 - 2025					2026-2030					Antecedent
							T1	T2	T3	T4	21	22	23	24	25	26	27	28	29	30	
Operation improvement: target conditions for exchanging FRR	Action 11	Trade model for cross border procurement of FRR	11.1	Model based on bilateral contracts	Multilateral coordination	All the countries part of the cooperation															7.4 (nice to have) 11.2
			11.2	Centralized process for FRR real time activation	Multilateral coordination	CDC															19
			11.3	Reservation of a FRR capacity band	Multilateral coordination	CDC											stop				7.3 11.2
			11.4	Monthly process	Multilateral coordination	All the countries part of the cooperation															7.4 11.3
			11.5	Weekly process	Multilateral coordination	All the countries part of the cooperation															7.4 11.4
			11.6	Daily process	Multilateral coordination	All the countries part of the cooperation												Imrpovement permanent process			7.4 11.5
National regulations improvement	Action 12	Legal or contractual measures for accessing the restoration reserve technically available on the existing generation units	12.1	Ensure access to the all existing FRR	Ministry of Energy	All the countries part of the cooperation															/
			12.2	Gas availability for activating the reserves	Ministry of Energy	All the countries part of the cooperation															/
			12.3	Implementation of national capacity markets	Ministry of Energy	All the countries part of the cooperation															/
	Action 13	National grid codes (connection)	13.1	Enact grid codes in Countries expecting significant RE integration	Ministry of Energy																/
			13.2	Adapt Pakistanis grid code	Ministry of Energy																/
			13.3	Enact grid codes in all the countries	Ministry of Energy	All the countries															/
	Action 14	Legal framework to promote renewable energy development			Ministry of Energy	All the countries															/
Regional cooperation framework	Action 15	CASA OH Implementation steps	15.1	Agree on implementation steps for urgent common rules	Multilateral coordination	All the countries part of the cooperation					transi-tory phase										17
			15.2	Rules regarding the security of operation	Multilateral coordination	All the countries part of the cooperation							transi-tory phase								15.1
			15.3	Complementary rules for countries with HVDC connections	Multilateral coordination	Countries connected with DC systems								transi-tory phase							15.1
	Action 16	Harmonization of national regulation with CASA OH			Ministry of Energy	All the countries part of the cooperation															15
	Action 17	Regional Multilateral agreement for regional cooperation			Multilateral coordination	All the countries part of the cooperation	Kazakhstan, Uzbekistan, Kyrgyz Republic, Tajikistan and Afghanistan							MLA possibly enlarged to Pakistan and Turkmenistan							/
	Action 18	Adapt existing agreements concerning FRR and other reserves			Multilateral coordination	All the countries part of the cooperation															15.1
	Action 19	Initiative for a regional security coordination centre	19.1	Stregthen coordination missions	Multilateral coordination	CDC															15.1
			19.2	Entrust CDC with new missions related to FRR procurement	Multilateral coordination	CDC															15.1
			19.3	Stregthen security coordination	Multilateral coordination	CDC															19.1 19.2 4.2
			19.4	Further evolution to daily process	Multilateral coordination	CDC													Improvement permanent proocess		19.3

1. Introduction

RTE International has been appointed by ADB as a Consultant for the TA-9365 REG: KSTA Regional Cooperation on Renewable Energy Integration to the Grid (51148-001).

The contract between ADB and RTE International was officially signed on December the 26th, 2017 and the works officially started on January the 3rd 2018.

The four key outputs that are to be achieved are:

- Output 1: grid reinforcement plan ready to accept intermittent renewable energy;
- Output 2: regional cooperation framework to share balancing capacity reserve;
- Output 3: dispatch operation support tool and approach analysis;
- Output 4: capacity building.

This report draws the main findings of output 1, and more particularly:

- Assesses the necessary regulation reserve in the region and the benefit of a regional cooperation (chapter 3). Main hypotheses and methodology are detailed in chapter 3.1; results for 2020, 2025 and 2030 are detailed in chapters 3.2, 3.3 and 3.4; In addition detailed hypotheses and results are presented in Annex 1 to Report for Output 1 – task 1/a : Hypotheses by countries and expected generation by power plant;
- Proposes a draft roadmap up to 2030 for a regional cooperation to accept intermittent renewable energy in the countries of the region. The detailed roadmap is presented in the “Annex 2 to Report for Output 1 – task 1/a” : Roadmap;
- Assesses the dispatching operation practices in Central Asia countries and provides recommendations. This analysis is detailed in Annex 3 to Report for Output 1 – task 1/b: Dispatching operation practice assessment;
- Presents the policy review that analyses the existing situation in each of the 7 countries and makes recommendations in order to create the best regulatory conditions for the growth of renewable energies (Annex 4 to Report for Output 1 – task 1/c”: Policy Review)
- Presents the capacity building provided to the working committee members during four workshops (chapter 7).

2. Objectives and Background

2.1. Objectives of Output 1

Output 1 is divided into four main objectives:

a) Balancing capacity reserve assessment: **identify the necessary balancing capacity reserve up to 2030** and analyse the **benefit of having a regional cooperation framework**. Such shall be done by:
    - Reviewing the existing long-term power development plan for each country and estimating the necessary capacity reserve for the key years 2020, 2025 and 2030;
    - Analysing the benefit of having a regional cooperation framework to share the balancing reserves, compared to the cost without cooperation;

- Developing a reserve's investment plan: identify the necessary investment in terms of new power plants and new interconnection transmission lines needed to enable the exchange of reserve capacity and balancing energy between countries;
- Proposing feasible steps to realize regionally-harmonized regulation reserve development by year 2030.

b) **Dispatching operation practice assessment**, identify the gaps in operation practice before the grid can manage large scale intermittent renewable energies, recommend appropriate operation practice including tools:
   - Review of the current practice in each country, in terms of frequency regulation, forecast, planning coordination, tools, skills on regulation practice, training;
   - Identify the gap towards the set target solution and complete the roadmap.

c) Policy and sector review, propose necessary completion or revision of policy and regulation - including grid codes to enable balancing reserve suppliers to provide enough reserve capacity:
   - Review the countries' renewable policy to promote renewable energy development;
   - Review the rules on ancillary service procurement and how balancing capacity reserve's contribution is compensated, in case private sector and IPP contribute to maintaining system frequency;
   - Propose target conditions for ancillary service procurement and financial compensation for ancillary service providers;
   - Propose harmonization of the grid codes with high level requirements for renewable energy sources;
   - Identify the gaps towards the target conditions and, the possible steps towards the target conditions.

d) Provide capacity building to the Working Committee so as to enhance its members' skills and knowledges in the field of intermittent renewable energy control in the grid.

2.2. Background

Central and West Asia countries have committed to reducing greenhouse gas emissions in the frame of the Paris agreement, relying on their important solar and wind generation potential power generation. These countries have asked the ADB to support this effort and help them develop incentives for clean power investment and invest in the consequently necessary grid adaptations. These countries are thus expected to integrate significant amounts of intermittent renewable energy sources in their systems, leading to increasing needs in reserve exchange.

Seven among these countries – namely Afghanistan, Kazakhstan, the Kyrgyz Republic, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan (the Region), have been selected by the ADB for this Technical Assistance because of their interconnected networks and potential for increasing regional cooperation in the field of power system operation and reserve management.

As a matter of fact, these seven countries being geographically connected, it makes it easier to share backup generators or storage capacity, all the more so as those countries have historically shared electricity between each other. The existing legacy sharing protocols and mechanism can be easily utilized in the frame of this Technical Assistance. Moreover, Kazakhstan, Uzbekistan, Kyrgyz Republic and the NEPS[6] of Afghanistan are connected together with the Russian system as of today.

As experienced in other regions worldwide, notably continental Europe, regional cooperation leads to a more efficient use of the grid. There are actually many benefits to operating interconnected power systems rather than isolated, among which:

- The possibility of exchanging energy between systems, so as to benefit from cheaper energy or reduce the installed capacity, where interconnected systems have different generating fleets, or peak load occurring at different periods, depending of the level of integration agreed between systems;
- The possibility to share the Frequency Containment Reserves (FCR – more commonly called primary reserve) among the interconnected systems and thus reducing the FCR requirements of each system;
- The possibility of exchanging Frequency Restoration Reserve (FRR – grouping the two types of reserves more commonly called secondary reserve and fast tertiary reserve) and Replacement Reserve (RR – rest of the tertiary reserve) across the borders and, in a more advanced stage of cooperation, to share them;

[6] North East Power System

- The increase of the inertia of the system, reducing the gradient of the frequency deviation following a supply - demand imbalance, leaving more time for the delivery of the primary reserve and reducing the maximum transitory frequency deviation (the final frequency deviation will remain identical).

The possible drawback is that a system may be affected by an incident occurring outside its borders, however as this report shows, benefits exceed such risk.

In the field of capacity reserves, on which this technical assistance (TA) focuses, the benefits of regional cooperation are twofold:

- It reduces the overall need of reserve capacity by exchanging and sharing reserve at regional scale, hence compensating local uncertainties on generation and load, and
- It reduces the overall need of reserve capacity by reducing the uncertainties linked to intermittent generation through a more accurate forecast of this type of generation.

3. Task 1/a Necessary regulation reserve and benefit of a regional cooperation on the period 2020 to 2030

3.1. Assumptions and approach

For the three key years, 2020, 2025 and 2030, the assessment of necessary regulation reserve is carried in two steps:

- Identify and assess the necessary amount of frequency restoration reserve (FRR) needed by each country;
- Assess the benefit of having a regional cooperation framework to allow cross-border procurement of these reserve and in a more advanced stage to share them between the countries, by comparing the cost of the situations with and without cooperation.

In 2020, Turkmenistan and Pakistan cannot join the regional cooperation since they are not connected to the networks of the other countries of the region and are operated independently (Turkmenistan being synchronously connected with Iran). Pakistan will be interconnected through CASA 1000 HVDC link by 2023/24. Turkmenistan is assumed to be synchronously connected to Uzbekistan and Afghanistan (and therefore to Russia) by 2025.

3.1.1. Assumptions

The Consultant studied the power system of the whole region in 2020, 2025 and 2030, based on the existing system updated with the assets planned to be commissioned or decommissioned in each country by 2020, 2025 and 2030: power plants, transmission facilities, RES projects or RES targets if the detailed projects are not known yet[7].

7 See report “Study hypothesis per country – annex to Report of Output 1 – task 1/a – 2018”

2020

The 2020 situation for each country is presented below:

Countries	Peak load (MW)	Demand in Energy (TWh)	RE installed capacity (MW)
Afghanistan	1,800	9.1	230
Kazakhstan	15,800	105.1	2,245
Kyrgyz Republic	3,300	15.2	0
Pakistan	28,095	162.7	2,800
Tajikistan	3,300	20.4	0
Turkmenistan	3,900	21.4	0
Uzbekistan	10,400	71.4	1,000

By 2020, Tajikistan network should be to operated synchronously with the Russian system (i.e with Kazakhstan, Uzbekistan, Kyrgyz Republic and the NEPS of Afghanistan) through reconnecting the existing lines (four 220 kV circuits between Sugd and Syr Darya, one 500 kV circuit Regar - Surkhan, two 220 kV circuits between Regar and Surkhan). It is also assumed that Sugd SS will be tapped In/Out on Syr-Darya - Uzbekistan 500 kV line in August 2020. The 500 kV line Regar - Guzar is assumed to remain disconnected (not included in the reconnection plan)[8].

Afghanistan is importing energy from Turkmenistan, from Uzbekistan during wintertime, and from Tajikistan during summertime. During wintertime, Kunduz remains supplied by Tajikistan.
The Afghan network is operated with split areas to avoid synchronisation between the part supplied by Turkmenistan and the part supplied by Uzbekistan and Tajikistan.

No energy exchange has been modelled between the countries (except for countries exporting to Afghanistan), since there is no firm exchange contract. But occasional energy exchanges between countries will not modify the results.

All the power plants are assumed to be capable of providing FRR, except those with technical restrictions, such as the running of river dams, HPP operated on irrigation mode, combined heat and power facilities (especially in Kazakhstan), old thermal units etc.

Toktogul and Nurek refurbishments are considered (on each HPP, all units are refurbished, each one been successively out of service during one year, one after another). These rehabilitations have been decided by the Kyrgyz Republic and Tajikistan to meet their own electricity demand. Regarding Regional cooperation, Toktogul and Nurek HPP will be the main FRR providers for the region. The available capacity of these two power plants is reduced at the beginning of the

[8] From information collected in May 2019, too late to be introduced in further network analysis, we understand that 500 kV line Rugar-Guzar (L-507) is also planned to be reconnected (source: ADB project “Tajikistan Reconnection to Central Asian Power System Project” - Grant 0622-TAJ, Selection of Consulting Services for Project Implementation Consultant - May 2019).

refurbishment period (due to the unavailability of units under refurbishment). This limitation will lead to reduce the opportunity to dispatch FRR on them and therefore the regional benefit of such cooperation.

2025

The 2025 situation for each country is presented below:

Countries	Peak load (MW)	Demand in Energy (TWh)	RE installed capacity (MW)
Afghanistan	2,360	12.4	850 (1)
Kazakhstan	16,941	110.5	3,430
Kyrgyz Republic	3,645	17.0	650
Pakistan	35,422	198.7	4,900
Tajikistan	3,695	23.0	750
Turkmenistan	4,452	23.8	1,000
Uzbekistan	12,531	85.0	2,500

(1) Projects planned by the Ministry of Energy and Water for 2030 for private sector include a 3,000 MW plan of intermittent RE (2,000 MW of PV + 1,000 MW of wind) in addition to 900 MW of Coal TPP and 1,665 MW of HPP, for a peak demand reaching 3,127 MW. Under these hypotheses, Afghanistan should be exporting energy. The consultant made the choice to reduce the RE development to 850 MW in 2025, which seems more realistic.

CASA 1000 HVDC link will be commissioned in 2023/24, connecting Pakistan to Tajikistan (Sangtuda-1 HVDC SS, connected to the Tajik network with a 500/220 kV transformation and a 500 kV line Sangtuda-1 - Regar).
By 2025, Turkmenistan is assumed to be synchronously connected to Uzbekistan (connection with the existing lines: Karakul - Serdar 500 kV and Karakul - Chardej 220 kV) and to Afghanistan (with the existing lines: Atamurat - Andkhoy 500 kV, Zelili - Andkhoy 110 kV, Serhetabat - Hyrat 220 kV).
The Afghan network will be operated synchronously (since Turkmenistan is synchronised with rusia), with the 500 kV backbone Andkhoy - Pul-e-Khomri.

No energy exchange has been modelled between the countries, since there is no firm exchange contract, except for countries exporting to Afghanistan and Pakistan (Kyrgyz republic, Tajikistan, Uzbekistan). But occasional energy exchanges between countries will not modify the results.

As in 2020, all the power plants are assumed to be capable of providing FRR, except those with technical restriction, such as the running of river dams, HPP operated on irrigation mode, combined heat and power facilities (especially in Kazakhstan), old thermal units etc.

In 2025, Toktogul refurbishment is normally achieved (since end of 2023) and Nurek refurbishment is still ongoing (6 units refurbished end of 2024one unit been successively out of service during one year, one after another). Regarding Regional cooperation, the increase of the rated power in Toktogul with the progress of the refurbishment program will allow to dispatch more FRR on these cheap units than in 2020.

2030

The 2030 situation for each country is presented below:

Countries	Peak load (MW)	Demand in Energy (TWh)	RE installed capacity (MW)
Afghanistan	3,127	16.5	1,600 (1)
Kazakhstan	17,982	117.3	4,700
Kyrgyz Republic	3,926	18.3	1,300
Pakistan	44,958	255.0	4,900
Tajikistan	4,154	25.9	1,500
Turkmenistan	5,037	26.5	2,000
Uzbekistan	15,480	105.4	4,000

(1) Projects planned by the Ministry of Energy and Water for 2030 for private sector include a 3,000 MW plan of intermittent RE (2,000 MW of PV + 1,000 MW of wind) by 2030 in addition to 900 MW of Coal TPP and 1,665 MW of HPP, for a peak demand reaching 3,127 MW. Under these hypotheses, Afghanistan should be exporting energy. The consultant made the choice to reduce the RE development to 1,600 MW in 2030, which seems more realistic.

No energy exchange has been modelled between the countries, since there is no firm exchange contract, except for countries exporting to Afghanistan and Pakistan (Kyrgyz republic, Tajikistan, Uzbekistan). But occasional energy exchanges between countries will not modify the results.

As in 2020 and 2025, all the power plants are assumed to be capable of providing FRR, except those with technical restriction, such as the running of river dams, HPP operated on irrigation mode, combined heat and power facilities (especially in Kazakhstan), old thermal units etc.

