Hydropower Potential in India: A Review

Varun Mishra, Ruchi Khare, and Rutuja Chavan

Abstract India being a developing nation, the requirements increase day by day which leads to the crisis of resources. Energy sources are mostly affected because of increase in the mechanisation and different development schemes. Specially if we talk about the energy sector, the increase in the demand is just an effect of urbanisation. As someone said very right, "Everything comes with a price", so the question is what price you willing to pay? Ample amount of production and distribution of energy becomes a major task today. The environmental aspect and continuous depletion of fossil fuels concern its availability in future and force it to look forward to alternative sources. Sources of energy which are considered to be renewable like hydro, wind and solar can become a boon for the future generation. Currently, in India, the energy contribution by hydropower by utilising water potential is around 12.4% (including small hydropower) of total energy generation, whereas renewable sources share up to 18%. So, there is a need for proper functioning and sustainable methods where the renewable sector can be uplifted. In India, hydroelectric energy capacity is roughly calculated as 148,700 MW having load factor of 60%. In India, the overall hydroelectric power for FY 2019–20 was 156 TWh (excluding SHP) having average CF as 38.71%. This paper reviews major literature on the generation capacity of hydropower. A review on different alternatives available to fulfil the energy demand and to investigate the different types of correlations developed by previous investigators. The study also focuses on small hydropower development its benefits and cause. In India, small hydropower plants contribute around 4671 MW of electricity, and around 526 MW is under construction. Using small hydropower can make a sustainable growth in the energy sector. Furthermore, the study also put forward the suggestions for development in the energy scenario along with policies offered by the government.

Keywords Energy · Hydropower · Renewable sources · Small hydropower plants

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1 Introduction

Electricity is amid the vital field of infrastructure, essential for economic advancement and well-being of country. The continual improvement of Indian economy requires development and expansion of infrastructure.

India's energy field is considered to be one of the most diversified in the world. Both conventional and non-conventional energy sources are responsible for power generation. The oil, coil, nuclear power, natural gas and hydro are some of major conventional sources while domestic waste, solar, wind and agriculture are feasible non-conventional sources.

In recent years, electricity consumption is increasing very rapidly and is expected to be further grow. So, to overcome the crisis and manage the proper distribution effectively in the country, massive addition to the installed generating capacity is obligatory [1].

In a survey of FY2018, India ranks fourth in overall power generation in Asia Pacific Region out of 25 countries. India secured 4th in wind power, 5th in solar power and 5th in renewable sources installed capacity until 2018. With these achievements and prudent steps to invest in the clean energy, India becomes the only country among G20 Nations that is on track to reach targets under Paris Agreement [1]. In FY2022 (until May 2021), the total installed capacity in India stands at 234.72 GW of Thermal Energy, renewable energy at 95.65 GW, 46.21 GW of Hydro energy and 6.78 GW of Nuclear energy. By the end of 2022, solar energy is expected to contribute 114 and 67 GW from wind power. Since government promoting renewable sources of energy, it is expected to boost up and achieve a target of 227 GW by 2022 [1].

According to World Water Assessment Programme (WWAP, 2014) and IEA 2011, India is at fifth position in world when it comes to production of electricity but still more than 288 million of India's population is living without electricity. There is a campaign called *power for all* initiated by the Indian government to make sure the accessibility of electricity in village areas by 2019. As per International Energy Agency (IEA) projections, country might put up more than 600 million new consumers of electricity by the end of 2040, due to which electricity demand may grow up to 5%.

India comprises many rivers which carry enormous amount of water potential and can be utilised to generate power. Using easily available native resources hydropower is capable of generating sustainable energy. This can solve chronic energy problem of the country [2]. With more than sufficient amount of water potential available, hydropower in India becoming the boon for Indian economy. As day-by-day population increases, power consumption and demand increase and to overcome that there is need of some alternatives which not only satisfy the demands but also comes as a supporting factor to boost and endorse the economy. Thermal source amid one of the high costs per kwh power generation comes with some limitations of polluting the environment but still maximum power generation in India is using coal as a fuel. This needs to be changed, when we have the alternatives and not only in sufficient

quantity but in massive, only what we need is proper engineering and steps to utilise that power. That alternative source is hydropower.

