International Journal of Arts and Sciences
3(9): 125 - 143 (2010)
CD-ROM. ISSN: 1944-6934

Hydro Power Vs Thermal Power: A Comparative Cost-Benefit Analysis

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Abstract: This study seeks to trace the importance of Hydroelectric Power (HEP) vis-à-vis coal based Thermal power (TP), and establish a case for HEP plant by way of a comparative cost-benefit analysis which proves that HEP is in fact cheaper than TP for a mega power plant (1000 MW) even if other factors like social and environmental benefits are not considered. While the analysis is neutral between various technologies for harnessing TP and HEP, it assumes real-time plant load factors (PLFs) of 85% and 45% for TP and HEP plants, respectively. Furthermore, it also tries to provide a brief analysis on the comparative CER earning potential from both HEP and TP (by employing supercritical technology)

Keywords: Hydroelectric Power, Cost-benefit Analysis, Real-time Plant Load Factor, CER earning

Glossary:

CEA	Central Electricity Authority
CER	Certified Emission Reductions
CERC	Central Electricity Regulatory Commission
DPR	Detailed Project Report
EA 2003	Electricity Act 2003
GCV	Gross Calorific Value
GHG	Greenhouse Gases
GoI	Government of India
HEP	Hydroelectric Power
IDC	Interest During Construction
JV	Joint Venture
MNES	Ministry of New and Renewable Energy
MoEF	Ministry of Environment & Forests
MoP	Ministry of Power
MT	Metric tonne
MU	Million Units
MW	Mega Watt
NPV	Net Present Value
PAF	Project Affected Family
PLF	Plant Load Factor
PSU	Public Sector Undertaking
R&R	Resettlement & Rehabilitation
RoE	Return on Equity
SEB	State Electricity Board
SHR	Station Heat Rate
tCO_2	tonnes of Carbon Dioxide
TP	Thermal Power

Background

The growing concern for energy security has become a threat posing to be at par with national security for a developing nation like India. One of the most significant contributors to this has been the question of becoming self-sufficient in power generation to meet the ever-increasing demand of a growing nation. While India has been the 2^{nd} best growing nation even in the economic downturn of 2008-09, there has been no doubt that a regular supply of electricity is essential for a strong economic growth. An estimate shows that for every 1% economic growth, power generation capacity for India needs to grow by 5-6 times to sustain the levels of growth for the years up ahead.

However, another concern while growing the sources of power generation is to look at the most viable resource mix which gives economically feasible power with a high level of efficiency, simultaneously maintaining the environmental standards of the region. Whereas coal is looked at as one of the most economical resource for power (thermal power or TP) in India, the nation's technology has still not been at par to harness coal's energy in supercritical plants. Such plants will be coming up in the near future, but even if they achieve supercritical levels, TP plants have a rising fuel cost (of coal, either domestic or imported), coupled with the rising social and environmental costs in the form of per unit carbon emissions (in tCO_2). This is resulting in rising pressure from the increasingly conscious local and global communities to cut down India's emissions by focusing on cleaner technologies/resource mix. Furthermore, another cause of concern is the scenario arising as a result of exhaustion and/or shortage of coal. Which resource would then be used that would provide cheap, inexhaustible, reliable, and ecological-friendly power? Hence, a greater emphasis is being laid on alternative sources of power (renewable energy, nuclear power, etc.) as long-term solutions to becoming power-sufficient. This has resulted mainly because of two factors: alternative sources becoming economically competitive with conventional fuels, and increasing awareness about environmental degradation caused by the use of conventional sources of energy.

In this regard, Hydroelectric Power (HEP), or the energy obtained from water, is a renewable form of energy that is being looked at as one of the major sources of power generation in the country, apart from TP. The main principle used in HEP is the kinetic energy of falling/flowing water is converted into electric energy using turbines. The resource is available in abundance and harnessing it does not emit as much carbon as well.

However, a few questions arise as a result, pertaining to the financial and economic viability of using this renewable resource. Is HEP financially feasible and economically beneficial for every geography and class of people vis-à-vis TP? Is it socially and environmentally beneficial? What is the impact of the recently developed carbon markets on the overall economic viability? These questions are pertinent to every economy, developing or developed, and need to be addressed for finding long-term solutions thereby facilitating smooth, rapid, and sustainable economic growth.

Need and Importance of Hydroelectric Power

The need and importance of HEP can be attributed to the following advantages:

- It is a renewable source of energy, and non-polluting in nature.
- Fuel cost of HEP plant is inflation-free and reduces with time, thereby bringing down the overall per unit cost.
- HEP plants have a long useful life, extending to 50-100 years, as compared to the 25 year life-span of a TP plant.

- HEP plants can be started or stopped instantaneously, providing for load variation management, and improved reliability of the power system.
- HEP is considered as the best choice for serving peak load.
- It helps in conservation of scarcely available fossil fuels.
- Storage type HEP plants can be used for multiple purposes like flood control, irrigation, provision of drinking and industrial water etc.
- HEP plants are usually set in remote/backward areas, thereby leading to their economic development.

Disadvantages of Hydroelectric Power Plants

In spite of the factors mentioned above, developing HEP does carry certain disadvantages:

- A variety of geological changes occur due to the construction of a dam on the river, especially in the downstream area.
- Various plant and animal ecosystems gets adversely affected due to their submergence in the water reservoir formed by the dam.
- The soil quality in downstream river declines.
- HEP plants are severely impacted by droughts. If water is not available, the plant would not be able to produce electricity.
- Fish population gets affected if fish cannot migrate to the spawning grounds upstream past impoundment dams, or if they cannot migrate downstream to the ocean.

