# INDIAN NATIONAL ACADEMY OF ENGINEERING



## INAE Monthly E-News Letter Vol. VIII, Issue 2, February 1, 2017



**From the Editor's Desk**

**Trust begets trust**

It is believed that both 'cold reasons' and 'hot emotions' are needed to take 'right decisions'. Trustworthy decisions emanate from a trustworthy mind. Being realistic, honest, and forgiving with yourself and with Read more...

**Purnendu Ghosh**
**Chief Editor of Publications**



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It is believed that both 'cold reasons' and 'hot emotions' are needed to take 'right decisions'. Trustworthy decisions emanate from a trustworthy mind. Being realistic, honest, and forgiving with yourself and with others are helpful to deal with the challenges of tough times. Matters related to trust occupy a huge amount of our mental energies. Under vulnerable circumstances we tend to depend more on trust. A person can be trusted in some contexts but not necessarily in all the contexts. A trusted person enjoys many advantages; even his vulnerability is accepted.

Trust is a kind of risk that is worth taking. 'Calculation-based' trusts calculate the value of creating and sustaining trust in a relationship relative to the costs of sustaining or severing the relationship. 'Identification-based trust' values other person's identity as an individual. More trustworthy and sustainable relationships grow out of identification-based trust. In 'benevolence-based trust' an individual does not intentionally harm another when gets an opportunity to do so. In 'competence-based trust' an individual believes that another person is knowledgeable about a given subject area and, therefore, can be trusted. We shift from one mode of trust to the other, depending upon our life circumstances. Competence and reliability are the two traits that determine and establish trustworthiness. Knowledge sharing is not possible unless trust is embedded into the system.

Distrust evokes a feeling of doubt and fear. The reasons of distrust could be purely imaginary, resulting out of a misplaced feeling. A little distrust is often helpful. It can avert herd mentality. Relationship experts say that a healthy amount of distrust can protect against the risk of exploitation.

All beautiful minds are trustworthy, decisive, and biased. Our biases and prejudices are subjective. We find it almost impossible to ignore the "subjective first person view of things." Because of distorted perceptions and wishful thinking, we see things more positively than they really are. We even distort our memory to suit our perception. We accept the arguments of those whom we like, and reject the arguments of those whom we dislike. We use one yardstick to judge success/ failures of the self and another yardstick for others. We all have 'bias blind spots'. We cross-check the bad news and we readily accept the good news. We take biased decisions based upon the irrational decisions we have taken in the past. We accept things, not necessarily because of merit but because of our familiarity with the thing. We overestimate the degree to which others should agree with us. Our brains are highly attuned to negative biases. Almost all our decision making biases favour conflict rather than concession. Hawks see only hostility in their adversaries. Doves often point to subtle openings for dialogue. In fact, a bias in favour of hawkish beliefs and preferences is built into the fabric of our mind, says Daniel Kahneman. Some of us like familiarity and certainty. Some of us like uncertainty and novelty. People in the first group are less receptive to new ideas, and are biased towards predictability and clarity. People belonging to the second group love to face new situations and are positively biased towards such people/issues.

### ACADEMY ACTIVITIES

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## ACADEMY ACTIVITIES

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### INAE-SIATI Seminar on "Innovation in Technologies, Process, Machine Tools & Quality Control for Manufacturing Excellence"

The INAE-SIATI Seminar on "Innovation in Technologies, Process, Machine Tools & Quality Control for Manufacturing Excellence" organized jointly by Indian National Academy of Engineering (INAE) and Society of Indian Aerospace Technologies and Industries (SIATI) On Dec 2-3, 2016 at Dr VM Ghatage Convention Centre, Bangalore as a part of the SIATI Silver Jubilee Celebrations. Shri AS Kiran Kumar, Secretary, Department of Space and Chairman ISRO was the Chief Guest. Dr BN Suresh, President, INAE and Shri Kaveri Renganathan, CEO, HAL -BC were the Guests of Honour. Dr CG Krishnadas Nair, President, SIATI delivered the Welcome Address during the Inaugural; Session on Dec 2, 2016 while the Inaugural address was delivered by the Chief Guest Shri AS Kiran Kumar, Secretary, Department of Space and Chairman ISRO. This was followed by the Presentation of awards, Inauguration of the Seminar and Address by Dr BN Suresh, President, INAE. Shri Kaveri Renganathan, CEO, HAL -BC delivered his address and the Silver Jubilee Special Issue was released. Dr AR Upadhya, Chairman, Organizing Committee proposed the Vote of Thanks.

Six companies were awarded the SIATI Award for their outstanding contribution towards indigenous development and four personnel were awarded with the "Life Time Achievement Award" for their outstanding achievements and contributions in developing and innovation and technology based industry, enhancing self reliance in Aerospace and Defence sector, creating wealth, employment and welfare. The format of the seminar included five Technical Sessions, an "Academy Industry Interaction workshop" and a Panel Discussion on "National Manufacturing Policy and Development Funds for Innovations in Manufacturing" on the second day. There were ten presentations on different topics in manufacturing on the first day and nine presentations on the second day. During the Panel Discussion at the end of the Seminar, the Members of the panel discussed the various ways and means to increasing the manufacturing base in India through innovation and automation.


*Inaugural Session – L to R: Dr AR Upadhya, Dr BN Suresh, Shri AS Kiran Kumar, Dr CG Krishnadas Nair, Shri Kaveri Ranganathan*

### IEEE-INAE Symposium on Electromagnetic Education and Research

The IEEE-INAE Symposium on Electromagnetic Education and Research was held during Dec 12-13, 2016 at SSN College of Engineering, Kalavakkam, Tamil Nadu. It was also financially supported by the IEEE Antennas and Propagation Society (AP-S). The symposium Chairs were Prof Krishnasamy

T. Selvan (SSN College of Engineering) and Prof S.V. Kulkarni (IIT Bombay). With the theme of the symposium being the promotion of quality EM teaching and research in the country, the symposium featured a keynote talk, several invited talks and some contributed papers by doctoral students. In order to promote scholarly interactions, 10 minutes of time was allotted for discussions at the end of each talk. The keynote speaker was Dr B.N. Suresh, President, INAE, and the invited speakers included Prof R.K. Shevgaonkar (IIT Bombay), Prof S.V. Kulkarni (IIT Bombay), Prof R.K. Mishra (Berhampur University), Prof Bratin Ghosh (IIT Kharagpur), Prof Rowdra Ghatak (NIT Durgapur), Dr Chandrakanta Kumar (ISRO) and Dr P.H. Rao (SAMEER). Prof Parveen Wahid (University of Central Florida) gave a presentation on IEEE AP-S activities, with a focus on its educational initiatives. There were student presenters from IIT Kharagpur, Shiv Nadar University, NIST Odisha and IIT Kanpur. The students were presented with Graduate Travel Awards that carried a certificate and a cheque for their train travel to attend the symposium. This presentation was done by Prof. R.K. Shevgaonkar. At a meeting held during the sidelines of the symposium, it was proposed to hold a symposium of this kind biennially. All the sessions of the symposium were very interactive. The oral and written feedback on the symposium from the participants were very positive.

*Group Photograph of Participants at IEEE-INAE Symposium on Electromagnetic Education and Research*

**INAE on Facebook and Twitter**

INAE has created a Facebook and twitter Account to post the news of recent INAE activities in the Social Media. The same can be viewed at the link below.

(a) Facebook -link https://www.facebook.com/pages/Indian-National-Academy-of-Engineering/714509531987607?ref=hl

(b) Twitter handle link https://twitter.com/inaehq1

All INAE Fellows are requested to visit and follow the above to increase the visibility of INAE in Social media.

**Research Journal -INAE Letters**

INAE has launched a quarterly journal "INAE Letters" published by M/s Springer. The objective of the journal is to provide a medium for rapid publication of new research results and invited short review articles across different domains of engineering science and technology. The first issue of the

Research Journal "INAE Letters" was released by the Shri M Venkaiah Naidu, Hon'ble Minister for Urban Development, Housing & Urban Poverty Alleviation and Information & Broadcasting on Sep 1, 2016 at IIT Madras, Chennai during the sidelines of the Engineers Conclave 2016. Dr Purnendu Ghosh, Chief Editor of Publications, INAE and Executive Director, Birla Institute for Scientific Research, Jaipur is the Editor-in-Chief of INAE Letters. The website for the Research Journal "INAE Letters" to include facility for submission of papers online has also been launched. The soft copy of the INAE Letters can be viewed at the link http://www.springer.com/engineering/journal/41403. Three issues of the Journal INAE Letters have been published so far.

*(**L. to R.** Dr BN Suresh, President, INAE, Shri Vinay Sheel Oberoi, Secretary, HRD; Hon'ble Minister, Shri M Venkaiah Naidu and Prof Bhaskar Ramamurthi, Director, IIT Madras during the release of INAE Letters)*

**Creation of Data for INAE Expert Pool**

INAE Expert Pool was created with the aim of identifying domain experts in various disciplines of engineering. There has been a good response from the Fellows and Young Associates in uploading their particulars on the INAE Expert Pool website. The INAE Fellows and Young Associates who have not uploaded their particulars are requested to submit their profile details online at the link http://inae.in/expert-search/index.php/inae-members-form The details of the INAE expert Pool have since been shared with DST, TIFAC, Niti Aayog and Office of PSA. The creation of the website on Expert Pool has been appreciated by all the agencies and the data would be used by them in identifying suitable domain experts and to involve the experts in their activities.

**Important Meetings held during January 2017**

- Apex Committee Meeting Chaired by Dr BN Suresh, President, INAE with the three Vice-Presidents - Dr KV Raghavan, Prof Indranil Manna Dr Purnendu Ghosh as Members, was held on Jan 20, 2017. Besides other Agenda, the Committee reviewed and finalized all activities to be conducted by INAE during the Calendar Year 2017.

**Academia Industry Interaction**

***AICTE-INAE Distinguished Visiting Professorship Scheme***

Industry-academia interactions over technological changes have become essential in recent times so that relevant knowledge that would be sustainable in the changing conditions can be imparted to the students in the engineering institutions. While industries could gain by using the academia's knowledge base to improve the industry's cost, quality and global competitive dimensions; thereby reducing dependence on foreign know-how and expenditure on internal R&D, academicians benefit by seeing their knowledge and expertise being fruitfully utilized practically and also by strengthening of curricula of educational programs being offered at engineering colleges/institutions. INAE together with All India Council for Technical Education (AICTE) launched "AICTE-INAE Distinguished

Visiting Professorship Scheme" in 1999. Under this scheme, Industry experts are encouraged to give a few lectures in engineering institutions. This scheme has become popular among industry experts as well as engineering colleges.

Brief details pertaining to recent visits of industry experts under this scheme are given below.

| | | |
|---|---|---|
| Dr Manish Roy<br>Scientist 'F', Defence Metallurgical Research Laboratory, Hyderabad | Department of Metallurgical Engineering, JNTU, Hyderabad<br><br>Dec 23, 2016 | Delivered lecture on "Degradation of Thermal Barrier Coatings". Has identified project based on requirement for naval and defense applications. According to the feedback from engineering college the scheme helps academicians to work on problems with practical and industrial relevance. It also provides an opportunity to fine tune existing curriculum and introduce new courses to cater the need of industry. |

**International Conferences/Seminars being organized by IITs/other Institutions**

To view a list of International Conferences/Seminars being held in the month of February 2017 click here.

**Honours and Awards**

| | |
|---|---|
| 1. | Prof K Bhanu Sankara Rao, FNAE, Ministry of Steel Chair Professor, Department of Metallurgical & Materials Engineering, Mahatma Gandhi Institute of Technology, Hyderabad has received Platinum Medal from the Indian Institute of Metals on Nov 14, 2016 at IIT Kanpur for his outstanding contributions to Metallurgical profession, research, materials development to fast reactors and contributions to the Indian Institute of Metals. |

**News of Fellows**

| | |
|---|---|
| 1. | Prof Bikramjit Basu, FNAE, Materials Research Centre, Indian Institute of Science, Bangalore has been elected as a Fellow of the American Institute for Medical and Biological Engineering (AIMBE). He will be inducted during the AIMBE's 2017 Annual Event being held on March 19-20, 2017 in Washington, DC, USA. |

International Conference on Emerging Trends & Innovation in ICT (ICEI-2017) on Feb 3-5, 2017 at Pune
http://www.conferencealerts.com/show-event?id=174837

International Conference on Inter Disciplinary Research in Engineering and Technology 2017 on Feb 9-10, 2017 at New Delhi
http://www.conferencealerts.com/show-event?id=174227

International Conference on Systems, Science, Control, Communication, Engineering and Technology 2017 on Feb 10-11, 2017 at Coimbatore
http://www.conferencealerts.com/show-event?id=174867

International Conference on Frontiers of Research in Engineering, Science and Technology 2017 on Feb 10-11, 2017 at Coimbatore
http://www.conferencealerts.com/show-event?id=174865

International Conference on Innovative Research in Electrical, Electronics and Communication Technology (ECT-2017) on Feb 11, 2017 at New Delhi
http://www.conferencealerts.com/show-event?id=179317

2nd International Conference on Recent Advancements in Chemical, Environmental & Energy Engineering (RACEEE-2017) on Feb 23-24, 2017 at Chennai
http://www.conferencealerts.com/show-event?id=178039

International Conference on Recent Research in Biomedical Engineering, Cancer Biology, Stem Cells Bioinformatics and Applied Biotechnology (BECBAB-2017) on Feb 25, 2017 at New Delhi
http://www.conferencealerts.com/show-event?id=179323

# Grassroot Innovation, Laboratory Experiments and Modeling: Case Study of Appropriate Technology Development

A W Date

## 1 Introduction

Research Scientists and Engineers working in Government labs and Educational Institutions often doubt if interacting with people in the unorganised sectors such as Tribal villages can provide opportunities for innovation and, hence, refrain from such an interaction. There is ample evidence in the country that shows that such opportunities readily present themselves and successful innovations are possible. Such innovations also offer research opportunities whose successful pursuits can also be presented for career advancement. Interactions with organised industry or engagements in frontier research are not necessarily the only ways to engage in satisfying research activity.

