Hydro Investment

(A Long-Term Policy to Mitigate Load Shedding in Nepal)

By

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Thesis

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FOREWORD

Firstly, I am extremely indebted to my thesis supervisor Professor Earling Moxnes for his enormous guidance during supervision time. Similarly, the credit also goes to the entire system dynamics group. Finally, my family members & friends are equally thankful for their support.

ABSTRACT

Background

Nepal has been facing acute load shedding problem though it has a large potential for hydropower generations. It has more than 6,000 rivers with commercially exploitable hydropower generating potential of about 42 GW. However, till date, only 1 GW hydro capacity is on hand. Load shedding increased significantly over the past decade. It tripled from 490 GWh/year to 1,160 GWh/year even though the import of energy heavily increased from 356 GWh/year to 2,581 GWh/year. This load shedding has hindered overall economic growth of the nation. Several previous researchers concluded that the load shedding problem can be abolished with the dynamic pricing policy in short-run. They do not talk much about long-term solution. However, the hypothesis of this study is that the foreign direct investment (FDI) policy for deficit financing of hydropower projects can eradicate the capacity shortage, increase the electricity supply, and mitigates the load shedding problem in long-run.

Method

Load shedding is a dynamic problem that requires analysis by dynamics models. Stella Architect software is used to analyze and find solutions to the problem.

Results

The research concludes that at least 9% of the deficit financing must be covered by the foreign direct investment to increase the hydro capacity and electricity supply to mitigate load shedding over the policy period in future. The net present value (NPV) of profits of Nepal Electricity Authority (NEA), the organization with the full responsibility of the production and distribution of electricity in Nepal, with the FDI policy is almost doubled than without policy.

Conclusion

The political leaders are believed to implement the FDI policy as the NPV of profits with the policy is higher than without policy even at constant price in the future. The study can be generalized to hydro industries seeking long-term solution of load shedding problem.

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1. INTRODUCTION

1.1 Problem

Nepal has been facing acute shortage of electricity though it has a large potential for hydropower, thermal and solar energy production. The potential of wind energy is yet to be explored. Nepal is rich in hydro resources, with development potential of 83 GW and commercially exploitable hydropower generating potential of about 42 GW. However, till date, only 1 GW hydro capacity is on hand that is very low out of total potentiality. Load shedding is frequent, and the country ranks 137th out of 147 countries in quality of electricity supply.

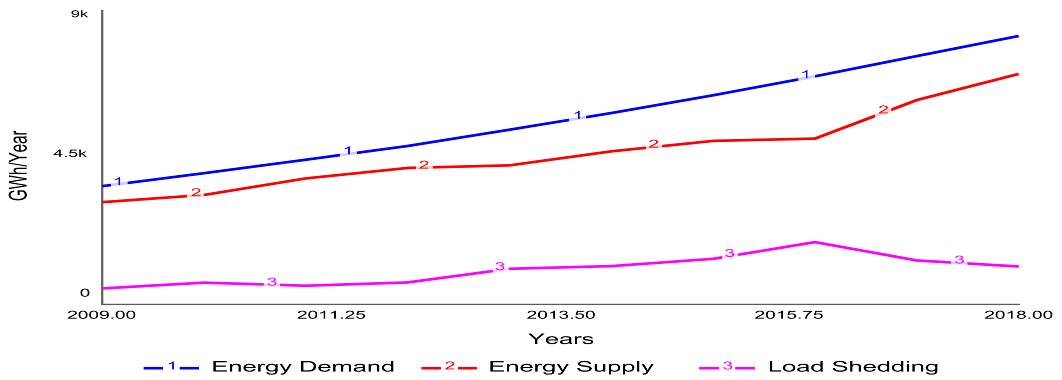

Figure 1: Energy Demand, Energy Supply & Load Shedding (Source: NEA Report, 2017/18)

Figure 1 clearly shows that the load shedding increased significantly over the past decade. It tripled from 490 GWh/year to 1,160 GWh/year. This load shedding has hampered overall economic growth of the nation. Further, Nepal Electricity Authority (NEA), the organization with the full responsibility of the production and distribution of electricity in Nepal, has been importing huge amount of energy from India to mitigate the deficit of energy. Over the decade, the import of energy heavily increased from 356 GWh/year to 2,581 GWh/year. Thus, solving the issue of energy deficiency from domestic production rather than import seems urgent for the long-term solution.

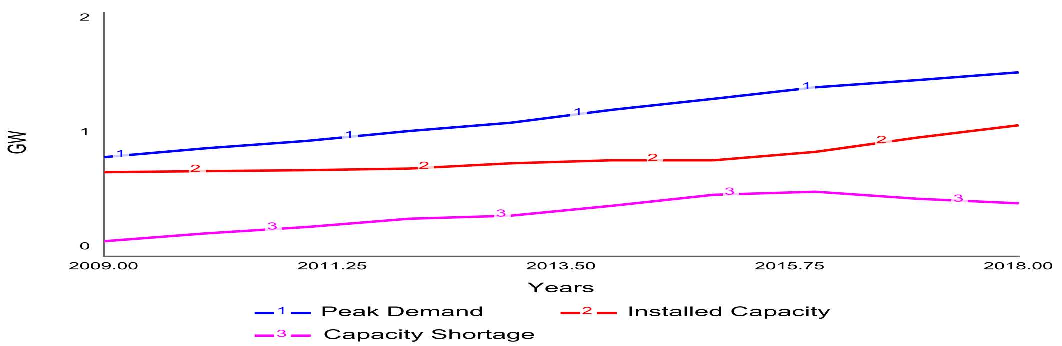

Figure 2: Peak Demand, Installed Capacity & Capacity Shortage (Source: NEA Report, 2017/18)

Similarly, Figure 2 depicts that the capacity shortage also tripled from 0.123 GW to 0.434 GW over the past decade. Therefore, there seems a perfect positive correlation between the load shedding and the capacity shortage. And, proper handling the capacity shortage may answer the problem of load shedding.

1.2 Hypothesis

The hypothesis is that the load shedding problem is caused by capacity shortages. And, capacity shortage is caused by lower level of investment in hydropower projects which ultimately originated from inadequate financing for these projects due to limited debt available from the domestic banks. However, following researchers conducted their research on the load shedding problem in Nepal.

Mr.David Sundøy Haldorsen, Mr.Håkon Nikolai Løhren Heiestad and Mr.Nikolai Hoelgaard Weum-Andersen jointly conducted a research on the topic of '*Hydro Power in Nepal'* in 2016. They found that dry season, lack of storage type facility and system loss are the main reason behind load shedding (blackouts) in Nepal.

Similarly, **Raunak Karanjit** conducted a research on the topic of *'Dynamic Pricing and the Future of Nepalese Electricity Market'* in 2016. He found that the dynamic pricing match the demand and supply of electricity in the short run to eradicate blackouts from the country.

And, **Pradip Regmi** conducted a research on the topic of *'Blackouts in Nepal and dynamic pricing'* in 2017. He found that the dynamic pricing policy is able to fill the gap between demand and supply of the electricity in the short run.

Conclusively, Raunak Karanjit and Pradip Regmi concluded that the load shedding problem can be abolished with the dynamic pricing policy in short-run. They do not talk more about the long-term solution. It is implicit that the load shedding rises with the increment in capacity shortage. Therefore, mounting the hydropower capacity with adequate investment helps to eradicate the load shedding problem in long-run future as more supply can be provided profitably at the current price. And, investing more is a trivial solution that requires analysis and good arguments to implement.

1.3 Analysis

1.3.1 Structure Analysis

NEA, a stakeholder, projected that the demand of electricity increases continuously in future. It is determined by the levels of total population and gross domestic product (GDP). Government of Nepal Water and Energy Commission Secretariat, 2017 stipulated that the total population of the country will be 1.4 times higher in 2040 as compared to the base year and the average GDP grows 4.5% per annum up to 2040.

On the other hand, the supply of electricity in future depends on the hydro production, internal power purchase (ipps), imports and thermal production. However, as internal power purchase, imports and thermal production are assumed to remain constant over the policy period in future, the supply is derived only by the hydro production. Further, the hydro production is the result of hydro capital & its productivity. Hydro capital increases with the investment and decreases with the scrapping. Therefore, if there is adequate investment in hydropower projects in future then the capital increases enough to meet the demand of electricity in the policy period. Accordingly, the supply of electricity balances the demand and the load shedding problem can be mitigated.

1.3.2 Behavior Analysis

The model explains the historical development. Further, it may also help to illustrate a trivial finding that more financing leads to more supply of electricity. The model addresses the following questions: Why do not these investments take place today? Is it due to lack of understanding laws, regulations and current policies? What is keeping investments down? What are the low cost solutions to the problem?

1.4 Policy

The purpose of the policy is to increase the hydro capacity with adequate investment on it. Domestic sources of financing is not large enough to meet the desired investment as local banks and financial institutions in Nepal can sanction only 50% of their paid-up capital for the hydropower projects as per the policy of the central bank of Nepal. Therefore, an alternative source of financing is needed to cover the deficit amount of financing. There may be various options on the market like public offering of shares & bonds and FDI. The public offerings are not appropriate due to under subscription chances. For instance, the public offering of Nepal Telecom, a government undertaking, was under subscribed. Therefore, we have considered the foreign direct investment (FDI) policy to meet up the deficit financing that has not been practiced till date. The 50% rule is not changed yet because of credit risk concentration on the single borrower.

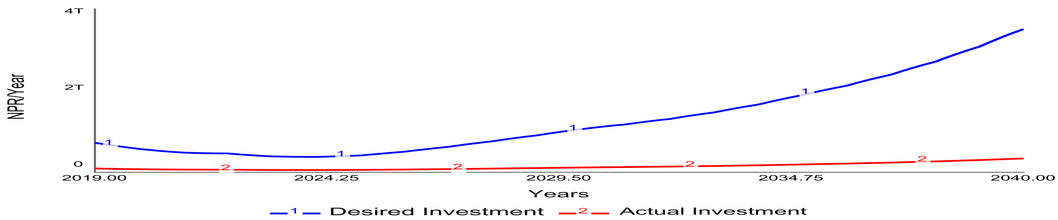

Figure 3: Desired Investment & Actual Investment

Figure 3 displays that there is remarkable gap between desired investment and actual investment. This is due to the fact that desired investment considers the peak load and actual investment considers required capital to mitigate load shedding. If there is profitability then the investors desire to build the hydro projects even to meet the peak load.

From the simulations, it is identified that 9% of the deficit financing must be covered by the foreign direct investment to increase the hydro capacity and electricity supply as needed to mitigate load shedding. This implies the FDI Coefficient of 0.09 when FDI Policy is on.

1.5 Implementation

The core reason of low investment is the scarcity of available money to invest on hydro projects from the domestic financing even though new hydro power is profitable at current price. The FDI policy is appropriate to cover the deficit financing that assist to increase the hydro capacity and hydro energy production to handle the burning issue of load shedding in Nepal. However, there are various factors that must be considered prior to implementing the proposed policy. The most important factor is the commitment of political leaders. Unless they have lack of understanding, it is impossible to implement the policy.