However, such occurrences happen rarely and their impact is very low, as compared to the huge benefits arising out of a HEP project development.

Impact of Hydroelectric Power Plants

Economic Advantage

Development of a HEP project is often deterred due to the substantial initial investment required. But this HEP project investment cost needs to be balanced against the longer project life and lower operation & maintenance costs, coupled with no consumption of fuel for energy production, vis-à-vis those of the TP plant. From an economic perspective, keeping in view the quality of the energy produced, the balance shows a clear advantage for hydropower. Moreover, from a development and growth perspective, the external benefits and costs associated with the projects need to be considered. If total costs for the lifetimes of the respective electricity generation options are considered, HEP appears to have the greatest advantage.

It was concluded at the 17th Congress of the World Energy Council in 1998 in Houston that development and use of appropriate renewable energies should be given clear priority, with the aim of restricting emissions resulting from the use of fossil fuels. It has been found to have longer plant life (of 100 years) and therefore, is a sustainable energy source.

Social Impact

Like any other economic activity, HEP project impacts the project area. These changes can be geographical and social like land use transformation, and displacement of people who were living in the reservoir area. However, these projects generate employment and further growth opportunities for the local population. New public services and infrastructure development, including schools, hospitals, roads, etc. come up in the area with the introduction of electricity to the rural/underdeveloped areas, enabling better growth of the nation.

But, the social effects of HEP schemes are variable and project-specific. However, with planned anticipation and subsequent addressing at the project planning stage, the adverse impacts can be efficiently tackled, and in some cases, evaded altogether. Implementation of an effective public participation programme from the early stages of a project becomes crucial. If a project is considered to be a development opportunity for the community, the project affected families (PAFs) will be able to enjoy a higher standard of living through associated infrastructure developments.

Hydro Power Development in the country

The country has a vast untapped resource of HEP. A study in 1987 by the CEA revealed the total hydro potential to be approximately 150000 MW, of which more than 84000 MW can be generated operating at a PLF of 60%.

Table 1: Hydropower potential in India

Basin/River	Potential at 60% Load Factor (MW)	Probable Installed Capacity (MW)
Indus	19988	33832
Ganga	10715	20711
Central Indian Rivers	2740	4152
West-flowing Rivers	6149	9430
East-flowing Rivers	9532	14511
Brahmaputra	34920	66065
Total	**84044**	**148701**

However, out of this capacity, only 34653 MW has been captured until the end of 10th plan, (36,647.76 MW harnessed till December 2008).

Table 2: Plan-wise Growth and Share of HEP

Plan Period	HEP Addition (MW)	Total HEP Installed Capacity (MW)	Total Installed Capacity from all resources (MW)	HEP as % of Total Installed Capacity (%)
1st Plan (1951 – 56)	380.19	1061.44	2886.14	36.78
2nd Plan (1956-61)	977.18	1916.66	4653.05	41.19
3rd Plan (1961-66)	2207.08	4123.74	9027.02	45.68
3 annual plans (1966-69)	1783.17	5906.91	12957.27	45.58
4th Plan (1969-74)	1058.39	6965.3	16663.56	41.80
5th Plan (1974-79)	3867.77	10833.07	26680.06	40.60
Annual Plan (1979-80)	550.90	11383.97	28447.83	40.01
6th Plan (1980-85)	3076.05	14460.02	42584.72	33.96
7th Plan (1985-90)	3828.41	18307.63	63636.34	28.77
2 annual plans (1990-92)	881.50	19194.62	69065.39	27.79

8th Plan (1992-97)	2427.65	21644.8	85019.31	25.46
9th Plan (1997-02)	4538.25	26261.23	103410.04	25.40
10th Plan (2002-07)	7886.00	34653.77	132329.21	26.19

As witnessed above, the share of HEP has been constantly waning since 1963, despite it being recognized as one of the cheapest and preferred source of power.

Table 3: HEP – Global Scenario

S.No.	Country	Installed Capacity in 2003 (MW)	HEP Share in Total Capacity (%)
1.	Burundi	300	100.00
2.	Benin	120	54.20
3.	Uganda	300	99.6
4.	Bhutan	1480	99.00
5.	Paraguay	7420	99.9
6.	Zambia	1790	93.50
7.	Norway	26610	98.90
8.	Colombia	13790	65.8
9.	Congo	2570	98.70
10.	Cameroon	900	89.60
11.	Albania	1670	86.50
12.	New Zealand	8410	62.30
13.	Tajikistan	4440	91.20
14.	Brazil	82460	79.20
15.	Georgia	4650	57.20
16.	Tanzania	860	65.00
17.	Ghana	1310	90.20
18.	Canada	114980	60.20
19.	**India**	**126340**	**21.30**

Therefore, it is apparent that harnessing of HEP potential in India is significantly lower at 17% (with PLF of 60% of total installed capacity), in comparison to other nations like Norway (58%), Canada (41%) and Brazil (31%). For a country like India, the ideal hydro-thermal mix should be in the ratio of 40:60. But this has been reduced to 26% of HEP due to various reasons resulting in delay, like:

- Long gestation period due to capital intensive nature of the projects.
- Slow implementation and action of states/SEBs in project development
- Hurdles in acquiring private land
- Obtaining clearances (like techno-economic clearance – TEC, environment and forest clearance) and other approvals
- Planning related issues like unsystematic basin development for the project
- Construction issues like lack of technical advancement, expert indigenous construction agencies and private sector participation/good contractors and skilled labor, adverse climatic conditions/geological surprises, etc.