Toktogul and Nurek refurbishment are assumed to be completed. In a regional cooperation frame, the corresponding increase of the rated power after completion of the refurbishment program is favourable for the regional cooperation (more available FRR).

These assumptions have been agreed with members of the Working Committee.

3.1.2. Types of reserve considered during the technical assistance

For the sake of evaluating necessary reserves, all types of reserves that may be used for frequency control and balancing activities will be considered. They mainly include three types of reserves:

- Primary reserve, (named Frequency Containment Reserve in the European Grid Codes), whose time of activation is typically from some seconds to 30 seconds for full activation. The primary reserve is used to stabilise frequency deviation, following the tripping of a generator or a load rejection. It is may also be activated, though in a limited amount, to cover prediction error in RE generation which would incur a continuous and slow deviation.

- Frequency Restoration Reserve (FRR), for which full activation time is typically 15 minutes be it automatic (aFRR, more commonly named secondary reserve) or manual (mFRR, mainly fast acting hydro reserve). This reserve is used to restore the frequency to its nominal value (50 Hz) after stabilization by the primary control. If needed, FRR can be activated permanently, without any time limitation.
- Replacement Reserve (RR) manually activated reserves with a time of activation longer than FRR full activation time. RR can be introduced for instance to enable FRR to be ready to face new uncertainties, or to ensure that the SO can rely on enough reserve to perform intra-day unit commitment.

3.1.3. Approach

This assessment has been carried in two steps for years 2020, 2025 and 2030:

- The assessment of the necessary Frequency Restoration Reserve (FRR) for each country;
- The identification of the best FRR dispatch between the synchronous countries, optimized on a technical-economic analysis.

The 1st step was the assessment of the level or FRR required for each country. Reserve aims to face Demand-Supply deviation between forecast situation and real situation. The Demand-Supply deviation has several causes:

- Demand forecast error;
- Generation forecast error, made up of 2 types:
  - Unit tripping due to forced outage;
  - RE Generation prediction error.

The 2nd step is dedicated to the assessment of the best FRR dispatch within the synchronous countries. A comparison with and without regional cooperation was used to assess the benefits.

3 situations are compared:

- Without regional cooperation: each country is providing its own FRR requirement,
- With regional cooperation based on FRR Cross Border procurement: FRR dispatch is optimised between the countries to reduce the procurement cost. The total amount of FRR requirement for the interconnected countries is the sum of the requirements of each country calculated as in the previous situation,
- With regional cooperation based on FRR sharing: FRR dispatch is optimised between the countries to reduce the procurement cost. The total amount of FRR requirement for the interconnected countries is limited to the 2 largest individual FRR requirements. It is assumed that an overall reduction of the FRR requirement is possible, considering that each country will not require its full reserve at the same time.

For each of two situations with regional cooperation, the analysis has been achieved in 2 types of simulations:

- For the 1st type of simulation, the software used by the Consultant is free to dispatch on an hourly basis the global amount of FRR between countries, but the reserve dispatch fluctuates significantly in each country from one hour to the next, which is very complex to implement during real operation.
- For the 2nd type of simulation, the situation is studied with a fixed cross-border procurement. Due to the seasonality of the results (mainly depending on hydro inflows on the reservoir cascade), a monthly approach is convenient: the requirement per country is be specified as a fixed value on a monthly basis, based on the monthly average reserve dispatch calculated with the 1st simulation.

For each of the situations, the generation cost is assessed. The benefit of the regional cooperation corresponds to the difference of the generation cost for each of the compared situations.

The study is based on a normal water inflow situation (a specific analysis will be carried out for low water inflow situation).

<u>Remark:</u> it is reminded that the ramping of units (variation limits of the unit's output, in MW/min) has been taken into account in the simulation. Each generation fleet is able to face the fluctuation of the net load (net load = load - generation of intermittent sources), especially the evening peak, combining a load increase and the PV generation decrease, reinforcing the generation increase requirement.

3.1.4. Reserves strategies with or without regional cooperation

This chapter compares the situations with and without regional cooperation for Balancing Frequency Restoration Reserve. In 2020, Turkmenistan and Pakistan are not yet interconnected and are therefore not included in this study.

Reserve Provision

Providing reserve on a power plant requires to operate it above the min stable level (MSL) or under the maximum output, the reserve is calculated as the difference between the actual set point for the generation output and the rated power or the MSL, and by the ramping capacity (MW/min) of the plant (to comply with the time constraint requirement for reserve delivery).

Providing reserve in a power system increases most of the time the generation cost for two reasons:

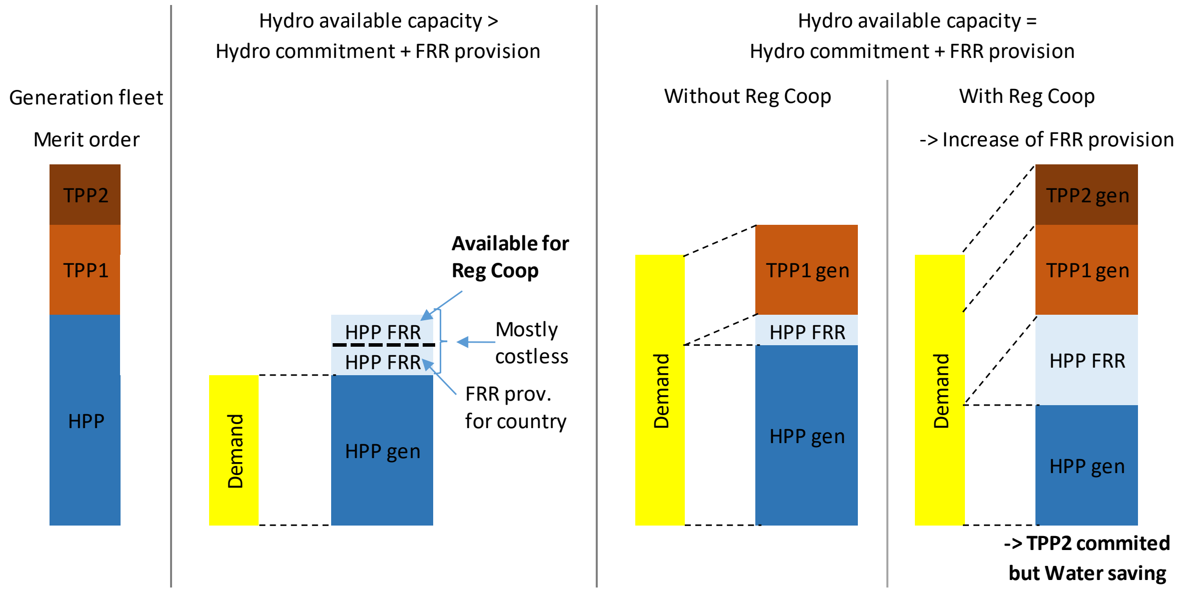
- Deoptimization of the economic unit commitment: the generation cost is increased because more units need to be started (with higher generation costs) to provide generation and reserve rather than to provide only generation (without reserve provision).

- Providing reserve with TPP decreases the efficiency of the plant since the plant cannot operate at the rated power (highest efficiency point): the MWh cost increases.

However, providing reserve on HPP is most of the time a costless solution for the system because HPP are usually operated at their optimum efficiency around 80% of their rated capacity, and the remaining 20% capacity beyond their efficiency set point can be used for providing reserve.

For these reasons, it is cheaper to provide reserves with hydro power plants than with thermal power plants.

In some cases, some TPPs need to be committed to enable HPP to provide more reserve, therefore it can slightly de-optimise the unit commitment and increase the generation cost in a country providing FRR with hydro resources. For the whole region, the unit commitment is still less costly than providing reserve on TPP in countries receiving FRR.



With regards to water regimes, it should be noted that FRR capacity reservation has no impact on the water regimes, as long as the reserve is not activated. Moreover, reserve activation is expected to have very little affect on the water regime because the reserves will be activated almost equally upwards and downwards.

3.2. Main results of the 2020 study on balancing capacity reserves

In 2020, we therefore propose that regional cooperation be introduced to countries where networks will be synchronized with Russia (Kazakhstan, Uzbekistan, Kyrgyz Republic, Tajikistan and Afghanistan). This regional cooperation will enable each national system operator to acquire a part of the Frequency Restoration Reserve they need for operating their own system from abroad. The overall regional amount of FRR remains unchanged, but the distribution is optimised. A cooperation based on FRR cross-border procurement will enable to reduce the annual generation cost of US$~130 million.

A more advanced regional reserve sharing mechanism is also possible, allowing for the pooling of reserves between countries and limiting the overall FRR capacity to the loss of the two largest requirements at the regional level. With this pooling strategy, only 1,410 MW of reserves would be needed for the entire region. Compared to the cross-border procurement scenario, FRR Reserve Sharing does not enables additional cuts in the annual generation cost. Moreover, this solution implies a strong regional integration based on the definition of rules to allocate the 1,410 MW of FRR between the countries. Due to the low economic benefits and the complexity of implementing such rules, it is not recommended to adopt such a pooling strategy in 2020.

Excluding Afghanistan, the existing network and works currently planned are enough to accommodate the planned RES in 2020 and is enough to allow sharing of reserves as studied whatever the regional cooperation scenario (cross border procurement or reserve sharing).

3.2.1. Frequency Restoration Reserve requirement

Simulations based on 1,000 random drawings on the 8,760 hourly situations have been carried out for each country, considering RES generation prediction errors, load prediction errors and generation forced outages.

The criteria used for sizing the reserve is the amount of reserve required to face 99.9 % of the situation (= except 9 hours per year where deficit could occur). The reserve requirement is the maximum value between:

- the size of the largest unit;
- the reserve requirement to face 99.9 % of the situations. This requirement corresponds to a high-quality supply.

The FRR requirements are presented below:

Country	FRR requirement (MW)	Largest Unit (MW)		Peak Load (GW)
AFG	75	Kabul NW GT	40 (1)	1.8
KAZ	610	Ekibastuz ST	500	15.8
KYR (2)	300 / 360	Toktogul HPP	300 / 360	3.3
PAK	660	B.Qasim port ST	660 (3)	28.1
TAJ	375	Nurek HPP	375	3.3
UZB	800	Talimarjan ST	800	10.4
TKM (4)	395	Mary CCGT (1/2)	395	3.9

(1) Afghanistan plans to commission two PV farms of 100 MW each by 2020. PV farms are made up of several PV modules and usually several step-up transformers in parallel: such PV farms cannot trip at once.

(2) the size of the largest unit in the Kyrgyz system increases from 300 to 360 MW with the commissioning of the 1st refurbished unit in Toktogul HPP planned in Oct 2020.

(3) In 2020, the installed capacity of Qaid e Azam PV plant will reach 1,000 MW. But it will be made up of plants of 100 MW each, each one being made up of several smaller modular units.

(4) Turkmenistan commissioned 2 CCGTs of 787 MW each in 2018. Each Combine Cycle Gas Turbine (CCGT) is a 2 Gas Turbine + 1 Steam Turbine plant. The loss of one Gas Turbine entails the loss of half of the output of the Steam Turbine, and therefore half of the output of the CCGT. The main generation loss is therefore 395 MW (half of one CCGT).

The necessary FRR requirement is calculated as the maximum value between the size of the largest unit and the reserve requirement to face 99.9 % of the situations.
In Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan, the size of the largest unit roughly corresponds to 10% of the country's peak load: the FRR requirement correspond to the size of the largest unit.
In Afghanistan and Kazakhstan, the FRR requirement exceeds the size of the largest unit, the ratio size of the largest unit / peak load is smaller than the ratio in the other ones: the impact of the deviation due to load prediction error is more significant in these countries. In addition, in Afghanistan, the deviation due to RE generation prediction error is also larger than the size of the largest unit, since 210 MW of the PV farms are located in the same area: there is no geographical diversity factor.

In the study, reserves are assumed to be symmetrical (raise/lower).

3.2.2. Situation without regional cooperation

In this situation, each country provides its own FRR, as per the amount presented here above, except Afghanistan which cannot provide all the required FRR because the sum of its import and its own generation does not always meet the demand.
The dispatch of the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter:
FRR provided in the interconnected system:

	FRR provided	
	(GWh)	%
HPP	14,270	75%
TPP	4,813	25%

This amount does not fully meet the FRR requirements. The FRR shortage amounts to 83 GWh (<0.5 %):

Country break down of FRR dispatch:

Without Cooperation: FRR provided by each country					
Country	FRR dispatch by country		Hydro/ Thermal	FRR dispatch by type of plants	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	629	3%	H	422	67%
			T	207	33%
KAZ	5,358	28%	H	4,797	90%
			T	561	10%
KYR	2,737	14%	H	2,696	98%
			T	42	2%
TAJ	3,331	17%	H	3,331	100%
			T	0	0%
UZB	7,027	37%	H	3,024	43%
			T	4,003	57%

In Uzbekistan, TPP are providing more than half of the FRR. In Kazakhstan, TPP are providing 10% of the FRR.

In some countries, the FRR requirement cannot be met, especially in Afghanistan (shortage of 29 GWh, 5% of the requirement, occurring from October to March). The rest of the shortage occurs in the Kyrgyz system (53 GWh, 2% of the requirement) in January, due to the forced outage of 700 MW of hydro units for 8 days (44 GWh of reserve shortage): it is therefore more related to unfortunate occurrence of several simultaneous forced outage.

The countries' situation, presented hereafter, details for 2020 the annual demand, generation, export or import, the unserved energy and the Generation Cost, that have been estimated by including Fuel cost, fixed and variable Operation and Maintenance.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	GWh	5,983	105,500	15,427	163,017	20,490	21,433	71,365
Generation	GWh	1,936	105,500	15,415	163,017	21,289	25,082	73,055
Net Interchange	GWh	-4,042 (1)	0	0	0	1,323	3,649 (2)	1,689
Unserved Energy	GWh	5.7	0	12	0	524 (3)	0	0
Total Gen. Cost	M$	127.8	3,860.0	92.7	4,665.2	127.8	2,116.2	3,627.4

(1) Afghanistan is importing 1,323 GWh from Tajikistan, 1,689 GWh from Uzbekistan, and 1,014 GWh from Turkmenistan.
(2) Turkmenistan is exporting 2,635 GWh to Iran and 1,014 GWh to Afghanistan (NEPS)

(3) some load shedding occurs in Tajikistan in winter time due to the lack of water in reservoir and of available capacity.

The regional generation cost (except Turkmenistan and Pakistan, which are not impacted by Regional Cooperation on FFR) amounts to US$ 7.8 billion.

Without cooperation, FRR in Afghanistan is mainly provided by hydro with reservoir at peak time (hydro with reservoir is only operating at peak time), and by TPP when the demand is met.

3.2.3. Regional cooperation for FRR

For the overall region, enabling each country to procure the FRR in foreign countries increases the dispatch of reserve on HPP and therefore decreases the dispatch on TPP. The regional generation cost decreases significantly.

From a country point of view, the situations diverge:

- The reserve provided in countries with a generation fleet mainly based on thermal power plants (Uzbekistan, Kazakhstan), decreases: the generation cost decreases also significantly
- On the contrary, the reserve provided in countries with a generation fleet mainly based on HPP (Kyrgyz Republic, Tajikistan), increases, which slightly increases the generation cost.

It is assumed that financial arrangements will be concluded between the countries to fairly share the benefit of this cooperation. Price of FRR exchanged between countries should be established in a way that countries selling FRR cover at least the increase of their generation costs and that procurement costs for countries buying FRR are lower than the savings on their generation costs.

FRR has not been dispatched in Afghanistan since Afghanistan cannot provide FRR permanently: the country is still lacking generation to meet its demand.

3.2.4. With FRR cross-border procurement (2,160 MW)

In this situation, the 2,160 MW of required FRR (2,220 MW from October to December) has been dispatched between the countries with a technical-economic optimisation.
As presented in the approach description, the study has been carried out in 2 steps:

1. Full optimisation of the cross-border procurement, with the inconvenience of significant hourly variations in the dispatch by country (free dispatch), which is too complex to implement in operation;
2. Simulation with a fixed monthly dispatch of the FRR per country.

