Website : http://www.dae.gov.in ISSN-09929-5523

Nuclear India

VOL. 40/NO. 7-8/Jan-Feb. 2007

Inter-Dunal area with sparse vegetation, Brahmagiri mineral sand deposit, Orissa

DAE carries out exploration for augmentation and identification of potential beach sand heavy mineral resources along the coastal areas. At Brahmagiri, Puri district, Orissa, a heavy mineral deposit containing 120 million tonnes of heavy mineral resources has been established. This is the largest single deposit of heavy mineral resources in the country. Besides, heavy mineral resources have also been identified at Narsapur, West Godavari district, Amlapuram, East Godavari district, Andhra Pradesh, Vayakkallur-Tuttor, Kanyakumari district, Tamil Nadu and Thotatapalli-Alappuzha, Kollam and Alappuza districts, Kerala. Total heavy mineral resources in the country were 632 million tonnes at the beginning of X Plan. During X Plan 235 million tonnes of additional heavy mineral resources have been identified and the updated inventory of heavy mineral resources now contains 867 million tonnes comprising ilmenite, rutile, monazite, zircon, garnet, and sillimanite.

"...Today, we take a momentous step towards realization of our common goal to seek a clean source of energy of a magnitude capable of supporting a decent quality of life for the entire humanity."

President Chirac, European Commission President Barroso, excellencies, ladies and gentlemen, I would like to begin with a Shloka from Rig Veda, one of our ancient scriptures.

सप्त त्वा हरितो रथे वह्न्ति देव सूर्य ।
शोचिष्केशं विचजज

Translated it means

Seven Bay Steeds harnessed to thy car bear thee, O thou farseeing One, God, Surya, with the radiant hair..........

Our ancestors intuitively grasped the importance of the Sun as the Ultimate Provider and Sustainer of Life on Earth! What they perhaps did not foresee is that one day their progeny would imitate the sun right here on earth to cater to vastly increased energy needs! India is proud to be a partner in this enterprise of getting the man made star - ITER - off the ground with our shoulders to the wheel ….like one of the seven mythological steeds pulling on the carriage of the Lord Surya - the Sun!

Today, we take a momentous step towards realization of our common goal to seek a clean source of energy of a magnitude capable of supporting a decent quality of life for the entire humanity. Fusion has the potential to provide abundant and clean energy based on resources available everywhere without significant ecological issues associated with mining of earth's resources. It is in this context that the Indian delegation is very happy to be a part of this historic human scientific endeavour. At this point, allow me to record our appreciation of the hard and sustained efforts on part of all those who have contributed to ITER project development and progress made to date.

Most current estimates suggest that the world's population would reach around 8 billion over the next 25 years with another billion in the following 20 years. Virtually all increase will be in the developing countries. Thus the core challenge for development is to provide access to energy for all at affordable prices based on a technology that is acceptable from the point of resource and environmental sustainability.

Speaking specifically about India, in spite of being one of the top 5 electricity producing countries, we still have very low per capita electricity consumption. The objective of electrification of all villages is yet to be realized. Studies indicate that even to reach a modest target of per capita generation of about 5000 kWh, total annual electricity generation has to be about 11 to 12 times the generation at present. While immediate increase would inevitably come from fossil fuels, nuclear energy has to play a significant role in the coming decades. We have an ambitious programme to tap fission energy based on closed fuel cycle approach. However, considering the size of our country and rapid growth in economy, even that is not likely to be sufficient in the long term. There is thus a need to look at new technologies such as fusion that provides even larger energy potential. We have been pursuing fusion science and technology programme at our Institute for Plasma Research, Gandhinagar. Our scientists have already designed and fabricated two tokamak devices Aditya and the steady state superconducting tokamak SST-1. Many technologies of relevance to the forefront of fusion research have been developed by our scientists and engineers in collaboration with our industries. We thus bring to the table a combination of strong commitment from the government and special scientific and technological skills, which are of relevance to ITER and to fusion research.

Ladies and gentlemen, we have gathered here today for a historic occasion. We have just signed the ITER agreement which is a unique step in the history of mankind. It is the first time that more than half of the world is standing together shoulder to shoulder and looking at a technological challenge in the eye and telling it with confidence "Thou shalt be conquered!" It is perhaps a harbinger of the future telling humanity how it must face up to its problems and solve them. A model to be followed again and again.

I am happy that all issues related to cooperation have been resolved, the Director-General, Principal Deputy-Director-General and the Deputy Director Generals have joined the ITER team in Cadarache. Now the next step is to strengthen the technical team at Cadarache with an

Contd. on page 15

Address by Dr Anil Kakodkar, Chairman, Atomic Energy Commission on the occasion of signing of the agreement on the establishment of the ITER International Fusion Energy Organization for the Joint Implementation of the ITER project, Paris (November 21, 2006).

Energy Security through Nuclear Energy in India

Subhash Chandra, Arun Srivastava and R.B. Grover
Strategic Planning Group, Department of Atomic Energy

1. Introduction

Indian economy has shown impressive growth in the recent past and it is expected that it will continue to do so for several decades to come. Growth in economy has to be accompanied by growth of primary energy and electricity consumption. Assuming i) India's Gross Domestic Product (GDP) growth rate remaining around 5 to 6 % for fifty years to come[1] and ii) applicable correlations between GDP growth rate and energy growth rate[2], as the GDP multiplies by nearly 15 times in the forthcoming fifty years, primary energy and electricity consumption would also go up. Estimates indicate that the domestic fossil resources would not be able to meet rising energy demands and one has to go in for a quantum increase and large imports of fossil fuels. Excessive dependence on imports can impact energy security in two ways, first due to price volatility in the international market and second due to disruption of fuel supplied in case of any regional disturbance. Moreover, excessive fossil fuel consumption using the present technologies impacts environment at local, regional and global level. This may change as new technologies are developed. In the coming yeras, new emerging technologies like carbon capture and sequestration, renewables and various nuclear technologies will compete with each other for their share. Based on energy growth scenario built by Department of Atomic Energy (DAE), it can be said that the cumulative primary energy requirement during the 50-year period between the years 2002 and 2052 would be about 2400 EJ. Domestic fossil fuel resources can provide only about half of it even when the total recoverable prognosticated hydrocarbon resources are taken into account. Hydro and non-conventional renewable sources can provide about 12%. The remaining energy has to be shared by nuclear and imported components. If DAE's vision of installing about 20 GWe of nuclear power capacity, consisting of Pressurised Heavy Water Reactors (PHWRs), Light Water Reactors (LWRs), and Fast Breeder Reactors (FBRs), by the year 2020 and then installing, as many as possible, metal based FBRs from the plutonium generated from all the thermal reactors materialize, it is possible that nuclear power contributes about a quarter of the total electrical power by the year 2052. In that case the cumulative nuclear energy will constitute about 10% of the total cumulative primary energy during the 50-year period and cumulative requirement of imported energy would be contained at 29%. The larger/smaller the nuclear energy production achieved the corresponding energy import will be smaller/larger. The success of the nuclear energy programme thus has very crucial bearing on energy security of India. The present article briefly describes energy trends of the present century, expected nuclear renaissance in the world and brief details of energy scenario in India for the next 50 years.

2. Energy trends in 21st century

Nearly a quarter of the world population is not getting even minimal commercial energy due to lack of purchasing power. A large disparity in the living standard of various sections of the society is one of the main causes of social tensions and disturbances. It is expected that the deprived section of people will gradually get its energy needs in the present century so as to improve its living standard thereby lessening the economic disparity. Developing countries like China and India will need huge amount of energy as their population is very large and increasing, and they are way below the world average energy consumption. The energy supply sustainability thus becomes an important issue. Energy should preferably be produced and consumed without any negative side effects on environment and without risking its availability to future generations. All forms of commercial energy coal, oil, gas, hydro, nuclear, wind and solar etc. need to be exploited to their full potential. As mentioned earlier, there is a correlation between GDP-growth of a nation and its energy growth and this correlation is very strong for the developing countries where per capita GDP is low (Fig.1). Per capita income in India is many times below the world average. Energy requirements of India are likely to increase at a high rate on two counts, first the increase in population and second rise in per capita income.

3. Preserving Earth's Climate

• <u>*Carbon dioxide emission and its stabilization*</u>

The atmospheric level of carbon dioxide in the pre-industrialization era was at around 280 ppm, which has already increased to about 380 ppm. Presently about 7 billion tonnes of carbon is being emitted annually to our atmosphere and if this trend continues

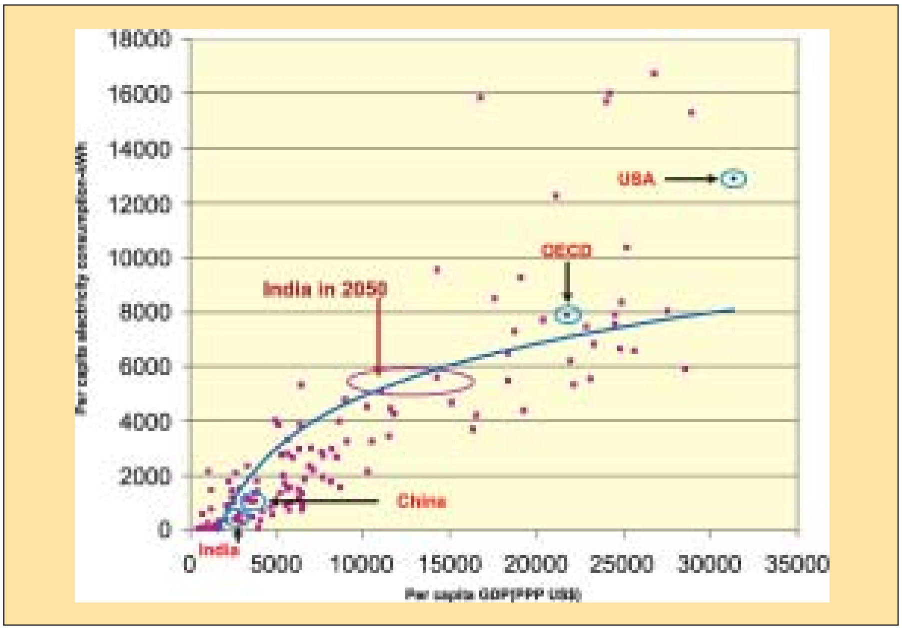


Fig.1: Per capita electricity consumption Vs Per capita GDP for various nations of the world

