TECHNO-ECONOMIC EVALUATION OF TELECOMMUNICATION SYSTEMS

ASSIGNMENT PART 3

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Contents

WHAT IS FTTH

Fiber to the home (FTTH) is the delivery of a communications signal over optical fiber from the operator's switching equipment all the way to a home or business, thereby replacing existing copper infrastructure such as telephone wires and coaxial cable.

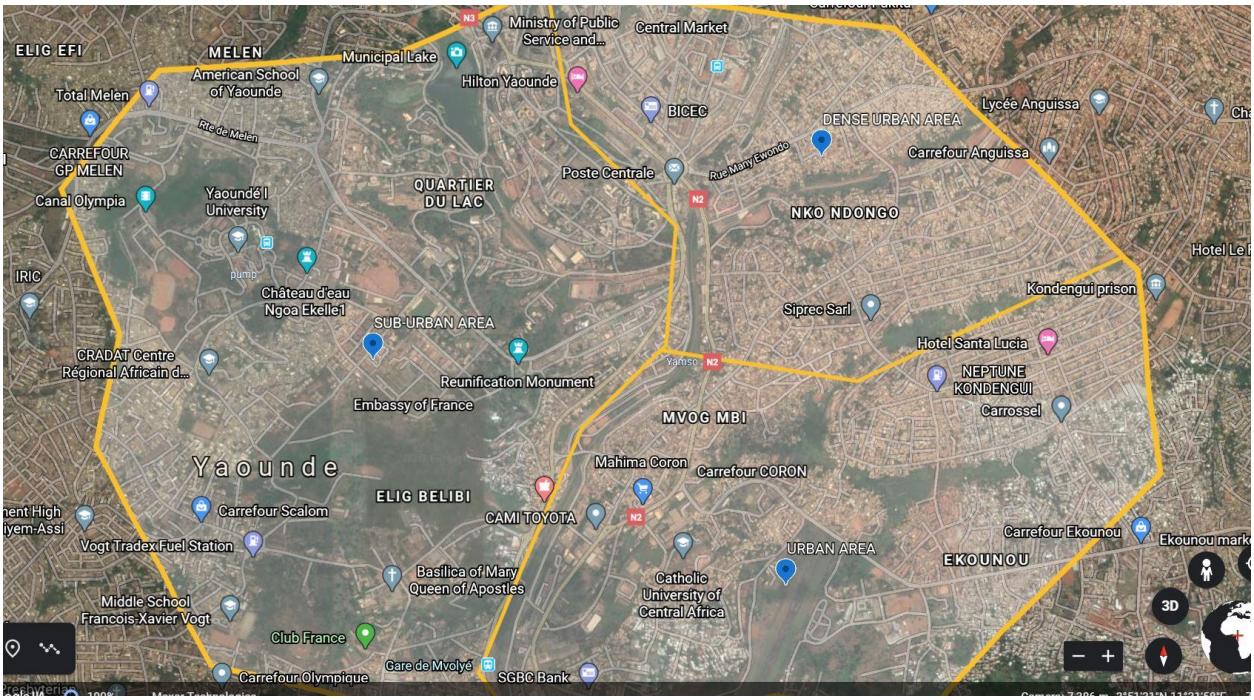
FTTH and associated technologies such as GPON and XGPON offer massive bandwidth capabilities given allowance for the deployment of different type of services to the end users at very high rates (50MB+).

In this part of the project, I would be evaluating the cost of deploying an FTTH network, evaluating the investments by method of investment valuation techniques, perform a scenario analysis on the model and finally calculated the amount of subsidization needed to reduce the payback period by a year.

GEOGRAPHY OF LOCATION

For this work, Yaoundé is the city of focus. Yaoundé is the capital of Cameroon and, with a population of about 2.8 million, the second-largest city in the country after the port city Douala. It lies in the Centre Region of the nation at an elevation of about 750 meters (2,500 ft) above sea level.

In this project I am using a small part of the city of about 16.4 sq. km superimposing the city's population in this area. Shots taken from google earth are shown below:



I divided the area of focus into three regions; Dense urban, Urban and Sub-urban based on the density of the different regions. More details on the characteristics and descriptions of these regions is provided in the next section.

CHARACTERISTICS AND ARCHITECTURE OF FOCUS AREA

Regarding the chosen city Yaoundé with a total population of about 2.8 million, I made the following assumptions;

- There are eight persons per apartment implying a total of 350,000 apartments
- A unit block exists and it made up of 9 buildings
- Represent this population in a 16.4 sq. km portion of the town shown above.

Area characteristic

Area type	Dense Urban	Urban	Sub Urban
Floors per building	8	8	4
Apartments per floor	4	3	4
Building per block	9	9	9
Blocks per area	5000	5000	4375
Population per area	116,667	116,667	116,667
Total Service area	3.52 sq. km	5.2 sq. km	7.2 sq. km
Area density(households/km2)	33,144	22,435	16,203
Number of LEX	8	10	8

Each LEX has 32 OLTs with each OLT having 16 xgpon ports. with a 10gbps capacity per port.

In the Dense urban and the urban scenario, each port is able to service a single building sufficiently, meaning 32 and 24 subscribers respectively.

For the sub urban case, a 1x2 splitter per port arrangement is made at each local exchange, meaning one port is able to sufficiently serve 2 buildings equivalent to 32 subscribers.

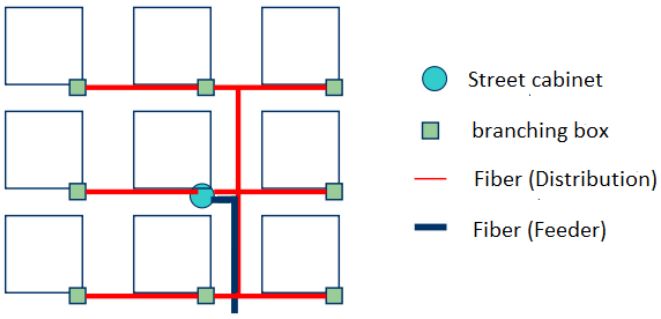
DIMENSIONING AND CAPEX CALCULATION

Dimensioning

Consider the following point:

1. For DU (dense urban), Urban and SU (sub-urban) areas, each building has 32,24 and 16 apartments respectively.
2. In my dimensioning process, I have made use of the following rational; each area consists of many blocks. A block has the following characteristics;

- Consist of 9 buildings
- Has 1 street cabinet and 9 branching boxes (no splitters inside, just for distribution in this case).
- Has a star-like network of fibers and trenches
- Has area 0.009 sq. km.



3. Each OLT has 16 xgpon ports. And each LEX houses 32 OLTs.

CAPEX EVALUATION

In this computation, I made use of the following price list:

Network Component	Cost	Remarks
LEX	80,000.00 €	Max 100.000 subscribers
ODF-OLT	2,000.00 €	per 1000 fibers
Trench	15.00 €	per m
Fiber 2 pair	0.80 €	per m
Fiber 24 pair	1.50 €	per m
Fiber 96 pair	3.50 €	per m
Duct	2.50 €	per m
Manhole	600.00 €	Every 500 m
Cabinet	5,000.00 €	
Splitter	25.00 €	1:32 or 1:16
BEP	300.00 €	per building
Floor Box	200.00 €	per 2 floors
CPE	30.00 €	per subscriber
2 fiber pair installation	0.80 €	total/m
24 pair installation	1.50 €	total/m
96 pair installation	3.50 €	total/m

Considering the equipment needed, the quantities and the unit cost, the expenditure was calculated as follows for the different areas based on area properties mentioned above:

Calculating Cost in Dense Area		
Components	**Quantity**	**Cost**
street cabinets	1	5,000.00 €
BEP	9	2,700.00 €
dark fiber length	279.650394	1,342.32 €
red fiber length	419.475591	1,719.85 €
Splitters	9	225.00 €
floor boxes	36	7,200.00 €
number of CPEs	288	8,640.00 €
Trench length	279.650394	4,194.76 €
internal fiber length	4032	16,531.20 €
manholes	3	1,800.00 €
	Total per blk	**49,353.13 €**
	Zone total	**19,992,586 €**

