Critical National Need Idea

Title: A New Generation of Thermal Insulation by Affordable Manufacturing

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A. Surge in Energy demands is threatening national security and the global climate

Economic growth has long been correlated with increasing energy demands. The major theme of the industrial revolution is to replace manual labor by use machines powered by fossil fuels. With the drastic improvements in manufacturing and in other supporting technologies, people began consuming even more energy to upgrade living standards. Our nation consumes 100 quadrillion BTU annually at a cost of $ 4-8 billion per quadrillion BTU. Our energy consumption is approximately 33% industrial, 21% residential, 18% commercial, and 28% for transportation. In a developing country, besides its high growth in industrial production, the simultaneous energy consumption growths in the other three sectors would account for significantly higher demands in energy supply. The high growth in energy consumption per capita, plus the sizes of their population, is the main reason that both China and India are demanding considerable fossil fuel resources.

Because more than half of our world's populations are suddenly demanding so much more energy, a short supply of energy could immediately trigger economic and social chaos. Energy supply has become a national security issue because a shortage threatens the stability of a country. Although no nations dared using military force to seize energy resources yet, the importance of energy to the economy and our daily life would suggest that many nations would consider using force to deal with a serious energy shortage emergency. Thus, the global energy needs should indeed be addressed as a global security matter.

A second emergency related to surge in energy consumption is its impact on global warming. Green house gas emission has been increasing at alarming rates. Although there have been many alternative energy ideas that might, in the long run, alleviate our demands in fossil fuels, they currently lack of the economic scale to compete with crude oil. Even when their scales reach the level of fossil energy, they may not completely reduce the burden on our environment and the seriousness of climate changes. No matter what energy form we choose to do work, thermodynamics dictates that more heat is released to the environment. In the long run, the only solution to our excessive energy use is by conservation. To save the global climate will require a worldwide shift in political to renewable energy, with new ways of living, and a human scale that matches the atmosphere's limits. Energy conservation should play a greater role part in this shift. Although energy's supply, price, and stability could all make strong arguments in support of energy conservation, climate change may be the most significant game changer keeping us on conservation path despite fluctuations in the energy market [1]. We need an "energy diet" to restore our environmental health, and the effort, similar to food dieting, should not be dictated by price. Among all energy efficiency technologies, advanced thermal insulation stands out as the one that could reduce energy consumption most effectively and at the largest scale [2]. According to report of Texas Utilities, utility plants require $1,500 per KW investment for fossil-energy plant, and $4,500 per KW for nuclear power plant. On the other hand, using insulation to save 1-KW would require only $125 investment. For developing countries desperately needing more electricity, investing in insulation is more sensible than new power plants because it simultaneously reduces power demand and gas emissions.

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[1] Chemical Engineering News, November 10, 2008, pp 32-34

[2] U.S. Greenhouse Gas Abatement Mapping Initiative: McKinsey and Co. 2007

We, as a country, had a serious run on becoming energy independent since the 1973 oil embargo. Since that effort, the introduction of smaller cars, higher energy codes of new appliances, and even limits on driving speeds as well as thermostat settings, have slashed energy intensity (energy used per dollar of GNP) by 27%, and cut $160 billion a year from this country's fuel bill. Unfortunately, that effort was only short lived. The continuous low oil price in more than 20 years had suffocated any further desire of being energy efficient. Even worse, most economists and policy makers agreed on growing the economy by stimulating consumption, with any conservation regulations often perceived as a restraint on economic growth.

This concept of growing the economy by finding and using more energy is wrong. In fact, energy inefficiency, and excessive energy consumption, in the past twenty years helped create the deep hole that our economy is in. Energy imports were an irreplaceable portion of the nation's trade deficits. Our dependence on foreign oil further paralyzed our economy when the oil price skyrocketed last year. At present, our energy consumption per GDP dollar is two times of that of Germany and three times of that of Japan. By applying new technologies to increase our nation's energy efficiency, we can altogether reduce our trade deficits, increase our competitiveness, and revitalize the national economy.

Advanced Insulation Technology could substantially improve our energy efficiency

Present insulation technology is almost 70 years old. It came around when the industrially processed low-density materials replaced the first generation, natural insulation such as cotton, wool, cork, and asbestos. Since the entrapped, quiescent air is the best insulating medium, lower density materials are better insulations. Second generation products achieved improved R/inch values at greatly reduced costs using synthetic materials of densities lower than natural insulations. These products include materials such as fiberglass, loose-fill cellulose, rubber and plastic foams, and other man-made porous substrates. The 2nd generation approach, however, had soon reached its limit because additional air inclusions compromised mechanical strength and, in fact, degraded insulation value due to more radiation heat loss through transparent air pockets.

