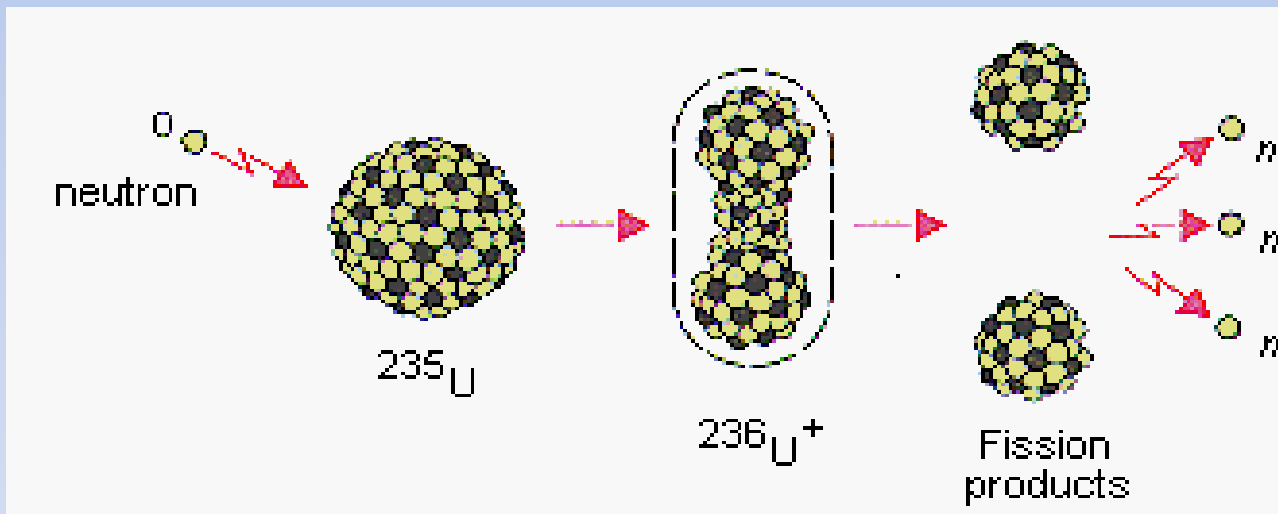
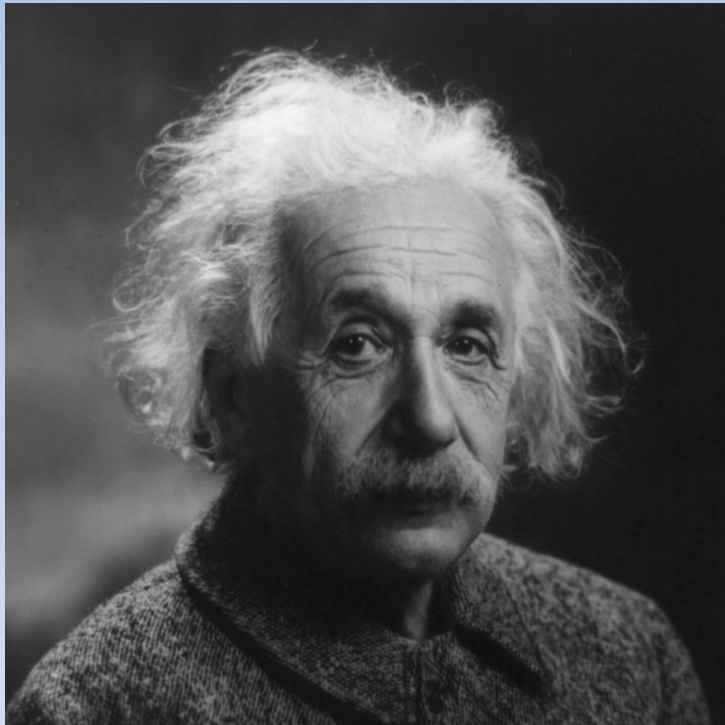


$$E=mc^2$$



-Sandeep Kumar
MSc (Engg)
Center For Sustainable Technology



Nuclear Energy & Society

Use of Nuclear Energy

**Medicinal
Use**

- X-ray, PET etc.
- Radiation Therapy

**Power
Generation**

- Electricity generation
- Nuclear Submarines

Weapon

?????

Topics of presentation



Nuclear Energy and sustainability

The need for society

Nuclear fuel cycle & technology

Pros & Cons of the Nuclear energy

Sustainability analysis of the Nuclear Energy

Conclusion

Nuclear Energy and sustainability

- Study of components of Nuclear energy program
- Impact of different components on
 - Environment
 - Society
 - Economy

Need of Nuclear Energy for Society

- Sustained nuclear chain reaction became a reality on December 2, 1942 in a squash court of University of Chicago converted into a nuclear reactor. Enrico Fermi and team demonstrated the ***controlled*** chain reaction.
- But society rather government during the second world war was interested in ***uncontrolled*** chain reaction or “**Nuclear Bomb**”.
- Germany and US were in race for the Nuclear Bomb. Einstein’s equation “ **$E=mc^2$** ” was key for victory in war and it proved so.
- After world war II was over, Nuclear scientists and socialists pushed the govt. for peaceful use of Nuclear Energy as in power generation.
- Though uneconomical, developed nations started experimental electric plants. The main intention was to get the bomb grade Plutonium – 240 out of the spent fuel. Breeder reactors and fuel enrichment plants were efficient in doing so, and was the technology used.

- It was in 1970's when oil prices surged in the market, Nuclear energy economy and feasibility put the designers on the drawing board for bigger and efficient design for fulfilling the need of “**power hungry**” developed nation.
- Doubling the price of fuel for Nuclear plant (Uranium) will impact only **7% increase in electricity cost in comparison to 70% increase in case of gas based plant**. This factor made economists to think Nuclear energy as the future.
- Some countries like **France** which were heavily dependent on import oil for electricity generation (over 70% during that era) turned towards Nuclear energy now producing **80% of its electricity demand through Nuclear power plants**.

Morphological Analysis

<i>Dimensions</i>	<i>Functional characteristics</i>	<i>Options available</i>
<i>Mines</i>	Extraction of mineral rich in Uranium from earth.	<ul style="list-style-type: none"> • Open mine. • Underground mine.
<i>Fuel Extraction</i>	Extraction of Uranium in form of UO_2 from mineral ore.	Extraction of UO_2 from U_3O_8 using CFC/HFC.
<i>Fuel Enrichment/Breeder Reactors (OPTIONAL)</i>	<ul style="list-style-type: none"> • Enrichment of U-235 from 0.7% U-235 in natural uranium to 3-5% for user in Light water reactor. • Generates Bomb grade Plutonium (Pu-239). • Also produces heat and electricity as by product. 	<ul style="list-style-type: none"> • Breeder Reactor (Th232-U233 based) • Fast Breeder Reactor (U238-Pu-239 based)
<i>Power Generation</i>	Generation of electricity economically.	<ul style="list-style-type: none"> • Heavy Water Reactor • Light Water Reactor (Safer design) • Pressurized water Reactor • Boiling water reactor • Liquid sodium – water Reactor
<i>Fuel Reprocessing (OPTIONAL)</i>	Uses spent nuclear fuel to produce plutonium rich nuclear fuel. Recycling of fuel.	<ul style="list-style-type: none"> • Breeder/Fast breeder Reactors
<i>Waste disposal</i>	Safe and clean disposal of nuclear waste away from biological contact.	<ul style="list-style-type: none"> • In the mountain terrain. • Under the sea. • Under water in containment area. • In remote inhabitable place.
<i>Decommissioning of plant</i>	Safe and clean disposal of the nuclear reactor components. Done with caution as all components have become radioactive over long exposure to fission products and radiations.	Destruction and disposal to remote place without human contact during whole process (Robots are used to complete the task).