- Financial constraints like high cost of developing the transport infrastructure to the project site, security costs, royalty, custom duties, etc.
- Disagreement over inter-state aspects
- Problems in power evacuation
- Tariff and regulatory issues like the existing tariff formulation norms for hydro projects (based on a cost plus approach) with no premium for peaking services and the provision for 12% free power to distressed states from the initial years are also proving to be deterrents.

All these factors need to be addressed for bringing in a much needed efficiency and effectiveness in the hydro sector.

Policy Response

<u>New Hydro Policy 2008 - Government of India (GoI) Initiative for HEP Development</u>

Objectives:

- To encourage private sector participation
- To harness huge untapped HEP potential
- Better Resettlement & Rehabilitation (R&R) measures
- To facilitate financial viability

Salient Features:

- Exempts private developers from tariff-based bidding up to January 2011
- Transparency in awarding potential sites to the private sector, based on financial strength, past track record (delivering on time), and ability to meet performance guarantee.
- Obligatory for the developer to go through International Competitive Bidding (ICB)
- Tariff to be fixed by the appropriate Regulatory Commission
- Expenditure incurred or committed to be incurred for site allocation by the developer will not be included in the project cost or tariff
- 12% free power to be provided to the host state government
- Provision of an additional 1% free power for local area and its people's development
- Provision of 100 units of electricity to the PAFs for 10 years
- Merchant sales allowed for up to 40% of the saleable energy
- Commissioning delay of every 6 months to result in 5% reduction of merchant sales
- Project authorities to bear the State Government's share of 10% of Rajiv Gandhi Gramin Vidyutikaran Yojana
- More liberal Resettlement and Rehabilitation
    - Special training programs by ITI's to local people for sustained livelihood
    - Support to cooperatives and self help groups for income generation schemes
    - Scholarships for meritorious students
    - Medical facilities to be extended
    - Irrigation support and subsidies on seed, pesticides, and fertilizers
    - Marriage grants

<u>Other Policy measures:</u>

Project development:

- Basin-wise development of hydro potential
- Renovation, Modernization & Uprating of existing HEP stations

- Promoting HEP projects in JV
- Selecting developer through bidding/MoU route
- Promoting small and mini HEP projects – 25 MW and below fall into “non conventional” category thereby, qualifying for benefits

Financial measures:

- Additional budgetary financial support for CPSU’s ongoing and new hydro projects
- Estimating realistic completion cost after considering new development on geological factor during execution.
- Hydro tariff rationalization to allow peak load premium on sale rate
- 5% surcharge on annual fixed charges to be levied on central HEP generation, for hydro development approved by CERC

Regulatory and Government support:

- Resolving inter-state issues on water and power-sharing
- Government support for land acquisition, R&R, developing the catchment area, etc.
- EA 2003 further liberalising procedures for clearances by CEA
- TEC transfer procedures simplified, streamlining of clearance process, and introduction of 3-stage clearance process for hydro project development in Central Sector/JV, etc.
- Emphasising upon the quality of survey & investigations

Capacity addition:

- To take advanced action for capacity addition, to be 10 years ahead of execution

<u>Tackling the major challenges:</u>

Environmental Impact:

- Comprehensive legislation laid out by GoI for Environmental Impact Assessment (EIA) studies
- Streamlining of EIA report preparation and impact mitigation study along with clearance procedures, cutting down on delays
- MoEF working on creating a Forest Bank entailing huge afforestation measures, with the project development agencies providing the funding in advance, enabling quicker project clearances

Rehabilitation & Resettlement (R&R) of PAF:

- Synthesizing expectations of people, local authorities and project development agencies to ensure greater degree of acceptability of the R&R system
- Provision of free power, and other sops to address R&R issues of PAF
- GoI contemplating a national policy on R&R for PAF
- Ministry of Power (MoP) and its PSUs coordinating efforts with State Governments to address R&R issues ensuring smooth project implementation
- Specific monitoring mechanism in place for large projects at senior most level in the government to carry out proper implementation of R&R plans by project agencies in letter and spirit

Dam Safety:

- Studies and findings on dam safety to provide higher degree of confidence
- Some Indian institutions equipping themselves both with hardware and software to properly address these concerns
- Project developers seeking expertise available anywhere in the world for in depth studies and guidance
- Streamlined procedures to see that project development process by way of permission and clearances is made faster prior to commencement of main plant construction
- Continuous search by MoEF, MoP, and other authorities for better solutions

Reliability of detailed project report:

- Quality of studies, investigations, analysis and findings need substantial improvement with respect to hydrology and geology
- Recent examples of project development have seen variations within limits, leading to better DPRs and estimates
- As a result, project could be completed without cost overruns, avoiding cost increases on account of variation in estimates due to inadequate investigation

Construction time:

- Two major difference-making aspects – construction management techniques, and construction technology
- Recent examples of making substantial improvement on both the fronts, recently sanctioned projects targeted to be completed within 4-5 years

Technological advancements:

- Benchmarks established, techniques and technologies need to be improved
- Serious consideration to technology choice
- Current schedule for project developers: target 4 years for completion of small projects, 4 ½ years for medium size projects, and 5 years for large projects
- These schedules are significant improvement over the past
- Further improvement in norms after the achievement of the current schedule

Increasing awareness:

- Reduce communication gaps with press, media and people at large on merits of HEP projects
- Mitigatory measures should be addressed at global level

Comparative analysis of Hydro Vs Thermal Power Plants

<u>Coal as fuel for Thermal Power Generation</u>

Out of the total installed capacity of 150000 MW, 81000 MW comes from coal based TP, making coal the mainstay of energy resource for the Indian economy. Out of the total domestic coal production, power sector consumes about 3/4th, making it the biggest consumer of coal. But this does not suffice the demand by power sector and it has to go for coal imports.

