Gains from Nepal-India CBET
IRADe Study for SARI/EI

South Asia Regional Initiative for Energy Integration(SARI/EI)

28th April, 2016 | Kathmandu, Nepal

Dr. Probal Ghosh,
Head Modelling Group,
IRADe

Mr. Vinay Kumar Saini,
Research Analyst,
IRADe

Integrated Research and Action for Development (IRADe), New Delhi

The Objective

- Assess Techno economic Feasibility of CBET
- At what price during what period of the year at what price how much electricity can be traded?
- i.e. The exporter is willing and able to export and the importer is willing and able to import
- What are the economic gains to NEPAL of such trade taking in to account earnings from export and its macro-economic impact on the economy

Approach

- Power sector development strategies from 2012 to 2047
- TIMES MARKAL Model solved for every 5th year simultaneously
- Detailed TIMES-MARKAL model with 288 time-periods per year
- For each time slice demand must equal supply
- TIMES-MARKAL model for each country has detailed plant wise data and options of different types of new plants
- Solution minimizes cost to meet specified demand and provides optimal solution and trade levels and prices for each 288 time-periods for all the years

Approach (Continued)

- However, trade will affect economic development and level of demand particularly true for NEPAL
- A macro-economic SAM based model covers the whole economy balances supply and demand for each sector, also investment and savings, balance of payment for each year, etc.
- So earnings from electricity export increases availability of resources for investment
- Higher Growth leads to higher domestic demand for electricity
- Iterate between the two models to get economically viable and technically feasible scenarios.

Steps in Iteration between SAM and TIMES-MARKAL Model

Nepal Model	Inputs	Outputs
Step 1 SAM Model	No constraint run	D 1, E 1, I 1, G 1 — Macro-economic Demand Obtained
Step 2 Integrated TIMES Model	D 1	E 2, I 2, G 2 — Technologically feasible energy profile
Step 3 SAM Model	E 2, I 2, G 2	D 2, E 2, I 2, G 2 — Technological and Macro-economic consistent demand
Step 4 Integrated TIMES Model	D 2, I 2	D 2, E 3, I 2, G 3 — Revised Technological and Macro-economic consistent energy profile
Step 5 SAM Model	E 3, I 2, G 3	E 3, I 2, G 3 — Technological consistent Macro-economic factors obtained

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

USAID FROM THE AMERICAN PEOPLE

SARI/EI

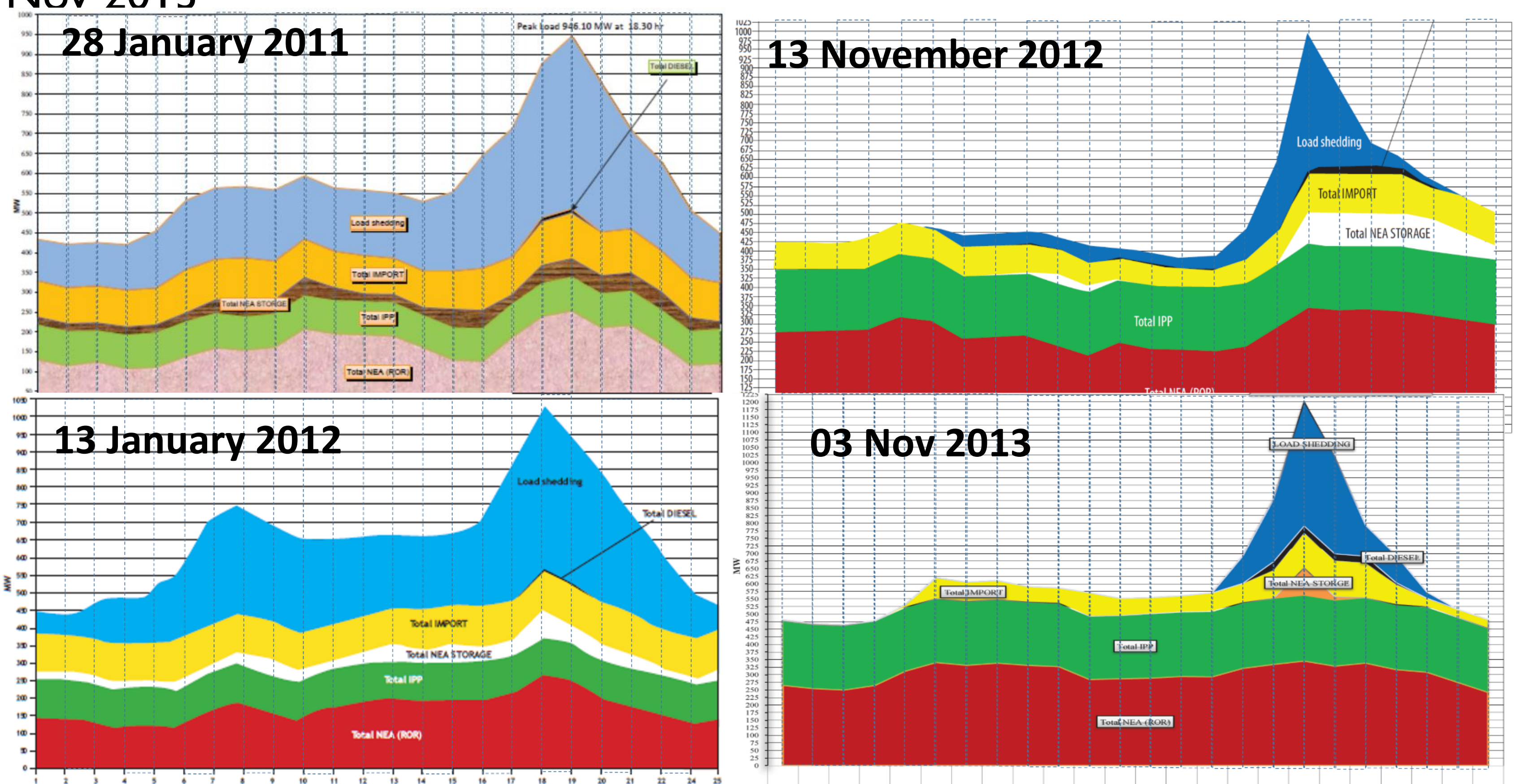
IRADe Integrated Research and Action for Development

Nepal Load Duration Curve Assumption

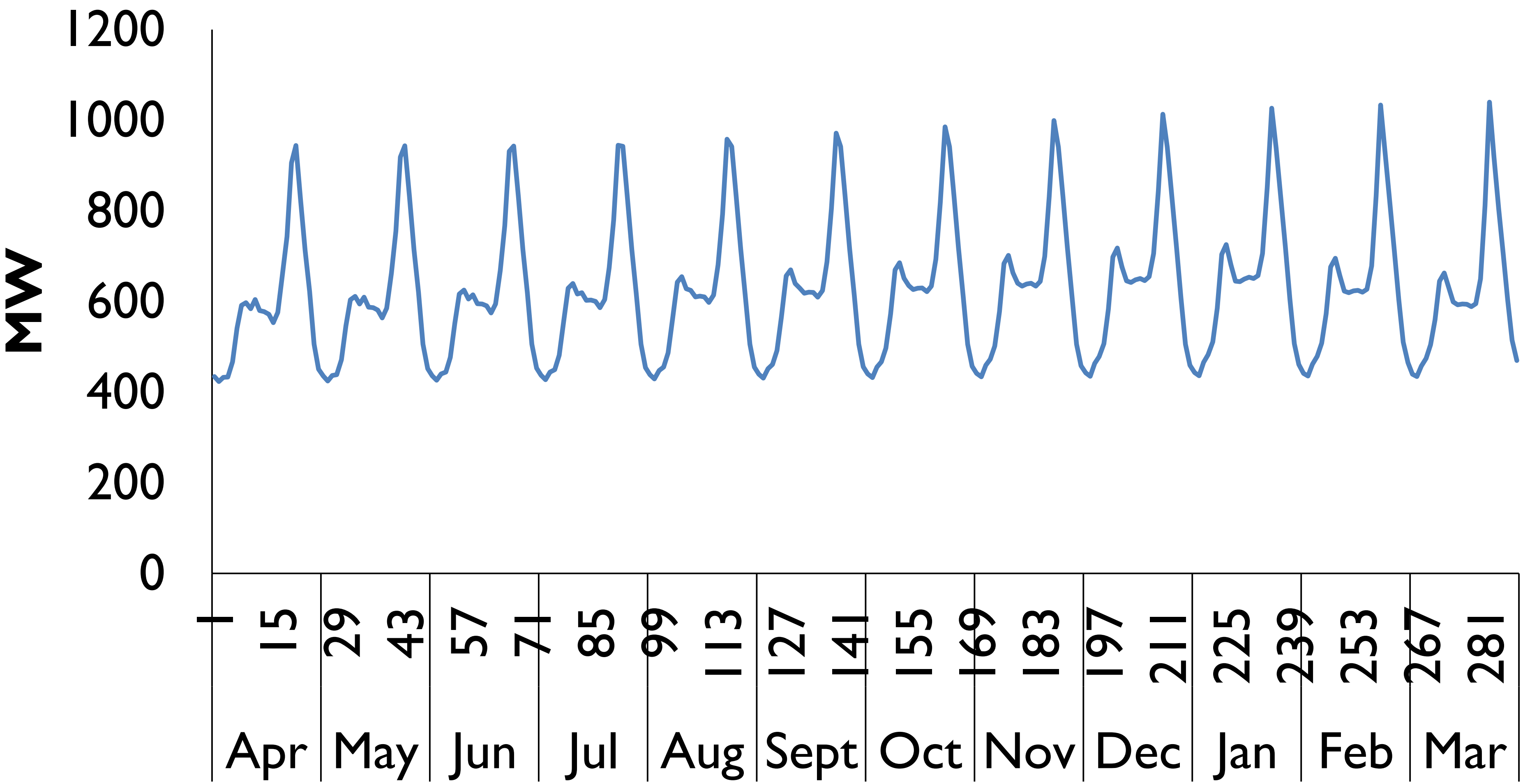
Single day Peak load curve was available from various NEA Annual Reports:

- 28 January 2011
- 13 January 2012
- 13 November 2012
- 03 Nov 2013

These various load curves were used for interpolating a continuous load curve for the year 2011-12 using hourly growth rates.



Derived Continuous Load Curve for 2011-12



Total Energy Demand as per the assumed load curve = 5,476 GWh

Nepal Hydro Assumption

- Economical Hydro Potential of 42 GW
- Plant Life assumed: 50 Years for both ROR, PROR and Storage

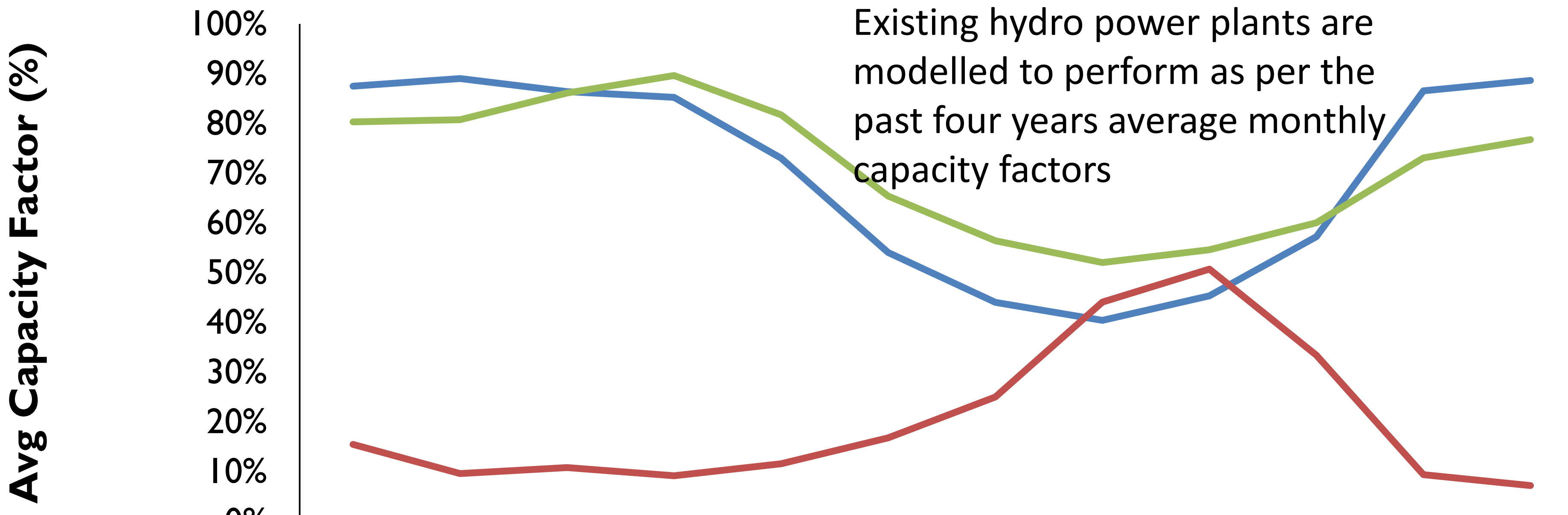
Plant Type	Capex* in Million NPR per MW (Million USD per MW)	O&M# Million NPR per MW (Million USD per MW)
ROR	142 (1.9)	4.7 (0.0556)
Pondage ROR	165 (2.2)	1.3 (0.0154)
Storage	251 (3.4)	1.5 (0.0181)

**Capex cost calculated as Average of various project cost from Final Report Summary "Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal" February 2014*

#O&M Cost calculated as the Average of Actual O&M cost of NEA hydro power plants for 2011-12

USAID FROM THE AMERICAN PEOPLE | SARI/EI | IRADe Integrated Research and Action for Development

Hydropower Technology-wise Four Year Average Monthly Capacity Factor (2010-14)



	July–Aug (Shrawan)	Aug–Sept (Bhadra)	Sept–Oct (Ashwin)	Oct–Nov (Kartik)	Nov–Dec (Mangsir)	Dec–Jan (Poush)	Jan–Feb (Magh)	Feb–March (Falgun)	March–April (Chaitra)	April–May (Baishakh)	May–June (Jestha)	June–July (Ashad)
PROR	88%	89%	86%	85%	73%	54%	44%	40%	45%	57%	87%	89%
ROR (selected)	80%	81%	86%	90%	82%	65%	56%	52%	55%	60%	73%	77%
STG	15%	10%	11%	9%	12%	17%	25%	44%	51%	33%	9%	7%

PROR   ROR (selected)   STG

*Selected ROR includes plant with Annual PLF greater than 50%

Source: NEA and IRADe Analysis

Capacity Factor Assumption for Upcoming Hydro Power Plants

Hydro Type	Annual	Monthly
Upcoming ROR & PROR Capacity	-	Monthly availability based on four years monthly average ***(ROR treated as base load and must run while modelling)***
Upcoming Storage	42%* 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)***

USAID FROM THE AMERICAN PEOPLE | SARI/EI | IRADe Integrated Research and Action for Development

Modelling Project wise Upcoming ROR Plants

Modelling of upcoming power plants as per the report summary of "Nationwide Master Plan Study on Storage-type Hydroelectric Power Development in Nepal" February 2014

Upcoming ROR Plants

Plant Name	Capacity in MW	Type	Commercial Operation	Annual PLF
Khani Khola	25	ROR	2015/16	52%
Upper Sanjen	11	ROR	2016/17	86%
Sanjen	42.9	ROR	2016/17	67%
Upper Trishuli 3A	60	ROR	2016/17	93%
Madhya (Middle) Bhotekoshi	102	ROR	2017/18	61%
Rasuwagadi	111	ROR	2017/18	63%
Upper Marsyangdi	50	ROR	2017/18	72%
Mistri	42	ROR	2017/18	61%
Upper Trishuli 3B	37	ROR	2019/20	91%
Upper Modi A	42	ROR	2020/21	58%
Tamakoshi V	87	ROR	2021/22	60%

Upcoming ROR Plants- Assumptions

Assumption undertaken for all upcoming ROR plants:

- Capex of 142 Million NPR per MW as individual project cost are not available
- O&M cost of 4.7 Million NPR per MW (same as existing NEA ROR average O&M Cost in the base year)

Upcoming PROR Plants

Plant Name	Capacity in MW	Type	Commercial Operation	Annual PLF
Chameliya	30	PROR	2015/16	70%
Upper Tamokshi	456	PROR	2016/17	57%
Rahughat	32	PROR	2017/18	66%
Upper Arun	335	PROR	2024/25	93%

Assumption undertaken for all upcoming PROR plants:

- Capex of 165 Million NPR per MW as individual project cost are not available
- O&M cost of 1.3 Million NPR per MW (same as existing NEA PROR average O&M Cost in the base year)

Upcoming Storage Plants

Plant Name	Capacity in MW	Type	Commercial Operation	Annual PLF	Project Cost (MUS$)	Cost in MNPR per MW
Kulekhani III	14	STO	2015/16	33%	-	-
Tanahu	140	STO	2020/21	39%	-	-
Budhi Gandaki	600	STO	2022/23	51%	-	-
Dudh Koshi	300	STO	2023/24	73%	1,141	282
Nalsyau Gad	410	STO	2023/24	39%	967	175
Andhi Khola	180	STO	2025/26	41%	666	274
Chera-1	148.7	STO	2027/28	43%	577	287
Madi	199.8	STO	2027/28	35%	637	236
Naumure	245	STO	2027/28	54%	954	288
Sun Koshi No. 3	536	STO	2028/29	40%	1,690	233
Lower Badigad	380.3	STO	2028/29	41%	1,210	235

Assumption undertaken for all upcoming Storage plants:

- Capex of 251 Million NPR per MW where project cost are not available
- O&M cost of 1.5 Million NPR per MW (same as existing NEA Storage average O&M Cost in the base year)

Export Oriented Power Plants

Plant Name	Developer	Capacity (in MW)	Annual share of Nepal in the Energy
Upper Karnali	GMR consortium	900	12%
Upper Marsyangdi	GMR consortium	600	Not Available
Tamakoshi-3	Tata Power & SN Power	650	Not Available
Arun-3	SJVN Ltd	900	22%

All capacity based on Pondage ROR. *(Information Received from IBN)*

Pancheshwar Plants- (Nepal Share)

Plant Name	Capacity in MW	Type	Commercial Operation	Annual PLF
Pancheshwar	2800	STO	2031/32	17%
Rupaligad	120	ROR	2031/32	58%

SARI/EI

IPP Power Plants- having PPA signed with NEA

- As on Dec 2015 about 46 no. of IPPs were in operation with capacity of 302 MW
- About 2,188 MW of IPP capacity is under construction for with PPA has been signed
- If IPPs are assumed to commissioned as per their PPA, then by 2017 about 1,224 MW of IPPs based hydro capacity will be added in Nepal
- Similarly, about 1079 M W of IPP based hydro capacity will be added in between 2017 to 2022.

