



CELLULAR AGRICULTURE

THE FOOD OF FUTURE



PROF. PRABHAT RANJAN

We live on a planet that is starkly different from that it was in the past, transformed completely by the number and activities of just one species- the human species! The transformation accelerated with technology revolutions beginning with the Industrial Revolution. Ever since this defining moment in the planetary or human history, the technologies have increased interconnectedness between human, natural and built systems and this today is prominently mirrored from the measure of greenhouse gas (GHG) emissions. Clearly the progress has hugely impacted earth's environment and our climate. While technology is hailed and nailed to be the cause of the climate change crisis, it ironically, is

the one which will be bail us out, just as did for the ozone hole!

Fortunately there has been a global consciousness on this mega-issue and TIFAC as a public foresight organisation has been following the global trends and technologies on horizon. Here we share interesting technologies in the area of Food which hold promise to confront climate change challenges- Cellular Agriculture being one and Vertical Multilayer Farming the other.

The data indicates that 18% of global anthropogenic greenhouse gas emissions come from livestock farming. By contrast, global transportation accounts for

PREPARING INDIA FOR CLIMATE CHANGE
03

LEARN TO LIVE WITH LESSER
04-05

DELHI GAINS 60% POLLUTANTS FROM OUTSIDE!
06

TECHNOLOGIES ON THE HORIZON
07

SNAPSHOTS
08

only 13%. At the same time 26% of Earth's ice-free surface is used for livestock farming, nearly 70% of all agricultural land. In addition, 27-29% of freshwater footprint is used for the production of animal products. Livestock farming is a top contributor to deforestation, land degradation, water pollution and desertification. Considering the impacts and challenges of livestock farming and also the fact that anticipated global demand for animal products to increase by 70% in 2050, it becomes extremely important to explore different ways to feed the growing population without destructing the earth's resources.

One way to do this is to promote Cellular agriculture and 3D food printing, the two new technologies that are expected to change the way people will source food from in near future. These technologies lead to animal-free, cultured & plant based versions of meat, milk, eggs and leather or in other words, they are milk without cow, eggs without hen and meat without animal. Over the last three years, several cellular agricultural startups have been created applying cellular agriculture to make a number of agricultural products and consumables.

serting the genes for casein and whey proteins into the yeast cells, and the fats are sourced from plants. They all are combined to make milk. As this milk is molecularly identical to milk from cows, it can produce cheese, yogurt, kefir and cream.

In fact, "Vegetarian Meat" based on plant sources is now available in India too. These alternate forms of growing meat have lead to saving many resources detrimental to environment as well as created better acceptance by vegetarian segment of society from nutrition point of view and also reduction in cruelty towards animals.

It offers significant promise for a more safe and diverse food system in a sustainable manner. If monitored and managed appropriately, cellular agriculture could allow humans to produce more food on less land than ever before while simultaneously addressing environmental problems.

The main question in the Indian context here is, are we ready to face these innovations in our food systems? Despite many benefits, any major innovation always comes with impending fears. People may oppose them

HARNESSING VERTICAL FARMING

Vertical farming can be defined generically as a system of farming whereby plants, animals, fungi and other life forms are cultivated for food, fuel, fiber or other products or services by artificially stacking them vertically above each other. The concept foresees the cultivation of fruits, vegetables, medicinal, fuel producing plants and other plant products in the cities and marketing the produce directly within the cities, thereby reducing the transportation costs and efficient utilization of land and water resources. Vertical farming is a step ahead from green house/polyhouse cultivation as it involves harnessing of resources in vertical arrays through appropriate technology.



IMAGE SOURCE: <http://www.evolo.us/architecture/the-quartz-vertical-farm/lands/>

Currently the technology for producing meat is developing fast in this sector both from plant sources as well as through Cell Culture. Some startups and food companies have already begun research in this direction and in some cases research has reached conclusive stage. For instance, the milk prototype was produced last year and testers have described the milk as 'having the same mouthfeel' as milk from cow. In this case, yeast is reprogrammed to produce milk proteins by in-

on different grounds – two most common grounds to oppose can be losing jobs and its acceptability. In reality, such inventions do not reduce the jobs, but merely change their pattern – conventional jobs are reduced, but new types of jobs are created.

All this technology-driven transformation has been deeply affecting people's lives and will continue to shape the future of food on earth.