Currently, India is the 3rd largest coal producer in the world. However, as can be seen from Table 4, Indian coal has a high ash content (35-50%) and low gross calorific value (GCV) which, combined with the inefficient technology for combustion makes it a huge emitter of Greenhouse

Gases (GHG), along with other particulates, contributing significantly to global warming. The ash is mainly inherent in coal, and comprising mainly of gypsum (an abrasive material), making it difficult to remove it from coal.

Table 4: Comparison of Indian coal with Imported coal (Ultimate analysis)

S. No.	Parameters	Chandrapur (Indian Coal)	Ohio (USA)
1	Fixed Carbon	27.5%	44.0%
2	Total Carbon	37.69%	64.2%
3	Hydrogen	2.66%	5.0%
4	Nitrogen	1.07%	1.3%
5	Oxygen	5.78%	11.8%
6	Sulphur	0.8%	1.8%
7	Ash	47.0%	16.0%
8	Total Moisture	5.0%	2.8%
9	GCV (Kcal/Kg)	3400	6378
10	Coal per unit of Electricity (Kg/kWh)	0.77	0.36
11	*Cost/ MT	$ 40	$ 180

* $1 = Rs. 45, Cost as on June 2008
1 kWh = 1 Unit of Power

On the other hand, Ohio coal's GCV is nearly double to that of Indian coal. This implies that generating an equal amount of steam (for power generation) would entail using double the amount of Indian coal compared to Ohio coal. However, a look at the cost of Ohio coal, that is 4.5 times that of Indian coal, makes it economically unviable to use imported coal.

Hence, the main issues associated with fuel for TP generation are:

Coal Availability:
One of the major concerns for Indian power sector is the availability of coal. Having a constantly escalating dependence on coal, the sector has become most vulnerable in case of non-availability. While a stockpile of 30 days is to be maintained to be in a secure position, many plants are barely surviving with 4-7 days of reserves.

Rising fuel cost:
The total coal reserves in the country amount to 202 billion tonnes, most of which lay in the Eastern states of West Bengal, Bihar, and Orissa. Transporting this coal to other far-flung parts of the country requires substantial energy consumption (rail, road, etc.), incurring a major cost on transportation, thereby increasing the overall fuel costs for the power plant. If the costs are too high, then the plant has to go for imported coal, which becomes economically viable if the power plant is situated beyond 1000 KMs from the pit head.

Environmental concerns:
The global rise in coal prices has shot up the price per unit of power generation, and if the plant uses Indian coal, the efficiency levels go down (due to the lower calorific value of Indian coal). Moreover, the ash content in Indian coal is significantly high making it one of the most polluting coals, implying higher environmental costs for the society.

Plant shutdown:
At the current level of T&D losses (approx. 30%), 1.5 units of power needs to be generated to supply the consumer with 1 unit. This makes the costs go further up to approximately Rs. 7/unit (imported coal) and Rs. 5/unit with domestic coal for non-pit head plants. The plants would become unviable if they would not be passing the costs to the consumers. This would not be agreeable with CERC, as it is looking to protect consumer welfare. This could ultimately lead to plant shutdown.

On the other hand, in case of HEP plants, no such difficulty is posed by the fuel required, which is water availability in the river basin. Therefore, it is inflation-free, environmentally benign, and is abundantly available. However, the level of power generation may go down if there is a drought or if the water freezes in the tributary during winters.

Hydro Vs Thermal: Cost of Power Generation
Table 5 below represents the assumptions, subsequent calculations, and resultant cost of generation per unit from a HEP plant and TP (supercritical technology) plant, respectively.

Table 5: Comparison of a 1000 MW HEP Project with a 1000 MW TP Plant

Parameters	**HEP Project**	**TP Plant (Coal Based)**
Per MW Cost (Rs. Cr.)	5.5	4.5
Plant Capacity (MW)	1000	1000
Total Project Cost (Rs. Cr.)	5500	4500
Plant Load Factor (%)	45%	85%
Gross Generation in MUs	3942	7446
Auxiliary Consumption (%)	0.50%	9.00%
Net Generation in MUs	3922.29	6775.86
Fuel Consumption (Coal in ton/year)	-	4839900
Fuel Cost (Rs. In Crore / Year)	-	871.182
O & M Cost (Rs. Cr. per year)	82.5	160
O & M Cost (Rs. In Cr./ MU / year)	0.021	0.15
Planned Outage (Days/Year)	30	35
Forced Outage (days/year)	16 to 37	51
Completion Time Period (Months)	61	44
Life of the Plant (Years)	35	25
Return on Equity	16%	16%
Interest During Construction (Rs. Cr.)	1017	669
Cost of Generation (Rs./kWh)	1.84	2.86

As can be seen from the above table:

- Per MW cost for HEP plants varies from Rs. 5 to 6 Cr. (average cost of Rs.5.5 Cr./MW), whereas for a TP plant, it varies between Rs. 4 to 5 Cr (average cost of 4.5 Cr/MW) for a 1000 MW plant.
- PLF is higher for TP plant (85%) as compared to HEP plant, which is at 45%.

