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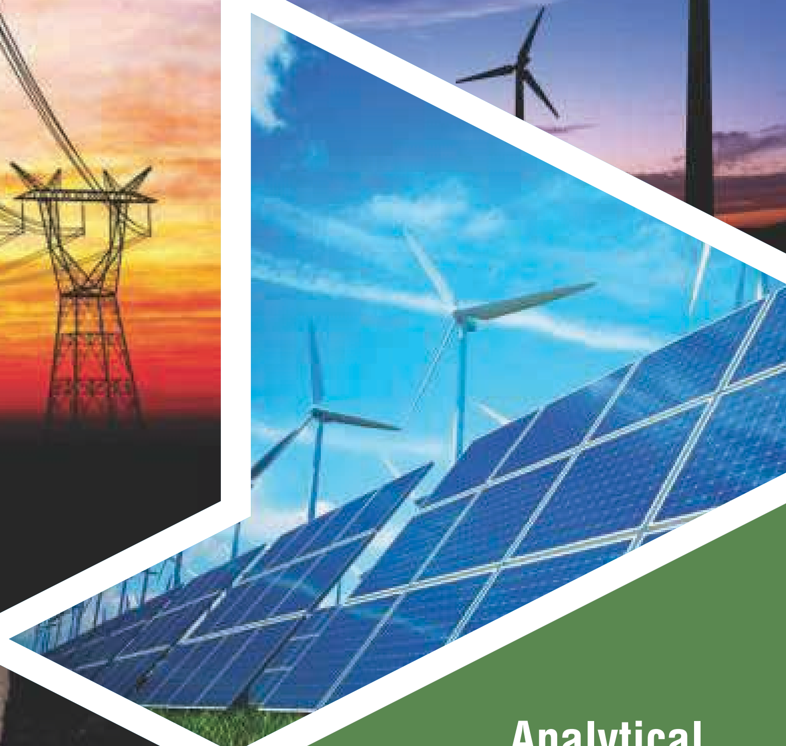
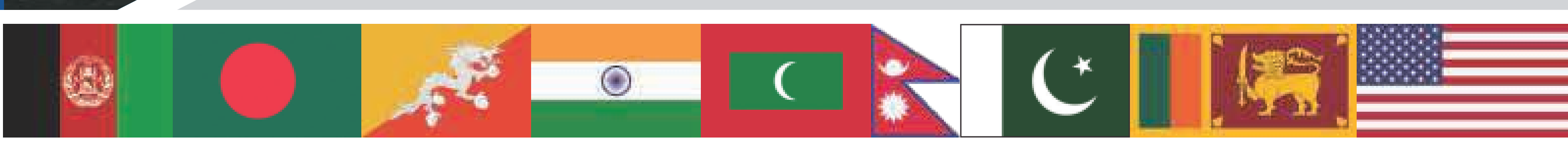
IRADe Integrated Research and Action for Development

SOUTH ASIA REGIONAL INITIATIVE FOR ENERGY INTEGRATION (SARI/EI)

Economic Benefits from Nepal-India Electricity Trade



Analytical Study



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SOUTH ASIA REGIONAL INITIATIVE FOR ENERGY INTEGRATION (SARI/EI)

Economic Benefits from Nepal-India Electricity Trade

Analytical Study

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Acknowledgements

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On the Nepal side, we thank our partners IIDS, Nepal, and Dr. Bishnu Dev Pant, Executive Director IIDS and Mr. Pramod Rijal, Economist, IIDS, in particular for the administrative and logistical support in organising the two stakeholder Workshops. IIDS's efforts to bring together various stakeholders, greatly improved the study's ability to address various issues and concerns related to power trade between Nepal and India. We thank Mr. Sher Singh Bhat, Deputy Managing Director, Nepal Electricity Authority (NEA) and Mr. Surendra Rajbhandari, Deputy Managing Director, NEA for their support in assessing the study results and validating assumptions of model parameters for appropriately reflecting the features of Nepal's power system through the technological model developed in the study. We also thank Mr. Sanjay Sharma, Former Secretary, Government of Nepal and Prof. Dr. Govind Nepal, ex-Chief Economic Advisor, Ministry of Finance, Government of Nepal, for their support, feedback and appreciation of the study.

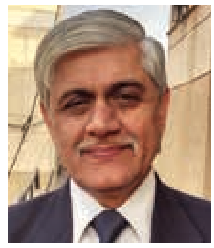
On the Indian side, we thank Mr. S.D. Dubey, Ex-Chairperson CEA, Mr. Pankaj Batra, Member (Planning), CEA and Mr. Pardeep Jindal, Chief Engineer, CEA for their efforts and support to organise the Focussed Group Discussion that brought together various stakeholders in the power sector in India and greatly helped to build the technological model, reflecting the behavioural features of India's power system.

We are grateful to the project team of SARI-EI and the Project Director Mr. V.K. Kharbanda for their inputs and valuable suggestions on the model results that greatly helped refine and present the results. Additionally, we thank Dr. Pradeep Dadhich who in his initial capacity as Senior Project Consultant, played a very important role in getting stakeholder interest and further discussions for the initial model building activities. We also thank Dr. Manoj Kumar Singh, Mr. Bhaskar Karmakar and Ms. Swati Khurana for their efforts, in the initial stages of the project.

Finally, we thank the IRADe administration, for their unflinching efforts in organising meetings in India related to the project and their support during travel to Nepal for meetings and Workshops.

Last, but not the least, we sincerely thank the USAID, Mr. Colin Dreizin, Former Director, Clean Energy and Environment Office, Mr. Michael Satin, Director, Clean Energy and Environment Office, Mr. Padu S. Padmanabhan, Strategic Energy, Water & Environment Expert and the Programme Officer of the SARI/EI project, Ms. Monali Zeya Hazra and Mr. Shankar Khagi from USAID, Nepal, for supporting this research study.

Foreword



South Asia is expected to remain the fastest growing region in the world and has been resilient to global turbulence in 2016. As South Asia remains one of the least integrated regions in the world, therefore it has a huge scope to enhance energy security by engaging in significant levels of power trading of themselves. The region is growing rapidly (per capita GDP growth rate of more than 6%) which can be sustained only with increased and improved access to energy.

The recent developments in South Asia such as (i) SAARC framework agreement on Energy Cooperation signed by member countries, (ii) signing of power trade agreement between Nepal-India and (iii) the agreement between India and Bangladesh to enhance transmission link from 500 MW to 1000 MW are strong signals that the region is moving towards enhanced energy security through promotion of Cross-Border Electricity Trade. USAID's SARI/EI program has also been working to promote cooperation among the South Asian Countries in this field through promoting CBET in the region.

I am glad to state that the SARI/EI IRADe has completed the study on "Macro-Economic Benefits of Cross-Border Electricity Trade between Nepal and India" which gives a broad perspective on the technical and macro-economic benefits of electricity trade both for Nepal and India as it utilises the two powerful optimisation modelling tools i.e. Social Accounting Matrix (SAM) for capturing macroeconomic aspects and TIMES (The Integrated MARKAL-EFOM System model) software for capturing the technical aspects. The report is an outcome of the consultation process with various stakeholders both in Nepal and India. The range of benefits to Nepal includes import of firm thermal power from India in the immediate future, resulting in improved power supply to its citizens and to its industry and commercial establishments, export of peaking power to India in the long run, thereby resulting in increase in export revenues, higher utilisation of hydropotential, increase in GDP, higher consumption gain, etc. The benefits for India include import of peaking power and balancing power for its huge renewable generation capacity program, a market for its thermal power generation, resulting in improved export revenues, higher utilisation of its thermal power generating capacity, etc. Both nations gain from reduced reserves of power generating capacity.

I would like to congratulate the work done by IRADe Team at SARI/EI/IRADe Project. I hope the findings of this report will be actively considered by Energy Utilities/Electricity Regulatory Institutions of South Asian Countries, for promotion of electricity trading to optimally utilise the available natural resources in the region and give a thrust to their economies.

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FOREWORD

Cross Border Electricity Trade (CBET) in South Asia is gaining momentum with more and more number of projects and interconnections being planned and proposed. Particularly in context with Nepal and India, promotion of CBET can help both the countries. Nepal has a huge hydro potential which is yet to be harnessed on a large scale and with CBET, Nepal can get access to South Asian power market. Electricity exports by Nepal can significantly contribute in economic development not only of an importing country but also of the whole region. Similarly for India, the hydro power based imports adds flexibility into the grid to adjust intermittent renewable generation sources.

With this background, I am happy to note that Integrated Research and Action for Development (IRADe), New Delhi, under its South Asian Regional Initiative for Energy Integration (SARI/EI) sponsored by USAID is working on macroeconomic and technical assessment of electricity trade between South Asian countries. IRADe has come out with its first report of Analytical studies that focus on Nepal and India ***"Economic benefits from Nepal- India electricity trade"***.

The report gives a broad perspective on the technical and macro-economic benefits of electricity trade both for Nepal and India as it utilizes the two powerful optimization modelling tools for capturing the technical and macroeconomic aspects. The report is a outcome of the consultation process with various stakeholders both in Nepal and India. The range of benefits to Nepal includes increase in electricity export quantum, increase in export revenues, higher utilization of hydro potential, increase in GDP, higher consumption gain, etc.

The study provides an evidence to the fact that the acceptance of CBET is beneficial both for Nepal and India. Further, one of the delayed scenario of the report highlights the impacts of delaying the CBET process both for Nepal and India.

I believe that the study of this kind will help enhancing the CEBT process that, when executed in full shape, will contribute in balancing the supply demand mis-match thus ensuring ultimately the energy security of the participating countries. I very much appreciate the effort made by IRADe in this regard and wish for its continuing success towards the upcoming regional endeavours.

Thank you!

16.01.2017

(Dinesh Kumar Ghimire)
(Joint Secretary)

FOREWORD

The USAID/India "South Asia Regional Initiative for Energy Integration" (SARI/EI) program, implemented by "Integrated Research & Action for Development" (IRADe), promotes regional energy integration including through Cross-Border Electricity Trade (CBET). The program focuses on three key outcomes including: i) harmonization of policy, regulatory and legal frameworks; ii) advancement of transmission systems interconnections; and iii) establishment of a South Asia Regional Electricity Market.

Three inter-governmental Task Forces have been constituted under the program with representations from each of the South Asian governments. The primary mandate of each of the Task Forces is to prepare the roadmap for promoting cross-border electricity trade in the region. The Task Forces are supported by the SARI/EI Secretariat through timely analysis to inform recommendations and generate consensus around power trade.

One of a critical requirement for promoting power trade in South Asia is political and public consensus. To help create this consensus, SARI/EI initiated a modeling study to assess the economic and environmental benefits of power trade between India and Nepal. This report *"Macro-economic Benefits of Nepal-India Electricity Trade"* has been developed using a detailed process with two models (power system and macro-economic models with iterative linkage between them) and extensive consultations with key stakeholders in both the countries.

The study demonstrates that there are huge benefits to accelerate Nepal-India power trade, as it is a win-win situation for both the countries. Nepal gains by developing its hydropower potential as its market and export earnings increase which, boost its economy and human well-being. The study estimates that Nepal's gross domestic product (GDP) could reach Nepali Rupees (NPR) 131,00 billion in 2045, which is 39 percent more than with existing trading mechanisms. The trade will also fuel Nepal's per capita electricity demand, which jumps from 139 kWh/year in 2012 to 1500 kWh/year by 2045 in the accelerated trade scenario. Per capita electricity demand reflects strongly on the Human Development Index of the country as increased access to electricity is directly linked to better quality of life. India on the other hand can promote renewable like solar and wind power whose intermittency can be balanced by import from Nepal's flexible hydropower. India also stands to gains from lower GHG emissions and deferred investments.

This evidence-based study seeks to inform civil society and political decision makers on the gains from power trade. I hope this report will be useful for building larger consensus towards accelerating power trade between India-Nepal and in the region. I would like to take this opportunity to commend IRADe for this excellent report. I hope the report is useful and is actively used to inform policy decisions by the South Asian Country Governments.

Thank you,

Michael S Satin

Michael Satin
Regional Energy Director
Clean Energy & Environment Office,
USAID/India

Preface

We are happy to present the "Economic Benefits from Nepal-India Electricity Trade" report with long-term perspectives, carried out under the South Asian Regional Initiative for Energy Integration (SARI/EI) project of USAID. It was felt that macroeconomic benefits of the power trade can help to bring wider consensus among power sector experts, economists, financers and policy makers. We had many stakeholders' discussions and focused group discussions with electricity planners. It was a painstaking and novel exercise where the power system models of two countries were linked during seasons and peak and off-peak hours on one day of every month to capture the compatibility for trade. It assesses the scope for trade and gain to both the countries. This gave us very different insights than doing it once based on annual overall demand and supply. We also linked this to the macro models of each country to capture macroeconomic benefits, especially to Nepal. Our aim was to see if Nepal could transform its economy as Bhutan did and reach another level altogether in less than two decades.

Before the modelling work, the expectations were that India could always accommodate Nepal's exports from hydropower. However, now it seems that Nepal will go through a long phase of importing from India during the construction stage of hydropower plants, before exporting.

We are now encouraged to also look at Bangladesh and India. We intend to complete the Bangladesh–India exercise and link it to the Nepal–India exercise. This may transform the economies of the two countries and make a case for regional integration among BBIN (Bangladesh, Bhutan, India and Nepal). The link can be extended to the Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) involving countries along the Bay of Bengal.

We are grateful to the USAID for supporting this fascinating modelling exercise. I am grateful to our Nepalese, Indian and USAID colleagues who assisted our work. I thank the IRADe team that worked diligently, enthusiastically and relentlessly for many months.

Professor Jyoti Parikh, PhD
Executive Director, IRADe

The Process

The study has been undertaken through a consultative process wherein stakeholders in Nepal and India were consulted through stakeholder consultations and Workshops. The various stakeholder consultations undertaken for this study follow:

Study Tours for Stakeholders Interest and Buy-in, Kathmandu, Nepal

31st August–3rd September, 2015

Meeting with representatives of government ministries and channelisation of contacts for data gathering for macro model and technology model of Nepal and seeking local partner in Nepal. On October 2015, formal contract with IIDS, Nepal for local partnership.

SARI/EI Annual Project Steering Committee Meeting, Mumbai, India

9th December, 2015

Presentation of initial Nepal technology model results to the PSC members including senior officials from the respective South Asian country governments.

Second Stakeholder Meeting, Kathmandu, Nepal

18th–19th January, 2016

Initial results of Nepal technology model and its economic impact on Nepal's power system to important stakeholders in Nepal presented; validation of parameters and results by the stakeholders in Nepal and their suggestions to improve on the model results assesed.

Workshop on Regional Power Trade, Kathmandu, Nepal

28th April, 2016

Presentations on results of India–Nepal hourly Electricity Trade Model after integration with the India Technology Model, and results of Nepal macro model showing the economic impact of electricity trade on Nepal's economy.

Focussed Group Discussion on India Technology Model, CEA, New Delhi, India

1st July, 2016

Key assumptions and outputs of India technology model were shared with the CEA representatives and suggestion from CEA for improving it were taken.

National Conference on Post Paris Climate Action on India Technology Model, New Delhi, India

12th July, 2016

Key results from India technology model were presented to more stakeholders and the model was further updated.

Abbreviations

ADB	Asian Development Bank
AEEI	Autonomous Energy Efficiency Improvement
APT	Accelerated Power Trade
BCM	Billion Cubic Metres
BkWh	Billion Kilowatt Hour
BT	Billion Ton
CAGR	Compound Annual Growth Rate
CBET	Cross-Border Electricity Trade
CC	Combine Cycle
CEA	Central Electricity Authority
DCA	Delayed Capacity Addition
EFOM	Energy Flow Optimisation Model
ExOP	Export Oriented Plants
FDI	Foreign Direct Investment
GAIL	Gas Authority of India Limited
GDCF	Gross Domestic Capital Formation
GDP	Gross Domestic Product
GDS	Gross Domestic Savings
GMS	Greater Mekong Sub-region
GOI	Government of India
GW	Gigawatt
GWh	Gigawatt Hour
HDI	Human Development Index
IESS	India Energy Security Scenarios 2047
IGCC	Integrated Gasification Combined Cycle
IIMac	IRADe India Macro
IITec	IRADe India Technology
INDC	Intended Nationally Determined Contributions
INHET	India-Nepal Hourly Electricity Trade Model
INMac	IRADe Nepal Macro
INR	Indian Rupee
INTec	IRADe Nepal Technology
IODD	Intermediate Consumption Demand
IPP’s	Independent Power Producers
IRADe	Integrated Research for Action and Development
kWh	Kilowatt Hour

LPG	Liquefied Petroleum Gas
LWR	Light Water Reactor
MARKAL	MARKet ALlocation
MkWh	Million Kilowatt Hour
MMBTU	Million British Thermal Units
MOC	Ministry of Coal
MT	Million Tons
NEA	Nepal Electricity Authority
NIETTP	Nepal-India Electricity Transmission and Trade Project
NPR	Nepalese Rupee
NREL	National Renewable Energy Laboratory
O&M	Operating and Maintenance
OC	Open Cycle
PFCE	Private Final Consumption Expenditure
PHWR	Pressurised Heavy-Water Reactor
PLF	Plant Load Factor
PROR	Pondage Run of River
PSA	Power Sale Agreement
PTC	Power Trading Corporation of India
PV	Photovoltaic
PV-STG	Photovoltaic with Storage
RBI	Reserve Bank of India
ROR	Run of River
SAM	Social Accounting Matrix
SARI/EI	South Asia Regional Initiative for Energy Integration
SE4All	Sustainable Energy Access for All
SUBC	Sub-Critical
SUPC	Super-Critical
T&D	Transmission and Distribution
TFPG	Total Factor Productivity Growth
TH	Thermal
TH-STG	Thermal Storage
TIMES	The Integrated MARKAL-EFOM System
TWh	Terrawatt Hour
USAID	United States Agency for International Development
USD	United States Dollar
USPC	Ultra-Supercritical
WB	World Bank

Introduction

Background

Countries in the South Asia are some of the poorest ones, which aspire for higher economic growth to improve quality of life in the coming years. However, availability of reliable and adequate electricity has been one of the main bottlenecks to achieve their economic potential. Per capita electricity consumption is very low in the region. Nepal faces load shedding of up to 16 hours a day during the dry season when available capacity of Nepal's hydropower decreases to one-third of the installed capacity (WB, 2015). In Pakistan, load shedding can stretch up to 8–10 hours a day. In India, 300 million people live without access to electricity. The potential electricity-demand growth rate is as high as 8–10% per annum across the region and is expected to continue at the same rate for many years to come. This implies a need for a rapid expansion of electricity supply systems in the region, as well as optimum utilization of power resource in the region, to both mitigate current shortages and meet future demands (WB, 2015).

Distribution of energy resources is not uniform across the countries. Nepal and Bhutan have massive hydropower potential which is barely exploited at present. Economic deployment of these hydro resources requires access to larger regional markets for the electricity generated. India's increasing overdependence on coal is a key concern as it damages local and global environment. Electricity trade across the countries could exploit the complementarity among these resources, provide electricity at lower cost to all, improve energy security and promote environment friendly socioeconomic development of the region by sharing energy resources, energy infrastructure and capacity reserves.

Electricity trading can be motivated by the following factors: (i) differences in energy resource endowments relative to demand; (ii) differences in the timing of peak loads and holidays; (iii) locational factors that favour cross-border connectivity; (iv) economies of scale from building large power plants or other facilities and linking electric power grids; (v) improved energy security and reliability via diversification of supply; and (vi) reduced environmental damage through increased access to clean sources such as hydropower and more efficient power generation and utilisation (ADBI, 2015). These factors should lead to lower energy cost and more reliable energy supply benefitting the economy and society in terms of higher growth and productivity, and better access to energy (energy security) for all the countries in the region. Also, income disparities across economies can be reduced and poorer economies can catch up with economic development of richer countries through investment and knowledge transfer in an integrated market (Sheng and Shi, 2011). Additionally, as India and most of the countries in the region plan for a higher share of variable sources of energy, like wind and solar, being part of a larger system would help tackle intermittency issues, as it provides access to capacity reserve of each other's systems, as has been proved in the case of Europe.

Electricity trade between Nepal and India can benefit both the countries. Nepal can gain by developing its major resource, hydropower potential, for which it will have a market and export earnings can boost its economy and human well-being. India, on the other hand, can promote renewable sources like solar and wind power whose intermittency can be balanced by import from Nepal's flexible hydropower.

Benefits of an inter-connected regional grid have been harnessed in many parts of the world. The savings resulting from expanding the interconnection of Greater Mekong Sub-region (GMS)[1] power systems alone are estimated at $14.3 billion, mainly from the substitution of fossil fuel generation with hydropower (ADB, 2012).[2]

1.1 Past Studies

Recognising that the South Asia region lags behind many regions in the world in intra-regional electricity cooperation and trading, despite the huge anticipated benefits, recently both the Asian Development Bank (ADB) and the World Bank (WB) have conducted studies separately.

An ADB working paper quantified the economic and reliability benefits of electricity trading among the countries in South Asia.[3] The benefits in terms of CO_2 reduction have also been quantified. The study undertook modelling based on optimal load-flow analysis, transmission-constrained investment and dispatch optimisation with Monte Carlo simulation to incorporate uncertainties. However, the analysis was limited the costs and benefits of six ongoing or planned cross-border electricity transmission interconnections at the time. Another major limitation was that the quantification of the benefits was restricted to a single year (2016–17). The benefits of each of these interconnections were estimated to range from $105 million to $1,840 million under different scenarios.

The WB study[4] used an electricity planning model that produces optimal expansion of electricity generation capacities and transmission interconnections in the long term to quantify the benefits of unrestricted Cross-Border Electricity Trade (CBET) in the South Asia during 2015–40. The study found that the unrestricted electricity trade provision would save USD 226 billion (USD 9 billion per year) of electricity supply costs over the period.

However, benefits quantified by the WB study are direct ones, limited to sharing power infrastructure (reduction in power sector investment, operating costs, fuel consumption, CO_2 emissions). It overlooks the economy-wide costs, and benefits along with multiplier effects arising due to investments and export earnings from the power sector. For example, additional investment on hydro projects contributing to export and earnings from export increases economic activities and the additional income in the host country causes further increase in electricity demand, in turn reducing export potential. However, the methodology used in WB study ignoring this feedback loop effect, may overestimate export potential. The socioeconomic and macroeconomic effects in terms of income growth and life quality improvement (with higher access to energy, health, education, etc.) would be of interest to a much larger group of stakeholders expected to be involved in promoting CBET (Cross-Border Electricity Trade), as that would affect the complex and sensitive sociopolitical dialogues involved in domestic resource utilisation policies. In addition, investment and trade in electricity sector as estimated by the stand-alone electricity model may not be consistent with the sustainability of the overall economy of the country. For example, the physical potential of electricity import estimated by the power system model may

1 Cambodia, Yunnan Province and Guangxi Zhuang Autonomous Region of the People's Republic of China, the Lao People's Democratic Republic, Myanmar, Thailand, and Viet Nam.

2 Asian Development Bank (ADB). 2012. Greater Mekong Sub region Power Trade and Interconnection: 2 Decades of Cooperation. Manila: ADB.

3 ADB, 2015, Cross-border power trading in South Asia: A techno-economic rationale, ADB South Asia Working Paper Series, No. 38, August, 2015

4 WB, 2015, How much could South Asia benefit from regional electricity cooperation and trade, Policy Research working paper 7341, World Bank Group, Development Research Group, Environment and Energy team, June 2015.

weaken the balance of payment (BoP) of the country. Therefore, one needs to come up with a feasible quantity of import consistent with the macroeconomic framework of the country. Similarly, unconstrained investment in the power sector, as estimated by electricity planning model, may deprive investment in other sectors causing economy-wide impacts, including on electricity demand.

1.2. Current Study

With this background, IRADe with the sponsorship from USAID under the SARI/EI project has undertaken this study to fulfil the gaps mentioned above. The study attempts to assess the potential for time-dependent power trade and the price of tradable electricity, acceptable to both the parties and consistent with complete macroeconomic sustainability. In addition, it quantifies and analyses the socioeconomic benefits of CBET between India and Nepal, taking into account its macroeconomic response. Once the study develops what we consider a robust methodology to quantify the macroeconomic feedback and socioeconomic benefits to India and Nepal, it could also be extended to other countries of the South Asian Region to understand the benefits in the larger Region.

1.2.1. Objectives

The primary objective of the study is to improve energy cooperation between the two countries by strengthening policy and decision makers and other stakeholders with necessary information on the scope and benefits of CBET to strategise its promotion and implementation. The study attempts to produce evidence for the policy and decision makers to build consensus between countries and within countries through informed dialogues and negotiations to support creation and implementation of the CBET.

1.2.2. Key Questions to be Answered

Some of the key information policy and decision makers/investors/regulators/planners need and other stakeholders may want to include physical quantity of electricity trade, electricity price, savings in new capacity addition due to trading, investment potential, export earnings and macroeconomic benefits from export earnings and investment. Therefore, the study is designed to answer the following key questions:

- How much electricity can be traded, at what price agreeable to both buyer and seller and during what period of the year?
- What would be the impact on per capita consumption levels?
- How would per capita electricity use change?
- What would be the impact on generation capacity creation and investment potential?
- What are the macroeconomic benefits to Nepal and India in terms of growth in Gross Domestic Product (GDP), investment (in rest of the economy) fuelled by impact from electricity trade such as export earnings and investment in the sector?
- What are the consequential environmental benefits?

1.2.3. Scope

To our knowledge, this is the first study that attempts to assess the economy-wide impact of electricity trade. The period of the analysis is 2012–2050. Scope of the study is as follows:

- Analytical work to assess
    - Electricity trade potential and technoeconomic feasibility of the trade between two countries
    - Impact of CBET on two countries on their power system development and economies

1.3. Report Structure

The report is structured in the following manner:

- Chapter 1 provides the background and rationale for the study, followed by the objectives, key questions to be addressed and their scope.
- Chapter 2 gives a short description of the economy and electricity sector of both countries.
- Chapter 3 presents approach and methodology.
- Chapter 4 presents the model structure and assumptions for the models and by countries.
- Chapter 5 presents the results and analyses.
- Chapter 6 covers conclusions and directions for future work.

Country Overview

This chapter presents an overview of the economy and electricity sector for Nepal and India.

2.1. Nepal

2.1.1. Economy

Unless stated otherwise, all economic indicators are at 2000–01 prices. Figure 2.1 presents the growth in GDP and per capita income. GDP (at factor cost) stood at 671 billion NPR (Nepalese Rupees) in 2011–12, registering a Compound Annual Growth Rate (CAGR) of 4.74% over the period 2001–12. The economy of Nepal has expanded 1.51 times in the past 11 years. The per capita income has grown from NPR 18,675 in 2001–02 to NPR 24,981 in 2011–12.