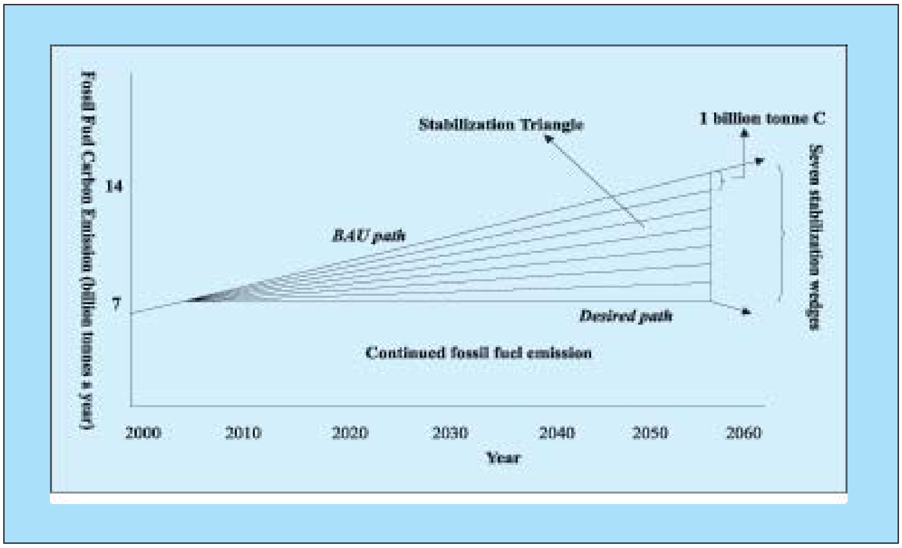


Fig 2. Stabilization Triangle
(Adapted from S. Pacala and R. Socolow, Stabilization Wedges: Solving the Climate Problem for next 50 Years with Current Technologies, in Science, Vol. 305, 13 August 2004)

than it may reach to about 14 billion tonnes per year fifty years from now (BAU path Fig. 2) taking the quantity of carbon in atmosphere to about 1200 billion tonnes which is double the figure of pre-industrialization era. The corresponding quantity of CO_2 in atmosphere would be 560 ppm, the level at which catastrophic climate changes might be triggered. The cost of such climatic changes may be very high, several percentages of the world GDP. In order to avoid such a disastrous situation and to flatten the carbon emission curve (Desired path) the world community has to immediately initiate development and deployment of suitable technologies. S. Pacala and R. Socolow have shown a way to solve this climate problem with current technologies[3]. They discuss fifteen such technologies or technology combinations, categorized as 'End user efficiency and conversion', 'Power generation', 'Carbon Capture and Storage', 'Alternative energy sources' and 'Agriculture and forestry' (Box-1).

Box-1

End-user Efficiency and Conservation

1. Increase fuel economy of two billion cars from 30 to 60 mpg

2. Drive two billion cars not 10,000 but 5,000 miles a year (at 30 mpg)

3. Cut electricity use in homes, offices and stores by 25%

Power Generation

4. Raise efficiency at 1,600 large coal-fired plants from 40 to 60%

5. Replace 1,400 large coal-fired plants with gas-fired plants

Carbon Capture and Storage (CCS)

6. Install CCS at 800 large coal-fired power plants

7. Install CCS at coal plants that produce hydrogen for 1.5 billion vehicles

8. Install CCS at coal-to-syngas plants

Alternative Energy Sources

9. Add twice today's nuclear output to displace coal

10. Increase wind power40-fold to displace coal

11. Increase solar power 700-fold to displace coal

12. Increase wind power 80-fold to make hydrogen for cars

13. Drive two billion cars on ethanol, using one sixth of world cropland

Agriculture and Forestry

14. Stop all deforestation

15. Expand conservation tillage to 100 percent of cropland

Each of the fifteen technologies shown in Box-1 is capable of avoiding 1 billion tonne a year of carbon emission to the atmosphere. Starting from now, the year 2006, if deployment of seven such technologies (Seven technology wedges Fig 2), taking care of any overlapping areas, is completed in fifty years then annual carbon emission will stabilize at the present level itself (Desired path Fig 2). Deployment of more such technologies will be required subsequently in 2056 to initiate further reduction in the annual carbon emission thus limiting the total cumulative quantity of carbon in atmosphere to well below the critical limit of 1200 billion tonnes. Individual countries, depending on their economical, social and other conditions, may decide how to contribute towards accomplishing the above startling feat. Nuclear energy is one of the most potent technologies in the present context. If twice of today's nuclear output is added to displace coal then one 'technology-wedge' is earned. There is adequate nuclear potential in the world to earn many such wedges. India also has a significant nuclear potential if a suitable fast breeder reactor route is developed and deployed. Moreover keeping the present domestic fuel resource base in mind, it is the only solution if India intends to limit the energy import dependence at the current level of about 29%.

4. Nuclear Energy

As of April 2006 about 440 reactors of 370 GWe-net installed capacity were under operation. India's share is less than 1% of the total. However India's share, out of 20 GWe under construction reactors, is 3.6 GWe about 18% of the total. Growth of nuclear power around the world was very high during the two decades 1970-1990. Largest capacity addition was achieved in the year 1985 (Fig. 3 and 4). While there was a decline in new constructions subsequent to 1985, nuclear electricity generation has continued to grow due to better plant performances.

Worldwide opinion is again tilting in favour of nuclear energy. The low projection of IAEA, assuming that the reactors already under construction will be the only additions, is 416 GWe in 2020, a modest increase from the current 370 GWe, before it's leveling off. The high projection incorporates the projects proposed beyond those already firmly committed. In that case the installed capacity would go up to 640 GWe, a substantial increase over the present capacity (Fig. 4). It is expected that this nuclear renaissance will be led by the developing countries, notably China and India, and the economies in transition (Russia and Eastern Europe) although quite a few reactors are expected in developed economies also[4].

The reason of this nuclear renaissance is not far to seek. Environmental considerations, specially recently observed climatic irregularities that are perceived by many to be related to global warming, oil and gas price hikes and burgeoning energy demand from developing world are the main driving forces behind this nuclear surge. Moreover vastly improved availability factors of nuclear plants and their smoother and safer operations have also contributed to it (Fig 5, 6 and 7). Relative economy of various future power technologies will however be the most important factor deciding their share.

Table 1, Table 2 and Fig. 8 summarize new power plant construction cost estimates and levelized power production costs from numerous studies carried out recently in many parts of the world. The estimates place the three alternatives, nuclear coal and gas on a level playing field.

According to the joint report of Nuclear Energy Agency (NEA), International Energy Agency and Organisation for Economic Co-operation and Development (OECD) titled 'Projected Costs of Generating Electricity: 2005 Update', in the study of which experts from 19 countries participated, at 5% discount rate, nuclear electricity is cheaper than gas electricity in all the countries and also cheaper than coal electricity in all the countries except South Korea and the US. At 10 % discount rate, nuclear electricity is cheaper compared to gas electricity in all the countries except Japan and the US, and to coal electricity in all countries except Japan, the US and Germany[5]. According to Indian studies nuclear power is cheaper than coal power at 5% discount rate and at sites 800 km away from coal pitheads (Table-2). A relatively very less fuel price

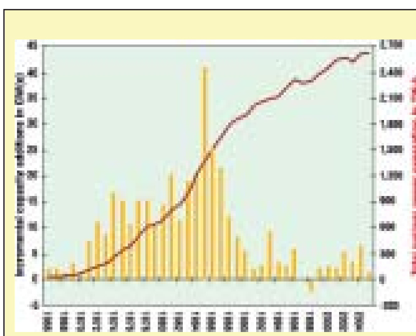


Fig. 3 Nuclear electricity Generation and capacity addition

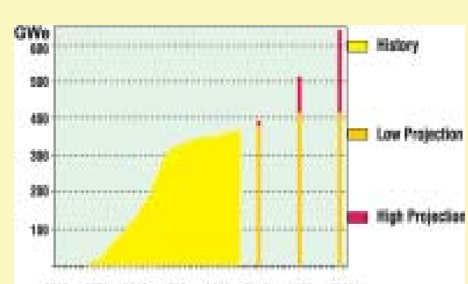


Fig. 4 Cumulative installed nuclear power capacity

(Courtesy: Nuclear Power and Sustainable Development, IAEA, April 2006, pg 2 and 3)

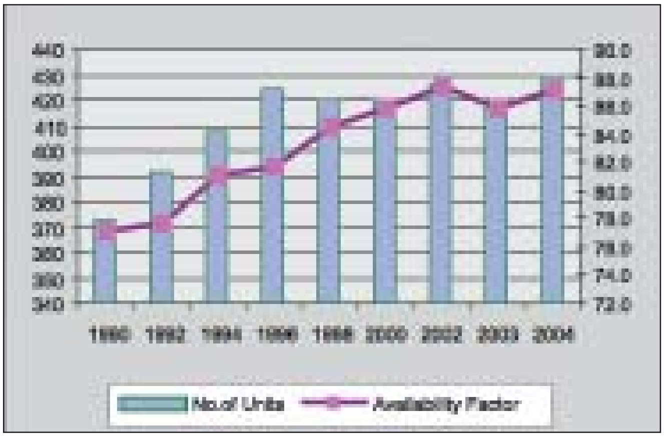


Fig. 5 Availability Factor Improvement (Based on: Nucl. Eng. and Des. 236 (2006) 1460 - 1463)

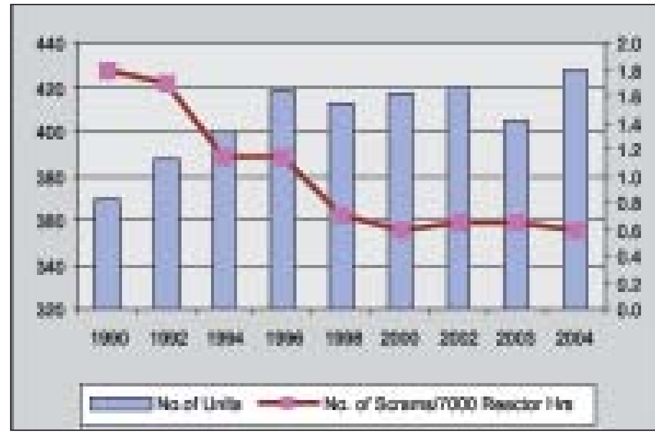


Fig. 6 Unplanned scrams/7000 hrs of Reactor Operation (Based on: Nuclear Power and Sustainable Development, IAEA, April 2006, pg 16)

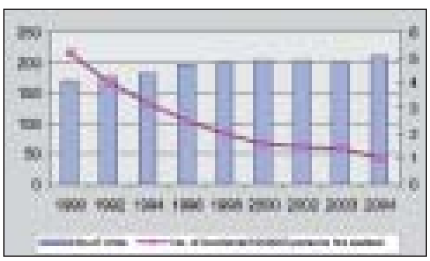


Fig. 7 Industrial accidents/1million man-hours (Based on: Nuclear Power and Sustainable Development, IAEA, April 2006, pg 17)

sensitivity of nuclear electricity also goes in its favour[6] (Table-3).