Period	IPP based Hydro capacity addition (in MW)
2012- 17	1224
2017- 22	1079

Total firm capacity addition over the years

Period	ROR (in MW)	IPP based Hydro capacity addition (in MW)	PROR (in MW)	Storage (in MW)	Export Oriented-PROR (in MW)	Total
2012-17	138.9	1224	486	14	-	**1,863**
2017-22	471	1079	32	140	-	**1,722**
2022-27	-	-	785	2240	2600	**5,625**
2027-32	120	-	-	2800	-	**2,920**
Total	**729.9**	**2,304**	**1,303**	**5,194**	**2,600**	**12,130.9**

USAID FROM THE AMERICAN PEOPLE

SARI/EI

IRADe Integrated Research and Action for Development

Assumed Hydro capacity addition beyond 2022 (Upper Bound)- Apart from firm capacity addition

Period	ROR & PROR Capacity Addition in MW	Storage Capacity Addition in MW
2022-27	5000	5000
2027-32	5000	5000
2032-37	5000	5000
2037-42	5000	5000

A total bound of 42 GW on all installed hydro capacity in a period.

Solar PV Potential and Assumption

Grid Connected Solar PV Potential: 2100 MW

Source: Solar and Wind Energy Resource Assessment in Nepal, Alternative Energy Promotion Center

Expected Solar PV installation in 2017:

- 50 MW through ADB Assistance and 25 MW through World Bank Assistance

Solar PV Assumption for TIMES Model:

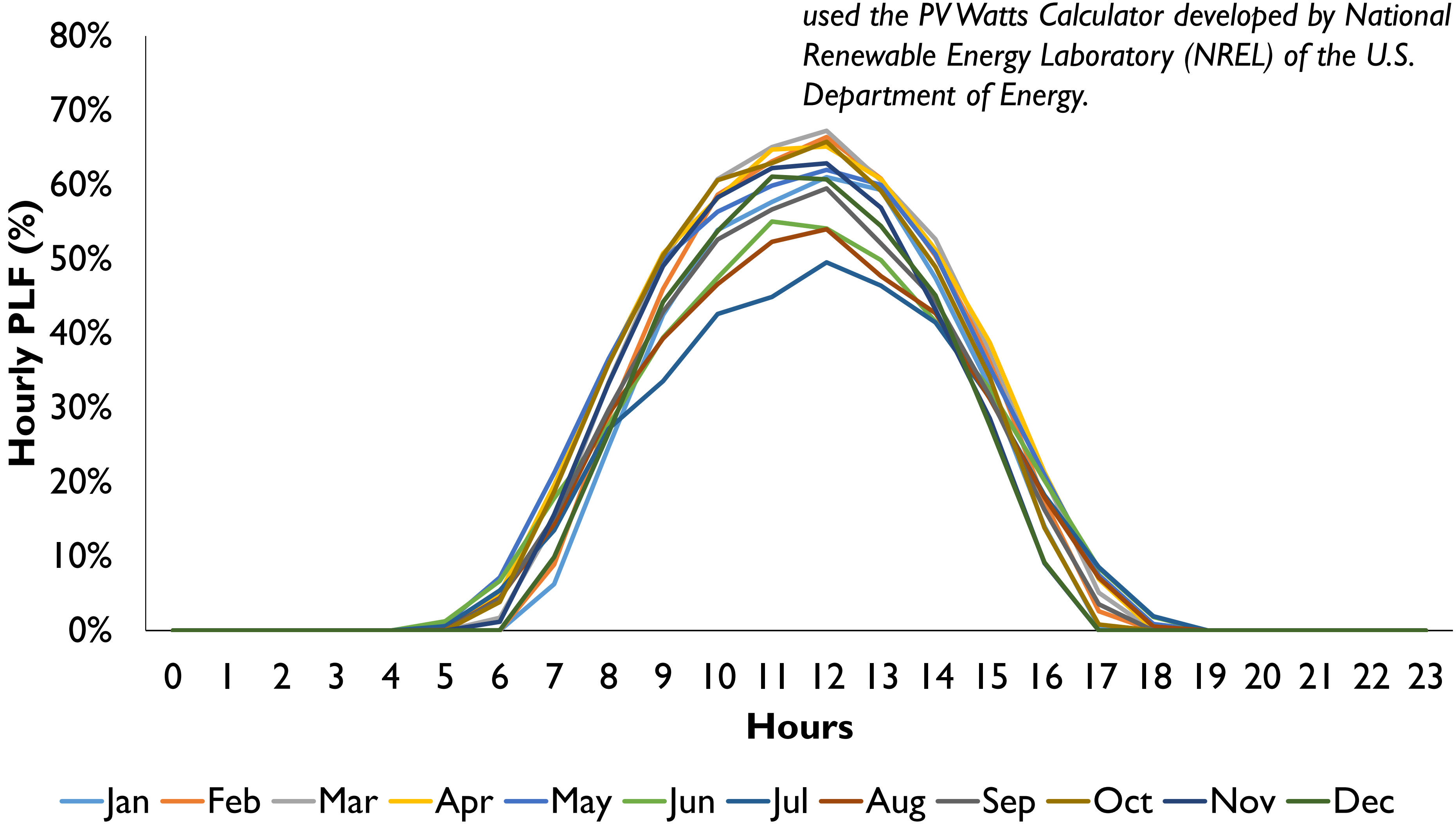
	2017	2022	2027
Assumed Installation Potential (in MW)	75 (firm)	500 (upper bound)	1000 (upper bound)

- Life of Plant assumed: 25 years
- Capex: assumed: 98.6 Million NPR per MW & O&M assumed: 1.1 Million NPR per MW (*based on CERC benchmark cost for FY 15-16*)

Hourly PLF variation over different months for a Solar Power Plant

Location Considered: Kathmandu

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.



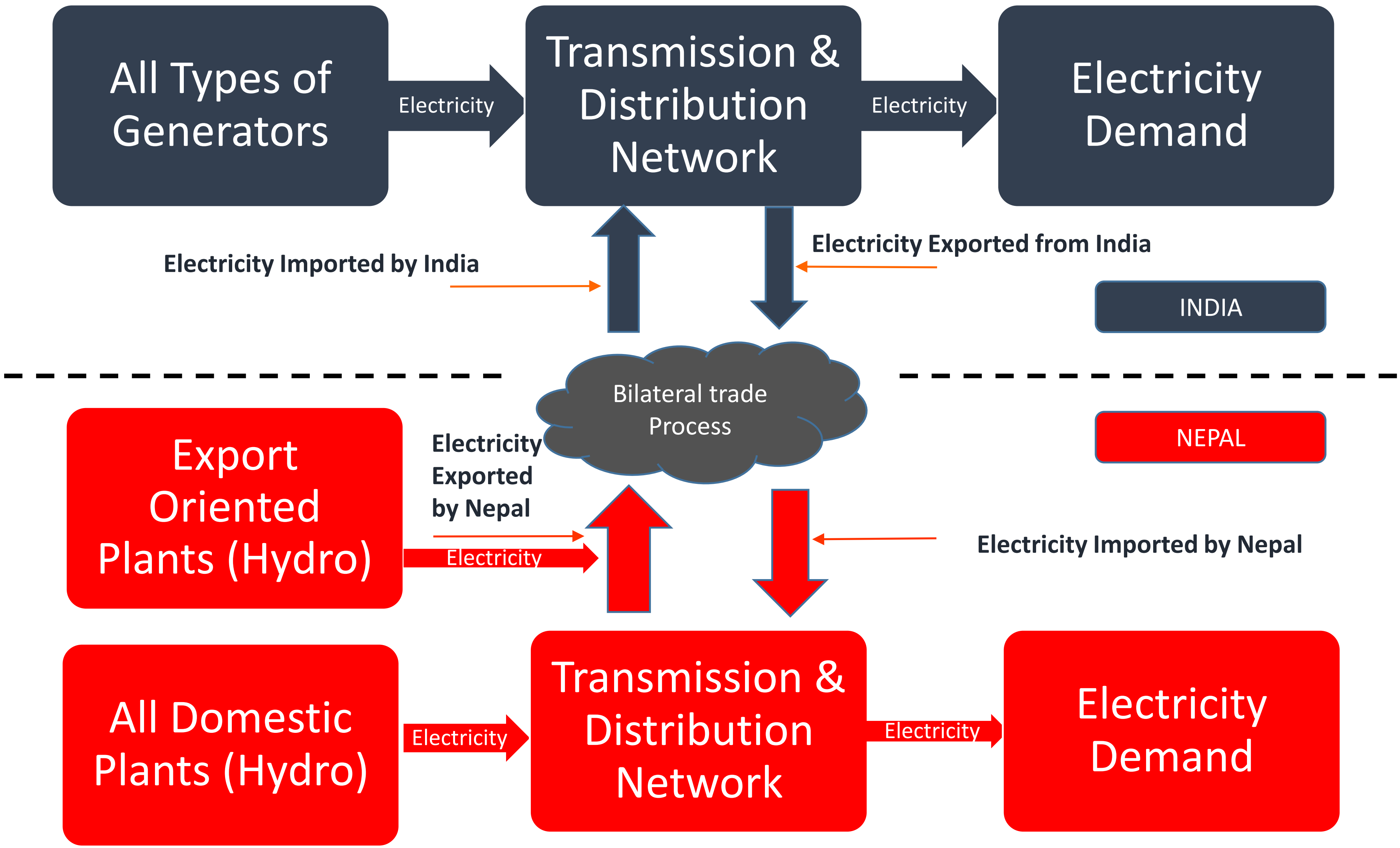
Source: PVWatts Calculator and IRADe Analysis

India-Nepal Integrated TIMES MARKAL Model Outputs- using demand from Nepal SAM model (with trade)

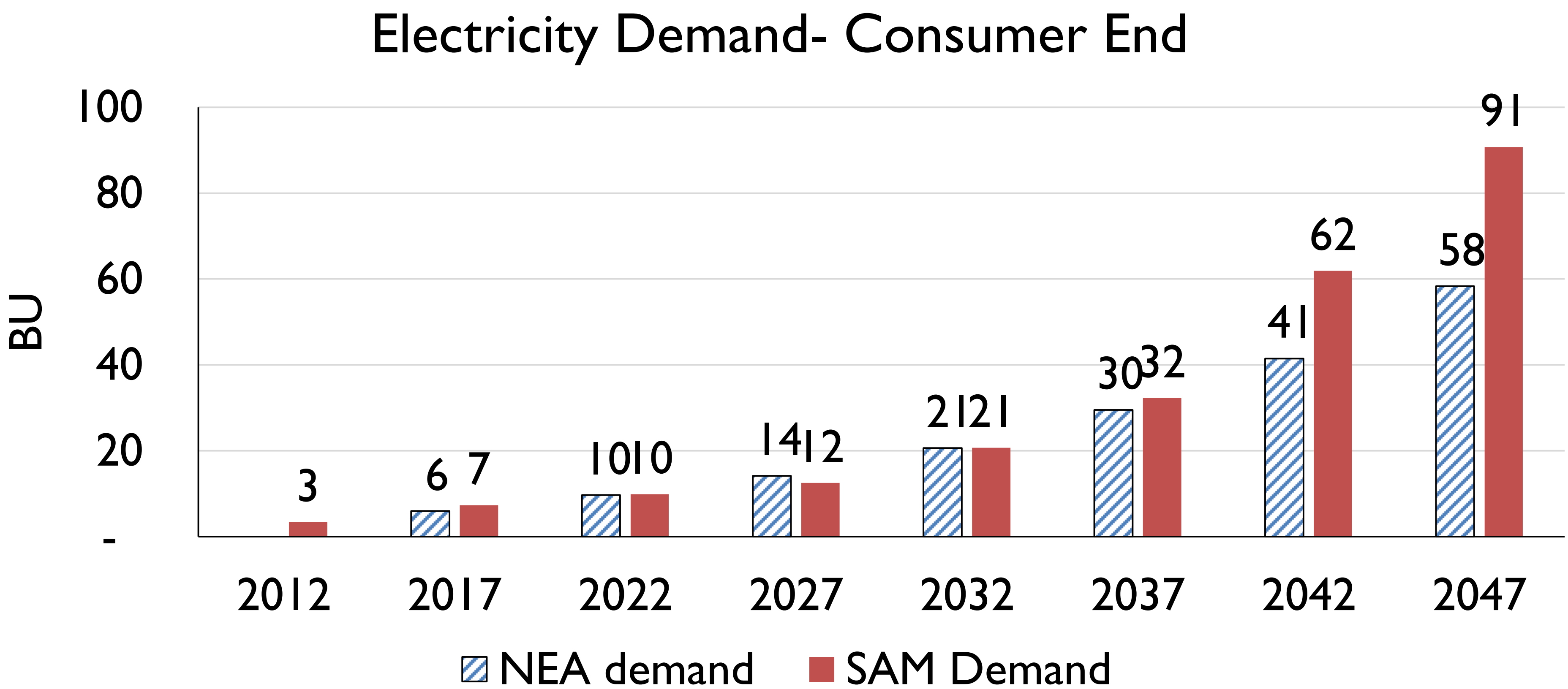
Model Results are for Discussion Purpose Only

USAID FROM THE AMERICAN PEOPLE SARI/EI IRADe Integrated Research and Action for Development

Bi-lateral Trade Process: Nepal & India



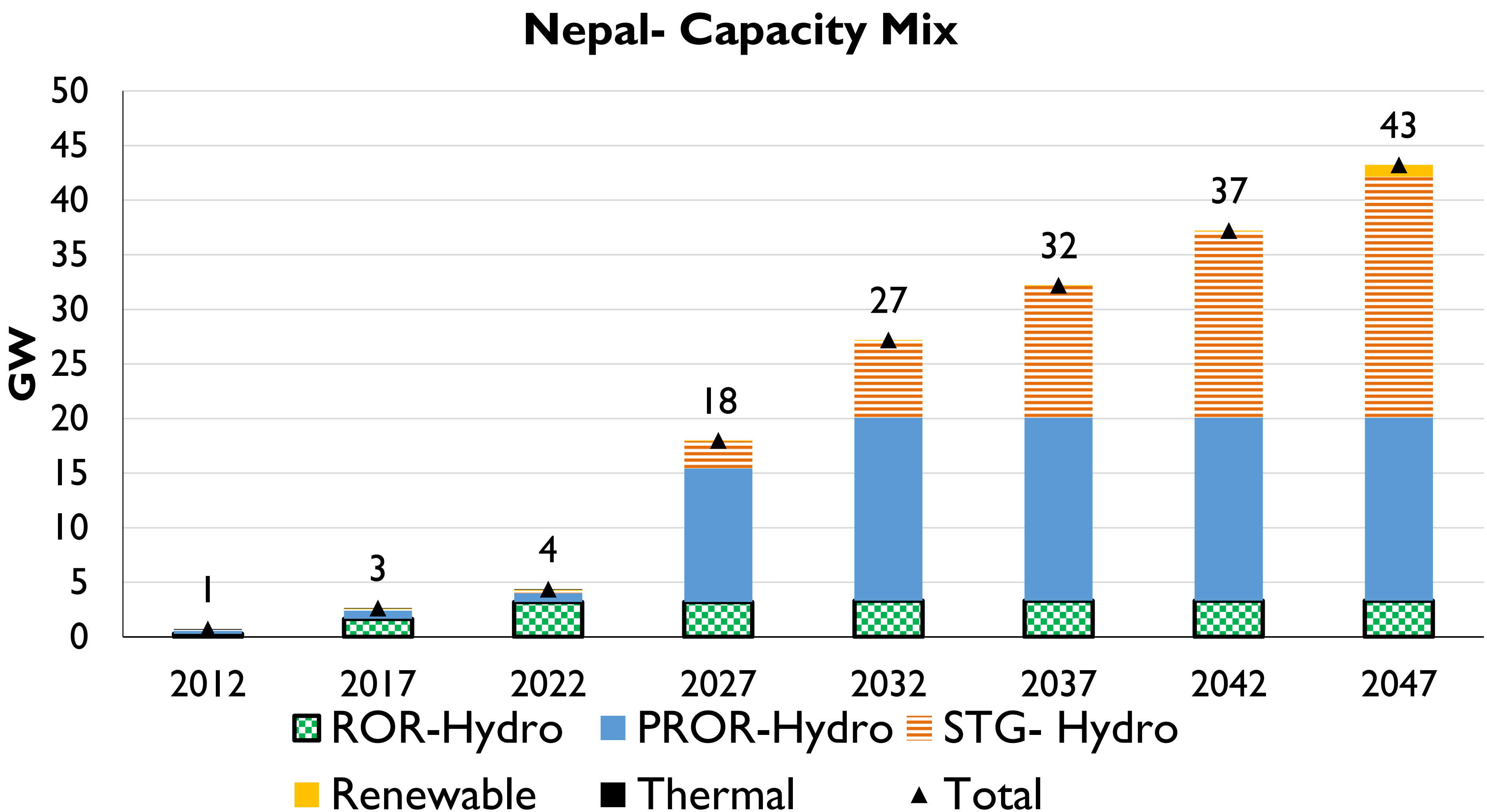
Nepal Demand Forecast (Consumption End)- using Nepal SAM Model