PREPARING INDIA FOR CLIMATE CHANGE

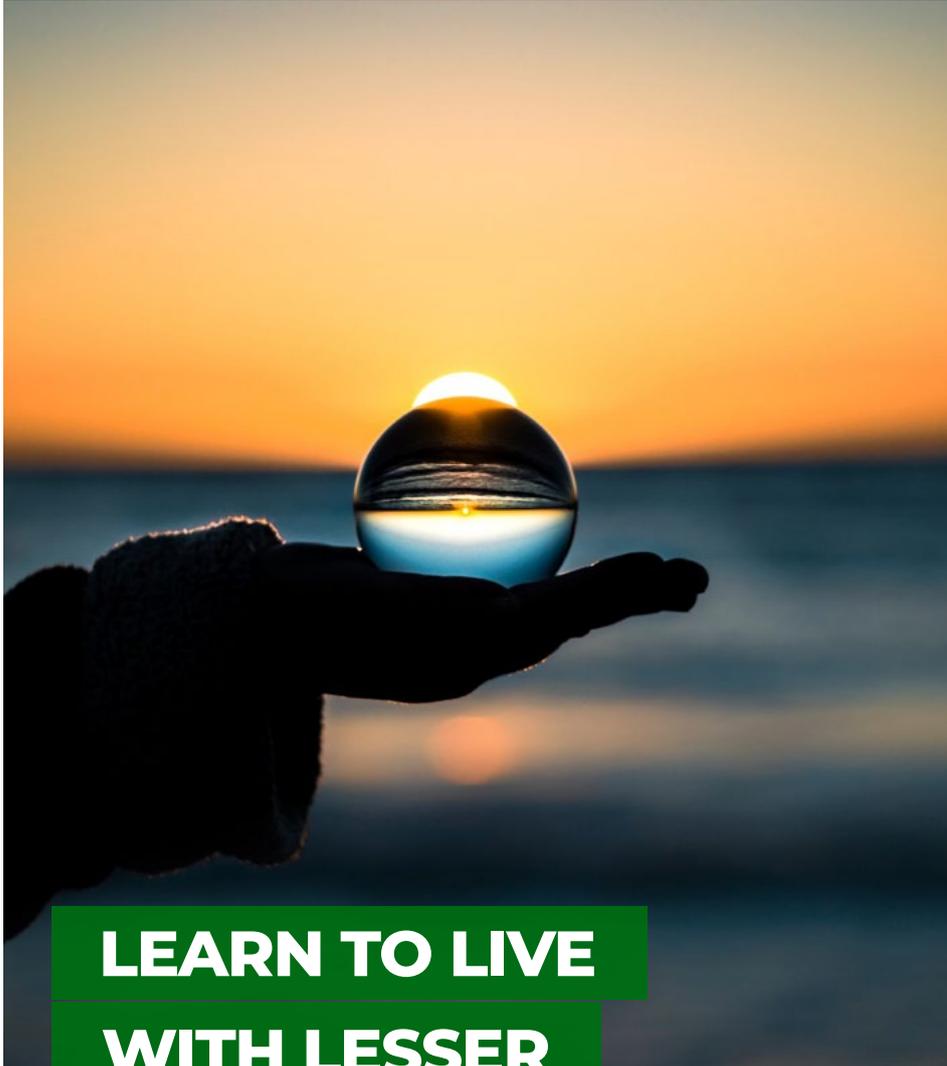
A look at global economic history brings out the fact that human population is a function of *inter alia*, the technologies humans have created to support themselves. The interactions between human and natural systems have dramatically expanded since the Industrial Revolution and has reached to a point when the humanity confronts the challenge of Climate Change, attributable to Greenhouse gas emissions (GHG). However, there is also an opinion that climate change is happening in natural course, based on analysis of historical data of the planet. Whatever be the source, the fact remains that temperature is rising and needs to be controlled.

Fortunately, the crisis has brought together the global community together on one platform even though many issues attached to it remained politically contested. The United Nations Framework Convention on Climate Change (UNFCCC), an international environmental treaty, that came into force on 21 March 1994 when a sufficient number of countries ratified it, binds them all. The parties to the convention have met annually from 1995 in Conferences of the Parties (COP) to discuss how to keep temperature rise below 20C. In COP 21 held in Paris, it was decided and agreed that every country made certain commitments in the form of 'Nationally Determined Contributions (NDC)' about their GHG emission reduction targets based on their capability, resource availability and the existing policies and thus making every country accountable. Even though India is a low-carbon economy, yet as a

responsible member it has made three very important commitments in its NDC namely, (i) reducing emission intensity of its GDP by 33-35% by 2030 from 2005 level, (ii) achieving 40% cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 and (iii) creating an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030. Fulfillment of these targets will depend on strong commitment coupled with firm technology path and conducive policies.