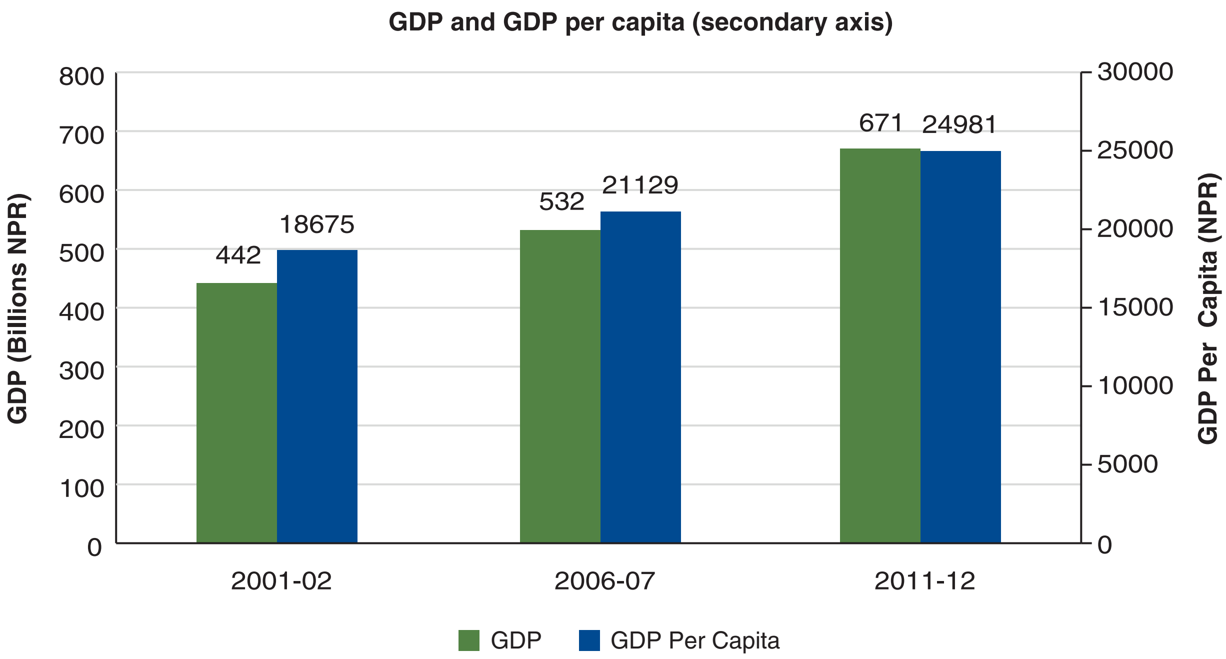


Figure 2.1: GDP and GDP Per Capita

Source: National Accounts Statistics (Nepal)

The Private Final Consumption Expenditure (PFCE) has increased 1.5 times in the last 11 years, from NPR 378 billion in 2001–02 to NPR 549 billion in 2011–12 (Figure 2.2). Per capita consumption as of 2011-12 stood at NPR 20,437. About 25% of Nepal's population lies below the national poverty line (Asian Development Bank - Basic Statistics 2016).

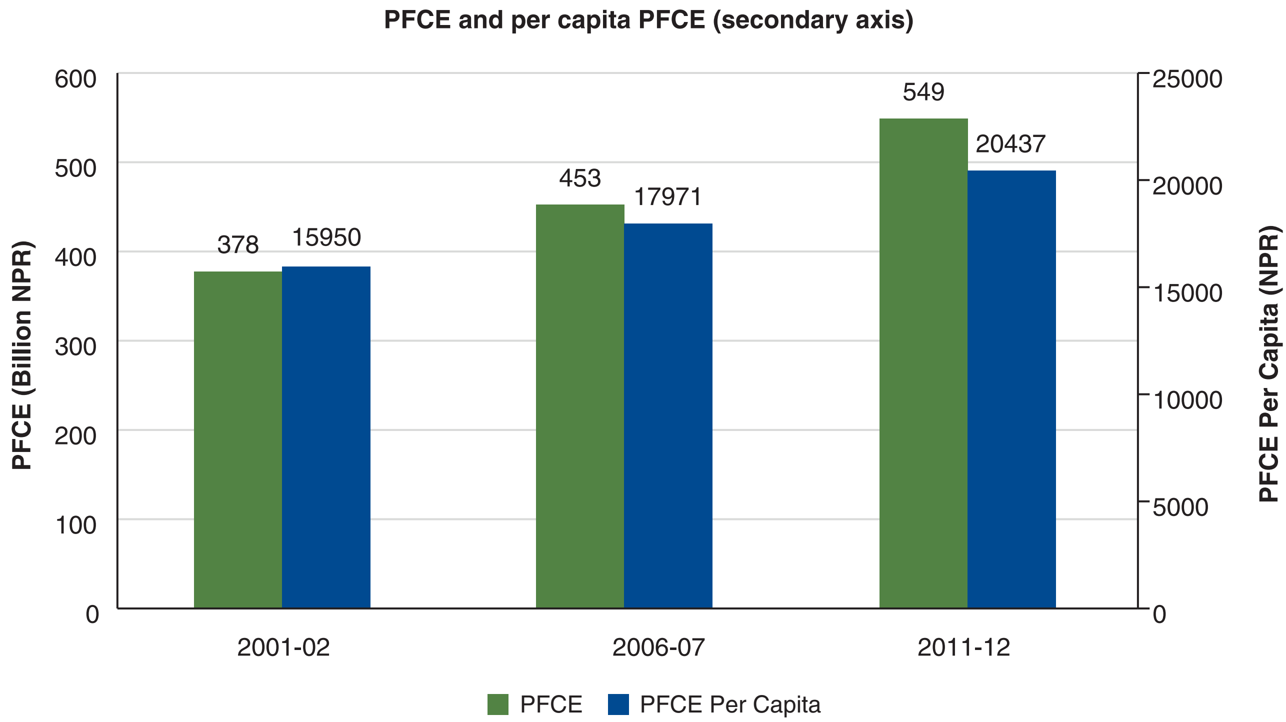


Figure 2.2: PFCE and Per Capita PFCE

Source: National Accounts Statistics (Nepal)

Figure 2.3 presents the Gross Domestic Savings (GDS) and Gross Domestic Capital Formation (GDCF) as a percentage of GDP (at current prices) (data from ADB). In 2002, the GDS of Nepal stood at 9.5% of the GDP and has risen to 11% in 2012. The GDF or investment in the economy, on the other hand, formed 20.24% of the GDP in 2002 and has risen to 34.5% in 2012, outstripping the savings ratio. The net capital flow has shown rapid growth over time (Figure 2.4).

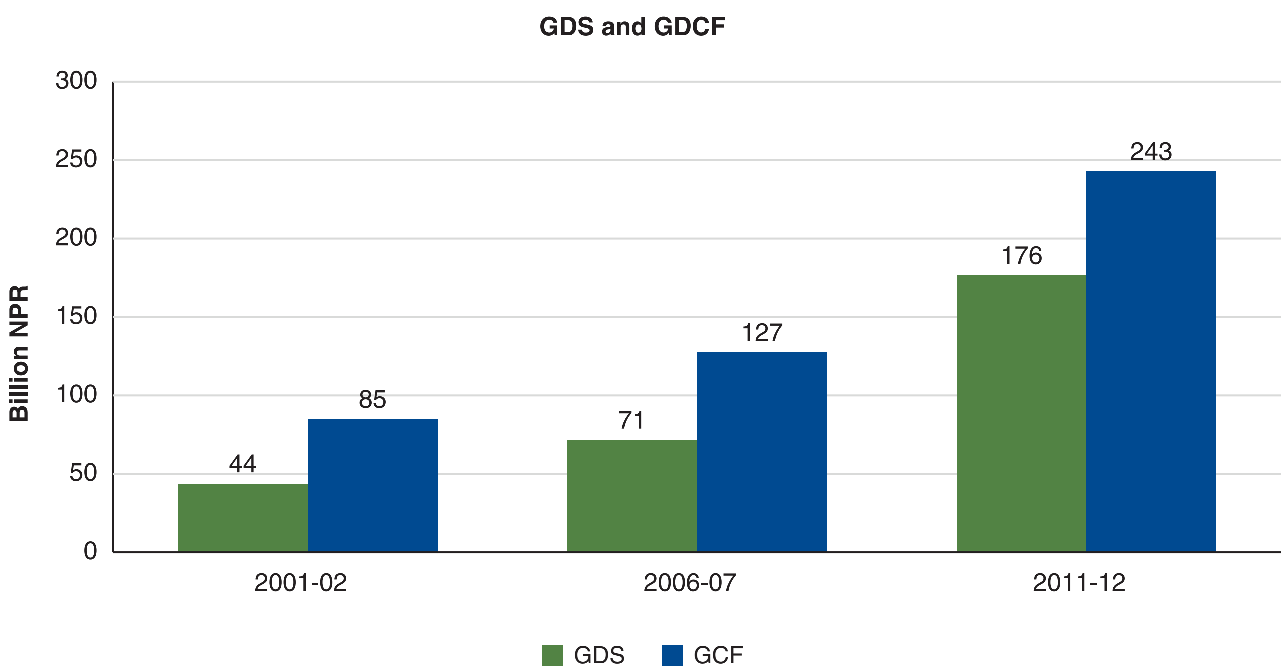


Figure 2.3: GDS and GDCF

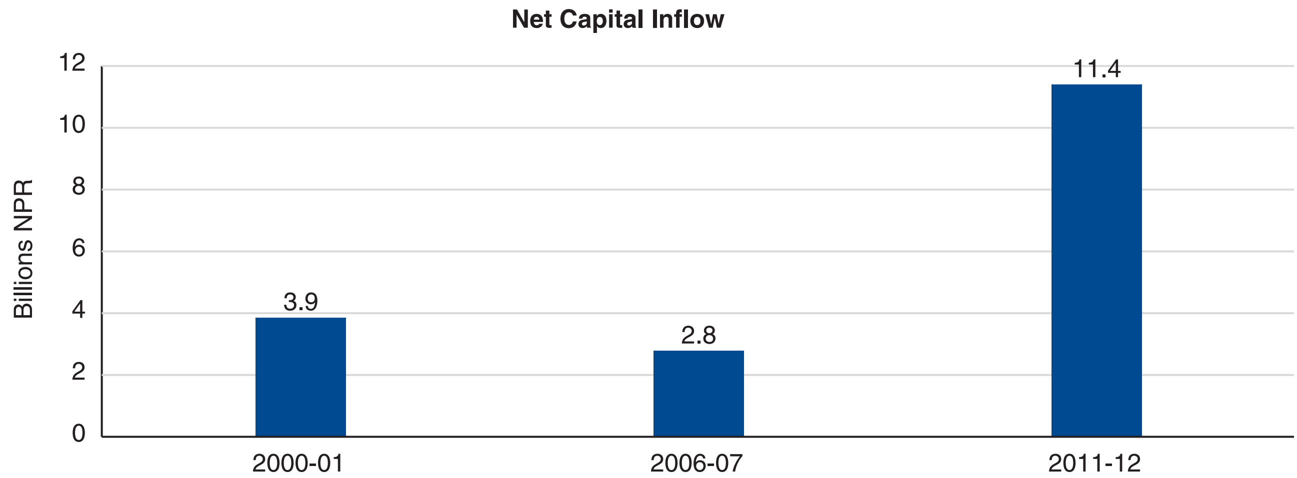


Figure 2.4: Net Capital Flow

Source: Asian Development Bank Key Indicators for Asia and the Pacific 2015

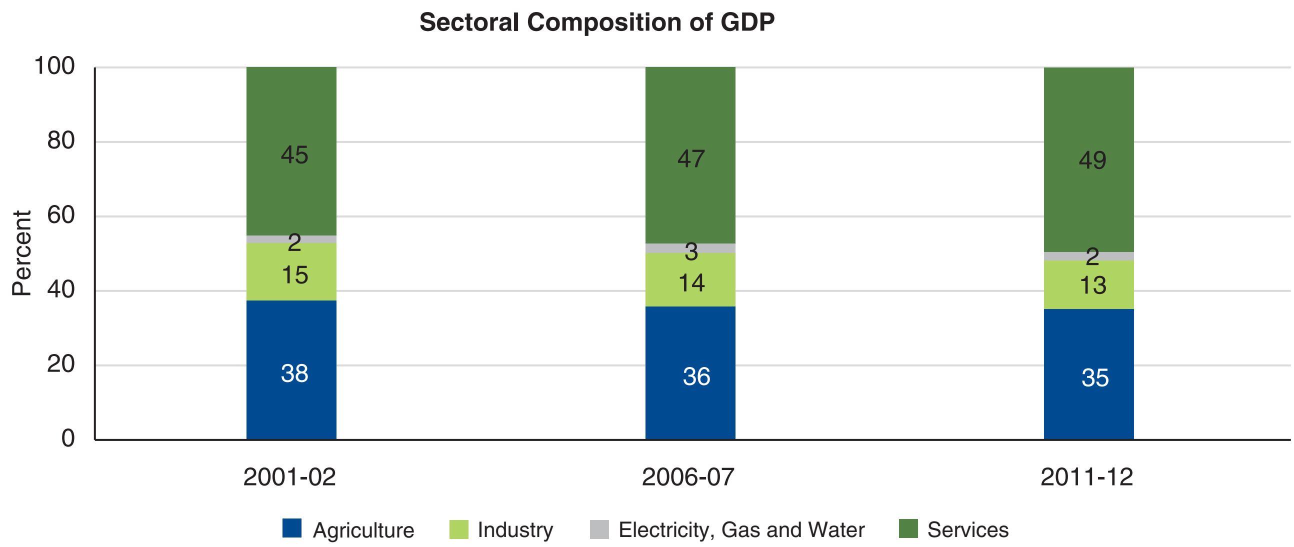


Figure 2.5: Sectoral Composition of GDP

Source: National Accounts Statistics (Nepal)

The services sector constitutes the largest share of Nepal's GDP (Figure 2.5). GDP at constant prices for services sector stood at NPR 3,16,988 million in 2012. Over the last 11 years, the share of services in the Nepal economy has grown from 45.1% to 49.5%. Agriculture accounts for 35.2% of the total GDP, followed by the industrial sector (excluding electricity). The combined electricity, gas and water sector contributes marginally to the nation's GDP at 2.3%.

2.1.2. Electricity sector

Nepal has a small, primarily hydro-based power system. Total installed power generation capacity was 856 MW in 2015–16, of which 802 MW is hydro, 53.4 MW thermal capacity based on oil products, and about 0.1 MW of solar PV (Figure 2.6). Of note is that hydropower generation capacity owned by independent power producers (IPPs) has increased over time. Peak load outstripped domestic power generation capacity, causing serious power shortage, partly met with by import from India. Electricity supply in 2015–16 was 5,100 GWh, of which 3,300 GWh was domestic generation, and remaining 1,758 GWh was import from India. Import has increased steadily from 746 GWh in 2011–12 to 1,758 GWh in 2015–16, an almost threefold increase. The system loss was 24.4% in 2014–15.

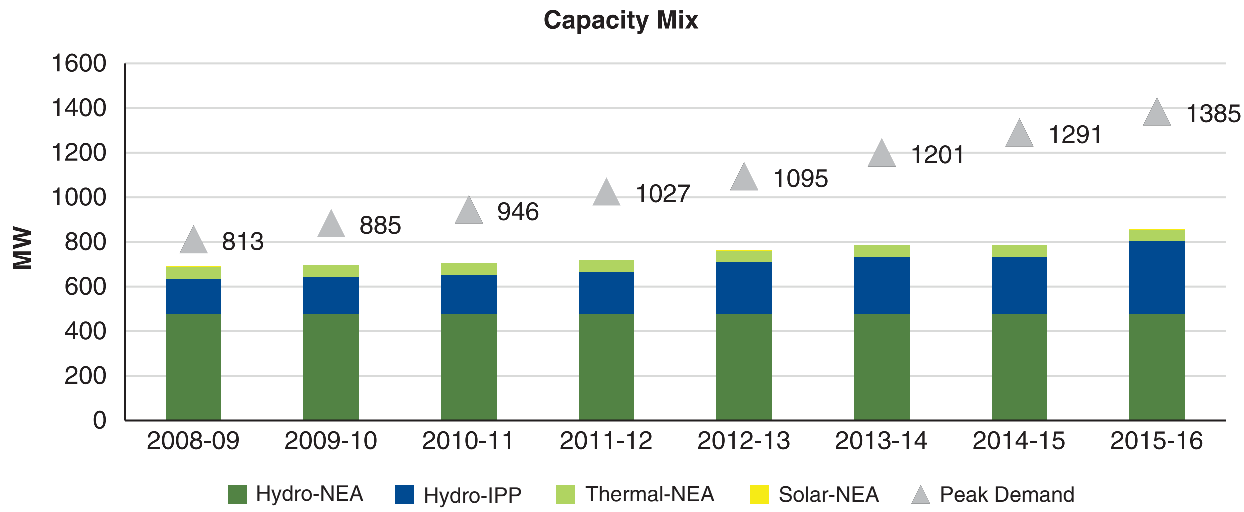


Figure 2.6: Development in Power Generation Capacity and Peak Load (Nepal)

According to the NEA annual report, electricity sales in 2014 (fiscal year) was 3,500 GWh, which has increased from 2,000 GWh in 2006 (Figure 2.7). Nepal also exports electricity to India, although at a very low quantity. Per capita electricity consumption is one of the lowest in the world, at 119 kWh in 2012 (WDI, 2015). According to the WB data, 76.3% of the population has access to electricity. NEA has projected the demand for energy and peak load as respectively 28.3 TWh and 5,785 MW for the year 2033–34.

Power ranging from 15 to 35 MW was imported under a short-term Power Purchase Agreement (PPA) with the Power Trading Corporation of India (PTC) Ltd., from Tanakpur point at 132 kV level, in the fiscal year 2014–15. Besides, a long-term Power Sale Agreement (PSA) has already been signed with PTC for the import of 150 MW power for 25 years through the 400 kV Dhalkebar–Muzaffarpur transmission line.

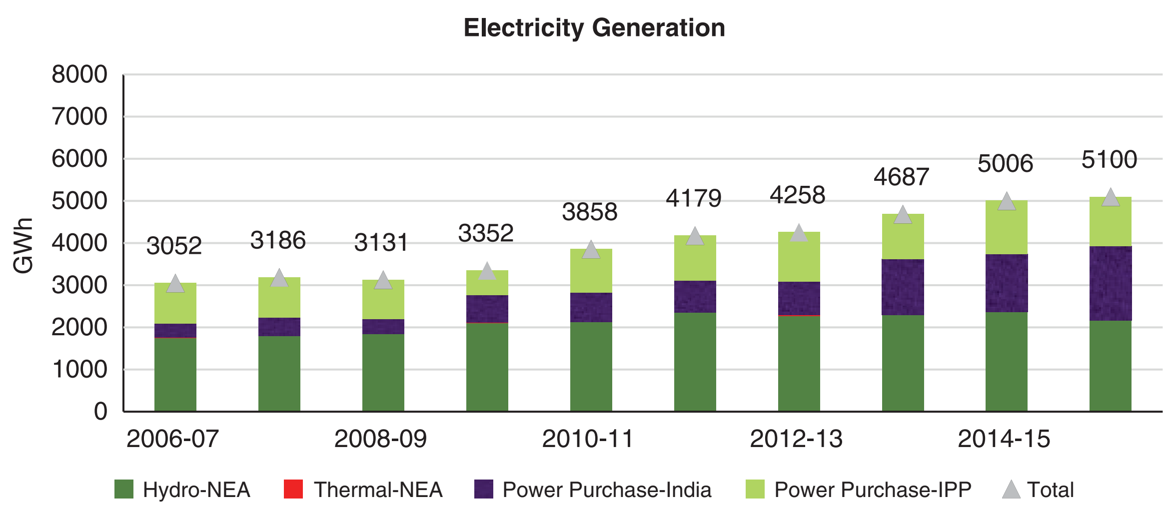


Figure 2.7: Development in Electricity Generation (Nepal)

The Nepal-India Electricity Transmission and Trade Project (NIETTP) Hetauda–Dhalkebar–Duhabi 400 kV transmission line started in 2010 under WB financing. The objective of the project was to establish cross-border transmission capacity of about 1,000 MW to facilitate electricity trade between India and Nepal and increase electricity supply in Nepal started with sustainable import of at least 100 MW of electricity.[5] The project is expected to be completed in 2016.

5 NEA, 2014/15, A year in review: fiscal year 2014/15, Nepal Electricity Authority, Kathmandu.

Nepal lacks fossil fuel sources and petroleum products used for power generation are entirely imported from India. However, it is endowed with substantial amount of hydro potential, estimated at 42 GW, with less than 2% exploited so far. Nepal also has solar energy resources, with estimated potential of 2100 MW. Wind potential in Nepal may range from 489 MW to 3,000 MW as per Solar and Wind Energy Resource Assessment (SWERA) Project.

2.2. India

2.2.1. Economy

Unless stated otherwise, all economic indicators are at 2004–05 prices. Figure 2.8 presents the growth in GDP and per capita income. GDP (at factor cost) stood at 57,417.91 billion INR[6] in 2013–14, registering a CAGR[7] of 7.73% over the period 2001–13. At 2004–05 prices, the Indian economy has expanded by 1.93 times in the past 10 years and 20.53 times since 1950–51. The per capita GDP (at factor cost) has doubled in 13 years from (Indian Rupees) INR 23,046.56 to INR 43,657.

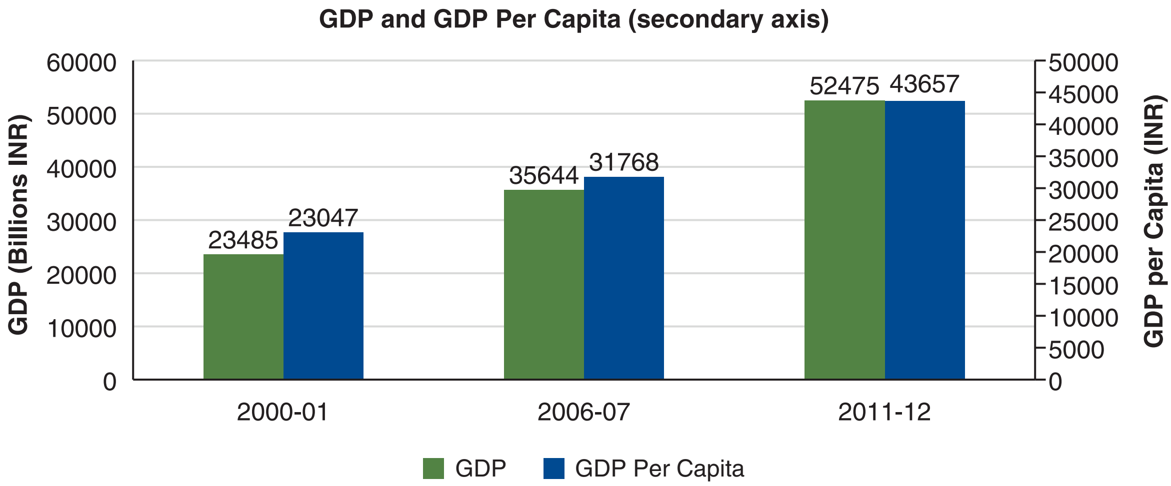


Figure 2.8: GDP and GDP Per Capita (India)

Source: RBI Handbook of statistics on Indian economy 2015, CSO

The PFCE has increased significantly from INR 16,181 billion in 2000–01 to INR 35,695 billion in 2012–13 (Figure 2.9). The per capita consumption expenditure in domestic market is INR 29,330 for 2014.

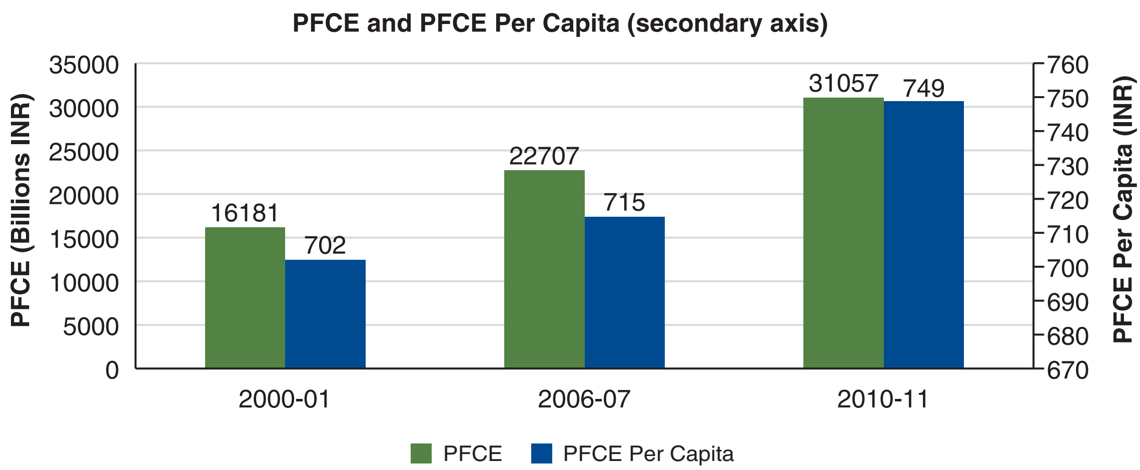


Figure 2.9: PFCE and PFCE Per Capita

6 At 2004–05 prices

7 Compounded annual growth rate (CAGR)

According to Tendulkar Methodology,[8] the percentages of rural and urban poor have been reduced to half during the period 1993 to 2011, from 50.1% to 25.7% in rural areas and 31.8% to 13.7% in urban areas.

Figure 2.10 presents the GDS and Gross Domestic Capital Formation (GDCF as percentage of the GDP). In 2000–01 the GDS was 23% of GDP, which has risen to 30% in 2012.[9] The GDCF (or investments) was 24.21% in 2000–01 and has risen to 34.7% in 2012–13. The net capital flow has increased from 411 billion INR in 2001–02 to 3,190 billion INR in 2011–12 (Figure 2.11).

