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Comparing feasibility of long distance transmission and locally generated solar energy over a period of 25 years in remote locations of the Indian Himalayan Region

[1] Saakshi Chauhan, [2] Subrat Sharma
[1] JPF, National Mission on Himalayan Studies
[2] Head, Climate Change Theme
GB Pant National Institute of Himalayan Environment and Sustainable Development
Kosi Katarmal, Almora-263643

Abstract: **It has been widely observed, especially in the Indian scenario, that development projects (road construction, energy infrastructure, etc.) which require large investment are usually implemented without considering alternate scenarios/solutions while other technologies/mechanisms are available. This study incorporates the use of Cost Benefit Analysis in order to ascertain the importance of determining the feasibility and efficiency of an energy project in a remote location of the Himalayas. The focus is upon electrification of remote villages which are located in challenging environments and difficult mountain terrain. The village Khati (Bageshwar district, Uttarakhand, India) is 20 kilometres far from the electricity distribution sub-station (village Karmi) and inaccessible by road, till date, and is located above 2210amsl. Net benefits from utilization of transmitted energy from sub-station was compared with a hypothetical situation of net benefits generated from utilization of same amount of energy being supplied from a solar power plant located in the village. The net benefit for the two scenarios has been calculated for a period of 25 years with the help of Net Present Value method. Benefits were much greater (more than Rs 2300 thousand) while having a decentralized local solar plant than the regular supply of transmission from centralized electricity grid. This study demonstrates the importance of feasibility analysis in such alternate scenarios especially in executing developmental projects in remote locations having difficult terrain and unstable climatic and environmental conditions.**

Index Terms:— **Cost Benefit Analysis, Net Present Value, Rural electricity, Remote Villages, Khati Village, Pindari Valley, Solar Energy**

INTRODUCTION

Electricity plays an important role in keeping households and businesses functioning smoothly. Consumption of electricity for daily chores like cooking and cleaning has made it a vital part of our lives. Electricity generation from renewable energy sources is becoming popular by the day which is indicated by an increase in capacity of 14.30 GW during the last two and half years under Grid Connected Renewable Power, which include 5.8 GW from Solar Power, 7.04 GW from Wind Power, 0.53 from Small Hydro Power and 0.93 from Bio-power (Press Information Bureau, Ministry of New and Renewable Energy, 2016). Many of the remote villages in India have decentralised hydro power generation mechanisms which have been quite successful in providing stable electricity. As far as the Himalayan Region is concerned, grid connected or transmitted power from great distances will not only cause higher transmission and distribution losses but will also be prone to natural hazards which could cause damage to the energy infrastructure. The village of Khati is situated at a remote location in Pindari Valley of Bageshwar, Uttarakhand which received electrical

connectivity for the first time, from substation Karmi (20 Kms from Khati) in November 2016. Before getting electrified, Khati was entirely dependent upon solar energy for electricity generation as every family owned at least one 2V solar panels which was enough for lighting 2(0-10W) bulbs for 3-4 hours. After the introduction of grid connected power, the residents started relying less on solar energy and more on the newly established connection which led to degradation of the solar panels as the villagers reduced their efforts in maintenance of the device. The village is supposed to receive power for ten hours in the night but this availability is very sporadic leading to an erratic pattern in the consumption and dependency on the source of power. Therefore, the cost effectiveness of each source needs to be determined as well as the dependency of the villagers on either source of power. This knowledge will be helpful in

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determining not just the feasibility of each source but also the same mechanism can be used to determine which source of power should be established or enhanced for another remote village which has not been electrified yet.

1.1 Environmental Issues and Importance of Project Feasibility

This section deals with the most fundamental and vital problems or issues related to energy generation in Khati and presents the prominent theme of this study. As mentioned in the previous section, the issue not only exists in electricity generation and distribution but also the degrading solar panels due to insufficient/improper maintenance since the villagers started depending more on power supplied from Karmi. Feasibility of electricity generation mechanisms is another issue which needs to be resolved. The villagers expected the electricity supply to be stable and continuous which, as it turns out did not happen due to a variety of reasons as mentioned below.