Government of India has launched several missions under National Action Plan on Climate Change (NAP-CC) and states too have launched State Action Plans on Climate Change (SAPCC) to fulfill the commitment. In order to cater to the technology needs of these missions, TIFAC is preparing Technology Needs Assessment Report for ten sectors with a broader objective to fulfill the NDC commitment by 2030. TIFAC is also keeping a watch on Global Technology Development in six sectors and select a few for large scale adoption in India. TIFAC has compiled a database of technologies benign to environment and these were showcased in COP 21, COP 22 & COP 23 in Paris, Marrakech and Bonn respectively. This reflects India's commitment as a responsible nation. India has always taken a positive approach to tackle climate change and would stick to its commitments as protecting environment is in the DNA of Indian Culture..

- DR. GAUTAM GOSWAMI



LEARN TO LIVE WITH LESSER

Passing on the Earth to next generation as we have received from the previous is perhaps the biggest responsibility and also a huge challenge for the present generation. This requires balancing social and economic development with the resources available to us- and is irrecusably by any measures a daunting task. Ever since the Industrial Revolution, human foot-prints on the Earth have constantly expanded due to increased industrial production and urbanization- both using massive resources of materials and energy. In the last hundred years, the human population on the planet has increased four-fold while use of material and energy has increased ten-fold! The United Nations forecasts that the world's urban population will increase by 270 crore people between 2010 and 2050; it should not be difficult to specu-

late how much resources urbanites will gobble up by then. The massive consumption of resources has already compounded into serious problems such as global warming, material depletion and enormous waste generation. Gradually pushed to the edge, we are forced to talk of sustainable cities, zero wastage, reduced food-prints and judicious use of our resources. The alarm bells may be ringing albeit at a distance but it is high time to get our acts together to reverse or at least arrest the tilting of scales against the Nature before the situation becomes irremediable.

Over the last couple of centuries, we humans have asserted ourselves as the center of the planet- extracting and devouring everything around and increasing our ascendancy over other creatures- by intensive application of technology in manufactur-

ing and agriculture. Demographical changes, growing social disparities, continuing urbanization processes with rapidly expanding cities further exacerbate pressure on our resources (materials, energy, water etc.). Intricately linked urbanization, material consumption and modern lifestyle are actually conspiring to deplete the natural resources. Let us see specifically how consumption of food and water and the generation of waste in cities is trending world over and how the statistics from the developed world can be a pointer to the way the things will pan out for emerging India.

According to recent reports of Food & Agriculture Organization (FAO), food worth Rs. 241500 crore is thrown away each year in the US and along with it goes half the water to be used in agriculture there. In Britain, 7 crore tonne food is consigned to bins every year, of which almost half is actually worth consuming. In Canada, Rs. 135000 crore worth of food is wasted annually and much of it is unconsumed or discarded as it hits the date of expiry. In Germany, food worth Rs. 19875 crore from homes, hotels, restaurants, canteens, retail markets and industrial units numbering 1.1 crore in all, goes waste. Likewise in Australia, 45 lakh tonne of food worth Rs. 26000 crore is wasted every year. Per capita wastage in Europe and North America per annum is anywhere between 94-114 kg and the corresponding figures for Asian and African countries is 6-11 kg. A synoptic view suggests that homes alone account for 42% of food wastage, the producers of food for another 39%, the caterers add around 14% and shopkeepers/retailers/vendors wasting the remaining 5%. These statistics clearly point towards the tendency of the individual consumers in the developed world to waste more. But the picture is even scarier when we look at water that is as important as food.