Similarly, there must be campaign to increase the public awareness so that electorates understand its benefits before switching the policy. The land and labor availability also influence the policy. Acquiring the land for project development is difficult task. There must be enough labors to build the desired capacity.

Corruption is another vital factor that needed to be controlled otherwise there will be cost escalation on the project. There are some examples of FDI withdrawn by foreigners due to excessive extortion in Nepal. The various demands of local people, where the project is located, also pose threat for the FDI. The officials buy time to grant permission for FDI is another obstacle. Therefore, prior to lunching the policy, the project owner needs to fix above mentioned issues.

2. MODEL DESCRIPTION

The dynamic problem discussed above can be solved using the system dynamics theory and technique. It has many features to address the dynamic problem. Modern computerized tool, Stella Architect, is used to understand and solve the problem.

2.1 Stock and Flow Diagram

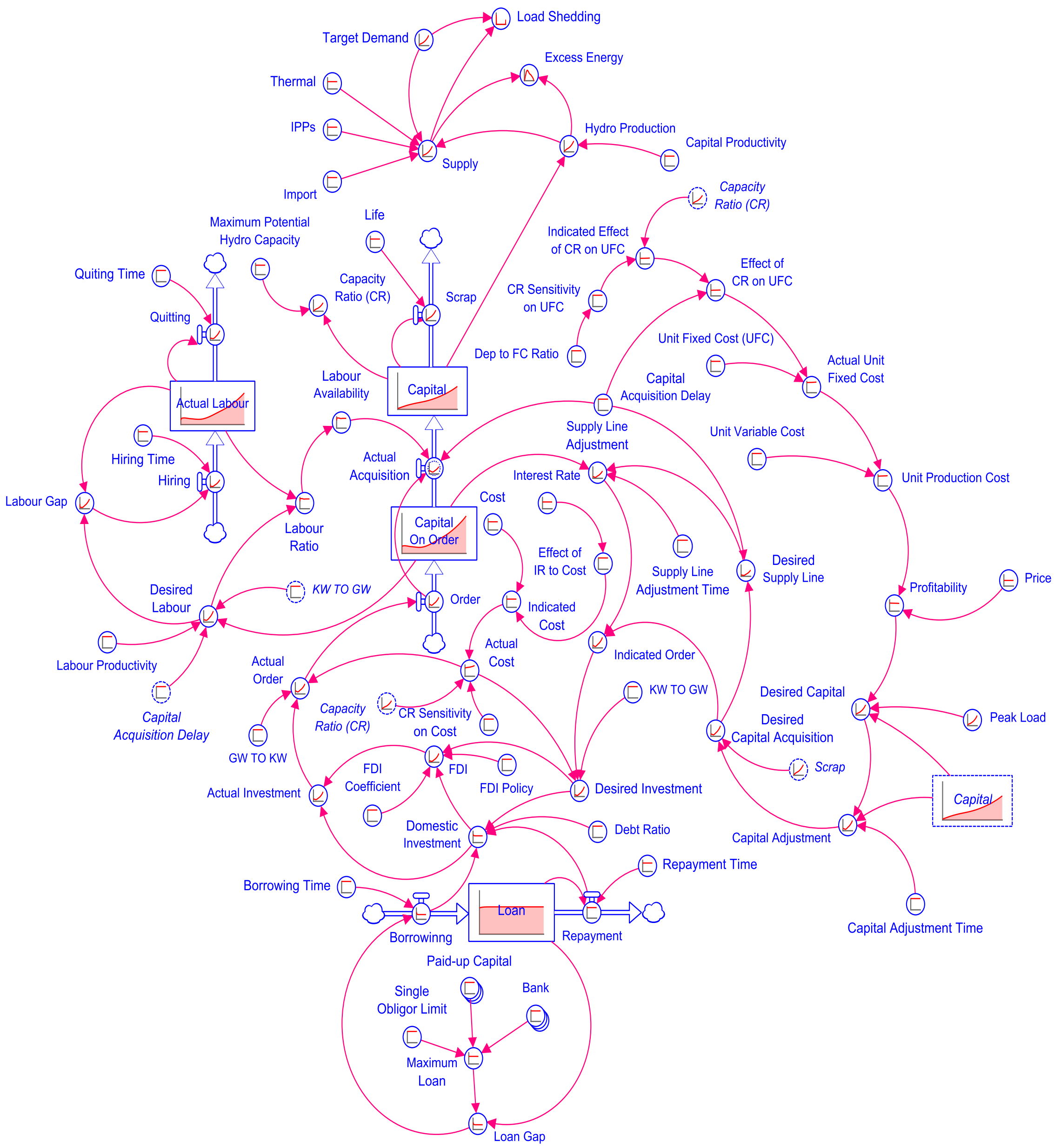

Figure 4: Stock and Flow Diagram

Above stock and flow diagram is explained in detail below. There are many variables on the model including key sectors; capital, bank financing, labor and profitability.

Load Shedding

$$LS = f(td, S) = td - S \quad (1)$$

is the difference between the target demand, *td*, and supply, S (Regmi, 2017). It increases with the increase in demand and decreases with the increase in supply of electricity. Nepal Electricity Authority has predicted its values over the policy period in future on its annual report, 2018.

Target Demand = GRAPH (TIME)
(2019.00, 8391.28), (2020.00, 10138.28), (2021.00, 12017.96), (2022.00, 13952), (2023.00, 15332.65), (2024.00, 16869.13), (2025.00, 18579.53), (2026.00, 20585.22), (2027.00, 22826.63), (2028.00, 25332.5), (2029.00, 28111.3), (2030.00, 31196.38), (2031.00, 34355.49), (2032.00, 37861.08), (2033.00, 41754.21), (2034.00, 46079.83), (2035.00, 50887.42), (2036.00, 56007.87), (2037.00, 61677.62), (2038.00, 67957.59), (2039.00, 74913.54), (2040.00, 82620.73)

Supply

$$S = f(HP, ipps, i, tp, td) = MIN\ ((HP + ipps + i + tp), td) \quad (2)$$

is the minimum of total of hydro production, *HP*, internal power purchase, *ipps*, import, *i*, and thermal production, *tp*, or target demand (Regmi, 2017). If the total of hydro production, internal power purchase, import and thermal production is higher than target demand then NEA supply just equivalent to target demand on the local market. However, if the total of hydro production, internal power purchase, import and thermal production is lower than target demand then NEA supply equivalent to the total of hydro production, internal power purchase, import and thermal production only. The amount of internal power purchase, import and thermal production can be found on the annual report, 2018 of NEA and these values are considered constant over the policy period in future.

Hydro Production

$$HP = f(C, cp) = C * cp \quad (3)$$

is the product of capital, *C*, and capital productivity, *cp* (Sterman 2000). Capital productivity implies that how much energy can be produced by one unit of capital per year. This information is derived from one of the hydropower project talked about on the NEA report, 2018. It is 6,140 GWh/GW/year.

Excess Energy

$$EE = f(HP, S) = HP - S \tag{4}$$

is the difference between the hydro production and supply.

Capital

$$C = \int (AA - SC)dt + C(0) \tag{5}$$

accumulates the difference between actual acquisition, *AA*, and scrap, *SC* (Sterman 2000). This formulation is obvious since capital accumulates over time. Initially capital, *C*(0), is equal to 0.507930 GW as per the NEA report, 2018. It increase with the actual acquisition and decrease with the scrap.

Scrap

$$SC = f(C, l) = C/l \tag{6}$$

is the ratio of capital and its life, *l* (Sterman 2000). Life of the hydropower plant is considered as 150 years as per practical evidence on the local market.

Actual Acquisition

$$AA = f(O, cad, LA) = DELAY3\ (O, cad) * LA \tag{7}$$

is the product of material delay function of order, *O*, & capital acquisition delay, *cad*, and labor availability, *LA* (Sterman 2000). The capital acquisition delay is assumed as 2 years which is normal time on local market to acquire the capital.

Labor Availability

$$LA = f(LR) \tag{8}$$

is considered as the linear graphical function of labor ratio, *LR*, in such a way that both move on the same direction.

Order

$$O = f(AO) \tag{9}$$

is equivalent to actual order, *AO*.

Capital on Order

$$COO \ = \int (O - AA)dt + \ COO(0) \tag{10}$$

accumulates the difference between order and actual acquisition (Sterman 2000). This formulation is obvious since capital on order accumulates over time. Initially capital on order, *COO*(0), is equal to 0.89 GW as per the NEA report, 2018. It increase with the order and decrease with the actual acquisition.

Labor Ratio

$$LR = f(AL, DL) = AL/DL \tag{11}$$

is the ratio of actual labor, *AL*, and desired labor, *DL*.

Desired Labor

$$DL = f(COO, cad, lp, kwtgw) = \left(\frac{\frac{COO}{cad}}{lp}\right) * kwtgw \tag{12}$$

is the product of the ratio of capital on order, capital acquisition delay & labor productivity, *lp* and KW to GW, *kwtgw*. The labor productivity is calculated on the assumptions that 12,000 KW hydropower project can be constructed by 100 labors within 2 years. It is 60 KW/person/year.

Actual Labor

$$AL = \int (H - Q)dt + \ AL(0) \tag{13}$$

accumulates the difference between hiring, *H* and quitting, *Q*. This formulation is obvious since actual labor accumulates over time. Initially actual labor, *AL*(0), is assumed 15,000 persons with tentative peoples working on hydropower projects construction which increases with hiring and decreases with quitting.

Hiring

$$H = f(LG, ht) = LG/ht \tag{14}$$

is the ratio of labor gap, *LG*, and hiring time, *ht*. The hiring time is assumed 3 months as per the practice in local market.

Labor Gap

$$LG = f(DL, AL) = DL - AL \tag{15}$$

is the difference between desired labor and actual labor.

Quitting

$$Q = f(AL, qt) = AL/qt \tag{16}$$

is the ratio of actual labor and quitting time, qt. The quitting time is considered as 2 years based on local market practice.

Actual Order

$$AO = f(AI, AC, gwtkw) = \frac{AI}{AC} * gwtkw \tag{17}$$

is the product of ratio of actual investment, *AI* & actual cost, *AC* and GW to KW, gwtkw. And, 1 KW = (1/1,000,000) GW.

Actual Investment

$$AI = f(DI, FDI) = DI + FDI \tag{18}$$

is the total of domestic investment, *DI* and foreign direct investment, *FDI*.

Actual Cost

$$AC = f(IC, CR, crsoc) = IC * (1 + CR * crsoc) \tag{19}$$

is the product of indicated cost, *IC* and one plus product of capacity ratio, *CR* & capacity ratio sensitivity on cost, *crsoc*. The CR sensitivity on cost is assumed as 1 indicating that capacity ratio has perfect positive correlation with the indicated cost. Further, it is assumed that the actual cost changes with the changes on capacity ratio because of new hydro projects more costly to build.