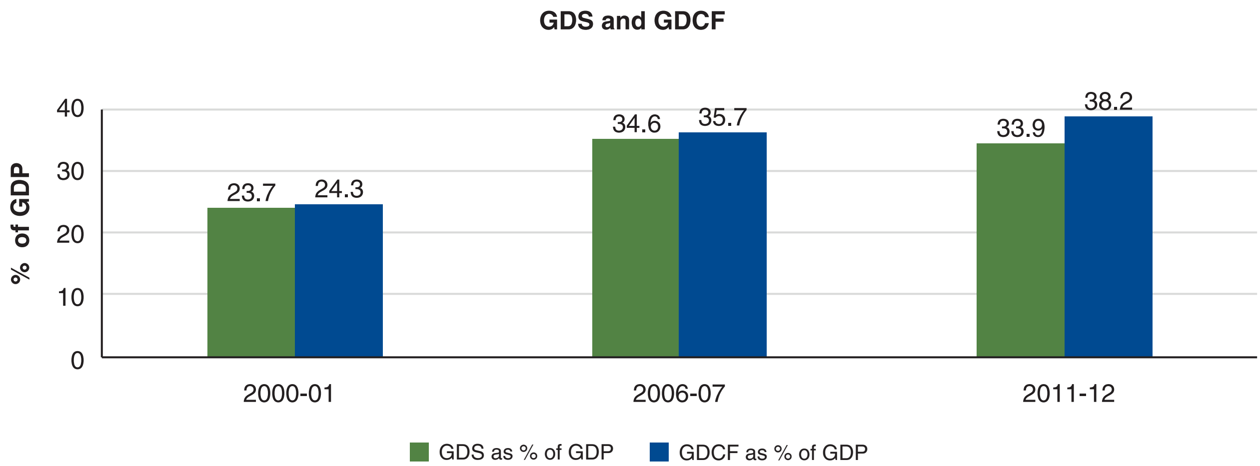


Figure 2.10: GDS and GDCF

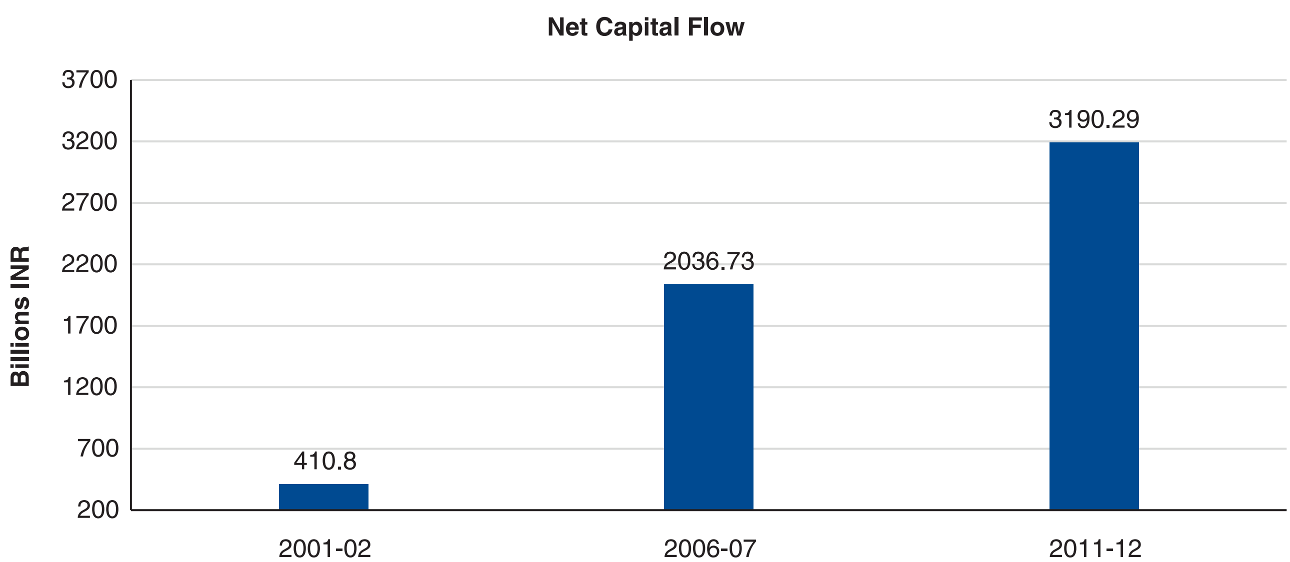


Figure 2.11: Net Capital Flow

The services sector is the largest sector of India. GDP at constant prices for services sector was INR 36 billion in 2012 (Figure 2.12). Over the last decade, the share of the service sector in total GDP has increased from 52% to 55%. Industry (excluding electricity sector) accounts for 26% of the total GDP, followed by the agriculture sector at 17%. Electricity sector contributes only marginally to GDP, at 0.02%, which remains almost same over the last decade.

8 Source: Planning Commission “Indian economy major sectors at glance 2014”

9 Source: Planning Commission “Indian economy major sectors at glance 2014”

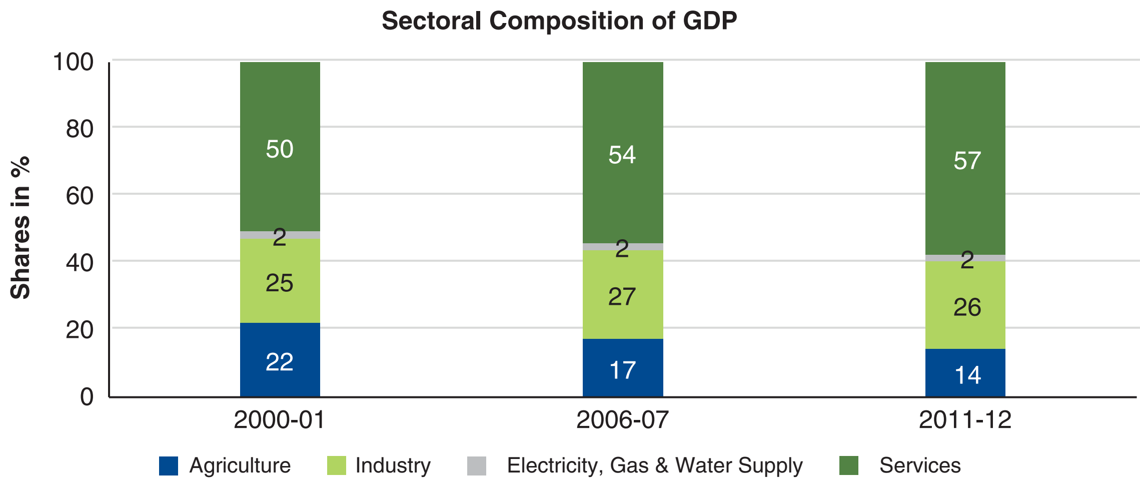


Figure 2.12: Sectoral Composition of GDP

2.2.2. Electricity Sector

India has rapidly grown in installing power generation capacity. As on March 31, 2016, installed power generation capacity (utility + non-utility) stood at 349 GW. Figure 2.13 presents the development in power generation capacity by fuel sources during the period 2006–07 and 2013–14. Coal dominates with a steadily increasing share of about 60%. Hydro power accounts for the second largest capacity and stood at 40.5 GW in 2012–13. However, the share of hydro power has fallen significantly. Renewable capacity during this period has increased four times from 7.9 GW to 31.7 GW.

Gross electricity generation almost doubled to 1,116 TWh in 2014–15 from 623.8 TWh in 2005–06, registering a CAGR[10] of 6.7%. Figure 2.14 presents the generation by fuel sources from 2006–07 to 2011–12. In terms of generation, coal is even more dominating, with a share of 68% in 2011–12. In 2014–15, the electricity sector consumed 527 million tonnes (MT) of coal, 10.7 billion cubic metre (BCM) of natural gas. Transmission and distribution loss was very high at 22.8% in 2014–15, although this has declined over time. Electricity consumption in 2014–15 was 948 TWh. Although consumption registered a growth of 8.5% compared to the previous year, India remains one of the lowest consumers of electricity when per capita consumption is considered (957 kWh in 2013–14). About 78.7% of the population has access to electricity (2012).

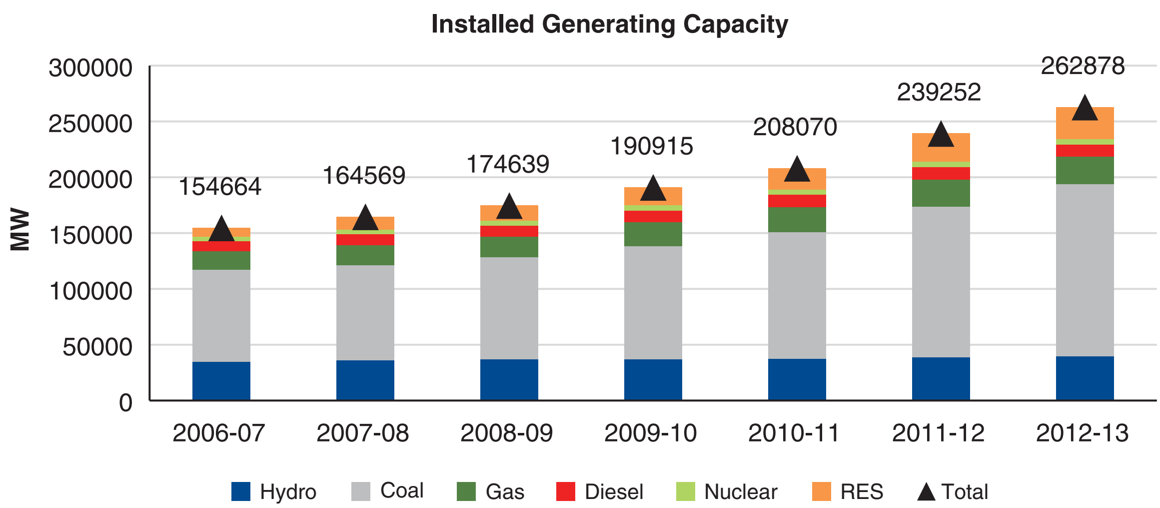


Figure 2.13: Development in Installed Power Generation Capacity

10 Compound Average Growth Rate

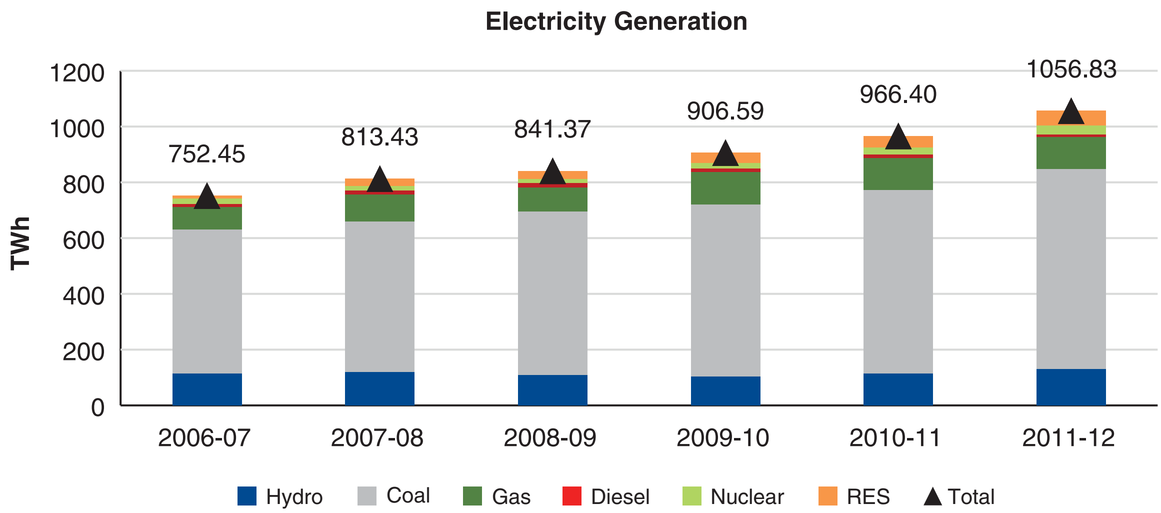


Figure 2.14: Growth in Electricity Generation

The Indian electricity system is connected with that of Nepal, Bangladesh and Bhutan. India is importing electricity from Bhutan since 1986 when the Chukha hydel power plant was commissioned with Indian support. Trade is increasing as a couple of plants have already been constructed or are under construction with support from Indian companies. Export to Nepal has grown over years, from 638 GWh in 2010 to 1318 GWh in 2014.[11] On 21st October 2014, India and Nepal signed a historic Power Trade Agreement allowing exchange of electricity and opening up new vistas of cooperation in the hydropower sector.[12] Recently (2013–14), India has started exporting electricity to Bangladesh. Current interconnection capacity between India and Bangladesh is 600 MW.

India is endowed with a large coal reserve: as on 31st March 2015, the estimated reserves of coal and lignite were 306 billion tonnes (BT) and 43 BT,[13] respectively. No wonder coal dominates India's energy supply including power generation. However, India's hydrocarbon reserve is not satisfactory and the estimated reserve stood at 763 MT of crude oil and 1488 BCM of natural gas. The total potential for renewable power generation in the country as on 31st March 2015 is estimated at 8,96,603 MW. This includes wind power potential of 1,02,772 MW (11.46%), SHP (small hydropower) potential of 19,749 MW (2.20%), biomass power potential of 17,538 MW (1.96%), 5,000 MW (0.56%) from bagasse-based cogeneration in sugar mills and solar power potential of 7,48,990 MW (83.54%).

11 Annual Report 2014-15, Nepal Electricity Authority, Kathmandu, Nepal

12 http://articles.economictimes.indiatimes.com/2014-10-21/news/55279635_1_power-trade-agreement-power-sector-mw-upper-karnali-project

13 GOI, 2016, Energy Statistics 2016, Central Statistics Office, Ministry of Statistics and Programme Implementation, Government of India, New Delhi.

Approach and Methodology

3.1 Approach

Assessment of the economy-wide impact of electricity trade from 2012 to 2045 needs to factor in the future development of the physical power system of the country involving its physical system orientation, operation, future investment plan, time-variant potential optimal acceptable electricity trade in physical quantity and tracing its two-way linkages and economic implications to the rest of the economy.

A modelling system is developed that applies two types of models – a power system model and a macroeconomic model – soft-linked to each other through an iterative process. The power system model assesses the physical (energy, capacity, traded quantity) and economic implications (electricity price, investment and trade revenue) related to the power system of the country. Generally, the demand for electricity is externally specified in such models. However, the cost of supply and earnings from trade would affect the growth of the economy and the demand for electricity. In our system, the macroeconomic model assesses this impact on the economy and the demand for electricity and the other segments of the economy through its linkage to the electricity sector. These models are solved iteratively to ensure that the power system requirement, plans, trade and revenues are consistent with the rest of the sectors in the economy. The models are used to develop scenarios and carry out analyses to quantify the CBET benefits.

3.2 Models

The physical power systems of each of the two countries are modelled separately using energy system modelling software TIMES.[14] TIMES is a technology-rich, least-cost, dynamic linear programming model representing the physical orientation and functioning of the energy (power) system. It quantifies new investment needs in generation and grid including interconnection, cost of generating electricity to meet requirement for each time period and sub-periods. The demand is specified for each 288 sub-periods of each year over the period 2012–2045. This captures the variation in demand and supply across the hours of the day and across the months of the year. The model provides the least-cost solution for meeting the requirement for each sub-period taking into account potential supply options (resource, technology, various costs, etc.) in the country. These two models are respectively named as INTec model for Nepal and IITec model for India.

Since, electricity demand varies from hour-to-hour and month-to-month and so does electricity availability from hydro, wind and solar plants, sub-periods are taken as hours of an average day for each month to balance supply, demand and trade.

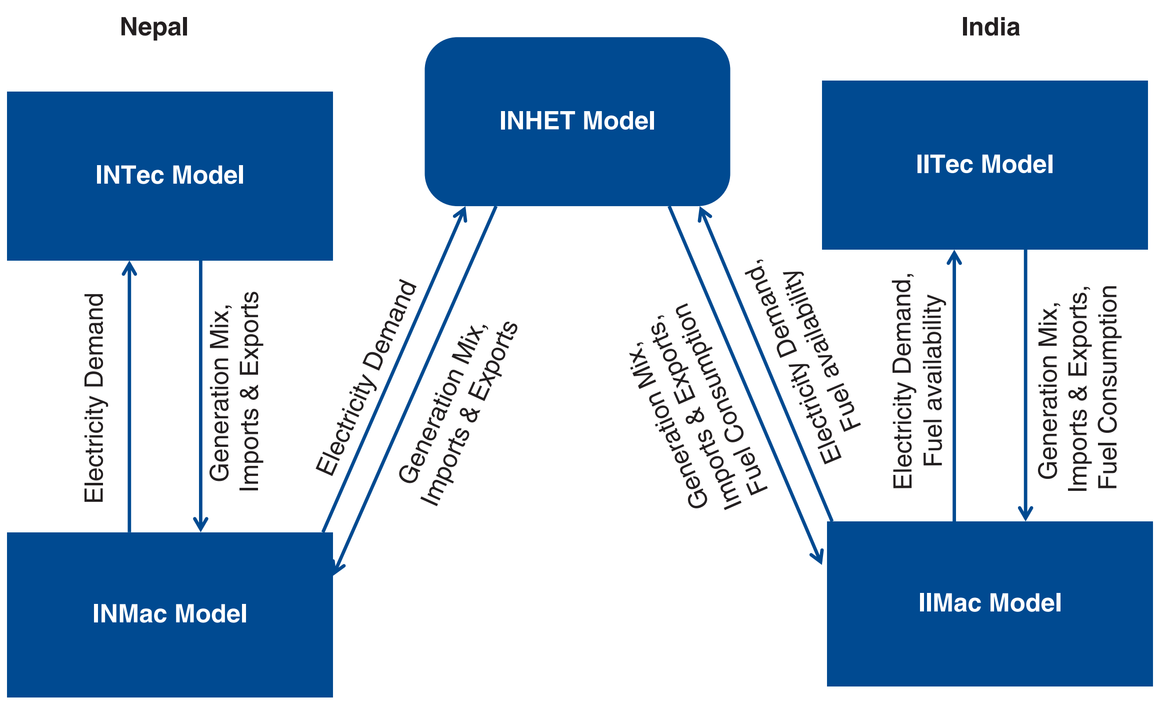
14 The Integrated MARKAL-EFOM System model, for details please see http://iea-etsap.org/index.php/etsap- tools/model-generators/times

The macroeconomic model applies a Social Accounting Matrix (SAM) based activity analysis model for India and Nepal separately using latest available SAM. The model optimises discounted values of total consumption flows in the economy subject to a set of constraints and solves for, among other things, demand (including electricity), production, trade and investment requirement for all sectors in the country.

To establish the link between the physical power system model and the macroeconomic model (represented in monetary value), the macroeconomic model has a detailed representation of the energy sector, especially the power sector, which includes the break-up of output by power generation technologies consistent with the power system model.

Although the power system of each country is modelled separately in the TIMES model generator, the TIMES software allows integration of two national power system models into one that can solve for optimal quantity of tradable electricity for each sub-period and price along with optimal investment on new capacity in each system, while minimising the net present value of the total power system costs taking both countries together. This integrated model is named INHET (India-Nepal Hourly Electricity Trade) model.

The IRADe *system for analysis of power trade and economic growth (I-SAPTEG)* modelling system has three power system models and two macroeconomic models: (1) **INTec-IRADe Nepal technology model;** (2) **IITec-IRADe India technology model;** (3) **INHET-India-Nepal Hourly Electricity Trade model;** (4) **INMac-IRADe Nepal macro model;** (5) **IIMac-IRADe India macro model**. Two of the three power system models represent the power system of each country separately; the third one represents the power system of two countries in an integrated framework so that they could interact for trading of electricity. Last two models capture the macroeconomic structure of each of the two countries separately. The modelling system including five models and their linkage is depicted in Figure 3.1.



Macro Model Names:
IIMac-IRADe India Macro
INMac-IRADe Nepal Macro

Technology Model Names:
IITec-IRADe India Technology
INTec-IRADe Nepal Technology
INHET-India-Nepal Hourly Electricity Trade Model

Figure 3.1: Modelling System (I-SAPTEG)

Inevitably, numerous assumptions are entered into all these models ranging from domestic energy resource availability, fuel imports, scheduled construction of power projects, available technology options and their respective technical and economic performances, fuel prices, cost of capital (discount rate), energy and environment policies, macroeconomic policies, development in productivity and savings rate over a period of 40 years. Experts in both countries were consulted for these assumptions, which are listed in Chapter 4.

3.3. Scenarios

To assess the potential gains from increased CBET, we develop three scenarios:

- BASE
- Accelerated Power Trade (APT)
- Delayed Capacity Addition (DCA)

The BASE scenario assumes no increased interconnections across countries beyond what are currently in place (CBET as in 2011–12) or are already committed to be built. In this scenario, each country independently makes its own capacity investments to satisfy its projected demand profile. Then, we develop the APT scenario that allows full potential of electricity trade. Delay in hydro project implementation is usual in Nepal as in many countries. Delays in decisions to initiate projects and in their implementation postpone the earning from exports and may increase the imports too until the projects are implemented. Therefore, the DCA scenario considers hydro project delay in Nepal and quantifies its effect on electricity trade and its macroeconomic implications. Delay of five years is assumed for hydro projects in Nepal. We compare the results of the trade scenarios with the BASE scenario to quantify the macroeconomic benefits of trade and we compare the delayed trade scenario with accelerated trade scenario to assess the cost of delay.

As stated earlier, quantification of power trade and its economic implications on the whole economy are carried out through the iterative simulations of the power system technology models and the macroeconomic models to ensure that the levels of trade, generation by different technologies and the demand for electricity taking into account earning from trade are consistent. The detailed working of the iterative process is described in the box.

The Iterative Process

Iterative process between power system model and macro-economic model works in the following manner (depicted in Figure 3.2):

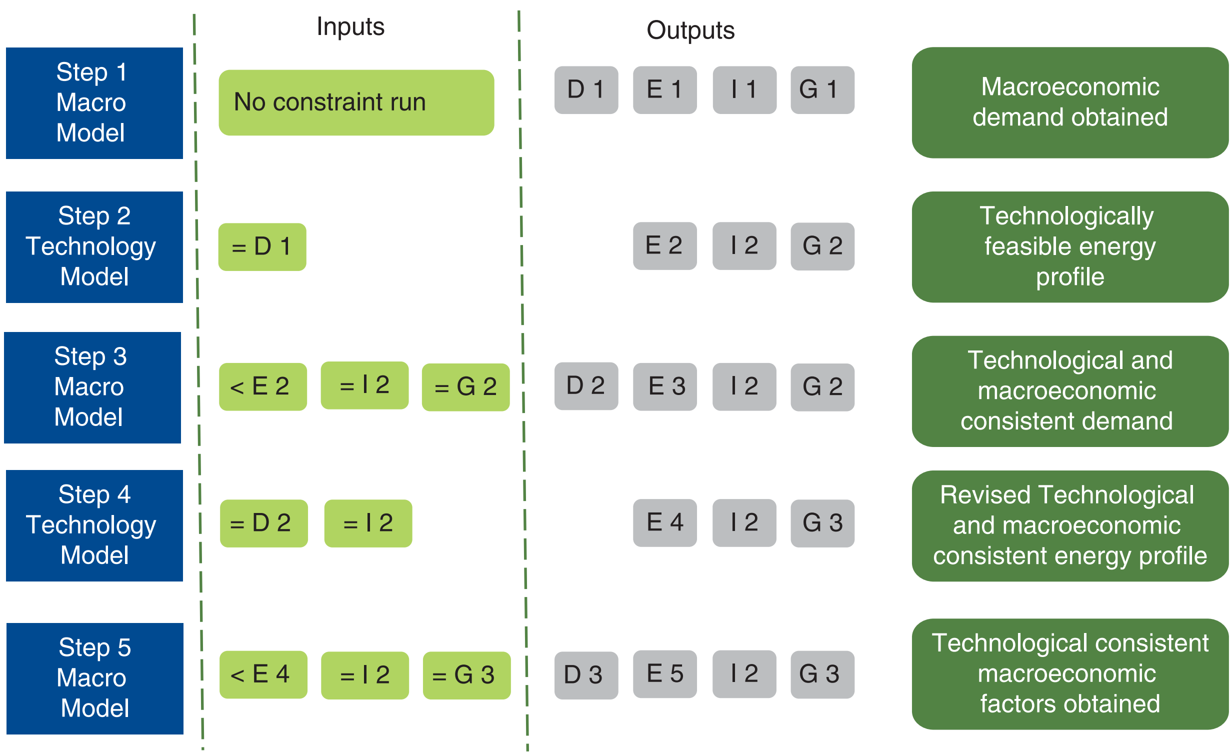
- For the BASE scenario, the iterative process is separately executed for India and Nepal, where India Technology model interacts with India macro-economic model for India, and Nepal Technology model and Nepal macro-economic model are iterated for Nepal. The steps in the iteration are as follows:
  - Iteration starts with the simulation of the macro-economic model of a country projecting electricity demand (D), exports (E) and imports (I). E and I are within prescribed upper bounds.
  - D, E and I are fed into the power system model of that country; which then calculates optimal electricity supply with technology mix, and trade levels within prescribed upper bounds (with limited quantities in the BASE scenario). Whereas the macro-economic model balances electricity demand and supply at the annual level, the power system technology model balances at hourly level. The technology mix is thus more realistic.
  - Optimal electricity output with electricity generation technology mix is fed into the macro-economic model along with opportunity cost of the electricity trade prices to make the electricity sector representation in the macro-economic model technologically consistent with the power system model. The macro model then calculates the new electricity demand with technology-wise output of the electricity sector consistent with the physical power system. The earnings from electricity trade are accounted for in the macro model that affects investment availability and consequently growth of the economy and demand for electricity. Though the generation mix is fixed, trade levels adjust to satisfy the change in demand. That electricity demand and balance of payment compliant electricity trade (small in this scenario) is fed into the power system model.

Contd...

- With the changed demand a new generation mix with technology is obtained, which is again fed into the macroeconomic model to compute income, production, consumption, trade and investment.
- The iteration stops when the outcomes between two successive iterations converge.

- In the APT and DCA scenarios, the models that participate in the iterative process include:
  (1) INHET model (with India and Nepal power systems in one framework interacting each other for optimal trading); (2) India macroeconomic model; and (3) Nepal macroeconomic model. Initial process is the same:
  - Final electricity demands of the two countries from the BASE scenario are fed into the respective power systems of the two countries in the INHET model framework.
  - In the integrated technology model, as trade option is not limited, it may be minimum cost to meet part of the demand in both countries at certain times of the year and certain times of the day through trade. Consequently, generation and technology mix and new investment also will be affected for both countries. The model generates country-wise new results on generation, technology mix, levels and prices of trade (import/export). It may be emphasised that these are levels of trade balancing supply and demand in both countries. These are fed into the respective country's macroeconomic model.
  - The country macro models generate new levels of electricity demand which will produce new electricity demands, macroeconomically consistent (complying with the balance of payment constraint of the country) with the levels of trade.
  - The iteration process continues until convergence. While the integrated technology model produces optimal hourly trade and electricity price, the macroeconomic model of each country produces income, production, consumption, GDP and trade.

Steps in Iteration between Macro and Technology Models



Where
D - Demand
E - Export
I - Import
G - Generation Mix

Macro Model Names:
IIMac - IRADe India Macro
INMac - IRADe Nepal Macro

Technology Model Names:
IITec - IRADe India Technology
INTec - IRADe Nepal Technology
INHET - India-Nepal Hourly Electricity Trade Model

Figure 3.2: Iterative Process

Modelling Structure and Assumptions

As stated in the earlier chapter, two types of models are applied: macroeconomic model and power system model. Key assumptions are presented in the following sections:

4.1. Modelling Nepal and Indian Economies

4.1.1. Population

The UN medium variant population is used for both Nepal and India. Figure 4.1 gives the rural and urban populations assumed in the models. For Nepal, urbanisation has been assumed to grow from 17% in 2010 to 21% in 2020 and further to respectively 25%, 30% and 36% in 2030, 2040 and 2050. Urbanisation in India is assumed to grow from 31% in 2010 to 35% in 2020, and further respectively to 39%, 45% and 50% in 2030, 2040 and 2050.

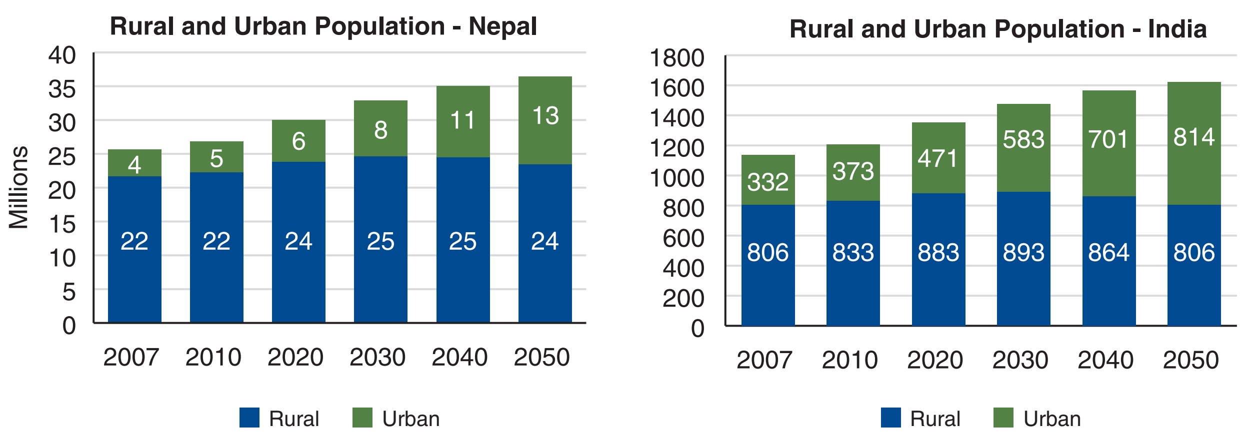


Figure 4.1: Development in Population and Urbanisation

* Population UN Medium Variant

4.1.2. Economic Assumptions

Inclusive growth policies are part of India's development model. These policies ensure access to electricity, clean cooking fuel, pucca houses, education and health services, as well as income transfer to poor. In keeping with the promise for sustainable energy access for all (SE4All), all the households consume at least 1 kWh per day of electricity by 2015. The government makes up the deficit from the household's normal consumption and provides it free of cost to the poor households. Additionally, the government supplements the poor households' expenditure on energy so that they can have at least six cylinders of LPG per year. The cost of implementing inclusive measures is assumed to be borne by the government and reduces the investment available for other economic activities.