The author was fortunate to be presented such an opportunity by the Bhumiputra Pratishthaan, an NGO in Thane District. Next section describes the innovation process which alerted the author to the need for carrying out systematic laboratory experiments as well as theoretical modeling for design optimisation.

The academic investigations aptly corroborated the contributions of the Tribal people to the innovation process. These contributions highlighted the need to respond to the beneficiary-concerns in a practical design because these concerns address the limit situations of the people in the unorganised sectors. Such new constraints lead to new innovations.

## 2 The Innovation

### 2.1 The Setting

On a rainy day in August 1973, the author paid a visit to village Kondhaan, Taluka Manor, Dist: Thane, Maharashtra where an NGO called Bhumi-Putra Pratishthaan ( BPP ) had initiated tribal development work in 1972 in con- sultation with National Inst of Bank Management ( NIBM ). The NIBM had conceptualised Farmer's Service Society ( FSS ) to enable otherwise non-credit worthy small and marginal farmers to obtain bank loans through group loans lent to the FSS to carry out cooperative activities. The NGO, the local branch of Bank of Maharashtra ( BoM ) and workers of a local people's movement Bhumi Sena ( BS ) were the partners in the project. In order to ensure recovery of loans, procedures were jointly laid out and several economic activities were to be supported through appropriate technological interventions. The organisational strength of BS, the spirit of service of the NGO and the financial strength of BoM were considered important attributes of the partners.

One major problem faced by the tribal farmers was that of *Khavti* loans taken at exorbitant rates from money-lenders. The need for such loans arose because by end-of-July, the farmers ran out of food stocks from the previous year's harvest ( about 600-800 kg / acre ). As such, to carry out the hard tasks of Paddy cultivation during transplanting and subsequent harvesting operations, farmers had to borrow money to buy rice from the market. In July, the prices are high and when the new crop arrives in September/October, the prices fall. As such, farmers ended up effectively making repayments at high interest rates.

In order to address this problem, NIBM proposed introduction of *Quick- Yielding Variety* ( QYV ) of rice invented at International Rice Research Inst ( IRRI ), Manila. QYVs mature in 90-100 days as against 120-135 days for middle- and late-varieties traditionally cultivated by the farmers. The introduc- tion of QYVs would thus not only obviate the need for *Khavti* loans but will also vacate the land for leguminous or vegetable crops to be taken during the remaining 30 days of monsoon. The leguminous crops fix Nitrogen in the soil whereas cash incomes can be realised from vegetables.

The QYVs, however, have a short dormancy period ( up to 72 hours after harvest ) and if not dried quickly after maturity, the paddy begins to germinate. Since sun-drying is not possible during the latter part of monsoon, farmers lost 30 to 40 per cent of their crop through germination. It is for this reason that farmers did not opt for extensive cultivation of QYVs. The need to cultivate QYVs, however, is particularly great for small and marginal farmers. In the absence of suitable means of drying their crop, small and marginal farmers agreed to commit only a part of their (typically 2.5 acres and less) land to QYVs. If a mechanical dryer were available not only would crops be saved, but farmers would also be encouraged to take two crops from their total land.

There were 3 more reasons why farmers were reluctant to commit larger portions of their land to QYVs. These were

1. The harvested paddy was difficult to thresh using their traditional method because of its high ( 26 % ) moisture content as against about 13-16 % in traditional sun-dried varieties. They did not have a mechanical thresher
2. QYVs required use of Chemical fertilizers which they had never used
3. The straw of QYV plant was shorter ( only about 1 ft high ) than traditional variety. This, they felt, will require too much straw for thatching roofs and more closely spaced rafts and bamboo perlins will be required.

In spite of these reservations, many farmers had agreed to commit 10 Gunthas of land for QYVs. In Aug 1973, therefore, when the crops had arrived, the chief of the NGO requested the author, during his visit, for a design of a suitable Dryer after being told that the author possessed a PhD in *Heat Transfer*[2].

[2]The author's PhD work involved solution of Partial Differential Equations of mass, mo- mentum and energy transfer in a particular situation. He had never dried anything!

## 2.2 The Problem Statement

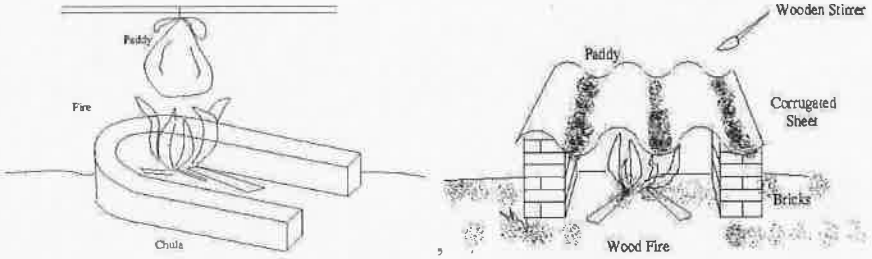
Work on finding an appropriate technology solution to the Drying problem began at IIT Bombay in 1973. Currently, the farmers obtained about 100 kg/acre of QYVs and the total yields were 800 kg to 1000 kg/acre. The farmers live in small hamlets with populations varying between 100 to 500 and land holding varying between 25 and 100 acres. The yield of the early variety of paddy thus varied between 2 and 10 tons per hamlet. This much paddy must be dried in ten days. It was quite possible that, if farmers were satisfied with the drying technique proposed to them, they would prefer to plant greater quantities of QYV paddy. Therefore, the Dryer design must be amenable to an augmentation in its scale ( to about 25 to 100 tons of paddy in ten days) without excessively increasing its cost and sophistication. The farmers would also be interested in using the Dryer for late varieties ( which are dried in the sun and which have poor milling characteristics, in addition to incurring considerable handling loss and loss to rodent attacks in the fields ) which mature in late October, to obtain greater yields after milling. All these constraints and requirements emerged through a dialogue and therefore the technical specifications for the Dryer were as follows:

1. Capacity per day: 0.5 tons to 10 tons.
2. To be simple to construct and operate by farmers themselves.
3. When the demand for the Dryer increases, the smallest-capacity unit must be amenable to an increase in the scale of operations without greater sophistication and without additional constructional and operational difficulties.
4. Since drying is a once-a-year operation the capital cost of the Dryer must by as low as possible.

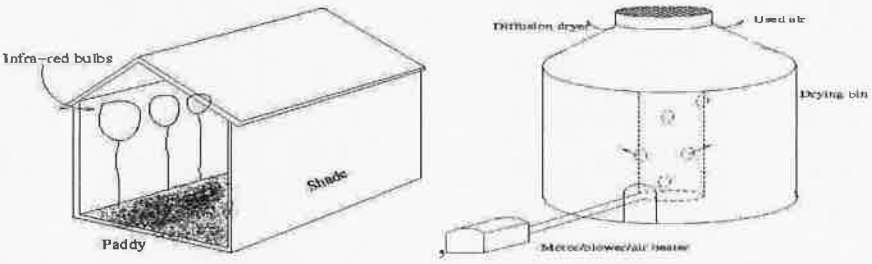
## 2.3 Alternative Solutions

After specifying the problem in technical terms, the spectrum of drying techniques was scanned in terms of capacity/batch, drying time, area requirement, uniformity of drying, mechanical and constructional sophistication, ease of operation, possibilities of self-help in construction at operation, suitability to purpose (consumption, market or storage), known users of each technique, pressure-drop and heat-mass transfer characteristics for paddy grains, Figure 1 shows the alternative solutions.

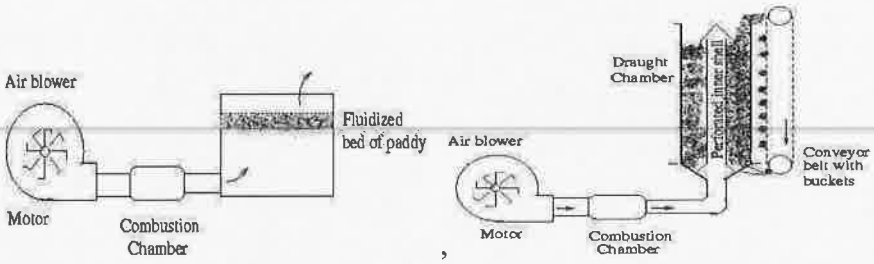
Figure 1a shows the solution developed by the farmer's themselves. Freshly threshed wet paddy was tied in a cloth and hung on top of the Chulas. Unfortunately, this did not result in even drying and, in fact, the paddy at the bottom got *cooked.* Therefore, the present author along with workers from the NGO assembled a *direct-contact dryer* ( Figure 1b ) from corrugated GI sheets that




( a ) Solution by farmers ( b ) Solution by the NGO




( c ) Solution by Agr Res station ( d ) Diffusion Dryer




( e )Solution in a Text Book ( f ) Moving bed Dryer - IIT Kgp

Figure 1: Alternative Drying Solutions for Paddy

were readily available with the NGO. This required continuous stirring to pre- vent cooking and was found to be very cumbersome although during one night of continuous work, nearly 6 bags ( about 500 kg ) of paddy was saved from germination.

While such *impromptu* solutions must be invoked in an emergency, a more reliable design must be sought. Further field work then brought to notice a solution practiced at the Agr Res Station ( AGR ) near Khopoli in Raigad Dist. The AGR used Infra-Red bulbs for *radiation drying* in a large shed on the floor of which Paddy was continuously stirred ( Figure 1c ). Obviously, such a solution will require a very large area.

Figure 1d shows the *Diffusion Dryer* routinely used on American farms. In this dryer, grains are stored in a bin and hot air infiltrates the stagnant grain mass through central perforated pipe. Diffusion drying is a slow process and therefore not suitable for rapid drying required to prevent germination of paddy. Diffusion dryers are used mainly to prevent fungal attacks during long-term storage. Library search showed that *Fluidised Bed Dryer* ( Figure 1e ) [1] may be used. The drying rate of such dryers is of course high but the area required tends to be large for the same quantity of grains. Also, for maintaining

fluidisation, large air flow rates are required. Finally, Figure 1f shows a *Moving Bed Dryer* developed at IIT Kharagpur. Hot, upward flow of air is bled through a central perforated pipe closed at the top. The air penetrates a downward flow of grains which are collected at the bottom and raised to the top outside the Dryer by means of a conveyor belt. The Dryer thus requires two driving motors; one for the air blower and the other to drive the conveyor. Although, counter-current moving bed dryers achieve a fast rate of drying with minimum area, there is considerable constructional and operational complexity and cost is high for application in a Tribal village.

## 2.4 Innovation Process

Since, none of the solutions listed above appeared to meet the requirement of rapid drying in a tribal village situation, it was decided to build on the field experience at Kondhaan. Experiments were initiated in the Mechanical Engg Dept of IIT Bombay.

Initially, a small quantity of grain were put in a conical hopper bin as shown in figure 2. A screen was inserted between the hopper-bottom and the connecting pipe to prevent grain from falling. The pipe was connected to an air blower. The intention was to stir the grain as in figure 1b while the air flow would bring about convection drying which will be faster than diffusion drying. To his surprise, as soon as the blower was started, the paddy grain flew into the face of the author! A colleague[3] then pointed out that it was nothing but a *spouted bed* that he had seen in USSR for combustion of coal.

This discovery of Spouting led the author to consult book on *Fluidization* by Leva [2]. This book, in a small half-page section on spouting, showed the principle of spouting as shown in figure 3 ( left ). Spouting is carried out in a cylindrical container with a hopper-bottom. When the air-blower is started, the upward moving air through the stagnant grain mass experiences increasing pressure drop while a spout is formed in the center of the vessel. The momentum of the air-jet penetrates further up the grain mass creating a *dilute phase* in the core while the surrounding annular *dense phase* descends due to gravity. The downward flow of grain is *entrained* in the dilute phase where it travels up the spout. Ultimately, if the air supply pressure is adequate to overcome the bed pressure-drop, the spout *ejects* out of the bed-top creating a fountain. The grains, after loosing their momentum, begin to *free-fall* back into the vessel. Thus, a grain circulation is established while the air is let off to the atmosphere.

