

# Review on the Grand Challenges for Engineering: A Framework for the Future

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## ABSTRACT

The paper presents the thrust research outcomes to solve the engineering grand challenges for the 21<sup>st</sup> century. Fourteen grand challenges were addressed and introduced in 2008 as a framework that capture the most immediate solution engineers need to address within the 21<sup>st</sup> century by the National Academy of Engineers. The grand challenges are grouped as 14 grand challenges in order to create focus groups. The fourteen challenges are comprehensively presented and a framework classification to identify our research directions towards societal purpose and value is presented.

**Keywords:** grand challenges, sustainable strategy, engineering solutions, grand challenges.

## 1. INTRODUCTION

The issues of sustaining civilization's advancements through improvement in the quality of life looms around this century as the population growth is challenged by nature and man-made scenario. This century poses challenges as formidable than in the previous era. Threats to personal and public health are on the high rise and it demand immediate effective for readily available treatments. Pandemic diseases, violence from the organized terrorist network, and disasters from the nature requires methods of protection and prevention as fast as possible. The products and processes that enhance the joy of living are of top priority through engineering innovation. Developing new sources of energy without degradation of the environment is the way forward for sustainability. As instant capturing that power from the sunshine through means that is affordable, storing it into useful forms in a provocative manner solve the power crisis engineering. However the major challenged lies is to make the whole of the energy capture to store to utilize in a formidable economically viable is a challenge need to be addressed [1-3].

Energy in long term is a vision of everybody and using fusion energy is a viable option with nuclear is already in place. However the developments suggest the goal of practical fusion power may yet be attainable. With both of the energy solution it remains unlikely to see to that the fossil fuels being eliminated from energy-source budget anytime soon, their environment-associated issues for engineers to address. The carbon dioxide put into the environment by the burning of fossil fuels is increasing the earth temperature and challenging climatic drastic. Technologic always of capturing the carbon dioxide and pushing it into the underground to convert to limestone is on the way as an engineering challenge. Another key chemical prevail that challenges the habitat in the environment is of nitrogen. The modern

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widespread use of fertilizers contributes to smog and acid rain and there by increasing the global warming. Countermeasure to solve the nitrogen cycle problems, while maintaining the ability of agriculture to produce adequate food supplies is need to be addressed at the least within this century. One major influence of the chemicals and the hydro carbon exposes is the quality and quantity of water, in many regions of the world is a challenging concern [1].

For a true and a balanced habitat it is necessary water must be available and sustainably provided to maintain quality of life. Desalination technologies in larger volume may be helpful, and for personal needs water purification is an option to look for. The direct impact of the water quality and the environmental concern is on the health of the person and of the society.

Modern medicines uplift the quality of the people in a larger stride however newer type of diseases that are deadly is booming and resurfacing and now medication needs to be more on the personalized approach. The biggest challenge is to use the medical technologies and methods towards the goal of personalized medicines. The process on administrating the personalized approach comes with the understanding how the body reacts to certain ways of reactions. Exploiting such information through methods that allow doctors to foresee the potential threats is a challenging aspect to be addressed. Through artificial techniques the replication on the function of the brain, to determine the benefits of helping treat diseases and also new approaches is the way forward to visualize this [1].

Utilizing the advanced computer intelligence, through automated diagnosis and prescriptions for treatment through health information systems improvise the effectiveness of different approaches towards prevention and therapy. Similar to that of the biological challenges in front of us bad is the violence from the organized terrorists network is another challenge to look into. Early detection for both the technological and the societal threats are on the pivotal balance in terms of the action required. The challenges in visualizing or foreseeing these through the utilizing the virtual realities tools is good to go aspects to solve or at least reach to a solution [2].

Equally are in no doubt being adopted for entertainment and leisure, furthering engineering’s contributions to the joy of living. The magnitude and the complexity in the addressed challenges may vary or none of these challenges be met within the period of time but the plans and the approach towards this would make