Domestic Investment

$$DI = f(DEI, B, R, dr) = MIN\ (DEI, (B\ +\ R)/der) \tag{20}$$

is the minimum of desired investment, *DEI* or (borrowing, *B* + repayment, *R*)/debt ratio, *der*. Debt ratio is considered as 70% on local market as per the practice.

Foreign Direct Investment

$$FDI\ = f(DEI, DI, fdic, fdip) = (DEI - DI) * fdic * fdip$$
(21)

is the product of FDI Coefficient, *fdic*, FDI Policy, *fdip*, and the difference between desired investment and domestic investment. FDI Coefficient is assumed as 0.09 indicating that only 9% of the insufficient financing from local market is financed through FDI. If FDI Policy is on (that is 1) then the deficit amount of investment is financed through FDI else not.

Desired Investment

$$DEI\ = f(AC, IO, kwtgw) = AC * IO * kwtgw \tag{22}$$

is the product of actual cost, indicated orders, *IO* and KW to GW. And, 1 GW = 1,000,000 KW.

Borrowing

$$B\ = f(LOG, bt) = LOG/bt \tag{23}$$

is the ratio of loan gap, *LOG* to borrowing time, *bt*. Borrowing time is assumed as one year as per the practice on local market.

Repayment

$$R = f(L, rt) = L/rt \quad (24)$$

is the ratio of loan, *L*, to repayment time, *rt*. Repayment time is considered as fifteen years as per the practice on local market.

Loan

$$L = \int (B - R)dt + L(0) \quad (25)$$

accumulates the difference between borrowing and repayment. This formulation is obvious since loan accumulates over time. Initially loan, $L(0)$, is equal to NPR 121,253,390,000 as per the NEA report, 2018. It increase with the borrowing and decrease with the repayments.

Loan Gap

$$LOG = f(ML, L) = ML - L \quad (26)$$

is the difference between maximum loan, *ML*, and loan.

Maximum Loan is the function of number of banks, their paid-up capital and single obligor limit. The following table shows their values.

Table: 1 Banks, Paid-up Capital and Single Obligor Limit

Type of Bank	Number of Banks	Paid-up Capital	Single Obligor Limit
Commercial Banks	28	8,000,000,000	0.5
National Level Development Banks	13	2,500,000,000	0.5
Development Banks (4-10 Districts)	1	1,200,000,000	0.5
Development Banks (3 Districts)	22	500,000,000	0.5

(Source: NRB Report, 2018)

Maximum Loan

$$ML = f(bcb, bnldb, bdbfttd, bdbtd, sol, puccb, pucnldb, pucdbfttd, pucdbtd) = (bcb * puccb + bnldb * pucnldb + bdbfttd * pucdbfttd + bdbtd * pucdbtd) * sol \quad (27)$$

is the product of single obligor limit, *sol, and* total of *Bank[Commercial Banks], bcb* "Paid-up Capital"[Commercial Banks], puccb; Bank[National Level Development Banks], bnldb*"Paid-up Capital"[National Level Development Banks], pucnldb; Bank[Development Banks 4 to 10 Districts], bdbfttd*"Paid-up Capital"[Development Banks 4 to 10 Districts], pucdbfttd & Bank[Development Banks 3 Districts], bdbtd*"Paid-up Capital"[Development Banks 3 Districts], pucdbtd)*

Indicated Cost

$$IC = f(c, eoirtc) = c * eoirtc \quad (28)$$

is the product of cost, *c* and effect of interest rate to cost, *eoirtc*. This implies that the cost increases with the interest rate and vice-versa. The cost information is derived from one of the hydropower project talked about on the NEA report, 2018. It is NPR 145,490/KW.

Effect of interest rate to cost is the graphical function of interest rate. The prevailing interest rate on the market is 12% per annum. Cost increase with interest rate and vice-versa. Effect of interest rate to Cost = GRAPH (Interest Rate)
(8.000, 0.9520), (10.000, 0.9860), (12.000, 1.0000), (14.000, 1.0240), (16.000, 1.0480)

Indicated Orders

$$IO = f(SLA, DCA) = SLA + DCA \quad (29)$$

is the total orders to cover the desired supply line, *DSL,* and desired capital acquisition, *DCA,* that depends on the supply line adjustment, *SLA,* and desired capital acquisition (Sterman 2000).

Supply Line Adjustment

$$SLA = f(DSL, COO, slat) = (DSL - COO)/slat \tag{30}$$

is the ratio of the difference between desired supply line &, capital on order and supply line adjustment time, *slat* (Sterman 2000). It indicates that how much order must be placed to cover the desired supply line. Here, supply line adjustment time is considered as six months.

Desired Capital Acquisition

$$DCA = f(SC, CA) = SC + CA \tag{31}$$

is the total of scrap and the capital adjustment, *CA*, since the scrap is added to avoid the depletion of capital (Sterman 2000).

Desired Supply Line

$$DSL = f(DCA, cad) = DCA * cad \tag{32}$$

is the product of desired capital acquisition and capital acquisition delay (Sterman 2000). This reveals that how much capital is required to cover the capital acquisition delay.

Capital Adjustment

$$CA = f(DC, C, cat) = (DC - C)/cat \tag{33}$$

depends on the desired capital, *DC*, capital and the capital adjustment time, *cat* (Sterman 2000). The capital adjustment time is assumed as one year.

Desired Capital

$$DC = f(P, PL, C) = IF\ (P > 1)\ THEN\ (PL)\ ELSE\ (C) \tag{34}$$

depends on the profitability, *P*, and peak load, *PL*, and capital. Peak load refers the maximum electric capacity demand. If profitability is more than 1 then the desired capital must be equivalent to peak load if not it must be equal to existing capital. Nepal Electricity Authority has predicted the peak load values over the policy period in future on its annual report, 2018.

Peak Load = GRAPH (TIME)
(2019.00, 1.842), (2020.00, 2.225), (2021.00, 2.638), (2022.00, 3.062), (2023.00, 3.365), (2024.00, 3.703), (2025.00, 4.078), (2026.00, 4.519), (2027.00, 5.011), (2028.00, 5.561), (2029.00, 6.171), (2030.00, 6.848), (2031.00, 7.542), (2032.00, 8.311), (2033.00, 9.166), (2034.00, 10.115), (2035.00, 11.171), (2036.00, 12.295), (2037.00, 13.54), (2038.00, 14.918), (2039.00, 16.445), (2040.00, 18.137)

Profitability

$$P = f(p, UPC) = p/UPC \tag{35}$$

is the ratio of price, *p*, and unit production cost, *UPC*. The price is NPR 10.04/KWh as per the NEA report, 2018. And, current unit production cost is considered as NPR 7/KWh which is just below the average power purchase rate of NPR 7.12/KWh as per the NEA report, 2018. Unit variable cost, *uvc*, is assumed as 10% of current unit production cost and remaining 90% as unit fixed cost, *ufc*, since hydro industry is heavily dominated by fixed cost.

Unit Production Cost

$$UPC = f(uvc, AUFC) = uvc + AUFC \tag{36}$$

is the total of unit variable cost and actual unit fixed cost, *AUFC*.

Actual Unit Fixed Cost

$$AUFC = f(ufc, EOCROUFC) = ufc * EOCROUFC \tag{37}$$

is the product of unit fixed cost and effect of capacity ratio on unit fixed cost, $EOCROUFC$.

Effect of Capacity Ratio on Unit Fixed Cost

$$EOCROUFC = f(IEOCROUFC, cad) = SMTH3\ (IEOCROUFC, cad) \tag{38}$$

is the information delay function of indicated effect of capacity ratio on unit fixed cost, $IEOCROUFC$, and capital acquisition delay as the effect of increase on actual cost to unit fixed cost takes after the project completion time which is equivalent to capital acquisition delay.

Indicated Effect of Capacity Ratio on Unit Fixed Cost

$$IEOCROUFC = f(CR, CRSOUFC) = 1 + (CR * CRSOUFC) \tag{39}$$

is one plus the product of capacity ratio, *CR*, and capacity ratio sensitivity on unit fixed cost, $CRSOUFC$.

Capacity Ratio Sensitivity on Unit Fixed Cost

$$CRSOUFC = f(dtfcr) = dtfcr \tag{40}$$

is depreciation to fixed cost ratio, *dtfcr*. As per the NEA report, 2018, Depreciation to fixed cost ratio is around 20%. This is a way of incorporating the effect of increased actual cost to unit fixed cost.

Capacity Ratio

$$CR = f(C, mphc) = C/mphc \tag{41}$$

is the ratio of capital to maximum potential hydro capacity, *mphc*. Maximum potential hydro capacity refers to the commercially exploitable hydropower capacity. It is 42 GW.

2.2 Net Present Value of Profit

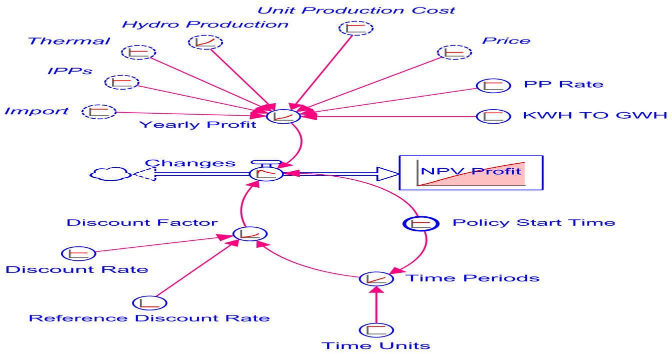

Figure 5: Stock and Flow Diagram NPV

Yearly profit

$$YP = f(HP, ipps, i, tp, p, ppr, UPC, kwhtgwh) = ((HP + tp) * (p - UPC) + (ipps + i) * (p - ppr)) * kwhtgwh \quad (42)$$

is the function of hydro production, internal power purchase, import, thermal production, price, power purchase rate, ppr, unit production cost and KWh to GWh, kwhtgwh. And, 1 GWh = 1,000,000 KWh.

NPV Profit

$$NPVP = \int(CHG)dt + NPVP(0) \quad (43)$$

accumulates the changes on NPV Profit, *CHG*. This formulation is obvious since NPV Profit accumulates over time. Initially NPV Profit, *NPVP*(0), is equal to NPR 1,010,210,000 as per the NEA report, 2018. It changes with the NPV of yearly profit over the time periods.

Changes

$$CHG = f(YP, pst, DF) = IF(TIME < pst)\ THEN\ (0)\ ELSE\ (YP/DF) \quad (44)$$

depends on yearly profit, policy start time, *pst*, and discount factor, *DF*.

Discount Factor

$$DF = f(dir, rdr, TP) = ((1+\mathrm{dir})/(1+\mathrm{rdr}))^\wedge\mathrm{TP} \quad (45)$$

depends on discount rate, dir, reference discount rate, rdr, and time periods, TP. Discount rate is considered as 12% per annum as per the widespread rate on the local market. Similarly, reference discount rate is expected as 0% per annum.