Much of our water use is for drinking, cooking, washing etc. and research shows that this quantity per person actually averages out to 220 litres

per day! Even more astonishing is the fact that we use many times this amount in ways we don't ever realize. The products we buy from the shops and supermarkets all have a water cost, as they require water in their growth, production, packaging etc. According to the Water Footprint Network (WFN), the water required for production of industrial products we use every day, such as paper, cotton and clothes, amounts for a person to about 450 litres per day. Much more water is associated with producing the food we eat—the water required to grow, raise, produce, package and ship it. This amounts to around 5,600 litres every day for each individual! Startling, when compared with the water we handle privately. If this is multiplied with the amount of food wasted per day world over (36-55 lakh tonne), the figures are quite mind-boggling and should rattle our conscience.

Another major challenge gripping the urban settlements is the mounds of waste that they generate each day. The share of materials in the waste stream- including plastics, paper and aluminum besides the organic refuse, tends to increase as people grow wealthier and move to cities. Municipal waste is on the rise and is growing at a faster rate than population itself, notably due to increasing rate of consumption and the shortening of product life-spans. As per the World Watch Institute, each person in an OECD nation generates over two kilograms of municipal solid waste every day which amasses to 16 lakh tonne each single day. In contrast, South Asia generates waste at a rate that is less than a quarter as much, under half a kilo per person, while the sub-Saharan Africa produces less than one-eighth as much, some 2 lakh tonne per day. Although some of this waste is eventually recycled, current projections indicate that the solid waste of 13 crore tonne per year presently would double by 2025. Therefore, we see that the developed world is not just consuming overwhelmingly but also generating waste and should this go full-on, the

tipping point should not be too far- a red flag for developing countries alike!

Concerns due to unchecked economic and population growth with finite resource supplies and limits to growth have been under focus of countries across the world for a few decades now. For a hugely populated country like India, aspiring to go notches up on developmental indi-

“Earth provides enough
to satisfy every man’s needs,
but not every man’s greed.”



~Mahatma Gandhi

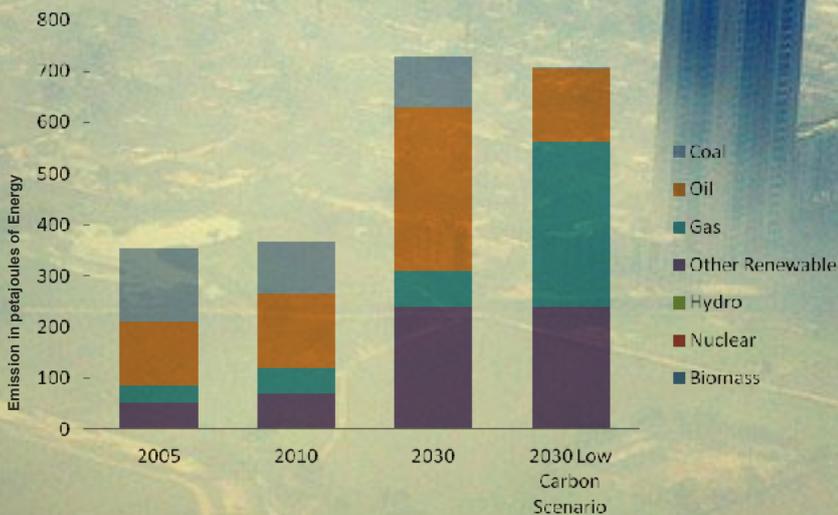
ces, to be bracketed with developed countries, the expectations of the people here for a better quality of life will place a demand on the resources. In the next 20 years, India would not only be the most populated but predictably one of the biggest economies- implying significant increase in economic activity and access to modern amenities accelerated by technologies. Manifolds increase in the pressure on urban infrastructure, demand for processed food and consumer goods and also energy would necessitate paradigm technological shifts in manufacturing, infrastructure, services and agriculture sectors with far greater per capita value addition. With all this and per capita income projected to almost double every ten years, the transformed India would acquire several attributes of developed economies of today- and that of a ‘consumerist’ being most prominent.

A study by McKinsey Global Institute brings out that India's consumer market hitherto was broadly defined as a pyramid- a very small affluent class with an appetite for luxury and high-end goods and services at the top, a middle-class at the center and a huge economically disadvantaged class at the bottom. This pyramid structure of the Indian market is slowly collapsing and being replaced by a diamond – a relatively large affluent class at the top, a huge middle class at the center and a small economically disadvantaged class at the lower end. The diamond represents increasing volume and value across all classes of Indian consumer market. With Indian consumer who is more discerning than ever, ready to place his money on brand, quality and convenience and eager to explore the market, Consumerism could well be the new religion. But will our over-fondness for things and the consequent ballooning of consumption make us a happy nation?