The location of the village plays an important role in assessing the problems related to energy availability in Khati. The terrain and weather are important parameters because frequent rains and storms may hamper the efficiency of solar panels. The weather may also affect the transformers and electric poles which supply power to the village as it may get struck by lightning, which happened in the month of May 2017, heavy rainfall may cause landslides and rockfall which could cause destruction upon impact on the vulnerable structures constructed in proximity of such hazardous regions.

Another problem associated with energy in Khati is that of construction of a solar grid which was initially proposed by an NGO but could not be continued because the village had already received electricity from Karmi. The villagers seemed contended at the time, however, with improper supply, the issue seems to have elevated as they are now more inclined towards having a solar grid rather than having the power lines which have already been laid. A cost benefit analysis shall be done in order to determine the feasibility of each energy generation/distribution technique.

Finally, the problem of financial matter seems to have arisen as the villagers have not paid the electricity bill as they have not installed an electric meter due to improper supply and the electricity department are not ready to properly supply electricity due to non-payment of electricity bill.

This section also briefly reviews the subject in concern and how it is important to conduct this research.

Hunt (1975) Images and expectations of a destination may have, as much as, or more to do with an area ‟s tourist image projection than the tangible recreational resources." As Khati is a stop for thousands of tourists annually, it is important to keep the place serene and erection of electric poles seem to have degraded that serenity. Bimla (1976) talks about economic development in hilly areas. Hilly areas can be fragile and one little mistake can disturb the entire ecosystem bringing the development of the place to a halt.

The importance of conducting a cost benefit analysis(CBA) has been advocated by many economists even though its role in policy formulation has been observed to be somewhat insignificant. Johansson and Kristrom (1992), commenting on the Swedish experience, conclude: "The general impression, however, is that these social cost-benefit evaluations have played a minor role in the actual outcome of the decision-making process. Even if a cost-benefit analysis shows that a project is highly profitable to the entire society, the project is not necessarily (or even generally) undertaken, and vice versa." Kumar (2015) explaining the importance of CBA: "Cost Benefit Analysis (CBA) of the proposed intervention – which could be in the form of policies, programs, or projects – is a method for demonstrating the superior efficiency of the proposed intervention. Application of CBA in the field of environment has attracted wide-spread attention in recent times due to variety of conceptual and empirical complexities that environmental issues pose."

Ministry of New and Renewable Energy published multiple case studies on solar energy consumption and development in various parts of India in 2012. The most striking information was found in the studies by Sahu, on SELCO, a company that makes energy accessibility easier for the poor people and focuses primarily on SPV (solar photo-voltaic) technology to provide electricity for lighting, water pumping, communications, computing, entertainment and small business appliances. This is quite similar to the work done by the NGO called Hans Foundation for the upliftment of Khati. Another study done by Bhasin on a small, previously unelectrified village in Rajasthan which depended entirely on Kerosene for cooking and lighting. This was later transformed by establishing a solar grid in the area, an initiative by Minda NexGenTech Ltd and the local sarpanch Ms. Chhavi Rajawat who installed a 240 W solar power plant which supplies electricity to the village.

1.2 Issues and Gaps

The main research issue here is to understand the necessity of developing the energy infrastructure in Khati in a sustainable way so that the residents of the village receive stable and continuous electricity and the infrastructure can remain reliable and sturdy even in times of environmental or climatic instability.

This section also concerns itself with the essential gaps observed in various studies and their relevance in the context of this research. There have been several studies done on energy production, consumption and proper distribution but it was observed that the places which have recently been electrified are not being studied. It is important to study such areas because only then it will be possible to determine whether the new electrification is

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working properly or having any advantages at all. Also, there has been no study which focuses on dependence of people on a certain source of energy production and the reliability of that source.
Cost benefit analyses were done for many places related to energy development, however, it has not been done for small villages which are either inaccessible by road or those in extremely remote locations. Also, a comparative study between the costs and benefits of the two sources of energy has not been done.

1.3 Objectives and Hypothesis

The previous section mentioned the important research gaps, based on which this section states the relevant objectives. In view of the above stated research gaps, the following research objectives have been set out for the study:

● To measure the difference between dependence of the population on locally generated and transmitted energy.

● To compare the feasibility of energy transmitted from Karmi substation and solar energy.