This and many other advantages of nuclear energy such as much smaller, as compared to fossil energy, land requirement, waste generation and environmental pollution arise basically from the fact that nuclear energy is a very compact form of energy, a million times more compact than fossil fuel energy.

There are some external costs associated with any energy technology. These are the costs that the public pays indirectly such as health costs due to air pollution. Neither the power plant owners nor the electricity buyers pay for such costs. External costs for nuclear power are very much smaller as compared to fossil fuel based power technologies and are expected to remain so in future also[7].

Table-1 Comparative cost estimates of power

	MIT	University of Chicago	Royal Academy of Engineering	DGEMP France	METI Japan	CERI Canada	OECD/NEA/ IAEA
Levelised cost	US cents/kWh	US cents/kWh	US cents/kWh	US cents/kWh	US cents/kWh	US cents/kWh	US cents/kWh
Nuclear	6.7	4.1 - 7.1	4.2	3.8	5.8	4.4 - 7.3	2.1 - 6.9
Coal	4.2	3.5 - 4.1	4.6 - 6.4	4.1 - 4.4	5.3	4.0 - 4.9	1.6 - 6.8
Natural gas	3.8 - 5.6	3.5 - 4.5	4.1 - 5.7	4.3	5.8	6.0 - 6.3	3.8 - 6.4
Oil					10.8		
Hydropower							4.0 - 24.2
Poultry litter			12.5				
Onshore wind			6.8 - 9.9				3.1 - 14.4
Offshore wind			10.1 - 13.3				5.2 - 12.3
Wave/marine			12.7				
Solar PV							22.1 - 187.8
Overnight cost	$/kW(e)	$/kW(e)	$/kW(e)	$/kW(e)	$/kW(e)	$/kW(e)	$/kW(e)
Nuclear	2000	1200-1800	2119	1823	2614	1868-2401	1074-2510
Coal	1300	1182-1468	1545-1311	1290-1419	2548	1541	719-2347
Natural gas	500	500-700	553	652	1536	586	424-1292
Oil					2338		
Hydropower							1541-6895
Poultry litter			1390				
Onshore wind			1364				876-1634
Offshore wind			1699				1637-2822
Wave/marine			2500				
Solar PV							3583-10064

(Courtesy: Nuclear Power and Sustainable Development, IAEA) from fig. 8

Table-2: Levelised electricity costs in India (at 2005-06 constant price)

Discount rate	Nuclear	Coal-Fired (800 km from pit head)	Gas-fired (LNG)
5%	152	164	182
10%	218	200	204

(Source: Cost Effectiveness of Electricity Generating Technologies, NPCIL, Sept. 2005)

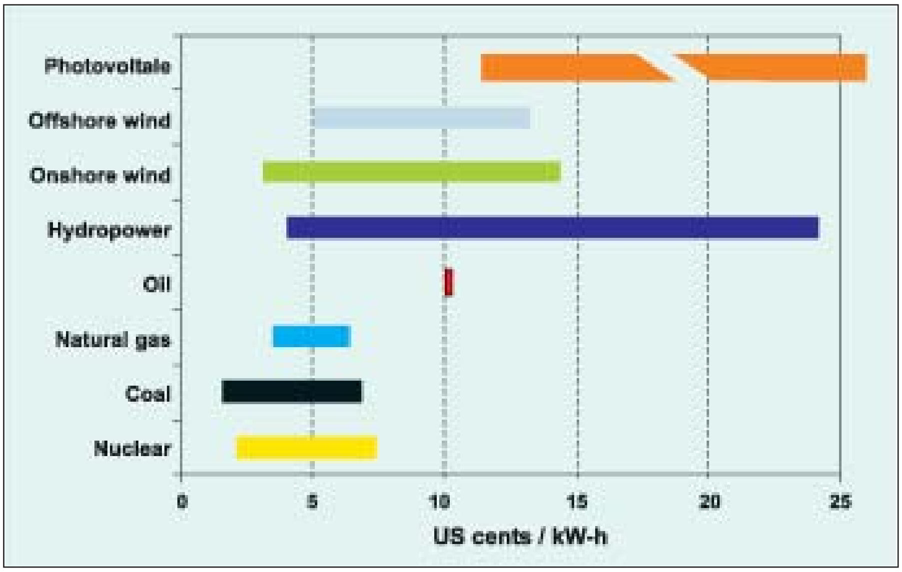


Fig. 8 Levelised electricity cost from new construction (Courtesy: Nuclear Power and Sustainable Development, IAEA, April 2006, pg. 9)

Table-3: Electricity generation cost sensitivity on fuel price

Fuel	Elect. Generation cost variation (%) (For 100% increase in fuel price)
Nuclear	9
Coal	31
Gas	66

(Source : Uranium Information Centre Ltd, Australia. Briefing Paper 8, November 2006)

- *Primary Energy and its components in the year 2002-03*

Tables 4, and 5 show contributions of different fuels to commercial primary energy and electricity respectively in the year 2002-03 in India. Over all energy import content is about 29% of the total. More than 92% of the primary energy comes from fossil origin and the remaining is shared mainly by the hydro (6%) and nuclear (2%). Similarly fossil fuel provides 86% share in the total electricity generation while the hydro (10%) and nuclear (3%) contribute the remaining.

- *Past Trends and Future Projections of GDP, Primary and Electrical Energy in India*

During the twenty years period between 1980 and 2000 average growth rates of the GDP, primary energy and electricity in India have been 6%/y, 6%/y and 7.8%/y respectively. There has however been a gradual decrease in the energy and electricity intensities of GDP. Based on 1) India's 50 year GDP projections referred to earlier[9], 2) 1.2%/y fall of the primary energy intensity of GDP[10]

5. Electrical Energy growth in India: A scenario

Future electricity demand in India is going to be an order of magnitude larger in fifty years from now. A scenario has been developed in the DAE for growth of electricity generation based on a careful examination of all issues related to sustainability, particularly abundance of available energy resources, diversity of sources of energy supply and technologies, security of supplies and self sufficiency. Present energy usage, domestic energy resources, future energy demands and the above scenario will now be briefly described.

Table-4: Contribution of different fuels to Primary Energy (EJ) in year 2002-03

	Energy Resource Components						Total
	Coal	Crude	NG	Hydro	Nuclear	Nonconv Ren.	
Contribution	6.40	4.83	1.18	0.79	0.23	0.08	13.46
%of total	47.53	35.97	8.97	5.85	1.72	0.19	100.00
Import	0.51	3.42	Neg	Neg	0.03	0.00	3.96
%of above	7.97	70.81	Neg	Neg	13.0	0.00	29.42

(Source: Growth of Electrical Energy in India, R.B Grover and Subhash Chandra)

and 3) extrapolation of fall of the electricity intensity of GDP from the past data till 2025 and a constant fall of 1.2%/y thereafter one can estimate the future growth of the primary energy and electricity for the next fifty years which can broadly be represented in two periods, 2002-22 and 2022-2052, (See Box-2). Cumulative primary energy requirement turn out to be 2400 EJ during the projected fifty-year period which will be provided by a variety of domestic fuels: fossil, nuclear, hydro and non-conventional renewable and imports.

Table 5: Contribution of different fuels to Electricity (TWh) in year 2002-03

	Thermal	Hydro	Nuclear	NonConv. Renewable	Total
Contribution in TWh	550.82	65.66	19.24	2.66	638.38
% of Total	86.3	10.3	3.0	0.4	100

(Source: Growth of Electrical Energy in India, R.B Grover and Subhash Chandra)

Box-2 : Historic Growth Rates (1981-2000)

Historic Growth Rates (1981-2000)

- 6%/y for GDP, 7.8%/y for Electricity, 6%/y for Primary Energy

Assumptions for future projections

- Primary Energy Intensity fall 1.2%/y (World Energy Outlook, 2002)
- Extrapolation of electricity intensity fall from past data till 2025 and a constant fall of 1.2%/y thereafter

Computed Future Projected Growth Rates (2002-2052)

Period (Year)	GDP	Electricity	Prim. Energy
2002-2022	5.8%/y	6.3%/y	4.6%/y
2022-2052	5.5%/y	4.5%/y	4.0%/y

- Computed Cumulative Primary Energy Requirement during the period 2002-2052: 2400 EJ

• *Domestic Energy Resource*

Domestic primary energy and electricity resources, as estimated in the year 2002-03, are shown in Table 6. Fossil fuel resource consists of coal, and hydrocarbon (oil and natural gas). Economically mineable coal can give about 667 EJ. Proven hydrocarbon resource consisted of about 60 EJ only. Based on the total prognosticated hydrocarbon reserves of about 30 billion tonnes in India, a recovery factor of 40% and the successful ongoing new exploration and licensing policy (NELP) of the government of India the hydrocarbon resource has been assumed to be 12 billion tonnes equivalent to about 511 EJ. Full potential of hydro and non-conventional renewable is limited to 6 EJ a year and 1.8 EJ a year respectively. The potential of nuclear energy comes from the modest amount of uranium and much larger amount of thorium. Domestic uranium can provide about 29 EJ from once through fuel cycle in PHWRs. The same uranium can however provide much larger energy, about 3700 EJ, through multiple cycle route in FBRs. Domestic thorium has still larger energy potential through breeder route. As thorium does not have any fissile component therefore the fissile seed in thorium-based reactors has to come from other reactors based on uranium. Stand-alone thorium systems coupled with neutron accelerators may also be possible in future. Nuclear energy thus has a very large potential and should find an important place in any balanced energy strategy.

The scenarios built by the Department of Atomic Energy is based on the following broad policies.

- Install about 20 GWe nuclear power capacity by the year 2020 (Box-3).
- Employ the most optimum combination of the FBR fuel and fuel cycle viz. metal-based Pu-U mix fuel and 1-year out-of-pile fuel cycle for development of FBRs beyond the year 2020. Any other FBR-fuel, oxide or carbide, or a slower fuel cycle e.g.