[3]Late Prof A Jaganmohan, Mech Engg Dept

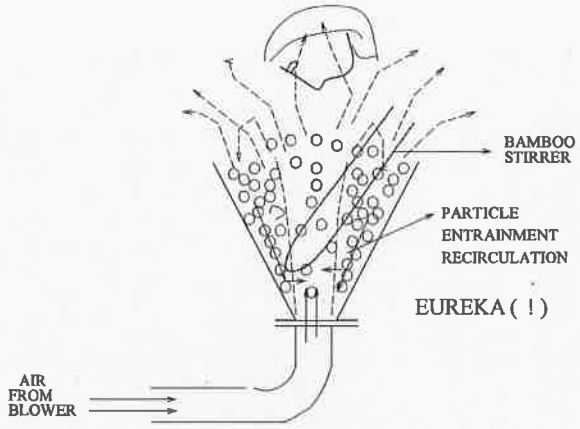



Figure 2: Eureka ! - Spouting Discovered

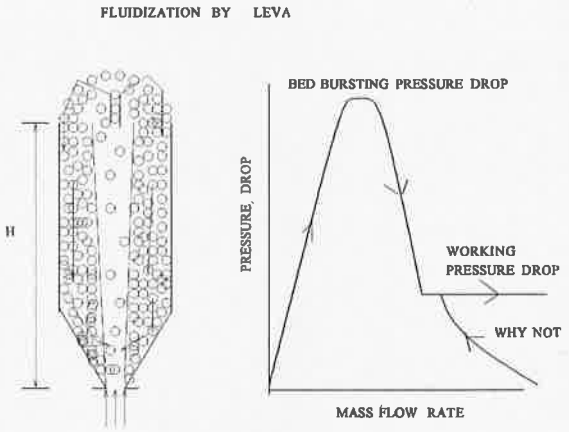



Figure 3: Principle of Spouting

The great advantage of this technique is that the hot-air used for drying itself brings about grain circulation and the need for a conveyor belt used in the moving bed dryer ( see figure 1f ) is obviated. Figure 3 ( right ) shows that till the spout penetrates the grain-bed, there is rise in pressure drop while the air mass flow rate increases. The pressure drop peaks and the value of this peak pressure drop is dictated by height H of the bed and the properties of the grain. However, after ejection through the bed, the pressure drop suddenly falls to a stable *working pressure drop* that hardly changes with increasing air flow rate. In practical dryers of this type, a separate *compressor* (a low mass flow - high pressure device ) is needed to overcome the peak pressure drop whereas a blower (high mass flow - low pressure device ) takes over during steady state operation [3]. Besides, the stability of spouting requires geometric precision to ensure *perfect verticality* of the vessel as well as *perfect axi-symmetry*. Failure to observe verticality and axi-symmetry results in collapse of spouting. This is of course not a desirable feature of Dryer used for village application. These shortcomings of the conventional spouting bed alerted the author to look closely at figure 3 ( right ) again. It was obvious from this figure to probe the question:

**Instead of raising the pressure drop to a peak value and then dropping down to a low working pressure drop, why not start with a zero pressure drop and high mass flow rate and approach the working pressure drop with a lower mass flow rate ?**

This question led to the a modification of the conventional spouted bed as shown in figure 4. In this dryer, an un-perforated draft tube ( PVC ) was held centrally by means of internal ring type locators. The bottom end of the tube rested on the screen between the air supply pipe and the conical hopper. The surrounding annular space is then filled with paddy to 1.2 m height ( equal to 85 kg or 1 bag of rice ). The air blower is started. Air experiences little pressure drop up its travel through the tube. The tube is then gradually *lifted* creating a space between the tube bottom and the hopper-bottom. The annular grain now entrain into the air-jet and travel up the tube. If not arrested by means of an *inverted conical cap*, the grains tended to fly-off. With the cap, the grains were directed downwards to fall onto the free surface of the annular grain bed. Thus, grain *circulation* was established. Further lift of the tube, increased the grin circulation rate further. However, after a certain lift, spouting ceased. This was because the supply pressure (about 18 cm of water) was not high enough to support spouting. An optimum lift height (h ) was determined from working experience.

There were several advantages achieved in this new design. The Dryer was taken to village Damkhind ( see figure 5( left ) ) in late August- early September 1974 and QYVs cultivated by the farmers were successfully dried in monsoon conditions.

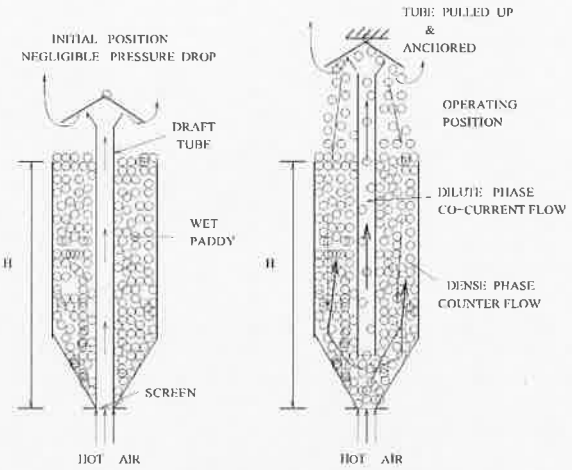



Figure 4: Spouted Bed dryer with a Draft Tube

Figure 5: Dryer in use at Village Damkhind, Taluka Manor

The cylindrical vessel was 40 cm dia, cone angle $40^0$, supply pipe and draft tube had same diameter = 50 mm. The air was heated in *an internally baffled box* which was placed above a wood-fire. 1 HP blower ( eff ▪ 30 % ) was used. Figure 5 ( middle ) shows a bag of wet paddy being emptied in the dryer. Figure 5( right ) shows villagers performing *the biting test* to determine whether the paddy was dried or not. This was necessary in the field conditions because there were no means to measure the moisture content of the dried paddy. Villagers experience came handy! Later, the approved dried paddy was collected in a Polythene bag and its moisture content determined in IIT Bombay. It was found to be 12.8 % ! (close to required 13 % ). 85 kg of paddy was typically dried in 2 hrs 30 min under monsoon conditions (or, approximately, 0.7 Tons in 24 hrs).

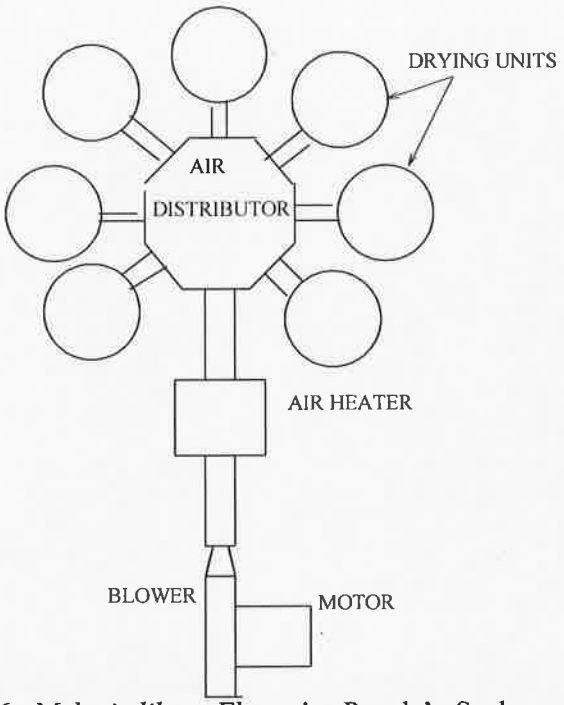



Figure 6: *Make it like a Flower*! - People's Scale-up Design

## 2.5 How to Scale-up ?

The villagers were satisfied with drying performance and soon queries began about scaling up issues because, in a single village, nearly 10-20 tons of paddy would have to be dried in subsequent years. Following a typical engineer's instinct, the author began to dream of a big, tall dryer[4]. However, the villager in figure 5(middle) quickly intervened, drew a picture on the ground by using a stick and said:

**Do not build a big dryer. Instead make it like a *Flower* !**

His suggestion is depicted in figure 6. The figure is self-explanatory and subsequent calculations showed that a 3.5 HP motor-blower with 6 drying bins operating in parallel will achieve drying rate of 5.4 tons / day using villager's design. The author was hugely impressed by the villager's power of expression. It showed that not only a *technical product* was transferred to the village but, in fact, the *Technology* was also transferred. This distinction between *technique or product* and *Technology*[5] is of paramount importance in Appropriate Technology Development.

[4]Such tall spouted bed dryers are used in Canada for drying wheat and peas ( see, for example, [4] )

The villager's suggestion for a parallel-design stemmed from the fear that a *big dryer will lead to quarrels*! He, therefore, preferred a Dryer in which each individual brings his bag(s) of paddy, loads it himself and takes away the dried paddy - no mixing which will require weighing before and after drying with inevitable *cheating* and hence, quarrels. Besides, in a large-bin dryer, there is no guarantee that the villager will get back paddy grown on his farm. Such apprehensions are very real and it is incumbent on the engineer to respect them.

**ACKNOWLEDGEMENT:**

The author wishes to thank the organisers of the National Symposium on *BARC Technologies for Development of Rural India* for inviting him to deliver a Keynote lecture on this largely unpublished work although some parts of the work have been reported in [7, 8]. The laboratory and modeling work was carried out by author's MTech and BTech students [9, 10, 11, 12] at IIT Bombay

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# Solar is the Solution

## SOLAR IS THE SOLUTION

**Gopal P Sinha**

## Save the only living Planet in the Universe

Let us plan as to what we can do to save the creation, save the life on the only living planet of the universe and back home, make our own Indian economy stronger and vibrant.

Today, let us limit ourselves to some suggestions about what we can do to make Indian economy stronger-strong enough to save the humanity from destroying itself.

Size-wise our planet is too small, insignificant, even tinier than a particle-of-sand-in-ocean, in this expanding universe.

Yet we are unique!

Ours is the only planet which has life and perhaps the most intelligent one!

That is why we need growing amount of energy to lead us to progress, to energize us for creating new infrastructure and devices. The big question is why do we source most of this energy from fossil fuel which has a limited reserve. Let us look at the balance sheet of energy. We get almost 23000 TW of energy from the Sun against the global requirement of only 16 TW. But we draw this all from our million year old reserve of coal(900 TW), oil(240 TW), natural gas (215 TW). This is only because these limited reserves are either carbon or hydro-carbon. Burning them is easy to produce energy. This energy, however, is not only accompanied with green house gas but also is from a limited source, belonging to all the generations, down the line. At the cost of coming generations, who are not here to claim on the oil-wells or gas-holes or the coal-blocks, we are consuming an accumulations of billions of years. The net effect is that, in our lust for material wealth we are destroying the planet's life bearing system – leaving the world less healthy for our next generations.

In contrast to this solar is a source which is all capable. All it needs is efforts and research to develop practical means of harnessing it to execute our activities and provide ambience for comfort. In one hour more sunlight falls on the earth than what is used by the entire populatins in one year.

Forget the future. The world already is nearly five times as dangerous and disaster-prone as it was in the 1970s. This is because of the increasing risks caused by climate change and global-warming due to green-house effect. The first decade of the 21$^{st}$ century saw 3,496 natural disasters from floods, storms, droughts and heat waves. That was nearly five times as many disasters as the 743 catastrophes reported during the 1970s – and all of those, the weather events are influenced by climate change.

# Solar is the Solution

The widening ozone–hole, shown in Fig.1, is a comparison of the current state with that of the one that existed in 1979. The fossil-fuel burning is responsible for this enlarging hole in the protective layer.

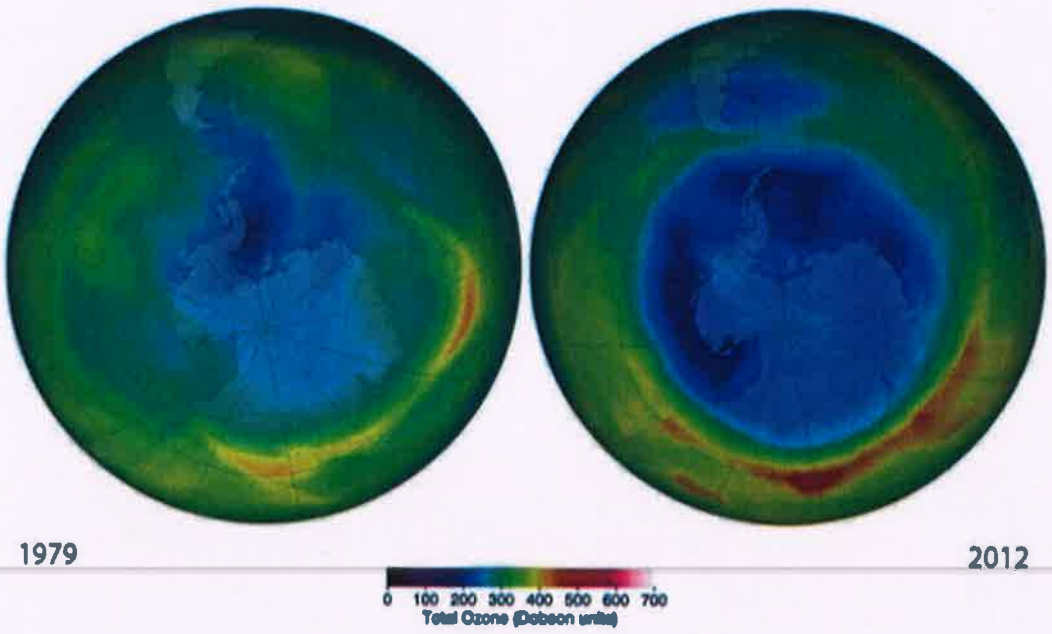


Fig.1 Ozone Hole [Courtesey "Physics World" Institute of Physics]

The bottom line is that natural disasters are occurring nearly five times as often as they were in the 1970s. But some disasters – such as floods and storms – pose a bigger threat than others. Floods and storms are also taking a bigger bite out of the economy. Heat waves are an emerging killer and the depletion in protective ozone layer is dangerous.