While Nepal lacks fossil energy resources, India possesses these resources. Reserves of these resources will grow over the years with exploration for new resources. The growth rate assumption for natural resources is provided in Table 4.1.

Table 4.1: Resource Growth Assumptions for India

Resource	Reserves in 2007	Growth rate in reserves
Coal and lignite (million tonnes)	1,53,103	1.0%
Crude petroleum (million tonnes)	725	0.0%
Natural gas (billion cubic meter)	1,055	1.1%

Hydro is the main natural resource that Nepal has. Economically exploitable potential is assumed as 42 GW, consistent with the assumption made in the power system model. India has substantial amount of large hydro and renewable resources, and their exploitable potential during the modelling period is presented in the next section.

Transport sector will continue to be the major energy consumer, especially in India. Transport policies, therefore, would have significant implication on energy demand including electricity and need to be modelled. Modelled transport policies are presented in Table 4.2.

Table 4.2: Transport Policies Included in the Model*

Transport Sectors Policies	
Share of railways in total freight movement	Stipulated to increase by 1.5% per year, from around one-third in the year 2015 to almost two-thirds by the year 2050
Greater use of public and non-motorised transport	Reducing marginal budget shares for petroleum products by 0.2% per year beginning 2015
Change in fuel mix in road transportation sector	Reducing petroleum products inputs in the transport sector by 0.5% per year, and replacing them by increasing inputs of natural gas and electricity in the ratio 60:40 respectively from 2015

*Assumed only for India.

Values of many parameters are exogenous to the model. Assumptions on exogenous parameters made in both countries are presented in Table 4.3.

Table 4.3: Assumptions on Certain Important Exogenous Parameters

Parameter	Sectors	Nepal	India
TFPG*	Agriculture	0.7% per year	1% per year
	Power	0% per year	1% per year
	Rest of the economy	0.70%	1.5% for all except new technologies in power sector
AEEI** for non-power sectors	Coal	na***	1.5% per year
	Petroleum products	na	1.5% per year
	Natural gas	na	1.5% per year
	Electricity	0.5% per year	1% per year
AEEI for power sectors	Coal	na	No AEEI for coal use in power sector technologies assumed
	Petroleum products	na	No AEEI for diesel use in power sector technologies assumed
	Natural gas	na	No AEEI for gas use in power sector technologies assumed
	Electricity	Reduction in auxiliary consumption and transmission and distribution losses is assumed in consistency with the Answer Times Technology Model for India	
Reduction in energy use by government and households	Petroleum products	na	1.5% reduction in marginal budget share of expenditure on petroleum products by households due to use of more efficient vehicles
	Electricity	na	2% reduction in marginal budget share of expenditure on electricity by households due to use of efficient appliances

*Total Factor Productivity Growth
**Autonomous Energy Efficiency Improvement
***Not applicable

Energy sector representation in this model replicates the policy assumptions made in the energy system model (presented in the ensuing section): for example, normal cost reduction for renewables (solar PV and wind) due to the efficient use of production factors, no investment in capacity and no fall in costs due to factor productivity for sub-critical coal are assumed from 2017. India has announced its intended nationally determined contributions (INDCs) and commitment towards low carbon growth. The government has announced various low carbon measures through support schemes and programme targets and these announced plans in power, energy efficiency, buildings and transport sector have been incorporated. The share of buildings complying with Energy Conservation Building Code (ECBC) is specified to grow 0.1% per annum. In transportation sector, higher vehicular efficiency, switch from conventional oil-based transport to gas- and electricity-based transportation and shift from private vehicle use to public transportation are assumed.

For Nepal, 57×57 sector Social Accounting Matrix (SAM) for 2007 (Selim Raihan and Bazlul Haque Khondker, 2011) forms the reference for the base year data of the model. The base year of the model is 2007–08 and 57×57 sector SAM for 2007–08 is aggregated to 6×13 sectors to capture the most appropriate representation of the power sector and its linkages with the Nepal economy. The economy is aggregated to six commodities: agriculture, manufacturing, power, gas, water supply, and transport and other services. The power sector, which is the main focus of this study, is disaggregated to eight power generating sectors.

For India, 78×78 sector SAM for 2007 (Saluja et al., 2013) forms the reference for the base year data of the model. The base year of the model is same 2007–08 and 78×78 sector SAM for 2007–08 is aggregated to 25×41 sectors for the most appropriate representation of the power and energy sector and its linkages with the overall economy. There are 7 agricultural sectors, 10 industrial sectors (excluding energy sectors) and 3 services sectors. There are three primary energy sectors and two secondary energy sectors. The major macroeconomic assumptions are provided in the Table 4.4.

Table 4.4: Assumptions on Important Macroeconomic Parameters

Parameter	Nepal	India
Maximum growth rate of per capita consumption	8%	10%
Government consumption growth rate	8%	8%
Maximum savings rate	Assumed to increase from 15% at present to 30% by 2045	40%
Discount rate	4%	4%
Post terminal growth rate	3%	3%

In addition, some trade-related assumptions are made, which are presented in Annexures 1 and 2.

4.2. India and Nepal Technology Models

Certain modelling procedures and assumptions are common to both the countries. These are described first and then country-specific key assumptions are presented.

The existing power system (2011–12) is the starting point. A mathematical representation of the current electricity supply system is created within the TIMES modelling framework. This includes characteristics of the various existing generating stations (vintage, technoeconomic performance, etc.), transmission and distribution, energy flows, demand, load characteristics, energy resources and import/export links. Variations in seasonal and daily load patterns as well as hydro generation and availability of solar and wind energy sources are captured by introducing semi-chronological load and supply curves. Based on the analyses of 8,760 hourly load and generation data for the year 2014–15 for India and hourly load curve of four peak days in the year 2011–12 for Nepal, to capture seasonal variation, the entire year is divided into 12 seasons (meaning each month represents a season). Average hourly load pattern for a day in a month (or season) represents the daily load pattern for that particular season (or month). Thus, average hourly load over 24 hours of a day in each month represents daily load pattern of each month in the model. Thus, we have 288 = 24 x 12 sub-periods for each year. Figure 4.2 presents the organised form of the 288 sub-periods' load curve for a year for India and Nepal used in the model.

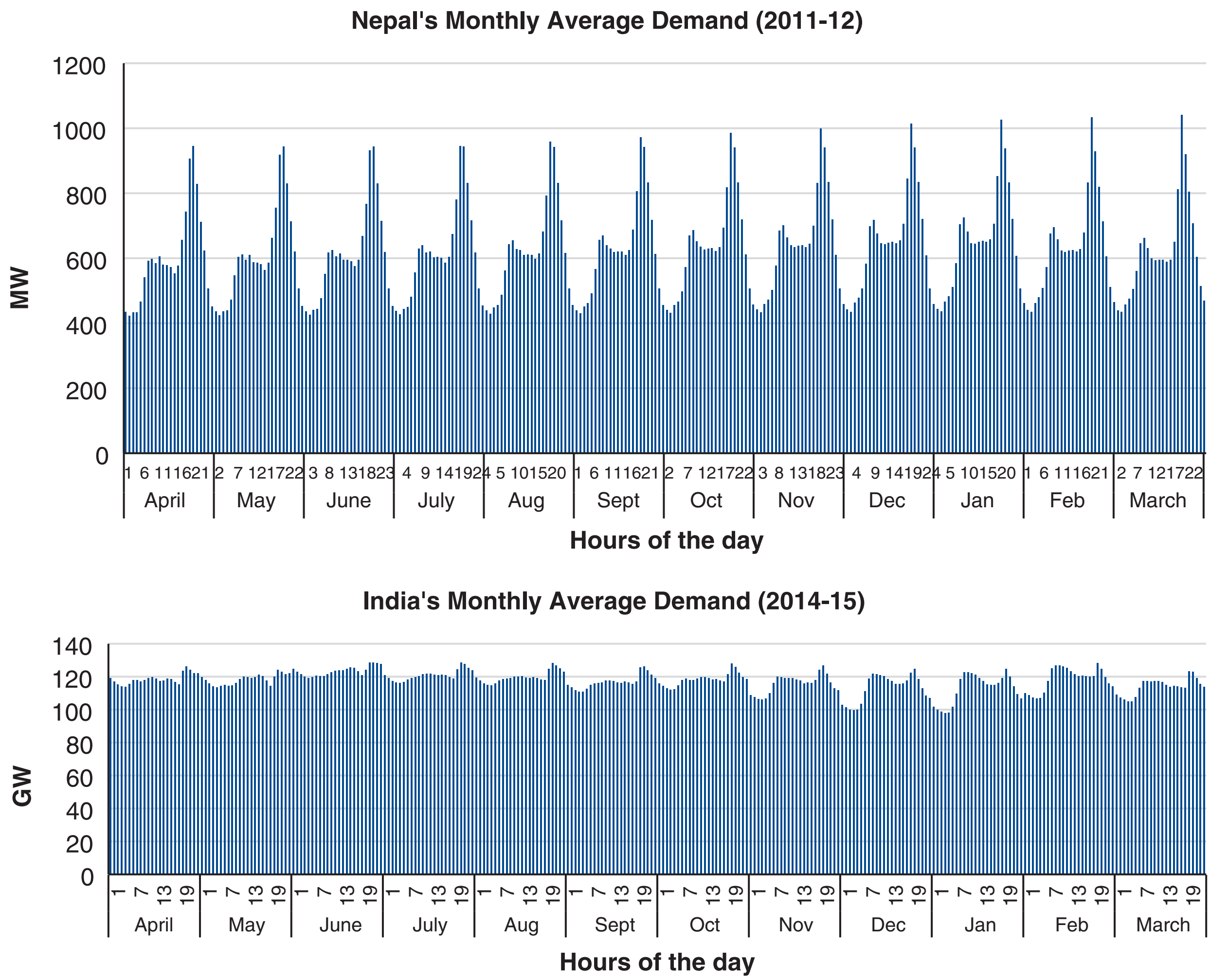


Figure 4.2: Load Curve Representation in the Model

All cost data are at constant 2011–12 US dollars and the assumed real discount rate is 4%. Exchange rates for Indian and Nepalese currencies are respectively INR 46.67 and NPR 74.02 for 1 USD. Policies and measures in place as of end-2015 are included in the model. Country-specific key assumptions are described below.

4.2.1. Nepal

The Nepal power system is relatively simple. Potential technologies for the future expansion of Nepal power system include the following: hydro (run of the river [ROR], pondage for a day, and storage), solar PV and thermal plants based on oil products. Table 4.5 presents the technical and economic data related to these technologies. Total hydropower potential is taken as 42 GW. IPP hydro projects having PPAs signed with

NEA and expected to be installed between 2017 and 2022 are included in the study. The study has also included hydro capacity addition as per Japan International Cooperation Agency's (JICA) national master plan,[15] accepted by NEA, and planned export-oriented projects. In addition, from 2022 and onwards, upper limit of 5 GW per period is imposed separately on new capacity addition based on storage and ROR + pondage together. Potential of grid connected solar PV is assumed as 2,100 MW.

Table 4.5: Assumptions on Technical and Economic Performance of Future Technology Options (Nepal)

Reference Energy System	Hydropower Plant			Solar Power Plant
Technology data	**PROR**	**ROR**	**STG**	**PV-W/O STG**
Availability factor	70%*	71%*	42%**	17.7%***
Operational life time (Year)	50	50	50	25
Economic data				
Capital cost ($/kW)*	2,233	1,916	3,395	Table 4.6
O&M cost ($/kW/yr)•	55.8	47.9	84.8	Table 4.6

* We have taken monthly availability based on past 4 years' monthly averages. If, PLF of the individual upcoming plant was available then the same was used, otherwise average PLF is used.

** Based on "Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal" February 2014 considering annual generation from Nalsyau Gad, Andhi Khola, Chera-1, Madi, Naumure, Sun Koshi-3 and Lower Badigad hydro plants (storage based)

*** For assessment of solar availability in Nepal, we have used the PV Watts Calculator developed by National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy

(*) Capital Cost calculated as average of various project costs from Final Report Summary "Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal" February 2014

(•) O&M Cost calculated as 2.5% of the average capital cost for hydropower plants

Table 4.6: Solar PV Without Storage Cost Assumption

	2012	2017	2022	2027	2032	2037	2042	2047	2052
Capital cost ($/kW)*	1,714	1,174	1,071	984	904	830	762	700	643
O&M cost ($/kW/yr)•	25.7	17.6	16.1	14.8	13.6	12.4	11.4	10.5	9.6

(*) Capital Cost calculated as average of various project costs from Final Report Summary "Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal" February 2014

(•) O&M Cost calculated as 2.5% of the average capital cost for hydropower plants

Nepal is expected to continue to import fuels (petroleum products) for power generation from India. Table 4.7 gives the fuel prices that are assumed to remain constant at 2012 level for the entire study horizon.

Table 4.7: Assumptions on Fuel Price (Nepal)

Fuel	Fuel Source	Unit	Year	Price	Data Source
Furnace oil	Import	Rs/Ltr	2012	89	Nepal Economic Survey
Diesel	Import	Rs/Ltr	2012	84.6	Nepal Economic Survey

The above technological assumptions were common to all the three selected scenarios, i.e., the BASE, APT and DCA. However, Table 4.8 gives the key assumptions on the Nepal model that differentiate the three scenarios, other than trade assumptions.

15 NEA, 2014, Nation-wide Master Plan study on Storage type Hydroelectric power development in Nepal, Final report, Japan International Cooperation Agency, February 2014.

Table 4.8: Key Scenario Assumptions (Nepal)

Parameter	BASE	APT	DCA
Under-construction plants*	Capacity commissioning assumed as per plans		
Export-oriented plants**	No capacity commissioning assumed	Capacity commissioned as per plans	Capacity commissioned with delay of 5 years as per plans
Planned and candidate hydro projects***	Capacity addition as per plans introduced as upper bounds; however, technology model chooses when and how much capacity addition is made.		Capacity addition as per plans introduced with a delay of 5 years as upper limit; however, technology model chooses when and how much capacity addition is made.
IPP's plants having PPA with NEA	Capacity addition as per plans introduced as upper bounds; however, technology model chooses when and how much capacity addition is made.		Capacity addition as per plans introduced with a delay of 5 years as upper limit; however, technology model chooses when and how much capacity addition is made.
Export and import quantum	Maximum limit based on 2011–12 exports/ imports	No limits on export/imports quantum; model chooses the optimal trade.	No limits on export/import quantum; model chooses the optimal trade.

* As per the Nation-wide Master Plan study on storage type hydroelectric power development in Nepal, Final report, Japan International Cooperation Agency, February 2014

** Commissioning year information as received from Investment Board Nepal

*** As per the Nation-wide Master Plan study on storage type hydroelectric power development in Nepal, Final report, Japan International Cooperation Agency, February 2014

4.2.2. India

- A comprehensive list of technologies is considered for the future expansion of the Indian power system. This includes the following:
  - o Various coal technologies (sub-critical, super-critical and ultra-super critical);
  - o Open cycle and combined cycle gas turbine using natural gas;
  - o Solar technologies like solar PV with and without storage, and solar thermal with and without storage;
  - o Wind onshore and off-shore;
  - o Large and small hydropower;
  - o Biomass-based power;
  - o Nuclear light and heavy water reactors.
- Assumptions used in the model on technical, economic and environmental performances of these technologies are presented in Table 4.9 to Table 4.11.

Table 4.9: Assumptions on Technical and Economic Performance of the Future Technology Options (India)

	Gas Power Plant		Coal Power Plant				Diesel Thermal	Nuclear Power Plant		Hydro Power Plant		Solar Power Plant				Wind Power Plant		Bio Power Plant
Technology Data	OC	CC	IGCC	SUBC	SUPC	USUPC		LWR	PHWR	Large	Small	PV-With STG	PV-W/O STG	TH-With STG	TH-W/O STG	ON-SHORE	OFF-SHORE	
Net Efficiency (PJ output/PJ input)	38%	55%	46%	30%	37%	43%	35%	163%	18%									25%
Fuel Type	Gas	Gas	Coal	Coal	Coal	Coal	Diesel	Enriched Uranium	Natural Uranium									Biomass
Availability Factor	85% (UP)	(55-85)%	(60-70)%	(60-70)%	(60-70)%	(60-70)%	70%	80%	80%	39%	41%	37%	18%	37%	18%	(21-28)%	(33-37)%	50%
Plant Availabilty Modelling Level	Annually	Annually	Annually	Annually	Annually	Annually	Annually	Annually	Annually	Monthly	Monthly	Hourly	Hourly	Hourly	Hourly	Hourly	Hourly	Annually
Operational Life Time (Year)	40	40	40	40	40	40	15	50	50	50	35	25	25	25	25	25	25	20
Economic Data																		
Capital Cost ($/kW)	482	771	2143	1028	1136	1307	1071	4500	1778	2036	1393	Refer Next Table				1286	3857	964.2
O&M Cost ($/kW/yr)	39	31	54	26	28	33	107	112	44	67	42	Refer Next Table				19	29	39

Table 4.10: Capital Costs (US$/kW) Assumptions for Solar Technologies (India)

	Storage	2017	2022	2027	2032	2037	2042	2047	2052
Solar Power Plant (PV)*	WO-STG	1173.6	1071.3	983.9	903.6	829.9	762.1	699.9	642.8
	With STG	3526.1	3223.7	2959.2	2716.3	2493.3	2288.7	2100.8	1928.4
Solar Thermal Plant (CSP)#	WO- STG	2314.1	2036.4	1873.5	1761.1	1708.3	1674.1	1640.6	1538.6
	With STG	3373.4	2968.6	2731.1	2594.6	2464.9	2366.3	2295.3	2111.7

(*) The Solar PV cost reduction is undertaken on the CERC benchmark cost for financial year 2015–16, which is 6010.4 $/kW (CERC Benchmark Cost 2015). The reduction is undertaken as per the Report "Current and Future Cost of Photovoltaics" of Fraunhofer-Institute for Solar Energy Systems, Germany. From the report, we have considered 20% cost reduction trajectory by 2025 and 40% cost reduction by 2050, which is still on the conservative side as the other scenarios in the report consider 36% reduction in 2025 and 72% reduction in 2050.

(#) For Solar Thermal Plants the cost reduction trajectory is as per the IESS 2047 V2.0 model of the NITI Ayog.

Table 4.11: O & M Cost Assumptions for Solar Technologies (India)

	Storage	2017	2022	2027	2032	2037	2042	2047	2052	% of Capex
Solar power plant (PV)	WO-STG	17.6	16.1	14.8	13.6	12.4	11.4	10.5	9.6	1.5%
	With STG	88.2	80.6	74.0	67.9	62.3	57.2	52.5	48.2	2.5%
Solar thermal plant (CSP)	WO-STG	28.9	25.5	23.4	22.0	21.4	20.9	20.5	19.2	1.3%
	With STG	42.2	37.1	34.1	32.4	30.8	29.6	28.7	26.4	1.3%

- The current (2015) policy and measures that are in place have been included. Renewable capacity of 175 GW will be achieved by 2022. As indicated in India's INDC, non-fossil capacity share would be 40% in 2030, linearly increasing to 50% in 2050. Until 2022, capacity addition of large hydro, nuclear and coal is according to the CEA transmission plan 2016–34. Potentials for large hydro and wind onshore are respectively taken as 145 GW and 302 GW. Additionally, the potentials for solar PV and solar thermal are taken respectively as 749 GW and 229 GW.
- Keeping in mind the regulatory guideline on technical minimum scheduling for operation of power plants, we have imposed the operational time range of coal power plants between 60% and 70%. However, negative impact on economic and technical performance due to low utilisation of power plants is not modelled.
- Price of fuels used for power generation is assumed to be constant at 2012 level for the entire study horizon and presented in Table 4.12.

Table 4.12: Fuel Price Assumptions

Fuel	Fuel Source	Unit	Year	Price in Model	Calorific Value	Data Source
Natural gas	Dom	INR/SCM	2012	8.387	10,000 Kcal/SCM	GAIL
	Imp	USD/MMBTU	2012	10	10,000 Kcal/SCM	GAIL
Coal	Dom	INR/ton	2012	1317.35	3,541 Kcal/kg	Coal Directory, MOC
	Imp	INR/ton	2012	5119	5,500 Kcal/kg	Coal Directory, MOC
Natural uranium	Dom	INR Cr/ton	2012	0.78		IESS
	Imp	INR Cr/ton	2012	0.78		IESS
Enriched uranium cost	Dom/ Imp	INR Cr/ton	2012	14.486		IESS
Biomass	Dom	INR/kg	2012	2.4	3751 Kcal/kg	IRADe Analysis

Results and Analyses

As stated in Chapter 1, the study intends to strengthen policy makers/planners/investors/civil society with information pertaining to the CBET needed for informed policy and decision making, least cost planning of the power system, investment decision making, negotiation and public consensus building on trade and use of the country's natural resources. The focus is on examining the development of hydro potential in Nepal for electricity export to India. Answers to the following questions would provide information of interest to these stakeholders:

- At what price agreeable to both buyer and seller, during what period of the year, how much electricity can be traded?
- What would be the impact on living standard measured through per capita consumption levels?
- How would per capita electricity use change?
- What would be the impact on capacity creation and investment potential?
- What are the macroeconomic benefits to Nepal and India in terms of growth in GDP, investment (in rest of the economy) fuelled by the impact from electricity trade such as export earnings and investment in the sector?
- What are the consequential environmental benefits?

Answers to these questions are sought applying the methodology described in the previous chapter. Consequently, this chapter deals with those answers through comparative analyses of the three scenarios, BASE, APT and DCA, described in the previous chapters. Unless both countries need to be addressed together, analysis is done for Nepal first followed by India.

- **At what price agreeable to both buyer and seller, during what period of the year, how much electricity can be traded?**

Figure 5.1 presents the Nepal–India electricity trade over the study horizon. Of note are the different scales used in the two diagrams. Nepal currently imports electricity from India. In the BASE scenario, it continues to do so until 2020. However, as hydropower plants under construction come into operation by 2022, the imports go down in 2025, but without specific policies to push up electricity trade, import rises again gradually, as hydro potential remains unexploited due to the lack of investment. Even then, in 2045 the import is only 465 MkWh.

Electricity trade with India would help Nepal to develop its hydropower potential and export electricity to India. Substantial amount of electricity export would be economically viable with the APT scenario. When development of hydropower projects is delayed by five years, export is delayed too and so are the benefits of trade to Nepal.

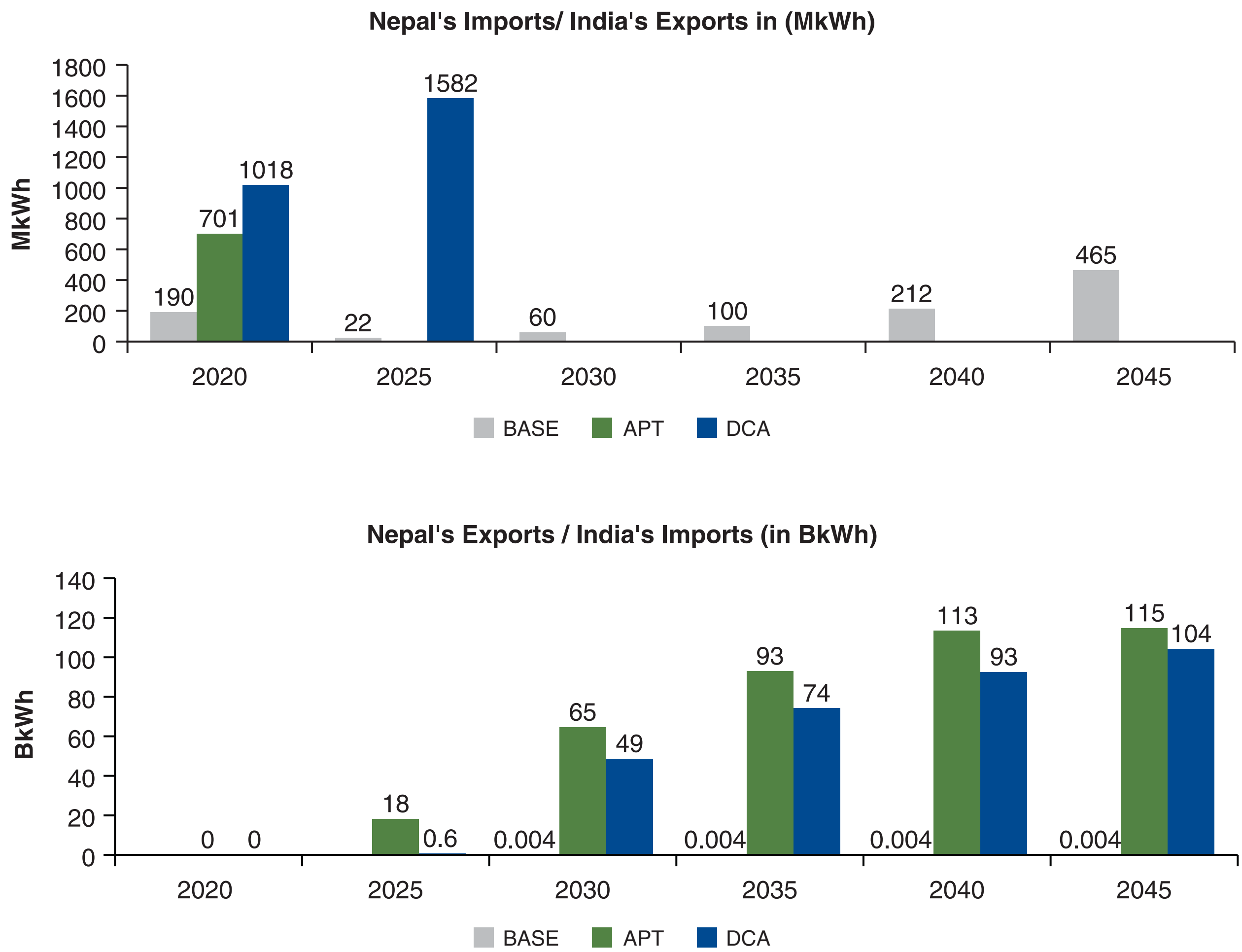


Figure 5.1: The Nepal–India electricity trade over the study horizon

Under the trade scenario, in the initial years, Nepal, which has severe power shortage, imports electricity from India, but once it builds generating capacity, the situation reverses and it gets ready to export, and imports become negligible. Given the long construction period of the hydro projects, electricity trade fuels the investment starting before or around 2020, making electricity demand higher in the APT scenario in 2020 than no trade (BASE) scenario resulting in higher electricity import in APT scenario. Nepal exports 18 bkWh in 2025, which jumps to 65 bkWh and 93 bkWh, respectively, in 2030 and 2035. Exports flatten out from 2040 to 2045 as its domestic consumption increases and exploitation of the viable hydro potential gradually reaches its maximum. In the DCA scenario, as hydropower plant constructions get delayed by five years, exports also get delayed by five years, but grow rapidly. By 2040, Nepal's exports in the DCA reach 104.3 bkWh.