Table 6: Primary Energy and Electricity Resource (Year 2002-03)

	Amount	Thermal Energy			Elec. Potential
		EJ	TWh	GWYr	GWe-Yr
Fossil:					
Coal	38-BT	667	185,279	21,151	7,614
Hydrocarbon	12-BT	511	141,946	16,204	5,833
Non-Fossil :					
Nuclear :					
Uranium - Met	61,000-T				
In PHWR		28.9	7,992	913	328
in Fast breeders		3,699	1,027,616	117,308	42,231
Thorium - Met	2,25,000-T				
In Breeders		13,622	3,783,886	431,950	155,502
Renewable					
Hydro	150-GWe	6,0	1,679	192	69
Non.Conv.Ren.	100-GWe	1.8	487	56	20

(Source: DAE Document No. 10, August 2004)

Box-3 : Indian Nuclear Power Programme 2020

REACTOR TYPE AND CAPACITIES	CAPACITY (MWe)	CUMULATIVE CAPACITY (MWe)
➤ 16 reactors at 6 sites under operation Tarapur, Rawatbhata, Kalpakkam, Narora, Kakrapar and Kaiga	3,900	3,900
➤ 4 PHWRs under construction at Kaiga (2x220 MWe), RAPS-5&6(2x220 MWe)	880	4,780
➤ 2 LWRs under construction at Kudankulam (2x1000 MWe)	2,000	6,780
➤ PFBR under construction at Kalpakkam (1 X 500 MWe)	500	7,780
➤ Projects planned till 2020 PHWRs(8x700 MWe), FBRs(4x500 MWe), LWRs (6x1000 MWe), AHWR(1x300 MWe)	13,900	21,180
➤ TOTAL by 2020		21,180 MWe

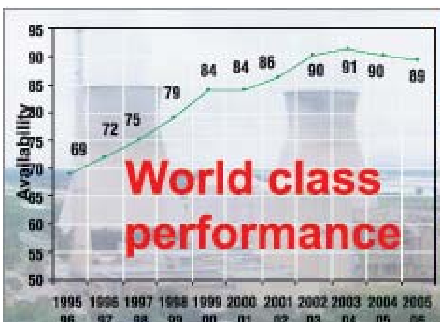
2-year out-of pile instead of 1-year out-of plie would give much lower share of nuclear power (Table-7)

• Employ all the plutonium produced in nuclear reactors to build fast breeder reactors (Stage II of DAE's nuclear programme, Box 4) of the above type so as to give maximum possible nuclear capacity by 2052.

Table-7: Nuclear Power in the year 2052

FBR		Breeding Properties		Nuclear Power Installed Capacity		Nuclear Electricity Generation	
Fuel	Fuel Cycle	System Doubling time (years)	Gr. Rate (%/y)	GWe	% of Total	TWh	% of Total
Oxide	Two Year	25.8	2.7	67	5	498	6.3
	One Year	18.9	3.7	93	6.9	691	8.7
Carbide	Two Year	14.7	4.8	102	7.6	758	9.8
	One Year	11.0	6.5	195	14.5	1449	18.2
Metal	Two Year	12.3	5.8	127	9.5	944	11.8
	One Year	8.9	8.1	275	20.5	2044	25.7

Box 4 : Three Stage Nuclear Power Programme



Stage – I PHWRS

- 14 - Operating
- 4 - Under construction
- Several others planned
- Scaling to 700 MWe
- Gestation period has been reduced
- POWER POTENTIAL ≅ 10,000 MWe

LWRs

- 2 BWRs Operating
- 2 VVERs under construction

Stage - II

Fast Breeder Reactors

- 40 MWth FBTR - Operating since 1985 Technology Objectives realised
- 500 MWe PFBR- Under Construction
- POWER POTENTIAL ≅ 530,000 MWe

Stage - III

Thorium Based Reactors

- 30 kWth KAMINI- Operating
- 300 MWe AHWR- Under Development

POWER POTENTIAL IS VERY LARGE
Availability of ADS can enable early introduction of Thorium on a large scale

- *Salient features of the Scenario*

Fuel-mix of the primary energy and electricity shows substantial changes from the present. The 92% contribution of fossil fuel in primary energy and 86% in electricity, in the year 2002-03, goes down to 76% and 63% respectively in 2052-53. This is mainly due to increased share of nuclear energy from 1.7% to 17% in primary energy and from 3% to 26% in electricity in the corresponding period. Out of the total cumulative primary energy requirement of 2385 EJ only 1688 EJ would be the domestic component leaving a shortage of 697 EJ (29% of the total), which needs to be necessarily imported. Thus the import dependence can be kept limited to the present level in principle by adopting the given strategy. Nuclear power reactor mix is shown in Fig. 8. Majority share is contributed by FBRs. This ambitious addition of FBRs is a theoretical limit of the present scenario; practically achievable addition would essentially depend on the successful and timely development and deployment of the required fuel (metal based Pu-U mix) and the corresponding fuel cycle (1-year out of pile). Technologies based on thorium, acceleration driven systems and fusion are also expected to play an important role.

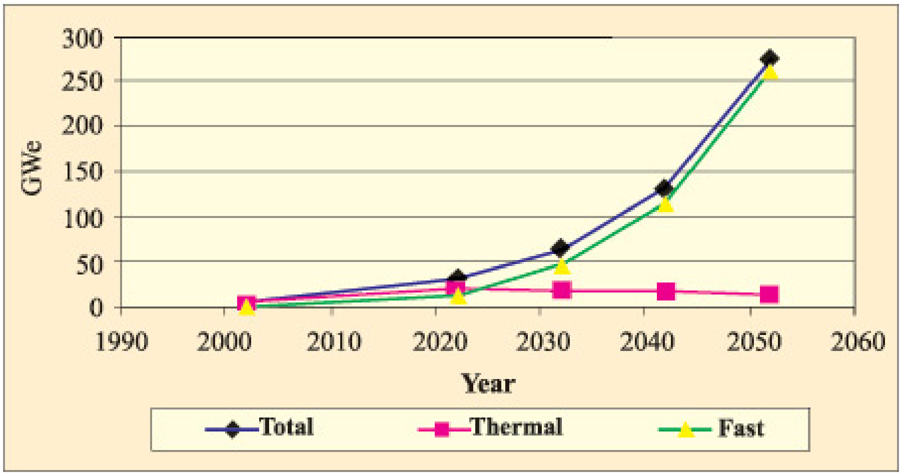


Fig. 8: Nuclear Power Installed Capacity – Type Mix

End Notes :

[1] *Dominic Wilson and Roopa Purushothaman, "Dreaming with BRICs: The Path to 2050", Global Economics Paper No: 99, Goldmann Sachs, 1st Oct. 2003 (http://www.gs.com/insight/research/reports/99.pdf).*

[2] *Primary Energy – GDP Correlation for developing countries (International Energy Agency, World Energy Outlook, Highlights-2002, page 32) and extrapolation of actual historical Electricity – GDP data of India.*

[3] *S. Pacala and R. Socolow, Stabilization Wedges: Solving the Climate Problem for next 50 Years with Current Technologies, in Science, Vol. 305, 13 August 2004 (www.princeton.edu/~cmi/resources/CMI_Resources_new_files/Wedges%20ppr%20in%20Science.pdf)-accessed 4th January 2006 and 'A Plan to keep Carbon in Check' in Scientific American September 2006, page 28*

[4] *Out of 168 reactors expected to start up by the year 2020 about 60 reactors are coming up in India and China and more than 20 in Russia and Eastern Europe (Source: New Scientist, 16th September 2006, page 7).*

[5] *M.R.Srinivasan, R.B.Grover, S.A.Bharadwaj, Nuclear Power in India Winds of Change, Economical and Political Weekly, December 3, 2005*

[6] *Uranium Information Centre Ltd, Australia, The Economics of Nuclear Power Briefing Paper 8 November 2006 (**www.uic.co..au/nip08.html** - accessed 8th January, 2007)*

[7] *Nuclear Power and Sustainable Development, IAEA, April 2006, page 11*

[8] *R. B. Grover & Subhash Chandra, 'A Strategy for Growth of Electrical Energy in India', Document No.10 August 2004 and R. B. Grover & Subhash Chandra, 'Scenario for growth of electricity in India', Energy Policy 34 (2006) 2834-2847*

[9] *Dominic Wilson and Roopa Purushothaman of Goldman Sachs published, in the year 2003, projections of GDP growth rates (5-6%/yr) in India for the period 2000 to 2050 in five years slabs. R.B. Grover and Subhash Chandra of DAE, in the year 2004, modified these growth rates assuming India's population to stabilize at 1.5 billion in the year 2050 instead of reaching 1.6 billion and considering the period of projection to be 2002-2052. The GDP growth rates, published by Dani Rodrik and Arvind Subramaniun of IMF in the year 2004, were higher (6.7%/yr) though for a shorter period (20years). Planning Commission of the Government of India, in the year 2006, gave still higher numbers (8-9%/yr) for GDP growth rates for the period 2005 to 2030.*

[10] *International Energy Agency, World Energy Outlook, Highlights 2002,*

Utilization of Waste Heat for Desalination by Low Temperature Evaporation (LTE) Technology

A Raha, I S Rao, G Kishore, M Majumdar, V K Srivastava and P K Tewari
Desalination Division, Bhabha Atomic Research Centre

In the world with finite energy resources and large energy demand, efficient use of the energy has become the main theme for sustainable technologies in twenty first century. Designing energy efficient as well as cost effective technologies that advance the progress of the process industries toward a more sustainable energy future is the foremost challenge to process engineers. Desalination by Low Temperature Evaporation (LTE) Technology developed by Desalination Division (BARC) demonstrates a sustainable technology by utilizing waste heat to produce pure water from sea water as a valuable end product.

Waste Heat Utilization

More than 80% of the total energy used in the process industry is the heat in the form of steam at different pressure levels and for firing furnaces. Most of this heat is eventually released to the atmosphere through cooling water, cooling towers, flue gasses, and other heat losses. We call this heat loss as 'process waste heat'. Most logical solution to this waste heat problem is to utilize the heat within the same process or at the same site. Almost all waste heat production can be associated with the consumption of any type of primary fuel. Therefore, the recuperated waste heat being recycled within the plant activities does not represent new energy production, but rather a more energy-efficient way of realizing a useful and economic activity.

Desalination and its Necessity in Process Industries

In many chemical industries, process water is a very precious utility. Due to rapid industrialization, industrial water demand is increasing very rapidly in India. It is estimated that by 2025 industrial water demand in India would increase to 15.7 cubic kilometres. In fact, India would be highly water stressed from 2020 onwards. Many of the inland and costal areas of our country are facing acute shortage of good quality water. In the coming days process industries have to implement more stringent water management policies under constrained water resources. Desalination is an efficient technology for augmenting this water supply.