The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter:

FRR provided in the interconnected system:

	FRR provided in the Region			
	Free dispatch		Monthly dispatch	
	(GWh)	%	(GWh)	%
HPP	18,928	99%	18,446	97%
TPP	178	1%	608	3%
Shortage	0	0	64	-

Country break down of regional FRR distribution:

FRR dispatch with free procurement

Country	FRR dispatch by country		Hydro / Thermal	FRR dispatch by type of plants	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	96	1%	H	96	100%
			T	0	0%
KAZ	3,690	19%	H	3,677	100%
			T	13	0%
KYR	4,122	22%	H	4,120	100%
			T	2	0%
TAJ	9,013	47%	H	9,012	100%
			T	1	0%
UZB	2,184	11%	H	2,023	93%
			T	161	7%

FRR dispatch with fixed monthly procurement:

Country	FRR dispatch by country		Hydro/ Thermal	FRR dispatch by type of plants	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	0	0%	H	0	-
			T	0	-
KAZ	3,701	19%	H	3,409	92%
			T	292	8%
KYR	4,122	22%	H	4,072	99%
			T	50	1%
TAJ	9,032	47%	H	9,029	100%
			T	3	0%
UZB	2,198	12%	H	1,936	88%
			T	263	12%

A fixed monthly cross-border procurement does not significantly deoptimize the dispatch of reserve nor reduce the benefit of the regional cooperation.

The monthly FRR dispatch (MW) is presented below:

FRR dispatch (MW)	AFG	KAZ	KYR	TAJ	UZB
January	0	560	210	1,100	290
February	0	540	510	920	190
March	0	520	600	850	190
April	0	440	590	930	200
May	0	430	540	920	270
June	0	330	460	1,110	260
July	0	330	460	1,110	260
August	0	280	430	1,210	250
September	0	350	410	1,130	270
October	0	350	570	1,060	240
November	0	450	530	950	290
December	0	480	390	1,060	290

The countries' situation for 2020 with cross border procurement is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	GWh	5,983	105,500	15,427	163,017	20,490	21,433	71,365
Generation	GWh	1,579	105,500	15,415	163,017	21,563	25,082	73,145
Net Interchange	GWh	-4,388 (1)	0	0	0	1,580	3,649 (2)	1,780
Unserved Energy	GWh	16	0	12	0	507	0	0
Total Gen. Cost	MUS$	81.4	3,853	95.1	4,665	129.3	2,116	3,539

(1) Afghanistan is importing 1,580 GWh from Tajikistan, 1,780 GWh from Uzbekistan, and 1,014 GWh from Turkmenistan.
(2) Turkmenistan is exporting 2,635 GWh to Iran and 1,014 GWh to Afghanistan (NEPS)

Without considering the Pakistanis and Turkmen Generation costs (Turkmenistan and Pakistan are not involved in the regional cooperation in 2020), the regional generation cost amounts to US$ 7.84 billion without regional cooperation and decreases to US$ 7.70 billion with regional cooperation, enabling a US$~130 million saving. This includes the generation cost reduction (US$ 45 million) in Afghanistan, due to the cross-border procurement of FRR, and an increase of imports from Uzbekistan and Tajikistan (leading to a generation cost increase in Tajikistan, and an increase of export sales).

The comparative table of generation costs with and without regional cooperation is presented below:

Gen. Cost (M$)	AFG	KAZ	KYR	TAJ	UZB	Total
Without Regional Cooperation	128	3,860	92.7	128	3,627	7,835
With Cross Border procurement	81.4	3,853	95.1	129	3,539	7,698
Difference	(saving with regional cooperation)					137

In 2020, Tajikistan and Kyrgyz Republic can provide the other countries with FRR, with benefits for all the countries. This regional cooperation will enable each national system operator to acquire abroad (in Tajikistan and Kyrgyz Republic) a part of the Frequency Restoration Reserve they need for operating their own system.

A cooperation based on FRR cross-border procurement will enable to reduce the annual cost of procurement by US$~130 million.

3.2.5. Impact of a low water inflow in on the FRR cross border procurement scenario

Previous simulations above have been carried out with the average water flow on the Vakhsh and Naryn rivers.

This section looks at a simulation with a low water inflow in these 2 rivers (based on the Naryn river figures: reduction of 20% of the inflow). The main results are presented comparing 3 situations:

- without regional cooperation,
- with regional cooperation and the same monthly FRR dispatch as before,
- with regional cooperation and optimization of the monthly FRR dispatch to this new situation.

Without regional cooperation (impact of low water inflow situation)

Generation cost in US$ million is presented below:

Generation cost in US$ million	AFG	KAZ	KYR	TAJ	UZB	Total
Average Water Inflow	128	3,860	92.7	128	3,627	7,836
Low Water Inflow	124	3,860	172	197	3,628	7,980
Difference	(additional costs compared to average water flow)					144

The FRR shortage is the same in both scenarios (64 GWh).
The Unserved Energy increases from 542 to 968 GWh (increase of 397 GWh in Tajikistan and 26 in Kyrgyz Republic).

In a severe low water inflow situation, the generation cost without cooperation increases by US$ 144 million.

With regional cooperation (impact of low water inflow situation)

With 2,160 MW of FRR and a regional cross border procurement, the same FRR monthly dispatch is considered as for average water inflow.
Generation cost in US$ million is presented below:

Generation cost in US$ million	AFG	KAZ	KYR	TAJ	UZB	Total
Average Water Inflow	81.4	3,853	95.1	129	3,539	7,698
Low Water Inflow	87.8	3,853	175	190	3,539	7,845
Difference	(additional costs compared to average water flow)					147

The FRR shortage doubles but remains limited (1%) (150 instead of 64 GWh)
The Unserved Energy doubles from 520 to 1,067 GWh (increase of 506 GWh in Tajikistan and 38 in Kyrgyz Republic).

In a severe low water inflow situation, the generation cost with cross border cooperation increases by US$ 147 million and the FRR shortage increases from 64 to 150 GWh.

In the case of severe low water inflow, the regional cost of production is US$ 7.98 billion without cooperation and US$ 7.85 billion with cooperation. **So, the benefit of regional cooperation in a severe low water inflow situation is US$~130 million,** same benefit as in the average water inflow situation.

With regional cooperation in Low Water inflow situation - Interest of the optimisation of the FRR fixed monthly dispatch

Another simulation has been carried out in a severe low water inflow situation, this time by adapting the monthly optimized FRR dispatch (MW) in each country and is presented below:

FRR dispatch (MW)	AFG	KAZ	KYR	TAJ	UZB
January	0	530	270	1,070	290
February	0	570	530	870	190
March	0	480	610	880	190
April	0	470	550	930	210
May	0	560	410	880	300
June	0	410	360	1,110	280
July	0	390	340	1,160	270
August	0	330	380	1,190	260
September	0	370	370	1,120	300
October	0	380	670	920	250
November	0	420	670	860	270
December	0	490	370	1,070	290

On an annual basis, the FRR dispatch increases by 30 MW in Kazakhstan and 10 MW in Uzbekistan and decreases by 15 MW in Kyrgyz Republic and 25 MW in Tajikistan.

Generation cost, in low water situation with regional cooperation, with this new FRR dispatch are presented in US$ million below:

Generation cost (US$ million)	AFG	KAZ	KYR	TAJ	UZB	Total
With Normal Water Inflow FRR fixed monthly dispatch	87.8	3,853	175	190	3,539	7,845
With Low Water Inflow FRR fixed monthly dispatch	89.5	3,854	174	189	3,540	7,846

This adjustment allows to divide by 2 FRR shortage (81 instead of 150 GWh)
The Unserved Energy is hardly modified 1,074 GWh instead of 1,067 GWh (increase of 506 GWh in Tajikistan and 38 in Kyrgyz Republic).

The optimisation of the FRR dispatch under low water conditions does not significantly change the generation costs in each country and has no change on the regional generation cost, the volume of unserved energy. The only positive effect is to reduce FRR shortage from 150 to 81 GWh (from 0.8 to 0.4 % of the total FRR required for the region).

There is therefore a limited benefit to adapt the FRR dispatch to the water conditions.

3.2.6. Reserve sharing enables to decrease necessary FRR to 1,410 MW

The activation of the full FRR in each country does not occur at the same time. It is therefore possible to reduce the regional size of the FRR. The regional size has been reduced to the main two FRR requirements: 1,410 MW (Kazakhstan and Uzbekistan).
In this situation, the 1,410 MW of FRR has been dispatched between the countries with a technical-economic optimisation.
As presented in the approach description, the study has been carried out in 2 steps:

1. Full optimisation, with the inconvenience of significant hourly variations in the dispatch by country (free dispatch), which is too complex to implement in operation;
2. Simulation with a fix monthly dispatch of the FRR per country.

The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter:

FFR dispatch on the interconnected system:

	FRR provided in the Region			
	Free dispatch		Monthly dispatch	
	(GWh)	%	(GWh)	%
HPP	12,255	99%	12,017	97%
TPP	139	1%	363	3%
Shortage	0	0	22	-

Country break down for FRR required for the region:

Free FRR dispatch:

Country	FRR dispatch by country		Hydro/ Thermal	FRR dispatch by type of plants	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	63	1%	H	63	100%
			T	0	0%
KAZ	2,931	24%	H	2,929	99%
			T	2	1%
KYR	2,880	23%	H	2,879	100%
			T	1	0%
TAJ	4,663	38%	H	4,663	100%
			T	0	0%
UZB	1,857	15%	H	1,720	93%
			T	137	7%

FRR dispatch with fixed monthly cross-border procurement:

Country	FRR dispatch by country		Hydro/ Thermal	FRR dispatch by type of plants	
	(GWh)	(%)		(GWh)	(%)
AFG	0	0%	H	0	-
			T	0	-
KAZ	2,955	24%	H	2,764	94%
			T	191	6%
KYR	2,814	23%	H	2,800	100%
			T	13	0%
TAJ	4,811	39%	H	4,811	100%
			T	0	0%
UZB	1,804	15%	H	1,642	91%
			T	159	9%

The fixed monthly cross-border procurement does not significantly deoptimize the dispatch of reserve nor reduce the benefit of the regional cooperation.

The monthly FRR dispatch is presented hereafter (MW):

FRR dispatch (MW)	AFG	KAZ	KYR	TAJ	UZB
January	0	400	160	600	250
February	0	430	380	440	160
March	0	380	410	470	150
April	0	320	300	630	160
May	0	320	300	630	160
June	0	240	340	610	220
July	0	300	300	600	210
August	0	250	310	640	210
September	0	320	280	570	240
October	0	270	400	540	200
November	0	390	370	410	240
December	0	420	320	410	260

The countries' situation is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	GWh	5,983	105,500	15,427	163,017	20,490	21,433	71,365
Generation	GWh	1,655	105,500	15,416	163,017	21,552	25,082	73,152
Net Interchange	GWh	-4,318 (1)	0	0	0	1,503	3,649 (2)	1,786
Unserved Energy	GWh	10	0	12	0	441	0	0
Total Gen. Cost	MUS$	83.1	3,852	92.0	4,665	150	2,116	3,539

(1) Afghanistan is importing 1,503 GWh from Tajikistan, 1,786 GWh from Uzbekistan and 1,014 GWh from Turkmenistan.
(2) Turkmenistan is exporting 2,635 GWh to Iran and 1,014 GWh to Afghanistan (NEPS)

Gen. Cost (M$)	AFG	KAZ	KYR	TAJ	UZB	Total
With Cross Border procurement	81.4	3,853	95.1	129	3,539	7,698
With Reserve sharing	83.1	3,852	92.0	150	3,539	7,717

Without considering the Pakistanis and Turkmen generation cost, the regional annual generation cost amounts to US$ 7.7 billion with reserve sharing, same amount as with cross-border procurement [9]. **FRR Reserve Sharing does not enables additional cuts in the annual generation cost compared to FRR cross-border procurement**.

[9] Looking at the results in a more detailed way, there is a small increase in the annual generation cost from US$ 7.70 billion with FRR cross-border procurement to US$ 7.72 billion with reserve sharing, due to an abnormal US$~20 million increase of the Tajik generation cost, results from a non-fully optimised calculation. The Tajik generation cost should have decreased with the reduction of the FRR requirements. These abnormal fluctuations in the results of

3.2.7. Countries' situation

3.2.7.1. 2020 situation in Kazakhstan

With regional cooperation, Kazakhstan imports FRR. Compared to its own FRR requirement (610 MW), a regional cooperation enables Kazakhstan to reduce the annual FRR provided in the country from 5.4 TWh to 3.7 TWh (with cross-border procurement) and to 3.0 TWh (with reserve sharing). The corresponding savings reach US$ 7 million with cross-border procurement and US$ 8 million with reserve sharing. Despite a high reduction of the FRR provided in the country when sharing the reserve, the saving is limited because it corresponds to reallocation of FRR from Kazakh HPP to Kyrgyz and Tadjik HPP, with very limited impact on the generation cost.

Kazakhstan	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatched in the country	GWh	5,358	3,701	2,955
Generation cost	M$	3,860	3,853	3,852
Savings	M$		7	8

With cross-border procurement, the FFR dispatch increases during winter (when HPP in Kyrgyz Republic and Tajikistan operate at reduced power due to the reduction of the reservoir head, and therefore the dependable output).

FRR provided in the country (MW):

FRR provided in Kazakhstan (MW)	Without Reg. Coop	With Reg. Coop	
		cross-border procurement	reserve sharing
January	610	560	400
February		540	430
March		520	380
April		440	320
May		430	320
June		330	240
July		330	300
August		280	250
September		350	320
October		350	270
November		450	390
December		480	420

The summary of the annual generation of each power plant is presented in annex.

optimisation are inherent to the optimisation process and are not significative (under the sensibility threshold of the model).

3.2.7.2. 2020 situation in the Kyrgyz Republic

With regional cooperation, the Kyrgyz Republic is generally an exporter except in January. Compared to its own FRR requirement (300 / 360 MW), a regional cooperation requires the Kyrgyz Republic to increase its annual FRR dispatch from 2.7 TWh to 4.1 TWh with cross-border procurement and to 2.8 TWh with reserve sharing. The cross-border procurement entails a US$ 2 million generation cost increase. The reserve sharing entails only a slight decrease of the generation cost (US$ 0.7 million) despite a slight increase of the FRR dispatch (+81 GWh). If the overall amount of reserve dispatch increases, the dispatch over the year fluctuates and is more optimal: the FRR dispatch decreases in January (160 MW instead of 300 MW without regional cooperation) during the peak load period.

Kyrgyz Rep.	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatched in the country	GWh	2,737	4,122	2,818
Generation cost	M$	93	95	92
Savings	M$		- 2	1

With cross-border procurement, the FFR dispatch increases except during January.

With reserve sharing, the FFR dispatch increases during summer and autumn when the reservoir head is high and unit capacity is close to the nominal power and decreases in December and January.

FRR provided in the country (MW):

<table>
<tr><th rowspan="2">FRR provided in In Kyrgyz Rep. (MW)</th><th rowspan="2">Without Reg. Coop</th><th colspan="2">With Reg. Coop</th></tr>
<tr><th>cross-border procurement</th><th>reserve sharing</th></tr>
<tr><td>January</td><td rowspan="9">300</td><td>210</td><td>160</td></tr>
<tr><td>February</td><td>510</td><td>380</td></tr>
<tr><td>March</td><td>600</td><td>410</td></tr>
<tr><td>April</td><td>590</td><td>300</td></tr>
<tr><td>May</td><td>540</td><td>300</td></tr>
<tr><td>June</td><td>460</td><td>340</td></tr>
<tr><td>July</td><td>460</td><td>300</td></tr>
<tr><td>August</td><td>430</td><td>310</td></tr>
<tr><td>September</td><td>410</td><td>280</td></tr>
<tr><td>October</td><td rowspan="3">360 *</td><td>570</td><td>400</td></tr>
<tr><td>November</td><td>530</td><td>370</td></tr>
<tr><td>December</td><td>390</td><td>320</td></tr>
</table>

* the 1st refurbished unit of Toktogul is assumed to come to operation in October 2020

The Toktogul reservoir operates as annual storage. It was modelled as an ideal tetrahedron, to assess the head variation of the reservoir, and therefore the available output of its units during the year (from 280 MW in October to 225 MW in April for 300 MW units).

The summary of the annual generation of each power plant is presented in annex.

3.2.7.3. 2020 situation in Tajikistan

With regional cooperation, Tajikistan exports FRR. Compared to its own FRR requirement (375 MW), a regional cooperation requires Tajikistan to increase its annual FRR dispatch from 3.3 TWh to 9 TWh with cross-border procurement and to 4.8 TWh with reserve sharing. The corresponding additional cost reach US$ 1 million with cross-border procurement. With Reserve Sharing mechanism, the generation cost increases due to thermal generation increase (+370 GWh) and water spillage increase in Nurek. This water spillage increase is hard to understand, since a better solution should have been to use the same unit commitment as the cross-border procurement situation, solution which was not picked-up by the optimiser.