Calculating cost in Urban zone		
Components	**Quantities**	**Cost**
street cabinets	1	5,000.00 €
BEP	9	2,700.00 €
dark fiber length	279.650394	1,342.32 €
red fiber length	419.475591	1,719.85 €
Splitters	9	225.00 €
floor boxes	36	7,200.00 €
number of CPEs	216	6,480.00 €
Trench length	279.650394	4,194.76 €
internal fiber length	3024	12,398.40 €
manholes	3	1,800.00 €
	Total per blk	**43,060.33 €**
	Zone total	**23,257,893 €**

Calculating cost in Sub-urban Area		
Components	**Quantities**	**Cost**
street cabinets	1	5,000.00 €
BEP	9	2,700.00 €
dark fiber length	279.650394	1,342.32 €
red fiber length	419.475591	1,719.85 €
Splitters	9	225.00 €
floor boxes	18	3,600.00 €
number of CPEs	144	4,320.00 €
Trench length	279.650394	4,194.76 €
internal fiber length	864	3,542.40 €
manholes	3	1,800.00 €
	Total per blk	**28,444.33 €**
	Zone total	**23,045,173 €**

LEX COSTS		
Local Exchanges	26	2,080,000.00 €
ODF/OLT	832	1,664,000.00 €
splitters DU	0	**0.00 €**
splitters urban	0	**0.00 €**
splitters SU	4096	**102,400.00 €**
	Total	**3,846,400.00 €**

Total CAPEX	**70,142,052.45 €**

SERVICE OFFERS

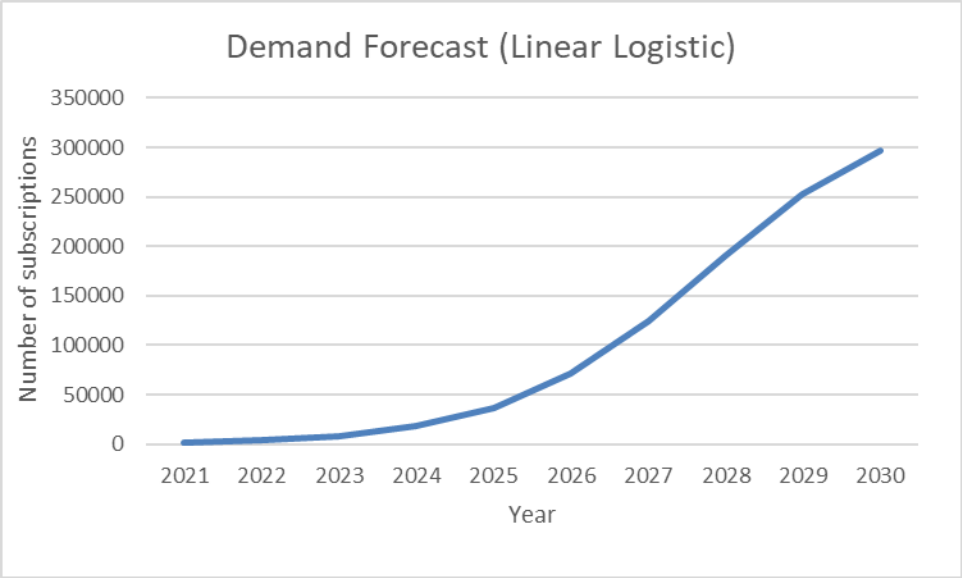
Acknowledging the fact that all subscribers don't have the same income levels, I have made three different service offers that present different options for the subscribers to chose from. As expected, the higher the price, the better the service.
To ensure that my tariffs are competitive, I made sure to cross correspond with tariffs of similar services from different operators.

Service type	Downlink/uplink (MB)	Additional Service	Price (€)	Demand (%)
Basic	100	Free installation and CPE	39.99	60
Premium	200	Free CPE and installation	59.99	30
Gold	300	Free CPE and installation	79.99	10

DEMAND FORECASTING

I used the Linear Logistic model parameters obtained from Assignment Part two since it had the best results (smallest error) for fixed broadband subscription predictions. I changed the saturation level to reflect the current situation (350,000). The parameters and graph are shown below

Linear Logistic Model Paramters	
S	350000
b	0.772048
a	-6.00026



INVESTMENT EVALUATION CRITERIA

Investment criteria
The criteria used here for investment evaluation are the following:

NPV
Net present value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. NPV is used in capital budgeting and investment planning to analyze the profitability of a projected investment or project. A positive net present value indicates that the projected earnings generated by a project or investment - in present euros - exceeds the anticipated costs, also in present euros. It is assumed that an investment with a positive NPV will be profitable, and an investment with a negative NPV will result in a net loss. This concept is the basis for the Net Present Value Rule, which dictates that only investments with positive NPV values should be considered.

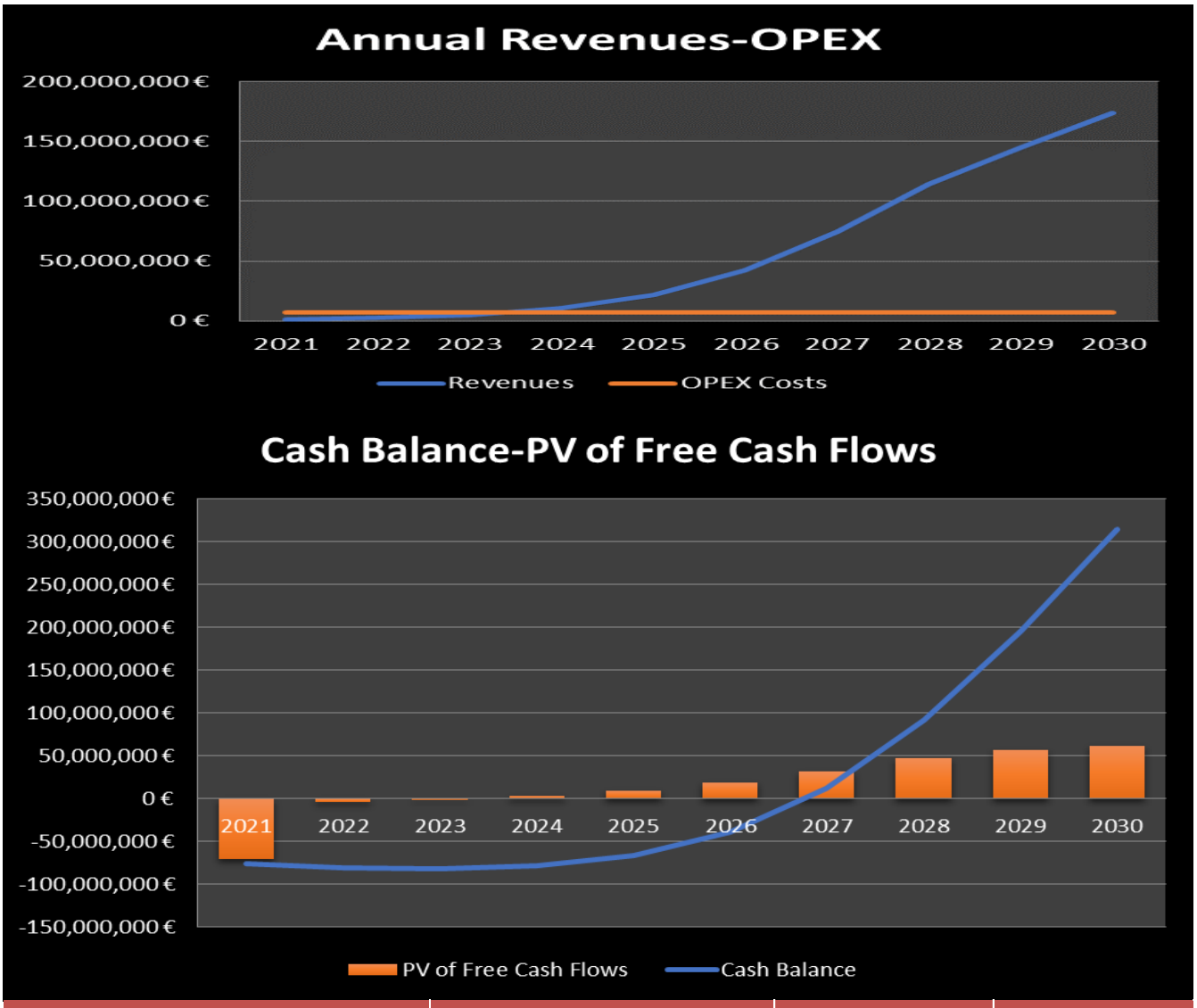
IRR
The internal rate of return (IRR) is a metric used in capital budgeting to estimate the profitability of potential investments. The internal rate of return is a discount rate that makes the net present value (NPV) of all cash flows from a particular project equal to zero. IRR calculations rely on the same formula as NPV does.