- NEA demand forecast was upto FY2034 which was further projected upto 2047 using last 10 years (2024-34) growth rate of 7%
- Per Capita electricity demand in 2047

SAM Model	2520 Units per person
NEA Demand Forecast	1619 Units per person

Nepal Capacity Mix- Integrated Trade Model

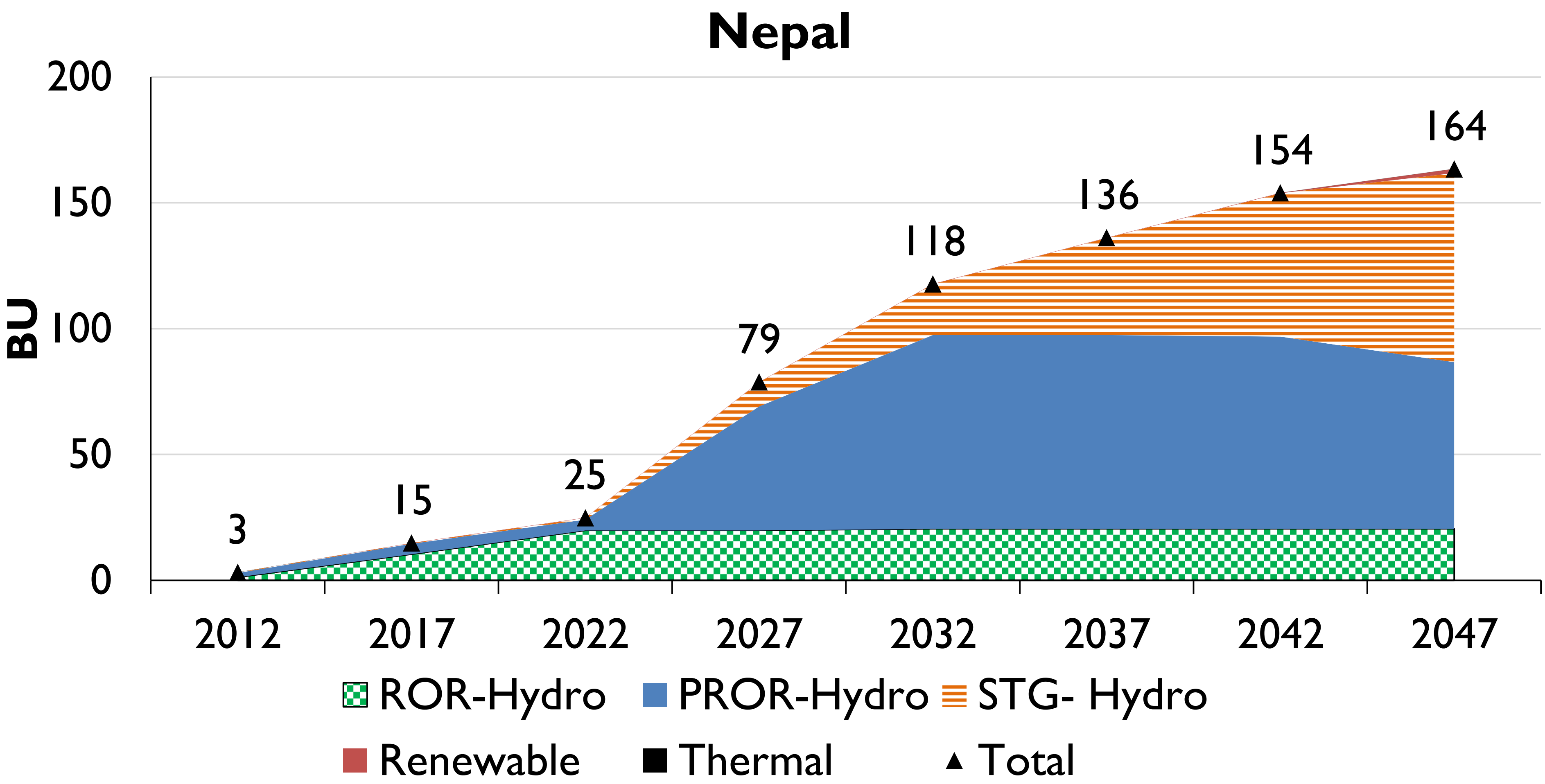


in GW	2012	2017	2022	2027	2032	2037	2042	2047
Total Installed Capacity in No Trade Scenario	0.7	1.1	1.5	2	4	6	9	13

SARI/EI

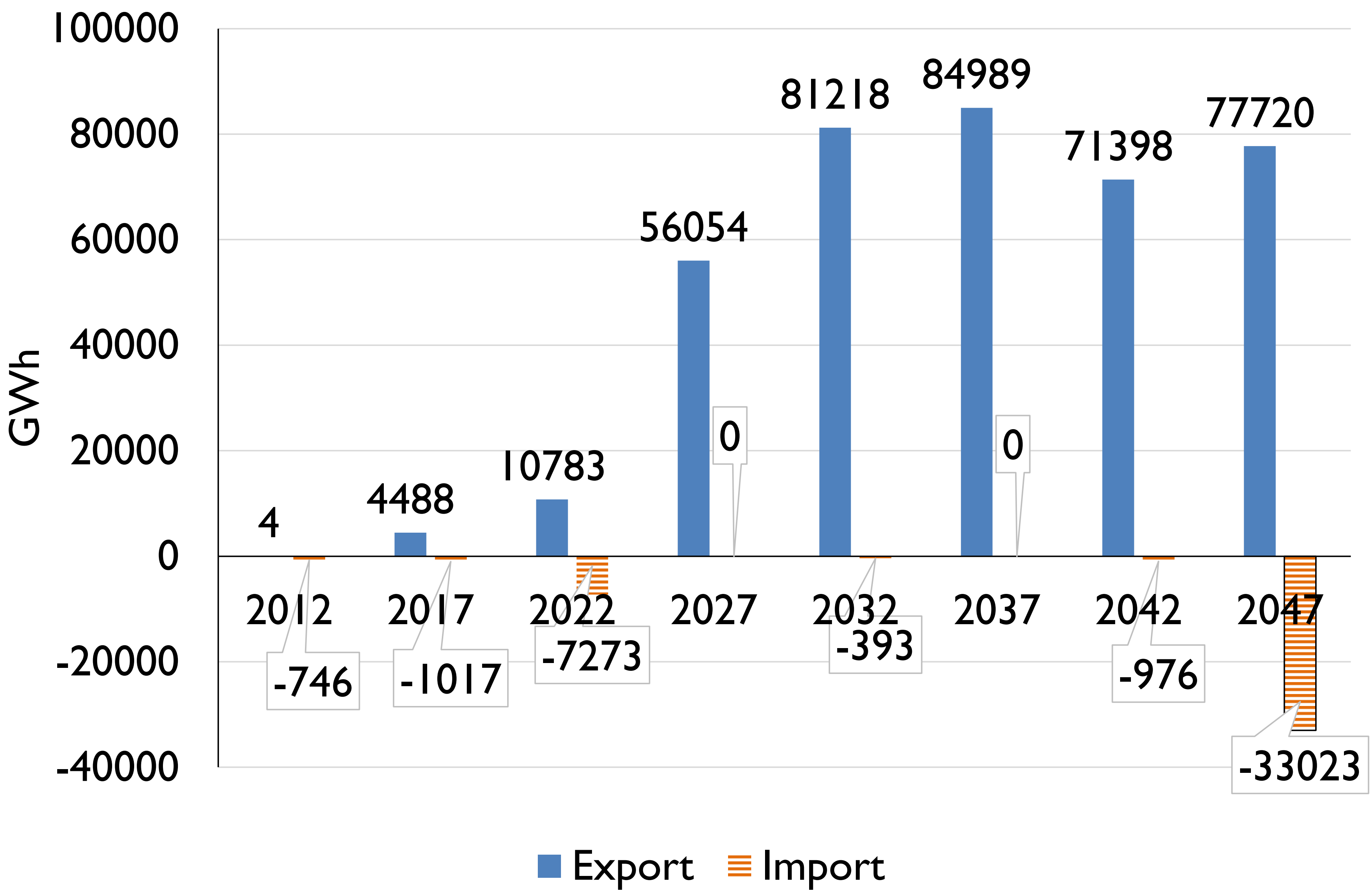
Integrated Research and Action for Development

Nepal Generation Mix- Integrated Trade Model

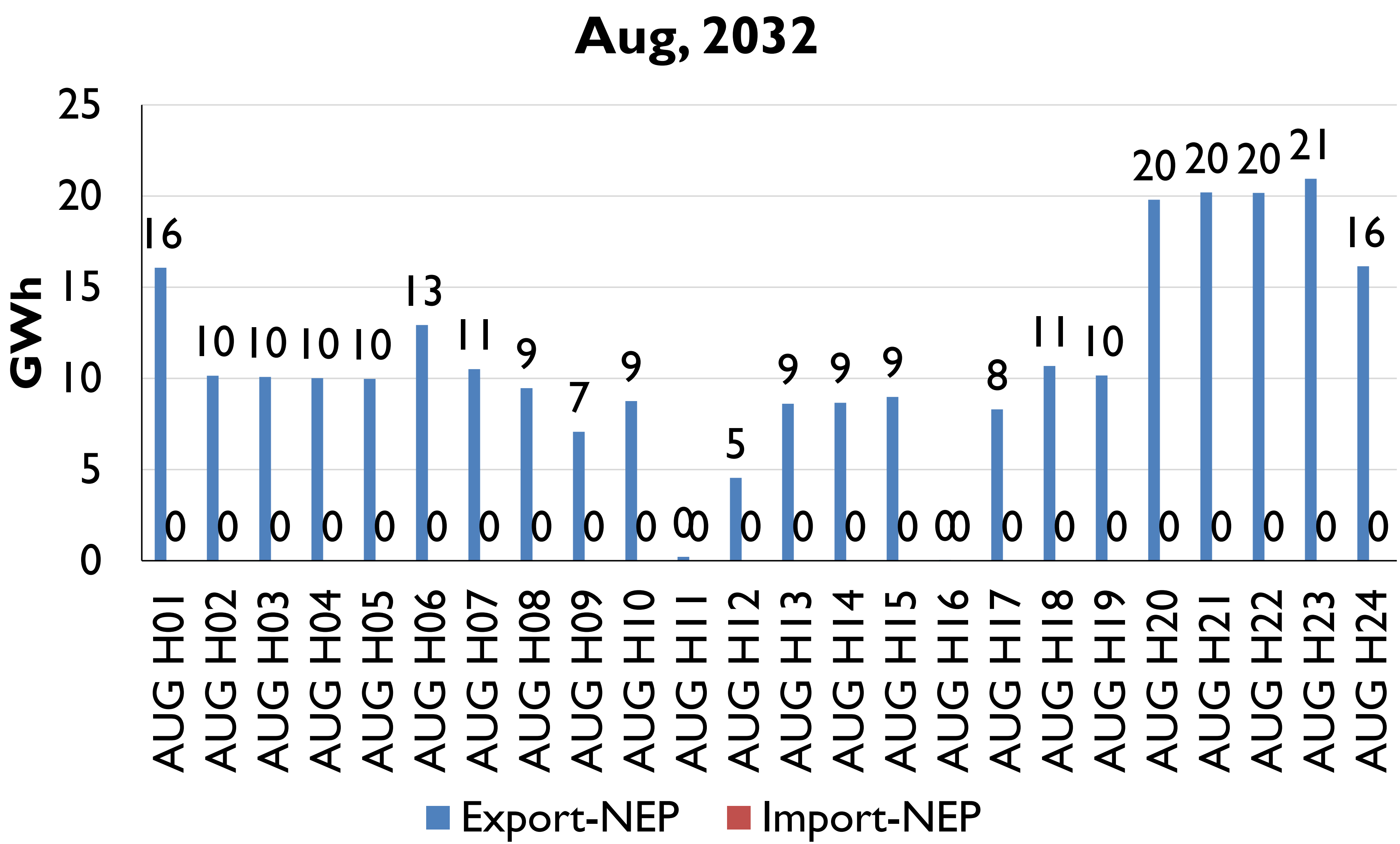


in BU	2012	2017	2022	2027	2032	2037	2042	2047
Total Generation in No Trade Scenario	3	5	7	12	19	30	45	67

Nepal Annual Electricity Trade - Integrated Trade Model



Nepal Electricity Trade - Integrated Trade Model
Hourly Quantity for a typical day for August, 2032 (Wet Season)