In accordance with the research objectives stated above, this section presents the null and alternative hypothesis as follows:

Null Hypothesis, H_0: The Net Present Value of Solar Energy Plant for a period of 25 years is less than the grid connected power from Karmi to Khati.

Alternate Hypothesis, H_a: The Net Present Value of Solar Energy Plant for a period of 25 years is greater than the grid connected power from Karmi to Khati.

1.4 Methodology
This section illustrates the methods of data collection and the methods for the analysis of data in order to fulfil the aforementioned objectives.
Secondary data was collected in order to do the cost-benefit analysis, statistical and descriptive analysis from various reports of the Central Electricity Authority, Government of India like Load Balance Generation Report (2012-2013), Executive Summary and Annual Reports. The data for cost of electricity generation and distribution was collected from studies by Chakrabarti and Chakrabarti, and Deshmukh and Bilolikar published in Energy Policy and Advances in Energy Research respectively. The cost benefit analysis was done by using the Net Present Value Method for a duration of 20 years with a discount rate of 7.75% as declared by the Central Bank of India.
Primary data was collected from 50 different households of village Khati which is equivalent to almost 60 % of the total number of households in the village. Data collected was analysed using descriptive statistics and the results are presented in the form of tables, charts and graphs.

1.5 Scope and Limitations
The study is a micro level study. It is geographically confined to Khati village in district Bageshwar of Uttarakhand, India. The type of data is cross sectional and the sampling technique is simple random sampling. The variables that have been used in this study are number of family members, education of household head, number of hours electricity is used for lighting from both sources and average annual income. The data collected on income may not be the same due to seasonal fluctuations as the population is majorly dependent on agriculture and availability of other opportunities in tourism sector.

2. Demand for Energy Services and Dependency on the Energy Source
Khati is a small village occupying an area of 562.42 hectares with a population of 440 people which are a part of 86 families living in 72 houses. The village had been entirely dependent on solar energy up until November 2016 when it received grid electrification from Karmi, a small town 20 kms from Khati. Each family has a solar panel which were donated to them along with 2 bulbs by an NGO which requires proper care and maintenance in order for them to function properly. However, once the village was electrified the people started becoming entirely dependent on the grid electricity leading to neglection and hence deterioration of the solar panels. As the village is located at a height of 2210m from sea level, unstable weather conditions, frequent occurrence of landslides and heavy rainfall is observed. Such episodes of landslides and rainfall makes the energy infrastructure highly vulnerable to damages. In the month of April and May, 2017 heavy rainfall caused damage to the transformer and hence the village did not receive electricity for over a fortnight. Since the solar panels had also become non-viable, the village temporarily became dependent on kerosene and candles for lighting. This lead to a huge unrest in the area and the people, as observed from the primary data, indicated that they were better off when the village had not been electrified. This called for the need to find a more dependable source, whether it is solar energy or grid connected electricity.

Table 2.1 presents the descriptive statistics on the number of family members, education of head of the household and approximate income:

Table 2.1 Family Size, Education and Monthly Income

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	N (Total No. of Samples)	Minimum	Maximum	Mean	Std. Deviation
No of Family Members	50	2	13.00	5.28	2.04
Education of Head	42	4th standard	Intermediate	9.17	2.56
Income per month	33	1000 Rupees	8000 Rupees	3166.66	1935.15

The table provides an overview of the population depicting 5 people on an average in a household and the education of the head is not beyond High School in maximum cases. The average income as shown is Rs 3166 per month ranging from Rs 1000 to Rs 8000. This however has a standard deviation of 1935.15 which indicates high fluctuation from the mean value. The reason for this is unstable weather conditions as people are majorly dependent on agriculture for their livelihood and hence the impact of heavy rainfall and storms causes crop degradation. Unstable weather also causes decrease in tourist incoming and hence the income from the hospitality sector also fluctuates. This affects the energy scenario as households with better income are able to afford more solar panels and are able to consume electricity for longer durations in a day,

hence increasing the overall demand for energy. This will impact the predicted values of demand for electricity and therefore, the costs and benefits. However, this does not limit the results of the second objective which uses Cost-Benefit Analysis as both costs and benefits are affected equally and hence there is no effect on net benefits.