2 Power Sector in India

India is enriched with many rivers which have a huge water potential available and can be utilised to generate power fulfilling the increasing demand and stabilise the fluctuation in peak hours. Power sector in India is divided in three sectors, private sector, Central (Federal) sector and State sector and renewable energy sources (RES) contains Wind Energy, Solar Energy, Waste Power from industrial and urban areas, Biomass Power and Gasifier and Small Hydro Project.

India's overall collective installed energy generation potential from various sectors is 386,888 MW (July 2021). Figure 1 shows that 27% of the total installed capacity is contributed by private sector, whereas 48% is contributed by and 25% by Central government. Further, fuel consumption wise scenario shown in adjacent figure where thermal sector using coal is on top with 56% and hydro contribute 12.1% of total installed capacity. With rising trend of small hydro plants, hydropower is becoming a supporting factor in the power sector of India. As SHPs can be installed at lower kinetic head with less than 25 MW of capacity, it acts as supporting hand for the fluctuating demands in power supply, specially at the peak hours [4].

Figures 2 and 3 show the total generation in power in last decade and percentage growth in total generation yearly.

2.1 Renewable Energy Sector

In Paris Agreement for the Period 2021–2030, Nationally Determined Contribution (NDC) embraces some special conclusions those are

1. Reduction in the emission concentration by 33–35% of its GDP by 2030 from 2005 level.
2. To reach around 40% aggregate electricity installed capacity using renewable energy sources by 2030 using low-cost global finance and transmission of technology.

India has reached a collective installed renewable energy potential (excluding large hydro) of about 92.54 GW within which 5.47 GW was built-on in the period April 2020 till January 2021. In the course of April 2014–Jan 2021, the installed renewable potential of India has increased by 2.5 times, and the installed solar energy potential has increased fifteen times. Internationally, today India ranks 4th in renewable energy potential, 4th in Wind power, and 5th in Solar Energy Capacity [4].

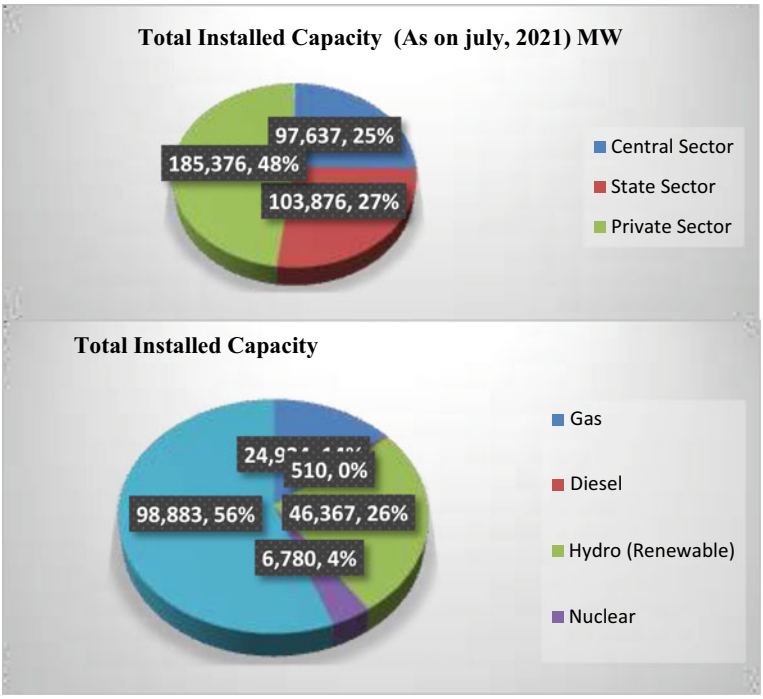

Fig. 1 Installed capacity of different energy sources [3]

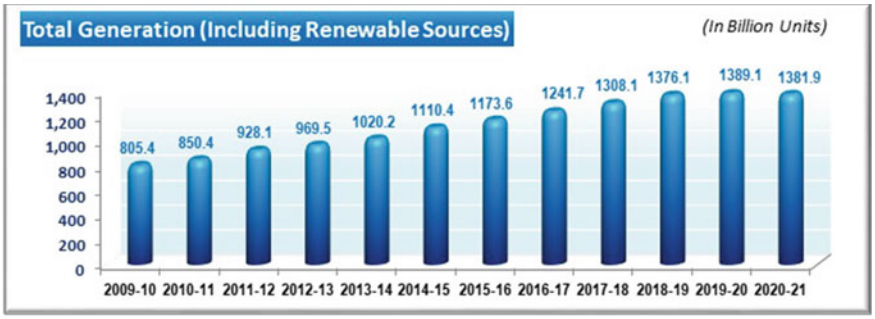

Fig. 2 Total power generation in last decade [1]