Time Periods

$$TP = f(TIME, pst, tu) = (TIME - pst)/tu \quad (46)$$

depends on TIME, time units, tu, and policy start time, pst. Time units and policy start time are assumed as 1 year and 2019 year respectively.

2.3 Causal Loop Diagram (CLD)

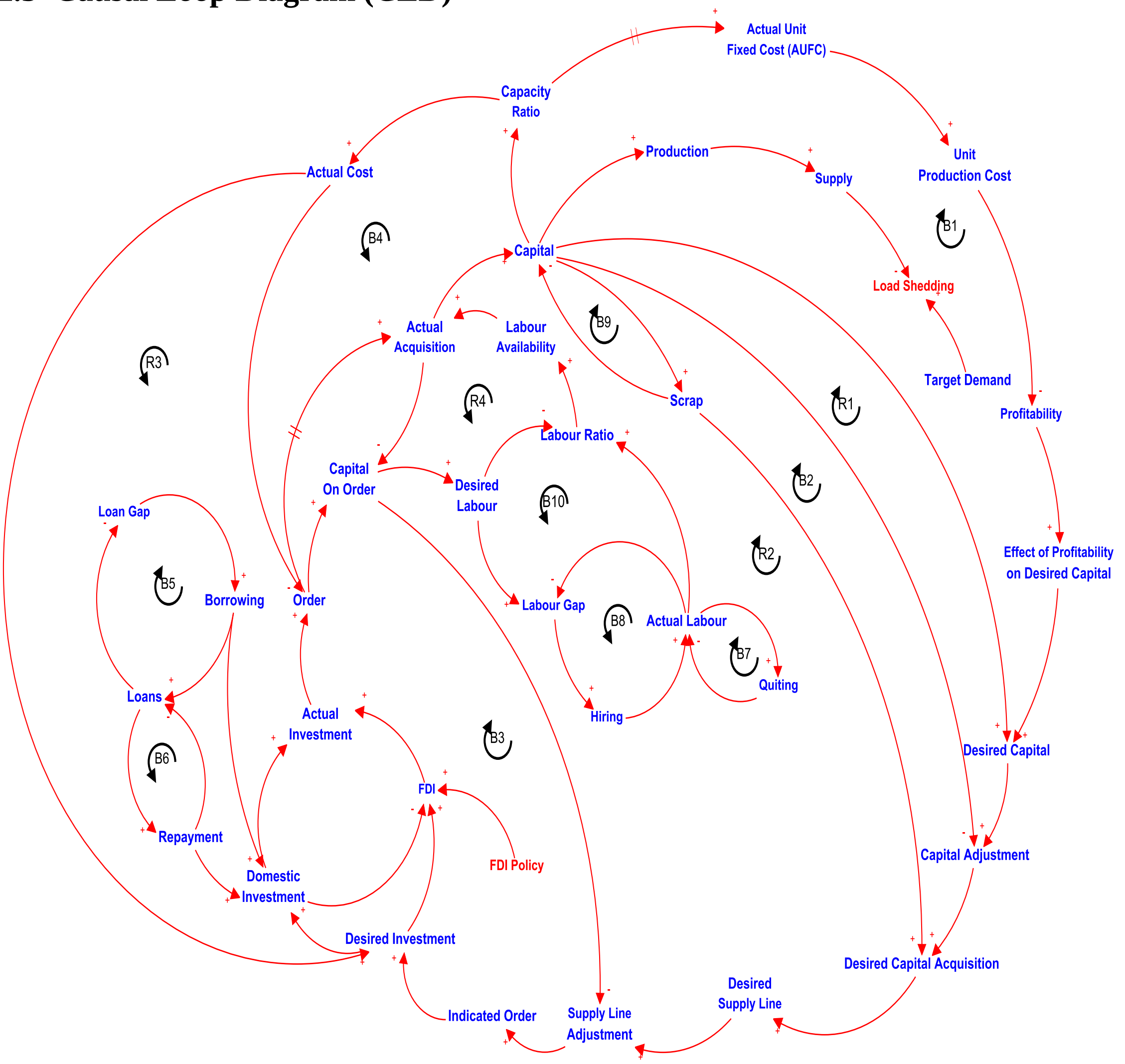

Figure 6: Causal Loop Diagram

Above causal loop diagram displays various loops working on the model. In fact, there are 4 reinforcing loops and 10 balancing loops. However, the reinforcing loops have dominance role in the model to achieve the goal. Out of 4 reinforcing loops, reinforcing loops 1 & 2 are most powerful to eliminate the load shedding problem in the policy period. They are explained in detail below.

Reinforcing Loop 1 (R1):

Reinforcing Loop 1 demonstrates that as FDI policy is on then there is the increase on FDI, actual investment, order, capital on order, actual acquisition, capital, desired capital, capital adjustment, desired capital acquisition, desired supply line, supply line adjustment, indicated order, desired investment and FDI again in sequence. Here, the increase in capital increases the supply through increase in production to decrease load shedding.

Reinforcing Loop 2 (R2):

Reinforcing Loop 2 also displays the similar effect of FDI policy on load shedding. As the FDI policy is switched on there is the increase on FDI, actual investment, order, capital on order, actual acquisition, capital, scrap, desired capital acquisition, desired supply line, supply line adjustment, indicated order, desired investment and FDI again in chain. Here also, the increased capital increases the supply through the increase in production to decrease load shedding.

Reinforcing Loop 3 (R3):

Again, Reinforcing Loop 3 also shows the similar outcome of FDI policy on load shedding. As FDI policy is on then there is the increase on FDI, actual investment, order, capital on order, actual acquisition, capital, capacity ratio, actual cost, desired investment and FDI again in cycle. The increased capital increases the supply via the increase in production to decrease load shedding.

Reinforcing Loop 4 (R4):

Reinforcing Loop 4 illustrates that as FDI policy is on then there is the increase on FDI, actual investment, order, capital on order and desired labor sequentially. The increase in desired labor decreases the labor ratio, labor availability and actual acquisition in series. As a result, the capital on order increases again.

Balancing Loop 1 (B1):

Balancing Loop 1 demonstrates that as FDI policy is on then there is the increase on FDI, actual investment, order, capital on order, actual acquisition, capital, capacity ratio, actual unit fixed cost and unit production cost serially. After that the profitability, desired capital, capital adjustment, desired capital acquisition, desired supply line, supply line adjustment, indicated order, desired investment and FDI decrease in series. The decreased FDI decrease the capital and increase the FDI again. Here, as the capital moves up and down in alternative way that affects on load shedding in the same way.

Balancing Loop 2 (B2):

Balancing Loop 2 demonstrates that as the policy is on then there is the increase on FDI, actual investment, order, capital on order, actual acquisition and capital in sequence. Beyond that point, capital adjustment, desired capital acquisition, desired supply line, supply line adjustment, indicated order, desired investment and FDI decreases sequentially. The decreased FDI decrease the capital and increase the FDI again. As the capital increase then the supply also increase and vice-versa giving opposite impact on load shedding. This loop reveals the forth and back movement of load shedding to counter balance reinforcing loops.

Balancing Loop 3 (B3):

Balancing Loop 3 shows that as the FDI policy is on then FDI, actual investment, order and capital on order increase on sequence. After that point, supply line adjustment, indicated order, desired investment and FDI decreases on series. This also depicts the back and forth movement.

Balancing Loop 4 (B4):

Balancing Loop 4 demonstrates that as the policy is on then FDI, actual investment, order, capital on order, actual acquisition, capital, capacity ratio and actual cost increases orderly. After that order and other variables that comes on sequence up to actual cost decreases.

Balancing Loop 5 (B5):

Balancing Loop 5 shows that as borrowings increase then loan also increase which in turn decrease the loan gap that force to decrease borrowings. The process revolves.

Balancing Loop 6 (B6):

Balancing Loop 6 shows that loans and repayment move on opposite direction continuously.

Balancing Loop 7 (B7):

Balancing Loop 7 also shows that actual labor and quitting move on opposite direction.

Balancing Loop 8 (B8):

Balancing Loop 8 shows that increase in labor gap increase hiring that increase actual labor. And, as actual labor increase that decrease labor gap and process repeats again.

Balancing Loop 9 (B9):

Balancing Loop 9 shows that capital and scrap move on opposite direction forever.

Balancing Loop 10 (B10):

Balancing Loop 10 shows that as the policy is on then the FDI, actual investment, order, capital on order, desired labor, labor gap, hiring, actual labor, labor ratio, labor availability and actual acquisition increase on sequence. After that capital on order decrease which decrease the desired labor and so on.

2.4 Dimensional Consistencies

The dimensional consistency implies that whether the units of each variable used in the model is correct or not. If the unit of one variable is wrong, then the model itself is wrong. The Stella software has automated dimensional analysis so no need not to check each equation separately. The model is dimensionally consistent as the software does not show any unit errors and warnings. Each and every equation can be checked separately.

2.5 Setting for Simulation of the Model

- Stella Architect Software is used to simulate the model
- The model starts on 2019 and end on 2040
- The time step (DT) is ¼
- Sim duration is 1 second
- Time units is years
- Euler integration method is used