Nuclear Energy
Impact on us

Impact of Mining

Impact of Waste Disposal/Decommissioning

Impact of Fuel Extraction/Enrichment/Reprocessing

Impact of Power Generation

WHO ARE US?

- Environment
- Society
- Economy

Mining:

- Uranium exists in form of U_3O_8 in nature, it is extracted from ore containing it, often called as “**yellow cake**”.
- It is found in many places across the world. Total output in 2006 being **39,429 Tones**.
- Canada is leading in production with 25%, Australia with 19% and Kazakhstan 13%. **India produces only 0.44% of world's uranium.**
- The mine waste is often dumped in nearest water body called trailing –lake. It has hazardous elements in the waste.
- India has Uranium mines only in near Jamshedpur in Jharkhand. There are three mines producing poorest grade of Uranium (with 0.06% of Uranium) in the world.
- Niger, 4th largest produce of uranium ore is the country having no Nuclear plant of its own and Uranium is the main export of the country. Its also one of the poorest country in the UN list of poor nations.

Enrichment and fuel processing

- Fuel processing and enrichment gives the nuclear fuel out of the low grade ore.
- U_3O_8 is converted to UF_6 and then back to UO_2 . This process causes leak of CFC responsible for global warming and ozone depletion.
- In general uranium has only 0.7% of fissionable U-235. Enrichment process is used to enrich the fuel to 3-5% of U-235. This is done in enrichment plant.
- Natural grade uranium with 0.7% of U-235 can be used in Heavy Water Reactor (HWR) whereas enriched grade uranium is used in Light Water Reactor (LWR).
- Enrichment and fuel processing also generates lot of radioactive waste and is dumped in water body or earth crust.

Nuclear Reactors

LWR

- Uses normal light water (H_2O).
- Needs enriched uranium.
- Uses light water both as moderator and cooler.
- Is safer than HWR reactor.
- 4 plants in India are based on this.

Breeder Reactors

- This is primarily used for fuel enrichment /reprocessing but inherently produces lot of heat also to generate power.
- Generates fuel for HWR.
- Also generates bomb grade Plutonium.

HWR

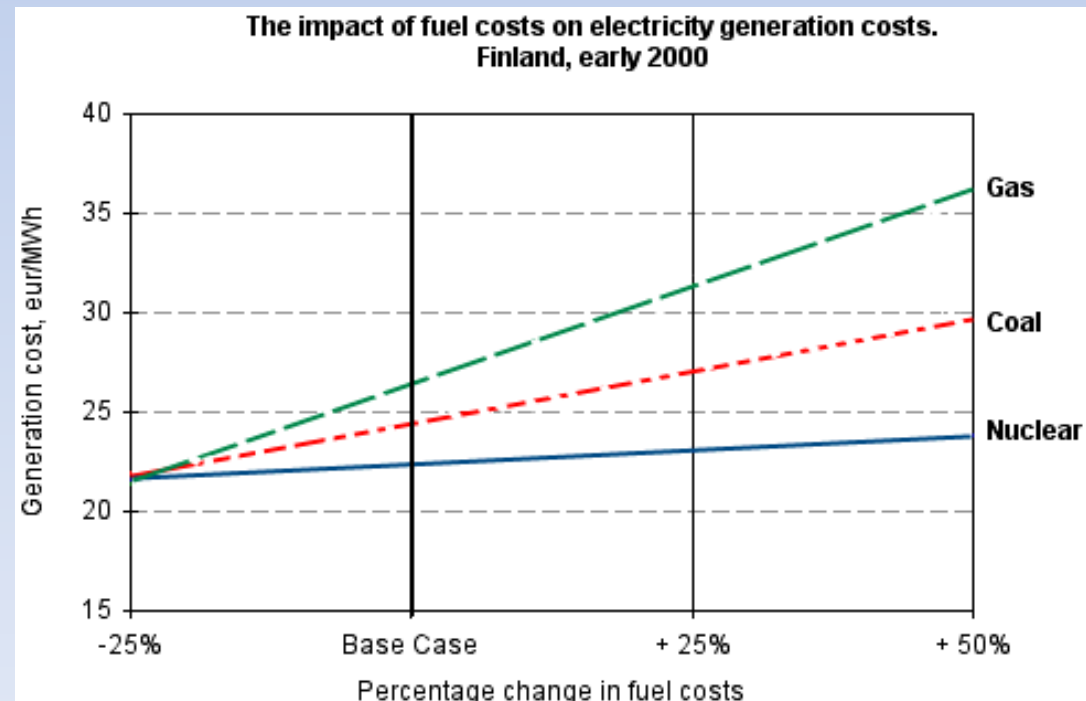
- Uses heavy water (D_2O).
- Uses natural uranium with 0.7% U-235.
- As the Heavy water acts as moderator and light water as coolant, is a bit unsafe than LWR.
- First 2 plants in India, CANDU reactors, were built as HWR.

Waste Disposal and Decommissioning

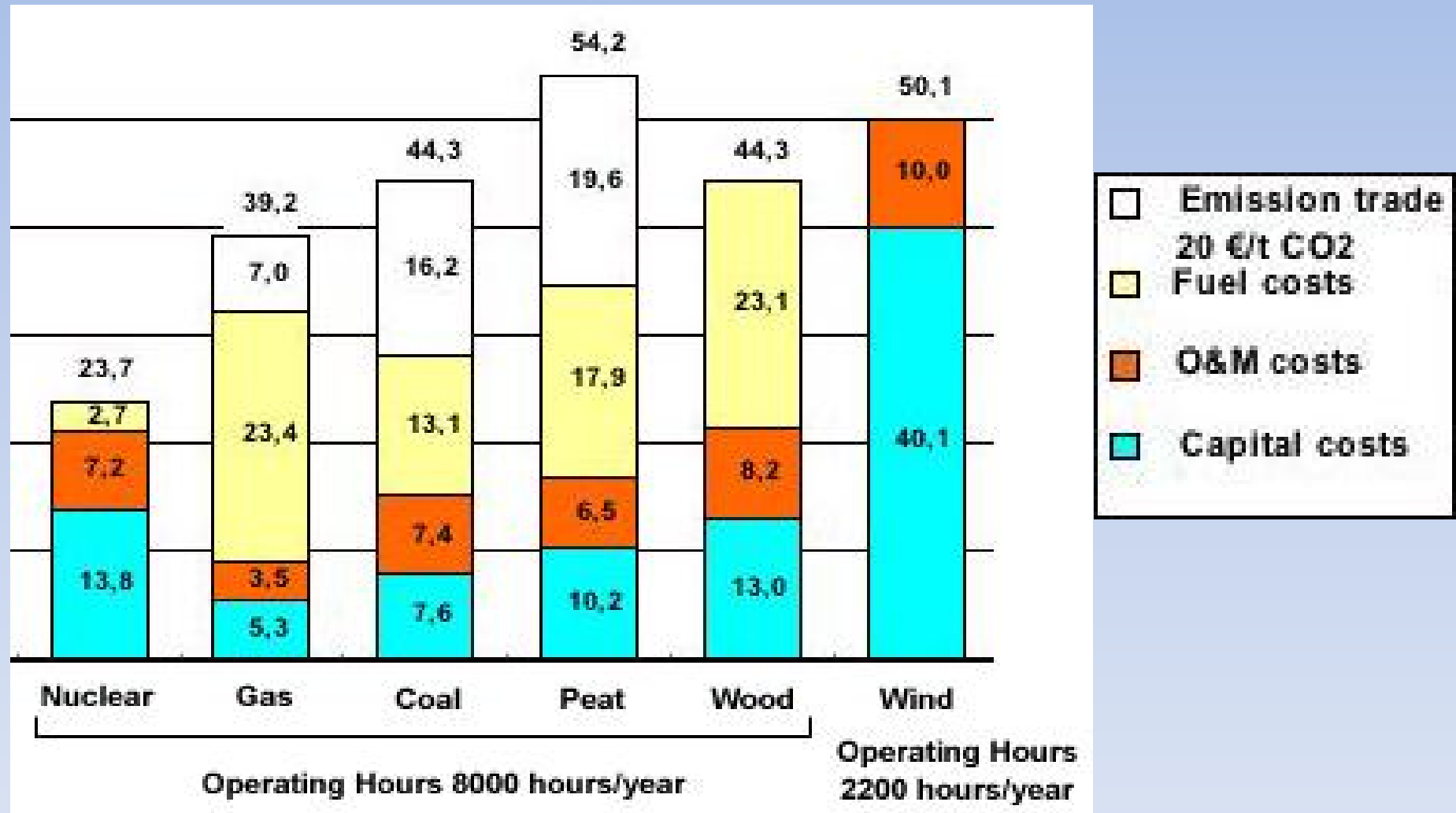
- **Decommissioning** of plant is process to dismantle the nuclear reactor and its component safely as Nuclear reactor components also becomes radioactive.
- Waste disposal is a menace for technologist/economist.
- Safe limit for waste disposal is **10,000 yrs of containment** away from biosphere. (300-600 yrs for HLW, 10,000 yrs for LLW)
- **No permanent waste disposal plan** has come out ever.
- Most of the Nuclear waste is still lying in temporary containment.
- US has over **19,000 tons of nuclear waste** waiting for safe permanent disposal.
- Its a tedious, costly and long process. Generally takes **10-20 yrs** and need **robots** to carry and dismantle the area.