## Energy strategies need to be drawn

Energy strategies need to be drawn such that the climate is not affected and we do not change the composition of atmosphere or sea. Clean energy neither emits the Greenhouse gas nor the ionizing radiation on an overall basis. India's per capita electricity consumption is expected to reach around 5000 kWh in 2020 from the current level of 1010. The human development index (HDI) is closely connected with the per capita electricity consumption. Our electricity need will thus grow to 518 GW. On a global basis, we will exceed 10 billion populations by the turn of the century. The decisions are normally weighed with the criterion of return on investment (ROI).

## We have a great role to play

It is a matter to think and introspect. Can we perform all tasks that we do today with less green-house-gas (GHG) emission? Can we reduce global warming, floods, landslides and climate change? The Table 1 and Fig. 2 shows that we are the fourth biggest emitter of GHG surpassed only by China, US and EU.

# Solar is the Solution

| Countries/Group of Nations | Percentage of total Emissions |
|---|---|
| China | 25.3 |
| U.S.A. | 14.4 |
| E.U. | 10.2 |
| India | 7.0 |
| Russia | 5.4 |
| Japan | 3.1 |

Table 1 Global CO2 Emissions Per region from Fossil-fuel use

## We have a situation

1. Our fossil fuel reserve is very limited compared to our requirement. Fossil fuel import is the major drain on our foreign exchange. If crude price increases by USD one per barrel, the net import bill increases by Rs. 7096 crore and if exchange increase by Rs 1 to a USD net import bill increases by Rs 7440 crore. We import more than 190 million tonnes of crude oil annually and increasingly higher amounts of coal.

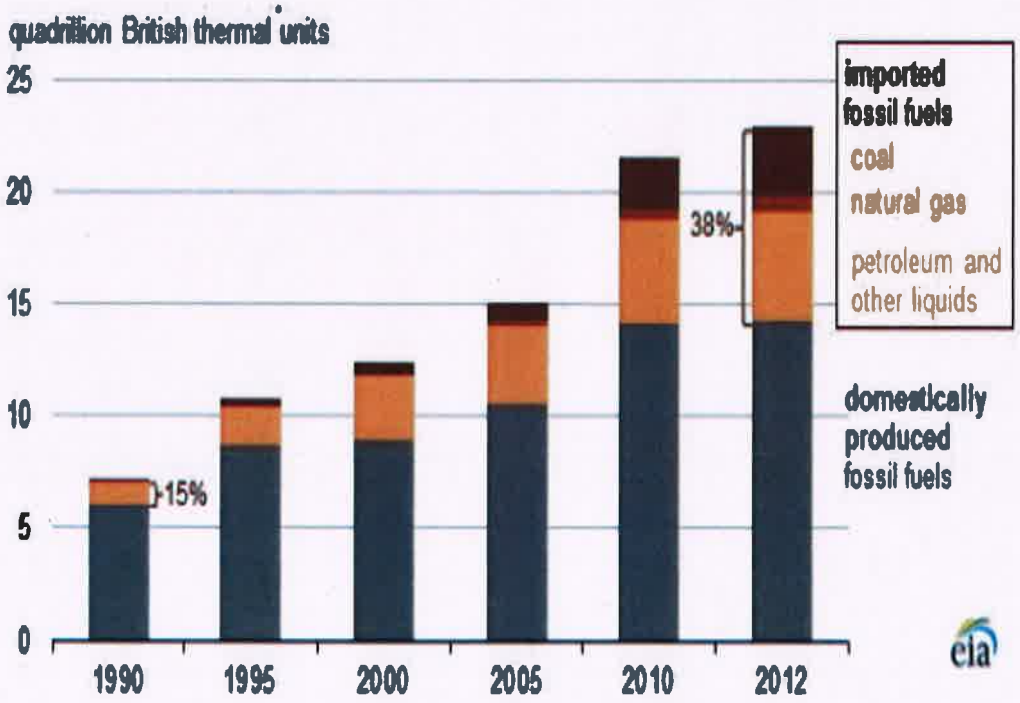


Fig. 2 India's Fossil Fuel Consumption

2. Even with this low per capita energy consumption the state of environment is quite pathetic.

# Solar is the Solution

3. If per capita consumption of energy for India attains the same level as that of developed nations such as the United States of America, then we will be emitting additional 30 Giga tonnes of $CO_2$ annually into the atmosphere. You can imagine state of global warming and pollution under such condition. Therefore, while we have to advance in energy consumption to a per capita level of United States, we have to see that the new energy is completely emission free. This is possible only through renewable sources and focus of this article is on planning to meet our energy requirement by 100% solar and other renewable sources. The transition will not be simple as it would call for innovation and inventions for each of the applications such as lighting, air-conditioning, water pumping and transport. Each of the applications will need a separate methodology for converting renewable energy to the application sector in the most efficient manner.

## The solution lies in going solar

Sun is the source of life on the earth. It is also the source of all energies including the fossil fuel ones. While renewable are replenished, the fossil fuel is a depleting reserve. The other and the more serious negative aspect of the fossil fuel is that it is mostly carbon based. The energy is derived mainly by burning carbon and emitting $CO_2$. How can we tap the energy that the sun gives us everyday. It is all renewable and inexhaustible and totally emission-free.

We the members of the current generation have great responsibility in reversing the climate change effect. The ultimate survival and strengthening of Indian economy depends on "*Harnessing Solar Energy*"

Energy drives our economy. The entire supply of energy required for growth and sustenance can be from the solar/renewable resources. For this we have to develop appropriate technologies for each of the application areas. The renewable energy-resources are mainly solar (inclusive of wind, tidal and micro-hydro).

## Nuclear energy is not Safe

Nuclear energy is often pleaded as an emission-free source of energy. However, it is neither renewable nor safe. At every stage, from mining of nuclear fuel, its enrichment, handling and disposal after reaction is hazardous for several generations down the line. The hazard described in the previous line is during the normal and safe operations. It is severely more in case of an accident, explosion and uncontrolled reaction, as was recently observed in Fukushima in Japan in 2011 and earlier in Chernobyl (Russia) and Three-Mile-Island (USA).

Major hydro-power disturbs ecology, inundates large areas and settlements. It also involves large scale dam-construction causing land-slides and tremors.

A small fraction, less than 1%, of the sunshine on our barren land and deserts can meet the entire global requirement of energy. So why mine coal and import crude oil ? Fossil fuel burning is neither desirable nor sustainable. Stop mining of coal and switchover to solar on rooftop, canal-top, barren lands and deserts. This will be climate-friendly and economy-strengthening. All this will require appropriate application-oriented technology-development.

# Solar is the Solution

Utilizing the sun does not mean only fixing photo-voltaic panels on the roof-top or unused area. It means developing appropriate technologies, specific to the use or application. A good example is solar water heater which doesn't involve generating electricity from solar panels storing it in batteries and then running geysers in bathroom through inverters. This would give 3-4% efficiency of harnessing in place of the present 20%. This is just an example. We have to develop application-based efficient technologies for each sector, if we have to switch over to 100% solar.

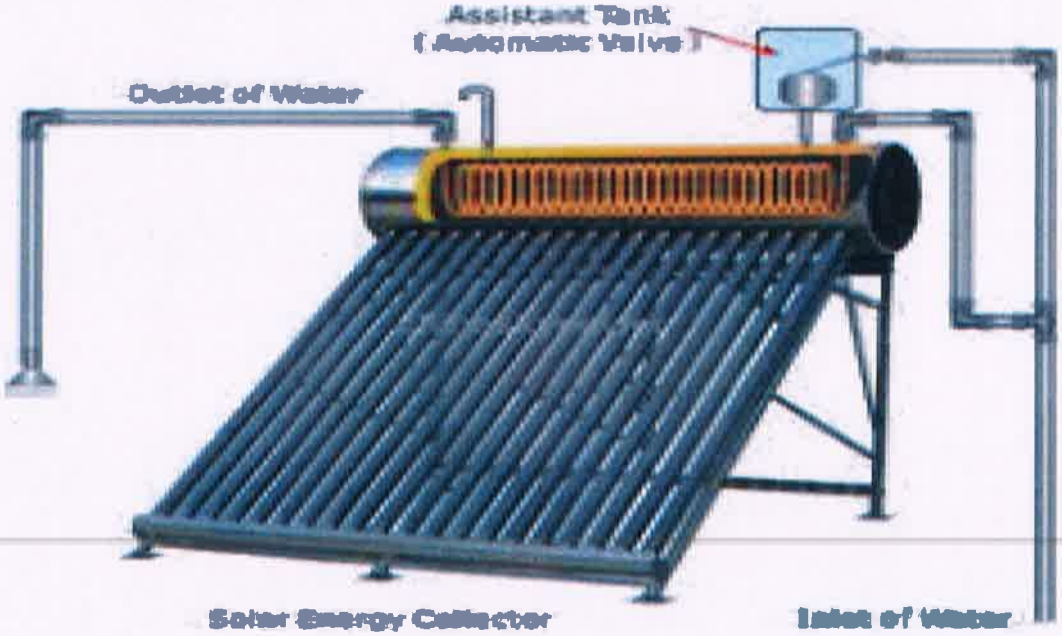


Fig.3 Solar Water Heater

## Solar Architecture for the New Housing Complexes

Similarly an appropriate building architecture can give better air conditioning effect than the conventional window or split ACs powered by solar panels. Solar architecture would involve proper orientation depending on the latitude, altitude and slope of the place. In case of multiple stories, the architecture can improvise a solar chimney for induced draft. The in-built solar chimney can also accommodate the down comers the sewer-lines, cables and ducts, when appropriately designed. The draft so induced can effect fountains and cool air for circulations in the habitats. We have to develop and showcase such technologies so that these can be adopted, scaled up and multiplied. Such architecture will differ from low-rise houses to multi-storied ones. Similarly the pumping of water can be effected by solar energy during the sunshine hours and stored in over-head tanks.

## India is rich in solar energy:

India is endowed with so much of Solar Energy that we can stop a major part of our petro-fuel import. This will stop the biggest drain of our foreign exchange and make our economy strong enough. Solar energy on $1/400^{th}$ of Thar Desert can power the entire nation. Delhi's rooftop is sufficient to meet the electricity need of the capital.

Incidentally, we can find from solar map that our remote areas such as Ladakh and Sunderbans, which pose difficulties in obtaining grid electricity is endowed with higher solar intensity. For

example, Ladakh and remote Himalayan region has higher solar intensity than most of areas in the Indian sub-continent. Ladakh gets around 8-9 kWh/m$^2$/day this is much more than our requirement. The rooftop areas in such region are sufficient to meet the energy requirement including the heating requirement in Himalayan region. The picture below (courtesy: Solar Energy Centre), maps the solar resources of our country:

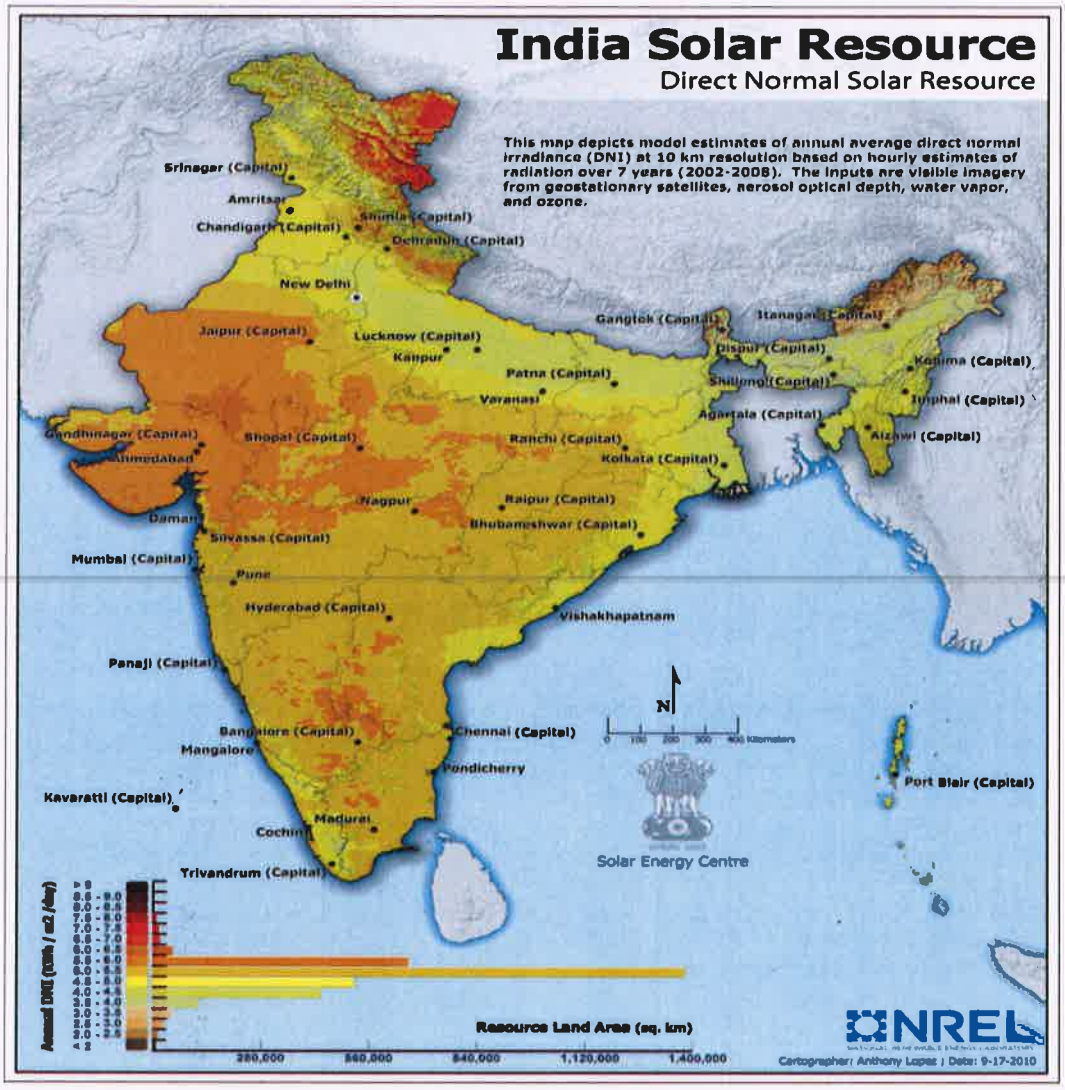


**Fig. 4 Solar-Map Of India** (courtesy: SOLAR ENERGY CENTRE, Government of India)

## Renewable Energy can sustain Our Requirement

While planning to make our nation economically strong and safe to live in, it is necessary to transit to 100% renewable energy by developing a set of application-oriented technologies for harnessing solar energy. Photo-voltaic is suitable for electrical end-applications. However, there are two challenges-(i) poor efficiency and (ii) the storage aspect as the demand does not follow the sunshine hours. Solar-thermal (for thermal applications) and solar-architectural are the other two major routes for harvesting the solar energy. The broad plan is shown in the graph below where we

# Solar is the Solution

conclude that a conversion of 300 GW of solar energy can make us totally self-reliant on energy matters, today. As we are in the beginning of the S-curve of solar technology with immense amount of renewable energy remaining to be harnessed through newer technologies, we see a good prospect of meeting our growing need of energy through the solar sources. This plan is shown in the graph below where we conclude that a conversion of 300 GW of solar energy can make us totally self-reliant on energy matters.