Determining Dependence of Population on the Sources of Electricity

Table 2.2 Number of Bulbs and Hours of Energy Consumption

	N (Total no. of Samples)	Minimum	Maximum	Mean	Std. Deviation
Total No. of Bulbs	50	1	10	3.28	1.77
Grid Bulbs	50	0	7	2.04	1.59
Solar Bulbs	50	0	4	1.24	.94
Grid Hours	50	1	6	2.90	1.02
Solar Hours	36	0	6	3.33	1.29

Table 2.2 indicates that each household has three bulbs on an average of which one is powered by solar energy and two are powered by grid connected electricity. Although the average number of hours these bulbs are used from different power sources indicates a higher consumption of energy from solar panels, which is approximately 15 percent greater than the energy consumed from the latter source. This indicates a higher dependence on solar energy even though the number of bulbs connected with grid electricity are greater. This may also mean that the population perceived the power supplied from substation Karmi was reliable and hence equipped themselves with more number of bulbs connected with this power. All the households have established electrical connectivity from the newly established power lines of which 70% have solar panels which are currently being in use. The rest 30 percent have been degraded due to improper maintenance. This fulfils the first objective of determining the difference in the amount of dependence on either source of electricity (dependent on solar energy by 15 percent more than that of transmitted energy). The next section deals with the second objective of determining feasibility of the two energy sources.

3. Cost Benefit Analysis for Generation, Production and Distribution of Energy: Long Distance Transmission vs Locally Generated Electricity (Solar Grid)

Cost benefit analysis (CBA), sometimes called benefit cost analysis (BCA), is a systematic approach to estimating the feasibility of projects (for example in transactions, activities, functional business requirements or projects investments); it is used to determine options that provide the best approach to achieve benefits while preserving savings. The CBA is also defined as a systematic process for calculating and comparing benefits and costs of a decision, policy or a project.

Broadly, CBA has two main purposes:

1. To determine if an investment/decision is sound (justification/feasibility) – verifying whether its benefits outweigh the costs, and by how much;

2. To provide a basis for comparing projects – which involves comparing the total expected cost of each option against its total expected benefits.

CBA is related to (but distinct from) cost-effectiveness analysis. In CBA, benefits and costs are expressed in monetary terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their net present value.

CBA usually tries to put all relevant costs and benefits on a common temporal footing using time value of money calculations. This is often done by converting the future expected streams of costs and benefits into a present value amount using a discount rate. Empirical studies and a technical framework suggest that in reality, people do discount the future like this. The following method is used to conduct the analysis:

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$$PVC = \sum_{t=1}^{T} \frac{C_t}{(1+r)^t},$$

$$PVB = \sum_{t=1}^{T} \frac{B_t}{(1+r)^t},$$

$$NPV = \sum_{t=1}^{T} \frac{B_t}{(1+r)^t} - \sum_{t=1}^{T} \frac{C_t}{(1+r)^t},$$

where Ct is the cost of the project in the year t,
Bt is the benefit of the project in the year t,
T is the life time of the project,
r is the discount rate
PVC: Present Value of Cost & PVB:
Present Value of Benefits

If NPV ≤ 0, then the project adds no net welfare to society and the project should not be pursued because society would not be made better-off, if all benefits of adaptations can be quantified and monetised. If NPV > 0, then the project adds welfare to society.
Table 3.1 presents the energy demand for Khati for each year as predicted for 25 years. This also takes into account the increase in population each year the rate of which was taken 0.42% per year. Since the growth rate of population is not available for Khati, the growth rate for district Bageshwar is used, stated by census 2011. These predicted values are used for calculation of costs and benefits.

Table 3.1: Predicted Annual Energy Demand for Khati (kWh) per year for 25 years

Year	Annual Energy Demand (Predicted) (kwh)
First	32095.84
Second	32230.64
Third	32366.01
Fourth	32501.95
Fifth	32638.45
Sixth	32775.54
Seventh	32913.19
Eighth	33051.43
Ninth	33190.24
Tenth	33329.64
Eleventh	33469.63
Twelfth	33610.20
Thirteenth	33751.36
Fourteenth	33893.12
Fifteenth	34035.47
Sixteenth	34178.42
Seventeenth	34321.97
Eighteenth	34466.12
Nineteenth	34610.88
Twentieth	34756.24
Twenty First	34902.22
Twenty Second	35048.81
Twenty Third	35196.02
Twenty Fourth	35343.84
Twenty Fifth	35492.28