Desalination by LTE Technology Using Waste Heat

Desalination is an energy intensive process. The energy cost contributes 25-40% to the total cost of desalted water. Heat is used as the separating agent in thermal desalination processes. Utilization of waste heat from process industrial streams for desalination is one of the ecofriendly ways to produce low cost desalted water as it supplements the energy that is wasted in the process with valuable end product i.e. pure water. The problem with the waste heat is that the temperature level ($<50^0$ C) of the waste heat is too low to be reused again at the same site. Keeping this in mind, the knowhow for the LTE desalination plant utilizing low grade waste heat (as low as 50^0 C) or low pressure steam (0.13 bar) to produce high purity water from sea water was developed. Low Temperature Evaporation (LTE) desalination is a technology suitable for producing desalted water from waste heat available from different process industrial streams.

A 30,000 litres/day LTE desalination plant was successfully tested and operated in BARC. Waste heat is available in the form of streams from industries. A second generation 50,000 litres/day LTE desalination plant with 2-effect is being put up to improve the overall thermal efficiency.

LTE Desalination Plant Process description

The 2-effect Low Temperature Evaporation (LTE) desalination plant (Fig. 1) is designed to produce high purity water which is required in any industry as process water. Raw water about 77 m^3/hr enters the condenser tubes and about 4 m^3/hr of the water from the condenser outlet is used as feed and fed to the first effect heater section. It enters the heater section at the bottom of the tubes. Hot water at 65^o C is circulated in the shell side of the 1st Effect. One-third of the feed is evaporated. The water and vapour mixture comes out of the heater tubes. The vapour rises through demisters in the separator section for removing entrained particles. The vapour generated in the first effect is used as heating medium in the second effect. It enters in the shell side of heater section of the second effect and is condensed there. Concentrated water from the first effect is used as feed in the second effect which is maintained at lower pressure. Vapour generated in this effect rises through the demisters and enters the horizontal condenser where it is condensed to produce fresh water. The condensate in the heater and condenser section

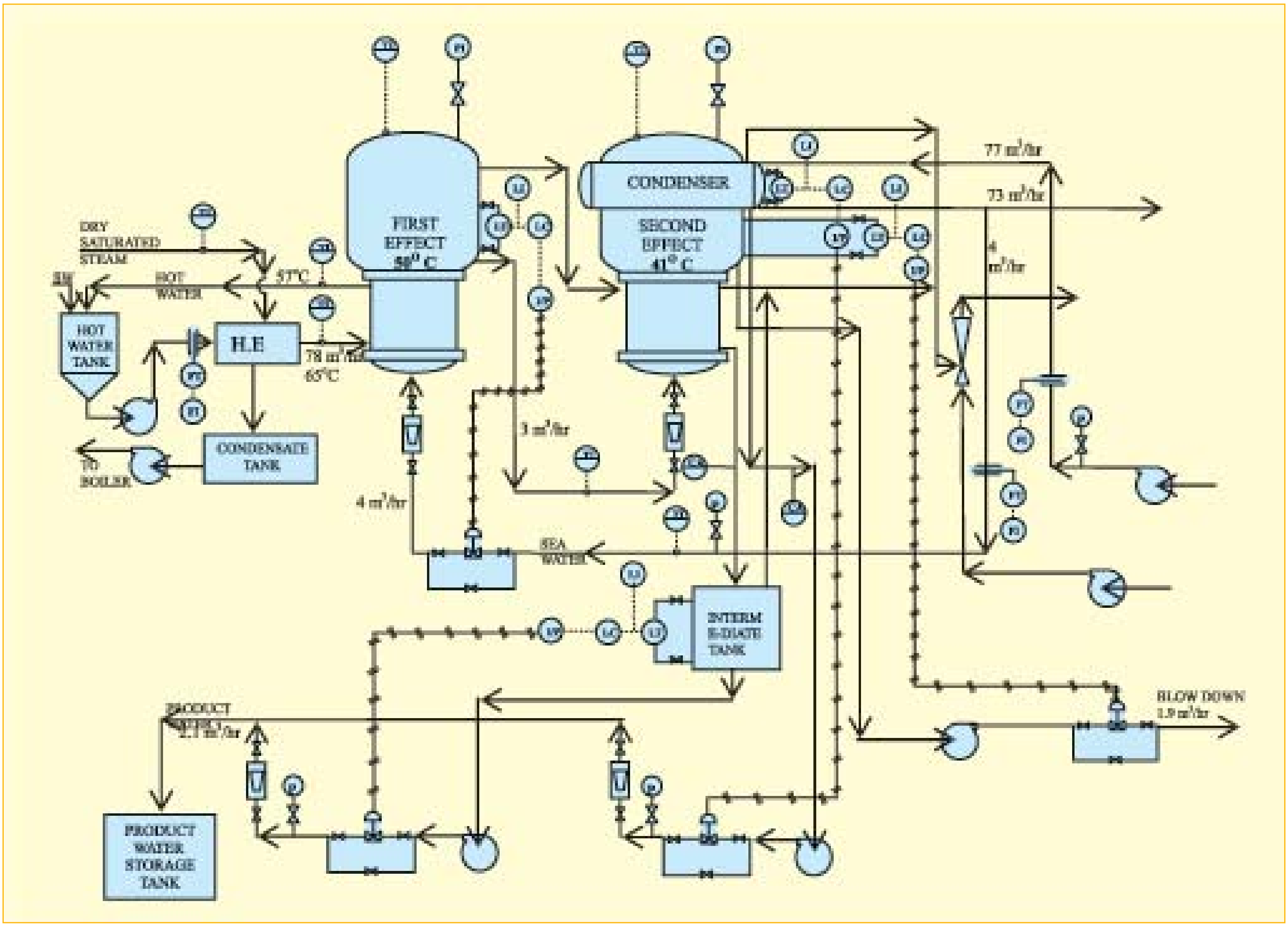


Fig. 1: Process Flow Diagram of 50,000 litres/day 2-Effect LTE Desalination Plant

(2.1 m^3/hr) is continuously pumped out. Concentrated water from the second effect (1.9 m^3/hr) is removed as blow down. The plant is in advanced stage of construction in BARC (Fig.2) and will be commissioned shortly.

Fig. 2: 50,000 litres/day 2-Effect LTE Desalination Plant (under installation)

Low Temperature Evaporator

This is a 2-effect evaporator. The first effect has two section viz. heater, separator and the second effect has three section viz. condenser, separator and condenser.

Heater

In the first effect, feed seawater enters the bottom of the unit at 37^0 C. It is heated up to 50^0 C and is partially vaporized in the tubes. Hot water that enters at 65^0 C in the shell side, is used as the heating medium. In the second effect, concentrated water from the first effect and part of the water from the outlet of the condenser enter the bottom of the unit. It is heated up to 41^0 C and is partially vaporized in the tubes. Vapour generated in the first effect is used as the heating medium in the second effect.

Table 1: Technical specificationsof the 2-effects LTE plant LTE Desalination Plant

1.	Product output (m^3/hr)	2.1
2.	Product water quality (µS/cm) approx	10
3.	Makeup water requirement (m^3/hr)	6
4.	Hot water temperature (^oC)	65
5	Sea water boiling temperature (^0C)	
	(i) First effect	50
	(ii) Second effect	41
6.	Waste heat requirement (MWth)	0.75
7.	Electrical power consumption (kW)	40
8.	Material of construction	
	(i) Tubes and Tube sheets	Cu-Ni (90-10)
	(ii) Shell	Carbon Steel A 515-70
	(iii) Shell of condenser section	SA 240 TP 304L
	(iv) Water jet ejectors	SA 240 TP 316L

Table 2 : Water Quality from LTE : Feed Sea water composition

Ion	Concentration (mg/l)	Ion	Concentration (mg/l)
Sodium	10,900	Chloride	19,700
Magnesium	1,310	Sulphate	2,740
Calcium	410	Bicarbonate	152
Potassium	390	Bromide	65
Strontium	13	Fluoride	1.4
Barium	0.05	Nitrate	< 0.7
Iron	<0.02	Silica	8
Manganese	<0.01		
TDS :	35,000 mg/l (Approx)		
pH :	8.1		

Table 3: Product water composition

Ion	Concentration (mg/l)	Ion	Concentration (mg/l)
Sodium	1.56	Chloride	2.81
Magnesium	0.20	Sulphate	0.40
Calcium	0.06	Bicarbonate	0.02
Potassium	0.05	Bromide	N.D
Strontium	N.D	Fluoride	N.D
Barium	N.D	Nitrate	N.D
Iron	N.D	Silica	0.02
Manganese	N.D		
TDS :	5 mg/l (Approx)		
pH :	7.98		

Separator

The separator is provided to reduce the entrainment of the feed droplets. As the water and the vapour mixture come out of the tubes of the heater section, vapour rises through this section. The vapour entrains water droplets along with it. Demister pads are used for entrainment separation of these water droplets. The excess concentrated feed water is drained out.

Condenser

Heater section in the second effect acts as a condenser for the first effect. In the second effect a horizontal condenser is provided at the top of the evaporator. This is a 1:4 shell and tube heat exchanger with a cut-out provided at the top of the shell for vapour to enter the shell side. The vapour generated in the heater is condensed on the tubes in this section to produce fresh water.

A part of the water from the outlet of the condenser is used as feed in the heater sections of the first and second effects and another part is connected to the suction of the pump to be used as motive fluid for the water jet ejectors.

Applications of LTE Technology

This technology finds application for the following purposes:

1. Production of demineralised quality (conductivity ~10 µS/cm) desalted water which is suitable for high purity water requirements in process industries.

2. Production of ultra-pure (conductivity < 0.1 µS/cm) desalted water by the combination of LTE with Electro Deionization (EDI) required in nuclear, pharmaceutical, semiconductor industries.

3. Production of potable water from seawater / brackish water for water scarce area and remote

locations.

4. Effluent treatment and water reuse.

Conclusion

The LTE technology is very useful in water scarce areas for producing pure water from highly saline water and has the following advantages:

- Utilization of waste heat
- Reduction in effluent volume and a step towards zero discharge
- Totally indigenous, reliable and rugged technology
- Reduction of specific energy requirement by employing more number of effects

Utilization of low quality waste heat has enormous potential to grow in coming years to satisfy the in-house process water requirement of coastal industries. Such plants would be ideal for industries where low quality waste heat is available in the form of process heat. It is an attractive alternative for producing pure water from high salinity or seawater for the rural water scarce areas where waste heat is available.

Contd. from page 2

appropriate balance of experienced and young engineers and scientists and to provide them with an environment which rapidly promotes the task of implementation of the project. We must do this ensuring that the critical human resource from original ITER teams is fully utilized and that long term and viable management tools for ITER are immediately put into place. Ladies and gentlemen, on behalf of the Government of the Republic of India and on my own behalf, I wish this cooperative venture a grand success.