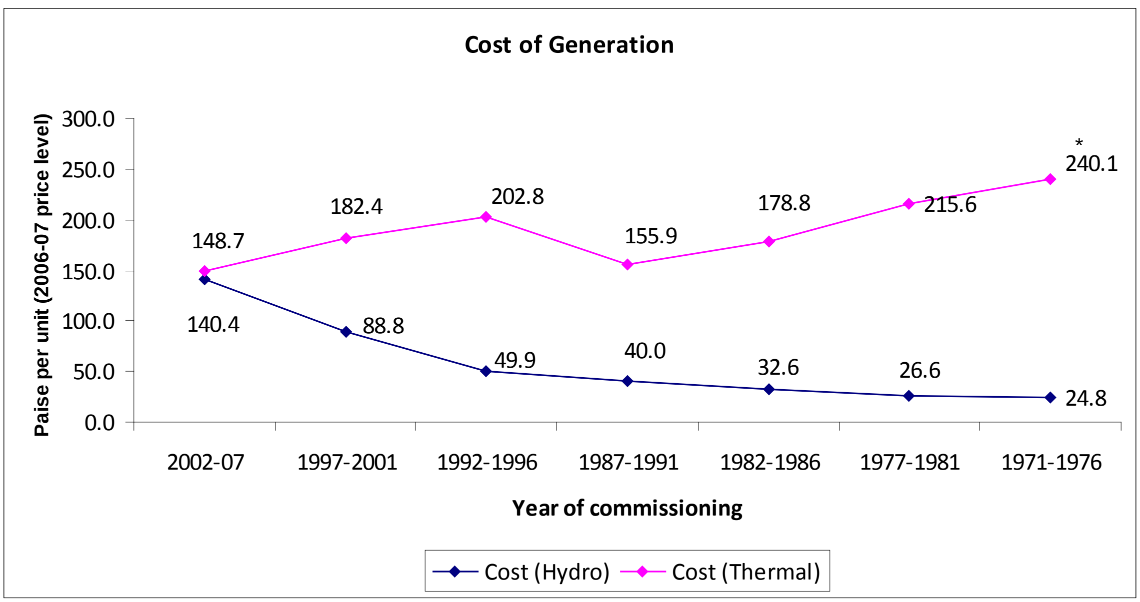
- Auxiliary consumption is 9% for a TP plant, whereas it is only 0.5% for the HEP plant.
- For a TP plant the overall efficiency is approximately 40% (due to more number of conversion stages) as compared to the HEP plant where the efficiency level is approximately 80% - 90% due to lower number of conversion stages.
- Fuel required (coal) for TP plant has been calculated assuming a Specific coal consumption of 0.65 Kg/kWh.
- Interest During Construction (IDC) is calculated at Rs. 1017 Cr. in HEP Plant and Rs. 669 Cr. For TP plant.
- Return on Equity (RoE) has been assumed at 16% for both the cases, as per CERC guidelines.
- As a result of the above assumptions and calculations, the levelized cost of generation comes out to be Rs. 1.84/unit from HEP plant and Rs.2.86/unit for the TP plant.

Clearly, HEP plant has a lower per unit cost of generation as compared to the TP plant. This is due to high fuel cost of coal, higher auxiliary consumption, higher level of O&M costs, and a lower life span in case of TP plant.

<u>More proof of lower generation costs of HEP: Year of commissioning</u>

Graph 1shows the cost of generation for both HEP and TP plants (refer to Annexure – I), according to the year of commissioning. It can be seen that the cost of generation declines over time for HEP plant, whereas it increases substantially for coal based TP plant. Hence, the older a HEP plant is, lower will be the per unit cost of generation.

Graph 1: Cost of Generation: HEP Vs TP



It is true that the HEP generation is extremely capital-intensive but it being a renewable source of energy, with no chargeable fuel involved; has low recurring cost. This would mean no high long term expenditure. As a result, it is cheaper as compared to coal or gas based power. It also brings down the uncertainty of financial losses arising due to frequency fluctuations or inflation rates as it does not use any fossil fuel and hence, is a more reliable source.

Hydro Vs Thermal: Revenue from Certified Emission Reductions (CERs)

Analysis: 1000 MW HEP Plant vis-a-vis 1000 MW TP Plant based on Super-critical technology

For a 1000 MW HEP Plant

Generation in MUs	3942 MU
CERs per MU	810
Sale Price/CER in Euro	12.5
INR/Euro	65
Rate/CER in INR	65 * 12.5 = Rs. 812.5

Total CERs = Generation in MUs * CERs per MU
= 3942 * 810
= 3193020 CERs

Revenue from CERs = Total CERs * Rate per CER
= 3193020 * 812.5
= Rs. 2594328750
= Rs. 2594.3 Million

Per MW CER Revenue from HEP Plant = Rs. 2.59 Million ~ Rs. 0.25 Cr./MW

For a 1000 MW TP Plant based on Supercritical technology

Gross Generation in MUs	7446 MU
Auxiliary Consumption	7%
Net Generation in MUs	6925 MU
Sale Price/CER in Euro	12.5
INR/Euro	65
Rate/CER in INR	65 * 12.5 = Rs. 812.5

Revenue from CERs in Million = Annual Emission Reduction (tCO_2) * Rate/CER
= 613,621 * 812.5 / 1,000,000
= Rs. 498.57 Million

Per MW CER Revenue from TP Plant = Rs. 0.498 Million ~ Rs. 0.05 Cr./MW

This implies that CER earnings from HEP plant are nearly five times that if TP plant with equal installed capacity. This leads to dilution of the excess capital cost of a HEP plant. Moreover, no fuel cost in case of hydro power makes it an attractive option for the developers.