Tajikistan	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatched in the country	GWh	3,331	9,032	4,811
Export	GWh	1,323	1,580	1,503
Thermal Generation	GWh	2,380	2,455	2,770
Unserved Energy	GWh	524	507	441
Generation cost	M$	128	129	150
Savings	M$		-1	-22 (*)

(*) not significative (see footnote 9)

With FRR regional cooperation, the Tadjik FFR dispatch increases sharply. Tajikistan is providing 47 % of the FRR regional requirement with cross-border procurement, and 39% with reserve sharing.

FRR provided in the country per month (MW):

FRR provided in Tajikistan (MW)	Without Reg. Coop	With Reg. Coop.	
		Cross Border procurement	Reserve Sharing
January	375	1,100	600
February		920	440
March		850	470
April		930	630
May		920	630
June		1,110	610
July		1,110	600
August		1,210	640
September		1,130	570
October		1,060	540
November		950	410
December		1,060	410

The dispatch reductions in March and October correspond to the generation maintenance period. The maintenance period has been selected when the load is at the lowest. The peak load occurs in winter and off-peak load in summer. But with the export to Afghanistan (in summer), the off-peak period is shifted to March/April and October/November.

The water flow of the Vakhsh river fluctuates from about 200 m^3/s in winter to more than 2,000 m^3/s in summer.

Nurek reservoir was modelled as an ideal tetrahedron, to assess the head variation of the reservoir, and therefore the available output of its units during the year (from 335 MW in August to October to 255 MW in April for 335 MW units).

The 2 units of Rogun are rated 200 MW each. For the first phase of the project, the head of the dam is lower than its final design and will be increased in the following phases. In 2020, it is assumed to reach 160 m. The reservoir volume is therefore limited and cannot store as much water as in its final phase.

The summary of the annual generation of each power plant is presented in annex.

Network: interconnection lines

Tajikistan network will be reconnected to Uzbekistan on Syr Darya and Regar sides with 500 kV line Regar - Guzar remaining disconnected (not included in the reconnection plan)[10]. An important power flow loop (between 200 and 900 MW, average value of 500 MW) occurs from Uzbekistan to Tajikistan in the Northern area (from Syr Darya to Sugd) and from Tajikistan to Uzbekistan in the West (from Regar to Surkhan). This flow is in parallel with the flow Syr Darya → Sogdiana → Guzar → Surkhan inside the Uzbek system, to supply the load in Surkhan (500/220 kV SS) and to export to Afghanistan in wintertime.

The activation of the Tajikistan FRR increases the flow on Regar - Surkhan 500 kV line up to 300 MW (max flow increased from 610 to 880 MW), and on the 220 kV lines from Regar to Surkhan by an average 30 MW each (the flow from Guzar to Surkhan is reduced, decreasing the loading of the line). The flow from Uzbekistan to Tajikistan in the North is reduced by an average value of 120 MW.

A simulation has been carried out with exchanges between countries corresponding to the FRR dispatch release presented here-above (2,160 MW of FRR requirement). This situation does not correspond exactly to the situation presented previously, with the release of the 2,160 MW FRR following demand-supply unbalance. However, this gives good information on the evolution of the flows on interconnection lines. In addition, it is very unlikely that each country is activating / requesting the activation of the full FRR all at the same time.

Unavailability of 500 kV line Surkhan - Regar

This simulation has been performed considering the 500 kV line Surkhan – Regar in outage during all the yearlong and the 500 kV line Regar – Guzar disconnected. This simulation shows that remedial actions exist to overcome the consequences of the unavailability of 500 kV line Surkhan - Regar (generation re-dispatching or modifications in network topology). This conclusion ensures that the interconnection network is very robust to contingencies and does not need reinforcement because simulation has been performed in very severe conditions for two reasons:

[10] From information collected in May 2019, too late to be introduced in the network analysis, we understand that 500 kV Line Rugar-Guzar (L-507) is also planned to be reconnected (source: ADB project “Tajikistan Reconnection to Central Asian Power System Project” - Grant 0622-TAJ, Selection of Consulting Services for Project Implementation Consultant - May 2019).

- The Surkhan - Regar line is considered in outage all year long while unavailability rate (outage and maintenance) of overhead lines (OHL) is usually limited to 1 or 2 % per year.
- Reconnection of 500 kV line Regar - Guzar is now planned at the same time of commissioning the 220 kV lines Sugd - Syrdarya (see previous foot note), that means the simulation corresponds to N-2 situation.

Without FRR activation, flow on the 220 kV lines Regar - Gulcha & Ravshan - Denau reaches the maximum transfer capacity of the lines in winter period (when Tajikistan is not exporting to Afghanistan). To avoid overloading these lines, desoptimisation of the unit commitment needs to be performed, mainly in Uzbekistan (+ US$ 30 million over one year).

With the full FRR activation, the 220 kV line Gulcha - Regar reaches its limit all year long (and the line Ravshan - Denau is 95% loaded permanently). It is therefore necessary:

- either to reduce the FRR provided in Tajikistan in case of unavailability of the 500 kV line;
- or to modify the network topology to force the FRR release to flow through Sugh SS (by disconnecting the two 220 kV interconnection lines between Regar and Surkhan, the Tajikistan remaining interconnected with Uzbekistan by Sugd in 500 and 220 kV (6 interconnection lines).

3.2.7.4. 2020 situation in Uzbekistan

With regional cooperation, Uzbekistan imports FRR. Compared to its own FRR requirement (800 MW), a regional cooperation enables Uzbekistan to reduce its annual dispatch from 7 TWh to 2.2 TWh with cross-border procurement and to 1.8 TWh with reserve sharing. The corresponding savings reach US$ 88 million with cross-border procurement. This saving has to be increased by the sales price of the additional export to Afghanistan (resp. + 91/+97 GWh). Uzbekistan is the country which benefits the most from the regional cooperation, and most of the benefits are reached with Cross Border procurement.

Uzbekistan.	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatched in the country	GWh	7,027	2,198	1,802
Export	GWh	1,689	1,780	1,786
Generation cost	M$	3,627	3,539	3,540
Savings	M$		88	88

A limited number of HPP can provide FRR (Charvak, Chodjiket, Gasalkent: 949 MW), since most of the HPP are Run on River type or operated on irrigation mode (Andijan1&2, Tuyamuyum).

FRR provided in the country (MW):

FRR provided in Uzbekistan (MW)	Without Reg. Coop	With Reg. Coop	
		Cross Border procurement	Reserve Sharing
January	800	290	250
February		190	160
March		190	150
April		200	160
May		270	160
June		260	220
July		260	210
August		250	210
September		270	240
October		240	200
November		290	240
December		290	260

The summary of the annual generation of each power plant is presented in annex.

3.2.7.5. 2020 situation in Turkmenistan

Turkmenistan is not connected to the rest of the system, and therefore not impacted by the regional cooperation in 2020. The FRR dispatch amounts to 7.6 TWh, for a cost of US$ 387 million. The total generation cost amounts to US$ 2.2 billion.

3.2.7.6. 2020 situation in Afghanistan

Afghanistan cannot procure all the 75 MW of FRR required for its system. Given that Afghan TPPs are the most expensive in the region, the cost of building up the possible FRR reaches around US$ 80 million. Imports on the 220 kV double circuit lines from Uzbekistan and from Tajikistan have been limited to 350 MW to face the line N-1 situation, leaving some margin for importing FRR.

3.2.7.7. 2020 situation in Pakistan

In 2020, Pakistan is not connected to the rest of the system, and therefore not impacted by the regional cooperation.

3.3. Main results of the 2025 study on balancing capacity reserves

In 2025, we propose that regional cooperation be introduced to the 7 countries. This regional cooperation will enable each national system operator to acquire a part of the Frequency Restoration Reserve they need for operating their own system from abroad. Compared to the situation without regional cooperation, the regional amount of FRR (2,700 MW without Pakistan, 3,800 MW with Pakistan) remains unchanged, but the dispatch is optimised. A cooperation based on FRR cross-border procurement will enable to reduce the annual generation cost of US$ ~150 million.

As in 2020, a regional reserve sharing mechanism is also studied (limiting the overall FRR capacity at the regional level to 1,420 MW[11] corresponding to the two largest national FRR requirements). Compared to the cross-border procurement scenario, FRR Reserve Sharing does not enables additional cuts in the annual generation cost. Moreover, this solution implies a stronger regional integration based on the definition of rules to allocate the 1,420 MW of FRR between the countries. Due to the lack of economic benefits and to the complexity of implementing such rules, it is not recommended to adopt such a pooling strategy in 2025.

The 2025 network (existing and works currently planned by 2025) is enough to accommodate the planned RES for 2025 and is sufficient to allow FRR regional cooperation whatever the scenario (cross border procurement or reserve sharing).

3.3.1. Frequency Restoration Reserve requirement

Simulations based on 1,000 random drawings on the 8,760 hourly situations have been carried out for each country, considering RES generation prediction errors, load prediction errors and generation forced outages.

The criteria used for sizing the reserve is the estimation of the maximum value between:
- the size of the largest unit;
- the reserve requirement to face 99.9 % of the situations (= except 9 hours per year where deficit could occur). This requirement corresponds to a high-quality supply.

[11] without considering Pakistan

The FRR requirements are presented below:

Country	FRR requirement (MW) (1)	Largest Unit (MW)	
AFG	150	Ishpushta ST	150
KAZ	620	Ekibastuz ST	500
KYR	360	Toktogul HPP	360
PAK	1,100	KaNuPP	1,100
TAJ	375	Nurek HPP	375
UZB	800	Talimarjan ST	800
TKM	395	Mary CCGT (1/2)	395

(1) FRR is assumed to be symmetrical (down requirement is equal to up requirement)

3.3.2. Situation without regional cooperation

In this situation, each country provides its own FRR, as per the amount presented here above. The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter: FRR dispatch in the interconnected system:

	FRR dispatch	
	(GWh)	%
HPP	24,676	74%
TPP	8,608	26%

The FRR shortage is lower than 1 GWh (<0.01 %):

FRR dispatch by country:

Without Cooperation: FRR provided by each country					
Country	FRR provided by country		Hydro/ Thermal	FRR provided by type of plant	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	1,314	4%	H	1,207	92%
			T	107	8%
KAZ	5,431	16%	H	4,279	79%
			T	1,152	21%
KYR	3,153	9%	H	3,147	100%
			T	7	0%
PAK	9,639	29%	H	8,230	85%
			T	1,409	15%
TAJ	3,284	10%	H	3,284	100%
			T	0	0%
TKM	3,460	10%	H	0	0%
			T	3,460	100%
UZB	7,003	21%	H	4,530	65%
			T	2,474	35%

In Turkmenistan, TPP are providing the full FRR. In Uzbekistan, TPP are providing 2/3rd of the FRR. In Kazakhstan, TPP are providing almost 20% of the FRR. In Afghanistan, TPP are providing 10% of the FRR.

The countries' situation, presented hereafter, provides for 2025 the annual demand, generation, export or import, the unserved energy and the Generation Cost, that have been estimated by including Fuel cost, fixed and variable Operation and Maintenance.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	10,6	110,5	17.0	198.7	23.0	23.7	85.0
Generation	TWh	5.7	110.5	19.8	192.9	31.0	26.4	85.0
Net Interchange	TWh	-5.0 (1)	0	2.8	-5.9 (2)	8.0	2.6 (3)	0
Unserved Energy	GWh	1	0	0	0	0	0	0
Total Gen. Cost	M$	25.7	2,909	60.0	2,423	103	1,347	3,038

(1) Afghanistan is importing 5.0 TWh from Tajikistan and the Kyrgyz Republic, 2 GWh from Turkmenistan and 2 GWh from Uzbekistan
(2) Pakistan is importing 5.9 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation
(3) Turkmenistan is exporting 2,6 TWh to Iran and 2 GWh to Afghanistan

The regional generation cost amounts to US$ 9.90 billion. The software optimises the dispatch to minimize the overall regional generation cost.

3.3.3. Regional cooperation for FRR

For the overall region, enabling each country to procure the FRR in foreign countries increases the dispatch of reserve on HPP and therefore decreases the dispatch on TPP. The regional generation cost decreases significantly.

From a country point of view, the situations diverge:

- The reserve provided in countries with a generation fleet mainly based on thermal power plants (Uzbekistan, Turkmenistan, Kazakhstan), decreases: the generation cost decreases also significantly
- On the contrary, the reserve provided in countries with a generation fleet mainly based on HPP (Kyrgyz Republic, Tajikistan), increases, which slightly increases the generation cost.

As in 2020, it is assumed than financial arrangements will be concluded between the countries to fairly share the benefit of the cooperation. Price of FRR exchanged between countries should be established in a way that countries selling FRR cover at least the increase of their generation costs and that procurement costs for countries buying FRR are lower than the savings on their generation costs.

About Pakistan, 2 situations are studied, whether it takes part to the FRR cross-border cooperation or not (this assumption will be justified by the results with and without the Pakistanis participation presented hereafter).

3.3.4. With FRR cross-border procurement (2,700 MW) without Pakistan participation

In this situation, the 2,700 MW of FRR requirement has been dispatched between the countries (except Pakistan, which provides its own FCR and FRR (1,100 MW each)) with a technical-economic optimisation.
As presented in the approach description, the study has been carried out in 2 steps:

1. Full optimisation, with the inconvenience of significant hourly variations in the dispatch by country (free dispatch), which is too complex to implement in operation;
2. Simulation with a fixed monthly dispatch of the FRR per country.

The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter:

FRR dispatch on the interconnected system:

	FRR dispatch			
	Free dispatch		Monthly dispatch	
	(GWh)	%	(GWh)	%
HPP	31,305	94%	31,913	93%
TPP	1,871	6%	2,221	7%
Shortage	0	0	5	-

Country break down for regional FRR dispatch:

FRR dispatch with free procurement:

Country	FRR provided by country		Hydro / Thermal	FRR provided by type of plant	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	276	1%	H	274	100%
			T	1	0%
KAZ	2,489	8%	H	2,421	97%
			T	68	3%
KYR	4,833	15%	H	4,828	100%
			T	5	0%
PAK	9,612	29%	H	8,175	85%
			T	1,437	15%
TAJ	13,937	42%	H	13,936	100%
			T	1	0%
TKM	191	1%	H	0	0%
			T	191	100%
UZB	1,838	6%	H	1,670	91%
			T	168	9%

FRR dispatch with fixed monthly procurement:

Country	FRR provided by country		Hydro/ Thermal	FRR provided by type of plant	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	276	1%	H	258	94%
			T	18	6%
KAZ	2,492	8%	H	2,230	89%
			T	262	11%
KYR	4,799	14%	H	4,751	99%
			T	48	1%
PAK	9,612	29%	H	8,175	85%
			T	1,437	15%
TAJ	13,931	42%	H	13,898	100%
			T	33	0%
TKM	188	1%	H	0	0%
			T	188	100%
UZB	1,836	6%	H	1,601	87%
			T	235	13%

A fixed monthly cross-border procurement does not significantly deoptimize the dispatch of the reserve nor reduce the benefit of the regional cooperation.

FRR dispatch (MW) with fixed monthly cross-border procurement is presented below:

	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	70	380	410	1,100	1,450	60	330
February	50	380	440	1,100	1,530	30	270
March	30	320	650	1,100	1,450	20	230
April	20	240	780	1,100	1,490	10	160
May	0	320	520	1,100	1,620	30	210
June	0	250	430	1,100	1,770	30	220
July	0	190	450	1,100	1,840	20	200
August	60	220	570	1,100	1,640	20	190
September	60	280	550	1,100	1,540	10	260
October	30	260	830	1,100	1,430	10	140
November	30	280	620	1,100	1,610	10	150
December	30	310	340	1,100	1,810	30	180

The countries' situation for 2025 with fixed monthly cross border procurement is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	10.6	110.5	17.0	198.7	23.0	23.7	85.0
Generation	TWh	5.8	110.5	20.1	192.8	31.0	26.4	85.0
Net Interchange	TWh	-5.1 (1)	0	3.0	-5.9 (2)	8.0	2.6 (3)	0
Unserved Energy	GWh	2	0	0	0	0	0	0
Total Gen. Cost	M$	18.0	2,900	63.0	2,420	104.3	1,253	2,986

(1) Afghanistan is importing 5.1 TWh from Tajikistan and Kyrgyzstan.
(2) Pakistan is importing 5.9 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation
(3) Turkmenistan is exporting 2,6 TWh to Iran

In 2025, the regional generation cost amounts to US$ 9.90 billion without regional cooperation and decreases to US$ 9.75 billion with regional cooperation, enabling a US$~150 million saving.