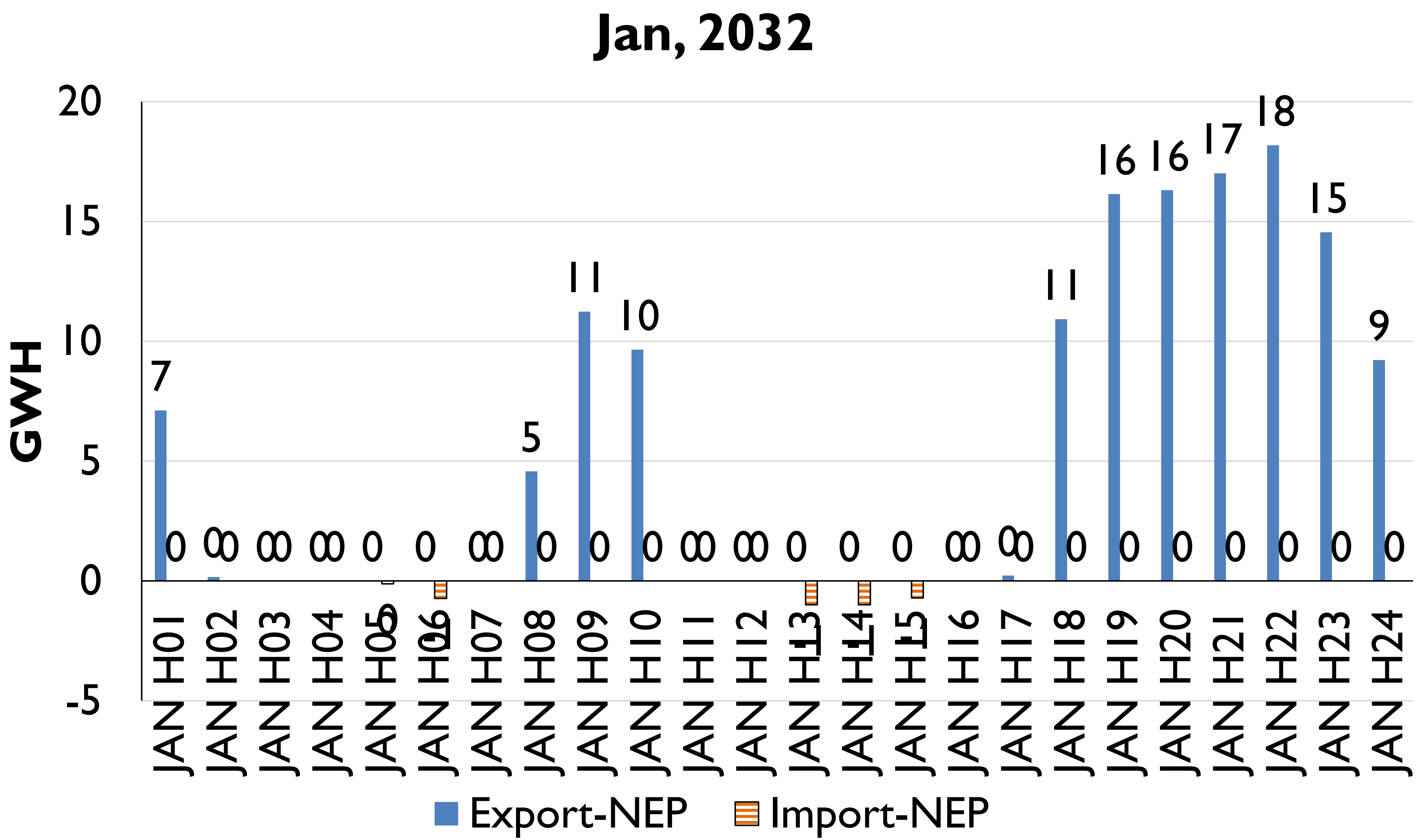


USAID FROM THE AMERICAN PEOPLE

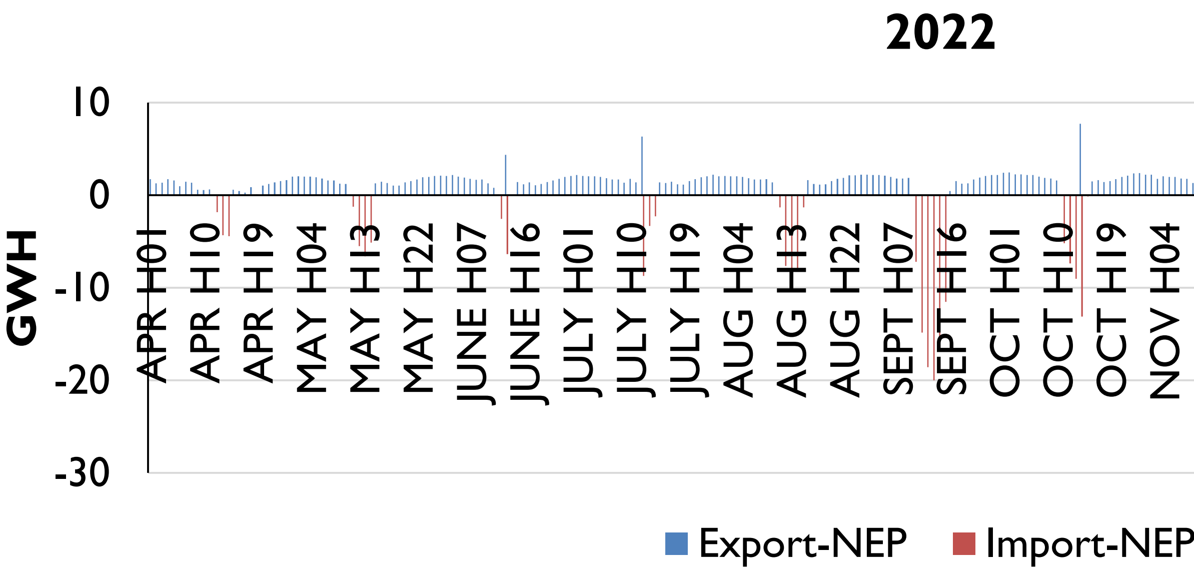
SARI/EI

IRADe Integrated Research and Action for Development

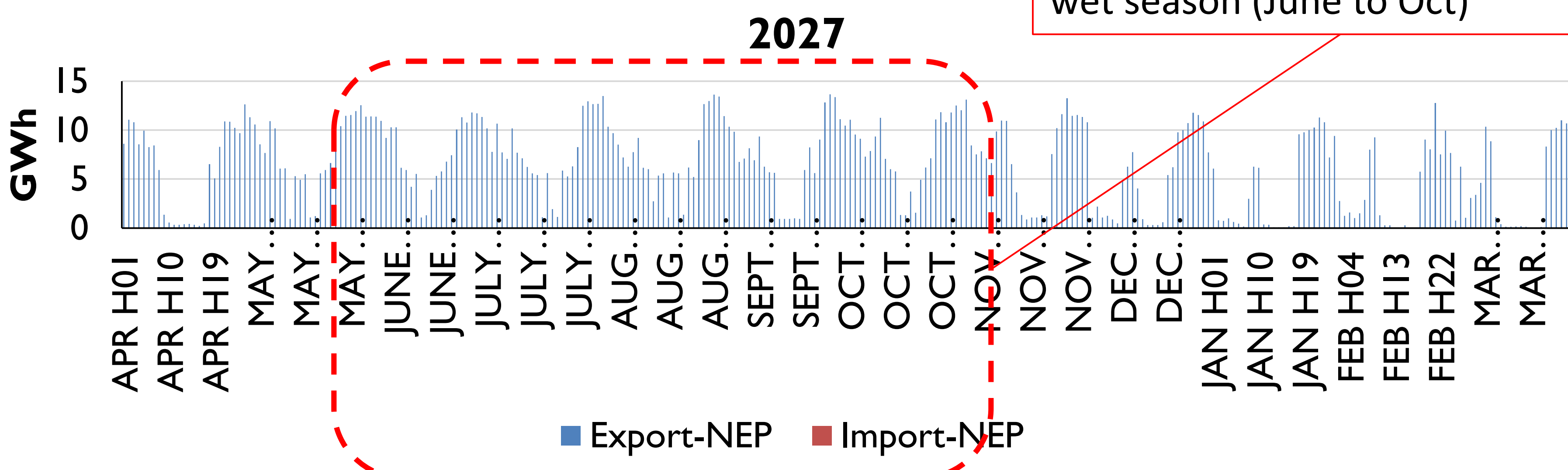
Nepal Electricity Trade - Integrated Trade Model
Hourly Quantity for a typical day for January, 2032 (Dry Season)



Nepal Electricity Trade - Integrated Trade Model
Hourly Quantity for a typical day in each month



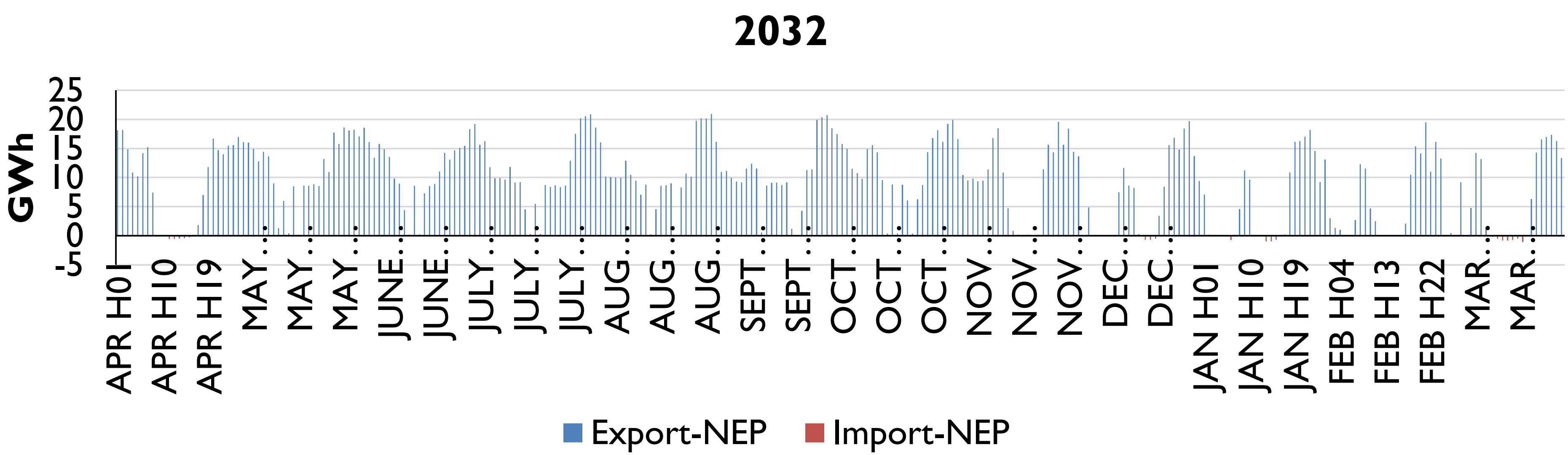
Higher level of exports during wet season (June to Oct)

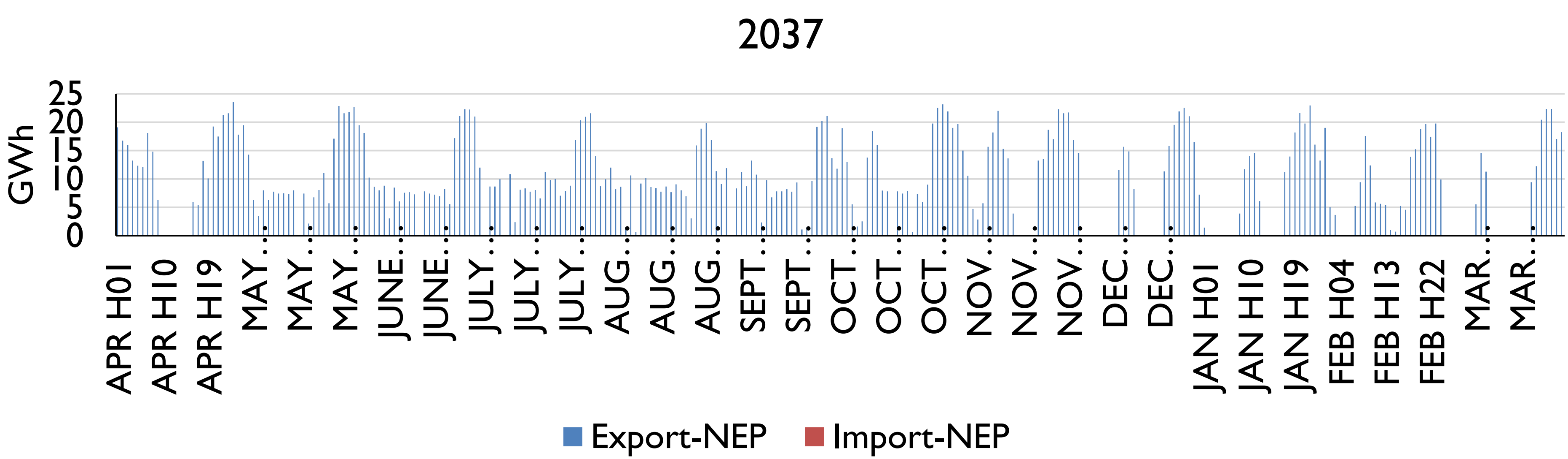


Integrated Research and Action for Development

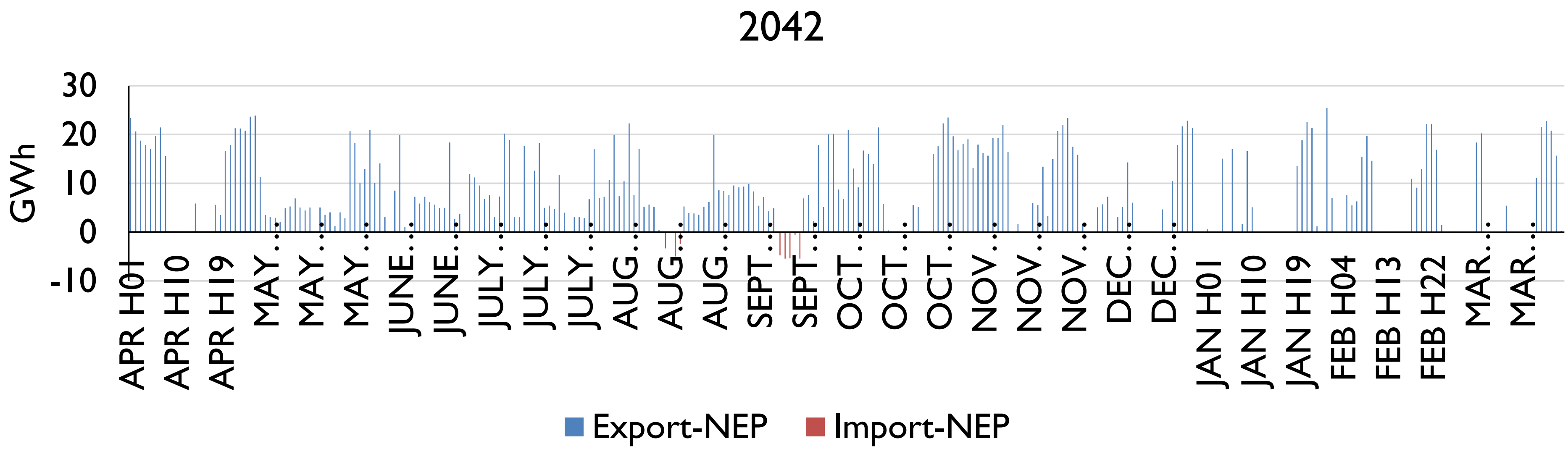
SARI/EI

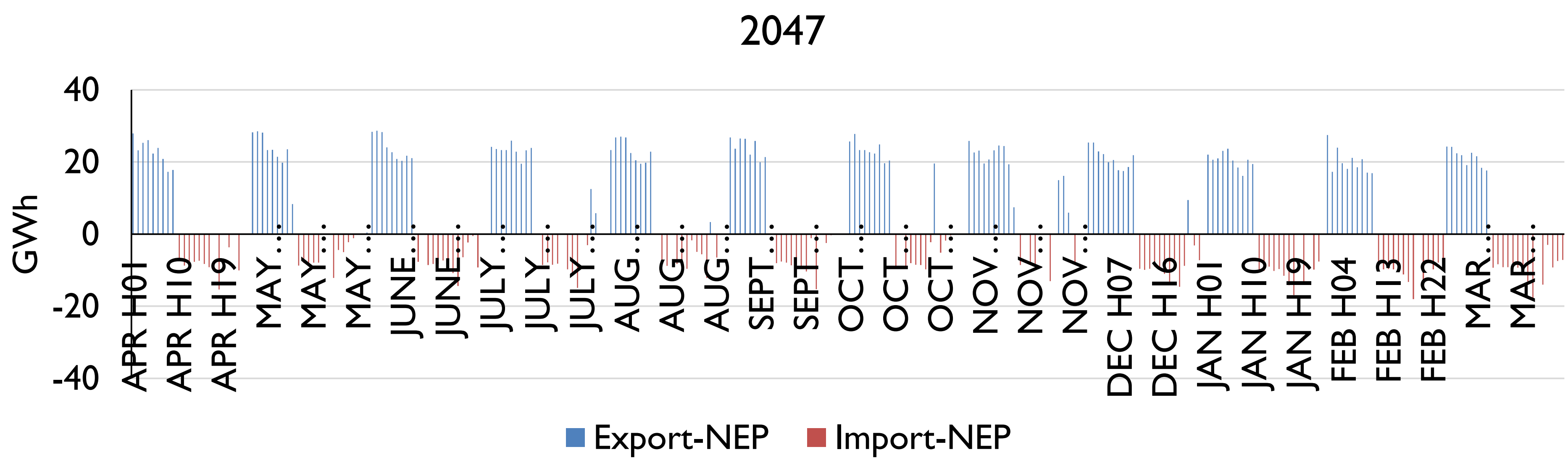
Nepal Electricity Trade - Integrated Trade Model
Hourly Quantity for a typical day in each month



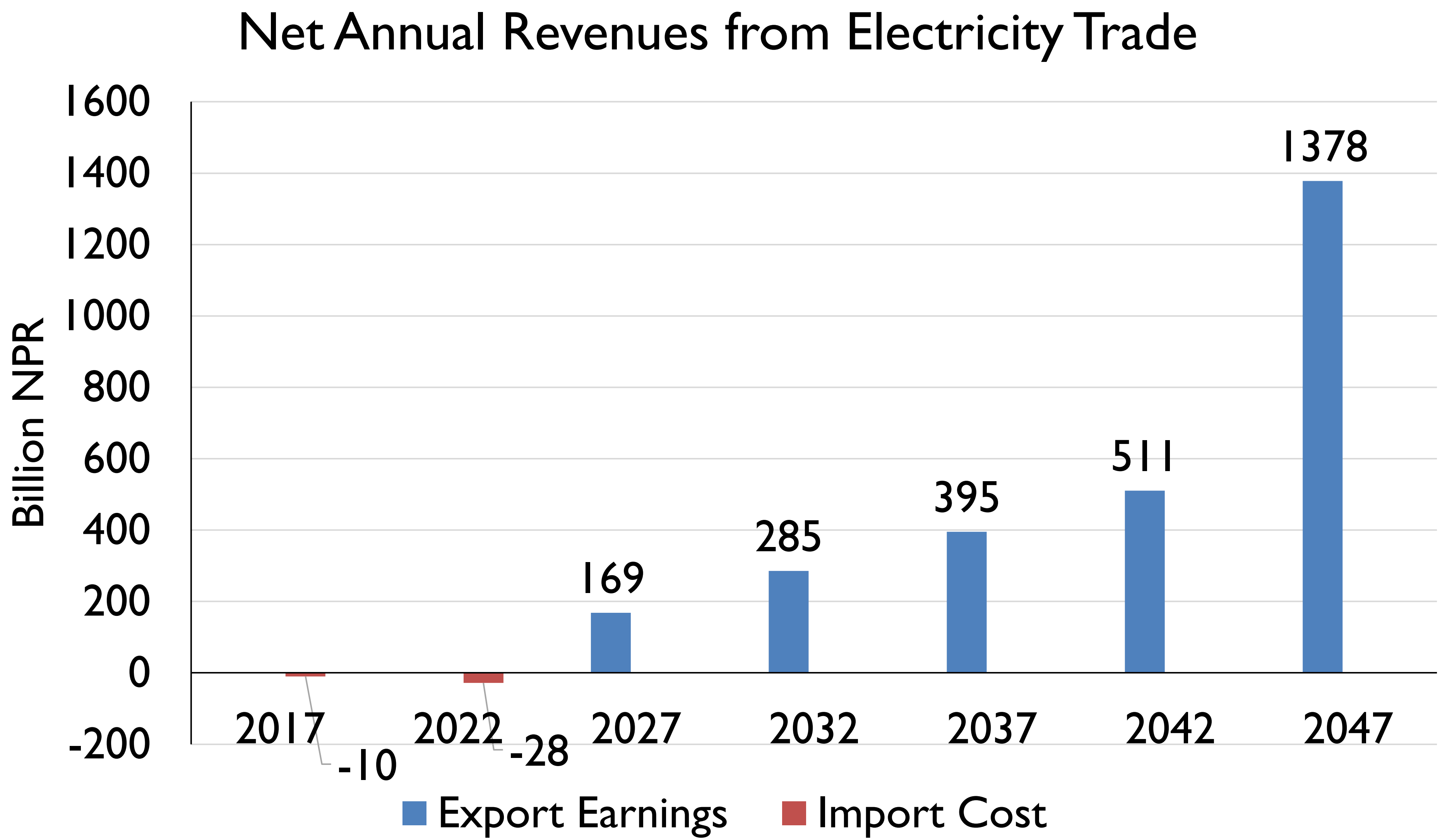


Nepal Electricity Trade - Integrated Trade Model
Hourly Quantity for a typical day in each month