It may be noted that India imports electricity from Nepal even when its own hydro potential of 145 GW is fully utilised.

Figure 5.2 shows hourly trade for selected years 2020, 2030 and 2045. In the year 2020, as Nepal constructs its hydro plants, it imports electricity to fuel the construction and other activities.

Import is high during the dry season (January to March) and as it is also cold season in Nepal, demand is high as well.

Export starts at 2025 (not shown here). By the year 2030, maximum 13 GW could be available for export during the rainy season or post-rainy season months of September and October in the evening during the peak hour in Indian power system. In the dry months of January to March, export falls, with about 8–10 GW available in the evening to meet the daily peak in India. It should be mentioned that January–March is the dry season, when it is also cold: so demand is high in Nepal. Annual peak occurs in March and in the evenings, which also reduces capacity available for export.

Available export capacity almost doubles in 2045. In the wet months of September and October, around 20–23 GW of capacity would be available for export to meet the evening peak in India. During the dry months, same pattern as seen for 2030 is seen; the maximum available capacity for export is in the range of 12–15 GW in the evening when peak occurs in the Indian system.

Peak load capacity requirement in the Indian system in 2030 is more than 300 GW and in 2045, it is more than 700 GW. Therefore, contribution of about 13 GW and 23 GW, respectively, from export in 2030 and 2045 is small, less than 5%. However, it would still reduce the investment in peak capacity in India and peak could be met at lower cost than the options available in India. Supplying electricity in the evening also helps to counter the intermittency of the solar PV in the Indian system, which would have a large capacity (327 GW in 2045 in BASE scenario).

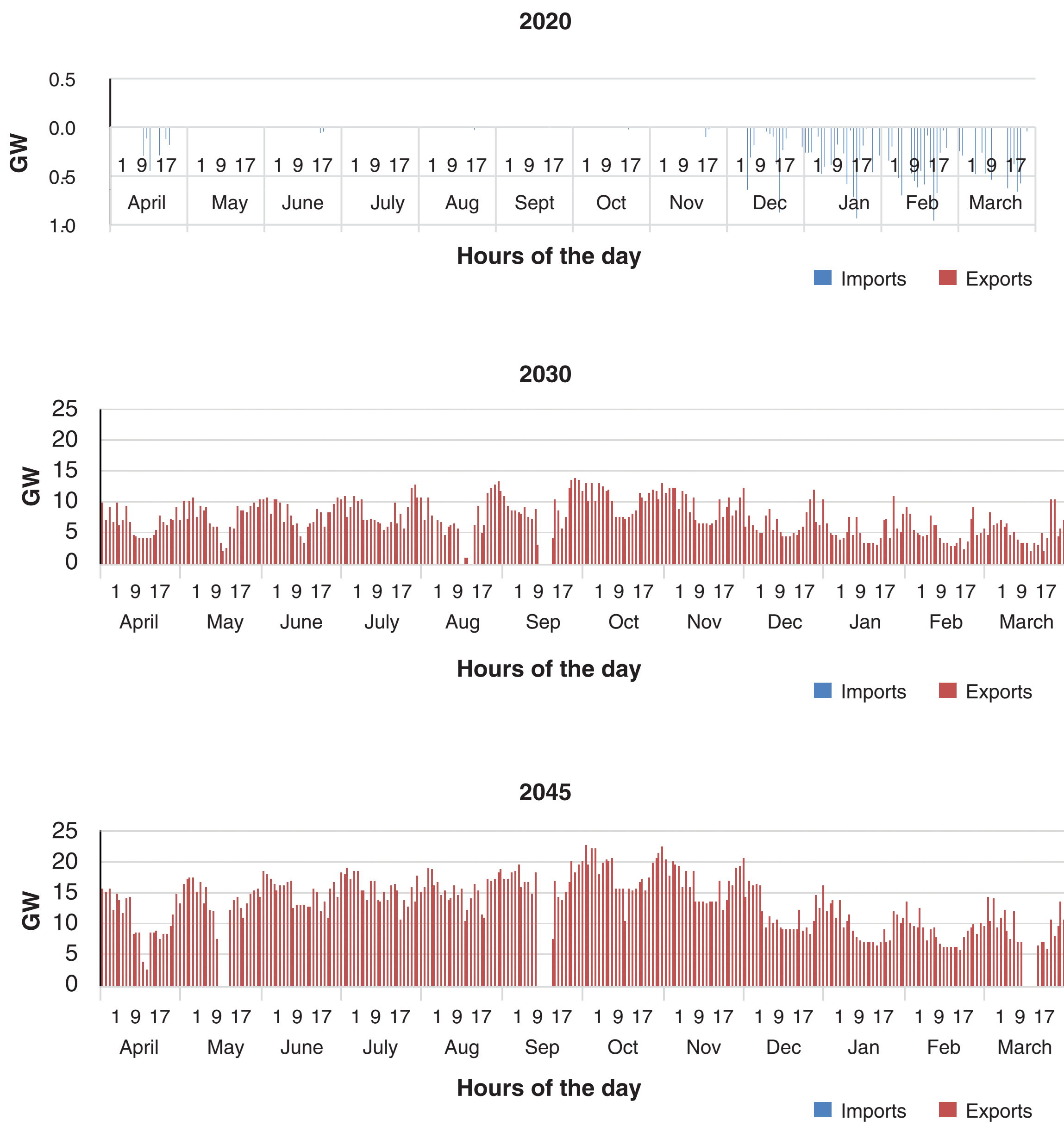


Figure 5.2: Hourly trade for selected years 2020, 2030 and 2045

Table 5.1 shows the average annual opportunity cost (weighted average of hourly trade costs) at which trade takes place. Of note is that these prices reflect the opportunity costs to the two countries, which is the marginal cost to produce electricity for the exporting country and the marginal cost to produce that electricity domestically for the importing country. As domestic demand increases and resource is limited, opportunity cost increases over time, however, remains less than cost of all generating options in the importing country—India—resulting in export becoming economic. The export earnings for Nepal are NPR 310 billion in 2030 and go up to NPR 1,069 billion by 2045, comprising around 5% to 6% of GDP and as high as 25% of total investment in 2040, and although decline still remain at 15% in 2045.

Table 5.1: Electricity Trade Volumes and Opportunity Costs

	2020	2025	2030	2035	2040	2045
Export opportunity cost (NPR/Unit)						
APT	0.00	2.43	4.79	6.08	7.41	9.31
DCA	0.00	4.79	5.05	6.21	7.49	9.57
Import opportunity cost (NPR/Unit)						
APT	8.65					
DCA	0.00	2.13				
Net revenue from trade for Nepal: Export–Import (billion NPR)						
APT	-6	44	310	565	840	1069
DCA	0	-0.4	246	460	693	998

We emphasise that the total hydroelectricity potential of Nepal is taken as 42.13 GW as the economically viable and technically feasible potential. However, the estimate of Nepal's theoretical hydropower potential is much larger at 83 GW. With changing economic and technological environment, viable and feasible potential can increase, in which case exports can keep increasing with higher gains to Nepal from trade.

In addition, if the Indian economy is to have more stringent carbon emissions constraints, it will have to rely even more on renewables like wind and solar. This would increase the need for balancing power from hydroelectricity from Nepal and much larger exports by Nepal can be absorbed by India.

Power trade supplies electricity at cheaper price to the people of the importing country and increases revenue to the exporting country. What does that mean to the people? Does it translate to a better quality of life? We address these questions in the ensuing sections.

- **Impact on Consumption Levels**

Per capita consumption level of households is a major indicator of well-being. Figure 5.3 shows its levels in the three scenarios. Table 5.2 shows the gains in percentage terms over the BASE scenario as cumulative gains also over the years.

The annual per capita consumption level in 2012 was merely NPR 27,000 per person. Power trade clearly brings substantial gains to the people of Nepal as Nepal earns large export revenue. That leads to per capita consumption reaching a level of NPR 2,84,000 per person in 2045 at 2007–08 prices compared with the BASE scenario where it reaches NPR 2,30,000 per person.

We see that under APT in 2045 Nepal's per capita consumption is 23% higher than in the BASE scenario. As the domestic economy grows, domestic requirement for electricity grows as well leaving less surplus available for export. With DCA the gain is only 10%. Thus, there is a substantial cost to delay.

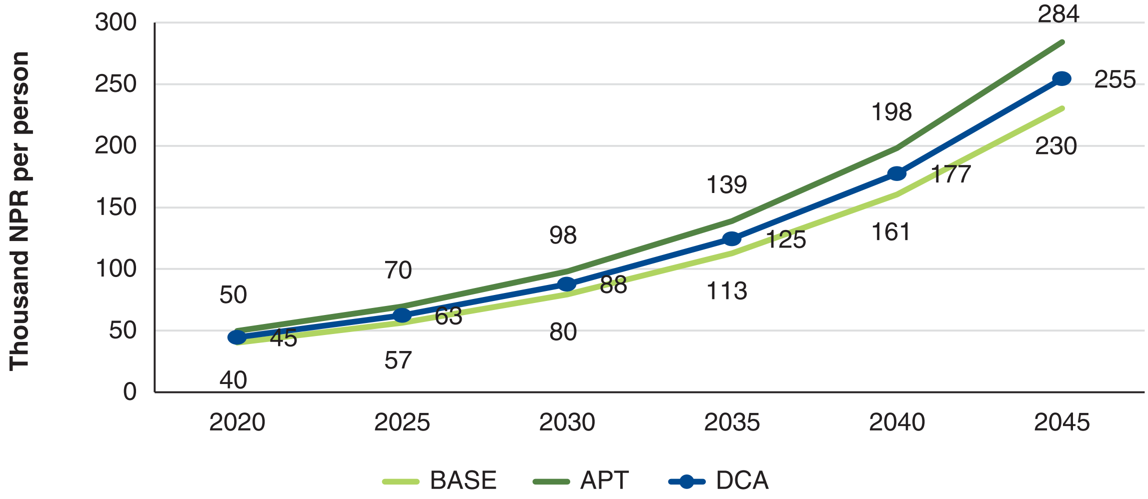


Figure 5.3: Per Capita Consumption by Households in Nepal (NPR in Constant Prices)

Table 5.2: Gains over BASE in Consumption by Households at Constant Prices

Year	BASE	APT		DCA	
	Billion NPR	Change over BASE	% Change	Change over BASE	% Change
2020	1,214	283	23%	127	10%
2025	1,755	408	23%	183	10%
2030	2,628	612	23%	274	10%
2035	3,835	893	23%	400	10%
2040	5,625	1,309	23%	587	10%
2045	8,297	1,931	23%	866	10%
Cumulative 2012–2045	1,03,098	23,891	23%	10,670	10%

The cost of delay in terms of cumulative per capita consumption level is 13%. It is important for Nepal to make all efforts to develop its hydro potential as soon as possible for the benefit of its people.

- **Impact on Growth of Nepal's Economy**

Consumption is a very important indicator of gains to the people of Nepal. However, the level of domestic GDP also matters in a developing country like Nepal as it brings other benefits. It creates employment and domestic capacity that makes country's economy more resilient to external shocks as well as to natural disasters and helps sustain stable growth for a long period.

Figure 5.4 shows the trajectories of GDP in the three scenarios. The gain in GDP in APT scenario in 2045 is 39% over the BASE scenario. With DCA, the gain is only 14% in 2045. This also shows how costly even a five-year delay in capacity addition can be.

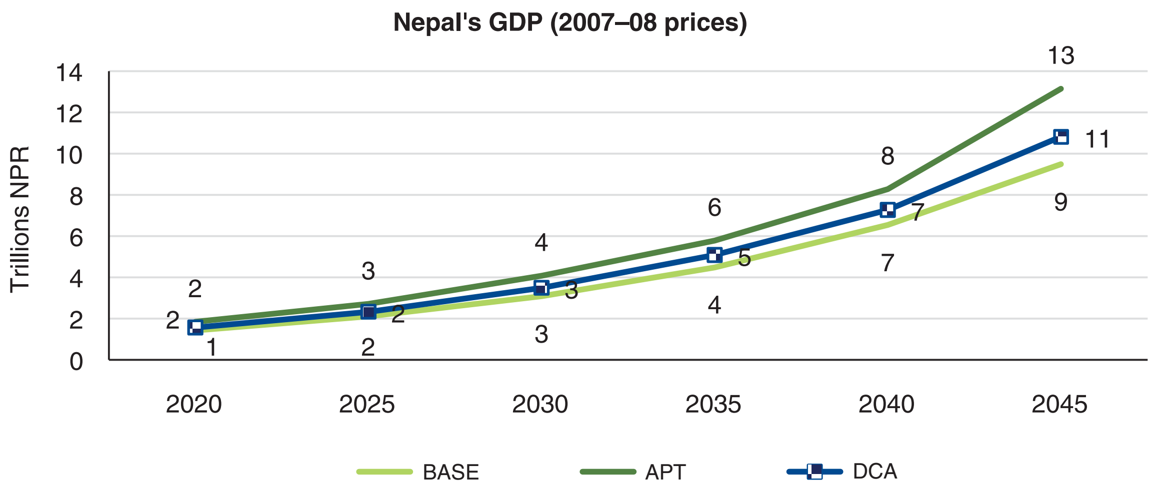


Figure 5.4: Growth of GDP of Nepal

- **Impact on Per Capita Electricity Demand**

Per capita electricity demand is strongly correlated with the Human Development Index (HDI). It is thus of interest to see how electricity trade affects it. Figure 5.5 shows the growth of per capita electricity demand in Nepal in the three scenarios. With large export revenue and improvement in macroeconomic conditions, higher investment would be available to build more power supply infrastructure.

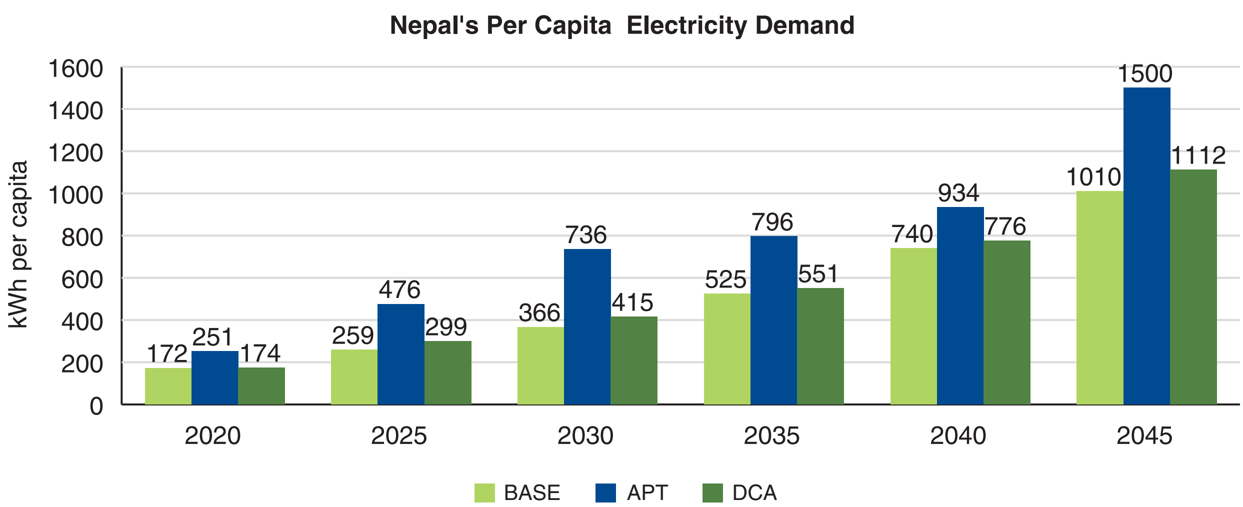


Figure 5.5: Per Capita Electricity Demand

Per capita electricity demand in Nepal was 139 kWh/year in 2012. This grows to 1,010 kWh/year in 2045 in the BASE scenario. With accelerated trade in APT, it increases to 1,500 kWh/year in 2045, an increase of 49% over BASE scenario. With DCA, the increase in per capita electricity demand is smaller than in APT and is only 10% above the BASE in 2045. Higher electricity access and use implies a better quality of life in many ways. Children can study more. Better health facility can be provided. Internet access becomes feasible. Exposure to fumes from kerosene lantern is eliminated. Work can become more productive and so on.

- **Electricity Generation, Exports and Use in Nepal's Economy**

Total electricity generation in three scenarios is shown in Figure 5.6 and domestic electricity consumption (generation + imports – exports) in the economy is shown in Figure 5.7.

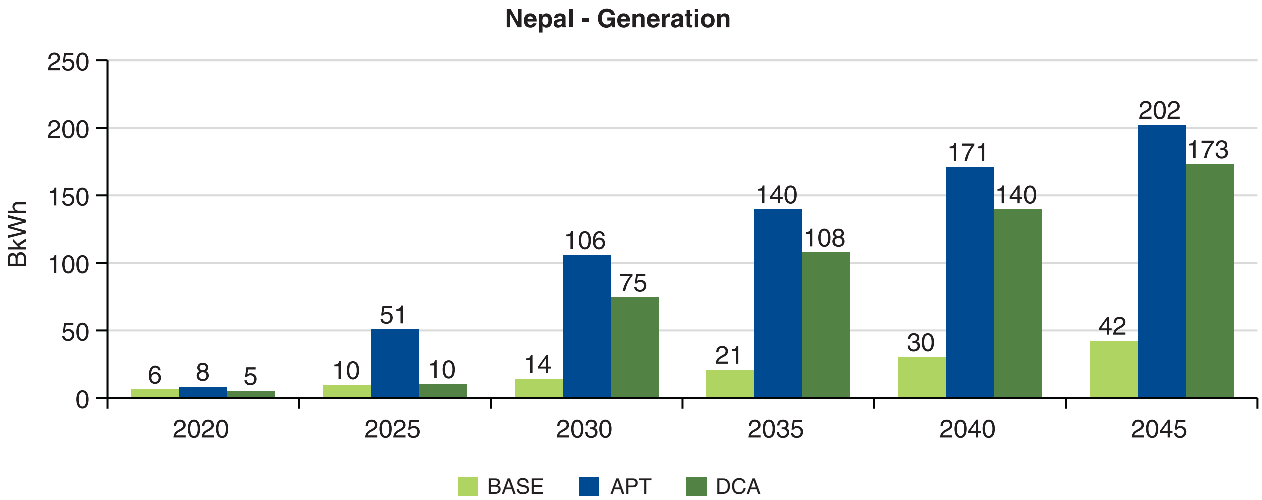


Figure 5.6: Electricity Generation in Nepal

Electricity generation, net exports and domestic use all grow significantly with trade. The electricity generation in 2045 is 202 bkWh with APT, as compared to only 42 bkWh in BASE scenario. However, exports account for bulk of the increase as the use in the domestic economy is less than 50% of the generation.

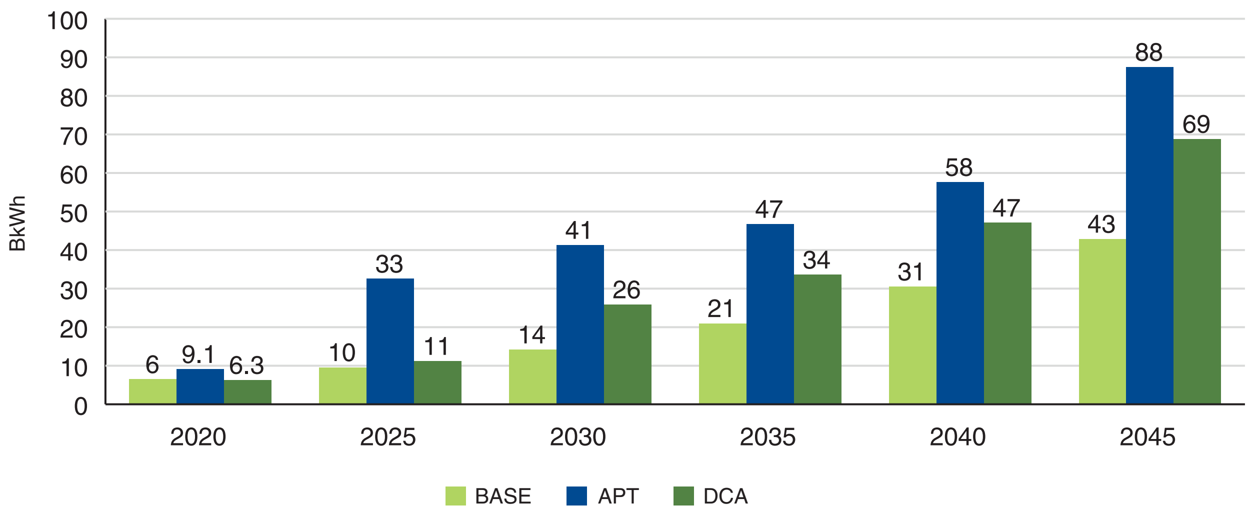


Figure 5.7: Nepal's Domestic Electricity Use

While electricity use in Nepal grows from 6 bkWh in 2020 to 43 bkWh in 2045 in the BASE scenario, with APT it doubles to 88 bkWh in 2045. The exports, however, in APT are even larger at 115 bkWh. As noted above, export earnings constitute a significant percent of Nepal's GDP and investment.

- **Sources of Electricity Generation**

Nepal's generation is mainly from hydroelectricity. We have considered three types of hydropower plants: storage based, run of the river with one-day pondage (PROR) and run of the river (ROR) plants. The plants under construction are built by three agents: NEA, IPP with PPA with NEA and Export-Oriented Plants (ExOP), where the investment funds come from abroad and about 12% of electricity generated is given free of charge to NEA and the rest exported. The plants under construction will all come online by 2022–23. Thereafter, all plants are assumed to be built by NEA and source of capital is Foreign Direct Investment (FDI). Figure 5.8 shows the growth of power generation capacity in Nepal.

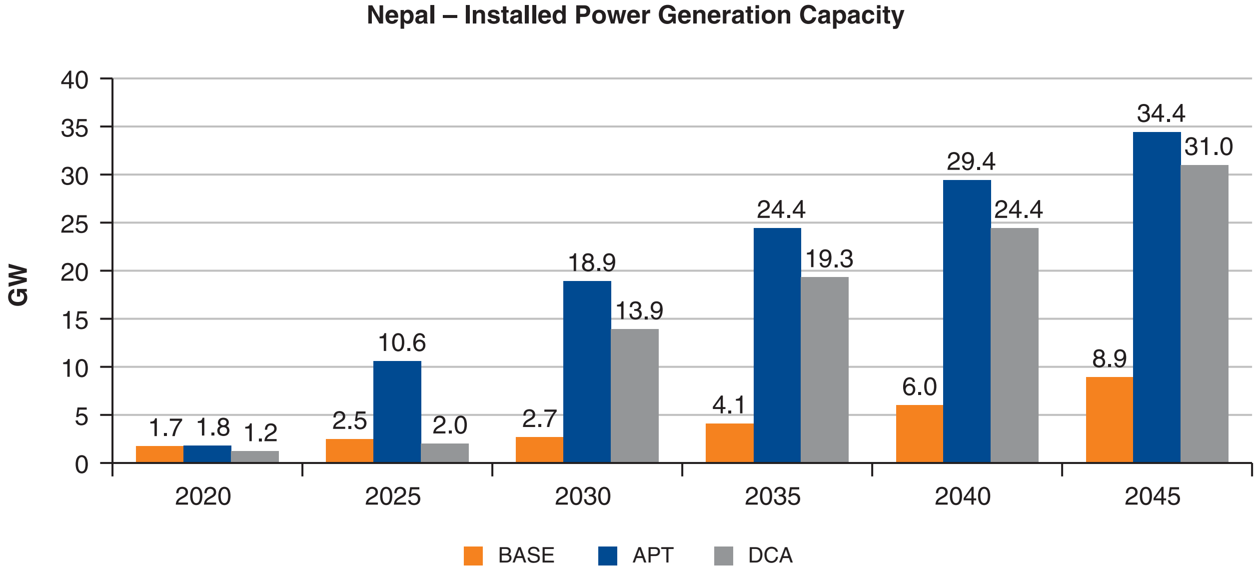


Figure 5.8: Build-up of Power Generation Capacity in Nepal

By 2045, 34.4 GW of capacity is created with APT compared to only 8.9 GW in BASE scenario. It should be noted that maximum economically exploitable hydro potential is assumed as 42.13 GW, however, 34.4 GW is macroeconomically viable exploitable capacity, complying with the investment availability, the BoP constraint of the country and so on. Figure 5.9 shows capacity by type of plants.

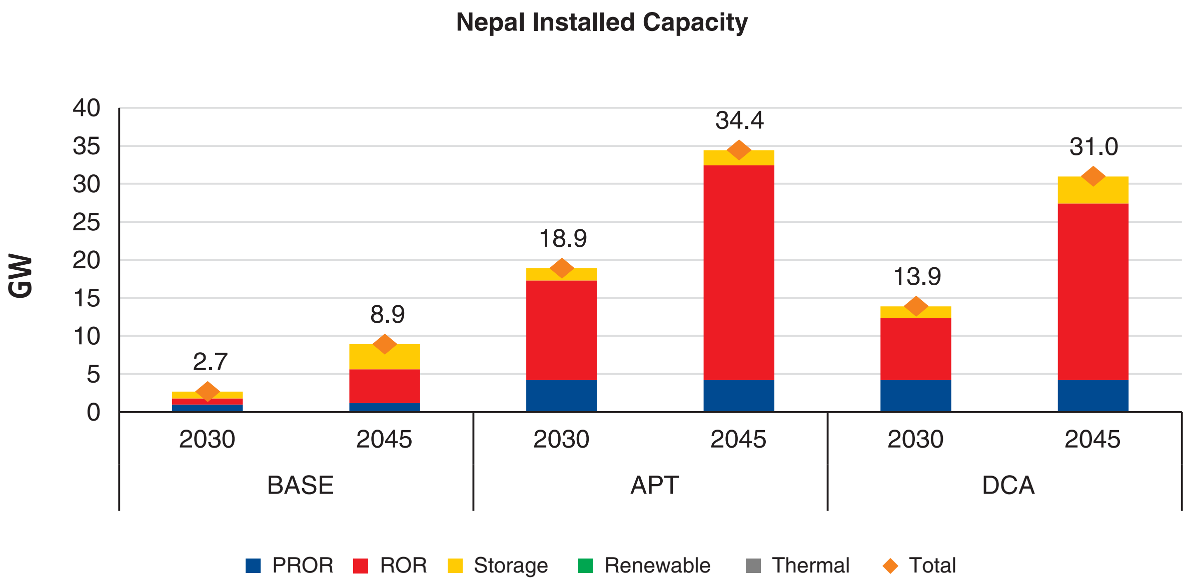


Figure 5.9: Generation Capacity Build-up by Types of Plants

It is seen that PROR plant capacity increases up to 2030 but no further addition is made to it after that. In fact, the bulk of the capacity in APT is in the form of ROR plants, which are cheaper and easier to construct. It is interesting that the capacity of storage plants is marginal in APT and in 2045 less than in BASE scenario. Without trade, Nepal has to invest more in storage plants to meet the seasonal variability in generation and demand. Since storage plants have larger environmental consequences, the lower storage capacity in APT is environmentally beneficial to Nepal.