Mahatma Gandhi could, almost a century back, foresee the perils of consumerism when he said “Earth provides enough to satisfy every man's need but not for every man's greed”, in a way sounding a note to change the attitude towards the resources we are blessed with. Inarguably, writing is already on the wall that we need to be “sensible citizens” and not “insensitive consumers” of the world- appreciate that era of surplus is not to last forever and make an attitudinal change to see the limits before it limits our existence. The responsibility squarely falls on the present generation that is in command, to reposition Earth as the center of our existence and contain the predatory attitude. In doing so, while the wisdom of older generation needs to be recalled and imbibed, the present generation should recalibrate its life-style and also practice what it would preach to the next generation- “learn to live with lesser”.

- DR. NEERAJ SAXENA &
MANISH KUMAR

TIFAC-NEERI-IIASA Study on Development and Application of the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-City Model for Indian Cities



Future Emission Projection in Delhi, based on GAINS model

DELHI GAINS 60% POLLUTANTS FROM OUTSIDE!

An analysis of Delhi's air pollution and future trends suggests that 60% of Delhi's particulate matter pollution comes from neighbouring Haryana and Uttar Pradesh. In fact, if Delhi were to adopt the cleanest grade fuel available, pollution would still persist well above globally recommended safe levels unless neighbouring states too adopted similarly stringent policies. This was the outcome of a study conducted by TIFAC-NEERI-IIASA on Development and Application of GAINS-City Model

WHAT IS GAINS?

The GAINS model of IIASA explores cost-effective emission control strategies that simultaneously tackle local air quality and greenhouse gases so as to maximize benefits at all scales. It is used as part of the standard modeling framework for negotiations under the Convention on Long-range Transboundary Air Pollution and the European Union.

for Indian Cities. The study finds that nearly a fourth of the 15,000 tonnes of PM_{2.5} emitted annually is due to road dust and about 40% due to power plants and residual and commercial combustion. Based on the model, the National Green Tribunal (NGT) has taken initiative on managing deteriorating quality of air in Delhi. The model has also discussed the management options to improve Delhi's air quality and associated co-benefits in the recent conference COP 22 held at Marrakech, Morocco. GAINS Delhi policy analysis model reveal current sources of pollution that threaten the health of Delhi's citizens and also talked about as to how to make use of the model for potential policy interventions that could effectively reduce environmental pollution and health impacts in the coming years. The presentation demonstrated that models could be effective tools for the regulators to consider proper controlled measures..

- SANGEETA BAKSI

TECHNOLOGIES ON THE HORIZON



**SUSTAINABLE ELECTRICITY
FROM OCEAN CURRENT – JAPAN**

Researchers from the Okinawa Institute of Science and Technology Graduate University (OIST) in Japan began a project titled “Sea Horse,” which aims to harness energy from the Kuroshio ocean current that flows from the eastern coast of Taiwan and around the southern parts of Japan. Using just 1% of the seashore of mainland Japan can generate about 10 GW of energy, which is equivalent to 10 nuclear power plants.

<https://www.oist.jp/news-center/news/2017/9/20/sustainable-future-powered-sea>



**USE OF HYDROGEN FUEL
CELL IN TRANSPORT – INDIA**

Tata motors & ISRO reveals India's first hydrogen fuel cell bus in India for zero-emission mass transport solution. Combining hydrogen gas and oxygen, the fuel cell produces electricity to power the electric motor, with water and heat as a by-product. This is the first time an Indian manufacturer has ventured in the direction of green technology and mobility solutions.

<https://auto.ndtv.com/news/tata-motors-reveals-indias-first-hydrogen-fuel-cell-bus-1652559>



**INDIA ACHIEVES 20 GW SOLAR CAPACITY
GOAL FOUR YEARS AHEAD OF DEADLINE**

In what appears to be a giant step for India towards solar energy, the country has achieved its target that was set for 2022, four years in advance. Latest data show that India has already achieved its solar capacity target of 20 GW in 2018. The latest data by Mercom India, a clean energy market tracker, mentioned that India achieved this goal in cumulative solar installations. The states leading in solar installations are Telangana, Karnataka, Rajasthan and Andhra Pradesh. In the calendar year 2017 alone, installations reached up to 9.6 GW that is 45 per cent of the total additions. The new target is set to be achieved with 60 GW of large and medium scale solar projects, and 40 GW will be dedicated to rooftop solar projects.