Thank you.

International Conference on "Radiation Processing of Agro and Allied Products: Recent Trends and Future Prospects (ICRAAP-2007)

The Indian Nuclear Society is organising the International Conference on "Radiation Processing of Agro and Allied Products: Recent Trends and Future Prospects (ICRAAP-2007)" during February 2007, at Hyderabad and New Delhi as per the following schedule:

- February 09-10, 2007 at Acharya NG Ranga Agricultural University, Hyderabad
- February 12-13, 2007 at Shriram Institue for Industrial Research, Delhi

The Conference will cover :

- Overview of development in food irradiation technology
- Commercial irradiation facilities: Global scene
- Design and engineering aspects of irradiation plants
- Design and adoption of electron beam facilities for food and agro products
- Synergy and complementary technologies such as cold chain and modified atmosphere
- Integrating packaging with food irradiation technology
- Economics and consumer aspects
- Forward and backward integration and linkages
- National and international regulations
- Dosimetry protocols
- Industry perspective
- Panel discussion & Recommendations

The resource persons include international and national experts in radiation technology and the presentations will be by invitation only.

Registration Fee : Rs.2,000 from Delegates from Industry; Rs.1,000 from INS Members and delegates from Universities / Research Institutes, and Rs.500 from Students.

Further details can be had from :

Dr. A.K. Sharma, Connvener ICRAAP-2007,

Head, Food Technology Division, BARC, Mumbai – 400085.

e-mail at ksarun@barc.gov.in .

Grid Project, Variable Energy Cyclotron Centre, Kolkata

Amitava Sur
Variable Energy Cyclotron Centre

ALICE (A Large Ion Collider Experiment) is a dedicated heavy ion experiment at the CERN Large Hadron Collider which will complement the other experiments (ATLAS, CMS) in the study of connection between phase transitions involving elementary quantum field, fundamental symmetries of nature and the origin of mass. ALICE will collect data in lead-lead collisions, proton-proton collisions and will produce simulation data. In one year of operation, ALICE will generate about 2.5 Pico byte of raw and calibration data. ALICE has decided to use GRID environment for their computing need. It will use MONARC model to deal with data processing involving installation of computing centres of various tiers depending on the load of computing.

GRID-based environment named AliEn(Alice Environment) has been implemented along with the LHC Computing Grid. It is a framework providing Grid functionality. It is built on the top of the latest standards for information exchange & authentication (SOAP, SASL, and PKI) and common open source components (such as GLOBUS/GSI, OpenSSI, OpenLDAP, SOAPLite, MySQL, Perl5). AliEn provides a virtual file catalogue that allows transparent access to distributed data-sets and provides top to bottom implementation of a lightweight Grid applicable to cases when handling of a large number of files is required (upto 2 PB and 109 files/year distributed on more than twenty locations world wide in case of ALICE experiment).

VECC is a Tier-II Centre for the ALICE experiment. Infrastructure is ready with Power Supply, Air Conditioned Space, Fire-Alarm System, and 34Mbps Network-Connectivity and is under regular operation since year 2004. The installation and commissioning of the Tier-II framework is completed with a limited capacity of recourses. The Present system consists of 13-Duel Xeon 4GB Nodes with capability of running 26 simultaneous independent batch jobs. Four servers cater to Grid-Middleware functionalities e.g. VO-Box & LFC, CE& MON, SE with DPM and the Domain name Servers. ALICE Environment (AliEn) is running on the VO-Box with AliEn-Cluster-Monitor, AliEn-CE, AliEn-SE, AliEn-Package-Manager and MonaLisa-Monitoring agent along with xrooted file transfer agents.

VECC is now under the umbrella of AsiaPacific Software Functionality Test running daily thrice for ensuring Security & Site Functionalities. VECC is presently participating in Physics Data Challenge 2006 since September 2006.

Frequently Asked Questions: Radiation Processing

What is radiation processing?

Radiation processing is controlled application of energy of short wave length radiations of the electromagnetic spectrum known as ionizing radiations and includes gamma rays, accelerated electrons and X-rays to have desired effect on the product.

What are the uses of radiation processing?

Some of the major objectives of radiation processing are:

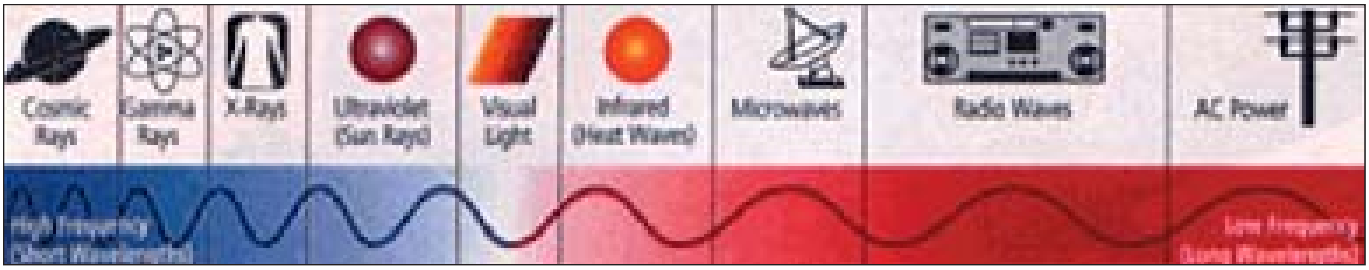
- Sterilization of medical and packaging products,
- Insect disinfestations of food products,
- Phytosanitation to overcome quarantine barriers in fruits and vegetables,
- Inhibition of sprouting in tubers, bulbs and rhizomes
- Delay in ripening of fruits,
- Enhancement in shelf life by destruction of spoilage microbes in foods,
- Elimination of pathogens and parasites in foods,
- Cross-linking of rubbers and polymers, and
- Colour enhancement of gemstones.

Does the radiation processing make food radioactive?

The radiation processing involves passing of food through a radiation field allowing the food to absorb desired radiation energy. The food itself never comes in contact with the radioactive material. Gamma rays, X-rays and electrons prescribed for food irradiation do not induce any radioactivity in foods.

What is the difference between the terms 'radiation processed' and 'radioactive' food?

Radiation processed foods are those that have been exposed to radiation as prescribed above to bring about the desired effect in food. Radioactive foods, on the other hand, are those that become contaminated with radionuclides. This type of contamination never occurs during radiation processing of food.



What are the chemical changes in radiation processed foods and are they harmful?

Radiation processing produces very little chemical changes in food. None of the changes known to occur have been found to be harmful. The radiolytic products and free radicals produced are identical to those present in foods subjected to treatment such as cooking, canning etc. Highly sensitive scientific tests carried out during the past 30 years have failed to detect any new chemical product in radiation-processed foods.

Do the free radicals or radiolytic products, which are produced during radiation processing, affect the safety of food?

There is no evidence to suggest that free radicals or radiolytic products affect the safety of radiation processed food. This has even been confirmed by much long term multigenerational studies in which laboratory animals were fed radiation processed products exposed up to a dose of 45 kGy.

Does radiation processing adversely affect the nutritional value of food?

In comparison with other food processing and preservation methods, the nutritional value is least affected by radiation. Extensive scientific studies have shown that radiation processing has very little effect on the main nutrients such as proteins, carbohydrates, fats and minerals. Vitamins show varied sensitivity to food processing methods including radiation processing.

The change induced by irradiation on nutrients depends on a number of factors such as the dose of radiation, type of food, and packaging conditions. Very little change in vitamin content is observed in food exposed to doses upto 1 kGy.

The Joint Expert Committee of the Food and Agriculture Organization (FAO), World Health Organization (WHO), and International Atomic Energy Agency (IAEA), in 1980 concluded that radiation processing does not induce special nutritional problems in food.

Can radiation processing be used to destroy microbial toxins and pathogenic viruses in food?

As in many other food processing procedures only food of good hygienic quality should be radiation processed. It is very important that foods intended for processing are of good quality and handled and prepared according to codes of good manufacturing practices (GMP) established by national and international standards.

Can radiation processing be used to make spoiled food good, or to clean up "dirty foods"?

Like any other food treatment, radiation processing cannot reverse the spoilage process and make food good. A food that looks smells and tastes bad cannot be saved by any treatment including radiation processing.

Why radiation process spices?

Most spices get heavily contaminated with microbes, including pathogenic bacteria during processing while drying in open. Since radiation processing does not involve increase in temperature and humidity, it extends shelf life of spices in packed form retaining colour, aroma and other sensory properties and at the same time eliminates bacteria and microbes without leaving any chemical residues.

Do gamma irradiators have radioactive waste disposal problem?

Cobalt-60, which is used as the source of radiation energy, decays over many years to non-radioactive Nickel. When the radioactivity falls to a low level, the source pencils are returned to the supplier, who has the option of safely storing them or process further for eventual disposal.

Are there any tests to detect whether food has been irradiated?

There are specific tests developed for certain class of foods. However, no single method has yet been developed that reliably detects irradiation of all types of foods or radiation dose levels applied. Thermoluminescence measurement and electron spin resonance pectroscopy can be used for detecting irradiated spices and meat containing bone tissue.

Will radiation processing increase the cost of food?

Any processing will add to the cost of food. In most cases, however, food prices may not necessarily rise just because a product has been treated. Many variables affect food costs, and one of them is cost of processing. But processing also brings benefits to consumers in terms of availability, storage life, distribution, and improved hygiene of food. Radiation processing can have a stabilizing effect on market price of commodities by reducing storage losses resulting in increased availability of produce.

Where can food be irradiated ?

Food can be irradiated in a food irradiation plant, which is authorized by the Atomic Energy Regulatory Board and licensed by the competent authority. The license to carry out food irradiation operation is given only after ascertaining the safety of the installation, its suitability to ensure proper process control, and availability of licensed operators and qualified staff. A facility could be put up as a private, public or joint sector company.

How can radiation processed foods be identified in the market ?

Irradiated food cannot be recognized by sight, smell, taste or touch. Codex Alimentarius Commission has endorsed a green irradiation logo. As per the PFA (Fifth Amendment) Rules, 1994, all packages of irradiated foods to be marketed in India will be labelled with this logo, along with the words "Processed by Irradiation method", and the date of irradiation, licence number of the facility and the purpose of irradiation. Consumers will have a free choice to buy radiation processed or non- radiation processed commodity.