Assumptions:

Conversion factor from ml. to gram	=	0.92
Specific consumption (ml.)	=	1.0
Gross Calorific Value of Coal (kCal/Kg)	=	3750
GCV of Secondary Fuel (kCal/Kg)	=	10,000
Station Heat Rate (kCal/kWh)	=	2320
Baseline emission factor (tCO_2/MWh)		0.941
Carbon content in coal		0.38

Conversion factor from Carbon to CO_2	3.67	(44/12)
Coefficient of emission factor	1.393	(0.38*3.67)

Annual Emission Reduction (tCO_2)
= Baseline emission (tCO_2) – Project emission (tCO_2)
= 7,006,686 – 6,393,065
= 613,621

Baseline emission (tCO_2)
= Baseline emission factor (tCO_2/MWh) * Generation in MUs
= 0.941 * 7446
= 7,006,686

Project Emission (tCO_2)
= Gross Coal Consumption (in MT) * Coefficient of emission factor
= 4,588,324 * 1.393
= 6,393,065

Gross Coal Consumption (in MT)
= Generation in MU * Primary Fuel Factor
= 7446*0.62
= 4,588,324 MT

Primary Fuel Factor (Kg/kWh)
= Heat by Primary Fuel (million kCal) / (GCV * Gross Generation in MU)
= 17,206,17.80 / (3750 * 7446)
= 0.62

Heat by Primary Fuel = Total Heat Generated – Heat from secondary fuel
= 17,206,17.80 Million kCal

Total Heat Generated (Million kCal) =
Station Heat Rate (kCal/kWh) * Gross Generation in MU
= 17,274,720 Million kCal

Heat from secondary fuel =
Specific consumption (ml.)* GCV *Conversion factor * Gross Generation in MU
= 68503.20 MM kCal

However, as per the 'New CERC guidelines' issued on January 19th, 2009 for tariff determination for the period from 2009 – 14, the CDM benefits have to be shared between the project developer and the beneficiaries as follows:

- 100% of the gross earnings by way of CDM to be retained by the developer in the 1st year after the date of commercial operation of the generating station or the transmission system.
- In the 2nd year, the beneficiaries' share shall be 10%, which shall be progressively increased by 10% every year until it reaches 50%, after which the earnings shall be shared in equal proportion by the generating company or the transmission licensee, and the beneficiaries.

Due to these new guidelines, the project feasibility and viability gets reduced due to lesser benefits to the developer and the equity IRR going down on account of this. And hence, the guidelines could play havoc to the development cycle of a sustainable source of energy.

Conclusion

It can thus be concluded that the benefits scored by hydroelectric power plants over thermal power plants have environmental benefits - on account of HEP being a renewable and sustainable source of energy, financial benefits - due to low cost of generation, the developers will have an advantage especially since merchant power sales is allowed in open market, coupled with a reasonable return on equity of 16%, and social benefits – like development of local area, provision of electricity, along with other bundled benefits like irrigation facilities, tourism, along with rise in demand for other industries' products like cement, iron and steel, transport, etc.. and assisting in the creation of a low carbon self sustainable economy.

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Annexure-1: Cost of Generation (2006-07) of Hydro Power Plants

Project	Sector	Agency	State	Installed Capacity (MW)	Cost (Paise/unit)
Bhakra Complex(Bhakra Plant.+Gang.+Kotla P.House)	CENTRAL	BBMB	PUNJAB	1480.3	13.5
Dehar Power House	CENTRAL	BBMB	PUNJAB	990	38.37
Pong Power Plant	CENTRAL	BBMB	PUNJAB	396	8.78
Maithon HEP	CENTRAL	DVC	JHARKHAND	60	81.41
Panchet HEP	CENTRAL	DVC	JHARKHAND	80	81.92
Tilaiya HEP	CENTRAL	DVC	JHARKHAND	4	205.75
Bairasiul	CENTRAL	NHPC	HIMACHAL PRADESH	180	69.71
Salal I & II	CENTRAL	NHPC	J & K	690	27.05
Tanakpur	CENTRAL	NHPC	UTTARAKHAND	94.2	96.77
Chamera - I	CENTRAL	NHPC	HIMACHAL PRADESH	540	59.06
Uri I	CENTRAL	NHPC	J & K	480	62.94
Chamera - II	CENTRAL	NHPC	HIMACHAL PRADESH	300	148.77
Dhauligang	CENTRAL	NHPC	UTTARAKHAND	280	119.07
Loktak	CENTRAL	NHPC	MANIPUR	90	104.74
Rangit	CENTRAL	NHPC	SIKKIM	60	230.02
Kopili HEP	CENTRAL	NEEPCO	ASSAM	275	65.7
Doyang HEP	CENTRAL	NEEPCO	NAGALAND	75	260.2
Ranganadi HEP	CENTRAL	NEEPCO	ARUNACHAL PRADESH	405	121.29
Nathpa Jhakri Hydro Power Station	CENTRAL	SJVNL	HIMACHAL PRADESH	1500	109
Tehri St. - I	CENTRAL	THDC	UTTARAKHAND	1000	350.54
Indira Sagar Project	CENTRAL	NHDC	MADHYA PRADESH	1000	88.44
Western Yamuna Canal, H.E. Hydel Project	STATE	HPGCL	HARYANA	62.4	99.86
Giri	STATE	HPSEB	HIMACHAL PRADESH	60	47
Andhra	STATE	HPSEB	HIMACHAL PRADESH	16.95	75
Gumma	STATE	HPSEB	HIMACHAL PRADESH	3	222
Bhaba/Sanja	STATE	HPSEB	HIMACHAL PRADESH	120	32
Nogil	STATE	HPSEB	HIMACHAL PRADESH	2.25	159
Ghanvi	STATE	HPSEB	HIMACHAL PRADESH	22.5	215