Thus we are making our climate sick and sick for the next generations.

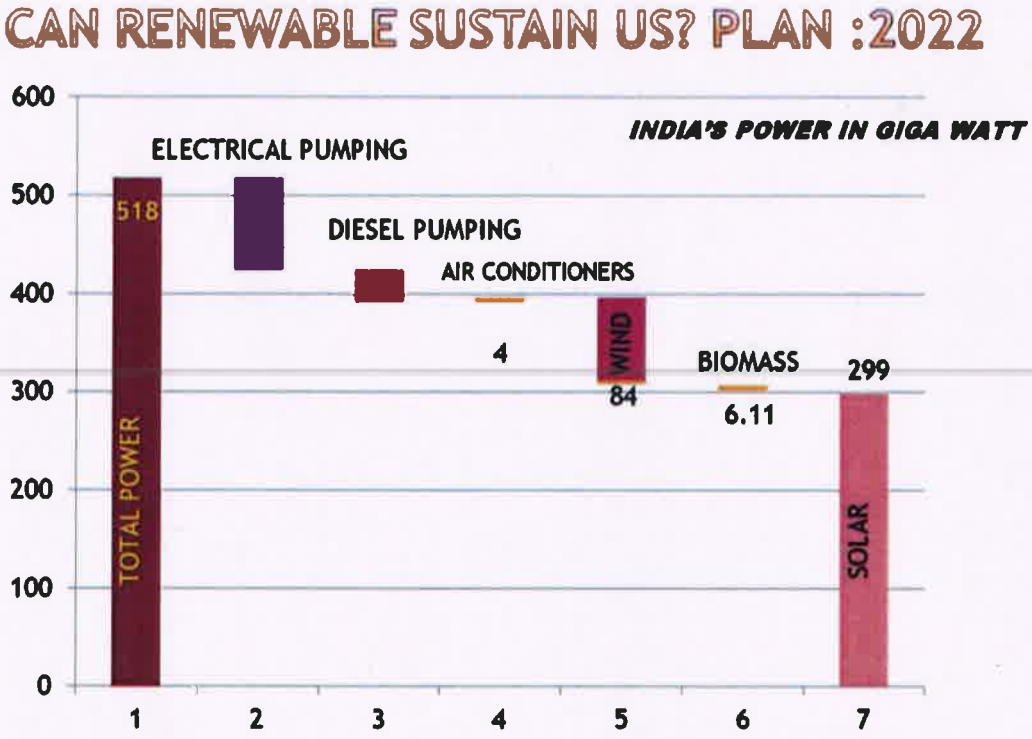


Fig. 5 The Solar Solution

This is equivalent to solar panel of 3600 sq. km. which is less than 1.5% of Indian Thar desert.

Some of the technologies that we may undertake to develop are:

- Solar thermal siphon pump with no moving parts for multi-storey buildings
- Solar thermal siphon pump for irrigation
- Solar melting furnace for metal melting and refinement
- Solar Hybrid Vehicle
- Solar Inverter like TESLA's wall charger
- Solar Kiln
- Solar electrolysis for generating Hydrogen from water for running IC engines
- Solar drying of grains
- Solar fabric dyeing

# Solar is the Solution

- And many others as identified by our team.

## Let us save the globe by our action

This will not only engage us in new technology development but will also showcase our strength and offer new technology for adoption and multiplication.

A brief write-up on the first three of the nine technologies identified for development and mentioned above are given in the following paragraphs:

(i) **Solar thermal siphon pump with no moving parts for irrigation and multi-storey buildings**

This invention is the development of solar energy based pump for irrigating agriculture fields by lifting ground water. The most attractive part of the pump is the absence of any moving component, which makes it almost maintenance-free. Solar thermal energy is used to create a pressure higher than the atmospheric pressure over the water table of the ground water. This pressure(higher than that of atmosphere) lifts underground water through a tube dipped in ground water and delivers at a head H given by $H = (P_c - P_a)/\rho g$. Where Pc is pressure created by solar energy, $P_a$ is atmospheric pressure, $\rho$ is mass density of liquid and g is acceleration due to gravity.

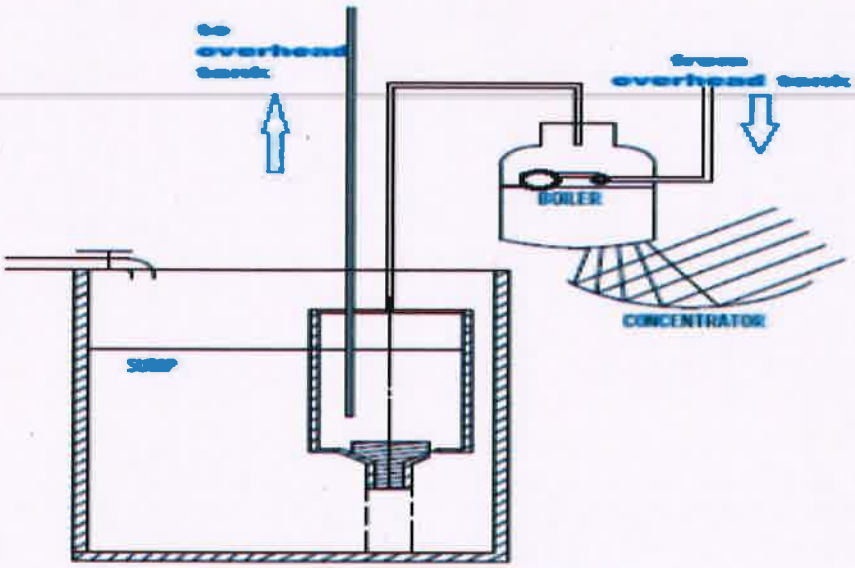




Fig. 6 Solar Thermal Siphon Pump For Multi-storey Building

# Solar is the Solution

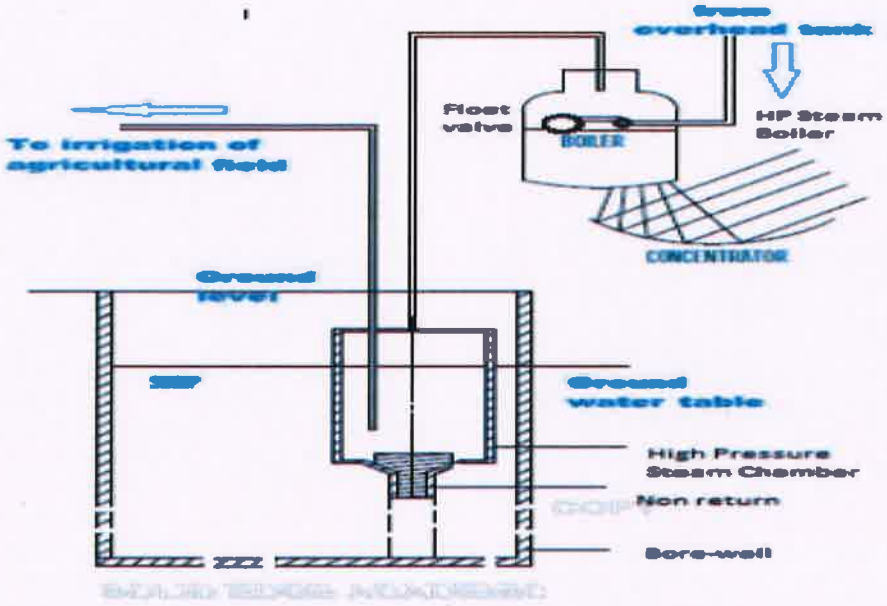


Fig. 7 Solar Thermal siphon Pump For Lift Irrigation

The following specifications are given below.

1) **Pressure, Discharge, Height and Solar Power Required.**

Head of Discharge = H in meter

Mass density of water, $\rho = 10^3$ kg/m$^3$

Acceleration due to gravity, $g = 9.81$ m/s$^2$ or say 10 m/s$^2$

Atmospheric pressure = $10^5$ Pa.

Pressure head= $\rho.g.H$

$= 10^3.10.H$

$= 10^4.H$ Pa

Pressure required on water table for achieving the discharge head = Atmospheric pressure+ Pressure head

$= 10^5+10^4$ H in Pascal

Assuming no friction loss.

Exerted Steam Pressure = Pressure required on water table = $10^5 + 10^4$ H in Pascal.

m= flow rate in kg/sec

1 gallon=3.785 liter=3.785 kg of water

The average discharge rate for a 1H.P conventional pump is 2200 gallon per hour

Average discharge rate taken for unit pump is

# Solar is the Solution

= 2200*3.785 kg/hr

= 2200*3.785/3600 kg/sec

=2.313 kg/sec

Average head of water pumping for Delhi (average depth of water level in delhi) is= 20 m below ground level (bgl)

Power required maintaining the delivery rate of 2.313 kg/sec (m) for a head of 20 m (H)=m.g.H=2.313*9.81*20 in watt

Solar energy required to deliver this power is = Effective Aperture area* solar constant

Pressure required on water table for achieving the discharge head= exerted steam pressure

$= 10^5+10^4.20$

= 300 kPa

Boiling temperature of water for exerted steam pressure ($T_{boiling}$) = from steam table

= 134 $^0$C at 303 kPa.

2) **Specifications of Solar Concentrator (SC).**

Projected area for heat required = Effective Aperture area of solar concentrator = $A_a$ m2

Diameter of solar concentrator =D

Eff. Aperture Area, $A_{ea}= \pi D^2/4$

Solar Constant = 1000W/m2 (Standard for India)

Efficiency of conversion of solar energy is taken as 50% thus (including losses), solar constant taken as = 500W/m2.

Eff. Aperture area of SC = $A_{ea}$ m2

Solar Power converted = Eff. aperture area*solar constant*efficiency

$2.313*9.81*20=A_{ea}*500$

$A_{ea}= (2.313*9.81*20)/500$

$= 0.9076$ m$^2$

Eff. Aperture Area, $A_{ea}= \pi D^2/4$

$=0.9076$ m$^2$

Diameter of solar concentrator, D= 1.07499 m

Or

D= 1.2 m

Eff. Aperture area = Aperture area – boiler's projected area.

# Solar is the Solution

**3). System Efficiency Estimation.**

**Optical Efficiency** = $\eta o = \beta m * \alpha a * \gamma * \tau c [(1 - \tan \Theta) \cos \Theta]$

Where $\beta m$ = SC material reflectivity.

$\alpha a$ = Receiver boiler absorptivity.

$\gamma$ = Intercept Factor.

$\tau c$ = Transmittance of cover material.

(All above efficiency parameters based of standard value of used material)

## "Solar Furnace"

This invention is development of solar energy based metal furnace for the purpose of casting and foundry practices. The most attractive part of invention is use of solar energy for the foundry practices which has not been practiced so far.

The basic principle of this furnace is use of concentrated solar thermal energy focused on the solid metal pieces for recycling of metal scrap using 100 % green energy. This furnace will not need any fossil fuel and it will be completely emission free.

Specification:

1. Biconvex lens is proposed to focus the solar energy on metal pieces for melting.
2. The melting vessel is provided with an adjustable fixture to align and focus the solar energy.
3. The molten metal can be evacuated through a discharge mouth in the middle of the melting vessel.
4. Shutter is provided to protect the lens during the pouring of molten metal.

Calculations:

The area of lens required to focus the solar energy to melt the metal is given as

$$\Delta h = S_c.A.t$$

The model of proposed furnace for Lead and Tin melting is under fabrication with specification. However furnace for other metal can also be developed with due consideration of their melting point.