India is a country which has highest growth rate in terms of renewable energy sources. According to REI Report, around 64.2 billion US dollars is the estimated investment in renewable energy projects and programmes between 2014 and 2019 [3, 4] (Table 1).

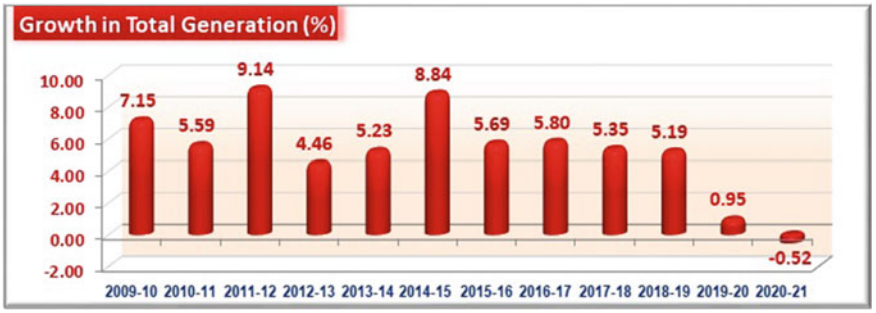

Fig. 3 Percentage growth in total power generation [1]

Table 1 India's RE sector at a glance [3]

Year	Installed RE capacity (in GW)	% share of RE in total installed capacity	Generation from renewable sources (in BU)	Total generation from all sources (in BU)	% share of RE in generation
2014–15	39.55	14.36	61.78	1110.18	5.56
2015–16	46.58	15.23	65.78	1172.98	5.60
2016–17	57.90	17.68	81.54	1241.38	6.56
2017–18	69.77	20.24	101.83	1303.37	7.81
2018–19	78.31	21.95	126.76	1375.96	9.21
2019–20	87.07	23.52	138.32	1390.93	9.95
2020–21	92.54	24.53	111.92	1017.81	11.00
	(Up to Jan	(Up to Jan	(Up to Dec	(Up to Dec	(Up to Dec
	2021)	2021)	2020)	2020)	2020)

2.2 Scenario of Hydropower in India

Concept of hydropower is developed by taking benefit of kinetic energy unconstrained falling water. Conversion of water's potential energy into mechanical and electrical energy using turbine rotation by water is the idea behind working of hydroelectric plant. Hydropower is a renewable, economic and non-polluting source of energy. Hydropower plants have essential adaptability of quick start, stop and load variations handout operational tractability and aid in enhancing reliability of power system. Hydropower sources are the best option for meeting the peak demand.

Hydropower is a clean and renewable source of energy which doesn't concern about the fuel economically as well as the availability is also not the factor of much deal. The efficiency of a hydropower is also high (90%) compared to thermal (35%) and gas of (50%). Hydropower projects are generally categorised in two segments, i.e. small and large hydro plants. In India, the main two highest energy contributors are large and small hydropower, which satisfy the demand under peak and

fluctuating load conditions. In Indian scenario, hydropower stations up to 25 MW installed capacity comes under SHP projects and comes under the Ministry of New and Renewable Energy (MNRE) [5].

Table 2 shows the state-wise installed Hydro projects as per consecutive year, starting from year 1981 when first plant (Baira Siul) has been installed in the country in Himanchal Pradesh with 180 MW capacity, three units of 60 MW each to Kishanganga project of J&K in 2018 with 330 MW capacity. Highest installed capacity is found to be in Madhya Pradesh since 2005 with 1000 MW of capacity [6] (Fig. 4).

In 2019–20 annual report, CEA gave some figures about the hydropower development according to the basins, in terms of installed capacity. In this report CEA mentioned, as on 31 March 2020, out of the installed capacity, venture in operation is only 28.15% or 40,913.6 MW, and those under working was 7.84% which is about 11,393.5 MW of the total capacity available. Thus, a lot of potential still needs to be developed [1, 6].