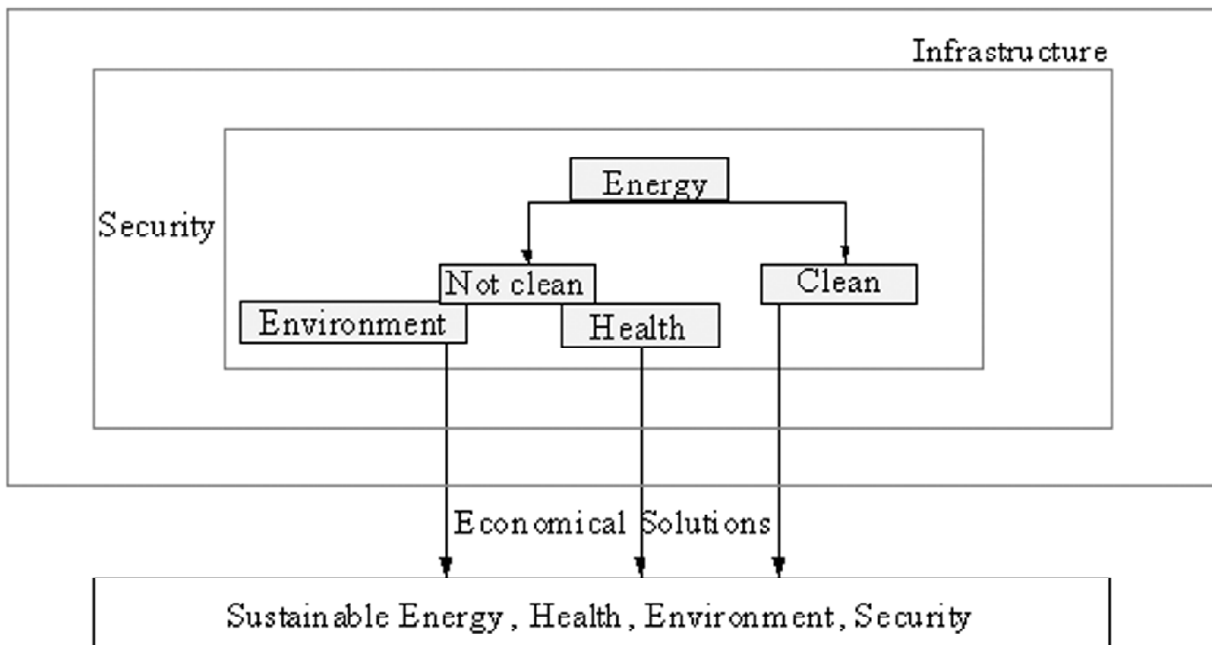


Figure 1: Grand Challenge Framework.

the earth to be sustainable more so it has more space to come up with solutions. The past engineering accomplishments make the world connected more inclusively and one day when we find a means to solve some of the engineering challenges we can make the world sustainable, safe, healthy, and joyous together with technologically merited place to live with [3]. Figure 1 shows the pictorial representation of the approach in the devising of the grand challenges in engineering.

## **2. ADDRESSING THE GRAND CHALLENGES**

Engineering today is no more to improve the quality of life but is essential to our health, happiness and safety shaping the future through the problem solvers. Addressing the grand challenges through various projects/works is presented here in an abstract approach.

### **2.1. Energy Revolution**

#### ***2.1.1. Make solar energy economical***

Solar energy is substantial—worldwide, solar electricity generation is a growing, multibillion dollar industry. But solar's share of the total energy market remains rather small, well below 1 percent of total energy consumption, compared with roughly 85 percent from oil, natural gas, and coal. Most often made from silicon, typically convert sunlight into electricity with an efficiency of only 10 percent to 20 percent, although some test cells do a little better. The challenging aspect is the efficiency percentage of useful energy conversion as more than half of them are lost as heat with the other drawback being material purity. Current solar cell designs require high-purity, and therefore expensive, materials, because impurities block the flow of electric charge. To make it more economical in standard cells, the impact of a particle of light (a photon) releases an electron to carry electric charge, but it also produces some useless excess heat. Lead-selenium nano-crystals enhance the chance of releasing a second electron rather than the heat, boosting the electric current output [4].

#### ***2.1.2. Energy from fusion***

Energy from artificial fusion here on earth is much more challenging than in the sun. In this principle the most advanced involves using magnetic forces to hold fusion ingredients together. It is still in experimental research with a huge built in thermonuclear experimental reactor in the southern France. This International Thermonuclear Experimental Reactor jointly developed by the United States, the European Union, Japan, Russia, China, South Korea, and India when in action would substantially support the clear energy slate but at least not in the nearest future [5].

### **2.2. Environmental Rejuvenation**

#### ***2.2.2. Develop carbon sequestration techniques***

Evidence is mounting that carbon dioxide's heat-trapping power has already started to boost average global temperatures as seen in the erratic climate variations since the past decade [6]. So it is imperative to capture the carbon and if possible convert it for some useful form. Carbon sequestration [7] is the technique for capturing the carbon dioxide produced by burning fossil fuels and storing it safely away from the atmosphere. One way which is more common is when atmospheric concentrations of carbon dioxide increased in geologic times to a certain unknown threshold; it went into the ocean and combined with positively charged calcium ions to form calcium carbonate – limestone. Enhanced oil recovery, in CO<sub>2</sub> is pushed into an oil reservoir to chemically mobilize hard-to-get hydrocarbons, making them easier to pump out. The injected gas is then either trapped in the oil reservoir or is “produced” while extracting oil and re-injected [8]. Combined heat power cycle is one of the solutions that could push the limit to rejuvenate as is the case reported in [9].

### ***2.2.3. Manage the nitrogen cycle***

The nitrogen cycle reflects a more intimate side of energy needs, via its central role in the production of food. Majorly nitrogen is from the burning of fuels and efforts to mitigate the agricultural disruption of the nitrogen cycle might have the effect of raising the cost of food, so such steps must be taken in concert with efforts to limit their effects on people living in poverty. Engineers are finding new ways to deliver nitrogen to plants in more sustainable ways. Global Positioning System (GPS) equipment to precisely apply fertilizer to areas that need it, limiting nitrogen runoff is one approach to reduce [10].