Specifications for solar furnace:-

A. Total heat required for melting of metal

$$Q_{total} = m.C_p.(T_{melt} - T_{min}) + LH.\ m + m.C_p\ (T_{max} - T_{melt})$$

Where,

$Q_{total}$ = Total heat required for melting of metal (KJ)

m = mass of metal (kg)

$C_p$ = Specific heat of metal (kJ/kg.K)

LH= Latent Heat of fusion (kJ/kg)

$T_{melt}$ = Melting temperature of metal (K)

$T_{min}$ = Temperature below ambient for

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$T_{max}$ = Temperature above meting Point of metal for maximum capacity of furnace (K)

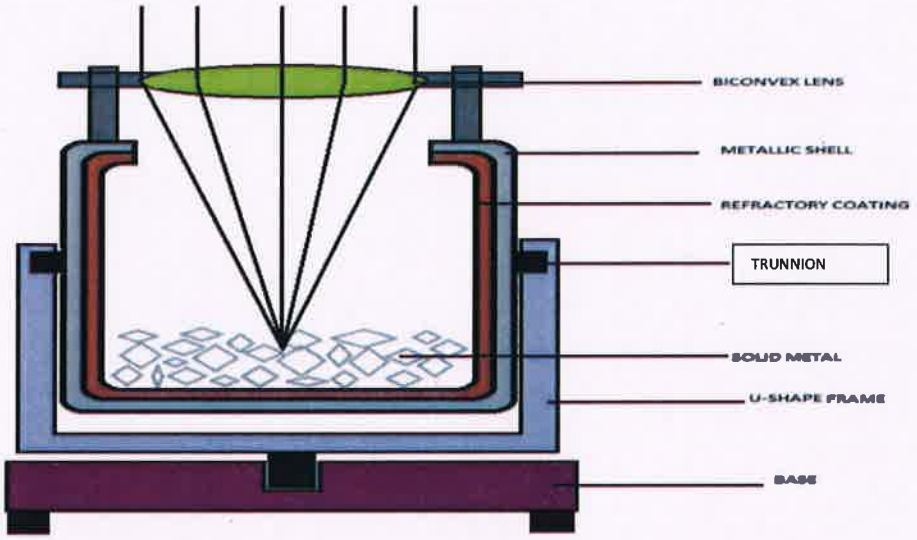



Fig. 8 Solar Furnace for Melting and refining Metals

B. Specification of Bi-convex lens

a. Area of Lens ($A_{lens}$)

$A_{lens} = Q_{total} / t.S_c$.

Where,

$A_{lens}$ = Area of Lens ($m^2$)

$Q_{totsl}$ = Total heat required for molten metal (kJ)

t= time taken by furnace for melting 'm' mass of metal(s)

$S_c$ =Solar constant (1 kW/$m^2$ average for India)

**** The value of Solal Constant varies place to place.**

b. Focal length of lens

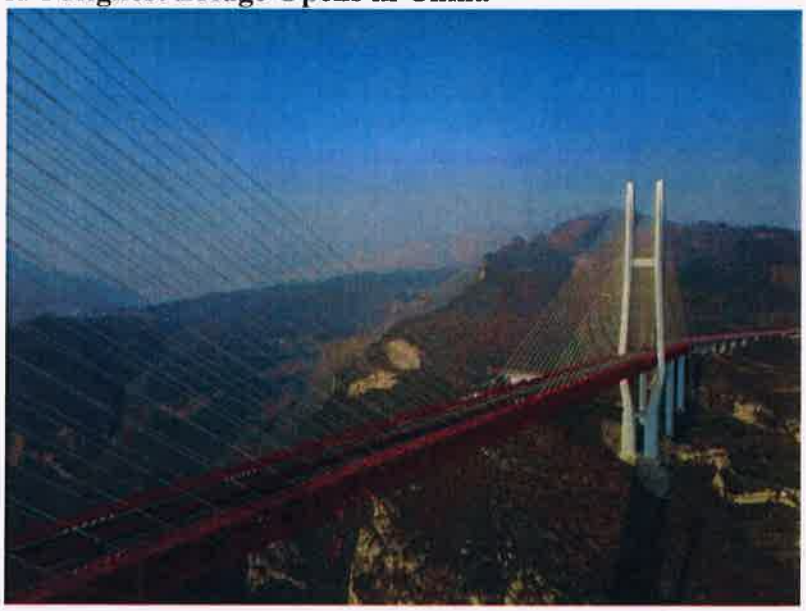
$$\frac{1}{f} = (n-1)\{\frac{1}{R1} - \frac{1}{R2} + \frac{(n-1)d}{nR1R2}\}$$

## Conclusion :

Solar-energy has the capability to perform all activities needed by us. However, each of the activities will require separate technology development as the electo-magnetic radiations carry energy in different form than the fossil-hydrocarbons that we have been burning to get energy in our power houses, automobiles and kitchens. The challenge before all of us, the engineers today is to develop such appropriate technologies.

## Civil Engineering

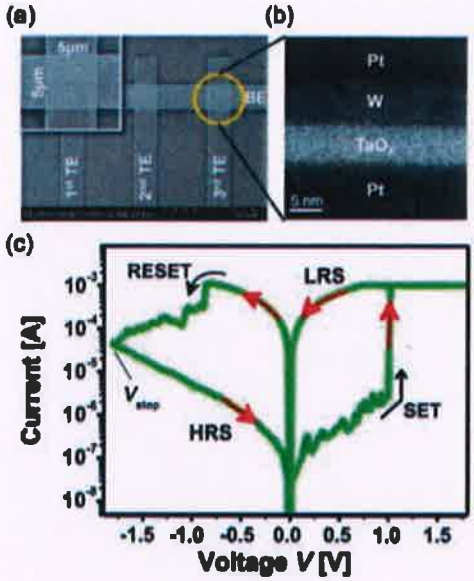
### 1. World's Highest Bridge Opens in China



The world's highest bridge has opened to traffic in China on December 30, 2016, connecting two provinces in the mountainous southwest and reducing travel times by as much as three-quarters. The Beipanjiang Bridge soars 565 metres (1,854 feet) above a river and connects the two mountainous provinces of Yunnan and Guizhou, the Guizhou provincial transport department said in a statement on its official website. The 1,341-metre span cost over 1 billion yuan ($144 million) to build. It overtook the Si Du River Bridge in the central province of Hubei to become the world's highest bridge. Several of the world's highest bridges are in China, although the world's tallest bridge — measured in terms of the height of its own structure, rather than the distance to the ground — remains France's Millau viaduct at 343 metres.

Source http://www.thehindu.com/news/international/Worlds-highest-bridge-opens-in-China/article16963400.ece

## 2. Scientists Turn Memory Chips into Processors to Speed Up Computing Tasks




*ReRAM Computing Circuit is under the microscopes.*

A team of international scientists have found a way to make memory chips perform computing tasks, which is traditionally done by computer processors like those made by Intel and Qualcomm. This means data could now be processed in the same spot where it is stored, leading to much faster and thinner mobile devices and computers. This new computing circuit was developed by Nanyang Technological University, Singapore in collaboration with Germany's RWTH Aachen University. It is built using state-of-the-art memory chips known as Redox-based resistive switching random access memory (ReRAM). Developed by global chipmakers such as SanDisk and Panasonic, this type of chip is one of the fastest memory modules that will soon be available commercially. However, instead of storing information the researchers showed how ReRAM can also be used to process data. Current devices and computers have to transfer data from the memory storage to the processor unit for computation, while the new NTU circuit saves time and energy by eliminating these data transfers. It can also boost the speed of current processors found in laptops and mobile devices by at least two times or more. By making the memory chip perform computing tasks, space can be saved by eliminating the processor, leading to thinner, smaller and lighter electronics. The discovery could also lead to new design possibilities for consumer electronics and wearable technology. Currently, all computer processors in the market are using the binary system, which is composed of two states -- either 0 or 1. For example, the letter A will be processed and stored as 01000001, an 8-bit character. However, the prototype ReRAM circuit processes data in more than just two states. For example, it can store and process data as 0, 1, or 2, known as a ternary number system. Because ReRAM uses different electrical resistance to store information, it could be possible to store the data in an even higher number of states, hence speeding up computing tasks beyond current limitations. In current computer systems, all information has to be translated into a string of zeros and ones before it can be processed. The quest for faster processing is one of the most pressing needs for industries worldwide, as computer software is getting increasingly complex while data centres have to deal with more information than ever. The researchers said that using ReRAM for computing will be more cost-effective than other computing technologies on the horizon, since ReRAMs will be available in the market soon. ReRAM is a versatile non-volatile memory concept. These devices are energy-efficient, fast, and they can be scaled to very small dimensions. Using them not only for data storage but also for computation could open a completely new route towards an effective use of energy in the information technology. The excellent properties of ReRAM like its long-term storage capacity, low energy usage and ability to be produced at the nanoscale level have drawn many semiconductor companies to invest in researching this promising technology. The research team is now looking to engage industry partners to leverage this important advance of ReRAM-based ternary computing.

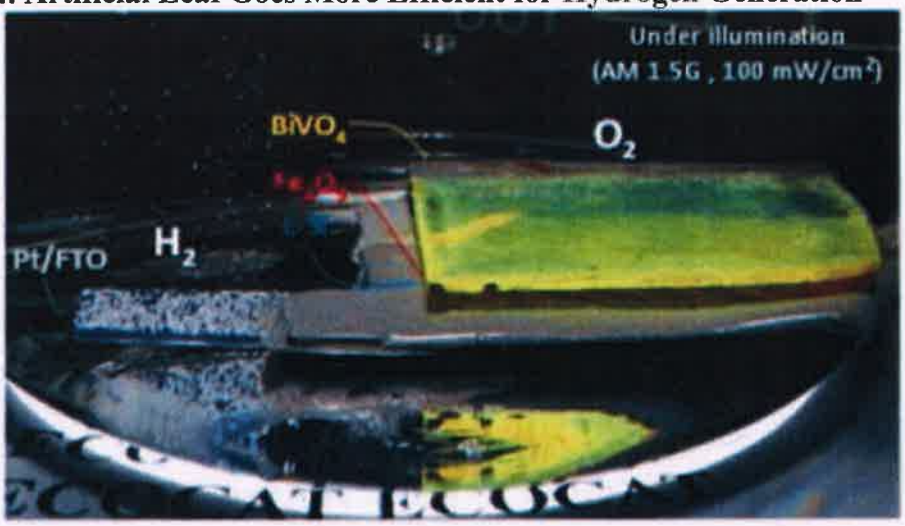
Source https://www.sciencedaily.com/releases/2017/01/170103101808.htm

**3. Additive Manufacturing: A New Twist for Stretchable Electronics?**

Electronic components that can be elongated or twisted -- known as "stretchable" electronics -- could soon be used to power electronic gadgets, the onboard systems of vehicles, medical devices and other products. And a 3-D printing-like approach to manufacturing may help make stretchable electronics more prevalent, say researchers at Missouri University of Science and Technology. Missouri S&T researchers assess the current state of the emerging field of stretchable electronics, focusing on a type of conductor that can be built on or set into the surface of a polymer known as elastomer. These conductors could one day replace the rigid, brittle circuit board that powers many of today's electronic devices. They could be used, for example, as wearable sensors that adhere to the skin to monitor heart rate or brain activity, as sensors in clothing or as thin solar panels that could be plastered onto curved surfaces. Key to the future of stretchable electronics is the surface, or substrate. Elastomer, as its name implies, is a flexible material with high elasticity, which means that it can be bent, stretched, buckled and twisted repeatedly with little impact on its performance. One challenge facing this class of stretchable electronics involves "overcoming mismatches" between the flexible elastomer base and more brittle electronic conductors, the researchers explain. "Unique designs and stretching mechanics have been proposed to harmonize the mismatches and integrate materials with widely different properties as one unique system," writes the research team. A relatively new manufacturing technique known as additive manufacturing may help resolve this issue, they say. Additive manufacturing is a process that allows manufacturers to create three-dimensional objects, layer by layer -- much like 3-D printing, but with metals, ceramics or other materials. The researchers suggest that additive manufacturing could be used to "print" very thin layers of highly conductive materials onto an elastomer surface. "With the development of additive manufacturing, direct writing techniques are showing up as an alternative to the traditional subtractive patterning methods," the S&T researchers say. Subtractive approaches include photolithography, which is commonly used to manufacture semiconductors. The researchers see additive manufacturing as a relatively economical approach to creating these new devices. At Missouri S&T, they are testing an approach called "direct aerosol printing." The process involves spraying a conductive material and integrating with a stretchable substrate to develop sensors that can be placed on skin. "With the increase of complexity and resolution of devices, higher requirements for patterning techniques are expected," they write. "Direct printing, as an additive manufacturing method, would satisfy such requirements and offer low cost and high speed in both prototyping and manufacturing. It might be a solution for cost-effective and scalable fabrication of stretchable electronics." Yet further challenges must be addressed before stretchable electronics become widely used as components in consumer electronics, medical devices or other fields, the researchers say. These challenges include the development of stretchable batteries that can store energy and the need to ensure that stretchable electronics and the malleable surfaces they're built upon perform and age well together. Nevertheless, the researchers are optimistic for the future of stretchable electronics. They foresee a growth in the types of materials that could be used as efficient conductors of electricity and as flexible surfaces on which to build stretchable electronics.