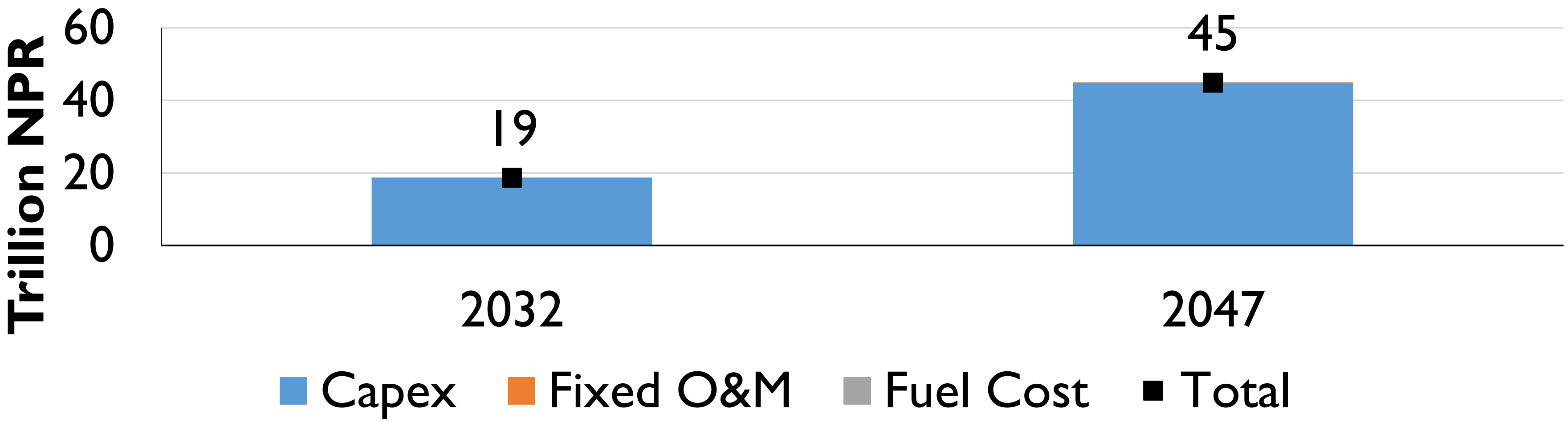
Nepal Net Annual Revenues from Electricity Trade - Integrated Trade Model



Revenues at 2012 price level

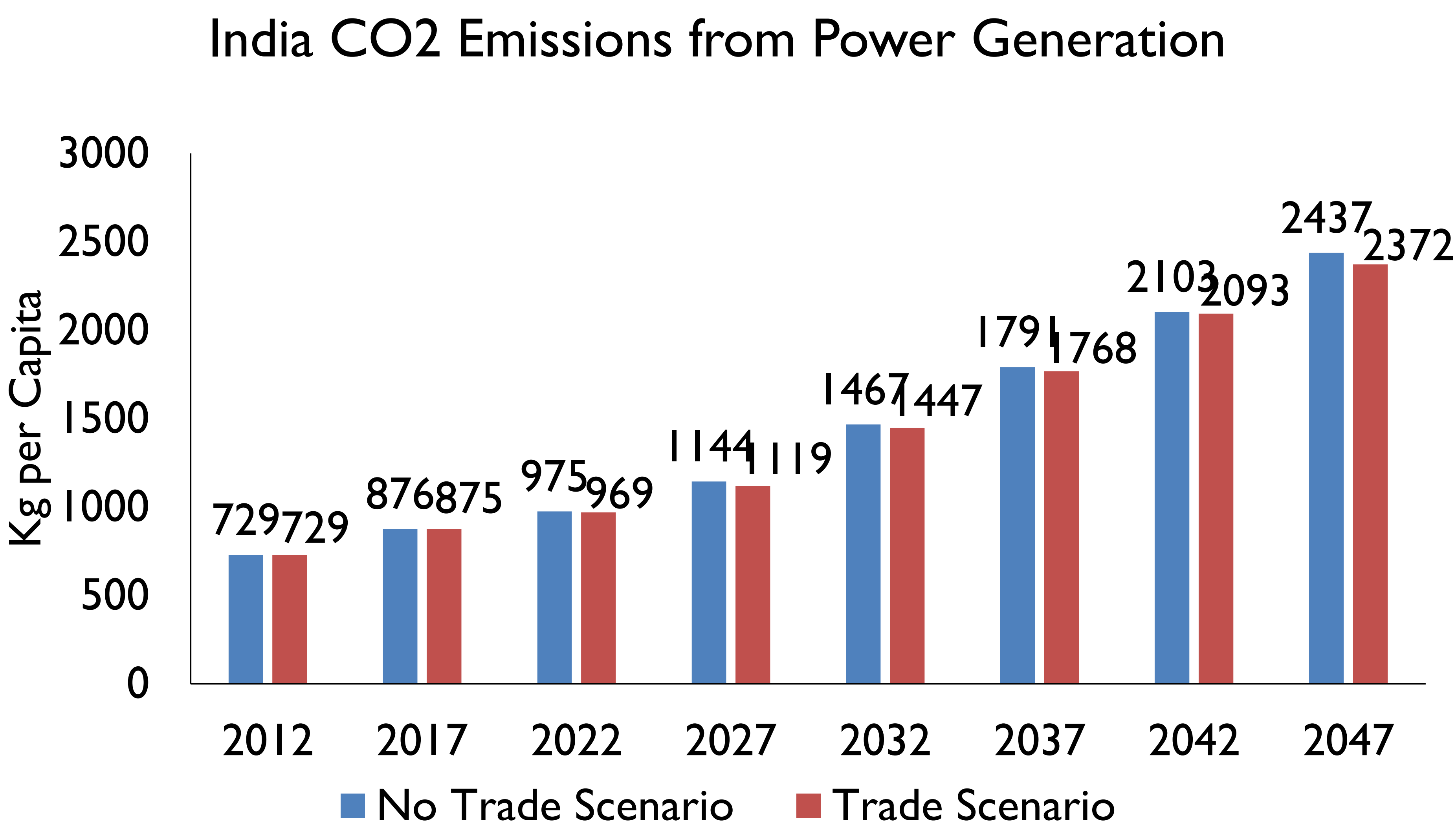
Cumulated Energy Cost Requirement- Integrated Trade Model

Nepal- Cumulated Total Energy Cost Requrement = (Capex + Fixed O&M + Fuel Cost)



in Trillion NPR	2032	2047
Cumulated Total Energy Cost in No Trade Scenario	3	12

India's CO2 Emissions from Power Generation- Integrated Trade Model



Key Findings

- Electricity Trade between Nepal and India supports early development of Nepal's untapped hydro potential
- Development of Storage based hydro capacities is important to add generation flexibility in the grid
- Development of PROR is also important as they provided generation flexibility with a day
- Nepal remains Net exporter from 2017 onwards however it will still needs to import electricity during certain time periods of a day

Economic Benefits of Power Trade- An Economic Model based Analysis For Nepal

Model Results are for Discussion Purpose Only

Basic Model Structure

- The model is a Linear Programming optimisation model based on a activity analysis framework
- Model maximises the sum of discounted value of the stream of consumption values over a time period of 50 years subject to a set of constraints
  – Macro-economic relationships,
  – technological feasibilities and potentials and
  – monotonicity constraints
- The economic relationships between sectors are modelled based on the Social Accounting (SAM) of 2007-08 for Nepal.
- The model is solved simultaneously for all years from 2007-2050
- The model incorporates changing demand pattern with changing incomes
- The income distribution is endogenously determined

Objective function of the model

$$MaxU = \sum_{t=0}^{T} \frac{POP_t * PC_t}{(1+r)^t} + \overline{PC}$$

- Discounted value of Private consumption over T periods
- Can have separate weights for diff. expenditure groups

Constraints Imposed on the model solution

- Commodity balance
- Investment Savings Balance
- Balance of Payments
- Capacity Limits
- Resource availability
- Capacity creation
- Net Foreign Capital Inflow
- Consumption monotonicity
- Upper & Lower bounds on Exports / Imports
- Household demand structure – LES based

Economic Linkages in the Model

USAID FROM THE AMERICAN PEOPLE SARI/EI IRADe Integrated Research and Action for Development

Demand & supply balance

- The model balances demand and supply of all commodities using the commodity balance equation

$$C_{it} + G_{it} + I_{it} + IO_{it} + E_{it} \leq Y_{it} + M_{it}$$

- Each component of demand and supply is projected in a consistent manner and demand and supply balanced.

Supply Side of the Economy

- The 57 × 57 sector SAM is aggregated to 6 × 6 sector SAM and included in the Model.
- The sectors considered in the SAM are
  - Agriculture :
  - Manufacturing:
  - Electricity
  - Gas & Water supply
  - Transport
  - Other Services
- The Electricity sector is disaggregated into 8 sectors of which 6 are Hydro power generation technologies.
- The availability of goods in the economy is obtained either through domestic production or imports from outside.
- Imports of goods and services in the economy are constrained to grow within bounds that are specified as ratios of Availability (Production + imports)

Electricity Sector

- The power generation technologies Considered in the model are
  - Hydro –ROR
  - Hydro-PROR
  - Hydro-Storage
  - Hydro-ROR with external funding
  - Hydro-PROR with external funding
  - Hydro-Storage with external funding
  - Solar
  - Diesel

Demand Side of the Economy

- Demand in the Economy is composed of
  - Private household consumer demand
  - Government consumption demand
  - Intermediate demand
  - Investment demand
  - Export demand
- The model maximizes the private household consumption.
- Government consumption is exogenously specified in the model.
- Intermediate demand in each sector is obtained as a function of production levels using the IO coefficients from the SAM.
- Exports are specified to grow within upper/lower bounds that are specified as ratios of domestic production.
- Investment demand is obtained through a set of behavioural equations and macro economic identities

Household Consumer demand

- The household sector is divided in to 10 expenditure classes each in rural and urban areas
- The different tastes and preferences of each household group is represented by its own demand parameter.
- Each household's demand preferences are represented by separate Linear expenditure system parameters
- Household class wise per capita expenditure and population Proportions is endogenously determined by separate log normal distributions for Rural and Urban areas
- People from a lower income group shift to a higher income group with higher levels of per capita consumption.

Investment and Savings

- Investments, Savings and capital formation is determined through a optimising behaviour based on a set of behavioural macro economic relations

$$\sum_i Z_{it} \leq Z_o + S*(VA_t - VA_0) + (FT_t - FT_0)$$

$$\sum (P_{i,j} * I_{j,t}) \leq Z_{i,t}$$

$$K_{j,t} = DEL(J) * K_{j,t-1} + I_{j,t}$$

Balance of payment

- The trade sector is endogenous to the model
- Trade variables like exports and imports are constrained to grow within bounds and also satisfy balance of payment constraint
- Net capital inflow is endogenous and a positive but falling function of GDP.

Specification of the Trade sector

- The trade related variables are determined by the following set of equations

$$\sum_i (M_{i,t} * MTT_i) = \sum_i E_{i,t} + FT_t$$

$$M_{i,t} \leq (1 + MGRL_i) * M_{i,t-1}$$

$$E_{i,t} \leq (1 + EXGRU_i) * E_{i,t-1}$$

$$FT_t = (a - b * t) * VA_t$$

Technological constraint

- Sectoral output at any time point is constrained by the capacity to produce given the capital stock in that sector in that time.

$$(X_{j,t} - X_{j,t-1}) \leq (K_{j,t} - K_{j,t-1}) / ICOR_j$$

- The electricity output from Hydro technologies is constrained by the maximum possible potential.
- Bounds are imposed on the maximum possible investment increase in each electricity sector.

USAID FROM THE AMERICAN PEOPLE

SARI/EI

IRADe Integrated Research and Action for Development

SALIENT FEATURES OF THE MODEL

- The model is a macro model covers the whole economy
- Bottom up – top down model
- Multi sectoral inter temporal optimization model
- 6 commodities – more can be added
- 13 activities – new activities can be included
- Endogenous GDP, production, consumption, Investment and demand.
- Endogenous income distribution – 20 expenditure classes (10 rural & 10 urban)

SALIENT FEATURES OF THE MODEL- Contd.
USP OF THE APPROACH

- Specific technologies can be assessed.
- Feedback / rebound effect captured.
- Optimal strategy to reach a goal/ target.
- Inter sectoral consistency.
- Can asses impacts on poor.
- Investment/ Consumption / Capacity consistency.
- Welfare impacts of various policies.
- **Can be extended to be a CGE model**

Results- Economic Impacts

Model assumptions

Parameter	Assumption
Discount rate	4% pa
Government Consumption rate	6% pa
Maximum bound for Private consumption growth rate	8%
Minimum bound for Private consumption growth rate	0%
Marginal Savings rate	25%
Autonomous Energy efficiency assumption	0.5%
Total Factor Productivity	0.7%
Population	UN Medium Variant
Depreciation	5%
Maximum Hydro Potential	**42 GW**

Trade Bounds

Commodities	Exports upper bound	Imports upper bound
Agriculture	1%	15%
Manufacturing	17%	30%
Electricity*	0%	14%
Gas & water Supply	10%	15%
Transport	6%	20%
Other services	6%	5%

*Electricity exports and imports are scenario specified the numbers presented only represent a Base case scenario

Scenarios

- **Base scenario**: marginal savings rate is assumed at 15% compared to 8% in SAM.
- **No Trade** : Electricity Exports are assumed to be zero and imports zero after 2011-12. Electricity generation profile same as in the TIMES-MARKAL model.
  - To reflect the ambition in NEA and Nepal's Plans

    the marginal savings rate raised to 25% compared to 15%
- **Trade scenario**: Electricity exports, Imports and technology wise production same as TIMES-MARKAL, the ratio of export price to domestic price from the TIMES-MARKAL model assumed in the SAM Model

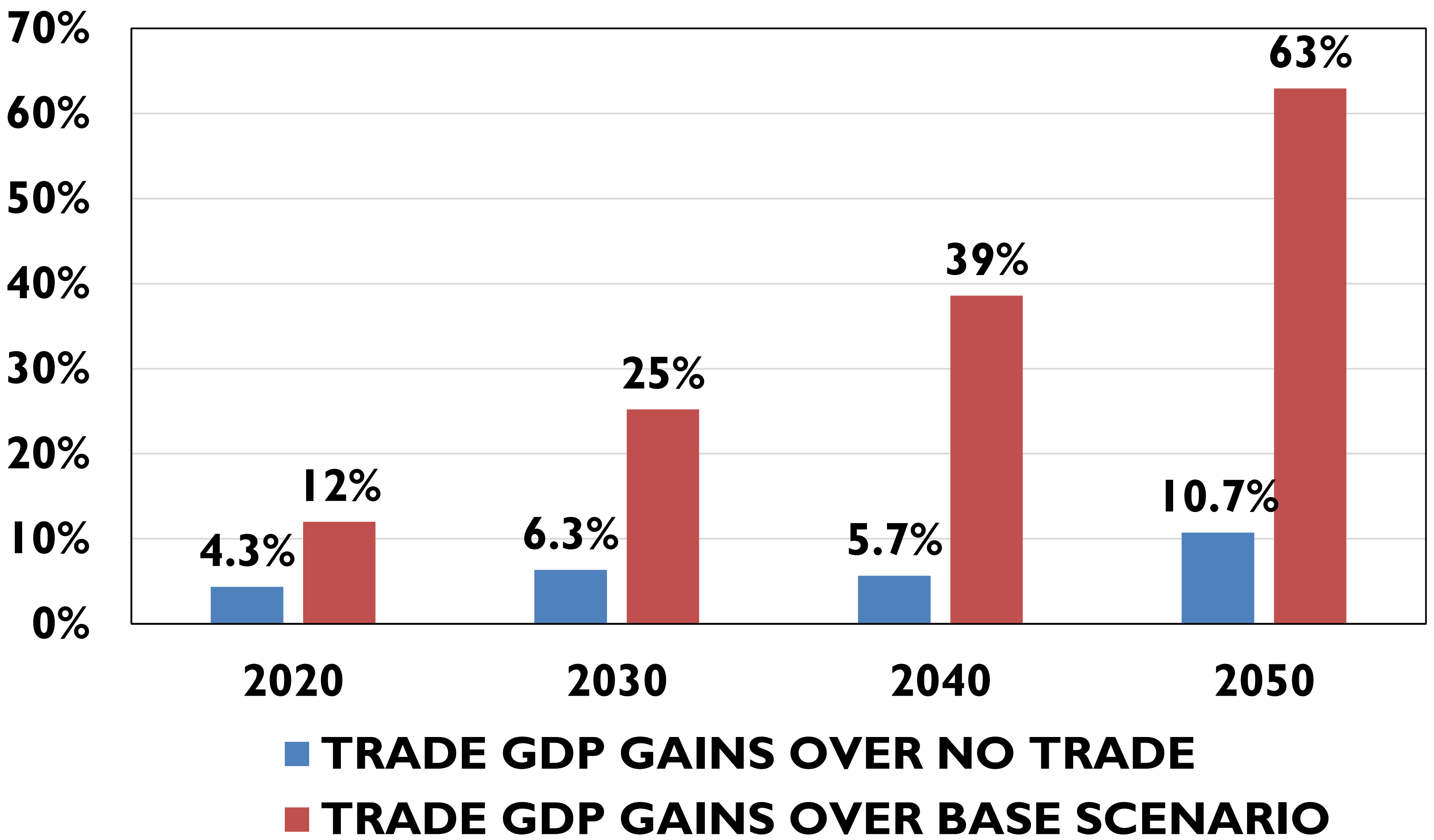
  Marginal savings rate 25%

Comparative Analysis

GDP Growth Rate(%)