This deadlock was seemingly disappearing with the emergence of nanotechnology. Modeling results had demonstrated for some time that making pore size close to, or smaller than the mean free path [3] of air, ~ 100 nm, could substantially reduce the thermal conductivity of the pore-entrapped air. Since a good insulation contains more than 95% air, the lowered air thermal conductivity would lead to a new generation of nanopore thermal insulations.

Between 1992 and 1995, a $4.5 million project supported by the Advanced Technology Program [4] demonstrated the feasibility of this new technology. The table below lists data of nanopore insulations in comparison with conventional fiberglass insulation.

[3] Mean free path: the average distance traveled by a molecule between two consecutive collisions.

[4] "Thermal Insulation Materials-Morphology Control and Process for the Next Generation of Performance", ATP award to Armstrong World Industries, Inc., 1992

Insulation Material	Thermal K (mW/M •°K)	R/inch
Fiber Glass	45	3.2
Granular Silica Aerogel	23	6.3
Aerogel with Layered Silicates Panels	16	9
Inverse-Emulsion Composite Panels	20	7.2
Aerogel-Polymer Microcomposites	17	8.7
Inorganic-Organic Composite Aerogel	13	10.5

However, it turned out that this approach solved only half of the problem. Because of the combination of extremely high porosity and the unprecedented small pore size, these nanopore insulations required very complicated processing schemes. Even up to this date, the processing complexity and consequential lack of mass production have remained as the biggest hurdle for commercialization.

For a good insulation with 95% of air and low solid content, the processing costs become the dominant factor in the performances/cost equation. Most nanopore insulations were made by a liquid sol-gel process and must be dried with supercritical CO_2 to preserve the fine pores. The drying process is a batch process, capital intensive, and extremely slow. If we can manufacture this new generation of thermal insulation by a process competitive to current insulation production process, such as gas foaming, or reactive extrusion, the new technology could be broadly applied and contribute appreciably to energy savings in every sector of our economy.

Because of the rising costs of buying and consuming energy (carbon taxes), the competitiveness of a future industry will no longer be measured only by manufacturing speed. Rather, it will be measured by how efficiently the energy is used in making a new product. Using super thermal insulation would be the most effective way of accomplishing this goal. Since most insulation has very long service life, installation of super thermal insulation could be the most sensible investment of increasing an industry's productivity (in terms of per unit of energy). If we, as a nation, would fully commit to energy conservation, we could, even in an energy crunch time, substantially grow our economy, maintaining environmental stability, and not compromising our national security in the long run.

With the development of the third generation of thermal insulation, we could see insulation material with resistance value (R-per-inch) several times higher than traditional insulation materials. However, this alone may not be enough to drive the energy efficiency trend, unless we are totally relying on government regulations. Customers are always motivated best by higher investment returns. Installation of thermal insulation is indeed a sound investment because of the immediate payback from energy savings and especially if we can keep the cost low. Lower insulation costs, combined with rising energy expenses, would automatically expand the efforts in energy efficiency. Super insulation is also cheaper to transport and also can increase the service life of heating and refrigeration equipment.

The super thermal insulation technology could be applied to all three major energy consumption sectors, Industry, Transportation, and Buildings. That is why it would be the

technology with the biggest scale of energy savings. In future, the super insulation technology and the solid-state lighting technology could jointly reduce our nation's energy consumption far below what it is now. There are currently no other technologies that could accomplish such a big impact in terms of dealing with energy disasters. Even more promisingly, with the advancements of Nanotechnology in so many different fronts, we could really see some breakthroughs leading to the most advanced thermal insulation technology ever.

B. Maps to Administration Guide: Creating a New Segment in Future Economy

Using advanced technology to improve our energy efficiency and conservation will greatly improve the strength of our economy. With proper planning and swift actions, this trend of conserving energy and material resources could, by itself, create a new industry segment in future economy and society. For a societal change of this magnitude, Government's leadership would be an indispensable part of the total effort.

The Kyoto agreement has set specific time lines to control total CO_2 emissions of each country. In the future, industrial growth would be severely limited by the emission quota allowable to each economy. Thus, energy efficiency becomes the lifeline of future industrial productions. Many industries, especially those in the developing countries, were not designed for efficient use of energy. A super thermal insulation would be extremely valuable to future industries because it could directly increase their energy efficiency and thereby their competitiveness. Future competitiveness of an industry will be measured by its energy intensity, i.e. energy consumed per dollar of product. Super thermal insulation will become an integral part of reducing the production costs, especially for those energy intensive processes.