Positive Factors in Nuclear Energy

- It is considered to be sustainable energy source. The fuel is enough to meet the human demand till the sun is shining.
- It's clean and green energy. It has almost zero-carbon emission during operation.
- The fuel price impact on electricity cost is very less. For doubling the fuel price, only 7% hike in electricity cost in case of Nuclear energy against 70% in gas based power plant.



- The prices are very competitive to the fossil fuel based plants (**2.54 cents/KWh** compared to **3.33 in coal** based and **3.92 in gas** based plants in France) and is very less than other plants based on renewable energy.



Cost in Euro/MWh

Negative factors in Nuclear Energy

- Radioactive waste
- Radiation Pollution
- Security threat
- CFC pollution
- Its not that green
- Initial cost is very high
- Embodied energy in the plant is very high
- Failure of Nuclear plant will be disastrous
- Changing the attitude of the people/government towards easy energy than energy conservation.
- Socio-Political impact leading to imperialism

Lets discuss each point one by one.....

Radioactive waste

- The fission process releases the daughter elements. We can classify them into two broad categories:
 - High level waste – shorter life time (300-600 yrs)
 - Low level waste – longer life time (upto 10000 yrs)
- They have large impact on ecological system as they enter in the food chain (Iodine -131) or atmosphere (Radon gas).

Nuclear energy and radiation

- All over the world people are target of natural radiation level or called background radiation. ***Global average is 5 mSv/yr.*** But there is lot of differences in background radiation level on different region.
- In ***Kerala, the background radiation level is 38mSv/yr and in Ramsar (Iran), its 100 mSv/yr.***
- Atomic energy deptt. has given safety guidelines for radiation level in areas where nuclear radiation are used. ***20 mSv/yr*** is the maximum dose for people working in Nuclear plants, Radiotherapy or X-Ray lab and are not allowed to work for more than ***5 yrs.***
- Radiation level should not increase above ***1 mSv/yr*** outside the Nuclear plant fencing.
- So, the **Nuclear energy use seems to be much within safety limits.**

If radiation level are so much within safety limits, then why so much cry about Nuclear radiation?????

- Though radiation levels are within control, its within control for “**Humans**” only.
- Radiation effect is studied and regulated for Humans only. But we are not the only one species in Biosphere.
- Humans are higher animals with in built mechanism of genetic correction due to accidental mutation. So, the chances of mutations are less in humans. Also, in case of mutation, it’s the individual suffering as the survival and chance to propagate the mutated gene is less.
- But in lower animals or species especially ***prokaryotes and viruses***, who are very much vulnerable to genetic mutation are much more vulnerable to nuclear radiations. Owing to the fact that a single cell organism can be dangerous with the new gene pool.
- The effect of radiation are never considered on other living creature on earth and sea. Even its not feasible to study the effect on each of the millions of species on earth. So, effect of radiation could be disastrous any time in future.

Security threat

Let's put some facts here from past:

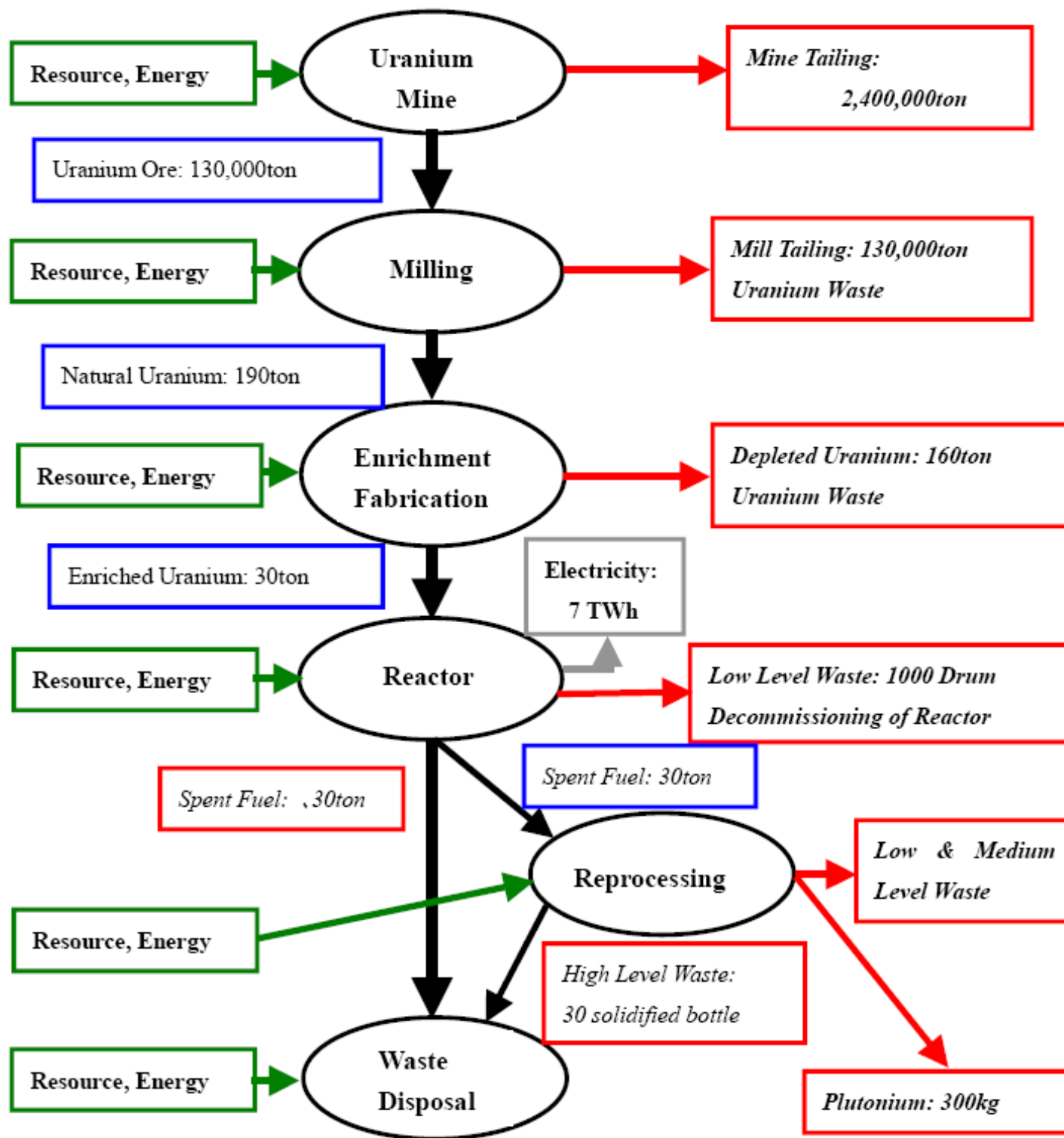
- In 1999, Russian nuclear plant workers attempted to sell 5gm of Nuclear waste.
- Again same year few workers were caught selling 4.5 Kg of enriched uranium.
- In 2003, 10Kg of enriched uranium was smuggled to Nepal from Hyderabad plant.
- Dirty bomb can be made using nuclear waste. It doesn't need any expertise and tons of waste is just lying unguarded.
- Even guarding nuclear waste will make it economically unfeasible as its transported through sea and road routes to far away places and its not possible to provide security in each and every point.
- Nuclear waste spread in any populated area or water body will cause large scale effect.
- Nuclear plant can be target of Ballistic missiles. It could cause radioactive material to spread in the near population areas causing long term disaster.