Source https://www.sciencedaily.com/releases/2017/01/170103135847.htm

## 4. Artificial Leaf Goes More Efficient for Hydrogen Generation

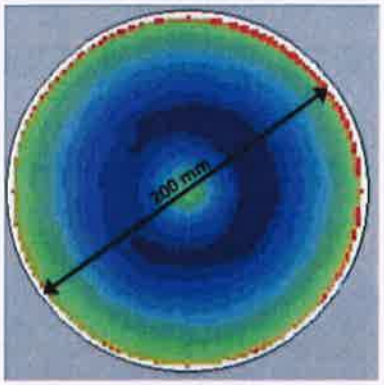



*This is the newly-developed hetero-type dual photoelectrodes*

A team of international researchers, affiliated with UNIST has recently engineered a new artificial leaf that can convert sunlight into fuel with groundbreaking efficiency. In the study, the research presented a hetero-type dual photoelectrodes, in which two photoanodes of different bandgaps are connected in parallel for extended light harvesting. Their new artificial leaf mimics the natural process of underwater photosynthesis of aquatic plants to split water into hydrogen and oxygen, which can be harvested for fuel. This study is expected to contribute greatly to the reduction and treatment of carbon dioxide emissions in accordance with the recent Paris Agreement on climate change. Because using hydrogen produced by artificial leaf as fuel, does not generate carbon dioxide emissions. In addition, it can be used as a cheap and stable hydrogen fuel for hydrogen fuel cell vehicles. Just like any other plants, marine plants also generate energy from the sun through photosynthesis. However, it is difficult to receive the full sunlight deep under the sea. Therefore, they are subjected to various types of photosynthesis that selectively utilize wavelengths reaching their depths. "We aim to achieve 10% enhanced light harvesting efficiency within three years," says a researcher. "This technology will greatly contribute to the establishment of the renewable-energy-type hydrogen refueling station by supplying cheap fuel for hydrogen fuel cell vehicles.

Source https://www.sciencedaily.com/releases/2017/01/170104103549.htm

## 5. GaN-on-Silicon for Scalable High Electron Mobility Transistors

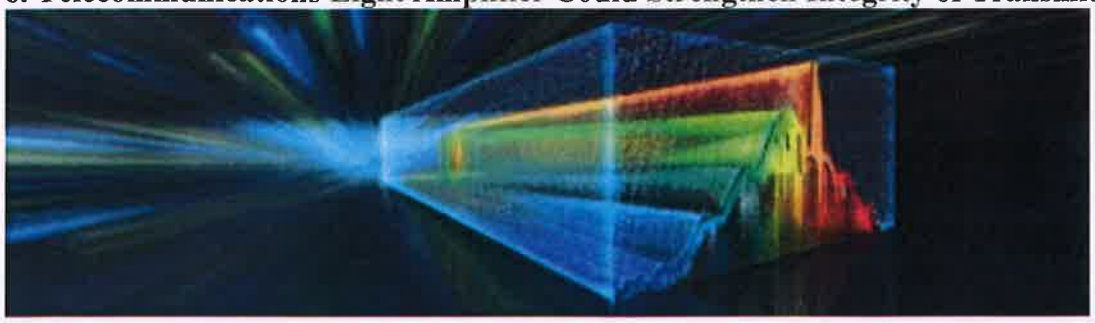



*This is a GaN on 200 mm Si wafer thickness mapping image.*

A team of researchers at the University of Illinois at Urbana-Champaign has advanced gallium nitride (GaN)-on-silicon transistor technology by optimizing the composition of the semiconductor layers that make up the device. Working with industry partners Veeco and IBM, the team created the high electron mobility transistor (HEMT) structure on a 200 mm silicon substrate with a process that will scale to larger industry-standard wafer sizes. Can Bayram, an assistant professor of electrical and computer engineering (ECE), and his team have created the GaN HEMT structure on a silicon platform because it is compatible with existing CMOS manufacturing processes and is less expensive than other substrate options like sapphire and silicon carbide. However, silicon does have its challenges. Namely, the lattice constant, or space between silicon atoms, doesn't match up with the atomic structure of the GaN grown on top of it. "When you grow the GaN on top, there's a lot of strain between the layers, so we grew buffer layers [between the silicon and GaN] to help change the lattice constant into the proper size," a researcher. Without these buffer layers, cracks or other defects will form in the GaN material, which would prevent the transistor from operating properly. Specifically, these defects -- threading dislocations or holes where atoms should be -- ruin the properties of the 2-dimensional electron gas channel in the device. This channel is critical to the HEMTs ability to conduct current and function at high frequencies. "The single most important thing for these GaN [HEMT] devices is to have high 2D electron gas concentration," said a researcher, about the accumulation of electrons in a channel at the interface between the silicon and the various GaN-based layers above it. "The problem is you have to control the strain balance among all those layers -- from substrate all the way up to the channel -- so as to maximize the density of the of the conducting electrons in order to get the fastest transistor with the highest possible power density." After studying three different buffer layer configurations, the research team discovered that thicker buffer layers made of graded AlGaN reduce threading dislocation, and stacking those layers reduces stress. With this type of configuration, the team achieved an electron mobility of 1,800 cm2/V-sec. "The less strain there is on the GaN layer, the higher the mobility will be, which ultimately corresponds to higher transistor operating frequencies," said another researcher leading the scaling of these devices for 5G applications. The next step for the team is to fabricate fully functional high-frequency GaN HEMTs on a silicon platform for use in the 5G wireless data networks. When it's fully deployed, the 5G network will enable faster data rates for the world's 8 billion mobile phones, and will provide better connectivity and performance for Internet of Things (IoT) devices and driverless cars.

Source https://www.sciencedaily.com/releases/2017/01/170109113756.htm

## 6. Telecommunications Light Amplifier Could Strengthen Integrity of Transmitted Data



*These are optical signals propagating through a USRN waveguide undergo 42.5dB of optical parametric amplification.*

Imagine a dim light which is insufficiently bright enough to illuminate a room. An amplifier for such a light would increase the brightness by increasing the number of photons emitted. Photonics researchers have created such a high gain optical amplifier that is compact enough to be placed on a chip. The developed amplifier, when used within an optical interconnect such as a transceiver or fiber optic network, would help to efficiently increase the power of the transmitted light before it is completely depleted through optical losses. Besides having the potential to replace bulky, expensive amplifiers used today for the study of attosecond science and ultrafast optical information processing, the newly developed nanoscale-amplifier also provides a critical element to the optical interconnects toolkit, potentially providing regenerative amplification in short to long range interconnects. This work was a collaborative effort between researchers at the Singapore University of Technology and Design (SUTD), A*STAR Data Storage Institute and the Massachusetts Institute of Technology. "We have developed an optical amplifier which is able to amplify light by 17,000 times at the telecommunications wavelength," said a researcher at SUTD who led the development of the amplifier. "We use a proprietary platform called ultra-silicon-rich nitride, with a material composition of seven parts silicon, three parts nitrogen, with the large nonlinearity and photon efficiency needed for high gain amplification, through the efficient transfer of photons from a pump to the signal. To give a sense of the scale, a conventional optical parametric amplifier costs several hundred thousand dollars, and occupies an entire optical table, while the newly developed amplifier is much smaller than a paper clip, and costs a fraction of the former." Providing high gain on such a small footprint could enable new opportunities in low cost broadband spectroscopy, precision manufacturing and hyperspectral imaging. The device's efficiency is also revealed through cascaded four wave mixing, which is a higher order mixing of the amplified and converted photons. This phenomenon also allows the amplifier to operate as a tunable broadband light source, enabling cheaper and more efficient spectroscopic sensing and molecular fingerprinting than what is available today. "The inefficiencies in highly nonlinear photonic devices are overcome here, by photonic device engineering for maximum nonlinearity, while still maintaining a sufficiently large bandgap to eliminate two-photon absorption at the telecommunications wavelength. We believe this is one of the highest gains demonstrated at the telecommunications wavelength to date on a CMOS chip" said a researcher. Achieving ultra-large amplification while maintaining high compactness was possible because the researchers managed to design and implement an amplifier which operates simultaneously with a high nonlinearity and photon efficiency. In other platforms which are compatible with processes used in the electronics industry today, either the nonlinearity or photon efficiency is low. "The results demonstrate the ultra-silicon-rich nitride platform to be extremely promising for highly efficient nonlinear optics applications, particularly in the field of CMOS photonics leveraging existing electronics infrastructure," says a Scientist at the A*STAR Data Storage Institute.

Source https://www.sciencedaily.com/releases/2017/01/170105123047.htm

## 7. New Simulation Software Improves Helicopter Pilot Training

Missions at sea, in mountainous regions or close to skyscrapers are extremely risky for helicopter pilots. The turbulent air flows near oil rigs, ships, cliffs and tall buildings can throw a helicopter off balance and cause a crash. To provide pilots with optimal preparation for these challenging conditions, engineers at the Technical University of Munich (TUM) are developing new simulation software. Providing helicopter pilots with the best possible preparation for extreme situations: That is the goal of the new simulation software being developed by researchers working at TUM's Chair of Helicopter Technology. For the first time, real-time computational analysis will be implemented for both fluid mechanics and flight dynamics. "Until now, flight simulators have not adequately reflected the reality of flying in close proximity to large objects," says Dr. Juergen Rauleder. "The problem is that, when it comes to wind conditions and the response of the helicopter, existing programs follow a rigid pattern. That means that local variations and changing conditions are not taken into account - unless the entire flow environment is known in advance." But it is the unforeseen air flows that can be the most treacherous: For example, a moving ship causes air turbulence and sudden local shifts in wind speed known by specialists as "ship airwake flow". It changes continually through wave action and fluctuating inflow conditions. In addition, turbulence occurs near the deck, the bridge and other ship structures. As a helicopter approaches the ship, there is interference between these air currents and the flow produced by the rotors. Conditions near a mountain slope or next to high buildings are similarly complicated. In all of these cases, the helicopter's flight characteristics are influenced by complex and overlapping aerodynamic effects. zealing with those situations takes a lot of skill and practice, both of which can currently be acquired only through on-the-job training. To become adept at landing on a ship in heavy seas, for example, a student pilot has to repeat this tricky situation dozens of times with an experienced flight instructor. That's the only way to gain the necessary experience to compensate for the complex interplay of air flows through perfectly timed adjustments to the pitch of the rotor blades. "Conventional training is expensive, risky and very stressful for student pilots. It also imposes heavy demands on the aircraft: Because the first attempts usually result in rather hard landings, the dampers and landing gear take quite a beating," explains Rauleder. His team has now developed a simulation program that combines flow mechanics and flight dynamics in real time: "The numerical model is extremely flexible and does not depend on stored flow data. We only have to enter the external conditions such as topography, global wind speeds and the helicopter type. During the simulation, our algorithms use that data to continuously compute the interacting flow field at the virtual helicopter's current location," the engineer explains. The new program also lets pilots instantly "feel" the impact of the local air flows on the helicopter. This allows them to try out the effects of their control movements in a stress-free situation: perfect preparation for a soft landing that is easy on the aircraft. The TUM researchers have successfully validated the new real-time simulation with established reference models. All that is left to do is the biggest test of all: the reality check. The specialists have measured air flows on a ship using hundreds of sensors. To check the flight dynamics, the team will also be using in-flight data collected by the German Aerospace Center (DLR). "The validation of the models and testing of our simulation environment by experienced pilots in our research simulator is enormously important for our developments," says Rauleder. "That's the only way we can ensure that the simulator training provides student pilots with optimal preparation for tough missions."