As per the annual report published by CEA in 2019–20, Fig. 5 shows the basin wise status of hydro potential which is assessed, developed and under developed. Brahmaputra basin has the highest potential assessed till date and some major projects are being developed. Central Indian River basins are among the lowest hydro potential development [1].

Government of India is also enforcing pumped storage schemes (PSS) for which 63 new sites has been assigned. The power estimated from this project is around 96,529.6 MW. Currently, 9 PS projects (> 25 MW) are constructed which has 4785.60 MW total installed capacity. 3 PSS (1580 MW) are under development [1].

Under an initiative of 50,000 MW in the year 2003–04, CEA involved in the project of planning of Preliminary Feasibility Reports (PFRs) for 162 hydroelectric projects which planned to be spread over 16 states. Out of 162 projects (47,930 MW), 37 projects (20,435 MW) have already been prepared.

In the FY2018-19 itself hydro potential of 140 MW additionally has been accomplished against the target of 840 MW in the year 2018–19. This shows the venture of new projects specially concerning hydroelectric plants. Similarly, for the FY 2019–20, 300 MW of capacity additionally potential gained against the target of 1190 MW in the year 2019–20. Table 3 shows the surplus energy gained during the year 2019–20. Against the estimated target of 136.93 BU, the actual potential generated in the year 2019–20 was 155.76 BU, found out 13.75% more than the target [1].

3 Development of SHP in India

There is no any proper explanation of small hydropower (SHP). In general, SHPs are defined by its power output. Different nations have their different criteria of categorisation, having 5–50 MW as upper limit. Ministry of New and Renewable Energy (MNRE) is responsible for SHP classification in India. SHP is those hydropower

Table 2 State-wise installed capacity in India [6]

Name of project	State/UT	No of units × unit capacity	Total capacity (MW)	Year of commission
Baira Siul	Himachal Pradesh	3 × 60	180	1981
Loktak	Manipur	3 × 35	105	1983
Salal	UT of Jammu & Kashmir	6 × 115	690	1987
Tanakpur	Uttarakhand	3 × 31.4	94.2	1992
Chamera-I	Himachal Pradesh	3 × 180	540	1994
Uri-I	UT of Jammu and Kashmir	4 × 120	480	1997
Rangit	Sikkim	3 × 20	60	2000
Chamera-II	Himachal Pradesh	3 × 100	300	2004
Indira Sagar	Madhya Pradesh	8 × 125	1000	2005
Dhauliganga	Uttarakhand	4 × 70	280	2005–06
Dulhasti	UT of Jammu and Kashmir	3 × 130	390	2006–07
Omkareshwar	Madhya Pradesh	8 × 65	520	2007
Teesta-V	Sikkim	3 × 170	510	2008
Sewa-II	UT of Jammu and Kashmir	3 × 40	120	2010
Chamera-III	Himachal Pradesh	3 × 77	231	2012
Teesta Low Dam-III	West Bengal	4 × 33	132	2013
Nimmo-Bazgo	UT of Ladakh	3 × 15	45	2013
Chutak	UT of Ladakh	4 × 11	44	2013
Uri-II	UT of Jammu and Kashmir	4 × 60	240	2014
Parbati-III	Himachal Pradesh	4 × 130	520	2014
Teesta Low Dam-IV	West Bengal	4 × 40	160	2016
Jaisalmer	Rajasthan	1 × 50	50	2016
Solar power	Tamil Nadu	1 × 50	50	2018
Kishanganga	UT of J&K	3 × 110	330	2018