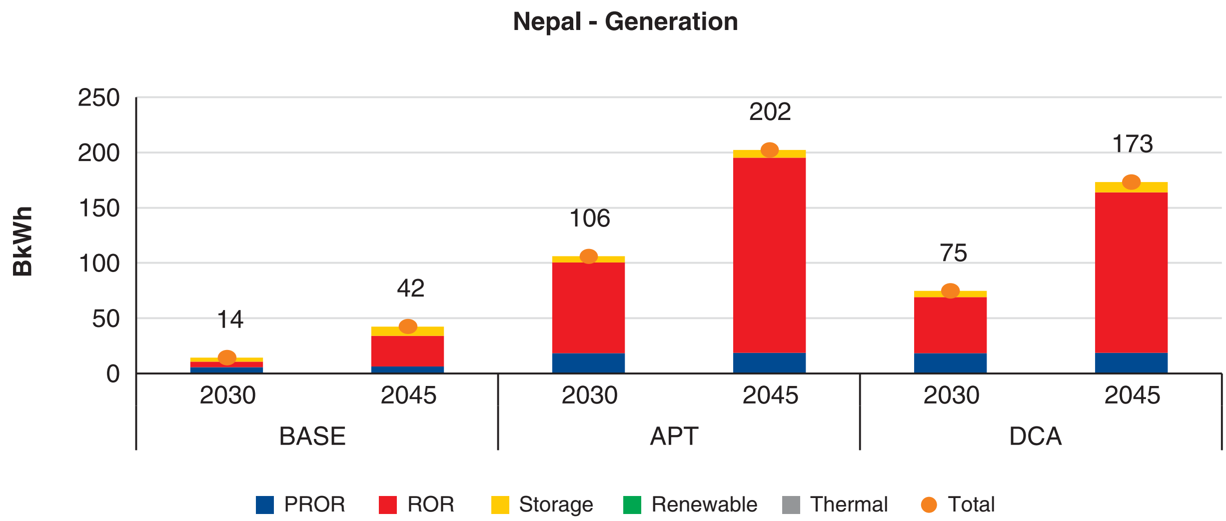


Figure 5.10: Electricity Generation by Type for 2030 and 2045

Generation mix reflects the capacity mix, large generation from ROR type hydropower plants. Generation is many fold higher in APT case (Figure 5.10), and as explained in the beginning of this chapter, a large part will be exported.

Figure 5.11 presents the investment in new generation capacity development in three scenarios for the period 2012–30 and 2012–45. Nepal needs cumulative investment of NPR 384 billion (US$ 5.4 billion) at 2011–12 prices to build hydro capacity over the period 2012–30 in BASE scenario. Average annual investment requirement is NPR 21 billion at 2011–12 prices. If we consider the period 2012–45, cumulative investment is NPR 1143 billion at 2011–12 prices.

As expected in APT scenario, investment is substantially higher, by about respectively NPR 2,596 billion and NPR 4,812 billion during 2012–30 and 2012–45. However, this much investment remains within the tolerance limit of all macroeconomic parameters in the country. Investment in delayed scenario is lower than in the trade scenario, but substantially higher than in the BASE scenario.

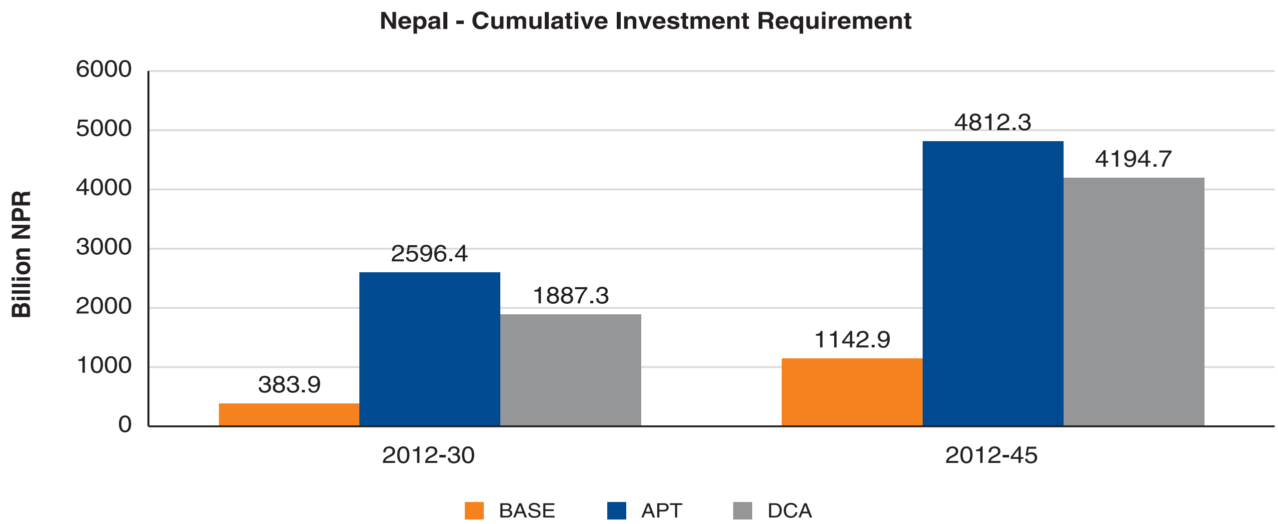


Figure 5.11: Cumulative Investment in Nepal Power Generation Capacity

Power sector investment increases due to trade and export earnings from electricity trade fuel investment in other sectors too. Investment in the economy is substantially higher in the trade case and reasonably higher in DCA compared to that in the BASE case (Figure 5.12).

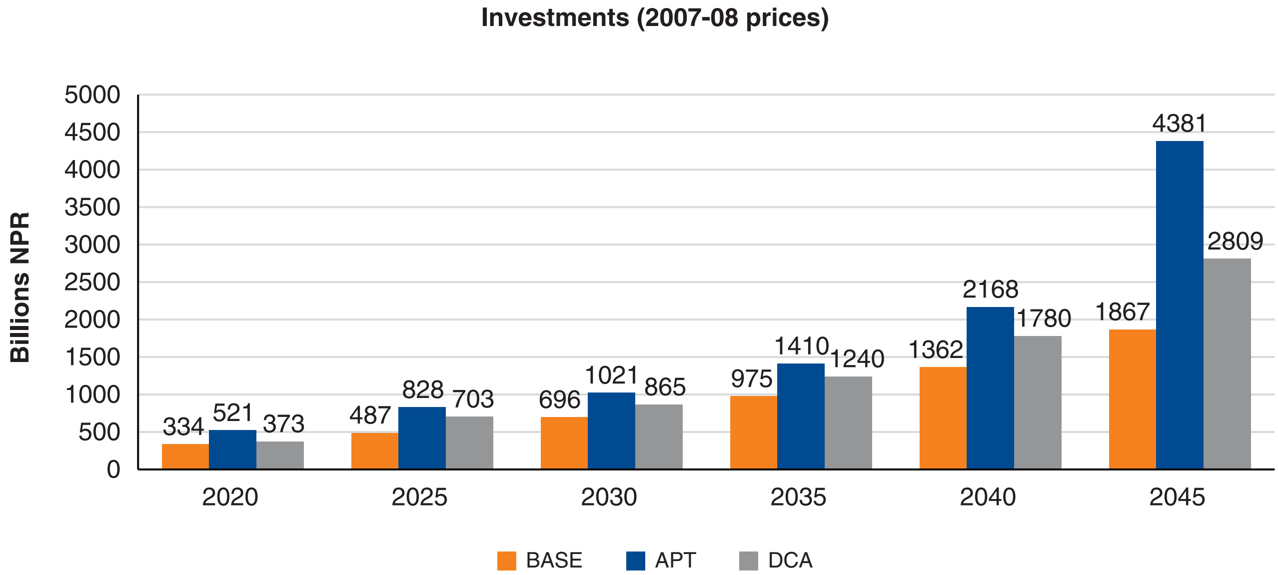


Figure 5.12: Investments in Nepal's Economy

Figure 5.13 shows the net foreign inflow into Nepal's economy. The increase in Nepal's GDP due to trade makes its economy more attractive for investment from abroad, thus leading to higher net foreign inflow. The net foreign inflow increases substantially (87% higher in 2025) when electricity trade is accelerated, however, slows down in DCA case. A large part of the FDI goes into the power sector to finance hydro capacity development.

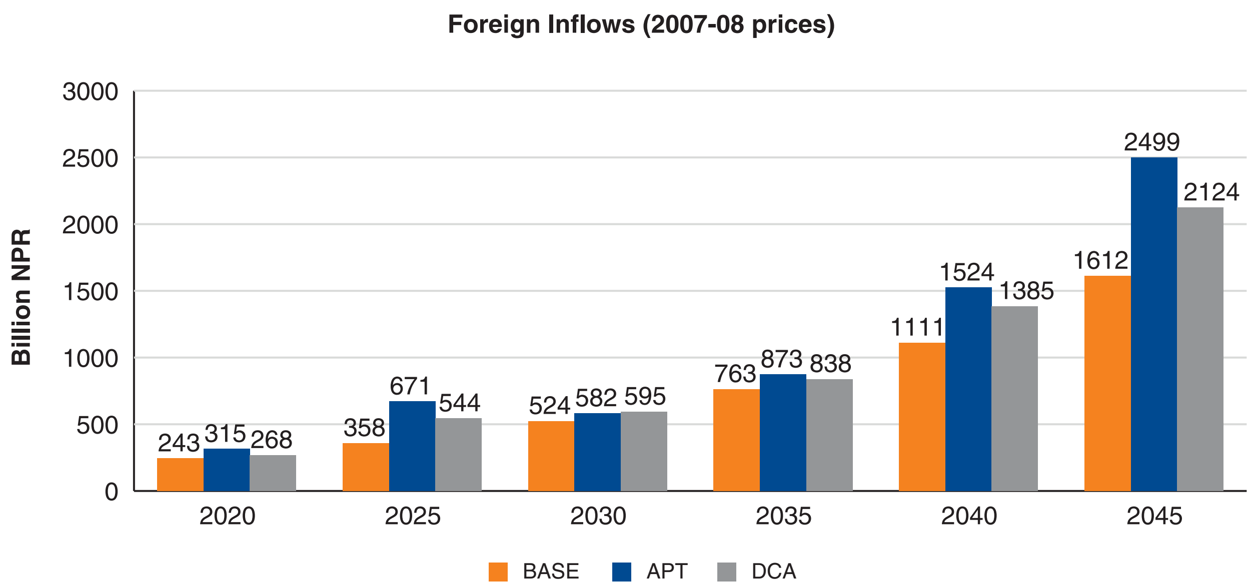


Figure 5.13: Foreign Inflows in Nepal Including Net FDI

- **Structural Change in Nepal's Economy**

Figure 5.14 shows the structure of Nepal's economy in 2045 with APT and BASE. Significant changes are seen. The share of industry in GDP increases to 30% compared to 21% in BASE. Considering that the GDP with APT is nearly 40% higher, in absolute terms, industrial GDP will be twice as large as in BASE. Higher industrial activity implies larger employment with better pay, technological modernisation and better skilled human resources.

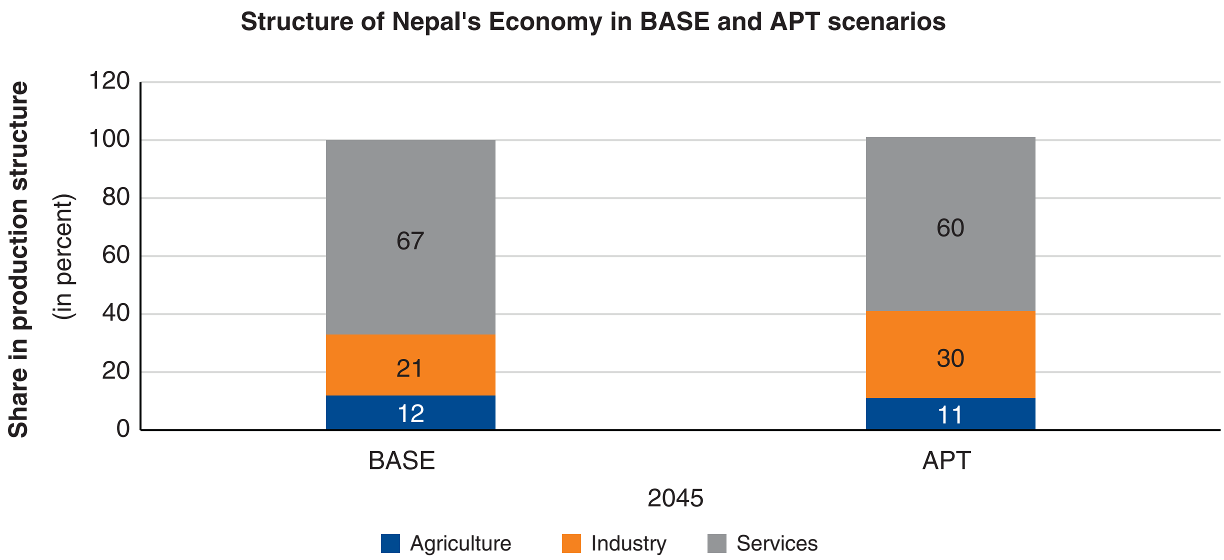


Figure 5.14: Structural Change with Trade

The additional export earnings from electricity trade create more resources for domestic investment and income generation. It, therefore, results in an increase in overall private consumption as well as higher investment creation in the economy. Electricity trade with India leads to higher electricity consumption in Nepal.

Structural change in sectoral composition of GDP is driven partly by changing demand structure in the economy on account of higher levels of income, higher investment flow into the economy and partly due to change in production structure due to increased availability of power, which is an essential input to production. We discuss in little more detail the changes that take place within the manufacturing and service sectors, as these two sectors are important in terms of job creation, and other effects like technological modernisation, skill development and so on.

Table 5.3: Percentage Change in Components of Supply and Demand in APT with Respect to BASE

	Year	Y	M	C	ID	Z	EXP	GC
Agriculture	2030	17	17	12	28	16		
	2045	27	27	9	49	105		
Manufacturing	2030	36	36	30	31	47		
	2045	60	60	23	46	135		
Gas and water supply	2030	79	79	42	166	47		
	2045	51	51	36	103	135		
Transport	2030	24	24	28	-40	47		
	2045	32	32	29	29	135		
Other services	2030	10	472	21	54	47	-100	
	2045	21	21	25	55	135	-67	

The availability of investible resources and power results in an overall increase in the availability of manufacturing in Nepal's economy (Table 5.3). Output (Y) and imports (M) both increase by 36% in 2030 and 60% in 2045, respectively. This leads to expansion of the manufacturing sector much more than others and thus contributes to higher share of industry in GDP by 2045. This increase in domestic supply caters to higher demand for manufacturing sector goods from private consumer demand by households and to investment demand of manufactured goods. Private consumption demand for manufactured goods by household increases by 30% in 2030 and 23% in 2050 in the APT scenario compared to BASE. Investment demand for manufacturing sector's output increases in the APT scenario by 47% in 2030 and 135% in 2045, respectively. Overall increase in economic activity results in an increase in intermediate demand for manufactured goods by 31% in 2030 and 46% in 2045 respectively.

The 'Other services', which forms an important part of the services sector, has an overall share of 67% in 2045 in GDP in the BASE scenario. This reduces to 60% under the APT scenario. This is reflected in the impact on other services and transport sectors. Demand for other services sector's output increases. However, its output increases only by 10% in 2030 and by 21% in 2045 respectively while imports increase by 472% in 2030 and 21% in 2045 respectively in the APT scenario compared to BASE. However, imports are a very small proportion of the total demand. Exports of services decreases by 100% in 2030 and by 67% in 2045 respectively in the APT scenario compared to BASE. Nepal's higher export earnings from electricity reduce the need to increase earnings from exports of other commodities and improve the terms of trade for Nepal, a heavy importer of most commodities from India. Increase in earnings from export of electricity relaxes the need to earn more from export of services. This leads to a lower expansion of services sector compared to the industrial sector. The increased supply of services sector caters to the increased demand from private consumer demand for services sector, which increases by 21% in 2030 and 25% in 2045 respectively; investment demand for other services increases by 47% in 2030 and 135% in 2045 and intermediate demand increases by 54% in 2030 and 55% in 2045 respectively. Refer Annexure 3 for more details.

Thus, overall we see that the increased flow of export earnings in Nepal's economy leads to creation of additional investment in the economy. This increases the demand for goods and services through investment requirement. The additional investment leads to higher output of all sectors and higher resources to import for all commodities (through higher export earnings). This leads to higher overall supply in Nepal's economy, which supports higher investment demand of all commodities and higher private household consumer demand and intermediate consumption demand. The analysis of the 2007–08 SAM, which forms the base data for Nepal's economic model, suggests that its economy has a high contribution from agriculture (30% in 2007–08). The share of services is also high (50%). The share of industry is low at 20%. The growth of industry is impeded by the lack of enough assured power supply. The availability of more electricity in Nepal's economy along with large export revenue helps in the expansion of the manufacturing and gas and water supply sectors and results in higher expansion of the sectors, which was constrained by lack of investment and availability of power in the BASE scenario.

Summary of Benefits to Nepal from Accelerated Electricity Trade

The main benefits are as follows:

- Model results demonstrate that a large economically feasible electricity export potential exists. Also freer trade makes it possible to import more electricity from India in the short or medium term when hydro projects are under development, therefore fuelling Nepal's development.
- APT leads to significant step-up of growth of household consumption, which increases by 23% over the BASE scenario. Per capita consumption in 2045 reaches a level of NPR 2,84,000 at constant 2007–08 prices, as against just NPR 27,000 in 2012.
- GDP reaches a level of NPR 13,100 billion at 2007–08 prices in 2045 with APT, which is 39% higher than in the BASE scenario.

- In BASE scenario, Nepal needs NPR 384 billion (at 2011–12 prices) cumulative investment in power generation capacity over the period 2012–30. It will increase more than six times in the same period in trade case.
- Investments in 2045 with APT become 33% of GDP, suggesting more robust growth in the future.
- The structure of the economy changes with APT. The share of industry in GDP becomes 30% compared to 21% in BASE, indicating more industrialisation, and therefore higher employment, technological modernisation, improvement in human skill and so on. Since GDP is 39% larger, in absolute value, industrial GDP doubles in APT.
- The increases in household consumption increase human welfare directly, while increases in GDP suggest other benefits such as employment, better public goods, etc. Similarly, change in the structure of the economy suggests better paying jobs.
- Per capita electricity consumption, traditionally strongly correlated with human development, increases by 50% in 2045 in Trade scenario.
- All these happen because Nepal's hydropower potential is utilised. The power generation capacity increases to 34.4 GW in 2045 with APT compared to only 8.9 GW without trade.
- Net export revenues from electricity exports are 1,069 billion NPR in APT and 998 billion NPR in DCA scenario in 2045 (at 2011–12 prices). The export earnings for Nepal are around 5% to 6% of GDP and as high as 25% of total investments in 2040, and although they decline in 2045, they still are at 15%.
- Most of the hydro plants with APT are the ROR type, which are the cheapest and easiest to construct. They also have the least environmental externality and less human displacement issue. Without emphasis on trade, Nepal will have to invest more in storage plants with their environmental and displacement consequences.

This is a long-term strategy, which highlights that the early years will be the import phase (up to 2025) that supports faster economic growth for Nepal and takes care of the internal unmet demand. Later years will be the export phase wherein Nepal is the net exporter of electricity that brings it economic gains. Nepal needs to take a decision now to build the infrastructure for import and export of electricity. Sooner it does this, the better it is, since cost of delay is substantial. In the following section, we discuss the impact of electricity trade on India.

Impact of Electricity Trade on India

India's is a much larger economy and has a far bigger power system. Current share of the power sector in GDP at 2007–08 prices is negligible at 1.5% in 2007–08, is expected to be further down in future as the economy grows. Moreover, although it looks large (115 bkWh in 2045), import constitutes only 2–2.5% of total generation requirement. Thus although trade consequences for India's economy would be relatively negligible on the total GDP and consumption, they do exist. More than macroeconomic gain, India gains in terms of lower electricity system costs, as due to trade India can forgo some of the investment it would have to make to meet its demand. The main impact will be on the power sector. Import of electricity from Nepal reduces its need for generation, capacity creation and investment for it. As stated earlier, as peak occurs in the evening in the Indian system, import helps to meet India's evening peak and renewable energy commitment as by 2045, India would have almost 327 GW solar PV, so imported capacity available in the evening helps to counter the intermittency and to meet the peak. Also, since Nepal's electricity is based on hydropower plants and India's power system is primarily coal based, imports from Nepal not only cut down India's carbon emissions, but also reduce global emissions. The benefits for India are listed in the ensuing sections.

Impact on India's Power Sector

Import reduces the power generation requirement for India by 4.9% and 5.3% under the APT and DCA scenario compared to BASE scenario in 2045 (Figure 5.15). The trade influence is maximum on coal-based generation, which is reduced by 209 bkWh (5.1%) and 217 bkWh (5.3%) under the APT and DCA scenario compared to BASE scenario in 2045. In the same year, gas-based electricity generation reduces by 13% and 20% under the APT and DCA scenarios (Table 5.4).

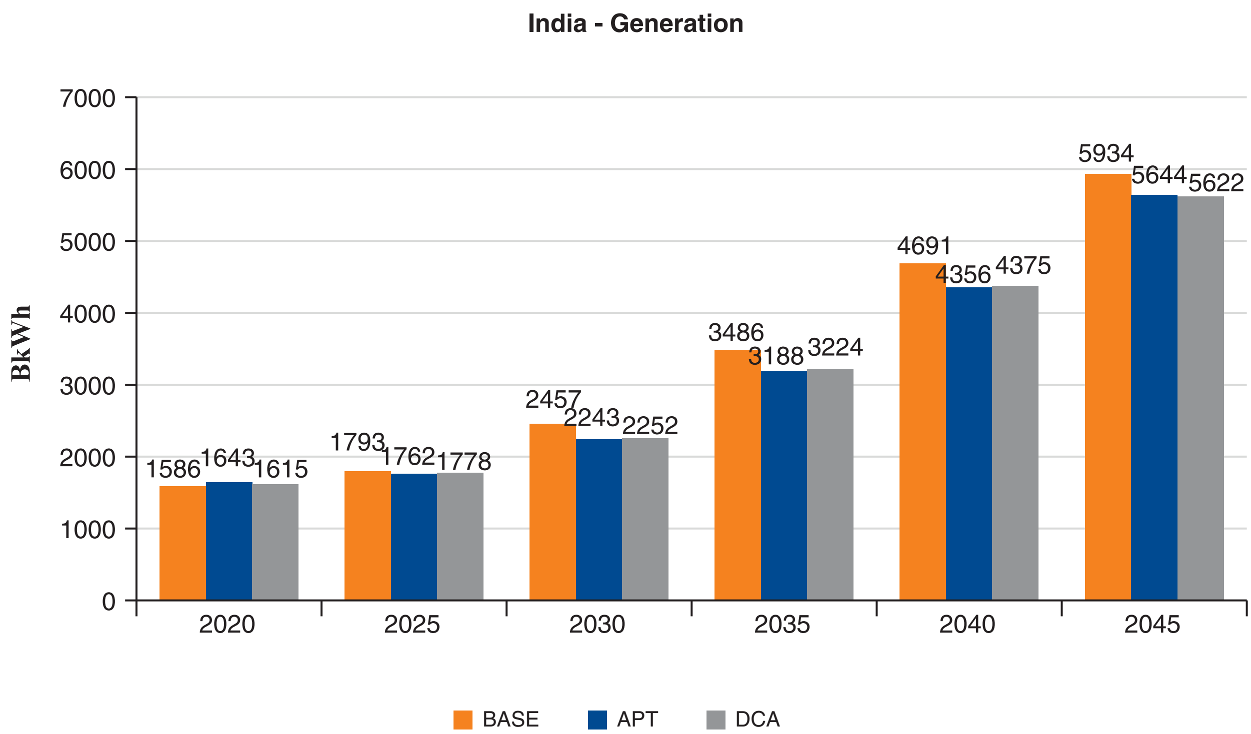


Figure 5.15: India's Electricity Generation

Table 5.4: Reduction over BASE in Electricity Generation Requirement by Fuel Type (in BkWh)

Year 2045	BASE	APT		DCA	
	in BkWh	Change over BASE (BkWh)	% Change	Change over BASE (BkWh)	% Change
Coal	4,042	209	5%	217	5%
Gas	101	14	13%	20	20%
Solar PV	518	19	4%	19	4%
Onshore wind	280	49	17%	56	20%
Total	5,934	291	5%	312	5%

Electricity trade reduces installed capacity requirements. The total installed capacity in BASE by 2045 is 1,410 GW, which reduces by 4.8% to 1,341 GW under the APT and by 5.2% to 1,335 GW under the DCA scenario (Figure 5.16). On technology type, the capacity reduction is observed for coal, gas, solar PV and onshore wind capacities (Table 5.5).

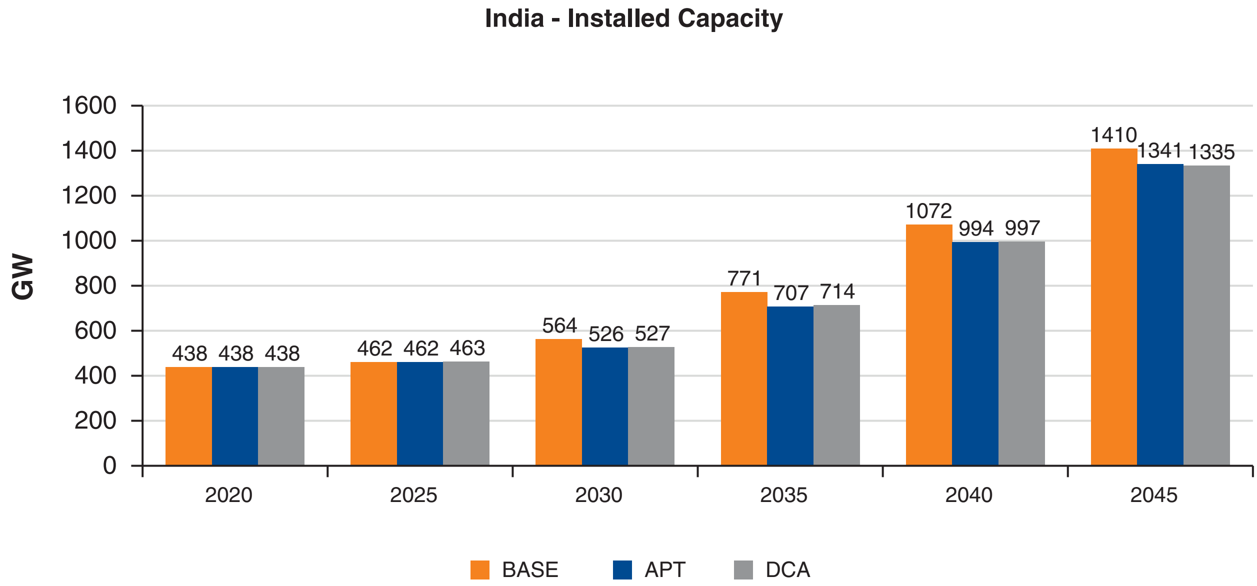


Figure 5.16: India's Power Generation Installed Capacity

Table 5.5: Reduction over BASE in Installed Capacity Requirement by Fuel Type (in GW)

Year 2045	BASE	APT		DCA	
Type	GW	Change over BASE (GW)	% Change	Change over BASE (GW)	% Change
Coal	694	35	5%	36	5%
Gas	49	1	1%	3	6%
Hydro	145	0	0%	0	0%
Solar PV	327	12	4%	12	4%
Onshore wind	93	20	22%	23	25%
Total	1,410	69	5%	75	5%

- **Gains to India's Economy from Electricity Trade with Nepal**

India's domestic electricity demand in 2012 was of the order of 785 TWh while that of Nepal was 3,822 GWh. The size of Nepal's demand is 0.5% of India's demand. This is also consistent with the size of Nepal's economy with respect to India's economy. Electricity trade between India and Nepal can be characterised by large country–small country trade, where monetary, fiscal or trade expansion in the small country does not affect the output or GDP levels much in the large country. However, changes in the large country have a significant impact on the small country.