<http://www.businesstoday.in/current/economy-politics/india-achieves-20-gw-solar-capacity-goal-4-years-ahead-deadline/story/269266.html>



**NEW RESEARCH BRINGS US CLOSER
TO CHEAP, TRANSPARENT, ORGANIC
SOLAR CELLS - EUROPEAN UNION**

The European Union has set a target of obtaining 20 percent of its energy from renewable by 2020 and 27 percent by 2030 (it's currently at 17 percent). Similarly, China has set a target of 20 percent renewable by 2030. While it might be possible to meet these targets with current technology, but the challenging task is to make renewable a widespread and affordable specifically the way we produce, transfer, and store the energy. A study published in Jan, 2018 in Nature by University of Michigan researchers showed that in the materials used to make solar cells, electrons travel not only further than they ever had before, but further than was even thought possible.

<https://singularityhub.com/2018/01/23/new-research-brings-us-closer-to-cheap-see-through-organic-solar-cells/#sm.000013r1rj1048dueu-7272g86mak8>



**SUN-LIKE STAR CAN HELP
DECODE SUN'S VARIABILITY, CLIMATE
EFFECT – LONDON, UK**

Scientists have found a star that is almost identical to the Sun except for the chemical composition -- which they believe is like a Rosetta Stone that can help shed light on sun's variability and its effect on Earth's climate. The star is located 120 light-years away in the constellation of Cygnus and, on the surface, it looks just like the Sun. It has the same mass, radius and age -- but inside, the chemical composition of the star is very different. It consists of around twice as many heavy elements as in the Sun. Heavy elements here means elements heavier than hydrogen and helium.

<http://zeenews.india.com/space/sun-like-star-can-help-decode-suns-variability-climate-effect-2072871.html>



**SCIENTISTS DEVELOP 'SPEED BREEDING'
TO FEED RISING POPULATION – JOHN
INNEN CENTRE, NORWICH (UK)**

Scientists are engaged in a race against time to breed staple crops that can sustain climate variability and yield bigger harvests. A new system called speed breeding, designed to grow six crops a year, has been developed in glasshouses to accelerate the process. Using LED lighting to aid photosynthesis, intensive regimes allow the plants to grow for 22 hours a day. Among the crops that can now be grown up to six generations a year are wheat, barley, peas and chickpeas. Using this technology, scientists can study the way plants deal with diseases, and their shape and structure and flowering time, and the growing cycle can be repeated every eight weeks. It is hoped that the technique will yield new varieties of crops that can be grown on a commercial scale within 10 years.

<https://www.theguardian.com/science/2018/jan/02/weatherwatch-scientists-develop-speed-breeding-to-feed-rising-population>

SNAPSHOTS



i



ii



iii



iv



v



vi

- i. Orientation programme for the 9th batch of KIRAN-IPR (WOS-C)
- ii. TIFAC in COP 23 at Bonn, Germany
- iii. Release of Technology Roadmap on Education
- iv. Steering Committee Meeting of IPP Sector, TNA project
- v. Presentation of Education 2035 Roadmap before the Committee drafting New Education Policy
- vi. Certificate distribution for TIFAC-CIPAM Training of Trainers on IPR

31ST TIFAC FOUNDATION DAY

FUTURE OF LIFE ON EARTH

ROLE OF DISRUPTIVE TECHNOLOGIES

10TH FEBRUARY, 2018
LECTURE HALL - 325,
LHC COMPLEX-III-DELHI
HAUZ KHAS, NEW DELHI - 110016



TECHNOLOGY INFORMATION, FORECASTING AND ASSESSMENT COUNCIL
An autonomous body of Department of Science & Technology, Government of India
Vishwakarma Bhawan, A Wing, Shaheed Jeet Singh Marg, New Delhi-110016
T: +91-11-4252 5644, 5710 & 5712 | F: +91-11-26961158 | E: tificinfo@tifac.org.in
f: <http://www.facebook.com/tifac.dst.india> | www.tifac.org.in

Published on behalf of
Dr. Prabhat Ranjan,
Executive Director, TIFAC

TIFAC TECH TEAM

Jancy. A,
Maan Bardhan Kanth,
Dr. Neeraj Saxena and
Yashawant Dev Panwar

Designed by
i-imagine [www.i-imagine.in]