PI
The profitability index (PI), alternatively referred to as value investment ratio (VIR) or profit investment ratio (PIR), describes an index that represents the relationship between the costs and benefits of a proposed project. It is calculated as the ratio between the present value of future expected cash flows and the initial amount invested in the project. A higher PI, the more attractive a project will be. The PI is helpful in ranking various projects because it lets investors quantify the value created per each investment unit. A profitability index of 1.0 is logically the lowest acceptable measure on the index, as any value lower than that number would indicate that the project's present value (PV) is less than the initial investment. As the value of the profitability index increases, so does the financial attractiveness of the proposed project.
One reason one might want to consider the profitability index metric is that looking at the NPV value alone could be deceitful since generally, projects with huge initial investments usually have higher NPVs than projects with smaller initial investments. PI presents us with the number of euros earned per unit euro invested.

Payback period

The payback period refers to the amount of time it takes to recover the cost of an investment. Simply put, the payback period is the length of time an investment reaches a break-even point. Shorter paybacks mean more attractive investments.

The following is the resulting values and graphs for the investment appraisal.



NPV	PV of Expected Cash Flows	IRR	PI
148,434,329.91 €	148,434,329.91 €	13.11%	3.116195987
148,434,329.91 €			

Comments

- The NPV is positive indicating that it is a good investment that would generate profit.
- The IRR is higher than the actual rate which is 7%, indicating that it is a fruitful investment.
- The profitability index is greater than 1. Indicating for every one euro invested, approximately 3.1 euro is generated in present euro terms.
- The payback period is between 2021 and 2027 (7years).

To compute the amount of subsidy on the investment cost needed to reduce the payback period of the investment by one year, consider the revenue table below;

Year	Revenues	OPEX Costs	Cash Balance
2021	1,120,015.90 €	7,014,205.24 €	-76,036,241.79 €
2022	2,408,971.73 €	7,014,205.24 €	-80,641,475.31 €
2023	5,144,762.44 €	7,014,205.24 €	-82,510,918.11 €
2024	10,825,447.74 €	7,014,205.24 €	-78,778,751.98 €
2025	22,101,699.85 €	7,014,205.24 €	-66,702,159.29 €
2026	42,610,407.32 €	7,014,205.24 €	-39,449,123.07 €
2027	74,593,092.38 €	7,014,205.24 €	11,471,100.09 €
2028	114,199,734.71 €	7,014,205.24 €	91,700,238.58 €
2029	145,385,865.69 €	7,014,205.24 €	195,007,113.99 €
2030	173,796,906.44 €	7,014,205.24 €	314,669,649.56 €

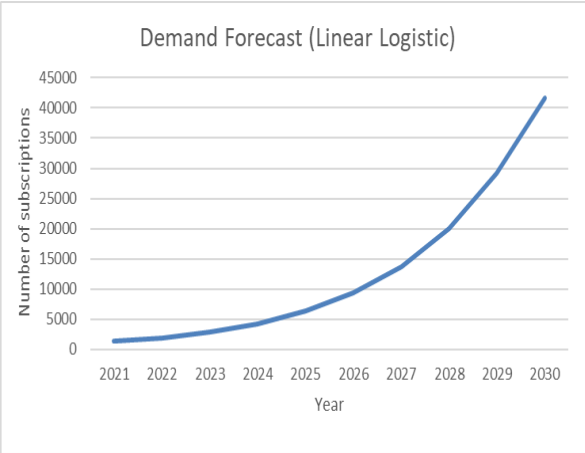
Subsidy = - (cash balance at payback year – 1)

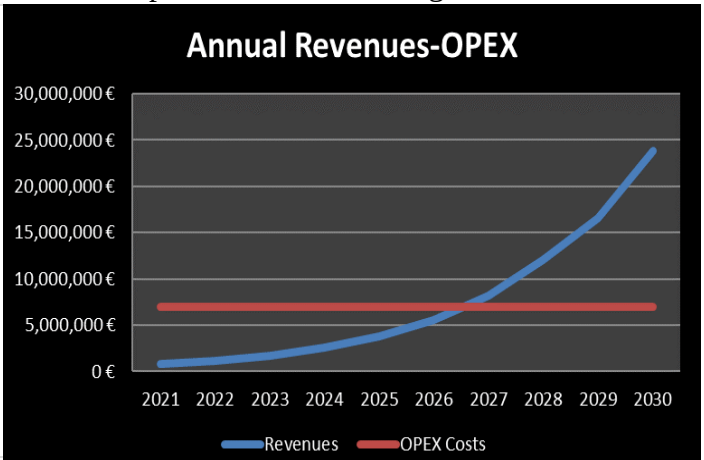
= 39,449,123.07 €

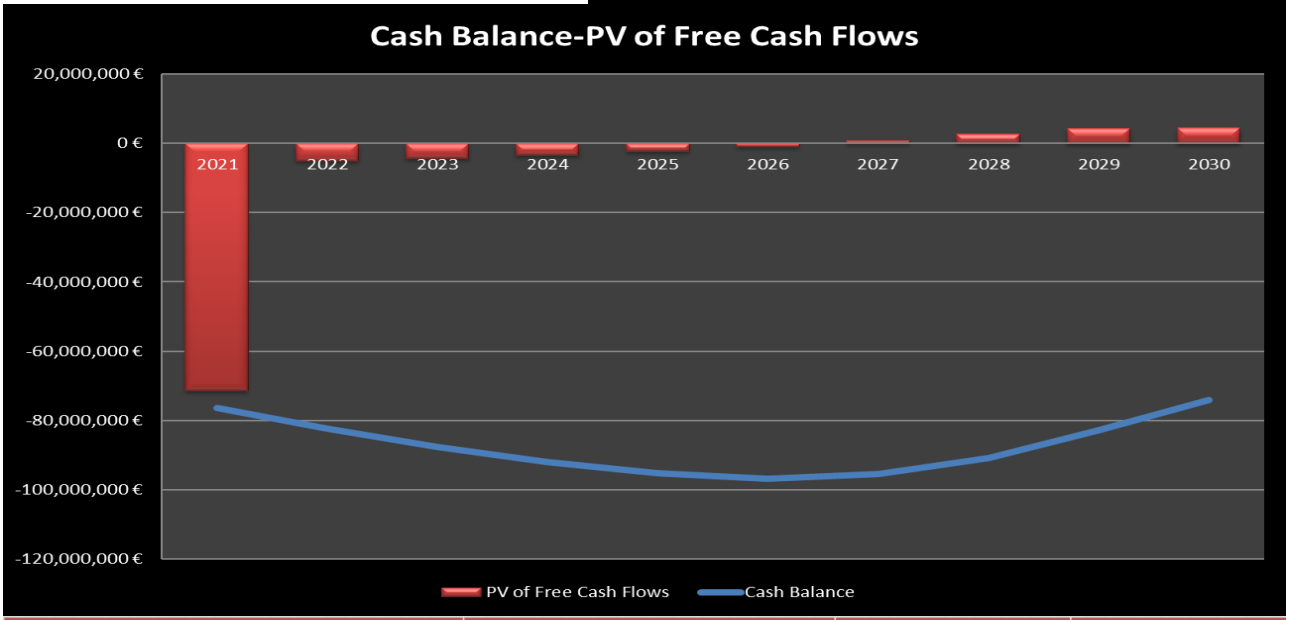
SCENARIO ANALYSIS

Decrease in the demand penetration rate

Decreasing the demand penetration rate from 0.77 to 0.4 produces the following results.







NPV	PV of Expected Cash Flows	IRR	PI
-75,302,332.28 €	-75,302,332.28 €	-21.95%	-0.073568988
-75,302,332.28 €			

Comments

Generally speaking, a reduction in the demand penetration rate would mean demand grows very slowly which implies a very slow change in annual revenue and this is not good for business and as seen above would affect the investment criteria negatively.