CFC pollution

- As discussed in earlier slides, UF_6 is an intermediate product in uranium extraction and enrichment.
- This fluoride is removed as CFC and gets leaked to atmosphere.
- After ban of CFC in refrigerants, enrichment plant in US is responsible for 93% of CFC release in air from US.
- Apart from ozone depletion, it's a potential green house gas, thousands times more potent than CO_2 .

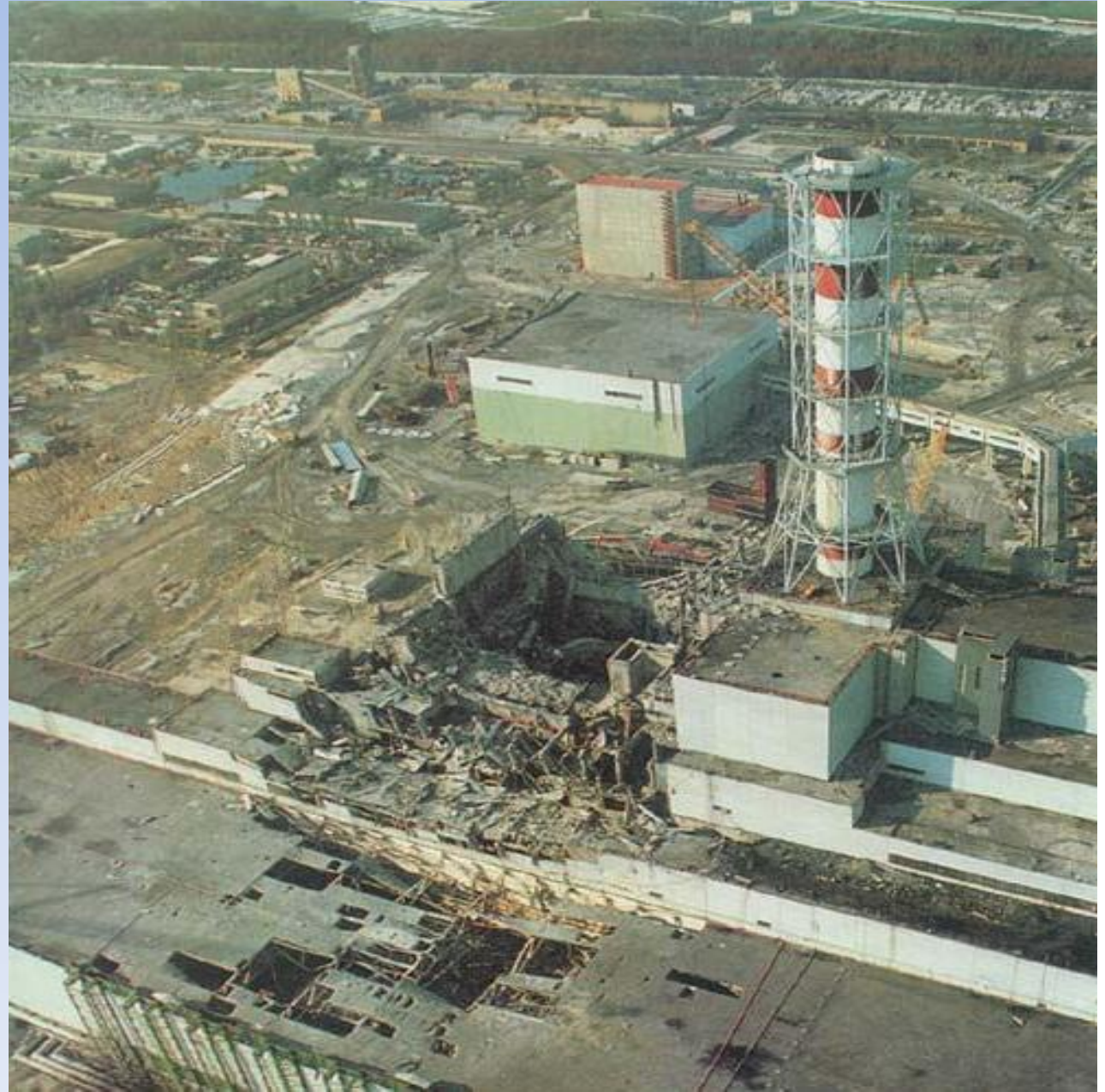
*Its not that **green**.....*

- The embodied energy in Nuclear power plant of 1GWe is on average **9 X 10¹⁶ Joules** (in Biomass based plant, its 6% only) and produces more than 4.8 Gtons of **residual** CO₂ (800 Gtons is current level ~ 0.6%).
- Apart from it, lot of energy goes into fuel processing and decommissioning process.
- Considering Carbon emission in manufacturing of plant, fuel mining, extraction and enrichment the net CO₂ emission is **1/3th of the gas fired power plant**, its not zero.
- In addition, it produces lots of radioactive waste also harmful to life.



Failure of Nuclear plant.....

- 26 April, 1986.....
..... two blast
in Chernobyl Nuclear
power plant and
thousands perished
to death.....





- Chernobyl was not the only nuclear disaster in history. There were many near-melt down and melt down of plants.
- India had experience one accident itself. During Tsunami in 2004, Nuclear power plant in **Kalpakkam** was hit and a wall was damaged. Though the damage was not much but it raise about the question of safety against dreaded natural calamity. India is planning for another Nuclear plant near Kanyakumari.
- After Chernobyl disaster, design were reviewed and corrected. But are we prepared for each and every disaster, especially in India which is a earthquake and cyclone prone area and has numerous fault zones?

Attitude of people/government

- Nuclear energy had sparked the hope in the society for unlimited power in future without addressing all the negative impacts on environment and society.
- European countries have electricity demand per capita less than 60% than that of US, but still people in both the region enjoy same level of comfort and luxury.
- Like other conventional plants, Nuclear power plant is also centralized plant. The loss in transmission and economy of providing power to remote and rural areas especially in countries like India, inhibits the power supply to them from central grid.