An important mission in trying to avoid energy disasters would be to educate policy makers as well as the general public, the value and importance of becoming energy efficient by using advanced insulation technology and other efficient measures. In fact, because of our revolutionary developments of the information, computing and micro-controlling technologies, we could now more effectively accomplish energy efficiency. (For example, it is possible to use our electrical grid system to monitor and alarm the unusual energy consumptions at any specific location on a grid.) Once the public know how easy and how effective energy conservation could help trim their energy budget and protect our environment, there would be many innovative energy-controlling technologies being invented and implemented in residential houses, commercial offices, and industrial factories to accomplish the smartest ways of energy utilizations.

The desperate needs of conservation, both in energy as well as many other material resources (petroleum chemicals and precious metals), are signifying a gradual transformation from the current industrial economy to a more efficient and intelligent "digital economy". The key element in the current industrial economy was the huge power generated by using cheap energy, while in the future economy; it would be the combination of using sufficient power with sophisticated controls by artificial intelligence. Advanced computing and controlling technologies would allow us to improve efficiencies in every possible way. A product's profit would never be dictated by just how fast it is being produced. Rather, its value would be judged by the ultimate efficiency standards, which would include the optimization of material and energy uses during production, and the perfectly designed scheme of recycling after the service

life. Digital microprocessors already revolutionized the efficiencies of information transfer, storage and processing, and could make an even bigger impact in improving efficiencies of using energy and material in our future economy.

These new technology developments could deliver us from the old industry economy to a new intelligent digital economy. An economy that every material and energy resource are being efficiently produced, smartly utilized and diligently recycled so that every generation could proudly pass along to the next a world with better environment and living conditions. Our current energy problems can be completely solved if we dedicate adequate resources (for R&D in new technologies) in the short term and maintain the right attitude (Energy diet) for the long run. We need to do a lot of work to correct the attitude towards efficient energy use. But it will happen because of the need. Even in late seventies, people were still ignorant in dieting and exercising. The concept of energy dieting will be fully accepted once the public are properly informed and educated. With science and technology being advanced at a rate never seen before, we could definitely reverse the current trend and restore our global environment and economy to a harmonious state.

C. Justification for Government Attention

Energy is the single, most important security concern of the nation. Because of the price fluctuation and threat of global warming, energy efficiency and independence have also become the lifelines of our economy. We cannot unwind thirty years administration and economic policies without Government's intervention. In fact, the current Government bail out plan of our economy could be utilized to accomplish the goals of energy independence and efficiencies.

It will take more than finding alternative energy sources to accomplish our energy independence. It is appealing to create a whole sector of alternative energy industry to replace foreign imported oil and lower our trade deficits. However, this approach takes a long time to reach the scale required for replacing foreign oil and the economy of scales could not all be created by subsidization. Super insulation technology (and other meaningful technologies to conserve energy and material) provided the best supporting technology to accomplish efficiency and independence.

The nation should quickly establish a Center of Advanced Thermal Insulation Technology, either by the Department of Energy (DOE), or by an alliance of the insulation businesses. Thermal insulation is a technology with substantial benefits to our environment, economy and energy security. Foreseeing the huge energy demands from both China and India, and the subsequent price hike and emission regulations, we can no longer delay this investment of inventing new insulation technologies. DOE should commission one or two of the national laboratories to support the development of the next generation of super thermal insulation technology, with a determination matching that of the Manhattan Project. The technical tasks would be much simpler and easier than the invention of our first atomic bomb. The broad and deep impacts of the super insulation technology would more than warrant a national effort of this magnitude. Funding from TIP to initial projects in this R&D direction could jumpstart the interests of the technology community.

D. Essentials for TIP Funding

Most insulation businesses in this country are either hampered by the class action lawsuits filed on behalf of asbestos victims, or by the depressing housing market further weaken by the credit crisis. Thus, there will be almost no investment in R&D of advanced insulation technology in foreseeable future. Venture capital funds normally treat Insulation Technology as a low level technology and lack of interests in inventing into this field.

TIP funding to Advanced Insulation Technology could serve as a nucleating mechanism to germinate this field. Should a few projects demonstrate the feasibility of making super thermal insulation by processes much cheaper than current supercritical drying process, the business community would immediately recognize the value of this new development. The progress will attract more venture capital funds and equity funds for the next round of business development.

Advanced Insulation Technology, although focused on reducing heat transfer, is a fundamental platform technology of producing nanostructured material at low cost. TIP's funding in this field is likely to create many more spin-off technologies of producing nanopore composites at much lower costs. These materials can be used beyond insulation for water treatments, opto-electronic materials, and biomedical applications.