GROWTH MODEL

Structured approach needed to shift from hydrocarbon to biomass based economy: Dr. Sivaram

The transition from a hydrocarbon based economy to a sustainable biomass based one would be fraught with known and unknown risks, according to Dr. S. Sivaram, Director, National Chemical Laboratory (NCL), Pune. However, he said that it was imperative to shift to a renewable carbohydrate based economy from the present dependence on diminishing non renewable hydrocarbons for ensuring a more sustainable planet.

Dr. Sivaram was delivering the 43rd Founder Memorial Lecture 2007 at the Shriram Institute for Industrial Research, New Delhi.

Carbohydrates or biomass produced by nature, through the process of photosynthesis, is believed to be the most abundant renewable resource on the planet. However, there are considerable challenges in building a carbohydrate based economy — viz. technological, logistics, land use competition and sustainability.

Biomass and materials manufacturing

Energy and materials can be generated from biomass resources such as food crops, primary and secondary agricultural residues (grass, reeds, straw, husk, bagasse etc.) and energy crops (like rapeseed, jatropha, sugarcane). According to Dr. Sivaram, the global production of fossil fuels (oil and coal) far exceeds biomass production in agriculture and forestry. However, only 5-10% of total annual production of fossil fuels is currently used for the manufacture of materials, like plastics, fibres, rubbers and bulk chemicals. "Thus, carbohydrate resources, derived from forest residues, agricultural wastes and residues as well as non-food crops can play a major role as renewable feedstock for the production of materials and chemicals in the future," he said.

Shift to carbon-neutral energy resources and its impact

The need to tackle carbon dioxide emissions and consequent climate change impact was also addressed by Dr. Sivaram. "Global energy consumption is expected to more than double during the 21st century. If one has to restrict carbon dioxide emissions to 2 billion tons of carbon per year by 2100, the requirement of carbon-neutral energy resources will have to grow to levels several times the present fossil fuels use," he stated.

Of the several carbon-neutral energy resources, like bio-energy, hydrogen, solar, wind, nuclear and fossil fuels with carbon capture and sequestration, bio-energy is relatively less expensive and ranks as one of few technological options capable of tackling climate change. However, supply constraints in biomass will mean that more expensive carbon-neutral energy sources will have to be deployed.

The NCL chief then spoke about the possible impact on the food chain. With energy being more expensive than food, he highlighted the possibility of farmers shifting to crops for bio-energy applications. This, in turn, will push up land and food prices, he noted. "The socio-economic consequences of higher land values and higher food prices are complex and unpredictable," he said and listed some of the concerns like conversion of biodiversity rich ecosystems into monocultural biomass plantations; prime cropland being used for bio-energy plantation, etc.

As regards the impact of increase in food prices, he said that in a world with unequal economic development, a large bio-energy demand in one part of the world with strong paying capacities may adversely impact food security and availability in another past of the world. "Diverting food crops to energy application is not sustainable," he asserted.

According to Dr. Sivaram, the complexities involved meant that the transition to more sustainable energy and material systems would not be easy or short. "There are formidable technology challenges. Also such transitions do not occur by themselves. Every nation has to have a strategy and a vision for such a transition," he said.

Investment initiatives

He highlighted the initiatives taken by several industrial nations and companies for replacement of fossil fuels as energy resources and material feedstock. Royal Dutch Shell's investments of US$1.25-bn in the last five years on renewable energy, Chevron's US$200-mn since 1999, Exxon-Mobil's commitment to contribute US$100-mn to Stanford University over a period of ten years on

research into carbon-neutral energy resources, BP's investment of US$1-mn on renewable energy were among the initiatives mentioned. However, he said that the investments were "still only a small drop in the ocean".

Speaking about the investments in bio-fuels, Dr. Sivaram informed that total equity investments in this area were US$2.6-bn over the nine-month period from the final quarter of 2005 to the third quarter of 2006. Currently, 10% of the global investment in energy is devoted to bio-fuels and is expected to increase to about 15% by 2010. Several nations have stepped up public funding to this area during the last few years.

Road map for transition: Careful consideration needed

He noted that the search for alternatives to fossil fuels had reached a point of inflection driven by technical, economic and geopolitical considerations. The rising investment in R&D in this area is likely to throw up many solutions and options, he added. "However, every solution must be evaluated based on rigorous and careful considerations of sustainability, as well as impact assessment," he warned.

"Utmost care must be taken while defining strategies for meeting the burgeoning fuels and materials needs of humankind. Long term sustainability issues must be assessed with a clear road map for transition. Short term solutions based on expediency or narrow stakeholder interests must be avoided. If these pitfalls are not avoided, this generation will be held responsible for causing greater damage to the global ecosystems, in many ways yet known, compared to what is attributed today as the ill effects of a fossil fuel based economy," he said.

Technology imperatives

The large scale shift in resources would, according to Dr. Sivaram, need total integration of innovative plant-resources and other bio-resources, synthesis of biomaterials and generation of bio-fuels and bio-power. "This will require careful orchestration of many disciplines of science and technology, like plant biotechnology, fermentative & enzymatic processes, chemical catalysis, novel separation processes and chemical engineering," he added.

Increasing global productivity of biomass would depend on identifying the fundamental constraints in productivity and addressing those constraints with modern genomic tools. "There is an urgent need to look for perennial plant resources as a source of feedstock for energy and materials," said Dr. Sivaram. The next generation of energy / material crops having desirable traits for use in modern bio-refinery operations will emerge from a fundamental understanding of plant sciences and genetics, he added.

Bio-refinery dynamics

By exploiting new chemical, biological and other related technologies, the biorefineries of tomorrow would be able to expand the use of renewable plant based materials, as well as transition it to a more energy-efficient and environmentally-sustainable chemical and energy economy, noted Dr. Sivaram. Just like fossil resources based petroleum refineries, bio-refineries will need to exploit economies of scale and efficient use of all products and by-products. Bio-refineries are expected to work on similar lines to a typical petroleum refinery where about 5% of the output goes into the manufacture of chemicals and materials and rest is consumed as energy and transportation fuels. "In a bio-refinery operation, high value chemicals present in the biomass such as fragrances, flavouring agents, high value chemicals, etc. will be first extracted. Thereafter, the carbohydrates will be transformed to building block chemicals containing two to six carbon atoms. Subsequently, the residues will be used for the generation of bio-fuels. Streams that cannot be used for either chemical or bio-fuel conversion will be used to produce other forms of energy like steam, electricity or both," informed Dr. Sivaram.

Technologies that would be critical for the bio-refineries will include improved ligno-cellulosic fractionation and pre-treatment methods, novel reactor designs for conversion of renewable feedstock, improved catalysts and application of novel separation processes.

Challenges ahead

"It is necessary to develop a vision of such bio-refineries, depending upon the local sources of feedstock. To gain economies of scale, they need to be large in size and centralised like the petroleum refineries of today," he said. Advanced bio-refineries will be a converging point for plant genetics, bio-chemistry, biotechnology, biomass conversion chemistry, and process engineering and separation technology.

"This will call for creative partnership between companies dealing with fuels and energy, as well as chemicals and materials with enterprises managing agriculture, agro-marketing and food chain. Traditionally, these businesses have stayed far apart. Therefore, new synergies and culture will have to be evolved," noted the NCL chief.

Traditionally, governments have had a greater say in agriculture, through direct subsidies, tax incentives, as well as political engagement, whereas chemical, materials and fuel industry are largely deregulated and function in a market driven economy. "The convergence of these two sectors can be expected to lead to conflicts and tension, which needs to be effectively managed," said Dr. Sivaram.