Table 3.2 (given in Annexure) first calculates the yearly benefit for 25 years by taking into account the yearly growth in energy demand as depicted in the table 3.1. It is hard to determine benefit because it is hard to quantify some parameters like ease of doing household chores with the help of electrical devices like vacuum cleaner and microwave etc., therefore, a proxy has been generated by calculating the total amount paid yearly to the power supplying authorities. This amount paid will serve as a proxy for total benefits received per year by the people of the village.
The annual cost for generation, transmission, distribution and maintenance of both sources of power (locally generated and transmitted) has been calculated by obtaining these costs (per KWh) from multiple sources of data (Chakrabarti & Chakrabarti, 2002, Executive Summary by CEA & Executive Summary "24X7 Power for All" by GoI and GoU) and multiplying these values with the predicted energy demand as mentioned in the previous table. The per unit cost for generation, transmission, distribution and maintenance of Solar Energy is 9.2Rs/KWh and for Grid connected Transmitted energy is 31.12 Rs/KWh. (Note: the solar energy is referred as locally generated energy due to presence of solar panels within the village itself and the grid connected power supplied from Karmi substation is referred to as transmitted electricity). The discount rate, for calculation of present values as given by the Reserve Bank of India is 7.75%. The Net Benefit here depicts the difference in the Net Present Values of both the sources of power, that is, NPV of Transmitted Power subtracted from NPV of locally generated (Solar) power. Figure 3.1 shows the Net Present Values for 25 years of both the power sources. It can clearly be observed that the NPV of locally

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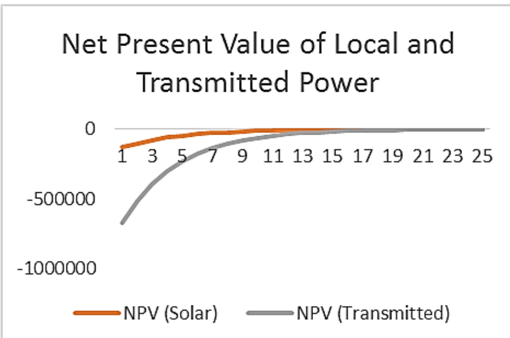
transmitted power(solar) is greater than the NPV of transmitted power from substation Karmi and hence locally transmitted or solar energy generation mechanisms should be preferred. In order to determine a numerical value as to how much benefit from solar energy is greater than transmitted energy, the summation of Net Benefits is obtained in table 3.2 for a period of 25 years. This was found to be 2297667.25 Rupees indicating a higher benefit from Solar energy than that of transmitted energy by almost 23 Lac for 25 years.

Figure 3.1 NPV of Local and Transmitted Power



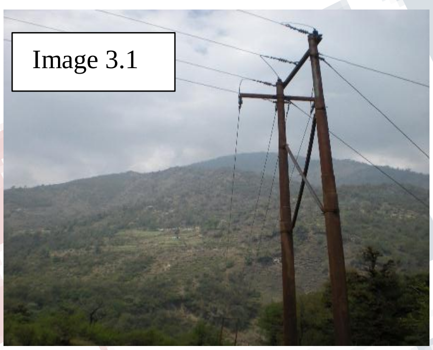


Image 3.1 Electric Poles vulnerable to climatic hazards in village Khati and solar panels installed in May 2017 in the village primary school

Image 3.1 depicts the terrain and weather which could impose danger on the infrastructure of the transmitted energy. The infrastructure may also be harmed by lightning as its occurrence is not uncommon during the monsoons. The solar panels have recently been installed in the primary school of the village (May 2017). It appears to be less vulnerable than electric poles and transformers, however, this can only be confirmed after a few months of usage (especially in the monsoons).

4. CONCLUSION

The average number of hours the bulbs are used from different power sources indicates a higher consumption of energy from solar panels, which is approximately 15% greater than the energy consumed from the latter source. A higher dependence on solar energy is observed but the number of bulbs connected with grid power is higher. This indicates the positive perception of the population towards power supplied from Karmi as they equipped themselves with more number of bulbs connected with this power rather than solar power on which the population relied upon for decades.