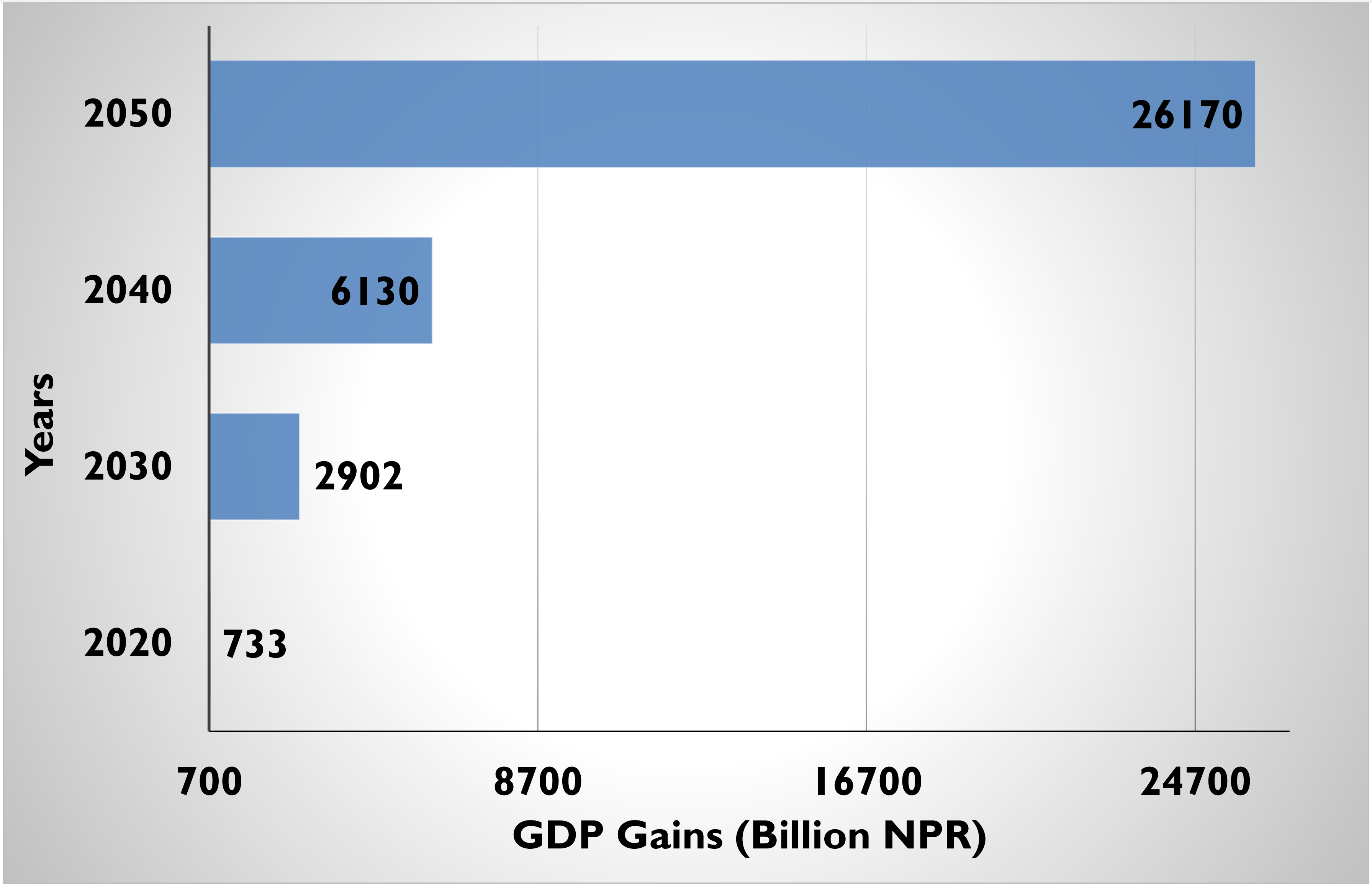
Time Period	Trade Scenario	No Trade Scenario	Base Scenario
2007-2030	7.5	7.1	5.9
2030-2050	8.7	8.0	6.7

GDP Gains in Trade scenario compared to no trade and base scenario



SARI/EI

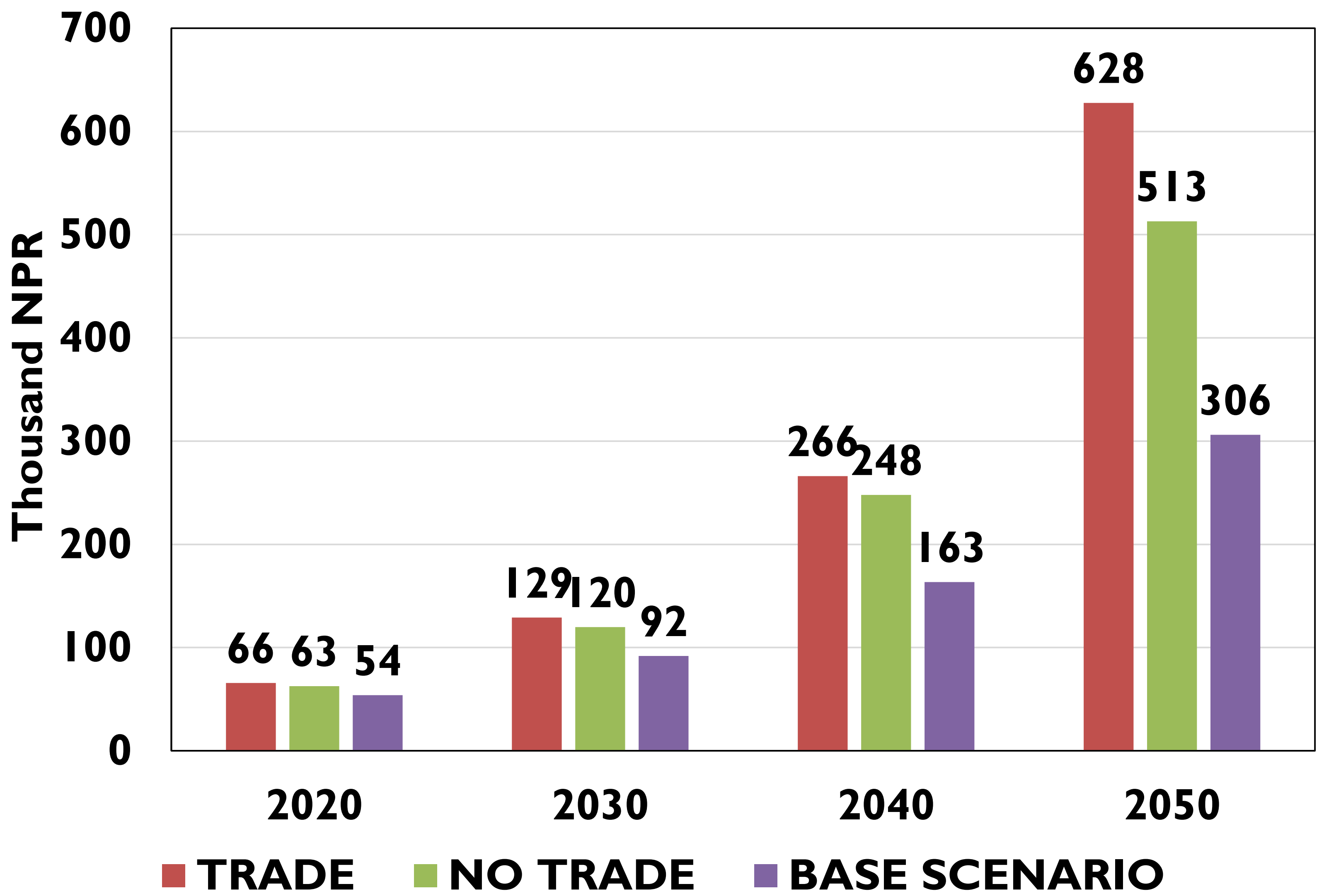
Cumulated GDP Gains From 2007 (Billion NPR)



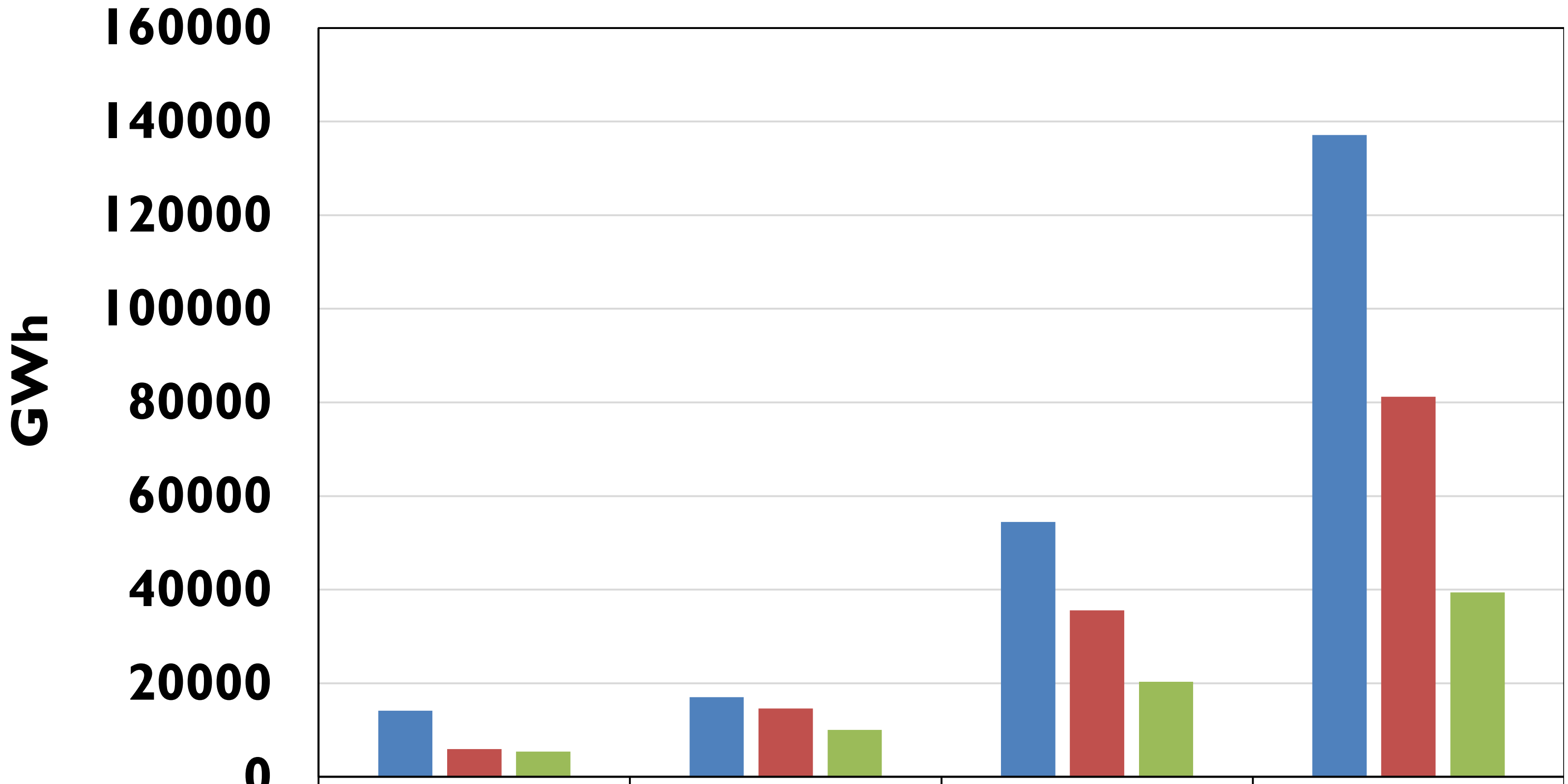
SARI/EI

Integrated Research and Action for Development

GDP Per Person (Thousand NPR)

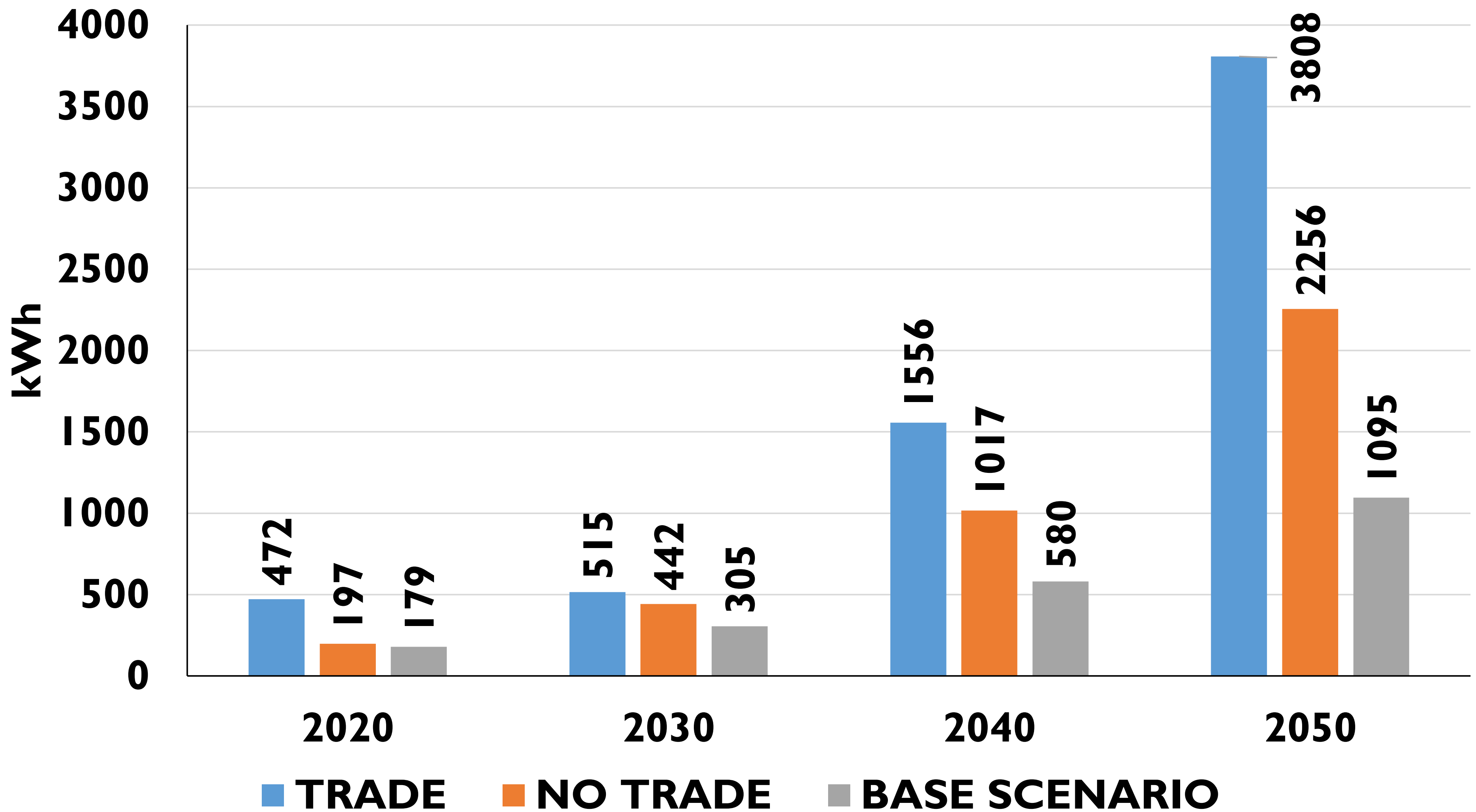


Power Demand (GWh)