Attributes & Indicators of sustainability of Nuclear Energy technology

Society:

- Health
 - Miners/workers – Gen I & II
 - Near by residents – Gen I & II
 - Far away residents – Gen I & II
- Energy Consumption – Domestic
- Energy Consumption – Industrial
- Energy Conservation/Efficient use
- Employment
- Electrification – Urban
- Electrification – Rural
- Employment

Environment:

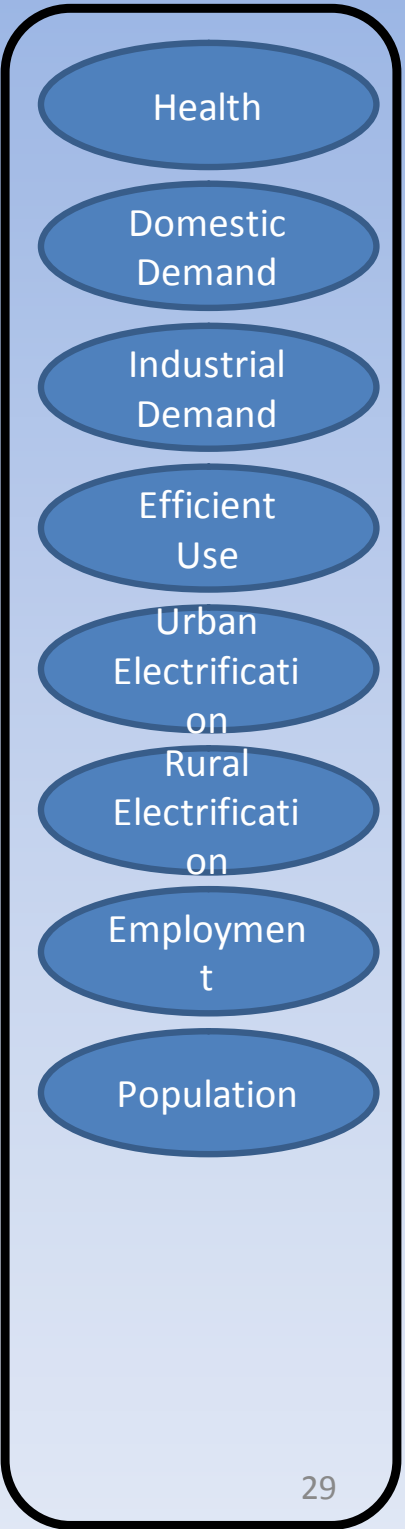
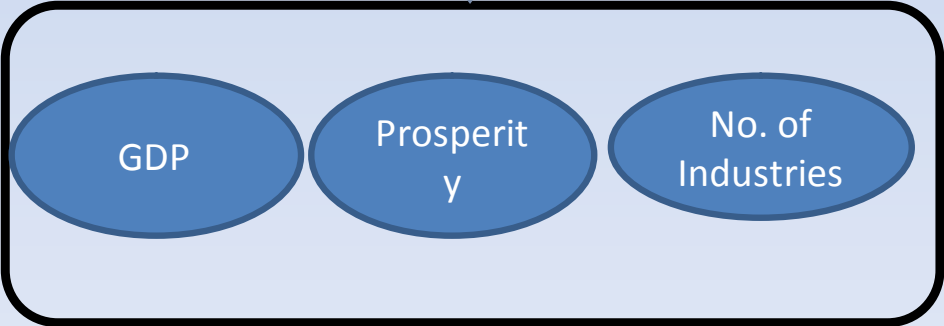
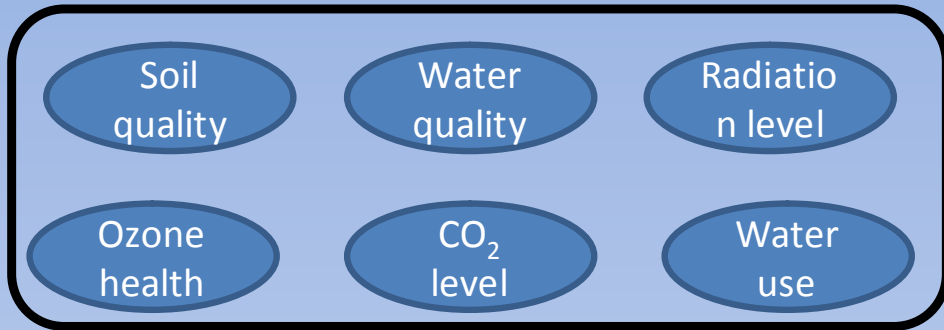
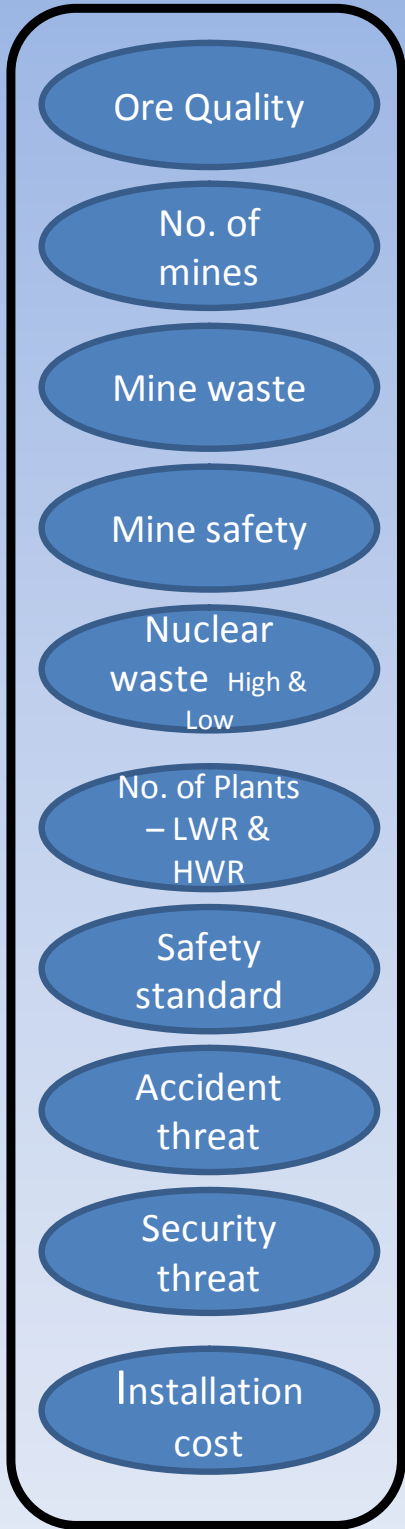
- Soil Contamination (Nuclear contamination)
- Water Contamination (Nuclear contamination)
- Radiation Pollution– Short term
- Radiation Pollution– Long term
- Ozone layer depletion
- CO2 level
- Quantity of water used

Economy:

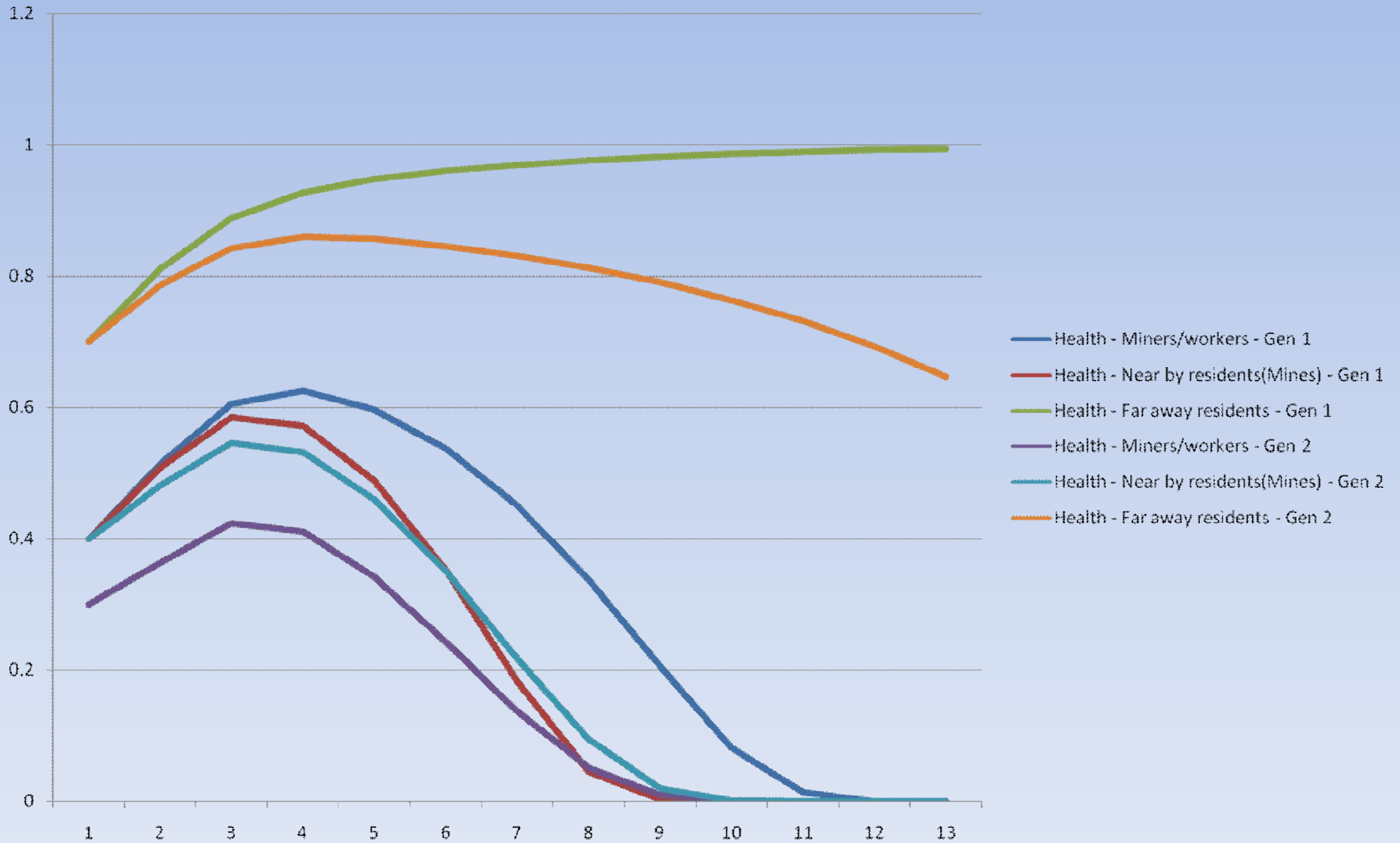
- GDP
- No. of industries
- Prosperity

Nuclear power plant:

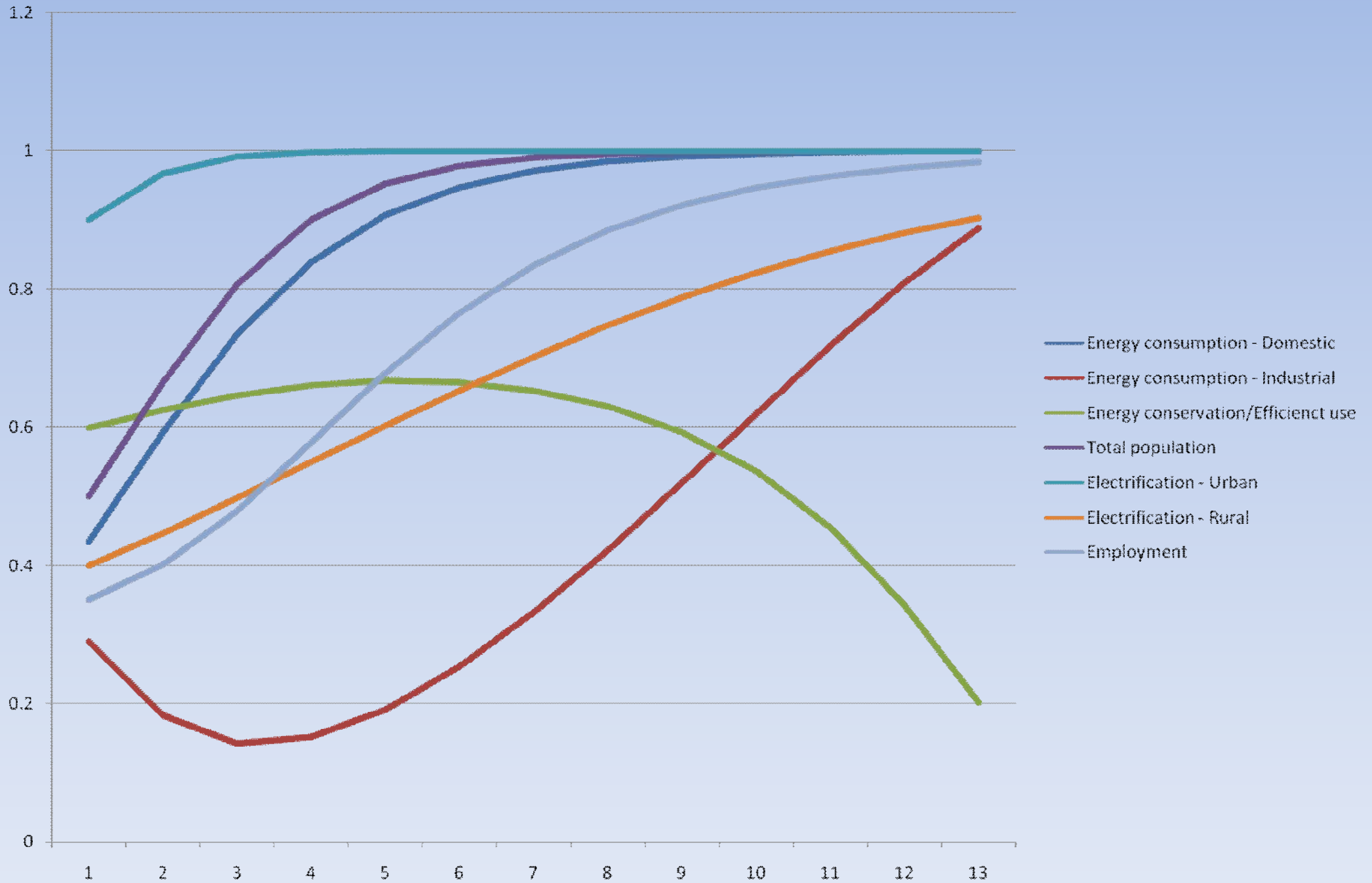
- Ore quality
- Mine safety
- Mine waste
- No. of mines
- Quantity of High level Nuclear waste
- Quantity of low level Nuclear waste
- Accident threat
- Security threat
- Cost of installation
- Safety standards
- No. of LWR
- No. of HWR