Source http://phys.org/news/2016-12-simulation-software-helicopter.html

## 8. A Wolverine-Inspired Material

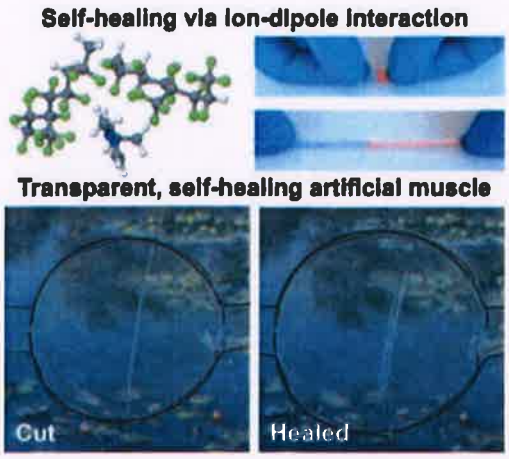


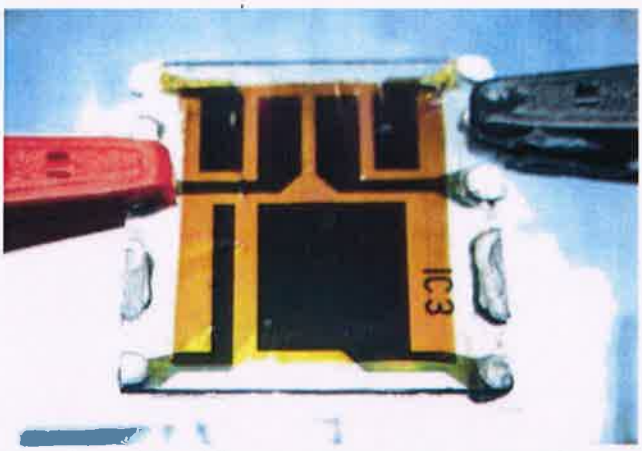

*Illustration showing self-healing via ion-dipole interaction.*

Scientists, including several from the University of California, Riverside, have developed a transparent, self-healing, highly stretchable conductive material that can be electrically activated to power artificial muscles and could be used to improve batteries, electronic devices, and robots. The findings represent the first time scientists have created an ionic conductor, meaning materials that ions can flow through, that is transparent, mechanically stretchable, and self-healing. The material has potential applications in a wide range of fields. It could give robots the ability to self-heal after mechanical failure; extend the lifetime of lithium ion batteries used in electronics and electric cars; and improve biosensors used in the medical field and environmental monitoring. This project brings together the research areas of self-healing materials and ionic conductors. Inspired by wound healing in nature, self-healing materials repair damage caused by wear and extend the lifetime, and lower the cost, of materials and devices. Ionic conductors are a class of materials with key roles in energy storage, solar energy conversion, sensors, and electronic devices. Another author of the paper previously demonstrated that stretchable, transparent, ionic conductors can be used to power artificial muscles and to create transparent loudspeakers -- devices that feature several of the key properties of the new material (transparency, high stretchability and ionic conductivity) -- but none of these devices additionally had the ability to self-heal from mechanical damage. The key difficulty is the identification of bonds that are stable and reversible under electrochemical conditions. Conventionally, self-healing polymers make use of non-covalent bonds, which creates a problem because those bonds are affected by electrochemical reactions that degrade the performance of the materials. The researchers helped solve that problem by using a mechanism called ion-dipole interactions, which are forces between charged ions and polar molecules that are highly stabile under electrochemical conditions. They combined a polar, stretchable polymer with a mobile, high-ionic-strength salt to create the material with the properties the researchers were seeking. The low-cost, easy to produce soft rubber-like material can stretch 50 times its original length. After being cut, it can completely re-attach, or heal, in 24 hours at room temperature. In fact, after only five minutes of healing the material can be stretched two times its original length. They demonstrated that the material could be used to power a so-called artificial muscle, also called dielectric elastomer actuator. Artificial muscle is a generic term used for materials or devices that can reversibly contract, expand, or rotate due to an external stimulus such as voltage, current, pressure or temperature. The dielectric elastomer actuator is actually three individual pieces of polymer that are stacked together. The top and bottom layers are the new material, which is able to conduct electricity and is self-healable, and the middle layer is a transparent, non-conductive rubber-like membrane. The researchers used electrical signals to get the artificial muscle to move. So, just like how a human muscle (such as a bicep) moves when the brain sends a signal to the arm, the artificial muscle also reacts when it receives a signal. Most importantly, the researchers were able to demonstrate that the ability of the new material to self-heal can be used to mimic a preeminent survival feature of nature: wound-healing. After parts of the artificial muscle were cut into two separate pieces, the material healed without relying on external stimuli, and the artificial muscle returned to the same level of performance as before being cut.

Source https://www.sciencedaily.com/releases/2016/12/161225231953.htm

## Energy Engineering

### 9. Researchers Solve Mystery that was Holding Back Development of Next-Generation Solar Cells

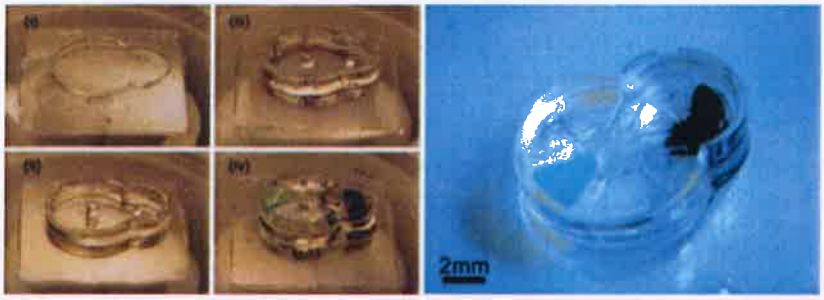



Scientists have identified an unexpected cause of poor performance in a new class of flexible and cheap solar cells, bringing them closer to market. Solar cells are the building blocks of photovoltaic solar panels. They are made from light-absorbing materials that convert sunlight into electricity. Normally the light-absorbing material is silicon, which has an energy-intensive manufacturing process. In the new study, scientists looked at solar cells made from materials known as perovskites. These can be produced cheaply from chemicals mixed into printable or sprayable ink, which then crystallises to form light-absorbing films.

However, perovskite films contain charged defects that are likely to impair their performance. Slow movement of these defects is thought to be responsible for a process known as hysteresis, which leads to irregularities in the efficiency with which light is converted to electrical current. Light-generated electricity exits the solar cell in the form of electrons to be harnessed. This is done via 'contacts' that sandwich the light-absorbing film. Previously, scientists have managed to remove hysteresis by using more 'selective' contact materials that ensure a one-way flow of electrons out of the solar cell. In theory, changing these contact materials shouldn't have any effect on the movement of the charged defects within the perovskite, so it has remained a mystery why this appeared to 'fix' the hysteresis problem. Now researchers from Imperial College London and collaborators have developed new experiments to follow which direction electrons move in the solar cell when they are generated with a short pulse of light. They found that the mobile charged defects are still present even in solar cells with very efficient contact materials, despite these cells showing no hysteresis. Hysteresis was only found when cells suffered the combined effects of both the defects and poor selectivity at the contacts. The researchers said: "The field has made amazing progress, and we're on the right track by reducing problems with the contacts. However, the results also show that improving the contacts is only part of the solution, and we still need to be concerned about the charged defects moving inside the perovskite." The charged defects may provide a chemical weak point which could lead to the eventual degradation of the perovskite film. This raises a potential concern over the solar cells' long term stability. The researcher said: "The new techniques we have designed will allow the community to assess the extent of charged defect movement to help the future research needed to improve the stability and bring this technology to market." Now that the causes of hysteresis have been uncovered, there are a few challenges that must be overcome before perovskite solar cells can be commercialized. One concern with current perovskites is that they contain small amounts of lead in their chemical structure. A replacement metal will probably have to be found before they are deemed safe at larger scales. Scientists will also have to reproduce their laboratory results with life-sized solar panels. However, the crucial challenge will be to find a way of improving the long-term stability of the perovskite materials.

Source https://techxplore.com/news/2016-12-mystery-next-generation-solar-cells.html

## 10. Implantable Microrobots: Innovative Manufacturing Platform Makes Intricate Biocompatible Micromachines




*Fabrication and complete assembly of a Geneva drive device using the iMEMS method. The left panel shows the layer-by-layer fabrication of support structures and assembly of gear components. The image on the right shows the complete device after the layers have been sealed.*

A team of researchers led by Biomedical Engineering Professor Sam Sia at Columbia Engineering has developed a way to manufacture microscale-sized machines from biomaterials that can safely be implanted in the body. Working with hydrogels, which are biocompatible materials that engineers have been studying for decades, Sia has invented a new technique that stacks the soft material in layers to make devices that have three-dimensional, freely moving parts. The study demonstrates a fast manufacturing method Sia calls "implantable microelectromechanical systems" (iMEMS). By exploiting the unique mechanical properties of hydrogels, the researchers developed a "locking mechanism" for precise actuation and movement of freely moving parts, which can provide functions such as valves, manifolds, rotors, pumps, and drug delivery. They were able to tune the biomaterials within a wide range of mechanical and diffusive properties and to control them after implantation without a sustained power supply such as a toxic battery. They then tested the "payload" delivery in a bone cancer model and found that the triggering of release of doxorubicin from the device over 10 days showed high treatment efficacy and low toxicity, at 1/10 of the standard systemic chemotherapy dose. Most current implantable microdevices have static components rather than moving parts and, because they require batteries or other toxic electronics, have limited biocompatibility. "Hydrogels are difficult to work with, as they are soft and not compatible with traditional machining techniques," says a researcher. "We have tuned the mechanical properties and carefully matched the stiffness of structures that come in contact with each other within the device. Gears that interlock have to be stiff in order to allow for force transmission and to withstand repeated actuation. Conversely, structures that form locking mechanisms have to be soft and flexible to allow for the gears to slip by them during actuation, while at the same time they have to be stiff enough to hold the gears in place when the device is not actuated. We also studied the diffusive properties of the hydrogels to ensure that the loaded drugs do not easily diffuse through the hydrogel layers." The team used light to polymerize sheets of gel and incorporated a stepper mechanization to control the z-axis and pattern the sheets layer by layer, giving them three-dimensionality. Controlling the z-axis enabled the researchers to create composite structures within one layer of the hydrogel while managing the thickness of each layer throughout the fabrication process. They were able to stack multiple layers that are precisely aligned and, because they could polymerize a layer at a time, one right after the other, the complex structure was built in under 30 minutes. Sia's iMEMS technique addresses several fundamental considerations in building biocompatible microdevices, micromachines, and microrobots: how to power small robotic devices without using toxic batteries, how to make small biocompatible moveable components that are not silicon which has limited biocompatibility, and how to communicate wirelessly once implanted. The researchers were able to trigger the iMEMS device to release additional payloads over days to weeks after implantation. They were also able to achieve precise actuation by using magnetic forces to induce gear movements that, in turn, bend structural beams made of hydrogels with highly tunable properties. In collaboration with an orthopaedic surgeon at Columbia University Medical Center, the team tested the drug delivery system on mice with bone cancer. The iMEMS system delivered chemotherapy adjacent to the cancer, and limited tumour growth while showing less toxicity than chemotherapy administered throughout the body. "These microscale components can be used for microelectromechanical systems, for larger devices ranging from drug delivery to catheters to cardiac pacemakers, and soft robotics," notes Sia. "People are already making replacement tissues and now we can make small implantable devices, sensors, or robots that we can talk to wirelessly.

Source https://www.sciencedaily.com/releases/2017/01/170104145738.htm

## Engineering Innovation in India

These 10 Transformative Inventions From 2016 Can Impact the Lives of Millions in India.. Here's a list of 2016's most impactful innovations that offer solutions to some of India's most pressing problems.

1. **SuryaGen Solar Water Purifier**

Developed by IISc. researchers and Suryagen Renewables, this open source solar water purifier can transform water from any source – be it from sea, river, pond, wells, or even water collected from rain – into potable water. The low-cost device can also provide clear drinking water in areas where the only sources are contaminated with arsenic, fluoride or sewage. In this device, impure water is evaporated using solar energy and the vapours are condensed to pure water on a cold surface. This leaves behind bacteria, heavy metals, arsenic, fluoride and other impurities. It can effectively produce 1.5 litres of potable water from 3 litres of impure water daily.

2. **Envigreen Edible Bags**

A young entrepreneur, Ashwath Hegde, created a combination of natural starch (from potato and tapioca) and vegetable oils to make a bag that looks and feels just like plastic with none of the negative environmental impacts of a plastic vessel. EnviGreen's bags will naturally degrade in 180 days and if they are submerged in water they disappear in a day. Oh and also – these bags are edible..

3. **Self-Repairing Roads**

Nemkumar Bhantia, a professor in the Civil Engineering Department at University of British Columbia (UBC) in the Canada, has developed roads that are self-repairing and sustainable. Built used ultra high-strength concrete and special fibres developed at UBC, the first such road in Karnataka is not only cost-effective, but has greater longevity., Banthia's self-repairing road uses 60 % fly-ash and only 40 % cement. The fibres used have a hydrophilic nano-coating, which attract water in the event of rains. The water then becomes a key component in healing cracks. When a crack appears, this water gives hydration capability to the un-hydrated cement, and produces more silicates, which actually close the crack before they grow larger.

4. **Ulta Chaata Harvester**

A couple passionate about conservation, Samit and Priya Choksi's first product is Ulta Chaata, an indigenous patented system that smartly converges rainwater harvesting and generation of renewable energy for open spaces in smart cities, industries, or large campuses. A single unit of Ulta Chata can help you harvest upto 100,000 litres of water and capture energy with maximum peak power of 1.5 Kw.

5. **Cane-based Prosthetic Limbs**

Bengaluru start-up, Rise Legs, has come up with a prosthetic leg for amputees made of cane, which is not only light but much more affordable too. Conventional low-cost prostheses in India, made of rubber wood or plastic, are often rigid, heavy and cumbersome, which makes walking and high level activities difficult for the user. Modern prostheses, while flexible, are made of material like carbon-fibre and Kevlar that make them far too expensive for most amputees in India.

6. **Low-Cost Wind Turbines**

Avant Garde Innovations, the startup founded by siblings Arun and Anoop George from Kerala, has come up with a low-cost wind turbine that can generate enough electricity to power an entire house for a lifetime. The size of a ceiling fan, this wind turbine can generate 5 kWh/kW per day and cost less than an iphone !

7. **No-Fuel Plough**

A farmer in Banda in Uttar Pradesh, 50-year-old Ram Prasad upcycled an old bicycle to make a low cost plough, and then inspired his neighbours to do the same. He converted an old cycle he found in his backyard, with some pieces of iron, into a plough.

8. **Solar Power Tree**

Developed by the Central Mechanical Engineering Research Institute (CSIR-CMERI), the Solar Power Tree generates the same amount of electricity as a conventional array (enough to light up 5 homes), but on a much smaller plot of land. With photovoltaic panels placed at different levels on branches made of steel,

"solar trees" could dramatically reduce the amount of land needed to develop solar parks. Solar power trees are also capable of harnessing 10 to 15 percent more power compared to ground-mounted solar arrays.

9. **DewDrop Water-from-Air Condenser**
Jawwad Patel, a 22-year-old engineering student from Hyderabad has designed a 3D-printed apparatus which can 'create' water from air. The water apparatus produces pure drinkable water with the help of computerised sensor interface with UV filter. In an hour, the device can extract nearly 1.8 litres of water from air.

10. **Unique Waste Disposal Bins**
Ganga Narayan Ghosh, an 87-year-old mechanical engineer, has designed some innovative waste disposal bins to tackle the problem of waste management in India in an organised way. He designed three unique bins – one for homes, another for housing complexes and schools and the largest one for markets and entire localities.

Source http://www.thebetterindia.com/80252/best-transformative-social-inventions-innovations-india/