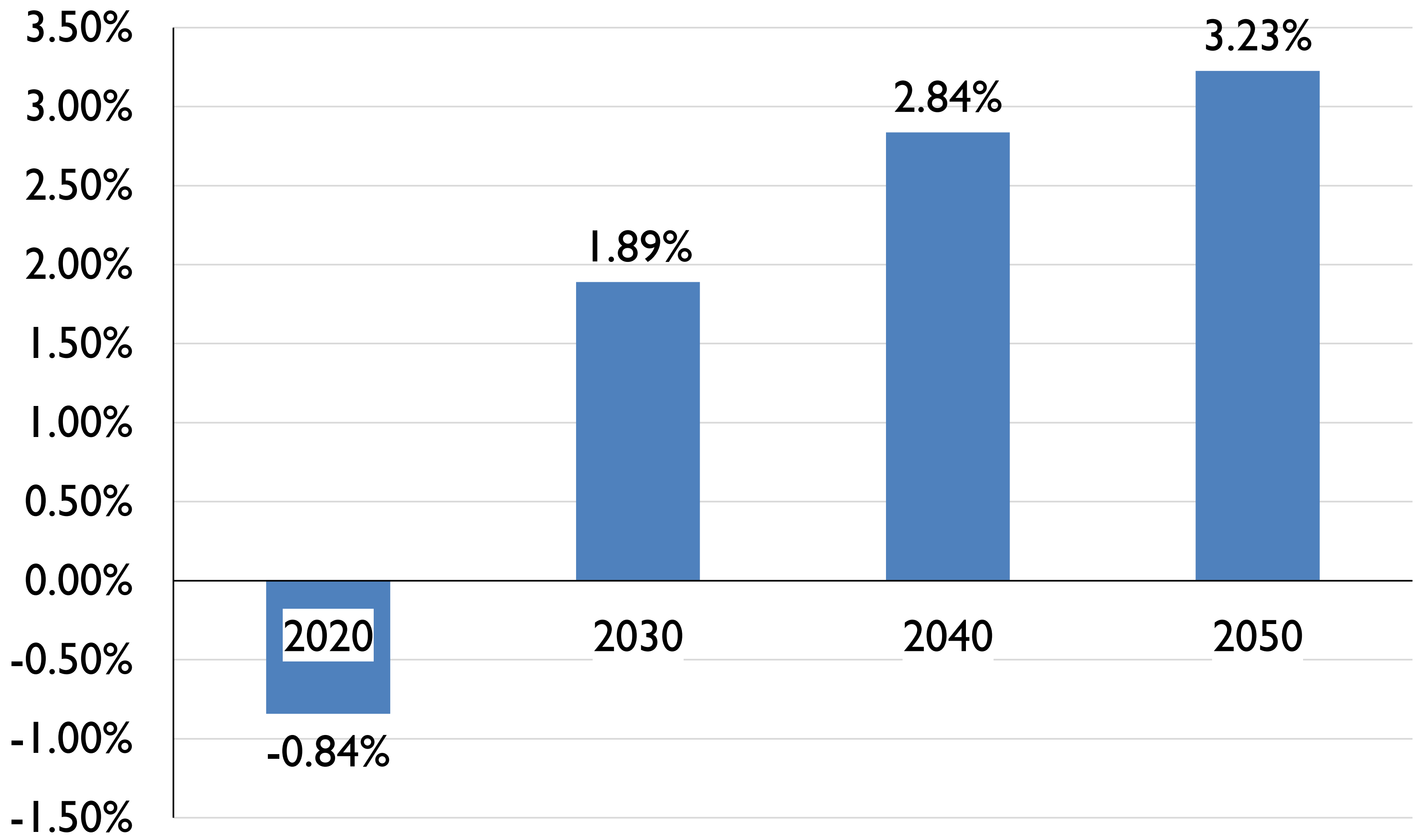


	2020	2030	2040	2050
TRADE	14151	17005	54457	137095
NO TRADE	5919	14577	35597	81201
BASE SCENARIO	5383	10065	20301	39436

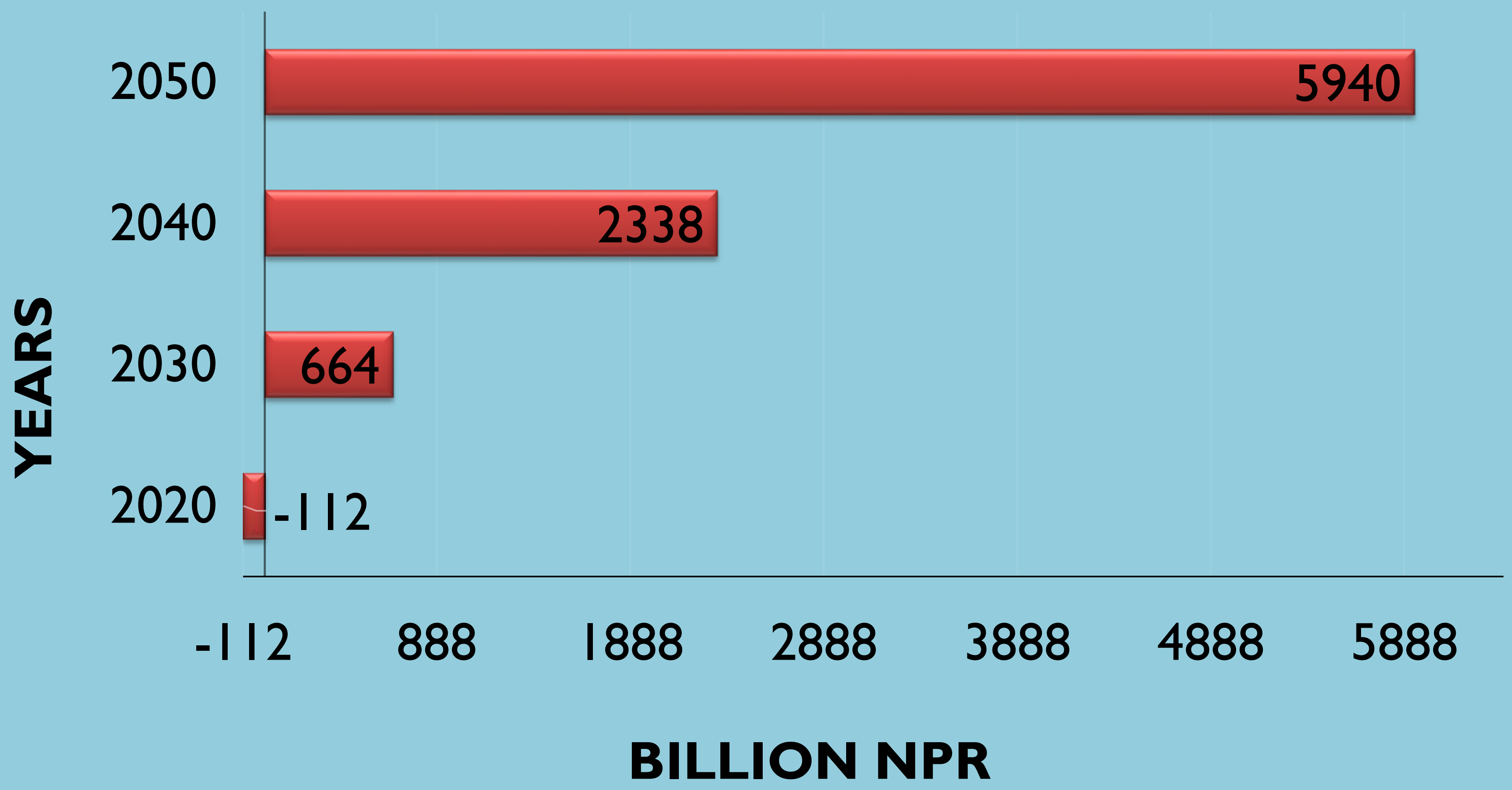
Per Capita Power Demand (kWh/person)



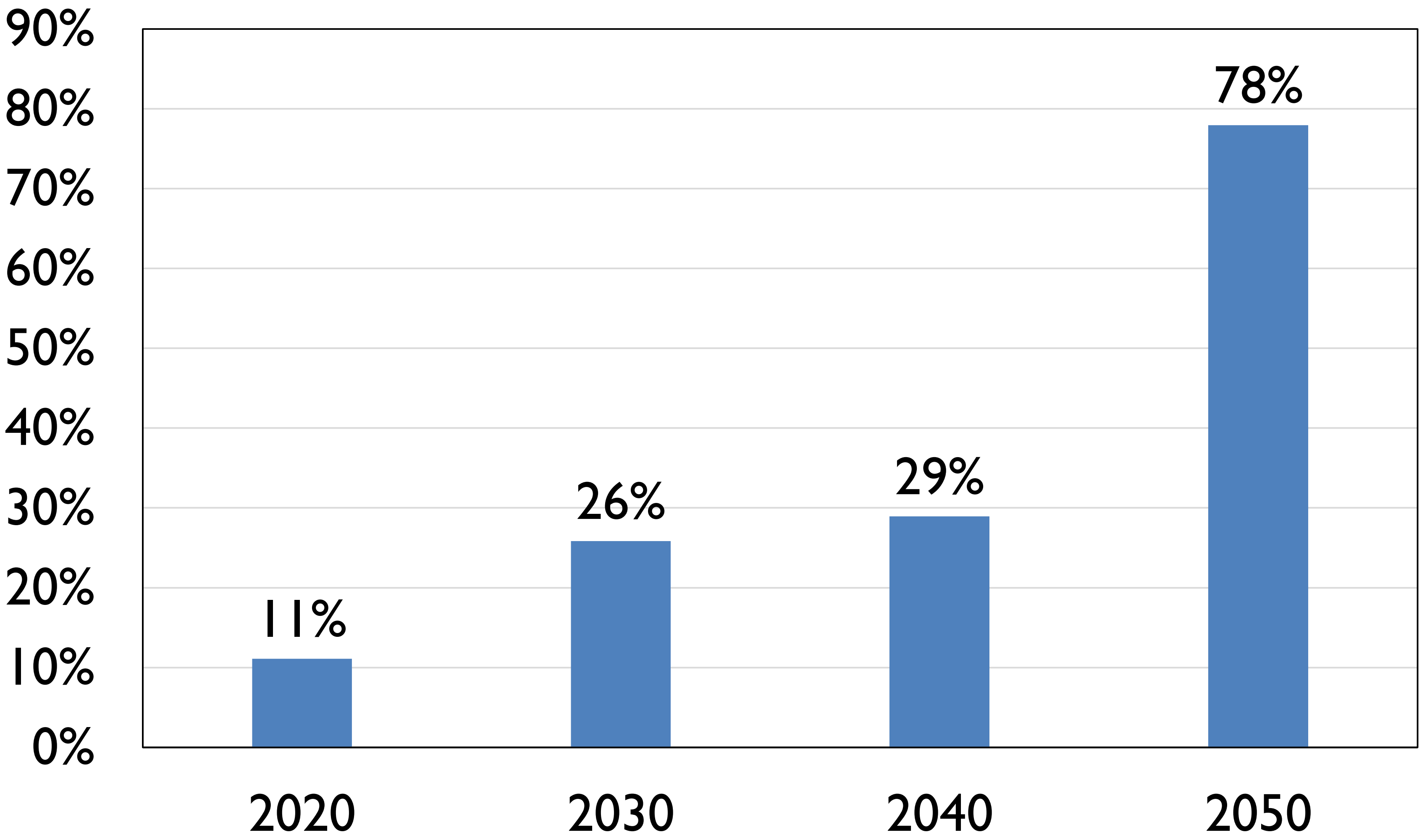
Household Consumption Gains as a Percent of No Trade



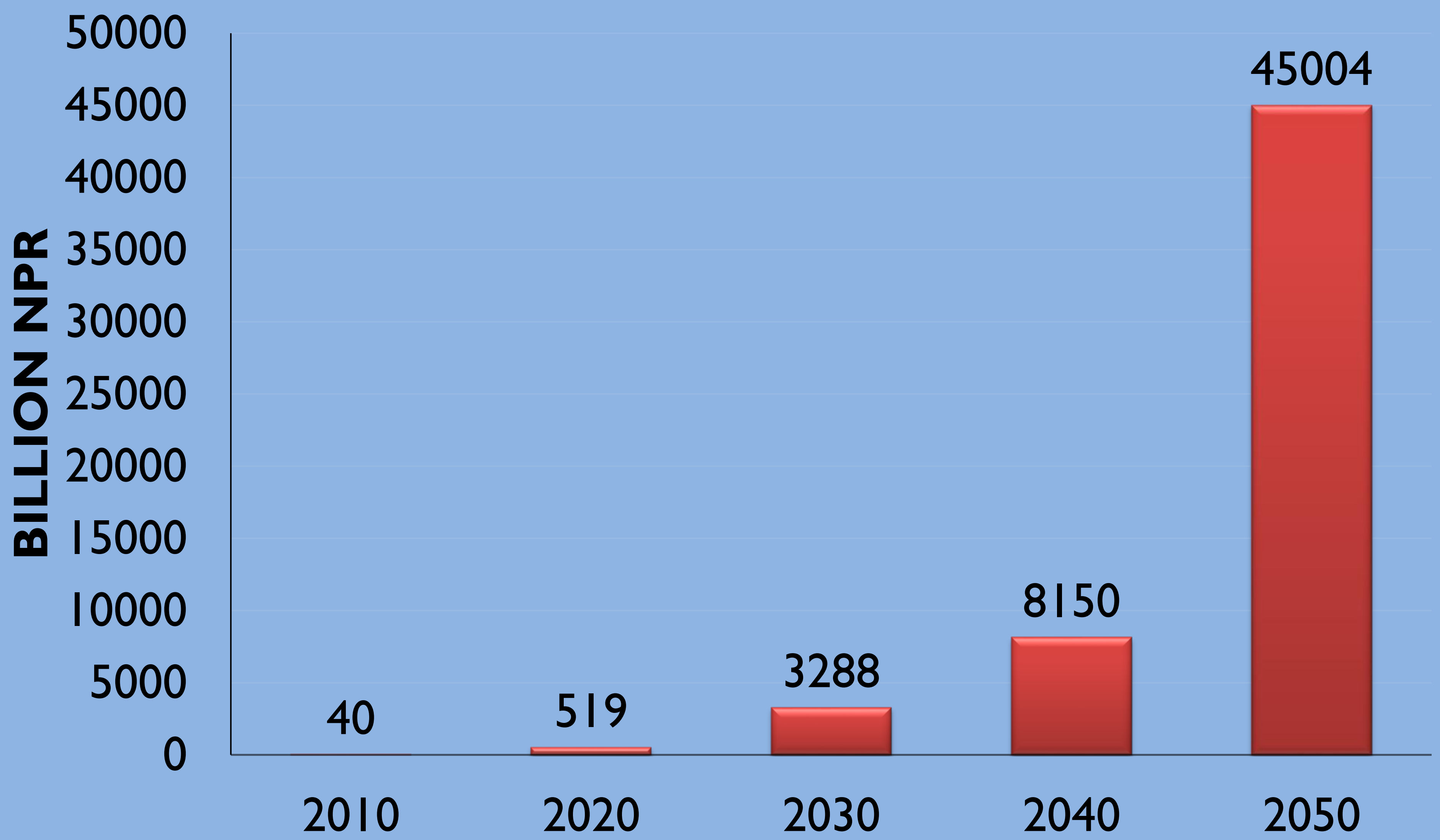
Increase in Total household Consumption(Billion NPR)



Total **investment increase as percent of no Trade**



Cumulated total investments increase (Billion NPR)