- The NPV is negative, indicating that with this lower demand penetration rate, this would be a poor investment.
- The IRR is less that the actual rate, thus another sign this a poor investment.
- The PI is less than 1, which indicates a loss.
- The payback period would not happen in the 10 years considered.

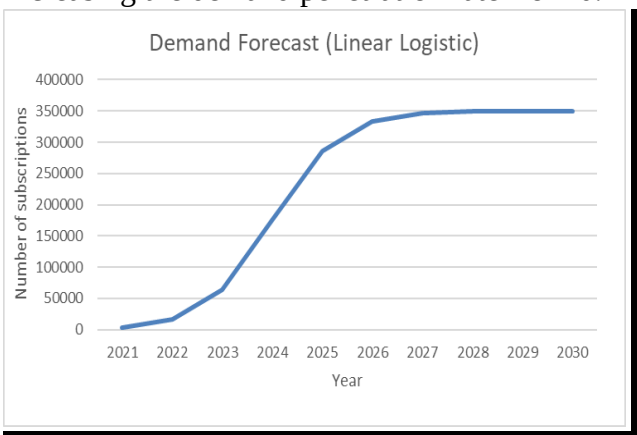
One can confidently say that if the demand penetration rate were half of what is actually is, this would be a very terrible investment.

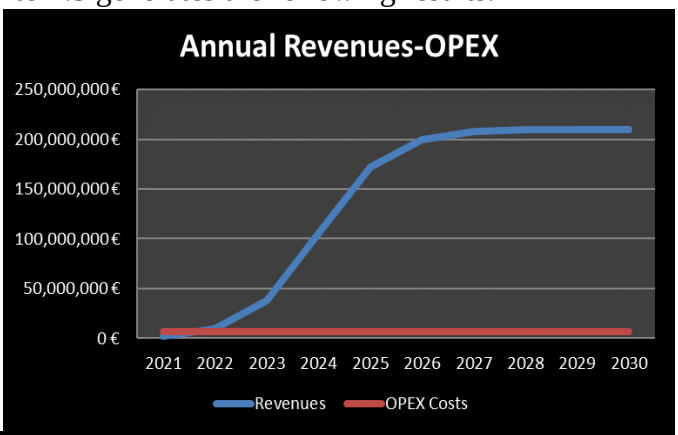
The actual values plotted above are shown below.

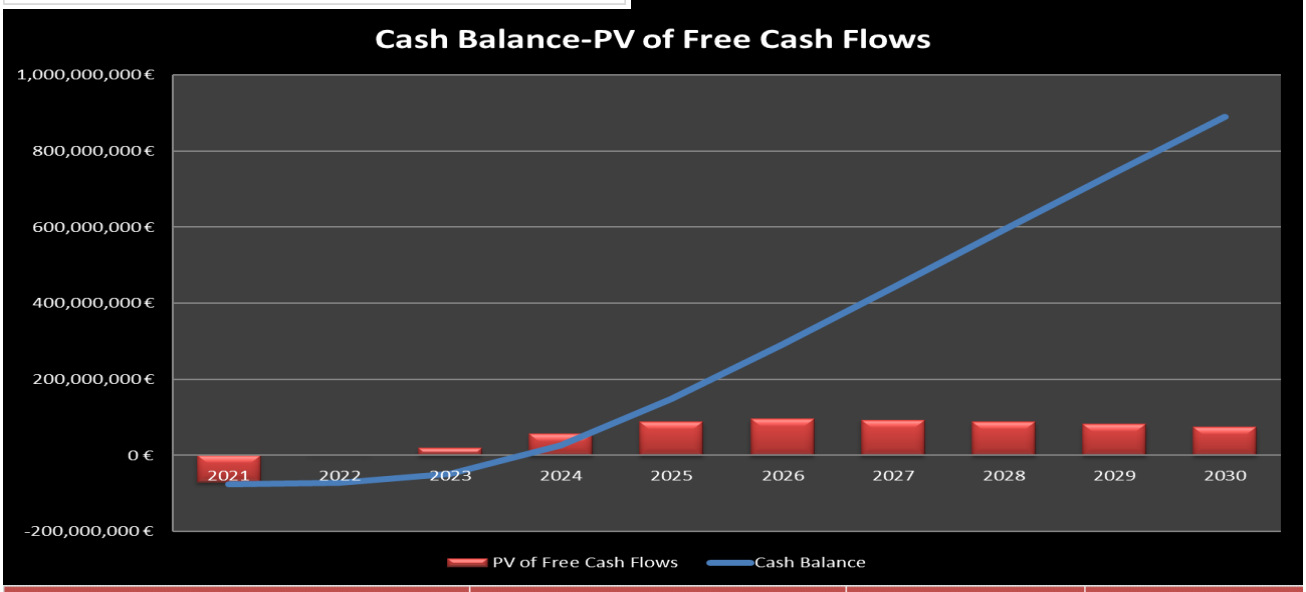
Year	Revenues	OPEX Costs	Cash Balance
2021	773,332.09 €	7,014,205.24 €	-76,382,925.60 €
2022	1,151,589.78 €	7,014,205.24 €	-82,245,541.06 €
2023	1,713,348.17 €	7,014,205.24 €	-87,546,398.14 €
2024	2,545,797.55 €	7,014,205.24 €	-92,014,805.83 €
2025	3,775,369.22 €	7,014,205.24 €	-95,253,641.85 €
2026	5,582,815.92 €	7,014,205.24 €	-96,685,031.18 €
2027	8,221,070.02 €	7,014,205.24 €	-95,478,166.40 €
2028	12,032,672.72 €	7,014,205.24 €	-90,852,653.79 €
2029	16,590,339.78 €	7,014,205.24 €	-82,854,467.55 €
2030	23,811,575.50 €	7,014,205.24 €	-74,181,076.88 €

Increase in the demand penetration rate

Increasing the demand penetration rate from 0.77 to 1.5 generates the following results.







NPV	PV of Expected Cash Flows	IRR	PI
528,795,328.83 €	528,795,328.83 €	36.59%	8.538920097
528,795,328.83 €			

Comments

As expected, increasing the demand penetration rate would have the reverse effect of the decrease seen above. The company is able to make huge revenues quickly as the demand rises at a faster pace.

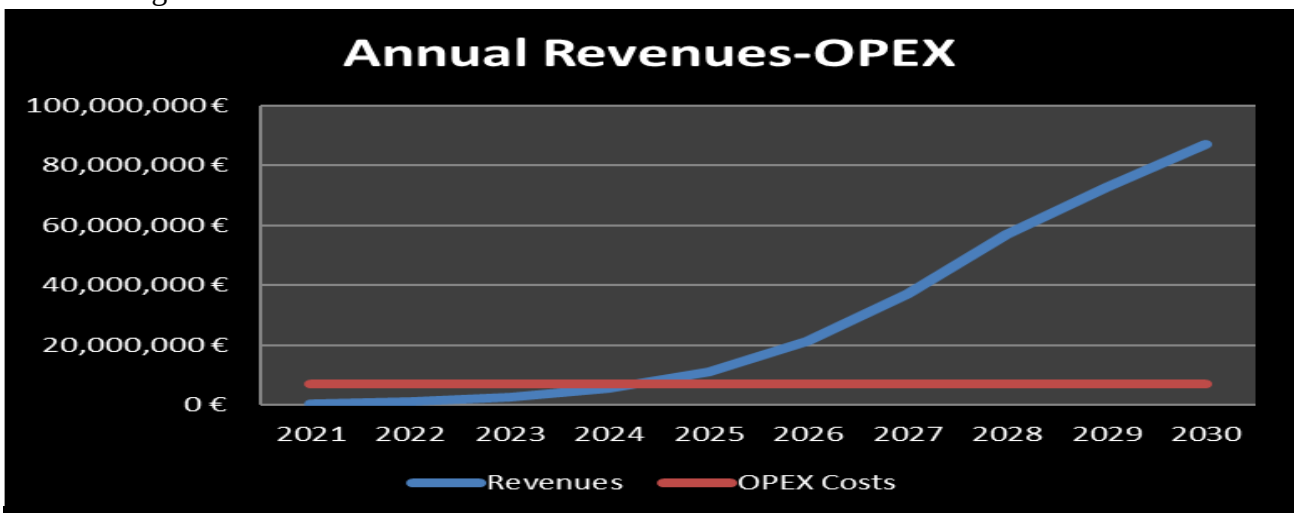
- The NPV is positive and higher than the normal value of about 148million euros. This suggests that an increase in demand penetration is good for business.
- The IRR is higher than the normal value of 13.11% and generally speaking, the higher the IRR, the better the investment.
- The payback period is reduced from 7 years to 4 years. Which is good.
- The PI increases from 3.11 to 8.53, suggesting that more money would be generated per unit euro invested.