Processed by Irradiation Method__________

Date of Irradiation __________

Licence No. __________

Purpose of Irradiation __________

Radiation Processing of Sea-Foods

Dr. Arun Sharma
Head, Food Technology Dn., BARC

Seafoods are a major commodity of trade in India, which ranks 3rd in world fish production. During the past few years, India has exported processed fishery products worth more than Rs. 5000 crore to almost all parts of the world contributing nearly 4% of the country's foreign exchange earnings. Fish and fishery products are highly perishable in nature because of their intrinsic characteristics as well as contamination of a variety of spoilage causing microorganisms. It is estimated that about 25 to 30% of total fish produced are lost due to their high perishability and therefore, fail to reach the consumers in the interior parts of the country. Further, fishery products are known as carriers of pathogenic microorganisms, parasites and insects. Presence of these hazards in processed products have caused problems with respect to their acceptability by importing countries. The European Union's ban on import of seafoods from India, a few years ago, was imposed due to the presence of pathogens such as *Salmonella* and *Vibrio* in certain consignments shipped from our country. Such quality problems are frequent in aquacultured fish species, a technology which is gaining commercial status throughout the country. With the implementation of Hazard Analysis Critical Control Point (HACCP) approach and Good Manufacturing Practices (GMP), there has been considerable improvement in hygienic quality. However, these alone cannot ensure safety of processed fishery products.

Radiation processing is one of the novel methods of food preservation and hygienization, which can be used to extend shelf life of fresh fish and eliminate pathogens and parasites in them. Research carried out at the Food Technology Division, Bhabha Atomic Research Centre, Mumbai, for the last three decades and also other parts of the world has established the efficacy of low dose radiation treatment for preservation and hygienization of fishery products. Radiation processing is the controlled application of the energy of ionizing radiations such as gamma rays, x-rays and accelerated electrons for facilitating conservation and distribution of foods and food ingredients. In the case of fish and fishery products three radiation processes are available, namely, Radurization, Radicidation and Radiation disinfestation.

Category of Seafoods Approved for Radiation Processing under Prevention of Food Adulteration Act Rules, 2001

Product	Purpose	Dose (kGy)	
		Min.	Max.
Fresh seafoods	Shelf-life enhancement	1.0	3.0
Frozen seafoods	Pathogen control	4.0	6.0
Dried seafoods	Disinfestation	0.25	1.0

Radurization is a process to pasteurize fresh chilled fish and shellfish by reducing the total microbial load so that the treated material can remain in acceptable condition for longer time in ice. Radiation dose required for this purpose is in the range of 1 to 3 kGy. The Food Technology Division, BARC has conducted extensive studies on shelf life extension of popular items viz. Indian mackerel, shrimp, white pomfret and Indian salmon. The treatment can give a shelf life of 18 to 28 days at ice temperature as compared with 5 to 10 days for untreated fish/shellfish species.

Radicidation is sanitization of frozen fishery products such as shrimp, fish fillets and minced fish blocks by elimination of non-spore forming pathogenic microorganisms such as *Salmonella* and *Vibrio*. Radiation dose required for this is in the range of 4 to 6 kGy. Cartons of frozen fish items can be sanitized prior to shipment for export by this method.

Radiation disinfestation is the process aimed at eliminating insects from dehydrated fishery products. For this purpose, a radiation dose in the range of 0.25 to 1.0 kGy. is used.

Value Addition of Seafoods

Seafoods are increasingly recognized for their role in human nutrition because they contain many nutrients such as easily digestible proteins, vitamins, minerals and polyunsaturated fatty acids which are therapeutically significant. Although several hundreds of species of fish are caught annually throughout the world, all of them are not equally important for processing from a commercial point of view. As a consequence of technological innovations of fishing operations and international competition, stocks of many fish species such as pomfret are becoming limiting. At the same time, approximately 30% of the total landings do not fetch much consumer value because of their peculiar characteristics such as typical appearance, odour, size, and bony nature. A large amount of such underutilized fish species belonging to *Elasmobranchs, Sciaenids and Carangids* are caught annually in India. While conventional techniques such as canning and freezing have limited scope for processing underutilized fish species, alternative technologies are required to make better use of these fish. Therefore a need has arisen for total utilization of the catch for meeting increasing consumer demands for the commodity.

A number of processes such as smoking, canning in special media, development of surimi (washed fish meat) and surimi based fish analogues, fermentation, pickling, isolation of components such as proteins, gelatin, oils, enzymes, pigments, and chitin have been attempted for making use of low cost fish species. At the Food Technology Division, BARC, several processes have been standardised for value addition of underutilized fish species. These include restructured fish steaks from shark meat, spray dried protein powders from miscellaneous fish, composite steaks from shark and other fish, dehydrated laminates of Bombay duck and protein hydrolyzate of tiny shrimp (Jawala). A process has also been developed for extended refrigerated storage of ready-to-prepare, high value fish/shellfish items. Followins is a brief description of these products.

Restructured steaks and paneer from shark meat

Various species of shark can be used for the product preparation. Deboned and deskinned shark meat is cut into small pieces, soaked overnight in cold water and the washed meat is homogenized in fresh cold water. The homogenate is converted into a gel by reducing the pH using a weak organic acid. The gel is moulded in the shape of fish steaks, steamed, cooled and packaged in polyethylene pouches. The product is stable against microbial growth and has a shelf life of 2 months in a refrigerator. Prior to consumption, the steaks are deacidified, salted, fried in vegetable oil and served hot. The gel can also be used as paneer. Various condiments could be added to suit the taste of consumers.

Spray dried fish protein powder

Meat mince from underutilized fish such as threadfin bream, dhoma, shark, Bombay duck is collected by mechanical deboning of the fish. The mince is washed repeatedly in chilled water and the washed mince is treated with weak organic acid to get meat dispersions. Proteins in the dispersion are highly heat stable. The dispersions are subjected to spray drying to get protein powder. The powder is colourless and odourless and has good functional and nutritional properties. The powder from threadfin bream has 93% protein, good solubility in water and emulsifying capacity. It had a protein efficiency ratio comparable to that of casein suggesting its nutritional quality. The powder can be used as a protein supplement in various starch preparations. For example, protein-supplemented extrusion cooked corn products can be prepared by incorporation of the powder. The powder may also be incorporated in chapaties and biscuits.

Biodegradable film

Accumulation of non-degradable packaging material is a major problem and therefore a need for development of environmentally friendly films has been realised. A process to make biodegradable film from low cost fish meat has been developed. The film is developed by air drying water dispersion of gel prepared from shark, threadfin bream or dhoma in thin layers. The film developed from shark meat has a thickness of 0.06 mm, tensile strength of 7.8 Mpa, elongation of 4.6% and water vapour transmission of 36 g/m2/24 hr. The material has potential to replace polyethylene as a wrapping material for frozen fishery products.

Bombay duck laminates

About 100,000 metric tonnes of the fish are landed annually in the country. The fish does not attract much consumer value and hence most of the catch is sun-dried on the shore and sold at cheap price. A process has been developed for good quality dehydrated laminates of Bombay duck. The fish is washed, beheaded, eviscerated and cut open in the middle. These fillets are pressed in a screw press to reduce some amount of free water. They are then air dried at 55-60 °C to reduce the moisture content to 15-20%. The dried products are roller pressed and the sides are trimmed to get attractive laminates. Bombay duck laminates prepared by this process have at least 88% protein, 2.5% lipids and are free from any discolouration and off-odour as compared with unattractive, sun-dried counterparts. It has a shelf life of at least six months at ambient temperature. The process helps better marketability of the fish, which can be ideally consumed after frying in vegetable oil.

Dehydrated ribbon fish laminates

Ribbon fish is a major catch from Indian waters, and constitutes four species, the major one being *Trichurus lepturus.* Average annual catch of the fish is about 62,000 metric tonnes. Pieces of eviscerated and beheaded fish were pressed under a screw press and the laminates obtained were subjected to air drying at 55°C to get a final product having 15% moisture, 70% protein and 10% lipids. The product packed in synthetic pouches has a shelf life of 100 days at ambient temperature. It can be consumed after frying in vegetable oil.

Jawala protein hydrolyzate

A process has been developed to prepare protein hydrolyzate from non-penaeid Prawns, Jawala. Homogenate of fresh Jawala is prepared in distilled water and incubated at 58°C for 2 h. The solubilized contents are filtered and vacuum dried. The dried product contains 70% protein. This product can be used as protein source in aquafeed formulations

Cook-chill process for enhanced refrigerated storage of shrimp and white pomfret steaks

A process has been developed for preparation of ready-to-use shrimp and white pomfret steaks which can help their better inland distribution and convenient use at the point of consumption. Fresh shrimps are peeled and deveined and subjected to a dip treatment in brine. In the case of white pomfret, steaks of the fish are subjected to dip treatment in brine. The brined product is given a dip in an aqueous solution of sodium tripolyphosphate in order to enhance its flavour. The salted products is then subjected to steaming. It is then immediately cooled, and packaged in synthetic pouches. The product has a shelf life of at least one month at 3°C. The products can be transported under refrigerated conditions to supermarkets and can be conveniently prepared for consumption after incorporation of preferred condiments.

Some frequently asked questions about seafoods

What are seafoods?

The term 'seafood' is used generally to encompass a variety of groups of biologically divergent animals consisting not only of fish, but also crustacea, such as shrimp, crab, lobster, molluscs, including, oyster, mussel, clam, scallop etc. Out of more than 25,000 known species, only a few hundreds are actually used as food, bulk of the supply being contributed by not more than a few dozens of species.

How much fish is available as food?

The annual global fish landing is around 120 million metric tons, while India produces more than 5.5 million tons. Of these all are not important as food. The total catch is not keeping pace with the demand. In recent times, aquaculture of preferred fish and shellfish is undertaken to fill the gap between availability and demand. It is expected that aquaculture might contribute 50% of total available fish in the near future in India.

What is the role of fish in nutrition?

Fish is considered as 'light' food, meaning it is easily digestible. It is rich in proteins and micronutrients including vitamins and minerals such as calcium, phosphorus and iodine. The amounts of fat soluble vitamins and minerals is considered higher in fish than in terrestrial animals. Fatty fish are also rich in omega-3 fatty acids, which are significant in reducing serum cholesterol level, blood pressure and the risk of coronary heart disease.

Why conservation of fish catch is important?

Fish are highly perishable due to their intrinsic characteristics as well a contamination of spoilage causing microorganisms from different sources. The freshness of fish is therefore required to be preserved for their distribution among the consumers in the interior parts of the country. In addition, at least 30% of the total catch consists of species that are commercially less important due to poor appearance, bony nature, smaller size and presence of compounds such as urea.

What are the techniques for preservation of fish?

Techniques such as chilling and freezing are the common methods for preservation of fishery products. Chilling can be integrated with other techniques such as low dose gamma irradiation or modified atmosphere storage to further enhance the freshness of fishery products.