As stated earlier, on the Indian side, electricity trade accounts for a very small share (2–2.5%) given India's large generation requirement. Economic benefits of electricity trade are very limited to India. However, if one looks from the point of view of efficiency in power systems operation, reduction in power systems cost, reduction in costs to meet peak load, achieving higher efficiency through lower fossil fuel use, managing intermittency of renewables especially solar, and environmental benefits, then India benefits substantially. The impact on India is presented in the ensuing discussions.

Figures 5.17 and 5.18 show the impact of electricity trade on India's GDP and per capita consumption trajectory from 2020 to 2045. Under the APT and DCA scenarios, the GDP for India is marginally below the GDP in BASE case. This is expected as in the trade scenarios, India can forgo some investments in capacity additions to meet its power demand. Lower creation of capacities implies lower production to meet the same demand. Lower production would imply lower GDP in power sector and by intersectoral linkages lower GDP in other sectors too. However, as the plots of per capita consumption show India gains in terms of marginally higher per capita consumption due to trade (APT and DCA). Higher gain is due to export earnings in the initial years and higher imports from Nepal and lower investment cost to meet the same demand and GDP, which results in welfare gain to India in terms of higher private household consumption. The cumulated total consumption gain for 2030 and 2045 is plotted in Figure 5.19.

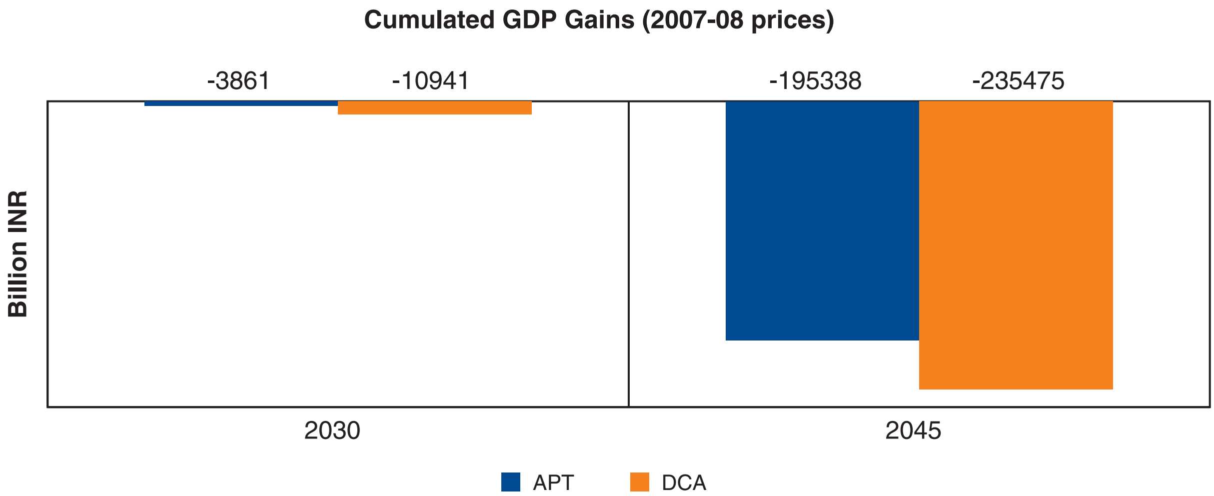


Figure 5.17: Impact of Electricity Trade with Nepal on India's GDP

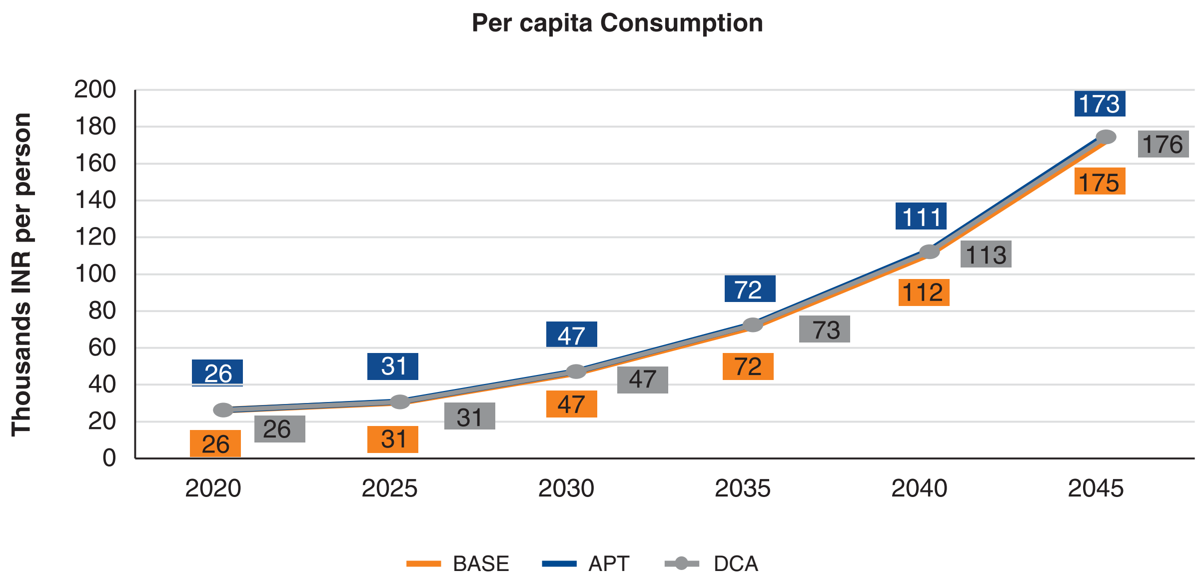


Figure 5.18: Impact of Electricity Trade on India Per Capita Consumption

Electricity trade with Nepal results in higher exports of electricity initially allowing India's power plants to earn more export revenues, and later by reducing the need for fresh investment in domestic power production and instead meeting the domestic demand through imports from Nepal. On both occasions, India gains economically resulting in lower investment requirement to have higher living standards. The cumulated total investment at 2007–08 prices in India's economy in the three scenarios is provided in Figure 5.20. The results show much lower investment requirement for India from 2030 onwards.

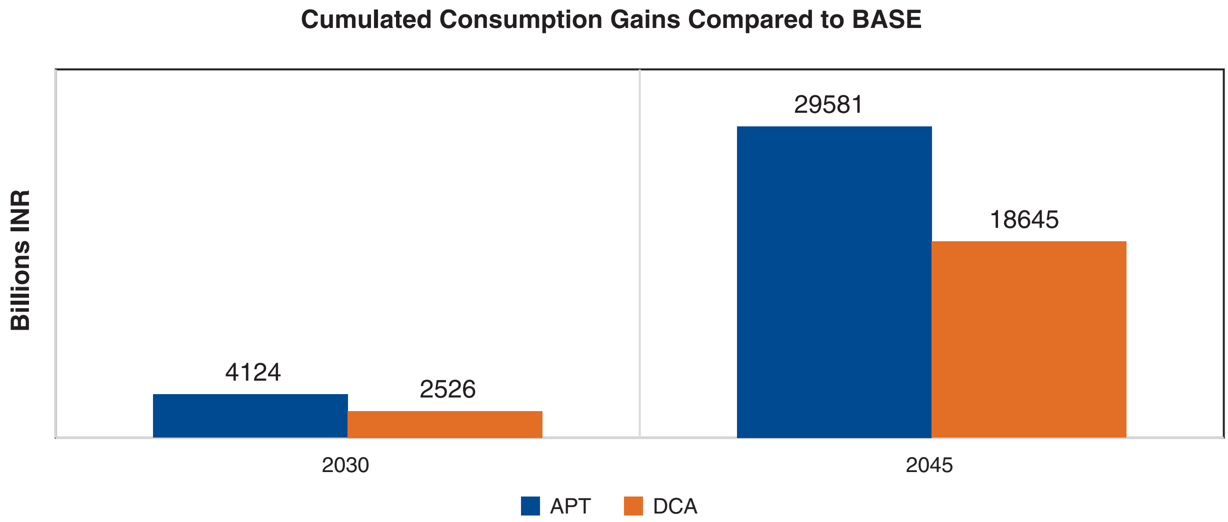


Figure 5.19: Impact of Electricity Trade on India's Cumulated Total Consumption (2012–2045)

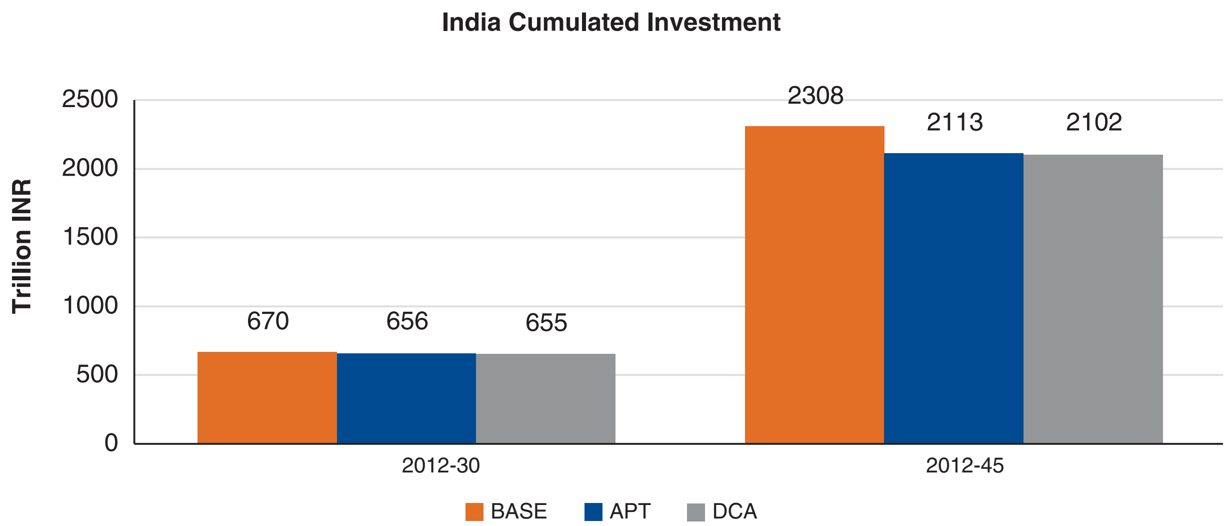


Figure 5.20: Impact of Electricity Trade on India's Cumulated Total Investment (2012-2045)

In the BASE scenario, to build new generation capacity over 2012–30, India needs cumulative investment of INR 21 trillion at 2011–12 prices, meaning INR 1.17 trillion (US$ 25 billion) every year (Figure 5.21). The reduction in installed capacity reduces the overall investment requirement of the power system. The investment requirement in the APT and DCA scenario reduces by 2,298 billion INR and 2,178 billion INR at 2011–12 prices respectively compared to BASE scenario over the period 2012–30. It would be much larger if we consider the period 2012–45.

As stated earlier, electricity import reduces its generation from coal and gas. Lower use of coal in power generation and partially lower GDP result in lower demand for coal and gas. Coal consumption in India's economy reduces by 143 MT in 2030 and by 353 MT in 2050, respectively, under the APT scenario compared to the BASE scenario. Gas consumption is reduced by 2 BCM in 2030 and by 6 BCM in 2045 in the APT scenario compared to BASE scenario.

This results in lower production and import of coal and gas. This, in turn, adds to lowering of the investment requirement and provides gains on the BoP side by saving foreign exchange due to lower import requirements. All these add up to higher consumption and environmental gains for India. Table 5.6 provides the production, imports and demand for coal and gas.

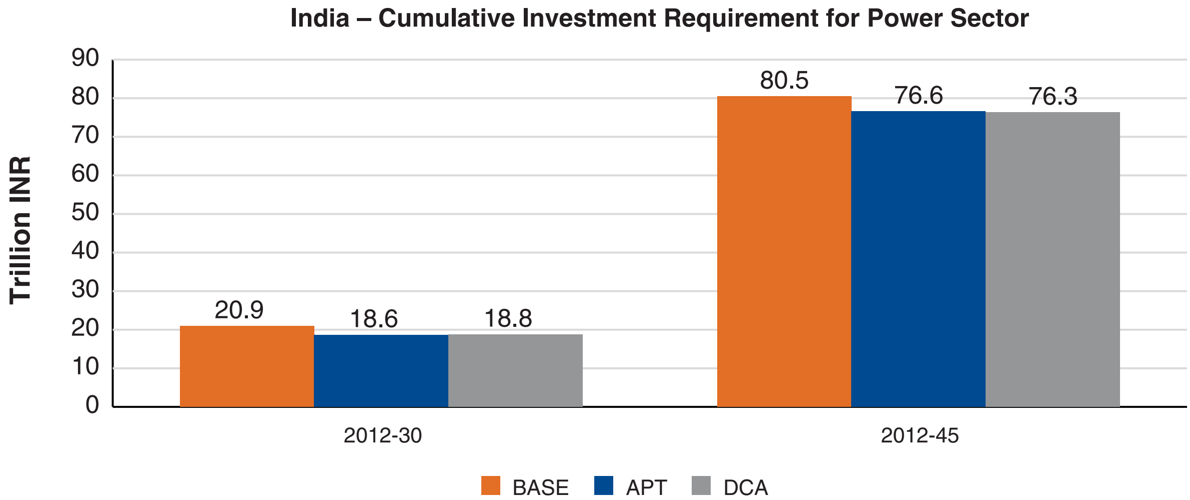


Figure 5.21: India's Cumulative Investment Requirement for Power Sector

Table 5.6: Impact on Fossil Fuel Use Due to Electricity Import from Nepal

	Coal Production (MT)			Coal Import (MT)			Coal Demand (MT)		
Year	BASE	APT	DPT	BASE	APT	DPT	BASE	APT	DPT
2025	1129	1196	1111	77	57	75	1206	1253	1186
2030	1789	1649	1643	42	39	38	1831	1688	1681
2045	3621	3276	3251	85	77	76	3706	3353	3327
	Gas Production (BCM)			Gas Import (BCM)			Gas Demand (BCM)		
Year	BASE	APT	DPT	BASE	APT	DPT	BASE	APT	DPT
2025	101	100	103	6	6	6	107	106	109
2030	122	122	122	16	14	13	138	136	135
2045	144	144	144	90	84	83	234	228	227

Reduction in fossil fuel use results in lower CO_2 emissions by India. Figure 5.22 gives the cumulated CO_2 emissions in the three scenarios. Compared to the BASE scenario, the APT scenario achieves a reduction in cumulated CO_2 emissions by 0.572 GT in 2030 and by 5.71 GT in 2045.

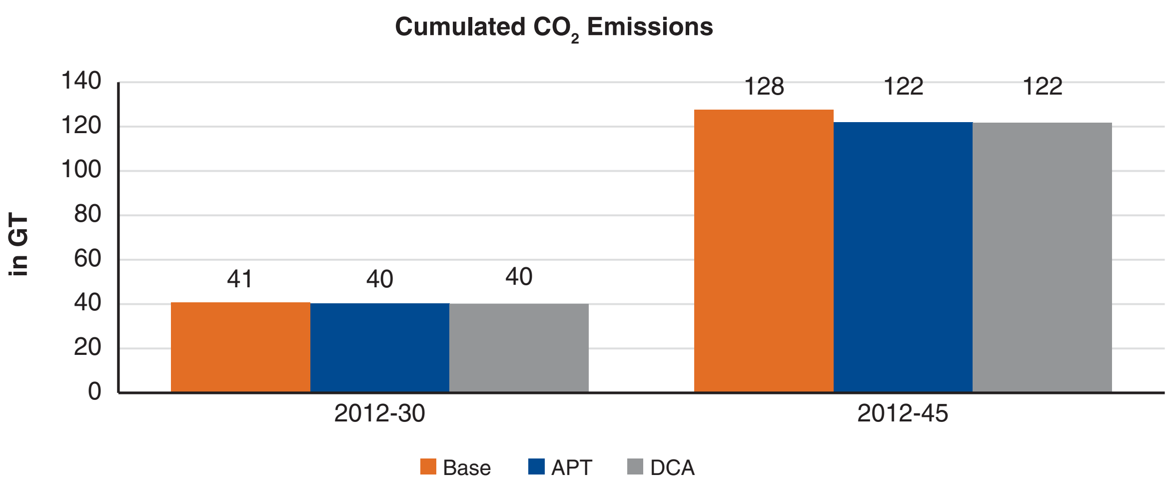


Figure 5.22: Impact of Electricity Trade on India's Cumulated CO_2 Emissions

In the BASE scenario, Indian power system will remain heavily dependent on coal. Electricity trade with Nepal primarily replaces the thermal generation, coal and gas in the APT and DCA scenarios, reducing by more than

5% in the year 2045. This reduction primarily based on coal helps in reducing the cumulated CO_2 emissions from Indian power generation by about 3,625 MT in the APT and 3,529 MT in the DCA scenario compared to BASE scenario from 2012 to 2045 (Figure 5.23). In percentage terms, under the APT and DCA scenarios the cumulated CO_2 emission from 2012 to 2045 reduces by 5.6% and 5.4%, respectively, compared to BASE scenario. As India wishes to play a leadership role in the global climate change battle, this is an important gain, all the more because emission reduction is achieved without compromising the growth, development and living standard of its people.

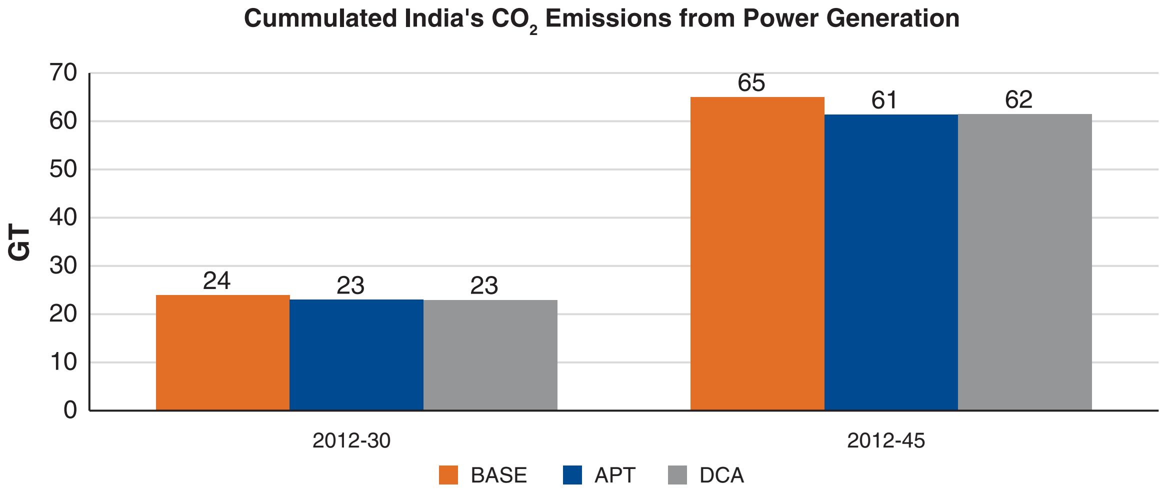


Figure 5.23: Impact of Electricity Trade on India's Cumulated CO_2 Emissions from Power Sector

Summary of Benefits to India from Accelerated Electricity Trade

The main benefits are as follows:

- As India has a much larger economy and a far bigger power system and the share of the power sector in GDP is negligible, trade consequences for India's economy would be relatively negligible in percentage terms; however, they do exist. The gain in cumulated total consumption over 2012 to 2045 is 47 trillion INR in 2007–08 prices, which in percentage terms is only 1.4% but is larger than gains in cumulated consumption in Nepal in absolute terms. The main impact, though, will be on the power sector.
- Given India's large appetite for generation, electricity import, despite seeming big (115 bkWh in 2045), constitutes only 1.6–2.5% of the total generation.
- It may be noted that India imports electricity even when its own hydropower potential of 145 GW is fully utilised.
- Trade lowers electricity supply costs by reducing capacity and investment requirements.
- As peak occurs in the evening in the Indian system and India's renewable energy commitment includes large presence of solar PV, import capacity in the evening helps to counter the intermittency and meet peak demand at lower costs.
- Trade reduces coal- and gas-based generation and hence use of coal and gas in power generation as well as in the rest of the economy, lowering the production and import of these fuels. Reduction in import saves outflow of foreign exchange.
- Trade causes marginal increase in per capita consumption and decline in GDP, as investment and production decline due to import. India gains economically by having higher living standard with less investment.
- Reduction in fossil fuel use results in lower cumulated CO_2 emissions from Indian power generation as well as from the Indian economy as a whole. Given India's desire to play an important role in combating global climate change, this is important as reduction is achieved without compromising the growth, development and living standard of its people.

Conclusions

Hydropower is one of the few resources Nepal has which remains primarily unexploited, whereas development of hydropower potential and electricity trading with India has benefited neighbouring Bhutan significantly in its socioeconomic development. Hydropower potential can be developed economically only if there is demand for the electricity generated, either domestic or external. Nepal-India CBET study is undertaken to answer the following key questions:

- Why trade electricity? What benefits will accrue to the people of Nepal and India? Are there macroeconomic benefits of electricity trade (from export earnings and investment in the sector)? Are there environmental benefits of such trade?
- What would be the tradable quantity of electricity and price agreeable to both buyer and seller?

To answer these complex technoeconomic questions, the study developed a modelling system, which deploys two types of models with a 30-year perspective, power system model that balances demand and supply on hourly basis and macroeconomic model that factors in impact on various sectors of the economy and its development. Iterative linkage between these models produces consistent solutions. The modelling system is used to analyse three scenarios. The BASE scenario assumes no increased interconnections across countries beyond what are currently in place (as in 2011–12), therefore each country independently makes its own capacity investments to satisfy its projected demand profile.

The APT scenario allows full potential of electricity trade. A DCA scenario on delay in hydropower project implementation by 5 years in Nepal due to delays in decisions to initiate projects and in their implementation has been developed as well, since delay may not only postpone the earning from exports, it may even increase the imports until the projects are implemented. We compare the results of the APT scenario with the BASE scenario to quantify the macroeconomic benefits of trade and we compare the DCA scenario with the APT scenario to assess the cost of delay.

Some of the key information that the study produced that would be useful to stakeholder groups includes physical quantity of electricity trade, electricity price with and without trade, savings in new capacity addition due to trading, investment potential, export earnings and socioeconomic benefits from export earnings and investment, and so on.

Key findings of the study are highlighted here separately for Nepal and India:

6.1 Nepal

- Nepal's hydropower potential could be a source of large economically feasible electricity export to India starting from the year 2025 as development of hydropower projects needs some time.
- The sooner the development of trade infrastructure takes place, the better it would be for Nepal as it would

allow import of much needed electricity from India in the short or medium term during the construction of hydropower projects, which would help fuel Nepal's development, and use the same infrastructure for export when the hydropower plants are ready.

- APT leads to significant step-up of growth of household per capita consumption, an indicator of improvement in well-being, which increases by 23% over the BASE scenario.
- Per capita electricity consumption, traditionally strongly correlated with human development, increases by 50% in 2045 in the APT scenario.
- In the APT scenario, net annual export revenue from the electricity trade is NPR 310 billion in 2030, which jumps by 2-1/2 times to NPR 840 billion in 2040, rises further to NPR 1,069 billion in 2045. Delayed capacity addition reduces earnings.
- GDP in 2045 with trade in APT is 39% higher than in the BASE scenario.
- Investments in 2045 with APT become 33% of GDP, suggesting even more robust economic growth in the future.
- Trade promotes industrialisation in the country as the share of industry in GDP becomes 30% compared to 21% in BASE and since GDP is 39% larger, the level of industrial GDP doubles in APT. Industrialisation can create better-paying employment.
- All this happens because Nepal's hydropower potential is utilised. The power capacity increases to 34.4 GW in 2045 with APT compared to only 8.9 GW without trade.
- In the APT scenario, substantial power capacity is built through FDI. The value of foreign inflow over 2012 to 2045 is 28,931 billion NPR. If this 4,649 billion NPR is used to fund investment in power capacity, it amounts to 51% of the total investment in power sector through outside support.
- The increase in household consumption and electricity use increase human welfare directly, while increase in GDP suggests other benefits such as employment, better public goods etc. Similarly, change in the structure of the economy suggests better-paying jobs.
- Even a five-year delay in capacity creation reduces these benefits substantially compared to APT. In 2045 GDP is higher compared to BASE by only 14% (39% in APT) and per capita consumption by only 10% (23% in APT).
- Without emphasis on electricity trade in the BASE scenario a number of storage type hydropower projects are required to meet domestic demand. With trade in APT, exploitation of hydropower potential is through ROR plants, which are the cheapest and easiest to construct. In addition, ROR plants cause less environmental externality and human displacement compared to storage type plants. Thus, electricity trade also provides environmental benefits to Nepal.

6.2 India

- India's is a much larger economy and has a far bigger power system. The power sector has negligible share in the GDP. Thus, economic benefits out of electricity trade in percentage terms are limited compared to its economy in India. However, India still gains in terms of economy and environment:
  - In APT per capita consumption in 2045 increases by 1.7% though GDP reduces by 6.33% compared to BASE. In absolute terms however, the gain in cumulated consumption from 2012 to 2045 is larger for India than for Nepal.
  - Electricity supply cost is lower as imported electricity is cheaper than domestically produced one.
  - The domestic generation, capacity creation and investment in the power sector are reduced.

- o More importantly, as India plans to have large solar capacity as part of its ambitious renewable target, and peak in the system occurs in the evening, available imported capacity in the evening helps to counter solar intermittency and meeting peak demand.
- o It may be noted that India imports electricity from Nepal even when its own hydropower potential of 145 GW is fully utilised.
- o Use of energy commodities (coal and gas) for power generation is lower, therefore their production and import needs are lower.
- o Reduced use of fossil fuels reduces pollution and brings environmental benefits.
- o As import is sourced from hydropower plants with their flexibility in generation, it helps India to meet its renewable target by providing balancing power.
- o The cumulated CO_2 emission from 2012 to 2045 reduces by 5.6% and 5.4%, respectively, compared to BASE scenario. This is important for India, with its increasing leadership role on climate change issues.
- o With reduced CO_2 emissions by India, the world also gains.

6.3 Way Ahead

The study shows that both Nepal and India gain significantly economically and environmentally. It also shows that the benefits are significantly lowered by delay. In addition, even though significant exports to India begin only by 2025 as capacity and infrastructure development will take time, Nepal benefits meanwhile through larger import of electricity from India. The decision on trade needs to be taken as soon as possible.

Policy, institutional and technical infrastructure are needed for electricity trade to materialise. Nepal is currently importing from India, so technical infrastructure (interconnection) exists. However, that needs to be enhanced manifold if the type of trade potential that the study indicates is to be realised. Both building hydropower projects and transmission infrastructure is highly investment intensive. Without a stable, long-term conducive policy and an institutional environment in place, which ensures payment security, it is unlikely that investors will put their money in this risky business. To keep the framework insulated from political volatility, a legislative framework may be more desirable.

Although slow, some development has taken place. Since its initiation, the SARI/EI project in 2012 being implemented by the IRADe has looked into all possible issues hindering electricity trade in the region. Three intergovernmental task forces (each represented by the national governments, national power transmission utilities, national electricity regulatory commission, power market institutions, and other in-country organisations) examined three key areas: (1) Coordination of policies, legal and regulatory framework; (2) Advancement of transmission system interconnections; (3) South Asia regional electricity market.