The comparative table of generation costs with and without regional cooperation is presented below:

Gen. Cost (M$)	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB	Total
Without Regional Cooperation	25.7	2,909	60.0	2,423	103	1,347	3,038	9,904
With Cross Border procurement (without Pakistan)	18.0	2,901	63.0	2,420	104.3	1,253	2,986	9,748
Difference	(saving with regional cooperation)							157

In 2025, Tajikistan and Kyrgyz Republic can provide the other countries with FRR, with benefits for all the countries. This regional cooperation will enable each national system operator to acquire abroad (in Tajikistan and Kyrgyz Republic) a part of the Frequency Restoration Reserve they need for operating their own system.

A cooperation based on FRR cross-border procurement will enable to reduce the annual cost of procurement by US$~150 million.

3.3.5. With FRR cross-border procurement (3,800 MW) with Pakistan participation

In this situation, the 3,800 MW of FRR requirement have been dispatched between the countries with a technical-economic optimisation.
As presented in the approach description, the study has been carried out in 2 steps:

1. Explore the top of the potential benefits of a FRR regional cooperation with Pakistan, using free dispatch and considering unlimited capacity to exchange FRR with Pakistan

2. Estimate the plausible benefits with the recommended mechanism (fixed monthly dispatch of the FRR by country) considering capacity limitations for FRR exchanges on CASA-1000 system by giving priority to commercial exchanges.

Top of potential benefits

The result of the simulation of FRR free dispatch (MW) with unlimited capacity to exchange FRR is presented here-after (displayed on a monthly basis):

FRR dispatch (MW)	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	99	439	488	691	1,624	73	386
February	68	425	496	841	1,648	40	282
March	46	362	755	848	1,511	25	254
April	25	268	1,041	224	2,003	18	223
May	9	374	589	529	2,001	41	258
June	15	265	504	538	2,013	48	290
July	5	213	587	481	2,180	44	290
August	78	202	619	744	1,837	32	288
September	63	304	631	631	1,837	23	312
October	33	266	958	445	1,909	12	178
November	28	305	762	348	2,142	16	200
December	33	333	447	442	2,288	41	213

Considering unlimited capacity to import FRR on CASA-1000 system, Pakistan benefits from cheap FRR provided by Tajikistan and the Kyrgyz Republic. With FRR imported from abroad, FRR provided locally in Pakistan is reduced and fluctuates from 450 MW to 1050 for a requirement of 1100 MW. The regional generation cost amounts to US$ 9.72 billion with a limited additional benefit (US$ ~30 million) compared to the previous situation (US$ 9.75 billion Cross Border procurement without Pakistan)

Plausible benefits

With the recommended mechanism (fixed monthly dispatch of the FRR by country) considering capacity limitations for FRR exchanges on CASA-1000 system, Pakistan cannot benefit from FRR avaible in Tajikistan and the Kyrgyz Republic.

In 2025, the regional generation dispatch optimisation leads to saturate CASA-1000 during the daily peak almost every day and there is no possibility for Pakistan to import FRR on a fixed monthly base. Pakistan should therefore provide its own FRR requirement (1,100 MW) as in the previous situation (Cross Border procurement without Pakistan).

FRR dispatch (MW) with fixed monthly procurement (plausible benefits) is presented below:

	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	70	380	410	1,100	1,450	60	330
February	50	380	440	1,100	1,530	30	270
March	30	320	650	1,100	1,450	20	230
April	20	240	780	1,100	1,490	10	160
May	0	320	520	1,100	1,620	30	210
June	0	250	430	1,100	1,770	30	220
July	0	190	450	1,100	1,840	20	200
August	60	220	570	1,100	1,640	20	190
September	60	280	550	1,100	1,540	10	260
October	30	260	830	1,100	1,430	10	140
November	30	280	620	1,100	1,610	10	150
December	30	310	340	1,100	1,810	30	180

The countries' situation for 2025 with fixed monthly cross border procurement is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	10.6	110.5	17.0	198.7	23.0	23.7	85.0
Generation	TWh	5.8	110.5	20.1	192.8	31.0	26.4	85.0
Net Interchange	TWh	-5.1 (1)	0	3.0	-5.9 (2)	8.0	2.6 (3)	0
Unserved Energy	GWh	2	0	0	0	0	0	0
Total Gen. Cost	M$	18.0	2,900	63.0	2,420	104.3	1,253	2,986

(1) Afghanistan is importing 5.1 TWh from Tajikistan and Kyrgyzstan.
(2) Pakistan is importing 5.9 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation
(3) Turkmenistan is exporting 2,6 TWh to Iran

In 2025, the regional generation cost amounts to US$ 9.90 billion without regional cooperation and decreases to US$ 9.75 billion with regional cooperation, enabling a US$~150 million saving. The comparative table of generation costs with and without regional cooperation is presented below:

Gen. Cost (M$)	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB	Total
Without Regional Cooperation	25.7	2,909	60.0	2,423	103	1,347	3,038	9,904
With Cross Border procurement (with Pakistan and considering import limitation on CASA-1000)	18.0	2,901	63.0	2,420	104.3	1,253	2,986	9,748
Difference	(saving with regional cooperation)							157

In a situation without grid limitation, it would be profitable for Pakistan to acquire part of its FRR abroad (cheap available FRR in Tajikistan and the Kyrgyz Republic), but since it is more profitable for Pakistan to saturate CASA-1000 interconnection with import, Pakistan cannot benefit from FRR regional cooperation with the recommended procurement mechanism (fixed monthly cross-border procurement). It should be necessary to have much more flexible rules for FRR cross-border procurement to benefit from a part of the potential benefits of the regional cooperation (enabling Pakistan to buy FRR abroad only during off-peak hours).

3.3.6. Reserve sharing enables to decrease necessary FRR to 1,420 MW without Pakistan participation

The activation of the full FRR in each country does not occur at the same time. It is therefore possible to reduce the regional size of the FRR. The regional size has been reduced to the main two FRR requirements: 1,420 MW (Kazakhstan and Uzbekistan).
In this situation, the 1,420 MW of FRR has been dispatched between the countries with a technical-economic optimisation.
As presented in the approach description, the study has been carried out in 2 steps:

1. Full optimisation, with the inconvenience of significant hourly variations in the dispatch by country (free dispatch), which is too complex to implement in operation;
2. Simulation with a fixed monthly dispatch of the FRR per country.

The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter:

FFR dispatch on the interconnected system:

	FRR dispatch			
	Free dispatch		Fixed monthly dispatch	
	(GWh)	%	(GWh)	%
HPP	20,387	93%	20,536	93%
TPP	1,524	7%	1,605	7%
Shortage	0	-	0	-

Country break down for regional FRR dispatch:

Free FRR dispatch:

Country	FRR provided by country		Hydro/ Thermal	FRR provided by type of plant	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	168	1%	H	168	100%
			T	1	0%
KAZ	1,878	9%	H	1,873	100%
			T	5	0%
KYR	2,525	12%	H	2,523	100%
			T	1	0%
PAK	9,616	44%	H	8,190	85%
			T	1,426	15%
TAJ	6,737	31%	H	6,737	100%
			T	0	0%
TKM	38	0%	H	0	0%
			T	38	100%
UZB	950	4%	H	896	94%
			T	54	6%

FRR dispatch with fixed monthly cross-border procurement:

Country	FRR provided by country		Hydro/ Thermal	FRR provided by type of plant	
	(GWh)	(%)		(GWh)	(%)
AFG	333	2%	H	332	100%
			T	1	0%
KAZ	1,888	9%	H	1,759	93%
			T	129	7%
KYR	2,550	12%	H	2,546	100%
			T	4	0%
PAK	9,616	43%	H	8,190	85%
			T	1,426	15%
TAJ	6,787	31%	H	6,786	100%
			T	1	0%
TKM	7	0%	H	0	-
			T	7	-
UZB	960	4%	H	922	96%
			T	37	4%

The monthly requirement does not significantly deoptimize the dispatch of the reserve nor reduce the benefit of the regional cooperation.

The monthly FRR dispatch is presented hereafter (MW):

	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	20	250	220	1,100	760	10	160
February	20	300	230	1,100	740	0	130
March	30	240	340	1,100	720	0	90
April	20	200	370	1,100	730	0	100
May	0	230	320	1,100	780	0	90
June	0	190	240	1,100	870	0	120
July	0	150	200	1,100	970	0	100
August	30	160	340	1,100	780	0	110
September	40	200	320	1,100	710	0	150
October	30	220	430	1,100	640	0	100
November	20	230	290	1,100	790	0	90
December	20	240	210	1,100	860	0	90

The countries' situation is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	10.6	110.5	17.0	198.7	23.0	23.8	85.0
Generation	TWh	5.5	110.5	20.0	192.8	31.1	26.4	85.0
Net Interchange	TWh	-5.1 (1)	0	2.9	-5.9 (2)	8.1	2.6 (3)	0
Unserved Energy	GWh	2	0	0	0	0	0	0
Total Gen. Cost	M$	17.7	2,902	61.5	2,417	103	1,250	2,983

(1) Afghanistan is importing 5.1 TWh from Tajikistan and Kyrgyz Republic

(2) Pakistan is importing 5.9 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation

(3) Turkmenistan is exporting 2,6 TWh to Iran

Gen. Cost (M$)	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB	Total
With Cross Border procurement	18.0	2,901	63.0	2,420	104	1,253	2,986	9,748
With Reserve sharing	17.7	2,902	61.5	2,417	103	1,250	2,983	9,735

In 2025, the regional generation cost amounts to US$ 9.7 billion both with Cross Border Procurement (FRR requirement of 2,700 MW) and with Reserve Sharing (FRR requirement of 1,420 MW). Almost all the benefit has been captured by Cross Border procurement.

3.3.7. 2025 countries' situation

3.3.7.1. 2025 situation in Afghanistan

With regional cooperation, Afghanistan imports FRR. Compared to its own FRR requirement (150 MW), a regional cooperation enables Afghanistan to reduce its annual FRR dispatch from 1.3 TWh to 0.3 TWh both with Cross-Border procurement and with Reserve Sharing. The corresponding savings are limited, since most of the FRR is already provided by HPP (90% without Regional Cooperation).

Afghanistan.	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatch	GWh	1,314	276	333
Import	GWh	4,964	5,125	5,111
Generation cost	M$	25.7	18.0	17.7
Savings	M$		8	8

The commissioning of Kajaki 2 (100 MW) and Baghdara (240 MW) increases the hydro capacity to provide FRR to the Afghan system.

FRR provided in the country (MW):

FRR provided in Afghanistan (MW)	Without Reg. Coop	With Reg. Coop	
		Cross Border	Reserve Sharing
January	150	70	20
February		50	20
March		30	30
April		20	20
May		0	0
June		0	0
July		0	0
August		60	30
September		60	40
October		30	30
November		30	20
December		30	20

The summary of the annual generation of each power plant is presented in annex.

In 2025, a new 500 kV line between Kabul and Pul e Khomri is assumed in service, tapping in and out in the future Ishpushta Coal fired TPP. Turkmenistan and Uzbekistan are assumed synchronized, with Pul e Khomri 500 kV substation operated in a single node connecting the two new 500 kV lines coming one from Turkmenistan (Andkhoy) and the other from Uzbekistan (Surkhan).

3.3.7.2. 2025 situation in Kazakhstan

With regional cooperation, Kazakhstan imports FRR. Compared to its own FRR requirement (620 MW), a regional cooperation enables Kazakhstan to reduce its annual FRR dispatch from 5.4 TWh to 2.5 TWh (with cross-border procurement) and to 1.9 TWh (with reserve sharing). The corresponding savings reach $ 5 million with Cross-Border procurement and US$ 7 million with Reserve Sharing. Despite a high reduction of the FRR provided in the country when sharing the reserve, the saving is limited because it corresponds to reallocation of FRR from Kazakh HPP to Kyrgyz and Tajik HPP, with very limited impact on the generation cost.

Kazakhstan	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatch	GWh	5,431	2,492	1,888
Generation cost	M$	2,909	2,904	2,902
Savings	M$		5	7

With Cross-Border procurement, the FFR provided in the country increases during winter when Kyrgyz and Tajik HPP have reduced capacity to provide FRR (reduction of the maximum continuous active power which these HPP can produce, due to the reduction of the water level in the reservoir).

FRR provided in the country (MW):

FRR provided in Kazakhstan (MW)	Without Reg. Coop	With Reg. Coop	
		Cross Border	Reserve Sharing
January	620	380	250
February		380	300
March		320	240
April		240	200
May		320	230
June		250	190
July		190	150
August		220	160
September		280	200
October		260	220
November		280	230
December		310	240

The summary of the annual generation of each power plant is presented in annex.

3.3.7.3. 2025 situation in the Kyrgyz Republic

With regional cooperation, the Kyrgyz Republic exports FRR. Compared to its own FRR requirement (360 MW), a regional cooperation requires the Kyrgyz Republic to increase its annual FRR dispatch from 3.2 TWh to 4.8 TWh with Cross-Border procurement and to decrease it to 2.5 TWh with Reserve Sharing. The generation cost is not significantly affected (variation within the precision of the calculation and model).

Kyrgyz Rep.	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatch	GWh	3,153	4,799	2,550
Export	GWh	2,820	2,621	2,942
Generation cost	M$	60.0	63.0	61.5
Savings	M$		-3	-2

With cross-border procurement, the FFR dispatch increases and is more optimal: for instance, the FRR dispatch decreases in December during the peak load and low water inflows period (340 MW instead of 360 MW without regional cooperation).

With reserve sharing, the FFR dispatch decreases all year through.

FRR provided in the country (MW):

FRR provided in Kyrgyz Rep (MW)	Without Reg. Coop	With Reg. Coop	
		Cross Border	Reserve Sharing
January	360	410	220
February		440	230
March		650	340
April		780	370
May		520	320
June		430	240
July		450	200
August		570	340
September		550	320
October		830	430
November		620	290
December		340	210

The summary of the annual generation of each power plant is presented in annex.

3.3.7.4. 2025 situation in Pakistan

In 2025, Pakistan is connected to Tajikistan and the rest of the system through CASA 1000 HVDC interconnection line.

With a regional optimisation of the generation costs, Pakistan imports on CASA 1000 reach its full capacity (1300 MW) for every daily peak. The annual energy import reaches 5.9 TWh (load factor of 52 %). Therefore, Pakistan cannot benefit from FRR dispatch in Tajikistan and the Kyrgyz Republic with the recommended procurement mechanism (fixed monthly cross-border procurement).

In a situation without grid limitation, it would be profitable for Pakistan to acquire part of its FRR abroad (cheap available FRR in Tajikistan and the Kyrgyz Republic), It should be necessary to have much more flexible rules for FRR cross-border procurement to benefit from the regional cooperation (enabling Pakistan to buy FRR abroad only during off-peak hours) .

The summary of the annual generation of each power plant is presented in annex.

3.3.7.5. 2025 situation in Tajikistan

With regional cooperation, Tajikistan exports FRR. Compared to its own FRR requirement (375 MW), a regional cooperation requires Tajikistan to increase its annual FRR dispatch from 3.3 TWh to 14.0 TWh with Cross-Border procurement and to 6.8 TWh with Reserve Sharing. The generation cost is not significantly affected (variation within the precision of the calculation and model).

Tajikistan	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatch	GWh	3,460	13,931	6,787
Export	GWh	7,990	7,996	8,087
Unserved Energy	GWh	0	0	0
Generation cost	M$	103	104	103
Savings	M$		-1	-

With FRR regional cooperation, the Tajik FFR dispatch increases sharply. Tajikistan is providing 42 % of the regional FRR with cross-border procurement, and 31% with reserve sharing.

FRR provided in the country (MW):

FRR provided in Tajikistan (MW)	Without Reg. Coop	With Reg. Coop.	
		Cross Border	Reserve Sharing
January	375	1,450	760
February		1,530	740
March		1,450	720
April		1,490	730
May		1,620	780
June		1,770	870
July		1,840	970
August		1,640	780
September		1,540	710
October		1,430	640
November		1,610	790
December		1,810	860

The dispatch reductions in March/April and October/November correspond to the generation maintenance period. The maintenance period has been selected when the load is at the lowest. The peak load occurs in winter and off-peak load in summer.

The 5th and 6th units of Rogun are assumed to be commissioned in 2025. Rogun's units are rated 366 MW each between 2022 and 2027.

The summary of the annual generation of each power plant is presented in annex.

Network: interconnection lines

Tajikistan network is connected to Uzbekistan on Syr Darya and Regar sides. Contrary to 2020, there is no significant power flow loop between Uzbekistan and Tajikistan (between the interconnection lines in the North area (from Syr Darya to Sugd) and in the West (from Regar to Surkhan). This is due to the absence of export from Uzbekistan to Afghanistan and the increase of the generation in the south of Uzbekistan (3 CCGGs of 450 MW).The export to Pakistan through CASA-1000 (export from Kyrgyzstan) generates power flows on Syr Darya - Sugd and Uzbekistan - Sugd.

