

and has 10 units, which results into a capacity of 6 GW. Its annual generation reaches 26.5 bln TWh, and its spillway capacity amounts to 13.6 m³/s.

However, the issue of HPPs' environmental safety has been worrying people since the tragedy at the Sayano–Shushenskaya Dam took lives of 75 people 10 years ago.

Tall dams can be dangerous if destroyed, accidentally or on purpose. HPPs constructed in the mountains face the problem of seismic activity that can lead to formation of cracks and eventual destruction. The most disastrous NPP accident in the history happened in 1975, when the Banqiao Reservoir Dam broke in China. Due to unusually abundant precipitation, the reservoir was overfilled; the sluice gates were blocked, which caused the dam to fail. This led to a cascade reaction destroying dams located downstream and killing 26,000 people. The following flooding caused deaths of 145,000 more people. The total number of victims reached 11 mln people. In 1979, an overflow and the following dam failure led to a catastrophe killing more than 2,000 people.

Hydropower has a negative impact on the environment, such as:

- Flooding of farmlands and populated areas
- Upset water balance upstream as well as downstream
- Impact on flora and fauna
- Impact on climate (changes in heat balance, increase in precipitation level, wind speed, cloud coverage, etc.)
- Silting of the reservoir upstream and bank erosion downstream
- Degradation of lotic water self-clarification and decrease in oxygen content
- Impairment of fish free movement
- Emission of large methane and CO₂ volumes

Greenhouse gas emissions of HPPs can exceed those of a conventional oil-fired TPP if the reservoir's area is large relatively to the HPP's capacity (less than 100 MW for 1 m³ of the area) and if the flooded area was not deforested.

Nevertheless, hydropower is the only renewable energy source that makes a noticeable contribution to the world's energy generation. This is the limit to the growth of hydropower.

Oceanic hydropower also has a range of negative environmental feature. Generation of any type of oceanic energy inevitably causes certain changes in natural state of the ecosystems affected. Construction of tidal power plants and the use of marine energy have a negative impact on the condition of shores leading to changes in submergence conditions, salting, shore erosion, formation of beaches, etc. For example, industrial wastewaters that pollute world ocean waters are prevented from spreading by natural barriers formed by temperature gradients, water-mass density, salinity, and speed. Moreover, new manmade watershed divides can be created in shorelands, which hamper the outflow of polluted waters that are caused by the use of long-distance lines of tidal power plants.

The conclusion is that hydropower can globally affect the environment. Therefore, its possible global impact should be thoroughly studied and analyzed before bringing it into wider use.

Wind energy also affects the environment in the following ways:

- Alienation of large land areas (in order to provide France with wind generated energy, more than 20,000 km² are needed, which is 4% of the whole area of the country)
- Air traffic, radio, and TV interference
- Negative impact on marine animals (from offshore wind farms)
- Local climate changes caused by disturbance of natural airflow circulation
- Destruction of birds and insects migration paths (the diameter of a 2–3 MW turbine can reach 100 m)

- Noise pollution (a 2–3 MW turbine should be turned off at nighttime)
- Visual pollution

Solar energy also harms the environment in the following ways:

- Alienation of large land areas, their possible degradation (in the central part of Russia, a solar power plant [SPP] with a capacity of 1 GW and energy conversion efficiency of 10% needs at least 67 km² and additional land for various industrial sites, where construction and operation material is produced)
- Dimming of large areas by solar concentrators
- Changes in heat balance, humidity, and wind direction around the SPP
- Danger of pollution of the surrounding environment with toxic substances such as sulphuric acid, lead, and cadmium, that are used to manufacture of solar panels
- Possible leaks of working fluids containing chlorates and nitrites
- Product pollution with toxic substances if solar systems are used in agriculture
- System overheating and spontaneous combustion
- Impact of space-based SPPs on climate
- Microwave radiation from space-based SPPs towards the Earth, which is dangerous for animals and human beings

Nuclear energy in the form that we use it in today (based on slow neutrons) is limited only by uranium resource. However, if humanity switches to exploiting fast neutrons, nuclear power will have no resource factor growth limit. Moreover, it does not require alienation of such vast land areas as wind and solar energy does.

Table 1 demonstrates a comparison of environmental effectiveness by indices on a scale from 0 to 10.

Table 1

Index	Score of various energy generation types			
	Hydropower	Solar energy	Wind energy	Nuclear power
	3	4	5	6
1. Greenhouse gas emission	0.1	0.7	0.3	0.1
2. Atmospheric emission of pollutants	0.1	5	0.1	0.1
3. Waste generation	0.1	3	3	0.1
4. Land alienation	10	3.3	5	0.1
5. Risk to human beings	0.9	2.9	0.2	0.5
6. Aggregate index of negative impact	16.5	22.1	18.9	16.1
7. Aggregate index of environmental effectiveness	3.95	2.95	3.45	4.05
8. Percentage of the best	97.5%	72.8%	85.2%	100%

Conclusion

The comparison of environmental indices of the limits to the growth of the most common renewables—hydropower, wind, and solar energy—showed that they all are limited due to the negative impact on the environment and environmental safety they have. Only one energy source has no limits to the growth, and it is nuclear power. Its innovative development towards the closed nuclear fuel cycle will help solve the issue of its impact on the environment and ensure environmental safety.

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