Task Force 1 works on the harmonisation of policies and regulations, framework for licensing, open access, tariff and trade negotiations, dispute resolution mechanism, and so on, thus creating conditions for a sustainable market for investment and the implementation of CBET projects.

Task Force 2 identifies import–export points for technically and economically feasible cross-border interconnections over the next 20 to 30 years. It also formulates the required coordination procedures for stable regional/national grid operations.

Task Force 3 explores market-driven, commercial practices in the trading of power, including long-term contractual instruments and medium-/short-term trading exchanges. It covers matters relating to agreements on guarantee mechanisms, tariffs, wheeling changes, attribution of transmission losses and transmission pricing.

These three task forces over the last four years have explored these issues and come up with solutions and recommendations. This shows that a consensus was arrived at among high-level technical and policy makers. Thus, solutions are mostly available and implementation at national or regional level is awaited.

For this, a wider consensus at the public and political level is needed. Recent speedy trade development between India and Bangladesh demonstrates what sincere political commitment of the trading countries can achieve. Trust needs to be built that CBET is mutually beneficial and that any delay in CBET only deprives people of the much-needed economic development they need. Civil society and political establishments need to work together to get quick results. Moreover, findings of this type of study could be useful to explain and convince people.

Some progress is observed in the South Asian countries. For example, SAARC foreign ministers have signed a regional energy cooperation agreement titled "SAARC Framework Agreement for Energy Cooperation (Electricity)" during the concluding ceremony of the 18th SAARC Summit held on November 26 and 27, 2014.[16]

The Parliament of Nepal endorsed the SAARC Framework Agreement for Energy Cooperation on 30 August 2016 to conduct CBET.[17] Recently, India has taken the lead in integrating the electricity grids of countries in South Asia. The government has issued guidelines on CBET policy to enable Indian producers to seamlessly exchange power with neighbouring nations.[18]

The study has assessed the economic, environmental and developmental benefits that can accrue to Nepal and India through bilateral trade. We are in the process of exploring the scope and impact of bilateral trade between Bangladesh and India. It would be a natural step to extend it to multilateral trade. We believe that much larger gains can be obtained if multilateral trade takes place first among, Bangladesh, Bhutan, India and Nepal and then extended to Myanmar.

16 http://www.saarc-sec.org/userfiles/SAARC-FRAMEWORK-AGREEMENT-FOR-ENERGY-COOPERATION- ELECTRICITY.pdf

17 http://sasec.asia/index.php?page=news&nid=516&url=saarc-framework-agreement-for-energy-cooperation

18 http://economictimes.indiatimes.com/articleshow/53643850.cms?utm_source=contentofinterest&utm_medium=text&utm_ca mpaign=cppst

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Annexure 1: Assumptions for Nepal's Economic Model

General Assumptions

The following are some of the key assumptions valid for all the selected scenarios:

a) Population

All the scenarios use the UN medium variant population for Nepal. The population of rural and urban areas assumed under the scenarios is given in Table 1.

Table 1: Total, Rural and Urban Population growth

Population* (in millions)				
Year	**Total**	**Rural**	**Urban**	**Urbanisation (in %)**
2005	25	21	4	15%
2010	27	22	5	17%
2020	30	24	6	21%
2030	33	25	8	25%
2040	35	25	11	30%
2050	36	24	13	36%

* Population UN Medium Variant

b) Resource Reserves and Growth Assumptions

Reserves of natural resources such as coal and lignite, crude oil and natural gas grow over the years with exploration for new resources. For scenarios, the growth rate assumption for natural resources is provided in Table 2.

Table 2: Resource Growth Assumptions

Resource	Potential
Hydro potential	43 GW
Solar Potential	2,100 MW

Table 3: Assumptions of Exogenous Parameters for Dynamic as Usual scenario

TFPG	Power	0%
	Rest of the economy	0.7%
AEEI for non-power sectors 0.5% per year Electricity	Electricity	0.5% per year
AEEI sectors for power	Electricity	Reduction in auxiliary consumption and transmission and distribution losses is assumed in consistency with the Answer Times Technology Model for Nepal

Table 4: Power Sector Policies in DAU Scenario

Cost reduction for renewables	Reduction in solar costs assumed in consistency with Answer Times Technology Model for Nepal
Growth of renewable	Levels projected by the Answer Times Technology Model for Nepal are assumed in the economic model
Minimum share of solar	Levels projected by the Answer Times Technology Model for Nepal are assumed in the economic model
Hydropower	Levels projected by the Answer Times Technology Model for Nepal are assumed in the economic model
Export-oriented power projects	Investment for export-oriented power plants assumed to come through developmental aids and foreign financing with Nepal paying back at the rate of 2 NPR per unit of electricity produced from them

Macroeconomic Assumptions

The 57×57 sector Social Accounting Matrix (SAM) for 2007 (Selim Raihan and Bazlul Haque Khondker, 2011) forms the reference for the base year data of the model. The base year of the model is 2007–08 and the sectors from the 57×57 sector SAM for 2007–08 is aggregated to 6×13 sectors for the most appropriate representation of the power sector and its linkages with the Nepal economy. The economy is aggregated to six commodities: agriculture, manufacturing, power, gas and water supply, transport and other services. The power sector, which is the dominant energy sector in Nepal, is disaggregated to eight power-generating sectors. The other major macroeconomic assumptions are provided in the following tables.

Table 5: Sectoral Classifications

Commodity Name	Production Activity Name
Agriculture	Agriculture
Manufacturing	Manufacturing
Gas and Water Supply	Gas and Water Supply
Transport	Transport
Other Services	Other Services
Electricity	Storage Hydropower
	ROR Hydropower
	PROR Hydropower
	Diesel
	Solar
	Storage Hydropower - Foreign Finance
	ROR Hydropower - Foreign Finance
	PROR Hydropower - Foreign Finance

Table 6: Macroeconomic Assumptions

Parameter	Assumption
Maximum growth rate of per capita consumption	8%
Government consumption growth rate	8%
Marginal savings rate	15% and is assumed to increase by 1.84% to reach a value of 30% by 2045
Discount rate	4%
Post-terminal growth rate	3%

Table 7: Trade, Exports and Imports Assumptions (in %)*

	Commodity	Export Upper Bound	Import Upper Bound	Import Lower Bound
1	Agriculture	3	15	1
2	Manufacturing	20	30	15
3	Electricity*	NA	NA	NA
4	Gas & water supply	0	15	5
5	Transport	6	20	5
6	Other services	16	5	1

* Import bounds are prescribed as percentage of total availability (Production of Imports), Export bound is prescribed as percentage of total output.

Annexure 2: Assumptions for India's Economic Model

General Assumptions

The following are some of the key assumptions valid for all the selected scenarios:

a) Inclusive Growth Policies (common to all scenarios)

All scenarios consider inclusive growth policies that are developmental in nature and differ only on nature of low carbon policies. These policies ensure access to electricity, clean cooking fuel, pucca house, education and health services, as well as income transfer to poor. The specification of inclusion policies is described below.

- **Income transfer:** To substantially reduce poverty, income transfer is given beginning with an amount of Rs.1,000 per person per year at 2007–08 prices, increasing to Rs. 2,000 by the end of the Twelfth Five Year Plan and to Rs. 3,000 thereafter. The coverage of rural and urban population is gradually increased over the Twelfth Plan period to reach the levels mentioned in National Food Security Act 2013, i.e., bottom 70% of the rural and bottom 50% of the urban population.
- **Housing:** The objective is to provide every person with a pucca house by 2030. This is accomplished by stepping up the Pradhan Mantri Awaas Yojana is reflected in the scenario by increased government demand for construction from 2015 to 2025 when an additional 0.7 million houses for the poor are built.
- **Electricity:** Keeping up its promise for sustainable energy access for all (SE4All), all the households consume at least 1 kWhr per day of electricity by 2015. The government makes up the deficit from the household's normative consumption and provides it free of cost to the poor households.
- **Cooking gas:** The poor households' expenditure on energy is supplemented by government so that they can have at least six cylinders of LPG per year.
- **Education and health:** Government expenditure on education and health is increased to 7.3% of GDP in 2015 and stays at that level thereafter.

The cost of implementing inclusive measures is assumed to be borne by the government and reduces the investment available for other economic activities.

b) Population

All the scenarios use the UN medium variant population for India. The population of rural and urban areas assumed under the scenarios is given in Table 1.

Table 1: Total, Rural and Urban Population growth

Year	**Total**	**Rural**	**Urban**	**Urbanisation (in %)**
2007	1158	812	346	30%
2010	1206	833	373	31%
2020	1353	883	471	35%
2030	1476	893	583	39%
2040	1566	864	701	45%
2050	1620	806	814	50%

* Population UN Medium Variant

c) Resource Reserves and Growth Assumptions

Reserves of natural resources such as coal and lignite, crude oil and natural gas grow over the years with exploration for new resources. For scenarios, the growth rate assumption for natural resources is provided in Table 2.

Table 2: Resource Growth Assumptions

Coal and lignite (million tonnes)	153,103	1.0%
Crude petroleum (million tonnes)	725	0.0%
Natural gas (billion cubic meter)	1,055	1.1%

Table 3: Assumptions of Exogenous Parameters for DAU Scenario

Parameter	Sectors	
TFPG	Agriculture and power	1%
	Rest of the economy	1.5% for all except new technologies in power sector
AEEI for non-power sectors	Coal	1.5% per year
	Petroleum products	1.5% per year
	Natural gas	1.5% per year
	Electricity	1% per year
AEEI for power sectors	Coal	No AEEI for diesel use in power sector technologies assumed
	Petroleum products	No AEEI for diesel use in power sector technologies assumed
	Natural gas	No AEEI for gas use in power sector technologies assumed
	Electricity	Reduction in auxiliary consumption and transmission and distribution losses assumed in consistency with the Answer Times Technology Model for India
Reduction in energy use by government and households	Petroleum Products	1.5% reduction in marginal budget share of expenditure on petroleum products by household due to use of more efficient vehicles
	Electricity	2% reduction in marginal budget share of expenditure on electricity by households due to use of efficient appliances

* Unless mentioned otherwise, the policies of the earlier scenarios continue and each is successively more focused on climate than the previous scenarios.

Table 4: Power Sector Policies Scenario

Costs for renewable	Normal cost reduction due to efficient use of production factors consistent with the assumption in Answer Times Technology Model for India
Growth of renewable	Levels projected by the Answer Times Technology Model for India assumed in the economic model
Minimum share of solar	Levels projected by the Answer Times Technology Model for India are assumed into the economic model
Nuclear power	Levels projected by the Answer Times Technology Model for India are assumed into the economic model
Thermal coal	No investment in capacity and no fall in costs due to factor productivity for sub-critical coal assumed from 2017 in consistency with Answer Times Technology Model for India assumed in the economic model
Hydropower	Levels projected by the Answer Times Technology Model for India assumed in the economic model
Gas-based power generation	Levels projected by the Answer Times Technology Model for India assumed in the economic model
Minimum penetration rate for ECBC buildings	The share of ECBC is specified to increase by 1%.

Table 5: Transport Sector Policies in DAU Scenario

Share of railways in total freight movement	Stipulated to increase by 1.5% per year, from around one-third in 2015 to almost two-thirds by 2050
Greater use of public and non-motorised transport	Reducing marginal budget shares for petroleum products by 0.2% per year beginning 2015
Change in fuel mix in road transportation sector	Reducing petroleum product inputs in the transport sector by 0.5% per year, and replacing them by increasing inputs of natural gas and electricity in the ratio 60:40 respectively from 2015

d) Macroeconomic Assumptions

The 78×78 sector SAM for 2007 (Pradhan, Saluja and Sharma, 2013) forms the reference for the base year data of the model. The base year of the model is 2007–08 and the sectors from the 78×78 sector SAM for 2007–08 is aggregated to 25×41 sectors for the most appropriate representation of energy sector and its linkages with the overall economy. There are 7 agricultural sectors, 10 industrial sectors (excluding energy sectors) and 3 services sectors. There are three primary energy sectors and two secondary energy sectors as shown in the tables. The other major macroeconomic assumptions are provided in the tables.

Table 6: Sectoral Classifications

Commodity Name Non-energy sectors	Production Activity Name
Agriculture	
Food grains	Food grains
Sugarcane	Sugarcane
Oil seeds	Oil seeds
Other Crops	Other crops
Animal husbandry	Animal husbandry
Forestry	Forestry
Fishing	Fishing
Industry	
Mining and quarrying	Mining and quarrying
Agro-processing	Agro-processing
Textiles	Textiles
Fertiliser	Fertiliser
Cement	Cement
Non-metallic minerals	Non-metallic minerals
Steel	Steel
Manufacturing	Manufacturing
Construction	Construction
Water supply and gas	Water supply and gas
Services	
Railway transport services	Railway transport services
Other transport	Other transport
Other services	Other services

Commodity Name Energy sectors	Production Activity Name
Primary energy sectors	
Coal and lignite	Coal and lignite
Crude petroleum	Crude petroleum
Natural Gas	Natural Gas
Secondary Energy Sectors	
Petroleum products	Petroleum products
Electricity	Sub-critical coal
	Gas combined cycle
	Hydropower
	Super-critical coal
	Onshore wind
	Solar photo voltaic without storage
	Solar thermal without storage
	Biomass

		Nuclear
		Diesel
		Solar photo voltaic with storage
		Solar thermal with storage
		Offshore wind
		Ultra-super critical coal
		Integrated gasification combined cycle coal
		Gas open cycle

Table 7: Macroeconomic Assumptions

Parameter	Assumption
Maximum growth rate of per capita consumption	10%
Government consumption growth rate	8%
Maximum savings rate	40%
Discount rate	4%
Post-terminal growth rate	3%

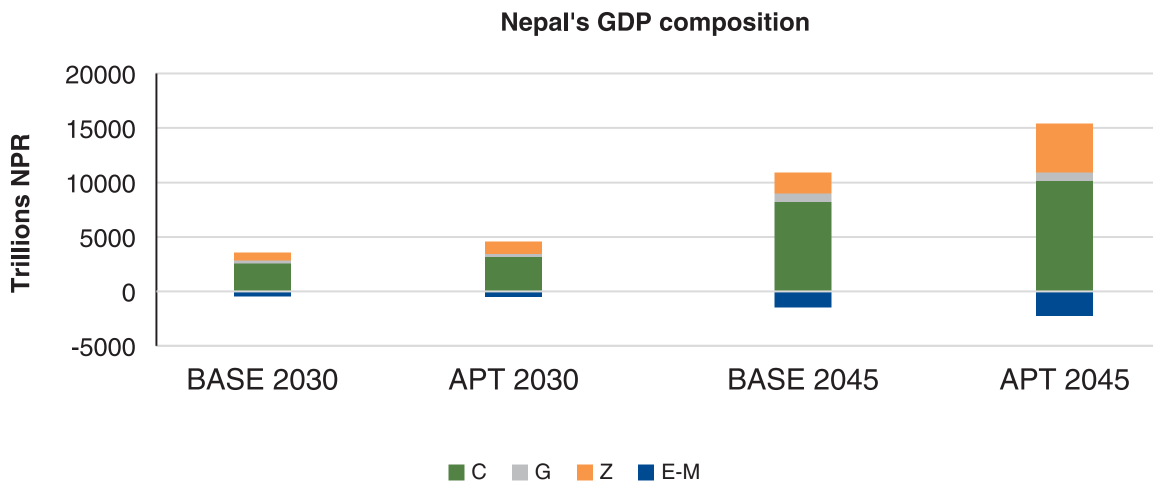
Table 8: Trade, Exports & Imports Assumptions (in %)*

	Commodity	Export Upper Bound	Import Upper Bound	Import Lower Bound
1	Food grains	10	10	0
2	Sugarcane	10	10	0
3	Oil seeds	10	10	0
4	Other crops	10	10	0
5	Animal husbandry	10	10	0
6	Forestry	10	10	0
7	Fishing	10	6	0
8	Coal and lignite	1	30	20
9	Crude petroleum	2	98	80
10	Mining and quarrying	99	45	0
11	Agro-processing	10	20	1
12	Textiles	50	30	0
13	Petroleum Products	20	20	5
14	Fertiliser	20	33	20
15	Cement	10	0.6	0.3
16	Non-metallic minerals	10	10	1
17	Steel	20	10	1
18	Manufacturing	40	30	1.5
19	Construction	0	0	0
20	Electricity*	NA	NA	NA
21	Water supply and gas	0	0	0
22	Railway transport services	30	0	0
23	Other transport	30	20	3
24	Other services	20	10	6
25	Natural gas	0	80	20

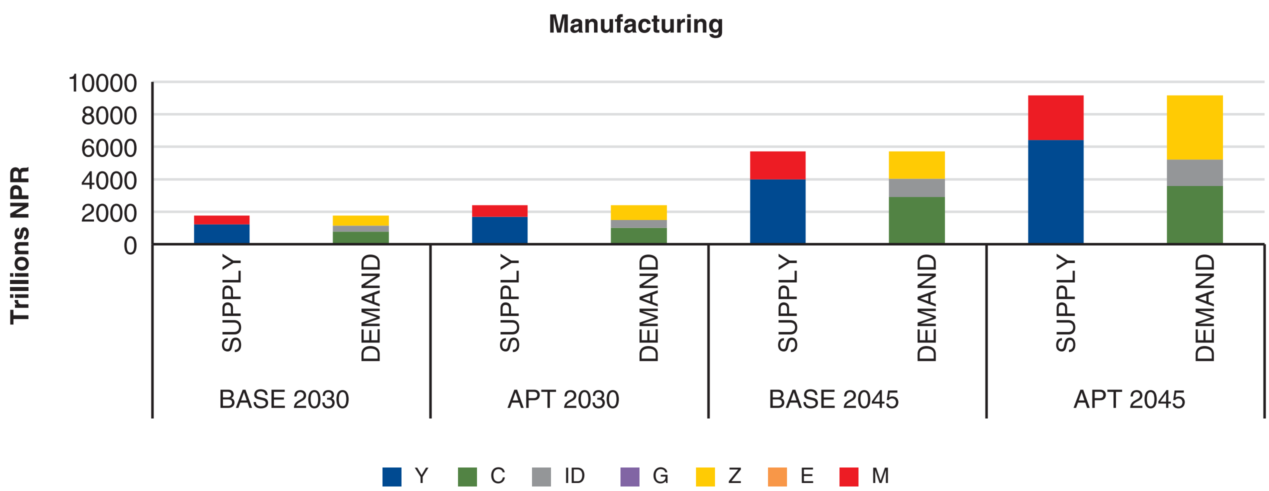
* Import bounds are prescribed as percentage of total availability (Production of Imports), Export bound is prescribed as percentage of total output.

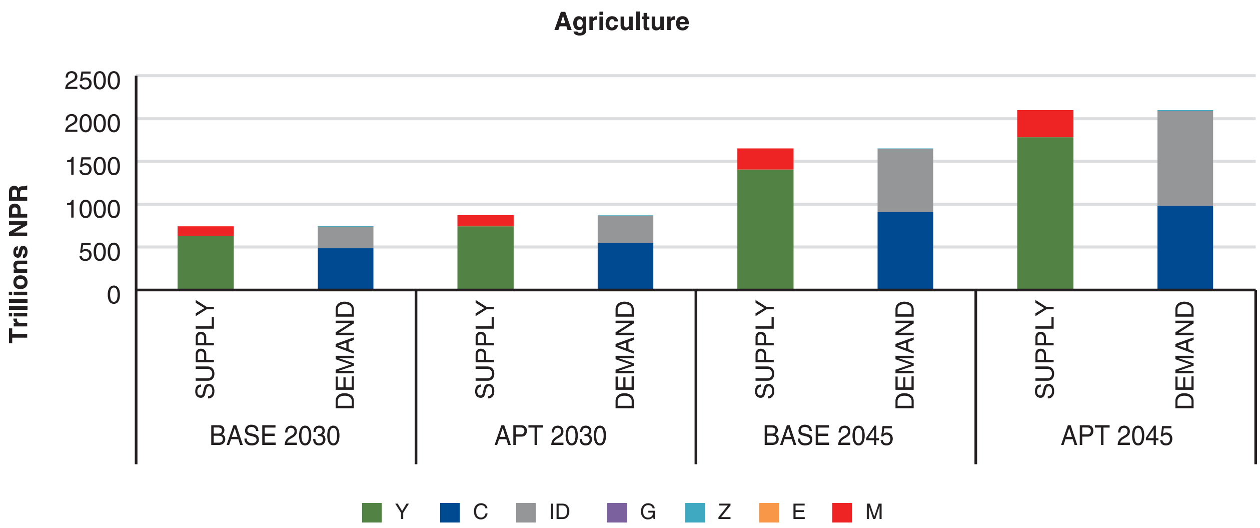
Annexure 3: Macro and Sectoral Impact on Nepal

The figures below show the classification of the impact on GDP to changes in the sources of GDP. Y denotes the domestic production, C denotes private household consumption, G denotes government consumption, ID is the intermediate consumption, Z denotes investment, E denotes exports and M denotes imports. Compared to base the share of private consumption (C) and investment (Z) increases in the APT scenario leading to higher GDP.



Corresponding to the impact at macro level, the sectoral impact is shown in Figure below. All values are reported in trillions NPR. Supply is denoted by Y+M. Demand is denoted by C+G+ID+Z+E.




Agriculture
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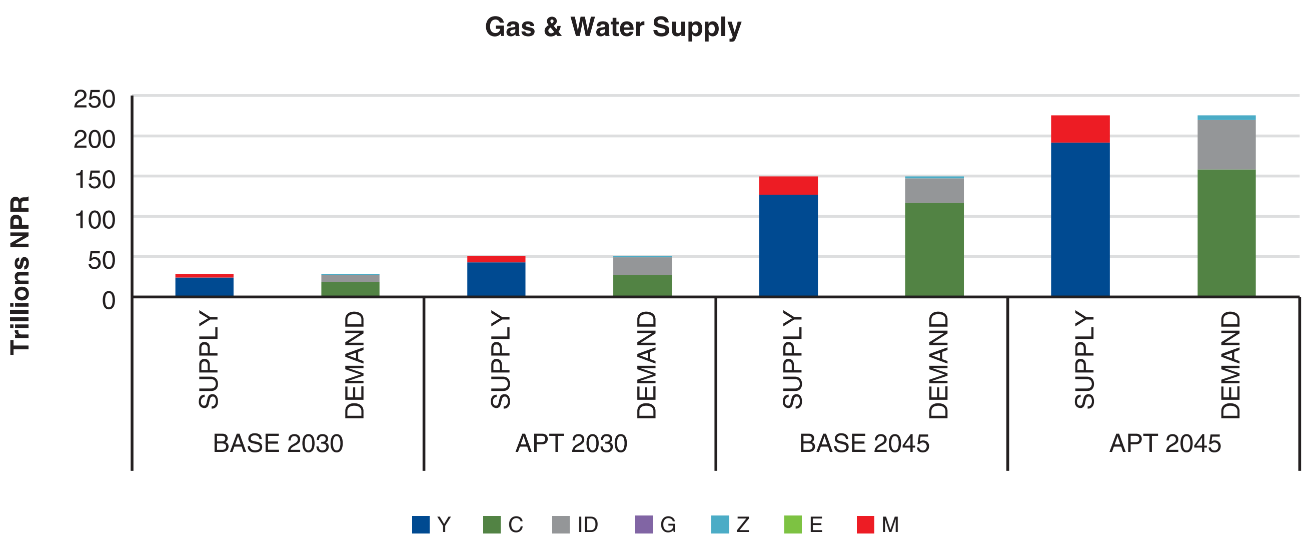
Gas & Water Supply
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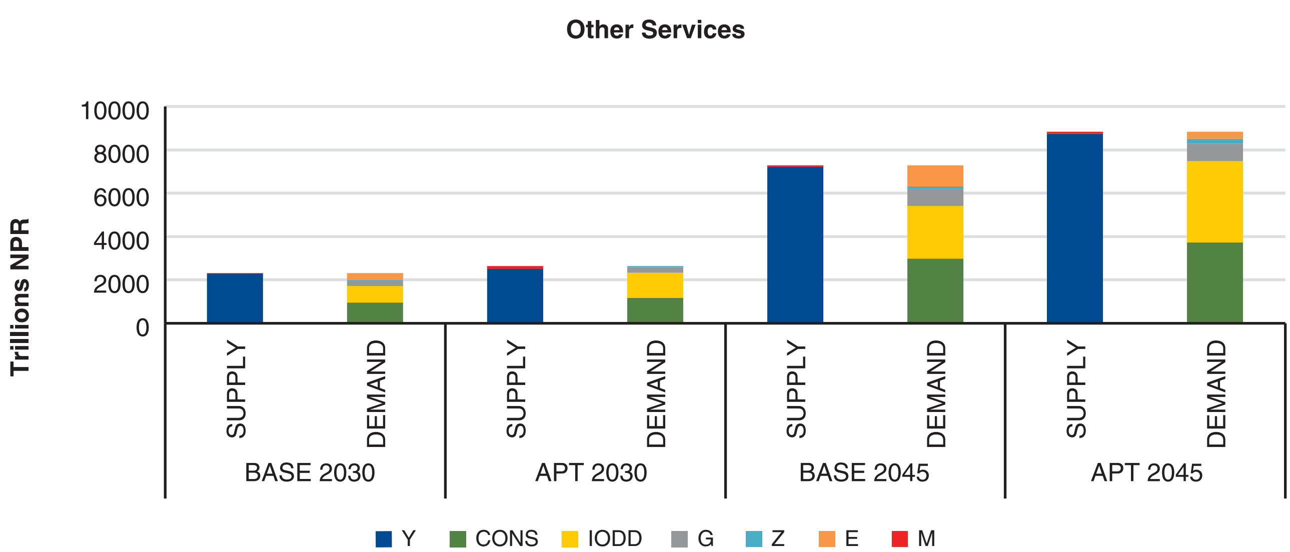
Other Services
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ABOUT SARI/EI

Over the past decade, USAID's South Asia Regional Initiative/Energy (SARI/E) has been advocating energy cooperation in South Asia via regional energy integration and cross border electricity trade in eight South Asian countries (Afghanistan, Bangladesh, Bhutan, India, Pakistan, Nepal, Sri Lanka and the Maldives). This fourth and the final phase, titled South Asia Regional Initiative for Energy Integration (SARI/EI), was launched in 2012 and is implemented in partnership with Integrated Research and Action for Development (IRADe) through a cooperative agreement with USAID. SARI/EI addresses policy, legal and regulatory issues related to cross border electricity trade in the region, promote transmission interconnections and works toward establishing a regional market exchange for electricity.

ABOUT USAID

The United States Agency for International Development (USAID) is an independent government agency that provides economic, development, and humanitarian assistance around the world in support of the foreign policy goals of the United States. USAID's mission is to advance broad-based economic growth, democracy, and human progress in developing countries and emerging economies. To do so, it is partnering with governments and other actors, making innovative use of science, technology, and human capital to bring the most profound results to a greatest number of people.

ABOUT IRADe

IRADe is a fully autonomous advanced research institute, which aims to conduct research and policy analysis and connect various stakeholders including government, non-governmental organizations (NGOs), corporations, and academic and financial institutions. Its research covers many areas such as energy and power systems, urban development, climate change and environment, poverty alleviation and gender, food security and agriculture, as well as the policies that affect these areas.

For more information on the South Asia Regional Initiative for Energy Integration (SARI/EI) program, please visit the project website:

www.sari-energy.org