The activation of the FRR reserve for Uzbekistan increases the flow on Regar - Surkhan 500 kV line by an average of 230 MW (max flow increased from 950 to 1,180 MW), and on the 220 kV lines from Regar to Surkhan by an average 30 MW each (the flow from Guzar to Surkhan is reduced, decreasing the loading of the line). The flow from Uzbekistan to Tajikistan in the North is reduced by an average value of 200 MW.

Unavailability of 500 kV line Surkhan - Regar

This simulation has been initially performed considering the 500 kV line Surkhan – Regar in outage during all the yearlong and the 500 kV line Regar – Guzar disconnected. This simulation shows that remedial actions exist to overcome the consequences of the unavailability of 500 kV line Surkhan - Regar (generation re-dispatching or modifications in network topology). This conclusion ensures that the interconnection network is very robust to contingencies and does not need reinforcement because simulation has been performed in very severe conditions for two reasons:

- The Surkhan - Regar line is considered in outage all year long while unavailability rate (outage and maintenance) of overhead lines (OHL) is usually limited to 1 or 2 % per year.
- Reconnection of 500 kV line Regar - Guzar is now planned at the same time of commissioning the 220 kV lines Sugd - Syrdarya (see 2020 analysis), that means the simulation corresponds to N-2 situation.

Without FRR activation, the 220 kV lines Regar - Gulcha & Ravshan - Denau reaches the maximum transfer capacity of the lines in winter period (when Tajikistan is not exporting to Afghanistan). This limit is respected through desoptimisation of the unit commitment, mainly is Uzbekistan (+ US$~10 million over one year).

With the full FRR activation, the 220 kV line Gulcha - Regar reaches its limit all year long (and the line Ravshan-Denau is 95% loaded permanently). It is therefore necessary:

- either to reduce the FRR provided in Tajikistan in case of unavailability of the 500 kV line;
- or to modify the network topology to force the FRR release to flow through Sugh SS (by disconnecting the two 220 kV interconnection lines between Regar and Surkhan, the Tajikistan remaining interconnected with Uzbekistan by Sugd in 500 and 220 kV (6 interconnection lines.

A complementary simulation has been performed considering the 500 kV line Surkhan – Regar in outage during all yearlong and the reconstruction of the 500kV line Regar – Guzar,. In this case, loads on 220 KV are reduced below the capacity limits in summer time (even if full FRR is activated in Tajikistan), but the disconnection of the 220 kV lines between Regar and Surkhan remains necessary during the rest of the year. However, Tajikistan remains interconnected with Uzbekistan in the West part by this 500 kV line and in the North by 500 and 220 kV lines coming from Sugd.

3.3.7.6. 2025 situation in Turkmenistan

With regional cooperation, Turkmenistan imports FRR. Compared to its own FRR requirement (395 MW), a regional cooperation enables Turkmenistan to reduce its annual dispatch from 3.5 TWh to 0.2 TWh with Cross-Border procurement and to 0 TWh with Reserve Sharing. The corresponding savings reach US$~90 million with Cross-Border procurement and Reserve Sharing. Tajikistan alongside with Uzbekistan, are the countries which benefit the most from the regional cooperation, and almost all the benefits are reached with Cross Border procurement.

Turkmenistan.	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatch	GWh	3,460	188	7
Export	GWh	2,630	2,629	2,614
Generation cost	M$	1,347	1,253	1,250
Savings	M$		94	97

FRR provided in the country (MW):

FRR provided in Turkmenistan (MW)	Without Reg. Coop	With Reg. Coop	
		Cross Border	Reserve Sharing
January	395	60	10
February		30	0
March		20	0
April		10	0
May		30	0
June		30	0
July		20	0
August		20	0
September		10	0
October		10	0
November		10	0
December		30	0

The summary of the annual generation of each power plant is presented in annex.

3.3.7.7. 2025 situation in Uzbekistan

With regional cooperation, Uzbekistan imports FRR. Compared to its own FRR requirement (800 MW), a regional cooperation enables Uzbekistan to reduce its annual dispatch from 7 TWh to 1.8 TWh with cross-border procurement and to 1 TWh with reserve sharing. The corresponding savings reach US$~50 million with Cross-Border procurement and with Reserve Sharing. Uzbekistan alongside with Turkmenistan, are the countries which benefits the most from the regional cooperation, and almost all the benefits are reached with Cross Border procurement.

Uzbekistan.	Units	Without Reg. Coop.	Cross Border procurement	Reserve Sharing
FRR dispatch	GWh	7,003	1,836	960
Export	GWh	2	8	1
Generation cost	M$	3,038	2,986	2,983
Savings	M$		52	55

Following the commissioning of Pskem, Mullalak and Verkhnepskemsk HPP, the hydro capacity which can contribute to FRR has been increased from 945 MW (Charvak, Chodjiket, Gasalkent) to 1,790 MW, leading to a reduction of the saving with Region Cooperation (compared to 2020)

FRR provided in the country (MW):

FRR provided in Uzbekistan (MW)	Without Reg. Coop	With Reg. Coop	
		Cross Border	Reserve Sharing
January	800	330	160
February		270	130
March		230	90
April		160	100
May		210	90
June		220	120
July		200	100
August		190	110
September		260	150
October		140	100
November		150	90
December		180	90

The summary of the annual generation of each power plant is presented in annex.

3.4. Main results of the 2030 study on balancing capacity reserves

In 2030, we propose that regional cooperation be introduced to the 7 countries of the region. This regional cooperation will enable each national system operator to acquire a part of the Frequency Restoration Reserve he needs for operating its own system from abroad. Compared to the situation without cooperation, the regional amount of FRR (3,390 MW without Pakistan, 4,490 MW with Pakistan) remains unchanged, but the dispatch is optimised. A cooperation based on FRR cross-border procurement will enable to reduce the annual generation cost of US$ ~230 million.

As in 2020 and 2025, a regional reserve sharing mechanism is also possible, allowing for the pooling of reserves between countries and limiting the overall FRR capacity to the loss of the two largest FRR requirements at the regional level. With this pooling strategy, only 1,840 MW of reserves (without Pakistan) would be needed for the entire region. Compared to the cross-border procurement solution, there is no additional benefit brought by the reserve sharing. (all the benefit of the regional cooperation has been captured by cross border procurement). Moreover, this solution needs a stronger regional integration and more complex rules to allocate the reserve between countries, it is not recommended to adopt it in 2030.

There is no network development planned for the interconnection system between 2025 and 2030. The 2025 network is enough to accommodate the planned RES for 2030 and is enough to allow FRR regional cooperation whatever the scenario (cross border procurement or reserve sharing).

3.4.1. Frequency Restoration Reserve requirement

Simulations based on 1,000 random drawings on the 8,760 hourly situations have been carried out for each country, considering RES generation prediction errors, load prediction errors and generation forced outages.

The criteria used for sizing the reserve is the maximum value between:

- the size of the largest unit;
- the reserve requirement to face 99.9 % of the situations (= except 9 hours per year where deficit could occur). This requirement corresponds to a high-quality supply.

The FRR requirements are presented below:

Country	FRR requirement (MW) (1)	Largest Unit (MW)	
AFG	220	Sall HPP	200
KAZ	640	Ekibastuz ST	500
KYR	465	Kambarata-1 HPP	465
PAK	1,100	KaNuPP	1,100
TAJ	466	Rogun HPP	466
UZB	1,200	Awattak NPP	1,200
TKM	395	Mary CCGT (1/2)	395

(1) FRR is assumed to be symmetrical (down requirement is equal to up requirement)

3.4.2. Situation without regional cooperation

In this situation, each country provides its own FRR, as per the amount presented here above. The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter: FRR dispatch in the interconnected system:

	FRR dispatch	
	(GWh)	%
HPP	29,118	74%
TPP	10,196	26%

The FRR shortage is lower than 2 GWh (<0.01 %).

FRR country break down:

Without Cooperation: FRR provided by each country					
Country	FRR provided by country (GWh)	FRR provided by country (% of the total amount in the interconnected system)	Hydro/ Thermal	FRR provided by type of plant (GWh)	FRR provided by type of plant (% of the total amount in the country)
AFG	1,927	5%	H	1,925	100%
			T	2	0%
KAZ	5,606	14%	H	4,504	80%
			T	1,102	20%
KYR	4,073	10%	H	4,068	100%
			T	5	0%
PAK	9,657	25%	H	9,457	98%
			T	200	2%
TAJ	4,081	10%	H	4,081	100%
			T	0	0%
TKM	3,458	9%	H	0	0%
			T	3,458	100%
UZB	10,512	27%	H	5,083	48%
			T	5,429	52%

This breakdown is quite the same as in 2025. In Turkmenistan, TPP are providing the full FRR. In Uzbekistan, HPP are providing half of the FRR due to commissioning of new plants (instead of one-third in 2025) . In Kazakhstan, TPP are providing almost 20% of the FRR.

The countries' situation, presented hereafter, provides for 2030 the annual demand, generation, export or import, the unserved energy and the Generation Cost, that have been estimated by including Fuel cost, fixed and variable Operation and Maintenance.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	14.1	117.3	18.3	256.0	25.9	26.5	105.0
Generation	TWh	10.7	117.3	23.5	248.2	31.9	29.1	105.0
Net Interchange	TWh	-3.4 (1)	0	5.2	-7.8 (2)	6.0	2.6 (3)	0
Unserved Energy	GWh	1	0	0	0	0	0	0
Total Gen. Cost	M$	7.7	3,360	38.6	2,079	61.8	1,498	3,486

(1) Afghanistan is importing 3.4 TWh from Tajikistan and the Kyrgyz Republic and 17 GWh from Turkmenistan

(2) Pakistan is importing 7.8 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation
(3) Turkmenistan is exporting 2,6 TWh to Iran and 17 GWh to Afghanistan

The regional generation cost amounts to US$ 10.5 billion. The software optimises the dispatch to minimize the regional generation cost.

3.4.3. Regional cooperation for FRR

As for 2020 and 2025, enabling each country to procure the FRR in foreign countries increases the dispatch of reserve on HPP and therefore decreases the dispatch on TPP. The regional generation cost decreases significantly.

From a country point of view, the situations diverge:

- The reserve provided in countries with a generation fleet mainly based on thermal power plants (Uzbekistan, Turkmenistan, Kazakhstan), decreases: the generation cost decreases also significantly
- On the contrary, the reserve provided in countries with a generation fleet mainly based on HPP (Kyrgyz Republic, Tajikistan), increases, which slightly increases the generation cost.

It is assumed than financial arrangements will be concluded between the countries to fairly share the benefit of the cooperation. Price of FRR exchanged between countries should be established in a way that countries selling FRR cover at least the increase of their generation costs and that procurement costs for countries buying FRR are lower than the savings on their generation costs.

About Pakistan, 2 situations will be studied, whether it takes part to the FRR cross-border cooperation or not (regional cooperation does not bring Pakistan many benefits).

3.4.4. With FRR cross-border procurement (3,370 MW) without Pakistan participation

In this situation, the 3,370 MW of FRR has been dispatched between the countries (except Pakistan, which provides its own FCR and FRR (1,100 MW each) according to a technical-economic optimisation.
As presented in the approach description, the study has been carried out in 2 steps:

1. Full optimisation, with the inconvenience of significant hourly variations in the dispatch by country (free dispatch), which is too complex to implement in operation;
2. Simulation with a fixed monthly dispatch of the FRR per country.

The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter:

FRR dispatch in the interconnected system:

	FRR dispatch			
	Free dispatch		Monthly dispatch	
	(GWh)	%	(GWh)	%
HPP	38,966	99%	38,006	98%
TPP	414	1%	591	2%
Shortage	0	0	8	-

Free FRR dispatch - Country breakdown:

Country	FRR provided by country		Hydro / Thermal	FRR provided by type of plant	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	1,339	3%	H	1,337	100%
			T	3	0%
KAZ	2,092	5%	H	2,081	99%
			T	11	1%
KYR	6,409	16%	H	6,407	100%
			T	2	0%
PAK	9,690	25%	H	9,495	98%
			T	195	2%
TAJ	18,408	47%	H	18,408	100%
			T	0	0%
TKM	89	0%	H	0	0%
			T	89	100%
UZB	1,352	3%	H	1,238	92%
			T	114	8%

FRR dispatch with fixed monthly cross-border procurement:

Country	FRR provided by country		Hydro/ Thermal	FRR provided by type of plant	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	1,338	3%	H	1,336	100%
			T	2	0%
KAZ	2,083	5%	H	1,934	93%
			T	148	7%
KYR	6,420	17%	H	6,404	100%
			T	16	0%
PAK	9,690	25%	H	9,495	98%
			T	195	2%
TAJ	17,653	46%	H	17,614	100%
			T	40	0%
TKM	72	0%	H	0	0%
			T	72	100%
UZB	1,340	3%	H	1,222	90%
			T	118	10%

The fixed monthly cross-border procurement for FRR does not significantly deoptimize the FRR dispatch nor reduce the benefit of the regional cooperation.

The monthly FRR dispatch (MW) is presented below:

	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	100	240	520	1,100	2 340	20	170
February	110	310	570	1,100	2 180	20	200
March	120	330	930	1,100	1 800	10	200
April	180	240	1000	1,100	1 830	0	130
May	200	240	650	1,100	2 190	0	110
June	190	180	630	1,100	2 260	0	130
July	180	180	680	1,100	2 240	0	110
August	250	160	910	1,100	1 940	0	130
September	150	260	820	1,100	1 930	10	210
October	110	210	710	1,100	2 210	10	140
November	130	260	810	1,100	1 040	10	140
December	110	250	560	1,100	2 270	20	180

The countries' situation for 2030 with cross border procurement is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	14.1	117.3	18.3	260.0	25.9	26.5	105.0
Generation	TWh	11.1	117.3	23.5	244.8	31.5	29.1	105.0
Net Interchange	TWh	-3.0(1)	0	5.1	-7.8 (2)	5.6	2.6 (3)	0
Unserved Energy	GWh	3	0	0	0	0	0	0
Total Gen. Cost	M$	10.3	3,350	37.5	2,078	63.0	1,395	3,364

(1) Afghanistan is importing 3.0 TWh from Tajikistan and Kyrgyzstan.
(2) Pakistan is importing 7.8 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation
(3) Turkmenistan is exporting 2,6 TWh to Iran

In 2030, the regional generation cost amounts to US$ 10.5 billion without regional cooperation and decreases to US$ 10.3 billion with regional cooperation, enabling a US$~230 million saving.

The comparative table of generation costs with and without regional cooperation is presented below:

Gen. Cost (M$)	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB	Total
Without Regional Cooperation	7.7	3,360	38.6	2,079	61.8	1,498	3,486	10,530
With Cross Border procurement	10.3	3,350	37.5	2,078	63.0	1,395	3,364	10,297
Difference	(saving with regional cooperation)							233

In 2030, Tajikistan and Kyrgyz Republic can provide the other countries with FRR, with benefits for all the countries. This regional cooperation will enable each national system operator to acquire abroad (in Tajikistan and Kyrgyz Republic) a part of the Frequency Restoration Reserve they need for operating their own system.

A cooperation based on FRR cross-border procurement will enable to reduce the annual cost of procurement by US$~230 million.

3.4.5. With FRR cross-border procurement (4,490 MW) with Pakistan participation

In this situation, 4,490 MW of FRR has been dispatched between the countries with a technical-economic optimisation.

As for 2025, the study has been carried out in 2 steps:

1. Explore the top of the potential benefits of a FRR regional cooperation with Pakistan, using free dispatch and considering unlimited capacity to exchange FRR with Pakistan

2. Estimate the plausible benefits with the recommended mechanism (fixed monthly dispatch of the FRR by country) considering capacity limitations for FRR exchanges on CASA-1000 system by giving priority to commercial exchanges.

Top of potential benefits

The result of the simulation of FRR free dispatch (MW) with unlimited capacity to exchange FRR is presented here-after (displayed on a monthly basis):

	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	74	251	491	1,320	2,149	19	167
February	115	314	517	1,441	1,874	18	192
March	98	276	793	1,522	1,596	8	180
April	187	247	1,093	882	1,933	6	127
May	202	256	551	1,144	2,193	8	124
June	249	228	836	356	2,623	5	174
July	206	191	808	463	2,639	6	160
August	277	167	1,009	621	2,218	5	178
September	113	251	757	1,431	1,726	8	188
October	103	215	772	1,474	1,776	6	132
November	128	245	837	1,246	1,881	8	130
December	93	232	541	1,812	1,607	15	170

Considering unlimited capacity to import FRR on CASA-1000 system, it would be profitable for Pakistan to benefit from FRR dispatch in the Tajik and Kyrgyz systems during summertime.
Out of the peak period, it is profitable for the overall region to dispatch additional FRR in Pakistan (on top of its own needs: 1,100 MW) which could benefit Uzbekistan, Turkmenistan, Kazakhstan or Afghanistan.