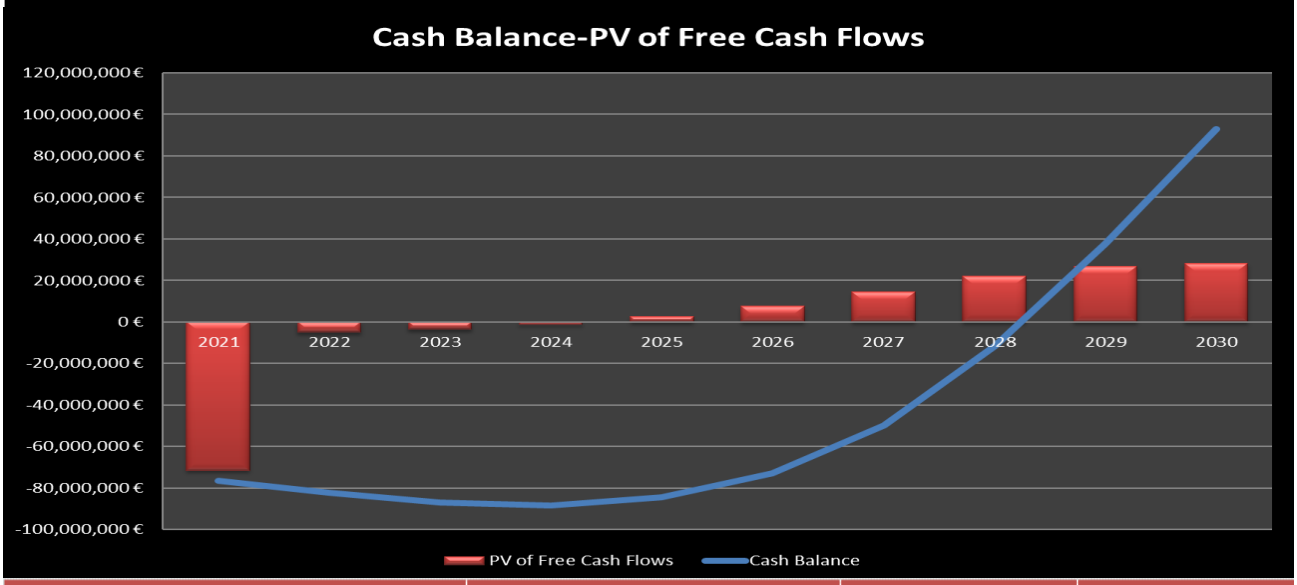
Actual values of revenue and cash balance are shown below.

Year	Revenues	OPEX Costs	Cash Balance
2021	2,306,193.94 €	7,014,205.24 €	-74,850,063.76 €
2022	9,954,936.28 €	7,014,205.24 €	-71,909,332.72 €
2023	38,293,427.15 €	7,014,205.24 €	-47,850,861.83 €
2024	104,965,134.99 €	7,014,205.24 €	25,544,672.87 €
2025	171,648,029.51 €	7,014,205.24 €	148,285,549.51 €
2026	199,998,052.72 €	7,014,205.24 €	292,005,443.32 €
2027	207,650,600.78 €	7,014,205.24 €	441,388,222.70 €
2028	209,438,716.18 €	7,014,205.24 €	592,094,207.47 €
2029	209,777,393.36 €	7,014,205.24 €	743,050,813.35 €
2030	209,917,656.17 €	7,014,205.24 €	889,442,703.72 €

Decrease (until half) in the ARPU

After cutting down the ARPU by half from 599.88 to 299.94 euros/subscriber annually, I obtained the following results.





NPV	PV of Expected Cash Flows	IRR	PI
20,625,348.57 €	20,625,348.57 €	1.73%	1.294051113
20,625,348.57 €			

Comments

The ARPU (average revenue per user) estimates the amount of money gotten for each subscriber for all the service per unit time (in this case I consider it per year). As one would expect, a reduction in the in the ARPU would mean less income for the company and adversely impact the investment criteria.

- The NPV drops from about 148 million to about 20 million euros. It still positive which still indicates a good sign for the investment therefore we would have to look at other criteria to get better insight.

- The IRR drops to 1.73 which is less than the actual rate of 7. Thus, a poor investment according to this criterion.
- The PI drops from 3.11 to 1.29 but it is still greater than one which still indicates gain.
- The payback period is pushed for 2 years to 2029.

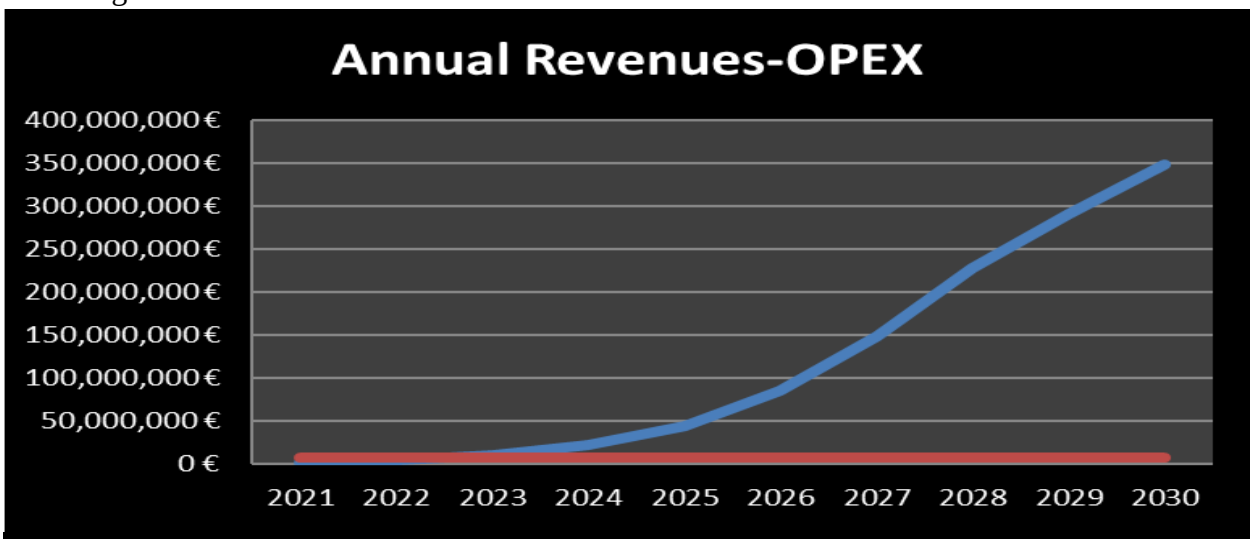
In all, it is clear that decreasing the ARPU by half did not totally discourage investment as some criteria still indicate positive signs.