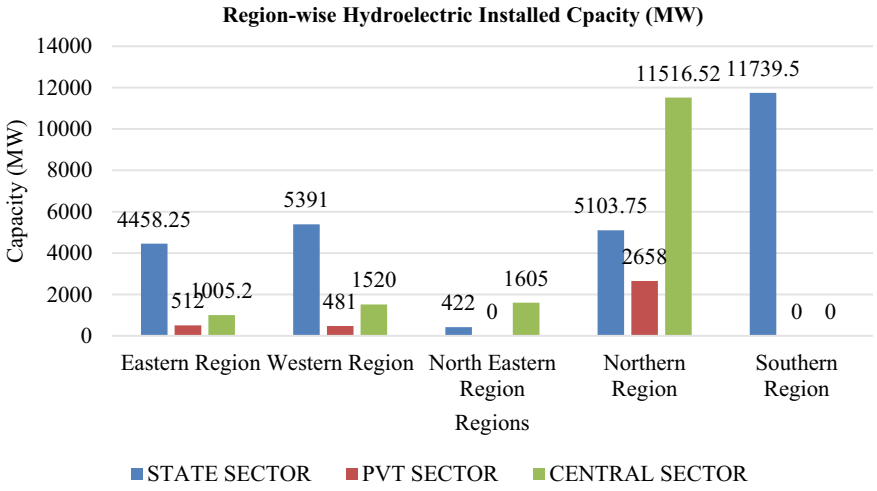

Fig. 4 Region-wise installed capacity [6]

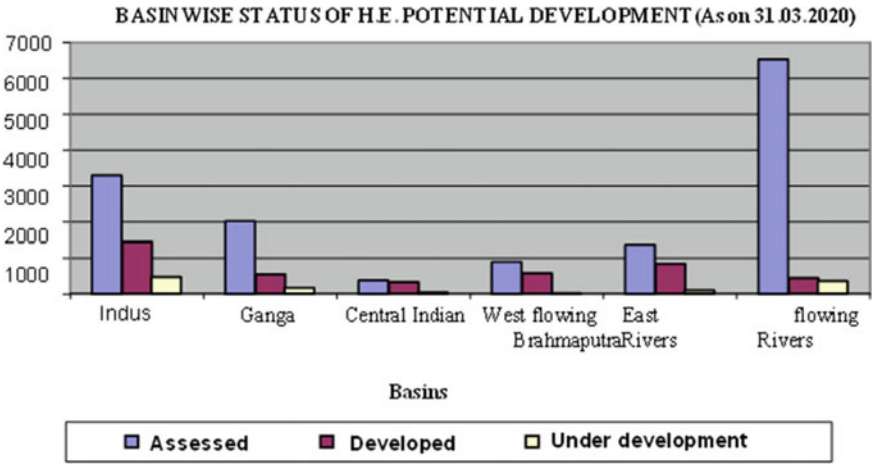

Fig. 5 Basin wise study of H.E. potential development [1, 6]

Table 3 Target versus actual energy generation in year 2019–20 [1]

Region	Generation (BU)		Deviation (±)
	Target	Actual	(%)
Northern	71.51	80.55	12.64
Western	12.20	17.81	45.98
Southern	27.12	31.75	17.07
Eastern	19.24	20.82	8.21
N-Eastern	6.85	4.82	− 29.63
All India	136.93	155.76	13.75

schemes which has capacity of up to 25 MW. In 1897, the first SHP was developed in Darjeeling Hills, West Bengal, having 130 kW capacity. Taking inspiration from this project in 1902 Karnataka also developed Sivasamudram plan (4.5 MW) in Mysore. This project was responsible for energy supply to kolar gold mines [5].

MNRE in India has been working in rising SHP projects. The SHP as renewable energy sources is very important because the technology used in it is indigenous. Also SHP is advisable because it does not fail in summer and provide maximum energy in peak cyclic demand. Such plants show potential of over 21,135 MW [7].

Alternate Hydro Energy Centre (AHEC) of IIT Roorkee has done a study in 2016 for estimating the overall potential from small/mini hydel projects and finds out 21,135.37 MW of power from 7135 sites generating enough potential to supply during fluctuating demands. The hilly States of country primarily Uttarakhand, Jammu and Kashmir, Arunachal Pradesh and Himachal Pradesh comprise about 50% of total potential. The probable States which are actively generating and contributing in power supply are Maharashtra, Chhattisgarh, Karnataka and Kerala.

MNRE as a governing body has taken the measures to encourage the development of SHPs in an organised way and expand reliability and quality of the projects. Commercial field and organisations have been attracted towards investing in SHP projects as by getting various physical and financial inducements. For remote village electrification, Ministry is endorsing new designs of water mills to make power generation more efficient. State government is also building up micro hydel projects up to 100 kW [8].

