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EDITORIAL

Careful with your energy efficiency program! It may 'rebound'!

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In May 2013, for the first time since its inception in 1950s, Mauna Loa Observatory, on the island of Hawaii, observed that the daily average of atmospheric carbon dioxide concentration exceeds 400 parts per million. It may be a small concentration in atmosphere, but it plays a significant role in dictating surface temperature on earth. Earth receives radiation from the sun and a significant portion of it is reflected and reradiated back into the space. A portion of the total radiation is absorbed by the atmosphere. To reach an equilibrium for the earth's climatic condition, the absorbed solar radiation should be in exact balance with radiation emitted to the space. In climatic science, externally imposed perturbations that disturb this balance are collectively known as *radiative forcing*. Carbon dioxide, a greenhouse gas, is one of the main culprits for global warming or increase of average temperature on earth's surface through radiative forcing. Global warming may have severe impact on earth's climate such as change in precipitation patterns, expansion of deserts, frequent occurrence of extreme weather conditions, and rise of sea level.

Carbon dioxide is not completely unwanted; rather it is essential to support life on earth. Carbon is exchanged between the different zones of overall earth's ecosystem through a sequence of events. Balance in every steps of this carbon cycle is essential to sustain life on earth. Post industrialization, carbon cycle is altered primarily due to anthropogenic impacts or impacts due to human activities, particularly due to unplanned deforestation and unrestricted use of fossil fuel. To de-carbonize our atmosphere (i.e., to remove excess carbon dioxide), the whole world has agreed to improve energy efficiency, improve energy conversion efficiency, and utilize low-carbon and renewable energy sources. Nuclear energy faces public resistances, especially after the 2011 Fukushima disaster; renewable energy systems face challenges such as low energy density, high initial capital investment, and relatively poor reliability and availability. In the interim period, efficient utilization of energy and energy conservation poised itself as a realizable target to de-carbonize energy system.

Improving energy efficiency and conservation of energy in commercial, industrial, and residential sectors can reduce overall energy requirement significantly. Other than reducing carbon dioxide in atmosphere, it offers significant economic benefits. In industrial practices, reduction of energy requirement for a given production is known as *energy management*. Increase in production by maintaining the energy requirement is known as *debottlenecking*. Energy management or debottlenecking can reduce the operating cost and lead to significant financial incentives. Furthermore, various energy efficiency measures provide other benefits such as improved energy security and reduction of peak demand. But energy efficiency programs are also not free of concerns.

Suppose, a 15 W energy efficient compact fluorescent bulb replaces a 60 W inefficient incandescent bulb; 75 % reduction in energy consumption is expected. Now user of the new bulb realizes that operation of the lighting system is much cheaper and starts using it more. Thus, realized energy conservation is much lower or a portion of energy saving is 'taken back.' Increase in energy efficiency leads to extra available income for consumers to utilize it more. For example, increase in efficiency of cars may lead to

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more driving and ultimate increase in gasoline consumption. On the other hand, availability of fuel efficient car may imply that people may drive to their work place in their own car, instead of taking public transport. These two are examples of direct effect on increase of energy requirement. There are indirect effects such as requirement of more energy to produce energy efficient devices or systems. This phenomenon is known as *rebound effect*. Sometimes the effect is more drastic and it actually increases the overall consumption (i.e., 'backfire'). In the book, The Coal Questions, British economist and logician William Stanley Jevons argued that the invention of a more efficient steam engine should have reduced overall coal consumption. However, the reality was completely different. He observed that due to availability of coal to many users at a much lower cost, overall coal demand and consumption were increased significantly. This is popularly known as *Jevons paradox*.

Energy economists are divided on the influence and extent of rebound effect on energy efficiency program. However, it should not be completely neglected. It is expected that some measures may lead to modest take back and some may lead to significant backfire. It may even be possible that some energy efficiency measures may lead to negative rebound with reduction in energy requirement more than the efficiency measures. We need to identify these measures. Along with this, we need to practice sustainable life style with demand conservation.