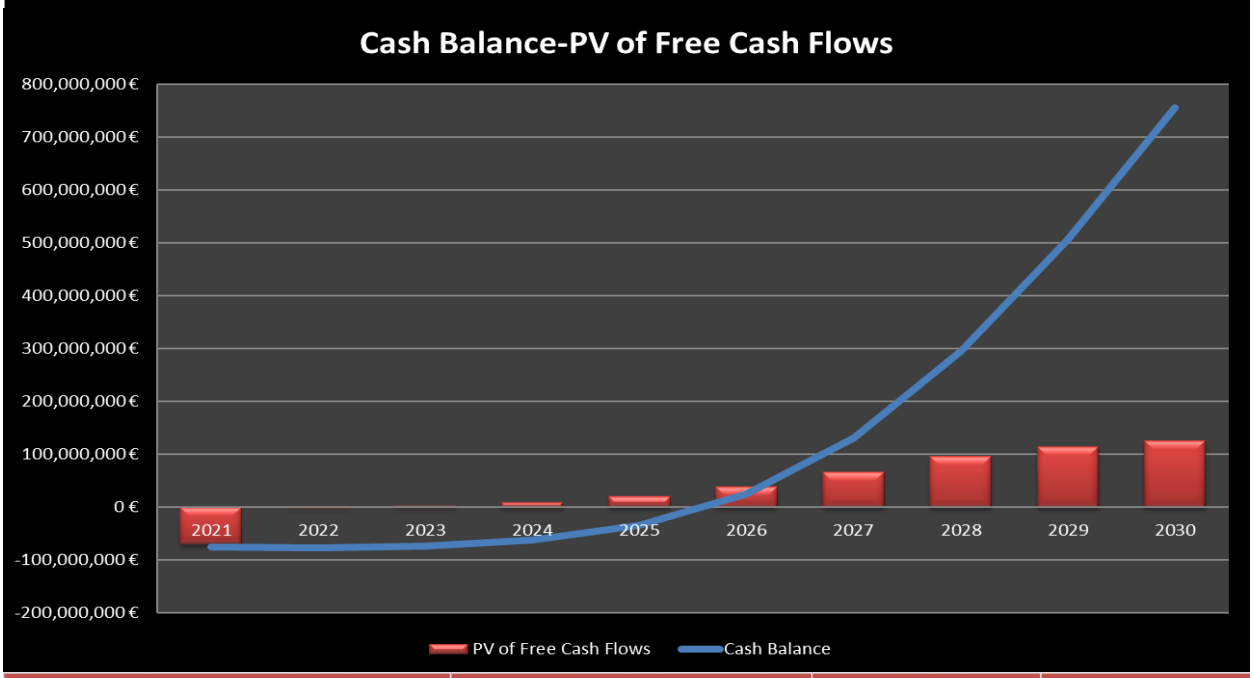
The following table shows annual revenues and cash balance plotted above.

Year	Revenues	OPEX Costs	Cash Balance
2021	560,007.95 €	7,014,205.24 €	-76,596,249.74 €
2022	1,204,485.87 €	7,014,205.24 €	-82,405,969.12 €
2023	2,572,381.22 €	7,014,205.24 €	-86,847,793.15 €
2024	5,412,723.87 €	7,014,205.24 €	-88,449,274.52 €
2025	11,050,849.92 €	7,014,205.24 €	-84,550,310.78 €
2026	21,305,203.66 €	7,014,205.24 €	-73,063,125.27 €
2027	37,296,546.19 €	7,014,205.24 €	-49,742,346.28 €
2028	57,099,867.36 €	7,014,205.24 €	-11,767,109.64 €
2029	72,692,932.85 €	7,014,205.24 €	37,746,995.47 €
2030	86,898,453.22 €	7,014,205.24 €	93,104,675.65 €

Increase (until double) in the ARPU

After increasing the annual ARPU of about 599.88 to 1199.76 euros/subscriber, I obtained the following results.





NPV	PV of Expected Cash Flows	IRR	PI
402,025,689.17 €	402,025,689.17 €	25.59%	6.731592891
402,025,689.17 €			

Comments

An increase in the ARPU directly affects total revenue generated which improves cash flow which also increases the NPV. A higher ARPU means more money for the company and is very much welcomed but despite this, the company has to ensure that the prices for its services remain competitive.

- The NPV is positive and higher the normal case. A good sign.

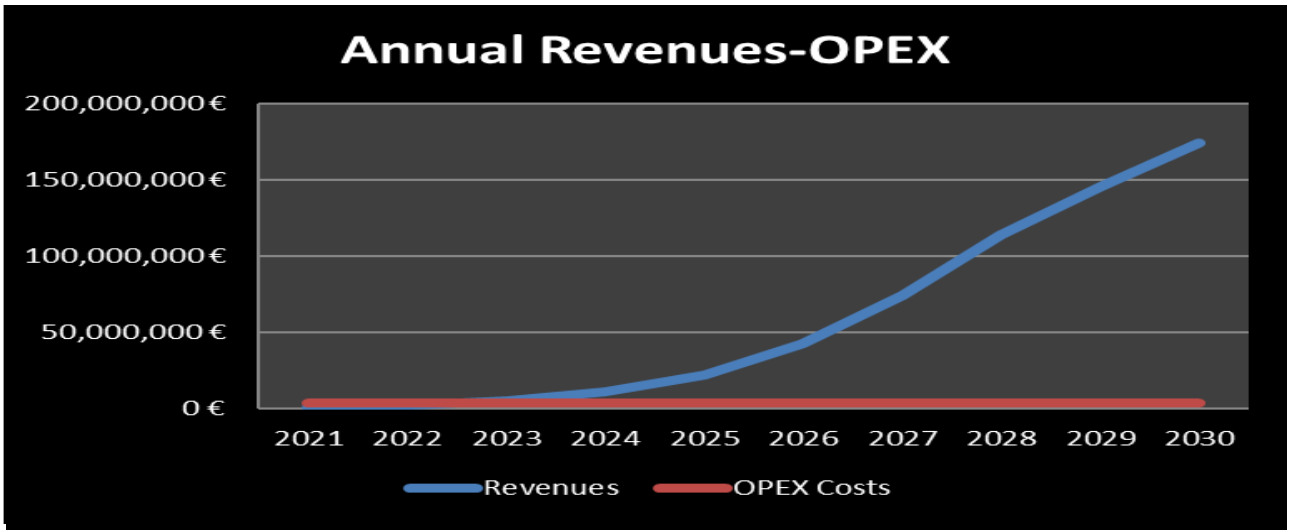
- The IRR increases from 13.11% to 25.59%, making such a scenario more attractive.
- The PI increases to more than double, indicating more returns per unit investment.
- The payback period in this case reduces by one year to 2026. The quicker the better.

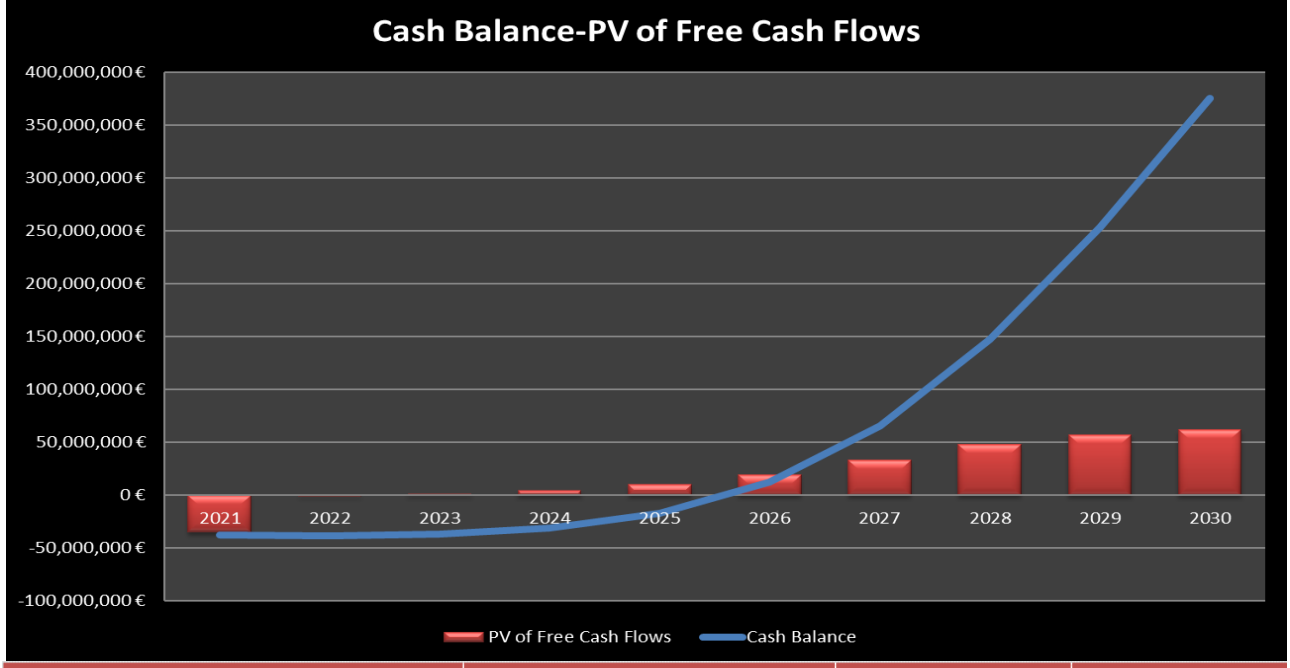
The revenue table is shown below.