4 Govt Policies and Norms

For promoting small hydel projects, government has taken some initiatives to encourage the development of SHPs. As water being State subject, the actual implementation of SHP projects is governed by the State policies. Only state has the right to control and develop the projects. The Ministry (MNRE), being the nodal Ministry for the development and establishing of small hydro sector in the country provides wide structure by way of motivating the sector development through various measures [8].

Recently govt emphasis on a Small Hydropower Projects, the main objective of this scheme is to inspire the State Government entities and Independent Private Producers (IPPs) to setup new plans to realise the 21,000 MW potential in phased manner [9]. Some salient features of schemes are providing subsidy for the private sector, renovation and modernization of existing projects, support of water mills and setting up micro-projects (up to 100 KW capacity) [8, 10].

To satisfy the whole country's peak demand and power requirement at the end of 12th Plan, a potential addition of more than 90,000 MW has been appraised during 12th Plan (2012–2017), which consist of 40,000 MW of hydroelectric power. Central Electricity Authority (CEA) has provided many hydroelectric power generation related reports and manuals which are available on official site. A few of them are the best application in hydroelectric power generation, preliminary ranking study

of hydroelectric projects, strategies for agreement of concurrence of hydroelectric scheme, instructions for building of DPRs for hydroelectric projects, project tracking status reports, project clearance status reports and status of 50,000 MW hydroelectric initiative reports [11].

5 Problems in Hydropower Generation

Hydropower is one of the major used renewable energy sources and contributing a huge share in overall electricity generation in developing countries like India. A few decades ago, hydropower reservoirs were found to be a clean source of renewable energy, but after the pre-industrial era (1990s), these reservoirs become one of the sources for affecting environment.

5.1 Climatic Effect on Hydropower

Some models have been developed to understand the climatic effect on the hydropower generation, based on the reservoir configuration and utility energy need to study the influence of weather sequences on the performance. Performance analysed on the basis of fluctuation of water level below the reservoir capacity. Models track daily water level of reservoir, but mainly focus on the minimum water level throughout the year, by which it can be found that the maximum size of dam needed to assure continuous operation and generation of electricity [12].

Various studies have been conducted at many locations by considering the model and all of this analysis however focus attention on the importance of sequence and timing of precipitation events, where the impact of changed, climate could guide to large variations or be almost insignificant. The results of model analysis and studies of climate-induced changes compared to technological changes vary between 10 and 12%. These results proved that hydroelectric generating systems are highly sensitive towards climatic fluctuations. In some measures, small climate changes can escort to major changes in the draw-down of reservoir levels. The climatic effect, however, varies greatly form one region to another. Finally, it can be concluded that an extreme value analysis of annual minima would give useful info regarding reservoir system performance, including signs of condition where reservoir may become dry, in future [13].

6 Conclusion

With the increasing world energy demand and consumption, the requirements cannot be satisfied for so long with fossil fuels. There needs an alternative to give an edge to the probability of the climate collapse and outspread of wars for natural resources. The twenty-first century in Indian history will be strongly interpret by the way India faces and resolves the energy crisis. It is found that the resources and potential available in the country, which can be utilised in a precise and formulated manner to satisfy the energy demand along with stabilising the fluctuation specially in summer. India enriched with much water potential, so, if its energy can be utilised properly, hydropower sector can be one of the best and most economical power sources in India. Government has recently developed some schemes to promote development of hydroelectric power and thus giving special benefits to accelerate hydropower development in its power development plans, a tariff subsidy been given to keep up the development of hydroelectric power and an effort to fulfil the country's energy requirement. In this era of new technologies, SHP and pump storage-based projects could become best choice to overcome the fluctuations in demand, as these projects cost less and can be installed without any massive dam or reservoir. In India, SHP projects expansion can also be a significant means for regional economic development, mainly for various underdeveloped states, having extreme potential for evolving new SHP projects, which is limitless and evergreen source of energy. It can be concluded that

- India contributes around 4671 MW of electricity and around 526 MW is under construction in the form of small hydropower plants.
- Collectively total installed energy generation potential from various sectors is 386,888 MW (till July 2021). Specially private sector with renewable energy sources on top with around 50% of contribution to total installed capacity.
- Highest installed capacity is found to be in Madhya Pradesh since 2005 with 1000 MW capacity.
- Brahmaputra basin has the highest potential assessed till date and some major projects are under developed, whereas Central Indian River basins are among the lowest hydro potential development.

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