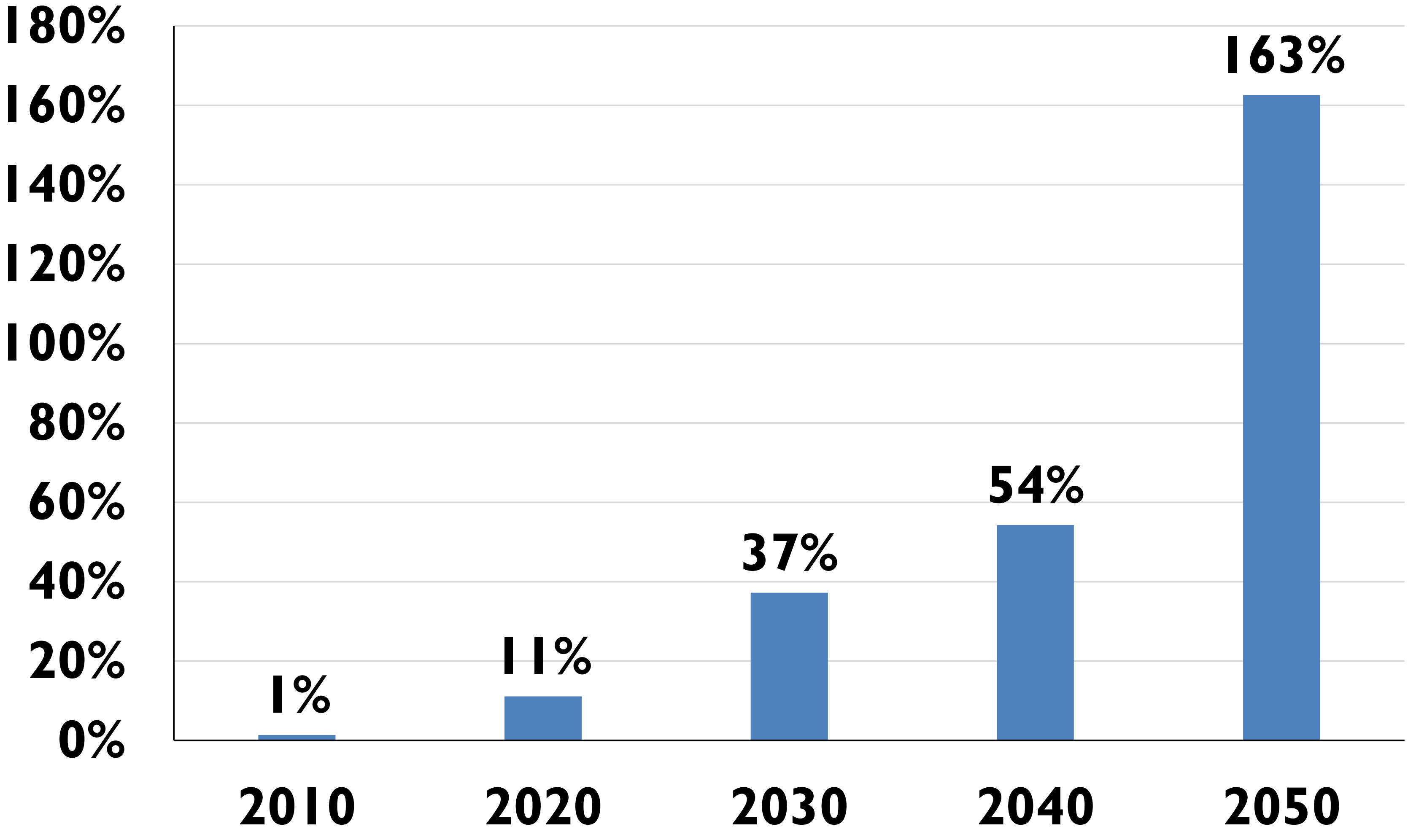


USAID FROM THE AMERICAN PEOPLE

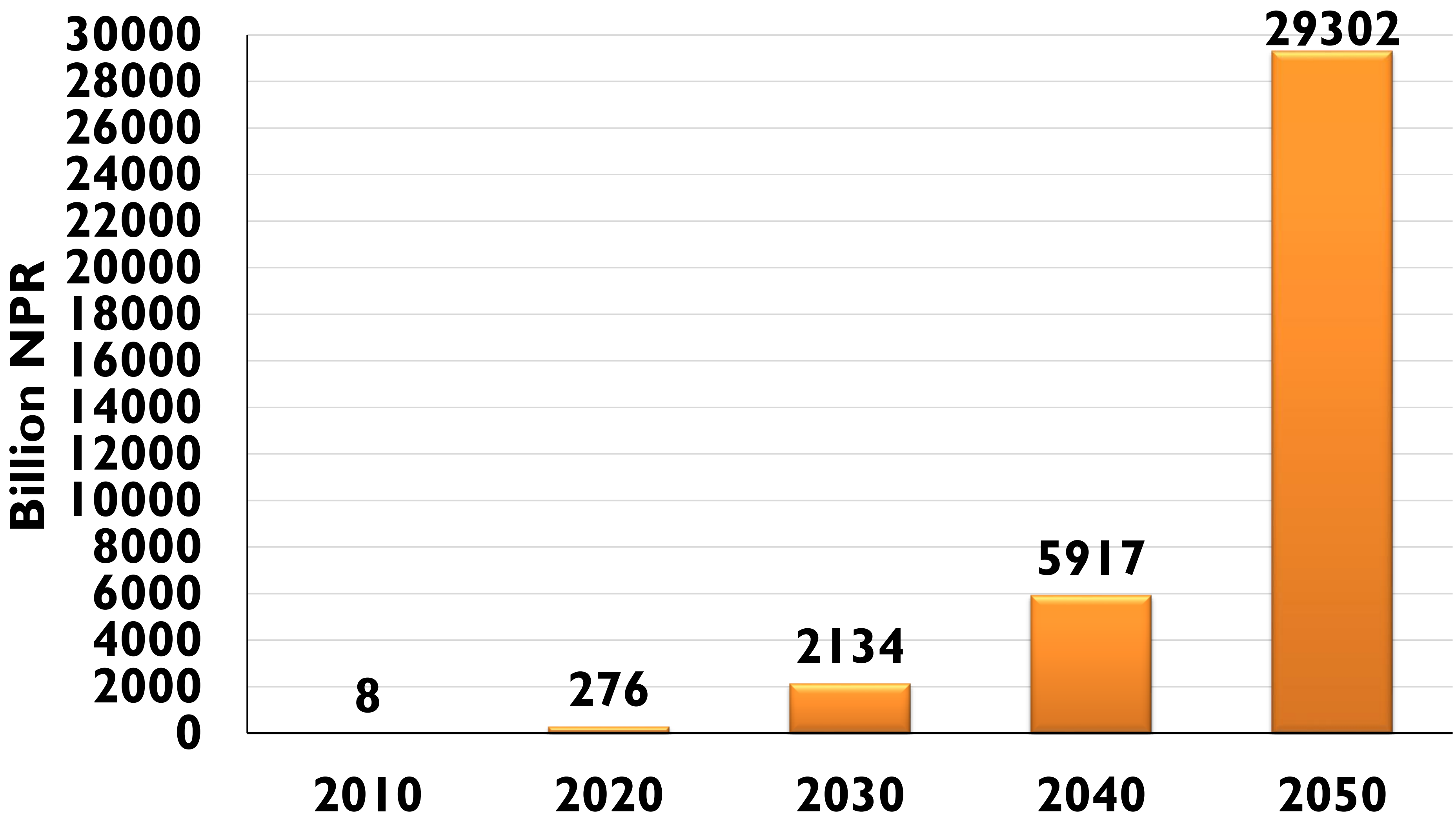
SARI/EI

IRADe Integrated Research and Action for Development

Foreign Inflows increase as a percent of No Trade



Increase in Foreign Inflows due to Trade (Billion NPR)

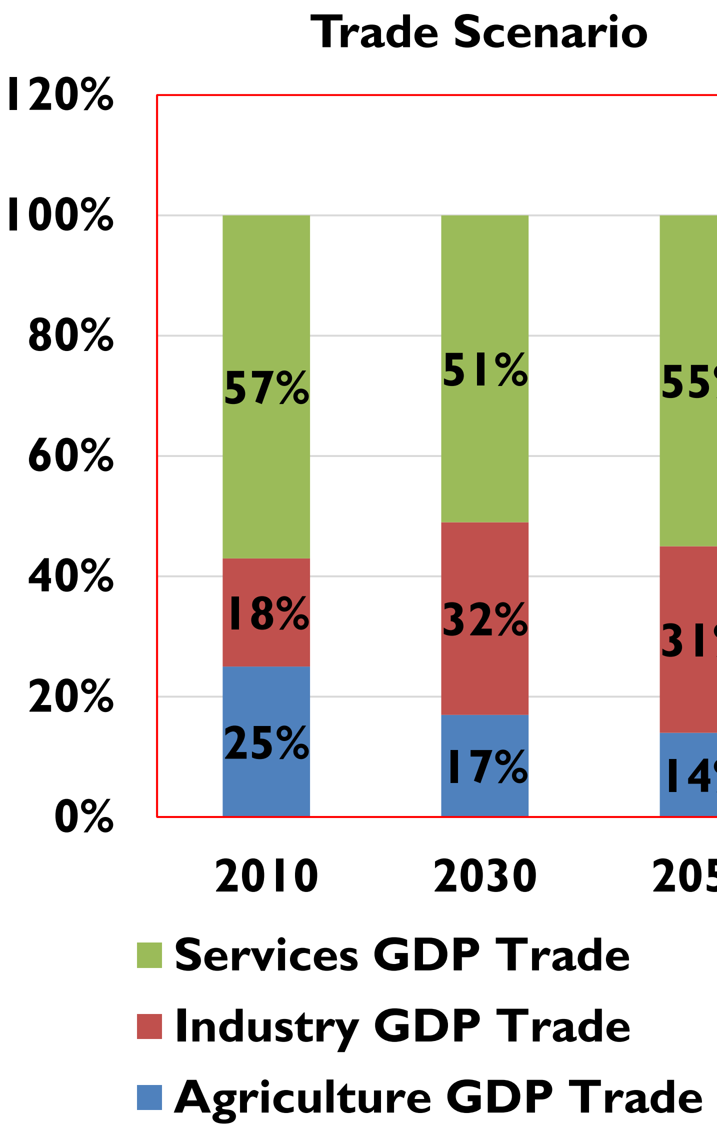


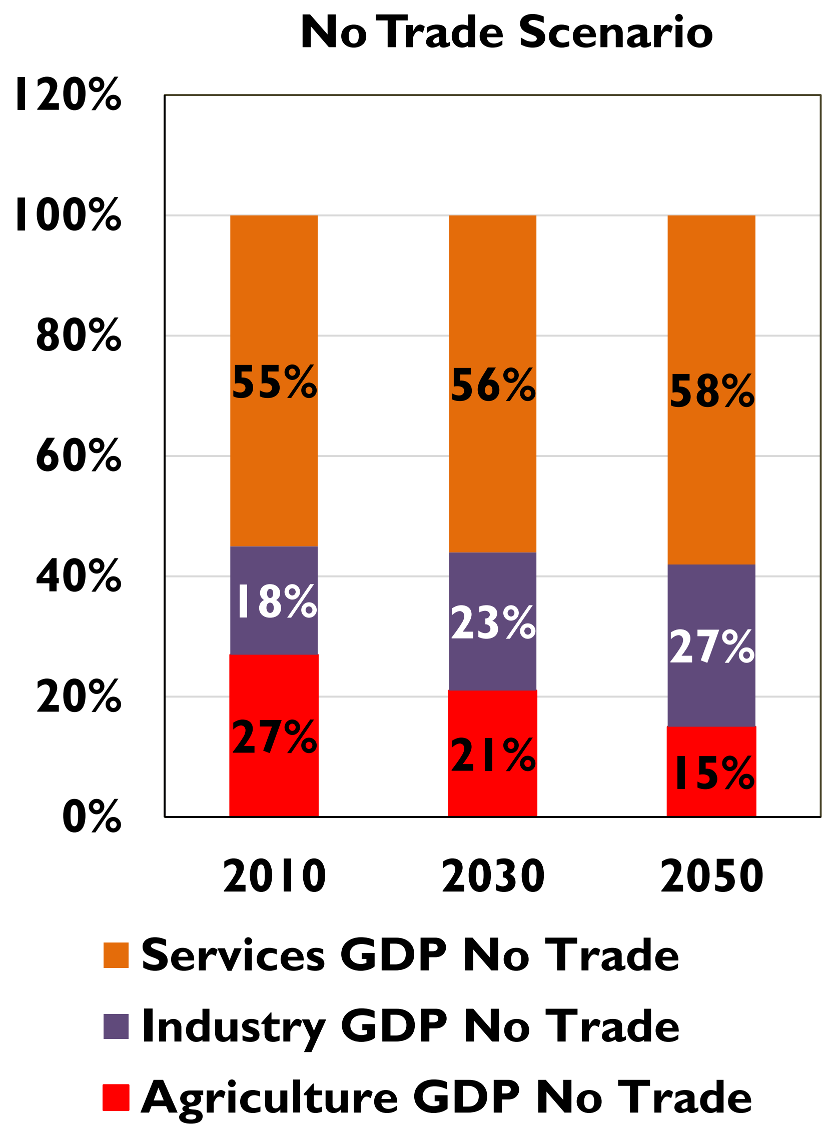
USAID FROM THE AMERICAN PEOPLE

SARI/EI

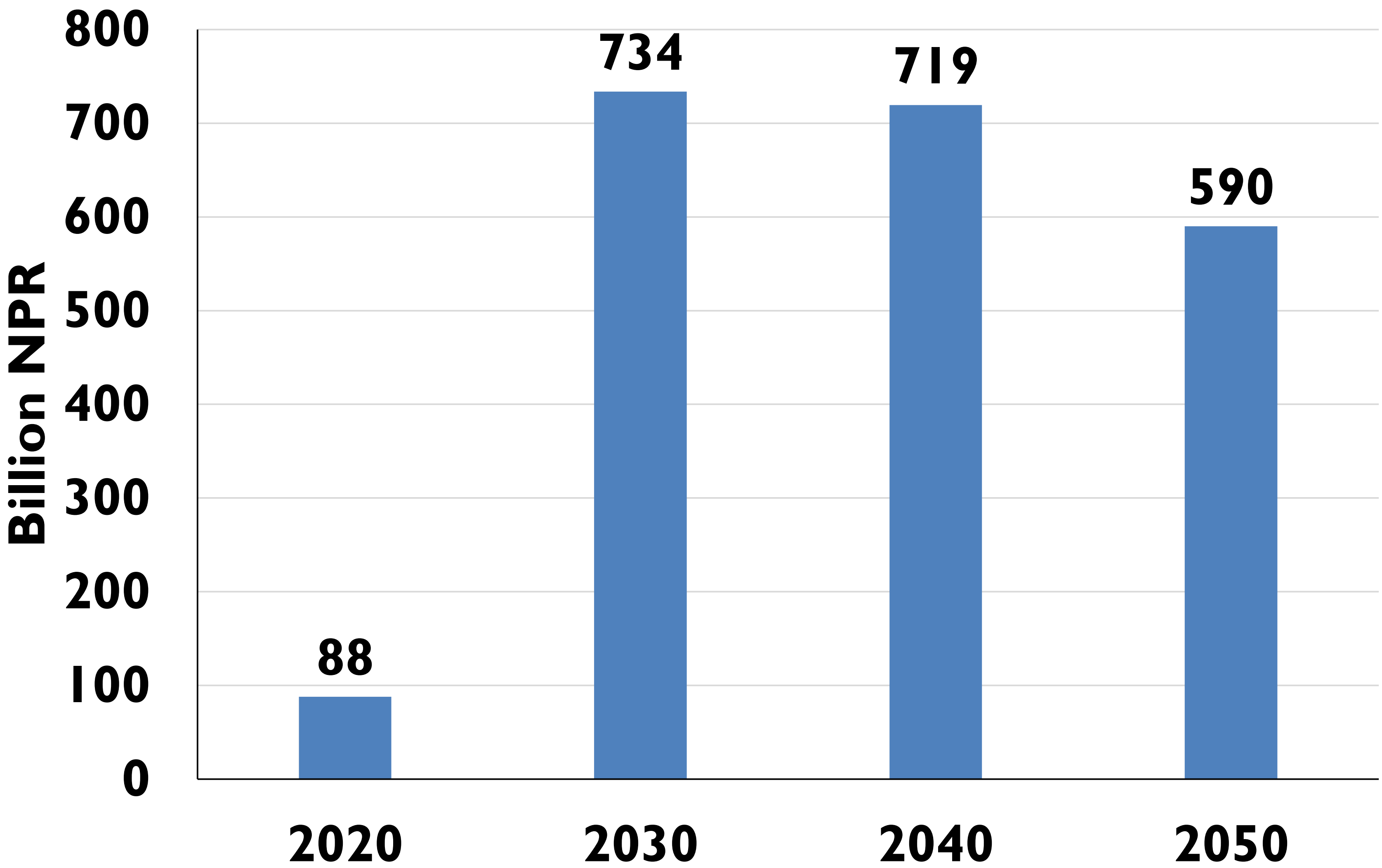
IRADe Integrated Research and Action for Development

Sectoral Shares in Trade and No Trade





Export Earnings from Electricity (Billion NPR)



Findings

- Cumulated GDP gains in 2030 is 2902 billions NPR and in 2050 is 26170 NPR .
- Cumulated consumption gains in 2030 is 664 billions NPR and in 2050 is 5940 billions NPR .
- Total Investments increases in the economy in 2030 is 3288 billions NPR and in 2050 is 45000 billions NPR .
- Total Foreign inflows increased in 2030 by 2134 billions NPR and by 2050 by 29302 billions NPR.
- The per capita power demand increased from 3277 billions NPR to 6415 billions NPR.
- The cumulated investments in electricity sector increased by 464 billions NPR to 558 billions NPR.

USAID FROM THE AMERICAN PEOPLE

SARI/EI

IRADe Integrated Research and Action for Development

Findings

- Per capita Electricity demand increases to 3808 kwh/person in the Trade scenario compared to 2556 kwh/person in the No trade scenario and 1095 kwh/person in the Base scenario. The increase in power demand is nearly 3 times as compared to the base scenario
- The economic gains are much more substantial if one considers the base scenario
- Per Capita GDP doubles in the Trade scenario as compared to Base scenario

Thank You

Determination of Consumption demand

$$C_{i,j,t} = COMC_{i,j} + \beta_{i,j}(PCTC_{j,t} - \sum_{i} COMC_{i,j})$$

$$\sum_{i} \beta_{i,j} = 1$$

Where,

$C_{i,j,t}$ is the per capita consumption of commodity i by household group j at time t.

$PCTC_{j,t}$ is the per capita total consumption expenditure of household group j at time t.

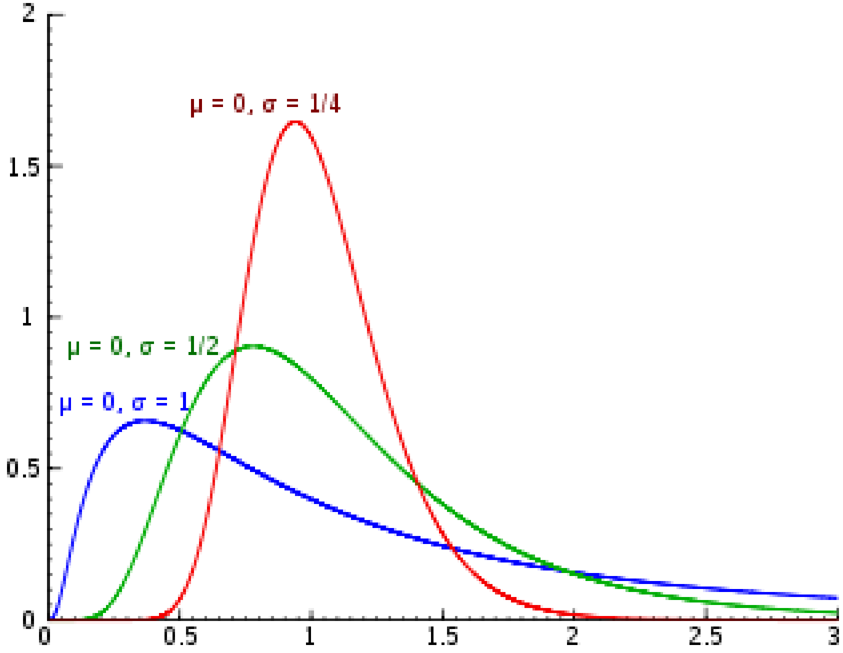
$COMC_{i,j}$ is the minimum consumption of commodity i by household group j

$\beta_{i,j}$ is the share of expenditure on commodity i by household group j in total expenditure left after making the minimum consumption expenditure.

Log normal distribution function

The mathematical form of the log normal distribution is given as

$$F_x(x;\mu,\sigma) = \Phi\left(\frac{\ln x - \mu}{\sigma}\right)$$



Where, $\Phi\left(\frac{\ln x - \mu}{\sigma}\right)$

is the standard normal cumulative distribution function, μ is the mean and σ is the standard deviation.

Incremental Capital-Output Ratio

Commodity	ICOR
Agriculture	1.62
Manufacturing	4.21
ElecHYdroStor	6.36
Gas&WaterSupply	1.69
Transport	2.31
OtherServices	1.06
ElecHYdroROR	2.88
ElecHYdroPROR	3.14
ElecDiesel	28.1
ElecSolar	6.29
ElecIPP-PROR	3.14
ElecIPP-ROR	2.88
ElecIPP-Stor	6.36

Cumulated Investment increase in Electricity Sector (Billion NPR)