Year	Revenues	OPEX Costs	Cash Balance
2021	2,240,031.80 €	7,014,205.24 €	-74,916,225.90 €
2022	4,817,943.46 €	7,014,205.24 €	-77,112,487.68 €
2023	10,289,524.88 €	7,014,205.24 €	-73,837,168.04 €
2024	21,650,895.48 €	7,014,205.24 €	-62,094,170.59 €
2025	44,203,399.70 €	7,014,205.24 €	-33,662,320.01 €
2026	85,220,814.65 €	7,014,205.24 €	25,122,417.63 €
2027	149,186,184.77 €	7,014,205.24 €	131,241,529.16 €
2028	228,399,469.43 €	7,014,205.24 €	295,978,471.34 €
2029	290,771,731.39 €	7,014,205.24 €	506,870,887.37 €
2030	347,593,812.88 €	7,014,205.24 €	755,143,133.70 €

Decrease (until half) in the investment's sunk cost

Decreasing the sunk cost by half from 70,142,052.45 € to 35,071,026.22 € produces the following results:





NPV	PV of Expected Cash Flows	IRR	PI
199,826,227.71 €	199,826,227.71 €	25.52%	6.697758213
199,826,227.71 €			

Comments

A decrease in the sunk cost (CAPEX) means a reduction in the money invested in the deployment of this network. This directed affects the NPV positively. Investors are always happy when they have to speed less and make more.

- The NPV is positive and moves form 148M to about 200M euros. This is good news for investors in such a scenario.

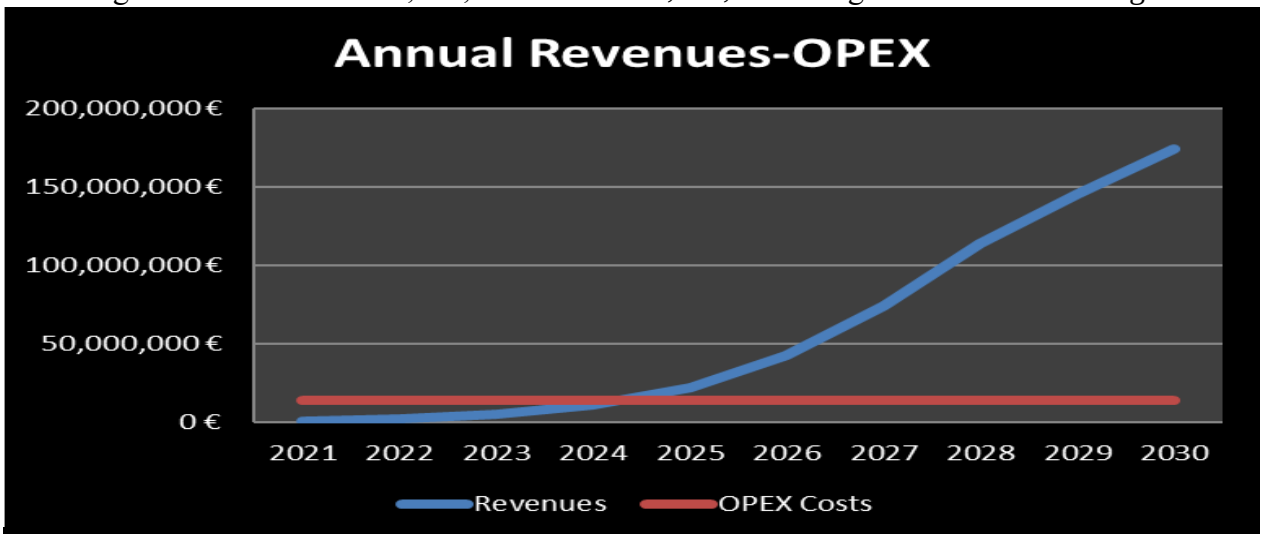
- The IRR is also higher than the the normal state of 13.11%. that is, a more attractive case.
- The PI is greater than 1 and also greater than the normal case of 3.11 thus depicting an advantageous position.
- The payback period is shortened by a year to 2026.

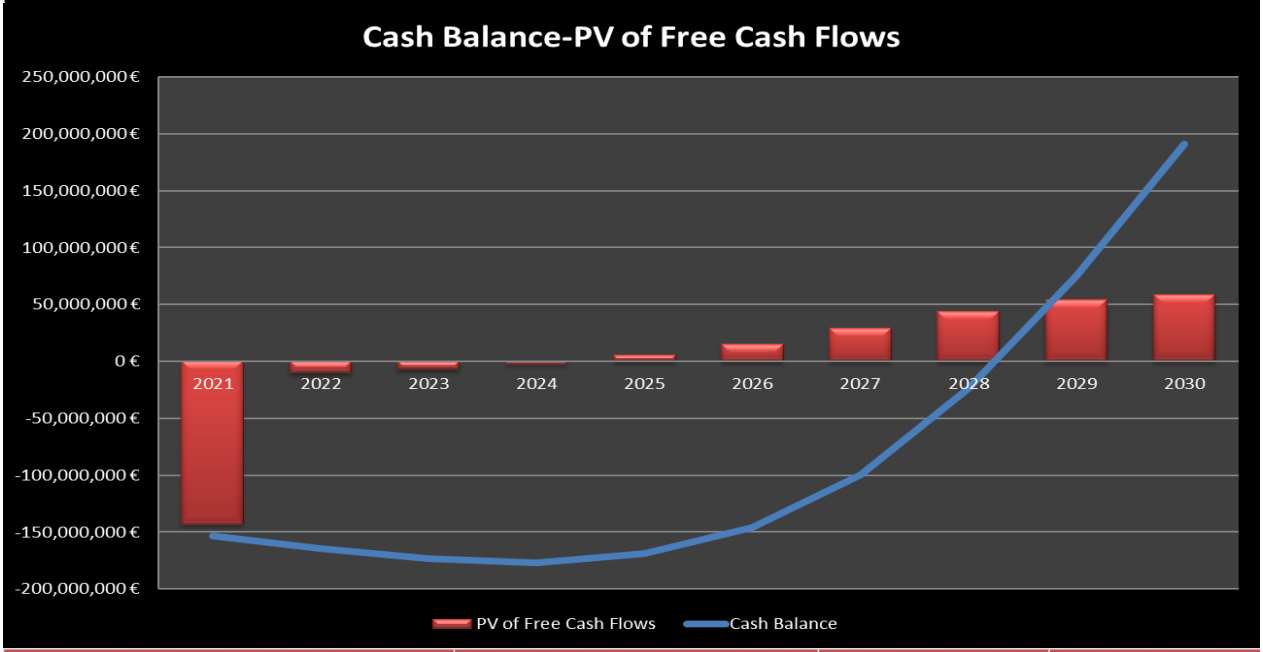
The revenue and cash balance annual values are shown below.

Year	Revenues	OPEX Costs	Cash Balance
2021	1,120,015.90 €	3,507,102.62 €	-37,458,112.95 €
2022	2,408,971.73 €	3,507,102.62 €	-38,556,243.84 €
2023	5,144,762.44 €	3,507,102.62 €	-36,918,584.02 €
2024	10,825,447.74 €	3,507,102.62 €	-31,047,085.29 €
2025	22,101,699.85 €	3,507,102.62 €	-16,831,160.00 €
2026	42,610,407.32 €	3,507,102.62 €	12,561,208.82 €
2027	74,593,092.38 €	3,507,102.62 €	65,620,764.58 €
2028	114,199,734.71 €	3,507,102.62 €	147,989,235.67 €
2029	145,385,865.69 €	3,507,102.62 €	253,435,443.68 €
2030	173,796,906.44 €	3,507,102.62 €	375,237,311.85 €

Increase (until double) in the investment's sunk cost

Increasing the sunk cost from 70,142,052.45 € to 140,284,104.90 € generates the following results:





NPV	PV of Expected Cash Flows	IRR	PI
43,623,930.90 €	43,623,930.90 €	1.89%	1.310968452
43,623,930.90 €			

Comments

Increasing the sunk cost directly affects the NPV adversely. Investors are not happy investing more money. A high capex would mean less profit.