Bassi	STATE	HPSEB	HIMACHAL PRADESH	60	26
Binwa	STATE	HPSEB	HIMACHAL PRADESH	6	105
Gaj	STATE	HPSEB	HIMACHAL PRADESH	10.5	111
Baner	STATE	HPSEB	HIMACHAL PRADESH	12	108
Chaba	STATE	HPSEB	HIMACHAL PRADESH	1.38	123
Rukti	STATE	HPSEB	HIMACHAL PRADESH	1.5	460
Rongtong	STATE	HPSEB	HIMACHAL PRADESH	2	563
Chaba	STATE	HPSEB	HIMACHAL PRADESH	0.3	298
Sal-II	STATE	HPSEB	HIMACHAL PRADESH	2	203
Killar	STATE	HPSEB	HIMACHAL PRADESH	0.3	420
Holi	STATE	HPSEB	HIMACHAL PRADESH	3	136
Thirot	STATE	HPSEB	HIMACHAL PRADESH	4.5	326
Khauli	STATE	HPSEB	HIMACHAL PRADESH	18	1148
Larji	STATE	HPSEB	HIMACHAL PRADESH	126	468
Shan	STATE	PSEB	HIMACHAL PRADESH	110	25.87
U.B.D.C.Pathankot	STATE	PSEB	PUNJAB	91.35	64.18
Anandpur	STATE	PSEB	PUNJAB	134	46.6
Mukerian	STATE	PSEB	PUNJAB	207	43.86
Micro Hydel	STATE	PSEB	PUNJAB	4.9	234.16
RANJIT Sagar Dam	STATE	PSEB	PUNJAB	600	311.33
L. Bank & R. Bank	STATE	PSEB	PUNJAB	684	13.34
Beas & Extn.	STATE	PSEB	HIMACHAL PRADESH	573	45.34
Rana Pratap Sagar	STATE	RVPNL	RAJASTHAN	172	102
Jawahar Sagar PS	STATE	RVPNL	RAJASTHAN	99	109
Mahi Hydel	STATE	RVUNL	RAJASTHAN	140	48.43
Mini Hydel	STATE	RVUNL	RAJASTHAN	23.85	257.27
Chibro	STATE	UJVNL	UTTARAKHAND	240	24.52
Ramganga	STATE	UJVNL	UTTARAKHAND	198	60.39
Chilla	STATE	UJVNL	UTTARAKHAND	144	19.32
Khodri	STATE	UJVNL	UTTARAKHAND	120	24.54
Tiloth	STATE	UJVNL	UTTARAKHAND	90	26.61
Dhalipur	STATE	UJVNL	UTTARAKHAND	51	27.52
Khatima	STATE	UJVNL	UTTARAKHAND	41.4	28.42
Dhakrani	STATE	UJVNL	UTTARAKHAND	33.75	36.31
Kulhal	STATE	UJVNL	UTTARAKHAND	30	26.84

Fipri	STATE	UPJVNL	UTTAR PRADESH	300	27.32
Obra	STATE	UPJVNL	UTTAR PRADESH	99	24.69
Matatila/Sheetla	STATE	UPJVNL	UTTAR PRADESH	30	20.43
Muzaffar	STATE	UPJVNL	UTTAR PRADESH	15.5	89.32
Khara/E/C	STATE	UPJVNL	UTTAR PRADESH	78	89.74
HEP Machadoli Bango	STATE	CSEB	CHHATTISGARH	120	39.35
HEP-Gangrel	STATE	CSEB	CHHATTISGARH	10	61.81
HEP Sikasar	STATE	CSEB	CHHATTISGARH	70	61.05
Mini Hydel	STATE	CSEB	CHHATTISGARH	0.85	-
Ukai	STATE	GSEC	GUJARAT	305	16
Kadana	STATE	GSEC	GUJARAT	242	87
Rani Avanti Bai HPS	STATE	MPPGCL	MADHYA PRADESH	90	18.87
Pench HPS	STATE	MPPGCL	MADHYA PRADESH	160	27.05
Gandhi Sagar	STATE	MPPGCL	MADHYA PRADESH	115	25.13
Tons	STATE	MPPGCL	MADHYA PRADESH	405	68.49
Rajghat	STATE	MPPGCL	MADHYA PRADESH	45	106.79
Sanjay Gandhi HPS	STATE	MPPGCL	MADHYA PRADESH	20	98.07
Madhikhera	STATE	MPPGCL	MADHYA PRADESH	40	0
Jhinna HPS	STATE	MPPGCL	MADHYA PRADESH	20	183.93
Koyna	STATE	MSPGCL	MAHARASHTRA	1960	26
Sardar Sarovar Project	STATE	SSNNL	GUJARAT	1450	163.05
Sharavathy	STATE	KPCL	KARNATAKA	891	13.15
Linganamakki	STATE	KPCL	KARNATAKA	55	101.19
Bhadra	STATE	KPCL	KARNATAKA	39.2	101.56
Nagjhari	STATE	KPCL	KARNATAKA	855	27.32
Supa	STATE	KPCL	KARNATAKA	100	27.32
Ghataprabha	STATE	KPCL	KARNATAKA	32	64.73
Varahi	STATE	KPCL	KARNATAKA	230	60.12
Mani	STATE	KPCL	KARNATAKA	9	60.12
Kalmala	STATE	KPCL	KARNATAKA	0.4	221.44
Sirwar	STATE	KPCL	KARNATAKA	1	221.44
Ganekal	STATE	KPCL	KARNATAKA	0.35	221.44
Mallapur	STATE	KPCL	KARNATAKA	9	221.44
Kappadgudda	STATE	KPCL	KARNATAKA	4.55	215.09
Kadra	STATE	KPCL	KARNATAKA	150	122.08
Kodasalli	STATE	KPCL	KARNATAKA	120	93.08
BRBC	STATE	KPCL	KARNATAKA		93.28