Why value addition is important and what are the techniques available?

A number of underutilized and bycatch fish, although nutritionally important, need novel technologies to make them acceptable by the consumers and hence enhanced marketability. Because of changing life styles and higher purchasing power, consumers also would prefer processed fishery products in supermarkets In ready-to-serve forms. The various techniques available for value addition include canning, cook-chill processing, fermentation, breading and battering, high pressure treatment, marination, smoking, modified atmosphere packaging and development of fish mince products such as sausages, surimi-based texturized seafood analogues etc. The advances in process machineries and packaging technologies can help in value addition of fishery products.

What is the difference between the terms"Irradiated"and"Radioactive" food?

Radiation processed foods are those that have been exposed to radiation as prescribed above to bring about the desired effect in food. Radioactive foods, on the other hand, are those that become contaminated with radionuclides. This type of contamination never occurs during food irradiation.

What are the chemical changes in radiation processed foods and are they harmful?

Irradiation produces very little chemical change in food. None of the changes known to occur have been found to be harmful. The radiolytic products and free radicals produced are identical to those present in foods subjected to treatment such as cooking, canning etc. Highly sensitive scientific tests carried out during the past 40 years have failed to detect any new chemical product in radiation processed foods.

Does irradiation adversely affect the nutritional value of food?

No. In comparison to other food processing and preservation methods the nutritional value is least affected by irradiation. Extensive scientific studies have shown that irradiation has very little effect on the main nutrients such as proteins, carbohydrates, fats and minerals. Vitamins show varied sensitivity to food processing methods including irradiation. For example, vitamin C and B1 (thiamine) are equally sensitive to irradiation as well as to heat processing. Vitamin A, E, C, K and B1 in foods are relatively sensitive to radiation, while riboflavin, niacin, and vitamin D are much more stable. The change induced by irradiation on nutrients depends on a number of factors such as the dose of radiation, type of foods, and packaging conditions. Very little change in vitamin content is observed in food exposed to doses up to 1 kGy. The Joint Expert Committee of the Food and Agriculture Organization (FAO), World Health Organization (WHO), and International Atomic.

Director, Raja Ramanna Centre for Advanced Technology, Indore is honoured

Rani Durgavati Vishwavidyalaya (formerly University of Jabalpur) has conferred the Honoris Cause Doctorate Degree on Dr. V C Sahni, Director, Raja Ramanna Centre for Advanced Technology, Indore. In picture above, Dr. Sahni is receiving the Degree from Dr. Balram Jhakkar, His Excellency Governor of Madhya Pradesh and Chancellor of the Rani Durgavati Vishwavidyalaya.

BARC develops Value Added products from ripe banana

Unlike the developed countries, in India the development of commodities of consumer interest by value addition of fruits is less than 2 % of the annual agricultural produce. Short shelf and increased production necessitates development of non-conventional products from banana. BARC has developed a bench level technology for extracting almost 60-70 % of the total soluble materials of banana in the form of its juice and the left over pulp can be dried into a fine powder. This process has been patented. Taste panel studies were conducted at Food Technology Division, FIPLY, BARC involving 30 panelists.

The technology is capable of extracting 600-700 ml juice from one kg of Basari '10 Gy'(developed by tissue culture at BARC) variety; 400-500ml from Harichal variety, and does not involve addition of any external agents such as water and enzyme. The left over pulp retains all aroma of banana. It can be dried and powdered to give ripe banana powder. Taste panel studies showed general acceptability of non-conventional products developed from banana. The dry powder can be used as an additive in confectioneries, milkshakes and baby foods. Other products developed from ripe banana powder in BARC laboratory include biscuits, cake and baby food. Banana juice can also be used for the production of banana wine by fermentation, which has a lot of commercial value. The extracted juice after a dilution is ready to serve as nectar and/after carbonation as a drink.

Scale-up of this technology provides an excellent scope for the development of non-conventional products from banana.

IN PARLIAMENT

Question 53 (Shri Suraj Singh) Setting up of Atomic Energy Centres (Dtd.: 22.11.2006)

(a) the number of Atomic Energy Centres proposed to be set up by the year 2010; and

(b) the measures taken by the Government for the modernisation and expansion of the existing centres?

Answer

(a) The Government is setting up one new Atomic Energy Research Centre near Vishakhapatnam on the Eastern Coast. In principle approval of the Government has also been obtained for establishing a Nuclear Power Plant at Jaitapur (Maharashtra) and for expansion of existing projects at Kakrapar (KAPP 3&4), Kudankulam (KK3&4) and Rawatbhata (RAPP 7&8) in addition to the expansion projects under construction at Kaiga (Kaiga 3&4), Rawatbhata (RAPP 5&6) & Kalpakkam (Prototype Fast Breeder Reactor).

(b) The modernization and expansion of the existing research centres has been an ongoing process and is being carried out through various plan projects by adopting state-of-the-art technologies developed in-house/available internationally. Modernisation and expansion of the existing Nuclear Power Stations is also being carried out to utilise their full potential. Enmasse replacement of coolant channels, replacement of feeders, modification to moderator system are examples of modernisation and expansion carried out in recent past.

Question 121 (Shri Jual Oram) Modernisation of Rare Earth Units (Dtd.: 22.11.2006)

(a) the number of Indian Rare Earth Units in the country;

(b) whether the Government has a proposal to modernise some of these Rare Earth Units;

(c) if so, the details thereof; and

(d) the funds earmarked therefor?

Answer

(a) Indian Rare Earths Ltd has Four Units, one each at (1) Rare Earths Division, Aluva, Kerala; (2)Chavara, Kerala; (3) Manavalakurichi, Tamil Nadu; and (4) Orissa Sands Complex (OSCOM), Orissa

(b) Yes, Sir.

(c) The Company has undertaken to modernize and expand the production capacities of their units in two phases as under (Table A):

(d) The funds earmarked for various expansion and modernization projects are as under (Table B):- (Rupees in Crores).

Table - A

Sr. No.	Unit annum)	Present Capacity (tons per Ilmenite Ilmenite	Capacity after Expansion Phase-I (tons per annum) Ilmenite	Capacity after ExpansionPhase-II (tons per annum)
1.	Manavalakurichi	90,000	1,50, 000	2,50,000
2.	Chavara	1,54,000	2,00,000	2,75,000
3.	OSCOM (Phase-1)	2,20,000	2,50,000	5,00,000
4.	RED, Aluva	28*	36*	—
	*Rare Earth (RE) products			

Table - B

Sr. No.	Unit	Expansion Phase-I X Plan	Modernization Projects in XI Plan	Expansion Phase-II	Modernization Projects in
1.	Manavalakurichi	56.50	16.16	65.00	25.00
2.	Chavara	47.08	41.89*	80.00	35.00
3.	OSCOM	48.00	10.95	100.00	35.00
4.	RED, Aluva	11.53	6.49	—	25.00
	* Includes cost of land for mining.				

Fluoride Detection Kit

In potable waters, a fluoride concentration of 1 mg/ml is necessary to prevent tooth decay. At higher concentrations (>2 mg/ml), it has adverse effects such as causing fluorosis. Dissolution from fluoride-bearing minerals and volcanic rocks contaminates the groundwater with fluoride. As many as 17 states of India have been identified to have the problem of excessive fluoride in groundwater. Long term consumption of such water (fluoride above 1 ppm) can cause damaged and discoloured teeth (dental fluorosis) and debilitating bone ailments (skeletal fluorosis) which are irreversible. The only way out is to prevent the intake of fluoride. In India, most of the people use their own water sources. In such cases, checking the fluoride content at every water source is practically impossible by government laboratories. To monitor fluoride, there is a need for fast, simple and cost effective method, which can be easily adapted by common man.

The first and most obvious step towards this is identification of fluoride-free sources of groundwater. Fluoride Detection Kit (FDK) provides an ideal technology to produce field-kits for this purpose.

A method for the estimation of fluoride based on the bleaching of zirconium-xylenol orange complex has been developed at BARC. Zirconium forms several complexes with xylenol orange. In this method, the metal to ligand ratio has been optimised. Acidity and dye concentration have been optimised such that distinct colours are produced at three different levels (deficient, normal and toxic) of fluoride. Zirconium ions, which get polymerized at a lower acidity, affect colour development. De-polymerization of zirconium ions has been achieved using specific treatment, which helps in instantaneous colour development.

The procedure is as simple as adding a specified amount of a reagent to the water sample and identifying the color developed. The color develops almost instantaneously and the distinction can be made with the naked eye. Water sample can be immediately categorized as being safe, marginal or unsafe for drinking from fluoride point of view. Even a layman can perform the test. The kit is an excellent tool for individual/ community level identification of fluoride free groundwater sources.

BARC provides complete know-how to produce the reagent, the kit and the testing procedures to the interested entrepreneurs.

Features

- *Instantaneous results*
- *Eliminates the use of sophisticated instruments for analysis*
- *Low investment on infrastructure for producing the kits*
- *Easy availability of the raw-materials*
- *Good accuracy for the intended purpose*

Further details can be had from :
Head, Technology Transfer & Collaboration Division,
Bhabha Atomic Research Centre
Trombay, Mumbai-400 085
Tel : 091-022-25505337
Fax : 091-022-25505151
Mail:headttcd@magnum.barc.gov.in

BARC serves the nation through its expertise in Isotope hydrology

The Central Water Commission (CWC), Central Board of Irrigation and Power (CBIP), Central Groundwater Board (CGWB), National Environmental Engineering Research Institute (NEERI), National Institute of Oceanography (NIO) and various port/ dam authorities and a host of institutions in the country call upon the expertise in BARC to find solutions to a variety of water resource problems. In addition, the International Atomic Energy Agency, which has a large isotope hydrology programme in the developing world often calls upon BARC expertise for a variety of assignments. BARC also provides training facilities for scientists and engineers from India and abroad in the area of isotope methods in hydrology. Isotope Applications Division, BARC provides group training, covering all aspects of isotope hydrology for Asia/ Pacific region.

Some of research programmes currently in progress in BARC are as follows:

- Isotope techniques in water resources investigations in arid/semi arid regions,
- Isotope techniques for management of coastal environment,
- Isotope response to dynamic changes in groundwater systems due to long-term exploitation,
- Isotope applications in dam safety and dam sustainability,
- Isotopes in the study of pollution behaviour in the unsaturated zone for groundwater protection, and
- Application of isotope techniques to investigate groundwater pollution and surface water pollution.

Edited and published by R K Bhatnagar, Hd. Publication Dn, Dept. of Atomic Energy, Govt. of India, Mumbai-1.