2.6 Integration Error

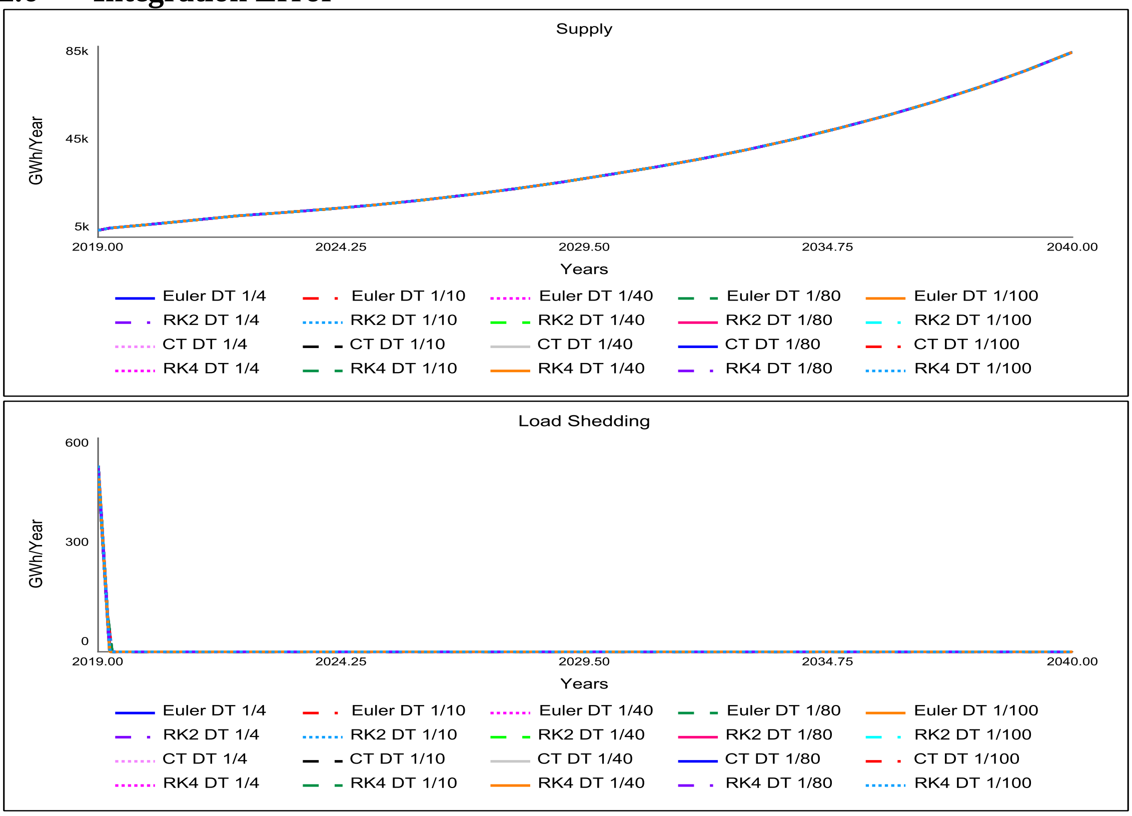

Figure 7: Supply and Load Shedding

Figure 7 depicts that supply and load shedding are insensitive under different method of integration at different DTs as they are almost same at ¼, 1/10, 1/40, 1/80 and 1/100 DTs under Euler, RK2, Cycle Time and RK4 method of integration.

3. TESTING THE HYPOTHESIS

Hypothesis testing is used to check that whether the proposed policy gives the desired result as mentioned on hypothesis or not. This section is divided in two sub-sections. First part deals with the behavior testing and second part with behavior sensitivity analysis.

3.1 Behavior Testing

Behavior testing reveals the effect of proposed policy on major variables of the model. The demand, supply, load shedding and NPV of profit are considered as the major variables of the model and they are discussed below.

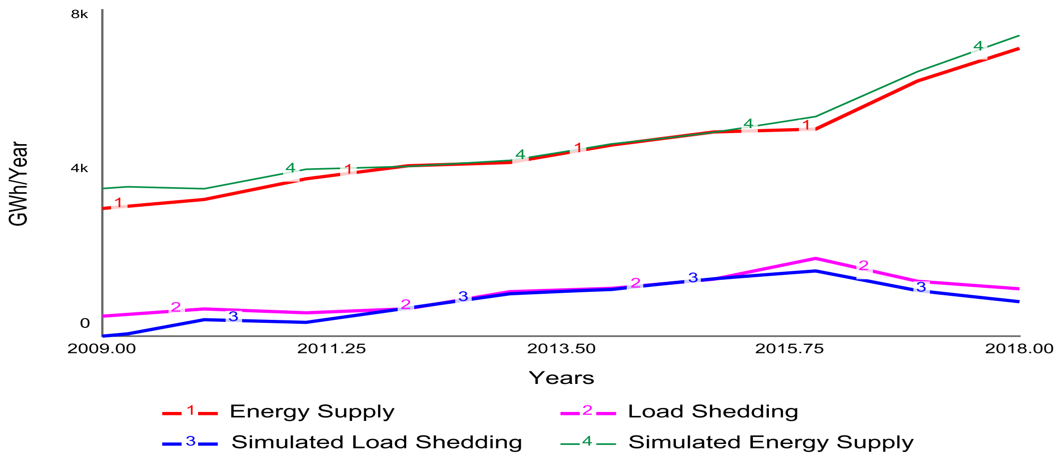

Figure 8: Energy Supply, Simulated Energy Supply, Load Shedding and Simulated Load Shedding

Figure 8 portrays that the model explains the historical development. The simulated energy supply and simulated load shedding both shift closely with energy supply and load shedding respectively. This is the indication of how much correctly the model is built.

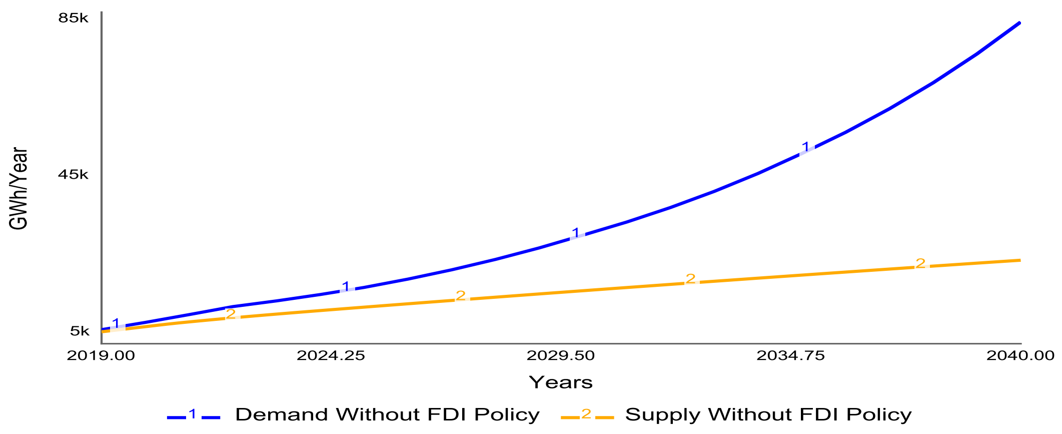

Figure 9: Demand & Supply without FDI Policy

Figure 9 depicts that both the demand and supply are increasing over the policy period in future without FDI policy. The demand rises rapidly than the supply. Load shedding can be eliminated with the speedy growth on supply.

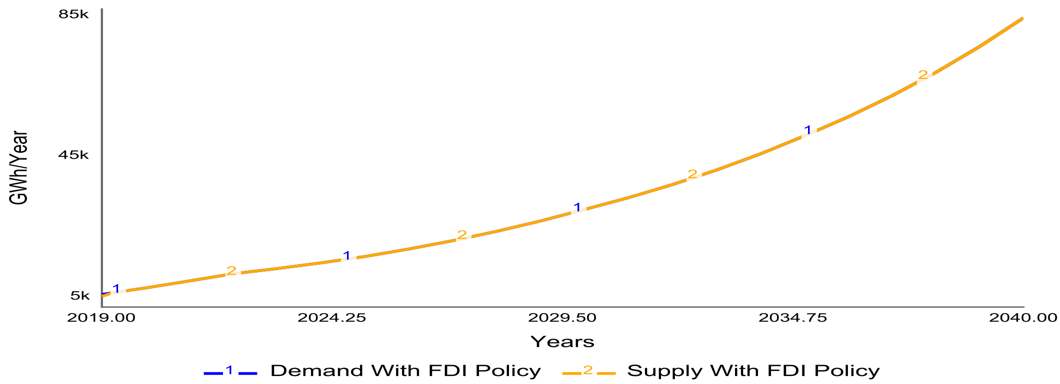

Figure 10: Demand & Supply with FDI Policy

Figure 10 shows that both demand and supply move equivalently in the future with FDI Policy.

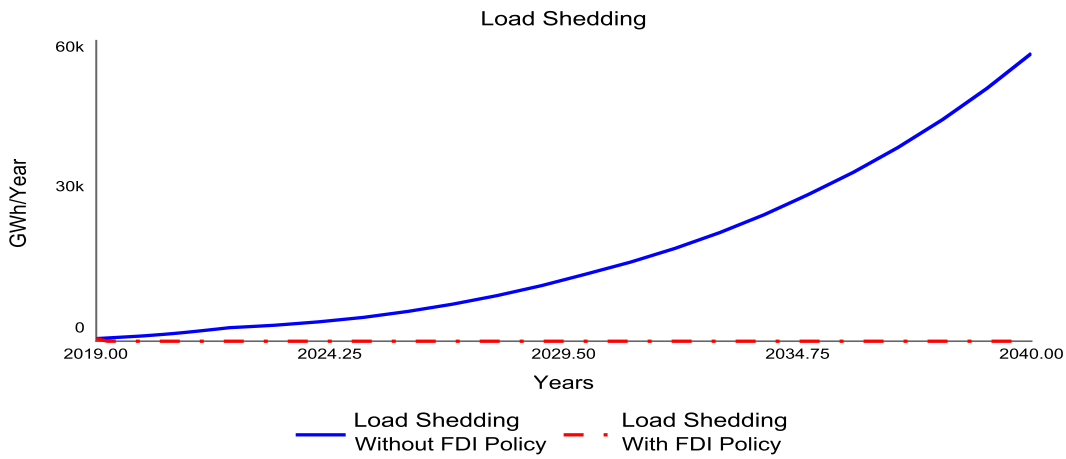

Figure 11: Load Shedding without FDI Policy; Load Shedding with FDI Policy

Figure 11 displays load shedding status before and after the FDI policy. Before FDI policy, Load shedding is projected to grow quickly because supply is very low than target demand in future due to inadequate actual investment in reference to desired investment. However, after the policy, load shedding is estimated to be zero because of adequate actual investment meeting the deficit amount of money from foreign direct investment.

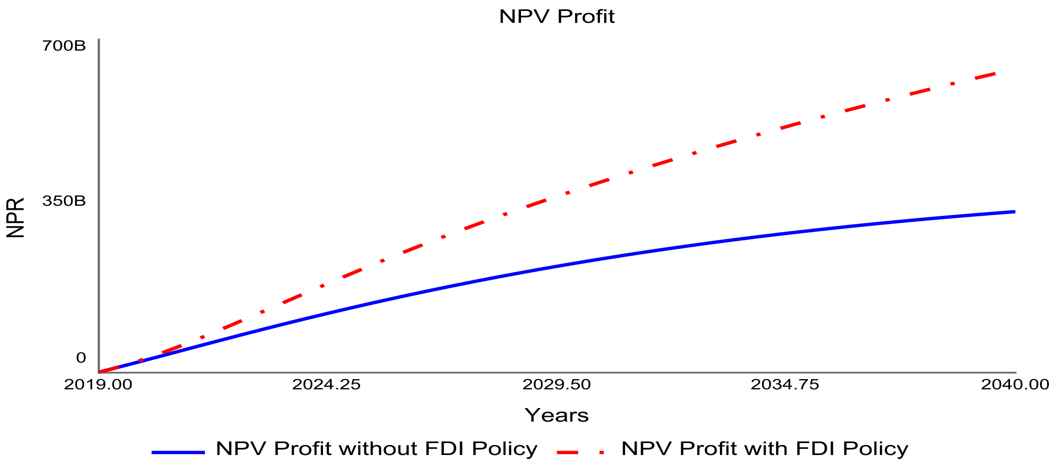

Figure 12: NPV Profit without FDI Policy; NPV Profit with FDI Policy

Figure 12 shows the NPV of profit before and after the policy. The figure clearly displays that the profit nearly doubled after the policy. This happens because there is larger supply of energy after the policy with positive profitability throughout the policy period in future.