Gerusoppa	STATE	KPCL	KARNATAKA	240	113.07
Almatti	STATE	KPCL	KARNATAKA	290	90.42
MGHE,	STATE	KPCL	KARNATAKA	120	35.33
Sivasamundrum	STATE	KPCL	KARNATAKA	42	46.43
Munirabad	STATE	KPCL	KARNATAKA	17.2	32.01
Shimshapura	STATE	KPCL	KARNATAKA	17	46.43
Pykara	STATE	TNEB	TAMIL NADU	69.95	46
Pykara Micro	STATE	TNEB	TAMIL NADU	2	64.27
Moyar	STATE	TNEB	TAMIL NADU	36	25.61
Maravakandy	STATE	TNEB	TAMIL NADU	0.75	166.18
Kundah	STATE	TNEB	TAMIL NADU	60	19.72
Kundah	STATE	TNEB	TAMIL NADU	175	17.44
Kundah	STATE	TNEB	TAMIL NADU	180	28.95
Kundah	STATE	TNEB	TAMIL NADU	100	38.89
Kundah	STATE	TNEB	TAMIL NADU	40	52.4
Parson	STATE	TNEB	TAMIL NADU	30	391.25
Mettur	STATE	TNEB	TAMIL NADU	40	65.94
Mettur	STATE	TNEB	TAMIL NADU	200	3.16
Barriage	STATE	TNEB	TAMIL NADU	120	73.12
Bavani	STATE	TNEB	TAMIL NADU	8	149.37
Lower	STATE	TNEB	TAMIL NADU	8	159.63
Poonachi	STATE	TNEB	TAMIL NADU	1	503.81
Sathanoor	STATE	TNEB	TAMIL NADU	7.5	1144.05
Mukurthy	STATE	TNEB	TAMIL NADU	0.7	90.84
Thirumurthy	STATE	TNEB	TAMIL NADU	1.95	844.12
Periyar	STATE	TNEB	TAMIL NADU	140	32.14
Vaigai	STATE	TNEB	TAMIL NADU	6	45.49
Suruliyar	STATE	TNEB	TAMIL NADU	35	64.59
Papanasam	STATE	TNEB	TAMIL NADU	28	35.77
Servalar	STATE	TNEB	TAMIL NADU	20	88.53
Sarkarpathy	STATE	TNEB	TAMIL NADU	30	8.97
Aliyar	STATE	TNEB	TAMIL NADU	60	18.64
Kadamparai	STATE	TNEB	TAMIL NADU	400	5662.98
Sholayar	STATE	TNEB	TAMIL NADU	70	6.3
Sholayar	STATE	TNEB	TAMIL NADU	25	16.59
Kodayar	STATE	TNEB	TAMIL NADU	60	36.65
Kodayar	STATE	TNEB	TAMIL NADU	40	52.61
Lower	STATE	TNEB	TAMIL NADU	2.5	755.02
Pykara	STATE	TNEB	TAMIL NADU	150	215.84
Bhavani	STATE	TNEB	TAMIL NADU	30	5.06
Sone Western Link Canal HEP	STATE	BSHPC	BIHAR	6.6	253
Sone Eastern	STATE	BSHPC	BIHAR	3.3	253
Eastern Gandak Canal	STATE	BSHPC	BIHAR	15	307

Kosi Hydel	STATE	BSHPC	BIHAR	19.2	52
LLHP (Lower Lagyap)	STATE	GoS	SIKKIM	12	111.54
Rimbi	STATE	GoS	SIKKIM	0.6	1063.89
Rongnichu	STATE	GoS	SIKKIM	2.5	570.98
Meyong	STATE	GoS	SIKKIM	4	87.73
Kalez	STATE	GoS	SIKKIM	2	242.31
Hirakud Power System	STATE	OHPC	ORISSA	347.5	75.5
Rengali HEP	STATE	OHPC	ORISSA	250	47.48
Upper Indravati HEP	STATE	OHPC	ORISSA	600	36.11
Upper Kolab HEP	STATE	OHPC	ORISSA	320	26.86
Balimela HEP	STATE	OHPC	ORISSA	360	21.05
Jaldhaka	STATE	WBSEDCL	WEST BENGAL	35	91.53
Ramam	STATE	WBSEDCL	WEST BENGAL	51	87.31
Teesta	STATE	WBSEDCL	WEST BENGAL	67.5	1736.78
Other	STATE	WBSEDCL	WEST BENGAL	14.2	403.17
ARUNACHAL PRADESH**	STATE	AP	ARUNACHAL PRADESH	34.24	118.88
MeSEB	STATE	MeSEB	MEGHALAYA	185.2	132.4
Likimro	STATE	NAGALAND	NAGALAND	24	212
Dzuza	STATE	NAGALAND	NAGALAND	1.5	198
Duilumroi	STATE	NAGALAND	NAGALAND	0.54	211
Duilumroi-II	STATE	NAGALAND	NAGALAND	0.2	211
Telangsao	STATE	NAGALAND	NAGALAND	0.6	215
Gumti	STATE	TSEB	TRIPURA	15	30.22
Vishnuprayag HEP	PRIVATE	JAIPRAKASH	UTTARAKHAND	400	143
Baspa II HEP	PRIVATE	JAIPRAKASH	HIMACHAL PRADESH	300	161
Malana HEP	PRIVATE	MALANA	HIMACHAL PRADESH	86	141.54