The benefit obtained from Solar Energy is higher than that of grid energy supplied from substation Karmi by approximately 23 Lacs as determined by the Cost-Benefit Analysis. This indicates that establishing a solar power generating grid in the village itself is more beneficial than establishing power lines which not only costs more but are also susceptible to damages from climatic activities due to the location of infrastructure in hazardous areas. However, the longevity of solar panels has not been considered. Generally, the life of a solar panel is 25 years which has been used as the duration for conducting the cost benefit analysis. This implies that each panel of the grid will need to be replaced and the cost of which will be a part of maintenance cost and has not been included in the current study. The implication of this could be an alteration in the currently obtained results if the cost of installing new panels is greater than the net benefits. This alteration can be set back by including further costs in the transmitted energy transmission and distribution mechanisms. These are the monetary values of various externalities related to construction of power lines, electric poles, transformers etc., which reduce the aesthetic value of the location. The cost of maintaining the infrastructure in case of damages caused by landslides, rainfall, lightning etc., has not been included which could play an important factor in balancing the further costs of maintaining solar panels and hence arriving to the original results.

In regard with the conclusions, the following suggestions are made:

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● A similar feasibility study may be conducted for areas located in remote locations in order to determine which mechanism is more efficient for that area (locally generated or transmitted).
● Awareness must be created in regard with the environmental and financial benefits of solar energy.
● The benefits from preserving the aesthetic values of a location must be communicated, especially in remote locations as well as remote tourist destinations.
● Transmission and distribution losses can be minimized by selecting the appropriate mechanism relevant to the location.

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ANNEXURE

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Table 3.2: Yearly Net Benefit for 25 Years: Comparison Between Locally Generated(Solar) and Transmitted Power

1	2	3	4	5	6	7
Year	Annual Benefit (in Rupees)	Annual Cost (Solar) (in Rupees)	Annual Cost (Transmitted) (in Rupees)	NPV (Solar) (in Rupees)	NPV (Transmitted) (in Rupees)	Net Benefit (5-6) (in Rupees)
1	123840.00	-130872	-667926	-130871.54	-667925.57	537054.03
2	123840.00	-100625	-512311	-100624.61	-512311.38	411686.76
3	123840.00	-77366.7	-392951	-77366.66	-392951.28	315584.62
4	123840.00	-59483.2	-301399	-59483.18	-301399.26	241916.09
5	123840.00	-45732.5	-231177	-45732.54	-231176.91	185444.38
6	123840.00	-35159.9	-177315	-35159.87	-177315.02	142155.15
7	123840.00	-27030.9	-136002	-27030.88	-136002.03	108971.14
8	123840.00	-20780.9	-104314	-20780.90	-104314.35	83533.45
9	123840.00	-15975.7	-80009.5	-15975.69	-80009.50	64033.81
10	123840.00	-12281.3	-61367.4	-12281.35	-61367.42	49086.07
11	123840.00	-9441.12	-47068.8	-9441.12	-47068.78	37627.66
12	123840.00	-7257.6	-36101.6	-7257.60	-36101.64	28844.04
13	123840.00	-5578.96	-27689.8	-5578.96	-27689.79	22110.83
14	123840.00	-4288.5	-21237.9	-4288.50	-21237.89	16949.39
15	123840.00	-3296.48	-16289.3	-3296.48	-16289.28	12992.80
16	123840.00	-2533.88	-12493.7	-2533.88	-12493.70	9959.83
17	123840.00	-1947.66	-9582.51	-1947.66	-9582.51	7634.85
18	123840.00	-1497.04	-7349.65	-1497.04	-7349.65	5852.61
19	123840.00	-1150.65	-5637.06	-1150.65	-5637.06	4486.41
20	123840.00	-884.397	-4323.52	-884.40	-4323.52	3439.12
21	123840.00	-679.74	-3316.05	-679.74	-3316.05	2636.31
22	123840.00	-522.433	-2543.34	-522.43	-2543.34	2020.90
23	123840.00	-401.523	-1950.68	-401.52	-1950.68	1549.15
24	123840.00	-308.591	-1496.12	-308.59	-1496.12	1187.53
25	123840.00	-237.163	-1147.48	-237.16	-1147.48	910.32

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