3.2 Behavior Sensitivity Analysis

Behavior sensitivity analysis is used to know that how the goal is influenced by the changes on the variables used on the model. Key influencing variables and their effects are discussed below.

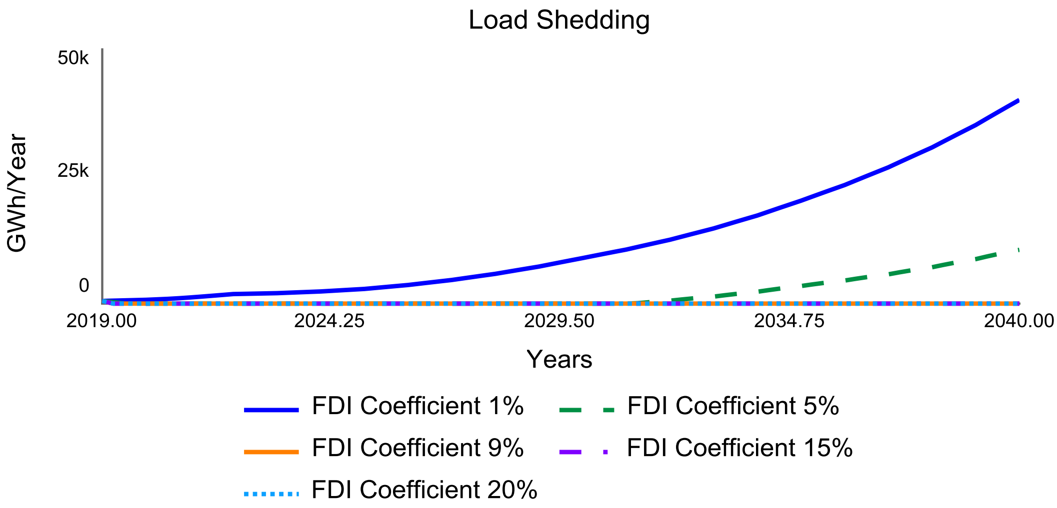

Figure 13: FDI Coefficient & Load Shedding

Figure 13 shows load shedding at FDI Coefficient of 0.01, 0.05, 0.09, 0.15 and 0.20. The graph predicts that load shedding is zero if FDI Coefficient is 0.09 or more. Therefore, load shedding is highly sensitive to FDI Coefficient.

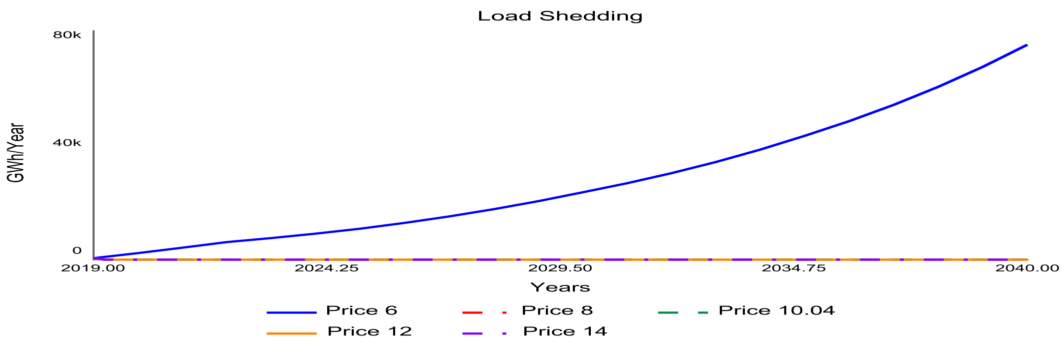

Figure 14: Price & Load Shedding

Similarly, Figure 14 shows load shedding at price 6, 8, 10.04, 12 and 14. This graph also indicates zero load shedding if price is 7.28 or more. Therefore, load shedding is sensitive to price.

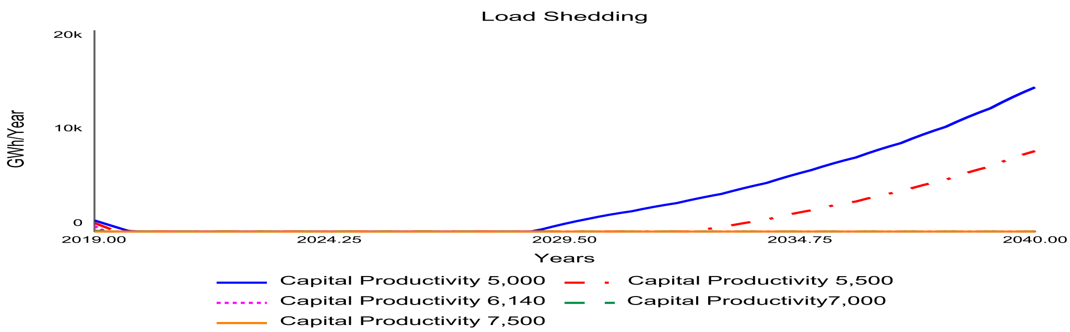

Figure 15: Capital Productivity & Load Shedding

Figure 15 shows load shedding at capital productivity of 5,000; 5,500; 6,140; 7,000 and 7,500. The graph predicts that load shedding is zero if capital productivity is 6,140 or more. Therefore, load shedding is sensitive to capital productivity.

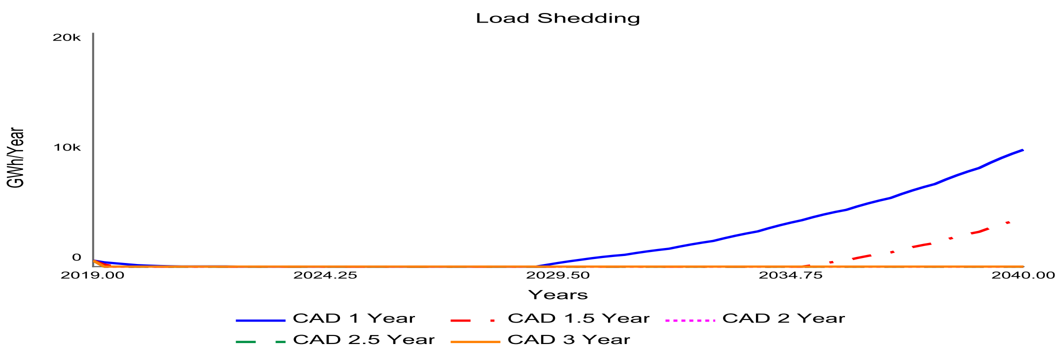

Figure 16 Capital Acquisition Delay & Load Shedding

Similarly, Figure 16 shows load shedding at capital acquisition delay of 1, 1.5, 2, 2.5 and 3. This graph also indicates zero load shedding if capital acquisition delay is 2 or more. Therefore, load shedding is sensitive to capital acquisition delay.

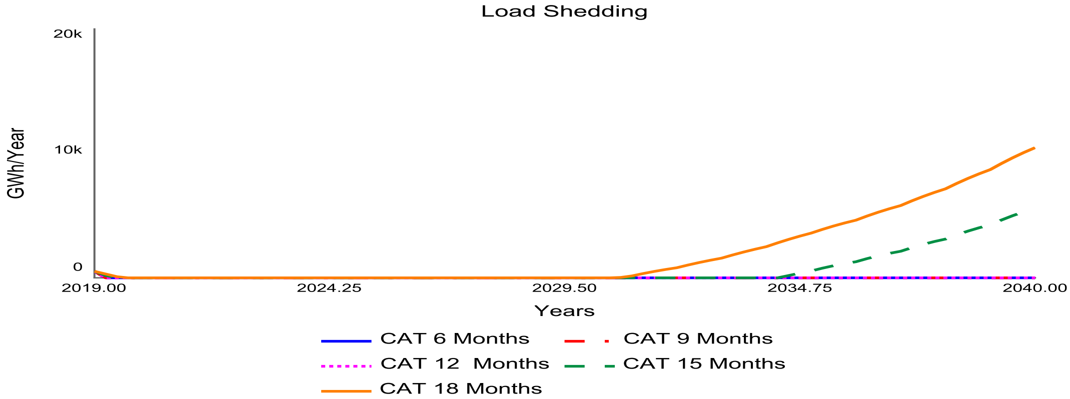

Figure 17: Capital Adjustment Time & Load Shedding

Figure 17 shows load shedding at capital adjustment time of 0.5, 0.75, 1, 1.25 and 1.5. The graph predicts that load shedding is zero if capital adjustment time is 1 or less. Therefore, load shedding is sensitive to capital adjustment time.

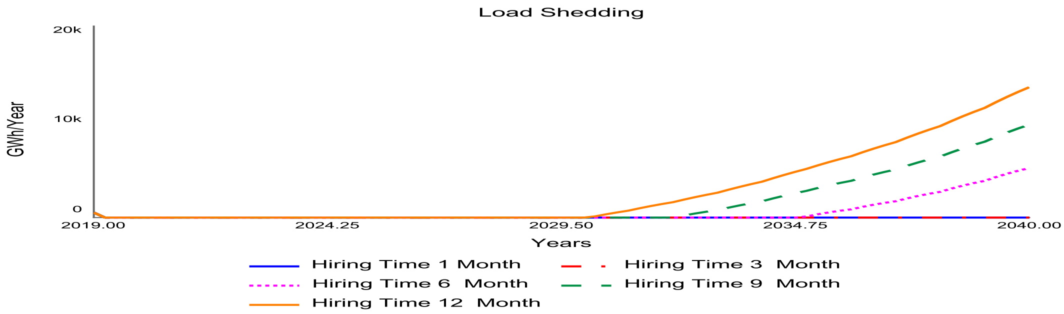

Figure 18: Hiring Time & Load Shedding

Similarly, Figure 18 shows load shedding at hiring time of 0.08, 0.25, 0.5, 0.75 and 1. This graph also indicates zero load shedding if hiring time is 0.25 or less. Therefore, load shedding is sensitive to hiring time.