### ***2.2.4. Provide access to clean water***

About three percent of the planet's water is fresh, but most of that is in the form of snow or ice. Lack of clean water is responsible for more deaths in the world than war. About 1 out of every 6 people living today do not have adequate access to water, and more than double that number lack basic sanitation, for which water is needed. Desalination is not a new idea and is already used in many regions, particularly in the Middle East [11].

Israel uses desalination technology to provide about a fourth of its domestic water needs [12]. Modern desalination plants employ a method called reverse osmosis, which uses a membrane to separate the salt. Proliferation of clean water is a biggest challenging factor along with the food production is on the high as most of the countries strategies towards this.

### ***2.2.5. Restore and improve urban infrastructure***

The combination of fundamental systems that support a community, region, or country is the vision of a completed living community. Ways and means to modernizing the fundamental structures that support civilization with integrated approach combining energy, water, and wastes (liquid and solid) into "neighborhood" systems is in place as vision for most of the countries. The architectural issues involved in providing environmentally friendly, energy-efficient buildings both for housing and for business are a measure of the green building index of the community and the governments are subsidizing those. Resilient power systems, integrating different energy sources – conventional and modernized with protection, stability, control is the way the future smart city are being built around the globe [13].

## **2.3. Health Revolution**

### ***2.2.6. Advance health informatics***

Health informatics is about the acquisition, management, and use of information in health with the aim in improving the quality of care through the use and application of new technologies. A robust health informatics system would enable health professionals to detect, track, and mitigate both natural health and terrorism emergencies. Big data analytics are using the networked data to achieve this in rapid changes in medical and pharmacist field [14] just similar to that of the statistical used in other areas.

### ***2.2.7. Engineer better medicine***

With the nature of the disease are mostly derived from the existing one administrating personalized medicine is the future in healthcare. In the synthetic biology, a number of novel biomaterials are being engineered to replace or aid in the repair of damaged body tissues [15]. A healthy future for the world's population depends on engineering new strategies to overcome multiple drug resistances.

## **2.4. Security**

### ***2.4.1. Prevent nuclear Terror***

Preventing the terror especially through an organized network inclusive of challenges on securing the material, detecting at a distance, rendering a potential device harmless, emergency response, eradicate and cleanup, the public communication after a nuclear explosion and action against the cause of those and the

studies to avoid those. In the nuclear car wash gamma rays collide with atoms inside detector arrays, causing them to glow that is measured by the photomultipliers on the top and bottom of a cylinder when exposed with a neutron beam inside the cylinder [16].

#### **2.4.2. Secure cyberspace**

A number of serious breaches of cybersecurity in financial and military computer systems have already occurred and is costing a braking in enhancing the trust on electronic handling of finances. The major challenge on this is the decentralization and vulnerable to individual privacy. World Wide Web is now becoming worldwide meshing and hence the perimeter defense is highly critically [17]. A number of stages is placed in the transaction process so that the security is enhanced. All engineering approaches to achieving security must be accompanied by methods of monitoring and quickly detecting any security compromises which is highly challenging. Recent time the encryption is getting faster than decryption which is good direction in solving this challenge.

### **2.5. Learning and computations**

#### **2.5.1. Enhancing virtual reality**

Virtual reality is simply an illusory environment, engineered to give users the impression of being somewhere other than where they are. They are used treat people suffering from certain phobias, and for serious simulations, reproducing sensations of sound, touch, and motion. The challenges of virtual reality research is identifying just what level of detail is necessary for a user to accept the illusion, in other words to respond to virtual events and simulations in a realistic way and is used in mainly in entertainment and in estimation logic [18].

#### **2.5.2. Reverse engineer the brain**

Artificial Intelligent (AI) systems attempting to replicate human abilities, such as vision, are now being developed with more, and more complex, connections. AI algorithms used in speech recognition and in machine vision systems in automated factories. A neural prosthesis [19-20] in the form of cochlear implants is used to treat hearing loss. Success toward fully understanding brain activity open new avenues for deeper understanding of the basis for intelligence and even consciousness, no doubt providing engineers with insight into even grander accomplishments for enhancing the joy of living.

#### **2.5.3. Advanced personalized learning**

Under different conditions, people might even switch their preferences, preferring examples in some contexts but questions in others in learning process. Web-based education systems, MOOC [21], creative commons, open source are some of the modern days used in personalized learning [23]. Ongoing research in neuroscience is providing new insights into the intricacies of neural processes underlying learning [24].

#### **2.5.4. Engineer tools for scientific discovery**

Nature is a wonderful engineering happening and inspiring it to solve engineering challenges is happening [1]. Use the micro wave approach it is possible and exploring the cosmos, with space mirrors in orbit reflect sunlight onto huge solar panels, and the resulting power is beamed down to Earth [25].

## **3. CONCLUSION**

Engineering grand challenges framework is introduced based on the NAE guidelines. With the approach towards improving the sustainability and improve the quality of life it is important for the engineers to address and find out economically feasible solutions as early as possible and it is seen that considerable effort and outcomes in this direction would help to realize it within this century.

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