- The NPV drops to about 43M euros which is a huge drift from the initial 148M. Despite this, it is worth mentioning that the NPV is still positive, indicating some benefits.
- The IRR drops to 1.89% and is less than the actual rate which is a poor sign.

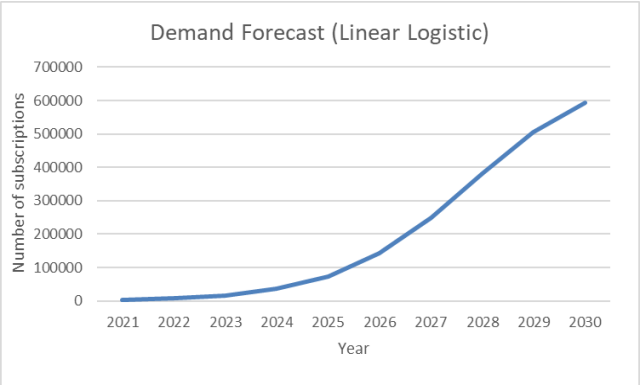
- The PI drops too, indicating less money is made per unit invested euro. It is still greater than one though.
- The payback period is extended by two years.

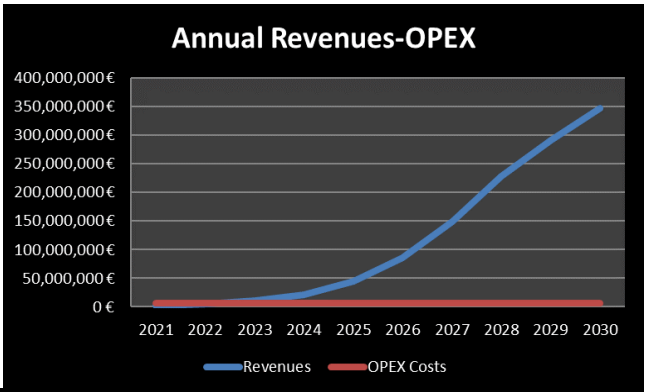
Annual revenue and cash balance table

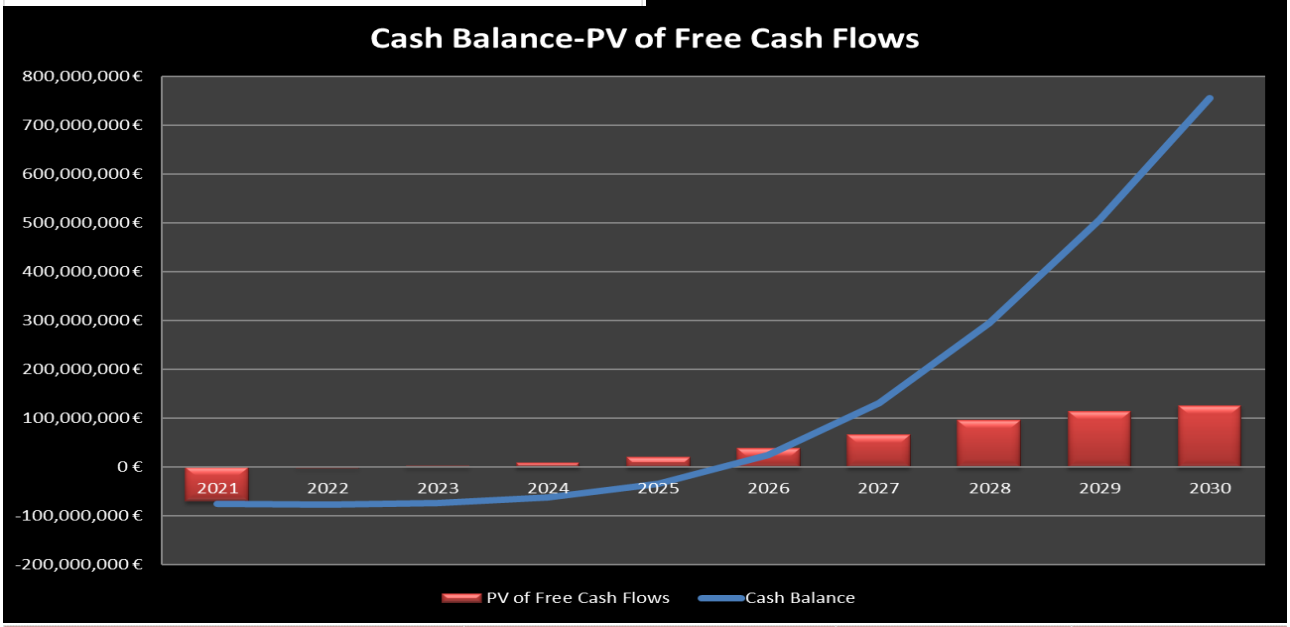
Year	Revenues	OPEX Costs	Cash Balance
2021	1,120,015.90 €	14,028,410.49 €	-153,192,499.49 €
2022	2,408,971.73 €	14,028,410.49 €	-164,811,938.25 €
2023	5,144,762.44 €	14,028,410.49 €	-173,695,586.29 €
2024	10,825,447.74 €	14,028,410.49 €	-176,898,549.04 €
2025	22,101,699.85 €	14,028,410.49 €	-169,100,621.55 €
2026	42,610,407.32 €	14,028,410.49 €	-146,126,250.53 €
2027	74,593,092.38 €	14,028,410.49 €	-99,484,692.57 €
2028	114,199,734.71 €	14,028,410.49 €	-23,534,219.28 €
2029	145,385,865.69 €	14,028,410.49 €	75,493,990.94 €
2030	173,796,906.44 €	14,028,410.49 €	190,877,861.31 €

Doubled total area population

Doubling the total area population by multiplying the number of subscribers by two thus moving from 350,000 to 700,000. The following results are obtained.







NPV	PV of Expected Cash Flows	IRR	PI
402,025,689.17 €	402,025,689.17 €	25.59%	6.731592891
402,025,689.17 €			

Comments

Generally speaking, an increase in the total area population means more subscribers for the company. This in turn means more revenue and more revenue generated means more profit. Therefore, as seen above and as expected, we see the investment criteria take a more positive and encouraging direction.

- The NPV is positive increases due to increased revenue
- The IRR increases to 25.59%, greater than the actual 7%.
- The PI increases to more than double, indicating more money to be gained from the investment.
- The payback period drops by a year.

Annual revenue and cash balance table

Year	Revenues	OPEX Costs	Cash Balance
2021	2,240,031.80 €	7,014,205.24 €	-74,916,225.90 €
2022	4,817,943.46 €	7,014,205.24 €	-77,112,487.68 €
2023	10,289,524.88 €	7,014,205.24 €	-73,837,168.04 €
2024	21,650,895.48 €	7,014,205.24 €	-62,094,170.59 €
2025	44,203,399.70 €	7,014,205.24 €	-33,662,320.01 €
2026	85,220,814.65 €	7,014,205.24 €	25,122,417.63 €
2027	149,186,184.77 €	7,014,205.24 €	131,241,529.16 €
2028	228,399,469.43 €	7,014,205.24 €	295,978,471.34 €
2029	290,771,731.39 €	7,014,205.24 €	506,870,887.37 €
2030	347,593,812.88 €	7,014,205.24 €	755,143,133.70 €

CONCLUSION

It is clear by now that the proper dimensioning of an FTTH network is very important as it not only defines the total CAPEX but also plays an important role in bandwidth distribution. It is also worth noting that during the dimensioning process, should follow strictly the rules set by the government of the chosen country.

Also, many criteria would influence the returns of an investment, so it is wise to make proper forecast and scenario analyst to reduce uncertainty. In addition, different parameters appear to affect the returns differently. For instance, a change in the demand penetration rate seems to have a bigger impact than the other scenarios.