Plausible benefits

With the recommended mechanism (fixed monthly dispatch of the FRR by country) and considering capacity limitations for FRR exchanges on CASA-1000 system, Pakistan cannot benefit from FRR available in Tajikistan and the Kyrgyz Republic.

In 2030, the regional generation dispatch optimisation leads to saturate CASA-1000 during the daily peak in summer period and there is no possibility for Pakistan to import FRR on a fixed monthly base. Pakistan should therefore provide its own FRR requirement (1,100 MW) in summertime.
Out of the peak period, it is profitable for the region to dispatch additional FRR in Pakistan (on top of its own needs: 1,100 MW) which could benefit Uzbekistan, Turkmenistan, Kazakhstan or Afghanistan. FRR up can be exported at any time to these countries, while FRR down can be exported only when CASA-1000 system is not fully loaded with commercial imports.

FRR dispatch (MW) with fixed monthly procurement (plausible benefits) is presented below:

	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	70	250	490	1,320	2,150	20	170
February	120	310	520	1,440	1,870	20	190
March	100	280	790	1,520	1,600	0	180
April	180	240	1,000	1,100	1,830	0	130
May	200	260	550	1,140	2,200	0	120
June	190	180	630	1,100	2,260	0	130
July	180	180	680	1,100	2,240	0	110
August	250	160	910	1,100	1,940	0	130
September	110	250	760	1,430	1,730	0	190
October	100	220	770	1,470	1,780	0	130
November	130	240	840	1,250	1,880	0	130
December	90	230	540	1,810	1,610	20	170

The countries' situation for 2030 with fixed monthly cross border procurement and Pakistan contribution is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	14.1	117.3	18.3	260.0	25.9	26.5	105.0
Generation	TWh	11.0	117.3	23.5	248.1	31.6	29.1	105.0
Net Interchange	TWh	-3.0 (1)	0	5.2	-7.9 (2)	5.7	2.6 (3)	0
Unserved Energy	GWh	2	0	0	0	0	0	0
Total Gen. Cost	M$	9.6	3,348	37.6	2,075	62.7	1,394	3,362

(1) Afghanistan is importing 3.0 TWh from Tajikistan and Kyrgyzstan.

(2) Pakistan is importing 7.9 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation

(3) Turkmenistan is exporting 2,6 TWh to Iran

With the contribution of Pakistan to the regional FRR (except in summertime), the regional generation cost amounts to US$ 10.3 billion. If Pakistan could acquire FRR abroad during summer time, the regional generation cost would decrease by US$~9 million.

The comparative table of generation costs with and without regional cooperation is presented below:

Gen. Cost (M$)	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB	Total
With CB procur. without PAK contrib..	10.3	3,350	37.6	2,078	63.0	1,395	3,364	10,297
With CB procur. with PAK contrib.	9.6	3,348	37.6	2,075	62.7	1,394	3,362	10,289
Difference	(saving with Pakistan's contribution to the regional cooperation)							9

This regional generation cost is very similar to the one without Pakistan contribution (US$9 million difference is within the calculation precision).

Pakistan can provide FRR up to the other countries of the region except in summertime (Pakistan annual peak period) even if CASA-1000 interconnection is fully loaded with imports. However, Pakistanis FRR replace low cost Tajik and Kyrgyz FRR provided by HPP and the economic benefit of integrating Pakistan to the regional cooperation is very low.

3.4.6. Reserve sharing enables to decrease necessary FRR to 1,840 MW without Pakistan participation

The activation of the full FRR in each country does not occur at the same time. It is therefore possible to reduce the regional size of the FRR. The regional size has been reduced to the main two FRR requirements: 1,840 MW (Kazakhstan and Uzbekistan).
In this situation, this FRR has been dispatched between the countries with a technical-economic optimisation.
As presented in the approach description, the study has been carried out in 2 steps:

1. Full optimisation, with the inconvenience of significant hourly variations in the dispatch by country (free dispatch), which is too complex to implement in operation;
2. Simulation with a fixed monthly dispatch of the FRR per country.

The dispatch on the FRR between Thermal (TPP) and Hydro (HPP) units is presented hereafter:

FFR dispatch in the interconnected system:

	FRR dispatch			
	Free dispatch		Fixed monthly dispatch	
	(GWh)	%	(GWh)	%
HPP	25,511	99%	26,461	99%
TPP	274	1%	301	1%
Shortage	0	-	0	-

Country breakdown for FRR required in the region:

Free FRR dispatch:

Country	FRR provided by country		Hydro/ Thermal	FRR provided by type of plant	
	(GWh)	(% of the total amount in the interconnected system)		(GWh)	(% of the total amount in the country)
AFG	988	4%	H	987	100%
			T	1	0%
KAZ	1,537	6%	H	1,534	100%
			T	3	0%
KYR	3,417	13%	H	3,416	100%
			T	1	0%
PAK	9,672	38%	H	9,477	98%
			T	195	2%
TAJ	9,390	36%	H	9,390	100%
			T	0	0%
TKM	31	0%	H	0	0%
			T	31	100%
UZB	750	3%	H	707	94%
			T	43	6%

FRR dispatch with fixed monthly cross-border procurement:

Country	FRR provided by country		Hydro/ Thermal	FRR provided by type of plant	
	(GWh)	(%)		(GWh)	(%)
AFG	988	4%	H	987	100%
			T	1	0%
KAZ	1,537	6%	H	1,534	100%
			T	3	0%
KYR	3,417	13%	H	3,416	100%
			T	1	0%
PAK	9,672	38%	H	9,477	98%
			T	195	2%
TAJ	9,390	36%	H	9,390	100%
			T	0	0%
TKM	31	0%	H	0	0%
			T	31	100%
UZB	750	3%	H	707	94%
			T	43	6%

A fixed monthly cross-border procurement does not significantly deoptimize the dispatch of the reserve nor reduce the benefit of the regional cooperation.

The monthly FRR dispatch is presented hereafter (MW):

	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
January	50	180	320	1,100	1,160	10	120
February	60	240	320	1,100	1,090	0	130
March	80	250	520	1,100	880	0	110
April	130	170	380	1,100	1,090	0	70
May	160	190	330	1,100	1,100	0	60
June	140	130	280	1,100	1,230	0	60
July	150	130	360	1,100	1,160	0	40
August	220	110	490	1,100	970	0	50
September	110	200	530	1,100	890	0	110
October	80	160	410	1,100	1,100	0	90
November	100	160	450	1,100	1,050	0	80
December	70	190	300	1,100	1,170	10	100

The countries' situation is presented hereafter. The Generation Cost includes Fuel cost, fixed and variable Operation and Maintenance cost.

Property	Units	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB
Load	TWh	14.1	117.3	18.3	260.0	25.9	26.5	105.0
Generation	TWh	10.6	117.3	23.7	248.3	31.8	29.1	105.0
Net Interchange	TWh	-3.5 (1)	0	5.4	-7.7 (2)	5.9	2.6 (3)	0
Unserved Energy	GWh	1	0	0	0	0	0	0
Total Gen. Cost	M$	7.7	3,348	37.3	2,080	61.3	1,394	3,362

(1) Afghanistan is importing 3.5 TWh from Tajikistan and Kyrgyz Republic

(2) Pakistan is importing 7.7 TWh from Tajikistan and the Kyrgyz Republic through CASA 1000 HVDC interconnection, based on economic optimisation

(3) Turkmenistan is exporting 2,6 TWh to Iran

Gen. Cost (M$)	AFG	KAZ	KYR	PAK	TAJ	TKM	UZB	Total
With Cross Border procurement	10.3	3,349	37.6	2,078	63.0	1,395	3,364	10,297
With Reserve sharing	7.7	3,348	37.3	2,080	61.3	1,394	3,362	10,290

In 2030, the regional generation cost amounts to US$ 10.3 billion both with Cross Border Procurement (FRR requirement of 3,370 MW) and with Reserve Sharing (FRR requirement of 1,420 MW). Almost all the benefit has been captured by Cross Border procurement.

3.4.7. 2030 countries' situation

3.4.7.1. 2030 situation in Afghanistan

With regional cooperation, Afghanistan is generally an importer except in August. The commissioning of Kajaki 2 (100 MW) and Baghdara (240 MW) HPP by 2025 and the commissioning of Qala-e-Mamaï (420 MW) and Sall (800 MW) HPP by 2030 increases the hydro capacity to provide the Afghan system with FRR.

Compared to its own FRR requirement (220 MW), a regional cooperation enables Afghanistan to reduce its annual dispatch from 1.9 TWh to 1.3 TWh with Cross-Border procurement (1.3 TWh with Pakistan contribution) and to 1.0 TWh with Reserve Sharing. There are no cuts on the generation cost both with cross-border procurement and with Reserve Sharing, since all the FRR is already provided by HPP without Regional Cooperation[12].

Afghanistan.	Units	Without Reg. Coop.	Cross Border procurement	Cross Border procurement with Pakistan	Reserve Sharing
FRR dispatch	GWh	1,927	1,338	1,253	988
Import	GWh	3,401	2,979	3,002	3.5
Generation cost	M$	7.7	10.3	9.6	7.7
Savings	M$		-3	-2	-

FRR provided in the country (MW):

FRR provided in Afghanistan (MW)	Without Reg. Coop	With Reg. Coop		
		Cross Border	Cross Border with Pakistan	Reserve Sharing
January	220	100	70	50
February		110	120	60
March		120	100	80
April		180	180	130
May		200	200	160
June		190	190	140
July		180	180	150
August		250	250	220
September		150	110	110
October		110	100	80
November		130	130	100
December		110	90	70

The summary of the annual generation of each power plant is presented in annex.

12 The slight increase in the Afghan generation cost with regional cooperation is not significant and certainly due to approximation in the optimisation process.

3.4.7.2. 2030 situation in Kazakhstan

With regional cooperation, Kazakhstan imports FRR. Compared to its own FRR requirement (640 MW), a regional cooperation enables Kazakhstan to reduce its annual FRR dispatch from 5.6 TWh to 2.0 TWh (with cross-border procurement) and to 1.5 TWh (with reserve sharing). The corresponding savings are limited. Despite a high reduction of the FRR provided in the country with Regional Cooperation, savings are limited because it corresponds to reallocation of FRR from Kazakh HPP to Kyrgyz and Tajik HPP, with very limited impact on the generation cost.

Kazakhstan	Units	Without Reg. Coop.	Cross Border procurement	Cross Border procurement with Pakistan	Reserve Sharing
FRR dispatch	GWh	5,606	2,083	2,033	1,537
Generation cost	M$	3,360	3,350	3,348	3,348
Savings	M$		10	12	12

With Cross-Border fixed monthly procurement, the FFR provided in the country are higher in winter than during the rest of the year to compensate for the reduction of HPP capacity to provide FRR in Kyrgyz Republic and Tajikistan (reduction of the maximum continuous active power which these HPP can produce, due to the reduction of the water level in the reservoir).

FRR provided in the country (MW):

FRR provided in Kazakhstan (MW)	Without Reg. Coop	With Reg. Coop		
		Cross Border	Cross Border with Pakistan	Reserve Sharing
January	640	240	250	180
February		310	310	240
March		330	280	250
April		240	240	170
May		240	260	190
June		180	180	130
July		180	180	130
August		160	160	110
September		260	250	200
October		210	220	160
November		260	240	160
December		250	230	190

The summary of the annual generation of each power plant is presented in annex.

3.4.7.3. 2030 situation in the Kyrgyz Republic

With regional cooperation, the Kyrgyz Republic exports FRR. Compared to its own FRR requirement (465 MW), a regional cooperation requires the Kyrgyz Republic to increase its annual FRR dispatch from 4.1 TWh to 6.4 TWh with Cross-Border procurement (6.2 TWh with

Pakistan contribution) and to decrease it to 3.4 TWh with Reserve Sharing. The generation cost is not significantly affected (variation within the precision of the calculation and model).

Kyrgyz Rep.	Units	Without Reg. Coop.	Cross Border procurement	Cross Border procurement with Pakistan	Reserve Sharing
FRR dispatch	GWh	4,073	6,420	6,174	3,427
Export	GWh	5,185	5,128	5,182	5,362
Generation cost	M$	38.6	37.5	37.6	37.3
savings	M$		-	-	-

Monthly FRR provided in the country (MW):

FRR provided in Kyrgyz Republic (MW)	Without Reg. Coop	With Reg. Coop		
		Cross Border	Cross Border with Pakistan	Reserve Sharing
January	465	520	490	320
February		570	520	320
March		930	790	520
April		1,000	1,000	380
May		650	550	330
June		630	630	280
July		680	680	360
August		910	910	490
September		820	760	530
October		710	770	410
November		810	840	450
December		560	540	300

The summary of the annual generation of each power plant is presented in annex.

3.4.7.4. 2030 situation in Pakistan

In 2030, Pakistan is connected to Tajikistan and the rest of the system through CASA 1000 HVDC interconnection line.

With regional cooperation, Pakistan exports FRR. Pakistan cannot import FRR from Tajikistan and the Kyrgyz Republic in summertime because CASA 1000 HVDC system is saturated with power import.

During winter period, Pakistan can provide other countries with FRR due to its huge hydro program, even when CASA-1000 is saturated with imports (FRR up).

Compared to its own FRR requirement (1,100 MW), a regional cooperation leads Pakistan to increase its annual FRR dispatch from 9.7 TWh to 10.0 TWh with Cross-Border procurement. The generation cost is not significantly affected (variation within the precision of the calculation and model).

Pakistan	Units	Without Reg. Coop.	Cross Border procurement
FRR dispatch	GWh	9,657	10,003
Import	GWh	7,784	7,870
Generation cost	M$	2,079	2,075
Savings	M$		4

Monthly FRR provided in the country (MW):

FRR provided in Pakistan (MW)	Without Reg. Coop	With Reg. Coop
		Cross Border
January	1,100	1,320
February		1,440
March		1,520
April		1,100
May		1,140
June		1,100
July		1,100
August		1,100
September		1,430
October		1,470
November		1,250
December		1,810

The summary of the annual generation of each power plant is presented in annex.

3.4.7.5. 2030 situation in Tajikistan

With regional cooperation, Tajikistan exports FRR. Compared to its own FRR requirement (466 MW), a regional cooperation requires Tajikistan to increase its annual FRR dispatch from 4.1 TWh to 17.6 TWh with Cross-Border procurement and to 9.4 TWh with Reserve Sharing. The generation cost is not significantly affected.

Tajikistan	Units	Without Reg. Coop.	Cross Border procurement	Cross Border procurement with Pakistan	Reserve Sharing
FRR dispatch	GWh	4,081	17,653	16,788	9,394
Export	GWh	5,983	5,645	5,692	5,897
Unserved Energy	GWh	0	0	0	0
Generation cost	M$	61.8	63.0	62.8	61.3
Savings	M$		- 1.2	- 1.0	+0.5

With FRR regional cooperation, the Tajik FFR dispatch increases sharply. Tajikistan is providing 46 % of the FRR regional requirement with cross-border procurement, and 35% with reserve sharing.

FRR provided in the country (MW):

FRR provided in Tajikistan (MW)	Without Reg. Coop	With Reg. Coop.		
		Cross Border	Cross Border with Pakistan	Reserve Sharing
January	466	2,340	2,150	1,160
February		2,180	1,870	1,090
March		1,800	1,600	880
April		1,830	1,830	1,090
May		2,190	2,200	1,100
June		2,260	2,260	1,230
July		2,240	2,240	1,160
August		1,940	1,940	970
September		1,930	1,730	890
October		2,210	1,780	1,100
November		1,040	1,880	1,050
December		2,270	1,610	1,170

The FRR dispatch reductions in March/April and October/November correspond to the generation maintenance period. The maintenance period has been selected when the load is at the lowest. The peak load occurs in winter and off-peak load in summer.

In 2030, the rehabilitation of Rogun HPP is assumed to be completed and Rogun’s units are rated 466 MW each.

The summary of the annual generation of each power plant is presented in annex.

Network: interconnection lines

The cross-border network is the same as in 2025. Tajikistan network is connected to Uzbekistan on Syr Darya and Regar sides. No significant power loop flows are occurring between Uzbekistan and Tajikistan (between the interconnection lines in the North area (from Syr Darya to Sugd) and in the West (from Regar to Surkhan)). This is due to the absence of export from Uzbekistan to Afghanistan and to the increase of the generation in the south of Uzbekistan (2 Nuclear Power Plants of 1,200 MW each). Power flows are observed from Syr Darya to Sugd and from Uzbekistan to Sugd driven by power export from Kyrgyz Rep. to Pakistan through CASA-1000.