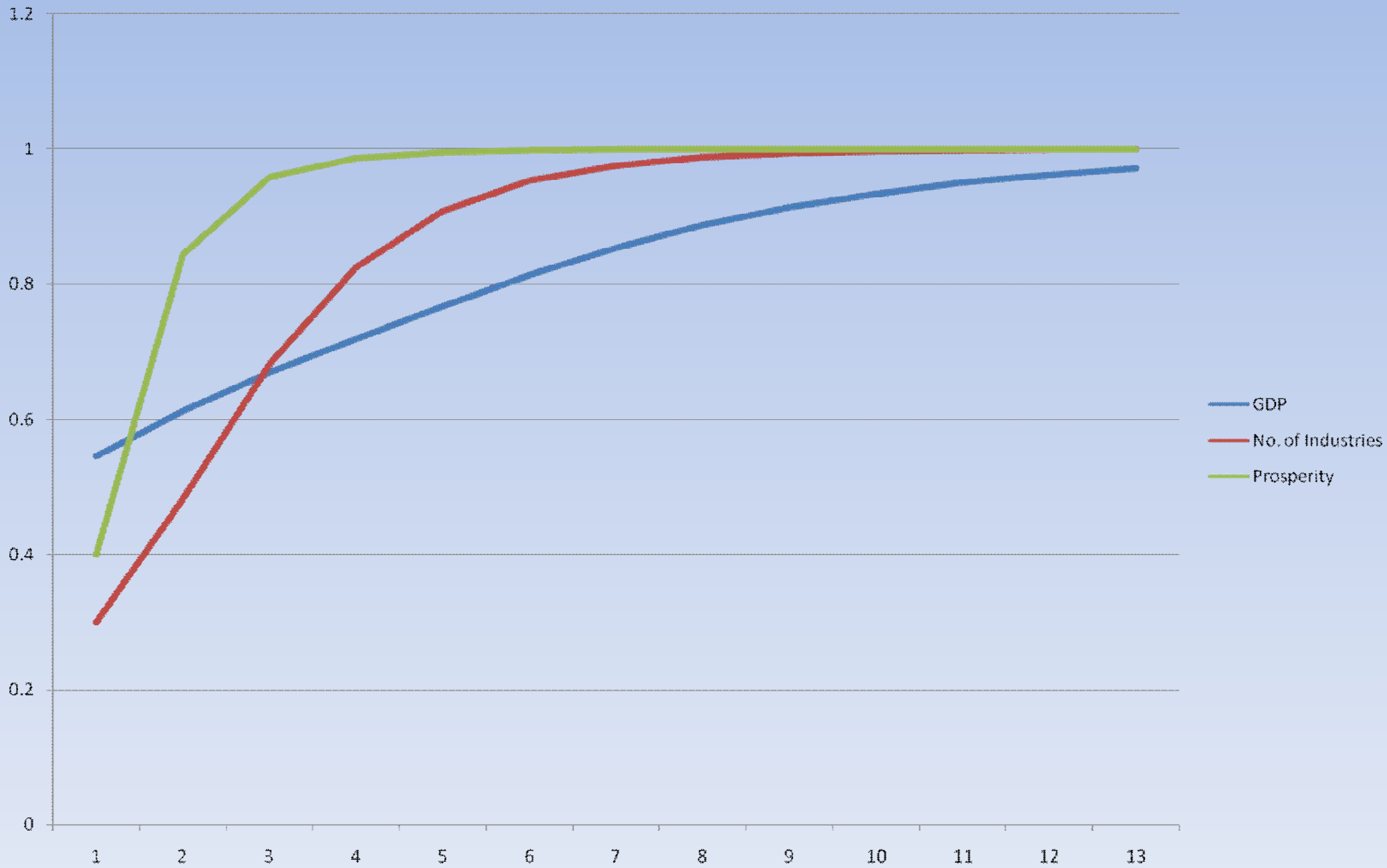
Society - Health



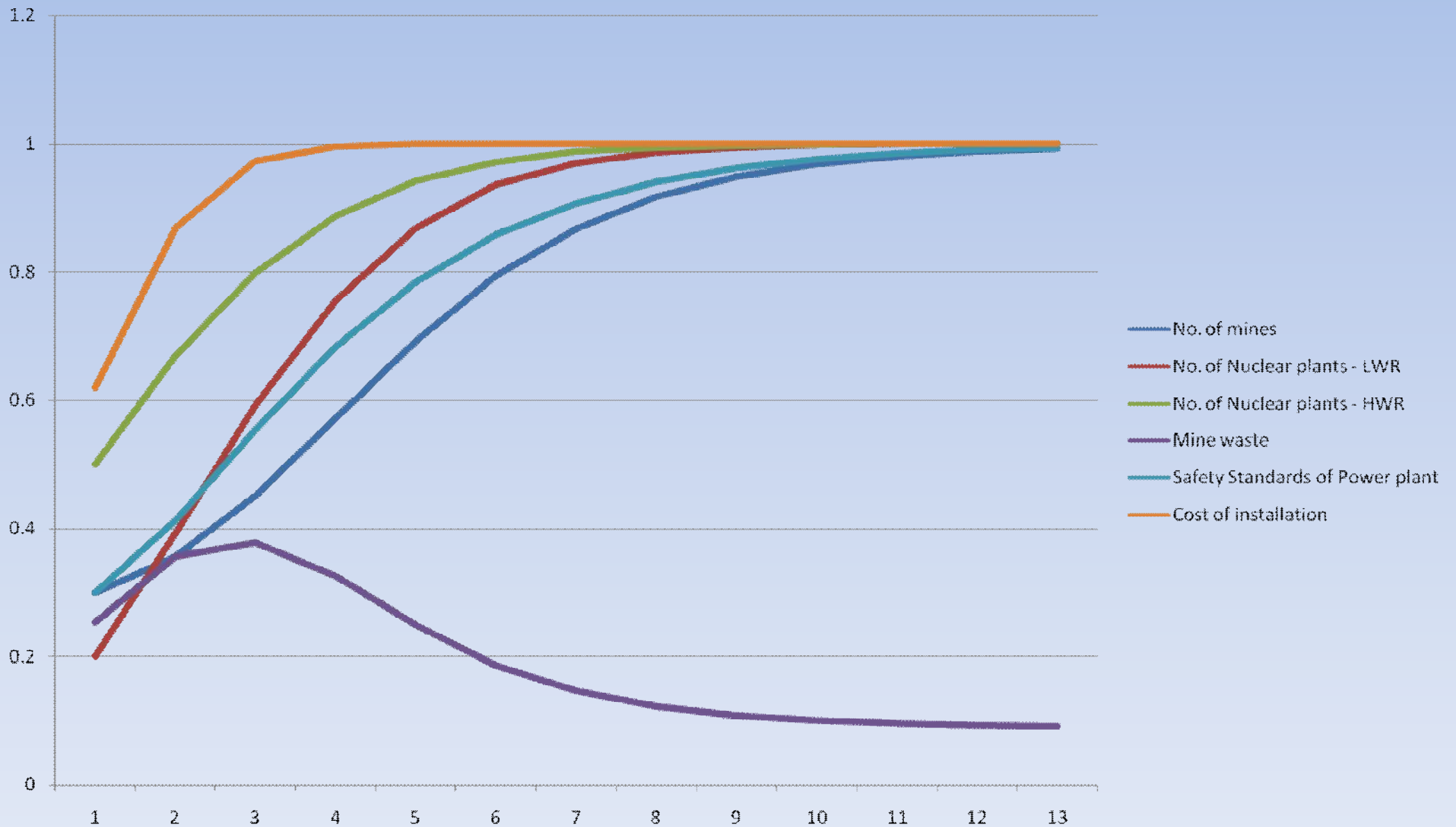
Society - Others



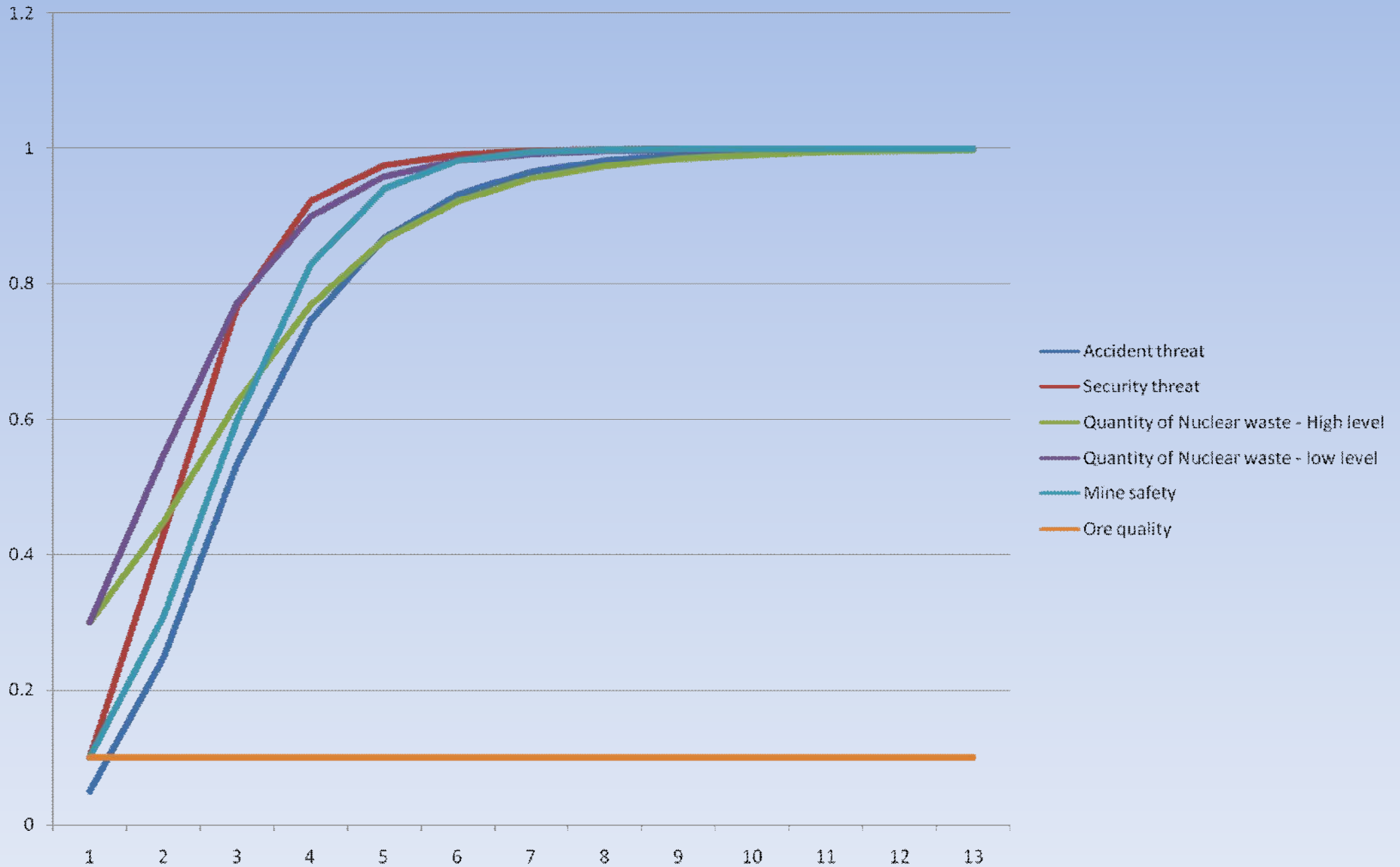
Economy



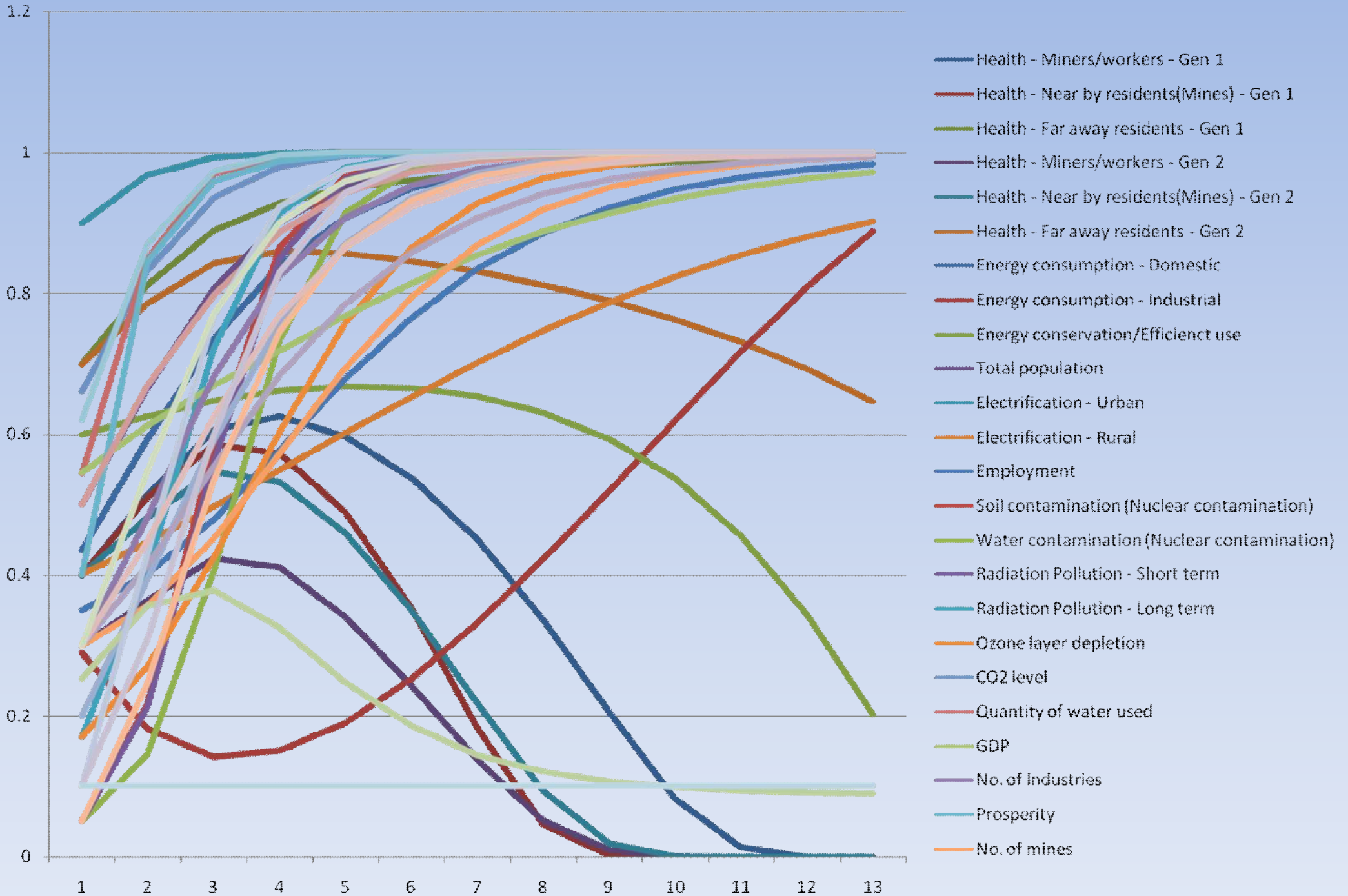
Nuclear Power Plant - I



Nuclear Power Plant - II



Complete Simulation Graph



Conclusion

- If we burn all fossil fuel, we will end up **doubling the CO2** level in atmosphere, definitely we need alternative.
- No doubt that Nuclear energy can provide the vast amount of energy to the power hungry world. But seeing to the negative impact of Nuclear energy on socio-political picture of world and no hard-core solution for radiation pollution and nuclear waste, we should be working on removing these challenges for providing sustainable energy source without creating inequity among societies.
- We should also be looking towards other non-conventional and renewable sources of energy to provide decentralized power and its benefit to the rural and remote areas.
- Initiatives should be taken within the society to reduce and efficiently use the available power. One thumb rule always be remembered, “ **No power will come free without its side effects on society and environment**”

Look above up the sky..... Giant Nuclear reactor is working nonstop for another 5 billion years giving energy to all..... Earth is providing enough shield from its harmful effect.....Go – Get it