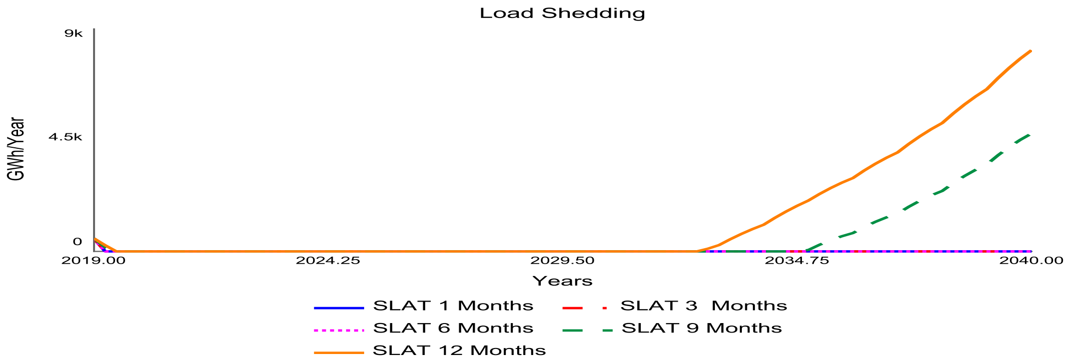

Figure 19: Supply Line Adjustment Time & Load Shedding

Figure 19 shows load shedding at supply line adjustment time of 0.08, 0.25, 0.5, 0.75 and 1. The graph predicts that load shedding is zero if supply line adjustment time is 0.5 or less. Therefore, load shedding is sensitive to supply line adjustment time.

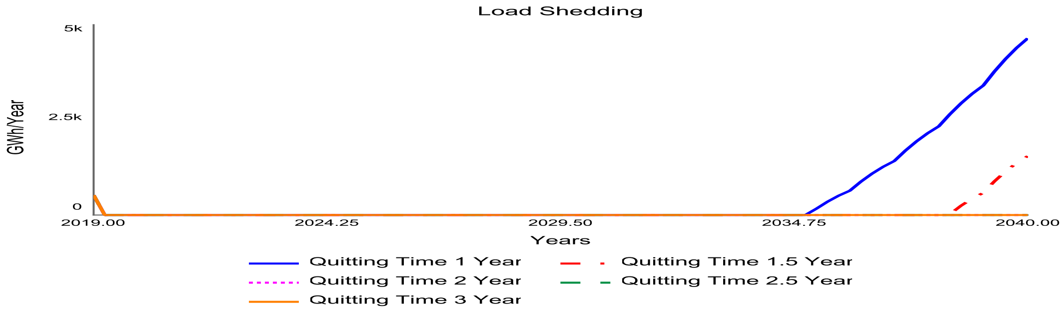

Figure 20: Quitting Time and Load Shedding

Similarly, Figure 20 shows load shedding at quitting time of 1, 1.5, 2, 2.5 and 3. This graph also indicates zero load shedding if quitting time is 2 or more. Therefore, load shedding is sensitive to quitting time.

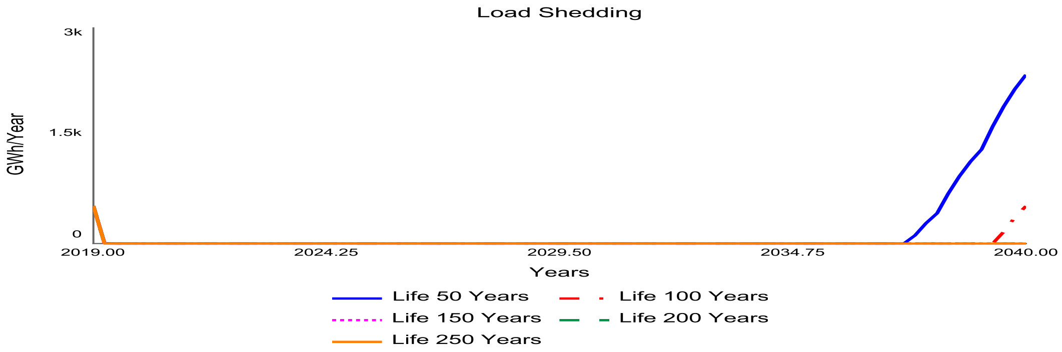

Figure 21: Life & Load Shedding

Figure 21 shows load shedding at project life of 50, 100, 150, 200 and 250. The graph predicts that load shedding is zero if project life is 139 or more. Therefore, load shedding is sensitive to project life.

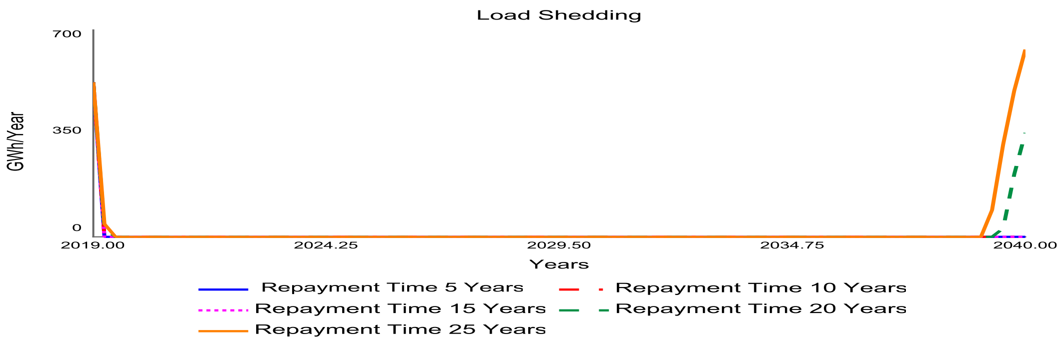

Figure 22: Repayment Time & Load Shedding

Similarly, Figure 22 shows load shedding at repayment time of 5, 10, 15, 20 and 25. This graph also indicates zero load shedding if repayment time is 15 or less. Therefore, load shedding is sensitive to repayment time.

4. POLICY TESTING

Policy testing is a way of judging the proposed policy to identify that whether the policy is appropriate or not prior to launching it.

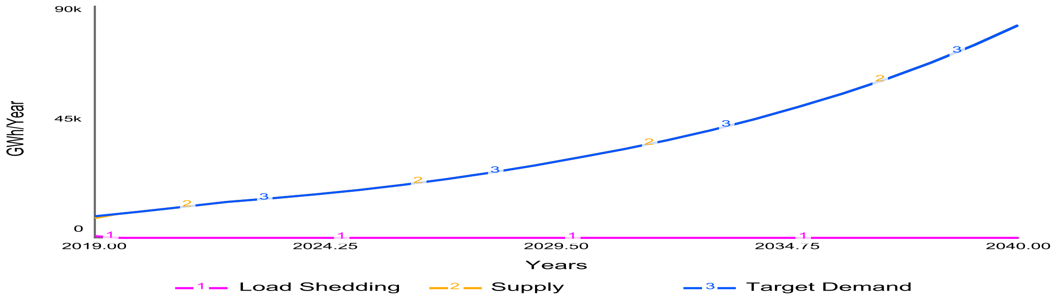

Figure 23: Load Shedding, Supply and Target Demand

Figure 23 illustrates that the simulation resulted no load shedding over the policy period in future with the proposed FDI policy. Now, we need to identify every pros and cons of the policy in advance to protect from the danger of failure on implementation. Also, the policy may impact each and every stakeholder of the society on specific ways so that they need to be addressed in advance.

4.1 Issues to Address

As load shedding is national level problem, the policy has effect on diverse sectors of the nation. First of all, we need to convince the political leaders to implement the policy in such a way that they fully understand how the policy is effective to eradicate the load shedding problem and impact positively on multiple sectors of the nation. Once leaders are convinced then they must start the campaigns to increase public awareness so that the public will take the ownership of the policy. The citizens must be insured that the policy is for their benefits. The benefits of the policy must be distributed equally among all stakeholders in the society in one or another way for the effective implementation.

Nepal government must restructure its traditional structure which requires long delays to approve FDI. This delay discourages FDI and creates the cost escalation as well. Further, there must be adequate availability of all type of resources to implement the policy. It may be land, labor, water and equipment. The leaders need to develop the conducive environment to acquire land and equipment timely. They must manage required labors to build the projects. Similarly, there must be assurance of enough water to rotate the turbine. Last but not least, the corruption is another serious issue that hinders the policy implementation. It increase the project cost itself. Therefore, handling the issue of corruption is urgent.

4.2 Pros and Cons of the Policy Implementation

There are multiple advantages of implementing the policy. The policy eliminates load shedding in future that creates the encouraging environment for every other sector of the nation. The manufacturing industries will grow because of lower cost of production as hydro electricity is cheaper than other alternative source of energy. The revenue from tourist sector also increases as more tourists get attracted. The employment rate as well increases due to the construction of new hydro projects. The infrastructure like roads expands rapidly prior to the construction of hydro projects. The transpiration cost decline because of electric vehicles. As a result, there will be lower import of petroleum products. The automation increases in every sector due to adequate availability of electricity. The pollution growth stops here as the hydro electricity is green energy. Further, hydro electricity is renewal energy as the water resources do not deplete due to hydro electricity production. The water resource is available free of cost for hydro electricity production. Conclusively, FDI policy increases the GDP and reduces the foreign trade deficit. For instance, Bhutan has realized optimum benefits from the production and sale (even export to India) of electricity. Accordingly, Bhutan has highest per capita in South Asian countries.

On the contrary, there are some disadvantages as well. The FDI policy increases foreign dependency. There may be environmental effects also because the virgin land gets polluted due to the excess of roads. The probability of landslide and flood increases due to the construction of new hydro projects on hilly side. The hydro electricity itself seems costly than other alternatives like solar and wind energy. Further, there may be the problem of droughts as most of the hydro projects in Nepal are run of the river type. The yearly hydro production capacity may differ due to the fluctuations on the precipitation level of water. The hydropower projects have large upfront cost.

Conclusively, the policy must be evaluated based on the net benefit data considering above pros and cons associated with the policy. And, it must be implemented if net benefit is positive.

5. CONCLUSIONS

This chapter incorporates learning from the study, the take-home messages for the readers, potentiality of implementation & generalizations of the policy.

5.1 Learning from the Study

Inadequate construction of new hydropower projects that is mainly caused by financing deficit is the basis of load shedding in Nepal. The research concluded that 9% of the deficit financing must be covered by the foreign direct investment to increase the hydro capacity & electricity supply to mitigate load shedding over the policy period in future. Even the figure seems very low; it is large enough to eradicate the load shedding problem because deficit financing is calculated based on the desired capital which lastly depends on the peak load. The hydro capacity and production of hydro energy are closely linked through the capital productivity of these hydro projects. As FDI increases, it enhances the hydropower capital which in turn increases the production and supply of electricity through the capital productivity of hydro projects. And, the increased supply of electricity mitigates the load shedding problem eventually. The study is focused on the long-run solution of the load shedding problem. However, previous researchers focused their studies on the short-term solution of load shedding problem and advised to adopt the dynamic pricing policy.

5.2 Take-home Messages for the Readers

The readers visualize that how the load shedding problem is interconnected with the associated multiple variables. They also understand the way of developing long-term solution of the load shedding problem through the FDI policy. Further, the readers are recommended to develop new model with FDI policy and dynamic pricing policy to observe their combined effect on the load shedding.

5.3 Potentiality of Implementation

As NPV Profit of Nepal Electricity Authority (NEA), the organization with the full responsibility of production and distribution of electricity in Nepal, is almost doubled with the FDI policy than the NPV Profit without policy even at constant price in future; there is high potentiality of implementing the proposed FDI policy.