The activation of the Tajikistan FRR increases the flow on Regar - Surkhan 500 kV line by ~350 MW (max flow increased from 800 to 1,200 MW), and on the 220 kV lines from Regar to Surkhan by an average 45 MW each (the flow from Guzar to Surkhan is reduced, decreasing the loading of the line). The flow from Uzbekistan to Tajikistan in the North is reduced by an average value of 360 MW.

Unavailability of 500 kV line Surkhan - Regar

This simulation has been performed considering the 500 kV line Surkhan - Regar in outage during all year long and the 500 kV line Regar - Guzar disconnected[13].

This simulation shows that remedial actions exist to overcome the consequences of the unavailability of 500 kV line Surkhan - Regar (generation re-dispatching or modifications in network topology). This conclusion ensures that the interconnection network is very robust to contingencies and does not need reinforcement because simulation has been performed in very severe conditions for two reasons:

- The Surkhan - Regar line is considered in outage all year long while unavailability rate (outage and maintenance) of overhead lines (OHL) is usually limited to 1 or 2 % per year.
- Reconnection of 500 kV line Regar - Guzar is now planned at the same time of commissioning the 220 kV lines Sugd - Syr Darya (see previous foot note), that means the simulation corresponds to N-2 situation.

Without FRR activation, flow on the 220 kV lines Regar - Gulcha & Ravshan - Denau reaches the maximum transfer capacity of the lines in winter period. To avoid overloading these lines, deoptimisation of the unit commitment needs to be performed, mainly in Uzbekistan (+ US$ ~10 million over one year).

With the full FRR activation, the 220 kV line Gulcha - Regar reaches its limit all year long (and the line Ravshan - Denau is 95% loaded permanently). It is therefore necessary:

- either to reduce the FRR provided in Tajikistan in case of unavailability of the 500 kV line;
- or to modify the network topology to force the FRR release to flow through Sugd SS (by disconnecting the two 220 kV interconnection lines between Regar and Surkhan, the Tajikistan remaining interconnected with Uzbekistan by Sugd in 500 and 220 kV (6 interconnection lines).

The disconnection all year long of the 220 kV lines between Regar and Surkhan remains necessary to transmit FRR activation in Tajikistan even if the 500 kV line Regar – Guzar is reconstructed. However, in that case, Tajikistan remains interconnected with Uzbekistan in the West by this 500 kV line and in the North by 500 and 220 kV lines coming from Sugd.

3.4.7.6. 2030 situation in Turkmenistan

With regional cooperation, Turkmenistan imports FRR. Compared to its own FRR requirement (395 MW), a regional cooperation enables Turkmenistan to reduce its annual dispatch from 3.5 TWh to 0.1 TWh with Cross-Border procurement and to 0 TWh with Reserve Sharing. The corresponding savings reach US$~100 million with Cross-Border procurement and Reserve Sharing. Tajikistan alongside with Uzbekistan, are the countries which benefit the most from the regional cooperation, and almost all the benefits are reached with Cross Border procurement.

Uzbekistan.	Units	Without Reg. Coop.	Cross Border procurement	Cross Border procurement with Pakistan	Reserve Sharing
FRR dispatch	GWh	3,458	72	42	14
Export	GWh	2,645	2,627	2,620	2,627
Generation cost	M$	1,498	1,395	1,395	1,394
Savings	M$		103	103	104

13 As previously explained, the Consultant became aware of the decision of the 500 kV line Regar - Guzar reconnection after having carried out the network analysis.

FRR provided in the country (MW):

FRR provided in Turkmenistan (MW)	Without Reg. Coop	With Reg. Coop		
		Cross Border	Cross Border with Pakistan	Reserve Sharing
January	395	20	20	10
February		20	10	0
March		10	10	0
April		0	0	0
May		0	0	0
June		0	0	0
July		0	0	0
August		0	0	0
September		10	0	0
October		10	0	0
November		10	0	0
December		30	20	10

The summary of the annual generation of each power plant is presented in annex.

3.4.7.7. 2030 situation in Uzbekistan

With regional cooperation, Uzbekistan imports FRR. Compared to its own FRR requirement (1,200 MW), a regional cooperation enables Uzbekistan to reduce its annual dispatch from 10.5 TWh to 1.3 TWh with cross-border procurement (with or without Pakistan contribution) and to 0.7 TWh with reserve sharing. The corresponding savings reach US$~120 million with Cross-Border procurement and with Reserve Sharing. Uzbekistan alongside with Turkmenistan, are the countries which benefit the most from the regional cooperation, and most of the benefits are reached with Cross Border procurement.

Uzbekistan.	Units	Without Reg. Coop.	Cross Border procurement	Cross Border procurement with Pakistan contribution	Reserve Sharing
FRR dispatch	GWh	10,512	1,340 (1)	1,294	740
Export	GWh	0	0	0	0
Generation cost	M$	3,486	3,364	3,362	3,362
Savings	M$		122	124	124

(1) In the situation with CB procurement, HPPs provide 90% of the FRR

Following the commissioning of Pskem, Mullalak and Verkhnepskemsk HPP by 2025 and Nijnechatkalskaya HPP by 2030, the hydro capacity which can contribute to FRR has been increased from 945 MW (Charvak, Chodjiket, Gasalkent) to 1,890 MW. This capacity increase for providing cheap FRR is not enough to meet the increase of the FRR requirement (+50%, from 800 MW to 1200 MW due to the commissioning of the nuclear power plant) and Uzbekistan benefits more from the regional cooperation in 2030 (around US$ 120 million) than in 2020 (around US$ 90 million) and in 2025 (around US$ 50 million)

FRR provided in the country (MW):

FRR provided in Uzbekistan (MW)	Without Reg. Coop	With Reg. Coop		
		Cross Border	Cross Border with Pakistan	Reserve Sharing
January	1,200	170	170	120
February		200	190	130
March		200	180	110
April		130	130	70
May		110	120	60
June		130	130	60
July		110	110	40
August		130	130	50
September		210	190	110
October		140	130	90
November		140	130	80
December		180	170	100

The summary of the annual generation of each power plant is presented in annex.

4. Task 1/a Roadmap

The Consultant has identified 19 actions which are recommended to be achieved for enabling countries of the region to accommodate large scale intermittent renewable energy in the grid and for implementing a regional cooperation. These 19 actions are described in detail in the appendix “Roadmap – Annex 2 to Report for Output 1 – task 1/a”. They are grouped in five domains:

- Necessary investments for a regional cooperation;
- Operation tools necessary investment;
- Operation improvement: target conditions for exchanging FRR;
- National regulation improvement;
- Regional cooperation framework.

This roadmap for implementing this regional cooperation has been established building on the findings of:

- the study of necessary regulation reserve and the benefit of a regional cooperation in 2020, 2025 and 2030 presented in this report;
- Output 2: “regional cooperation framework to share balancing capacity reserve”;
- Output 3: “dispatch operation support tool and approach analysis”;
- the NDLC Tour (see “Dispatching Operation practice assessment - Annex 3 to Report for Output 1 – task 1/b;
- the Policy review (see “Policy review - Annex 4 to Report for Output 1 – task 1/c”).

Critical prerequisites for the implementation phase of this roadmap have been identified by the Consultant:

1) Some countries are already engaged in international agreements. In particular, Tajikistan, Turkmenistan, Kazakhstan, Uzbekistan and Kyrgyz Republic have signed several international agreements within the framework of CIS. It may be necessary to update some of these existing agreements to be in line with the regional cooperation proposed to be introduced;
2) for implementing a regional cooperation in a secure way, a multilateral agreement needs to be signed between countries joining this initiative. This agreement will ensure that all the countries apply the same common rules.

5. Task 1/b Dispatching operation practice assessment

In this task, the Consultant assesses the dispatching operation practices in Central Asia countries and provides recommendations. This analysis is detailed in Annex 3 to Report for Output 1 – task 1/b: Dispatching operation practice assessment.

6. Task 1/c Policy Review

In this task, the Consultant analyses the existing situation in each of the 7 countries and makes recommendations in order to create the best regulatory conditions for the growth of renewable energies (Annex 4 to Report for Output 1 – task 1/c": Policy Review)

7. Task 1/d Capacity building

Capacity building has been provided to working committee's members during the workshops:

- Kick-off meeting, Astana (KAZ), January 2018
- Workshop n.2, Tashkent (UZB), April 2018
- Workshop n.3, Bishkek (KYG), July 2018
- Workshop n.4, Dushanbe (TAJ), November 2018
- Workshop n.5 and 6, Almaty (KAZ), May 2019

Presentations on the international best practices were provided on the following fields:

Presentations per output - v23052019

WS1		WS2		WS3		WS4		WS5 and 6			
Astana - jan 18	**Output**	**Tashkent - april 18**	**Output**	**Bishkek - july 18**	**Output**	**Dushambe - nov 18**	**Output**	**Almaty - May 2019**	**Output**	**Almaty - May 2019**	**Output**
2 TA_RE-integration_0127_lis ENG.pdf	NC	2 RTE I CAREC meeting final ENG.pdf	1 and 2	2 RTEi - Bichkek - reserves and procurement ENG.pdf	2	2 2020 Balancing capacity reserve assessment ENG.pdf	1	1405 PM 2020 results FRR regional cooperation.pdf	1	1705 grid code review WC Almaty May 2019 Rus.pdf	1
3 Kick-off meeting vdef ENG.pdf	1, 2 and 3	3 UZB Balancing capacity reserve assessment Tashkent ENG.pdf	1	3 RTE I WC Bishkek DSR TSO perspective ENG.pdf	2	3.1 2020_KYR Balancing capacity reserve assessment ENG.pdf	1	1505 AM - STAN - output 1 roadmap v6.pptx	1	1705 Policy Review vdef.pdf	1
4 Kick-off meeting Balancing ENG.pdf	1 and 2	4 RTE I WC Tashkent storage ENG.pdf	1	4 RTE I WC Bishkek hydro flexibility ENG.pdf	1	3.2 2020_KAZ Balancing capacity reserve assessment ENG.pdf	1	2030-Extension_AFG ENG.pdf	1	1705 Proposed Target Objectives for CDC Missions - V1.2.pdf	2
5 Kick off meeting RE Integration Coreso ENG.pdf	2	5 CORESO Presentation Tashkent ENG.pdf	2	5 European Connection Codes WC Bishkek July 2018 ENG.pdf	1	3.3 2020_TAJ Balancing capacity reserve assessment ENG.pdf	1	2030-Extension_KAZ ENG.pdf	1	1705 STAN - Output2 - Multilateral Agreement V1.pdf	2
		6 Dispatching Operation Practice ENG.pdf	1	6 RTE I WC Bichkek Renewable enregy forecast ENG.pdf	3	3.4 2020_TKM Balancing capacity reserve assessment ENG.pdf	1	2030-Extension_KYR ENG.pdf	1	2005 STAN - European practices for reserves	2
		7 Management of the Reserve ENG.pdf	1	7 RTE I WC Road map ENG.pdf	1 and 2	3.5 2020_UZB Balancing capacity reserve assessment ENG.pdf	1	2030-Extension_PAK ENG.pdf	1	2005 STAN - Rules proposal for Operation Handbook	2
		8 RTE I WC Tashkent Renewable energy ENG.pdf	3	8 Policy Review ENG.pptx	1	3.6 2020_AFG Balancing capacity reserve assessment ENG.pdf	1	2030-Extension_TAJ ENG.pdf	1	2105 STAN - IGCC and PICASSO	2
				9 KYR restoration reserve availability and cost ENG.pdf	1	4 Improvement of Dispatching Operation ENG.pdf	1 and 2	2030-Extension_TKM ENG.pdf	1		2
						5 RTE I Renewable forecast 11 2018 ENG.pdf	3	2030-Extension_UZB ENG.pdf	1		
						6 RTE I Regional cooperation Framework ENG.pdf	2	1605 2025 outlook scenario.pdf	1		
						7 RTE I Policy review ENG.pptx	1	1605 2030 results FRR regional cooperation.pdf	1		
						8 RTE I WC Road map 2020 ENG.pptx	1 and 2	1605 PM - STAN - Renewable forecast V1.1.pdf	3		

8. Annexes

8.1. Annex output 1 a/– balancing capacity reserve

Tashkent Workshop Presentation -April 2018 “3 UZB Balancing capacity reserve assessment”

Dushanbe Workshop Presentation –November 2018 - Presentations per country

Report “Study hypothesis per country –annex to Report for Output1 – task 1/a” – 2018”

Report “Generation break down per power plant –annex to Report for Output1 – task 1/a” – January 2019

8.2. Annex output 1 b/– dispatching assessment

Tashkent Workshop Presentation - April 2018 “6 Dispatching Operation Practice Assessment”-

Dushanbe Workshop Presentation - November 2018 “4 Improvement of Dispatching Operation”

Report “Dispatching Operation Practice Assessment –Annex to report for output 1 – task1/b“ - October 2018

8.3. Annex output 1 c/– policy review

Bishkek Workshop Presentation - July 2018 “8 Policy Review”

Bishkek Workshop Presentation - July 2018 “5 European Connection Codes WC Bishkek July 2018”

Dushanbe Workshop Presentation November 2018 “7 Policy Review”

Report “Policy and sector Review – Draft version –annex to report for output 1 – task 1/c” - October 2018

8.4. Capacity building

Astana Workshop Presentation -January 2018 “4 Kick-off meeting Balancing”

Astana Workshop Presentation -January 2018 “5 Kick off meeting RE Integration Coreso”

Tashkent Workshop Presentation -April 2018 “4 RTE I WC Tashkent storage”

Bishkek Workshop Presentation -July 2018 “4 RTE I WC Bishkek hydro flexibility”

8.5. Annex – contact list and Working Committee Members

Country	WC Member?	Name	Designation	Organization
AFG	X	Mr. Rohullah Arya	Engineer	DABS
AFG		Mr. Noori Mohibullah	Engineer	Ministry of Energy and Water
AFG	X	Mr Sharafmal Faridullah	Director of Renewable Energy Directorate	Ministry of Energy and Water
KAZ		Mrs. Baramysova Saule	Manager	National Power Grid (NPG) Development Department
KAZ	X	Mr. Alpysbaev Niyaz	Leading Engineer of dispatching service	KEGOC
KAZ		Mr. Kuanyshbayev	Managing Director	
KAZ		Mr. Zhandos Nurmaganbetov	General Director - Financial Settlement Center of Renewable Energy	KEGOC
KAZ		Mrs. Aizhan Kassymbekova	Chief Specialist	KEGOC
KAZ	X	Mr. Muslim DZHILKAIDAROV	National Power Grid (NPG) Development Department	KEGOC
KGZ	X	Mr. Emil MUSURKULOV	Deputy Chief of CDS	OAO “National Electric Grid of Kyrgyzstan” (NEGK)
KGZ		Mr. Abduvaliev Ermek Yusupzhanovich	Head of the Department for the Development of Renewable Energy Sources and Energy Saving	State Committee of Industry, Energy and Subsoil Use of the Kyrgyz Republic
KGZ	X	Mr Beknur MARATBEKOV	Chief specialist	Kyrgyz State Committee for industry, energy and subsoil use
PAK		Dr. Rana Abdul Jabbar Khan	GM Tech NTDC	NTDC
PAK		Mr. Syed Muhammad Azam Jaffri	Additional Manager, Planning (transmission)	NTDC
PAK	X	Mr Syed Mazhar Hussain shah		NTDC
PAK	X	Mr. Mubashar Hussain		NTDC
TJK	X	Parviz Yakyayev	Chief Specialist, Department for Development and Planning of Investment Projects	Ministry of Energy and Water Resources
TJK	X	Behruz Hasanov	Chief Specialist, Electroenergy Department	Ministry of Energy and Water Resources
TKM	X	Mr. Dadebai Gochakov	Head of Central Dispatch Administration	State Electro Energy Corporation “Turkmenenergo”

TKM	X	Mr. Erkin Gurbanov	Chief dispatcher of Central Dispatch Administration	State Electro Energy Corporation “Turkmenenergo”
UZB		Mr. Eso Sadullaev	Head of Strategic Development Department	Uzbekenergo
UZB	X	Mr. Muzaffar BOBOEV	Deputy Head of National Dispatch Center	Uzbekenergo
UZB	X	Mr Akmal ABBASSOV		Uzbekenergo
UZB		Mr Bakhtiyor SHAMSIEV	Deputy Head of Power Systems' Regims Dept, CDC Energy	CDC