5.4 Generalizations

The outcome of the study can be generalized to hydro industries seeking long-term solution of the load shedding problem.

6. REFERENCES

1. A. Lemma, G. Henley, S. Hoque and D. Willem (2017). *Nepal Labor Market: A Four Sector Case Study*, Supporting Economic Transformation.

2. D. Schlissel, A. Smith and R. Wilson (2008). *Coal-Fired Power Plant Construction Costs*, Synapse Energy Economics, Inc.

3. D. Gielen (2012). *Renewal Energy Techonoligies: Cost Analysis Series*, International Renewal Energy Agency.

4. David, S. H., Håkon, N. L. H and Nikolai, H. W. (2016). *Hydro Power in Nepal*. Sogn og Fjordane University College, Norway.

5. Government of Nepal Water and Energy Commission Secreteriat (2017). *Energy Demand Forecast Report (2015-2040).*

6. H. Kobayashi, J. Acharya, H. Zhang and P. Manandhar (2017). *Nepal Energy Sector Assessment, Strategy, and Road Map*, Asian Development Bank, South Asia Energy Division.

7. Karanjit, R. (2016). *Dynamic Pricing and the Future of Nepalese Electricity Market*. University of Bergen, Norway.

8. Regmi, P. (2017). *Blackouts in Nepal and dynamic pricing*. University of Bergen, Norway.

9. Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston, Irwin/McGraw-Hill.

10. U. Gautam and A. Karki (2004). *Hydropower Pricing in Nepal Developing a Perspective*, Jalsrot Vikas Sanstha, Nepal.

11. Nepal Electricity Authority (2018). *Annual Report*, Kathmandu.

12. Nepal Rastra Bank (2018). *Annual Report*, Kathmandu.

APPENDIX

Parameter Values and Initial Conditions

Parameter	Value	Initial Condition	Value
bcb	28 banks	*AL*(0)	15,000 persons
bnldb	13 banks	*C*(0)	0.507930 GW
bdbfttd	1 bank	*COO*(0)	0.89 GW
bdbtd	22 banks	*L*(0)	121,253,390,000 NPR
bt	1 year	*NPVP*(0)	1,010,210,000 NPR
cad	2 years		
cat	1 year		
cp	6,140 GWh/GW/year		
c	145,490 NPR/KW		
crsoc	1 dmnl		
der	0.7 dmnl		
dtfcr	0.2 dmnl		
dir	0.12 per year		
fdic	0.09 dmnl		
fdip	0 or 1 dmnl		
gwtkw	0.000,001 GW/KW		
ht	0.25 year		
i	2,581.8 GWh/year		
ir	12 percentage per year		
ipps	2,167.76 GWh/year		
kwtgw	1,000,000 KW/GW		
kwhtgwh	1,000,000 KWh/GWh		
lp	60 KW/person/year		
l	150 years		
mphc	42 GW		
puccb	8,000,000,000 NPR/bank		
pucnldb	2,500,000,000 NPR/bank		
pucdbfttd	1,200,000,000		

	NPR/bank		
pucdbtd	500,000,000 NPR/bank		
pst	2,019 year		
ppr	7.12 NPR/KWh		
p	10.04 NPR/KWh		
qt	2 years		
rdr	0 per year		
rt	15 years		
sol	0.5 dmnl		
slat	0.5 year		
tp	0.13 GWh/year		
tu	1 year		
ufc	6.3 NPR/KWh		
uvc	0.7 NPR/KWh		

Equations and Units

Equations	**Units**
$AA = f(O, cad, LA) = DELAY3\ (O, cad) * LA$	GW/year
$AC = f(IC, CR, crsoc) = IC * (1 + CR * crsoc)$	NPR/KW
$AI = f(DI, FDI) = DI + FDI$	NPR/year
$AL = \int (H - Q)dt + AL(0)$	Persons
$AO = f(AI, AC, gwtkw) = \frac{AI}{AC} * gwtkw$	GW/year
$AUFC = f(ufc, EOCROUFC) = ufc * EOCROUFC$	NPR/KWh
$B = f(LOG, bt) = LOG/bt$	NPR/year
$C = \int (AA - SC)dt + C(0)$	GW
$CA = f(DC, C, cat) = (DC - C)/cat$	GW/year
$CHG = f(YP, pst, DF) = IF(TIME < pst)\ THEN\ (0)\ ELSE\ (YP/DF)$	NPR/year
$COO = \int (O - AA)dt + COO(0)$	GW
$CR = f(C, mphc) = C/mphc$	dmnl
$CRSOUFC = f(dtfcr) = dtfcr$	dmnl
$DC = f(P, PL, C) = IF\ (P > 1)\ THEN\ (PL)\ ELSE\ (C)$	GW
$DCA = f(SC, CA) = SC + CA$	GW/year
$DEI = f(AC, IO, kwtgw) = AC * IO * kwtgw$	NPR/year
$DF = f(dir, rdr, TP) = ((1+dir)/(1+rdr))^{TP}$	dmnl
$DI = f(DEI, B, R, dr) = MIN\ (DEI, (B + R)/der)$	NPR/year

$DL = f(COO, cad, lp, kwtgw) = \left(\frac{\frac{COO}{cad}}{lp}\right) * kwtgw$	Persons
$DSL = f(DCA, cad) = DCA * cad$	GW
$EE = f(HP, S) = HP - S$	GWh/year
$EOCROUFC = f(IEOCROUFC, cad) = SMTH3\ (IEOCROUFC, cad)$	dmnl
$FDI = f(DEI, DI, fdic, fdip) = (DEI - DI) * fdic * fdip$	NPR/year
$H = f(LG, ht) = LG/ht$	Persons/year
$HP = f(C, cp) = C * cp$	GWh/year
$IC = f(c, eoirtc) = c * eoirtc$	NPR/KW
$IEOCROUFC = f(CR, CRSOUFC) = 1 + (CR * CRSOUFC)$	dmnl
$IO = f(SLA, DCA) = SLA + DCA$	GW/year
$L = \int (B - R)dt + L(0)$	NPR
$LA = f(LR)$	dmnl
$LG = f(DL, AL) = DL - AL$	Persons
$LOG = f(ML, L) = ML - L$	NPR
$LR = f(AL, DL) = AL/DL$	dmnl
$LS = f(td, S) = td - S$	GWh/year
$ML = f(bcb, bnldb, bdbfttd, bdbtd, sol, puccb, pucnldb, pucdbfttd, puca$ $= (bcb * puccb + bnldb * pucnldb + bdbfttd * pucdbfttd + bdbtd * pucdbtd) * sol$	NPR
$NPVP = \int (CHG)dt + NPVP(0)$	NPR
$O = f(AO)$	GW/year
$P = f(p, UPC) = p/UPC$	dmnl
$Q = f(AL, qt) = AL/qt$	Persons/year
$R = f(L, rt) = L/rt$	NPR/year
$S = f(HP, ipps, i, tp, td) = MIN\ ((HP + ipps + i + tp), td)$	GWh/year
$SC = f(C, l) = C/l$	GW/year
$SLA = f(DSL, COO, slat) = (DSL - COO)/slat$	GW/year
$TP = f(TIME, pst, tu) = (TIME - pst)/tu$	dmnl
$UPC = f(uvc, AUFC) = uvc + AUFC$	NPR/KWh
$YP = f(HP, ipps, i, tp, p, ppr, UPC, kwhtgwh) = ((HP + tp) * (p - UPC) + (ipps + i) * (p - ppr)) * kwhtgwh$	NPR/Year

ABBREVIATIONS

AA:	Actual Acquisition
AC:	Actual Cost
AI:	Actual Investment
AL:	Actual Labor
AO:	Actual Order
AUFC:	Actual Unit Fixed Cost
B:	Borrowing
bcb:	Commercial Bank
bdbfttd:	Development Bank 4-10 Districts
bdbtd:	Development Bank 3 Districts
bnldb.:	National Level Development Bank
bt:	Borrowing Time
C:	Capital
c:	Cost
CA:	Capital Adjustment
cad:	Capital Acquisition Dealy
cat:	Capital Adjustment Time
CHG:	Change
CLD:	Causal Loop Diagram
COO:	Capital on Order
cp:	Capital Productivity
CR:	Capacity Ratio
CRSOUFC:	Capacity Ratio Sensitivity on Unit Fixed Cost
crsoc:	Capacity Ratio Sensitivity on Cost
DC:	Desired Capital
DCA:	Desired Capital Acquisition
der:	Debt Ratio
Dep.:	Depreciation
DEI:	Desired Investment
DF:	Discount Factor
dir:	Discount Rate
DI:	Domestic Investment
DL:	Desired Labor
DSL:	Desired Supply Line
dtfcr:	Depreciation to Fixed Cost Ratio
EE:	Excess Energy

EOCROUFC:	Effect of Capacity Ratio on Unit Fixed Cost
eoirtc:	Effect of Interest Rate on Cost
FC:	Fixed Cost
FDI:	Foreign Direct Investment
fdic:	FDI Coefficient
fdip:	FDI Policy
GDP:	Gross Domestic Product
GW:	Giga Watt
GWh:	Giga Watt Hours
H:	Hiring
HP:	Hydro Production
ht:	Hiring Time
i:	Import
IC:	Indicated Cost
IEOCROUFC:	Indicated Effect of Capacity Ratio on Unit Fixed Cost
IO:	Indicated Order
ipps:	Internal Power Purchase
ir:	Interest Rate
KW:	Kilo Watt
KWh:	Kilo Watt Hours
l:	Life
L:	Loan
LA:	Labor Availability
LD:	Load Shedding
LG:	Labor Gap
LOG:	Loan Gap
LS:	Load Shedding
lp:	Labor Productivity
LR:	Labor Ratio
mhpc:	Maximum Potential Hydro Capacity
MIN:	Minimum
ML:	Maximum Loan
NEA:	Nepal Electricity Authority
NPR:	Nepalese Rupees
NPV:	Net Present Value
NPVP:	Net Present Value Profit
O:	Order
P:	Profitability

p:	Price
PL:	Peak Load
ppr:	Power Purchase Rate
pst:	Policy Start Time
puccb:	Paid-up Capital Commercial Bank
pucnldb:	Paid-up Capital National Level Development Bank
pucdbfttd:	Paid-up Capital Development Bank 4-10 Districts
pucdbtd:	Paid-up Capital Development Bank 3 Districts
Q:	Quitting
qt:	Quitting Time
R:	Repayment
rdr:	Reference Discount Rate
rt:	Repayment Time
S:	Supply
SC:	Scrap
SLA:	Supply Line Adjustment
slat:	Supply Line Adjustment Time
sol:	Single Obligor Limit
td:	Target Demand
tp:	Thermal Production
TP:	Time Periods
tu:	Time Unit
ufc:	Unit Fixed Cost
UPC:	Unit Production Cost
uvc:	Unit Variable Cost
YP:	Yearly Profit

LIST OF FIGURES & TABLES