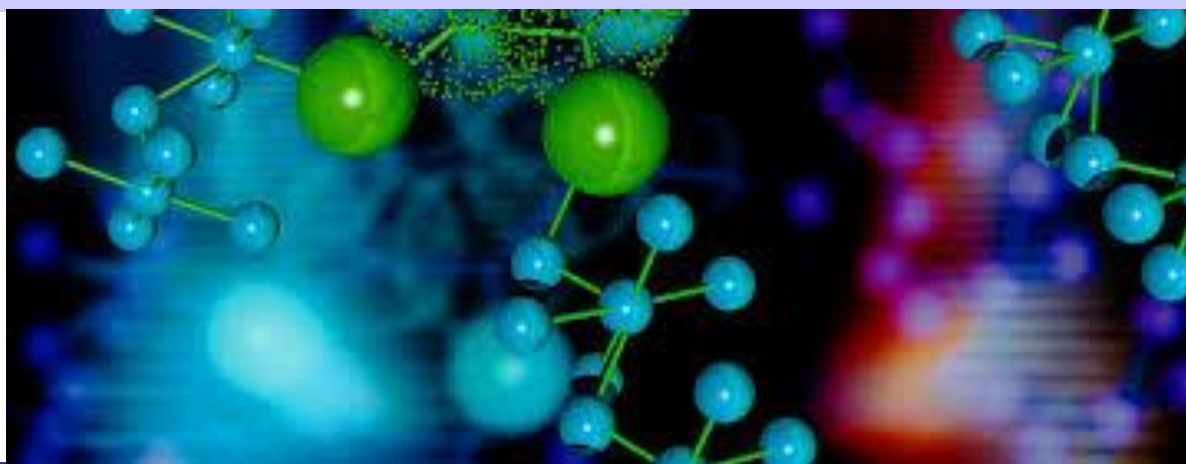




# Use Efficiency – A design paradigm for Green Innovations

*NEPIC: Bioresources Conference, Sep. 22<sup>nd</sup>, 2016, Durham, UK*

*Dr. Anil Kumar – Tata Chemicals Limited*



Innovation Centre, Tata Chemicals Ltd, Pune, India

Warm Autumn Greetings and  
Welcome

To

NEPIC Bioresources Conference  
Organizers

Members of NEPIC

Friends

*Season of mists and mellow  
fruitfulness,  
Close bosom-friend of the  
maturing sun;  
Conspiring with him how to load  
and bless .....  
- Ode to Autumn , John Keats*

# Context: Indians born in recent times will consume 13x more than their grandparents



Metric	Born in 1960	Born in 2009
Life Expectancy (years)	42	64
Per capita consumption at birth	\$241	\$802
Per capita consumption at death	\$531	\$6,190
Lifetime Consumption	\$14,645	13x \$184,898

## Growth in Multiple End Use Industries



Note: All figures in constant 2010 US\$ with a fixed 2010 exchange rate; Key assumptions: population growth flattens post-2050 and 3% GDP growth post-2020  
Source: World Bank, United Nations Dataset

# Cast of Characters

## Use Efficiency

(Overarching Design Paradigm)

(Renewables – Industrial  
Symbiosis  
&  
Low Carbon technologies)



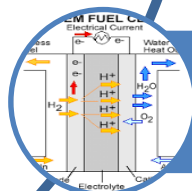
Renewables (Industrial Symbiosis) - Through Synergy  
- Natural crop protection agents



Renewables (Industrial Symbiosis) – Waste to Value –  
Novel Nanomaterials



Low carbon technologies – More from Less  
- Nutraceutical Formulations



Low Carbon technologies -Multi-functional materials  
- Fuel cell



## Synergy leading to use efficiency

- Tea Crop loss due to pests is around 30 to 40% annually
  - *Coffea arabica* is on the verge of extinction in India due to white stem borer
- 
- Promote ecological agriculture (Rain Forest Alliance)
  - NPM in tea & coffee production in India.
  - Gradually eliminate the use of chemical pesticides
  - Develop commercially viable portfolio of bio-pesticides for tea



Red Spider mite  
*Oligonychus coffeae*



Tea mosquito bug



Coffee white stem borer

## Chemistry Inside

## Biomimetic Chemistry:

- (A) Multiple targeting – Develop a mix of actives targeting different enzymes (biochemical pathways) in the pest
- (B) Mix of anti-feedants , inhibition of larval ecdysis & repellents
- (C) Formulation (Adjuvant formulation) to stabilize the actives
- (D) Principles of vrksayurveda, to enhance plant defence

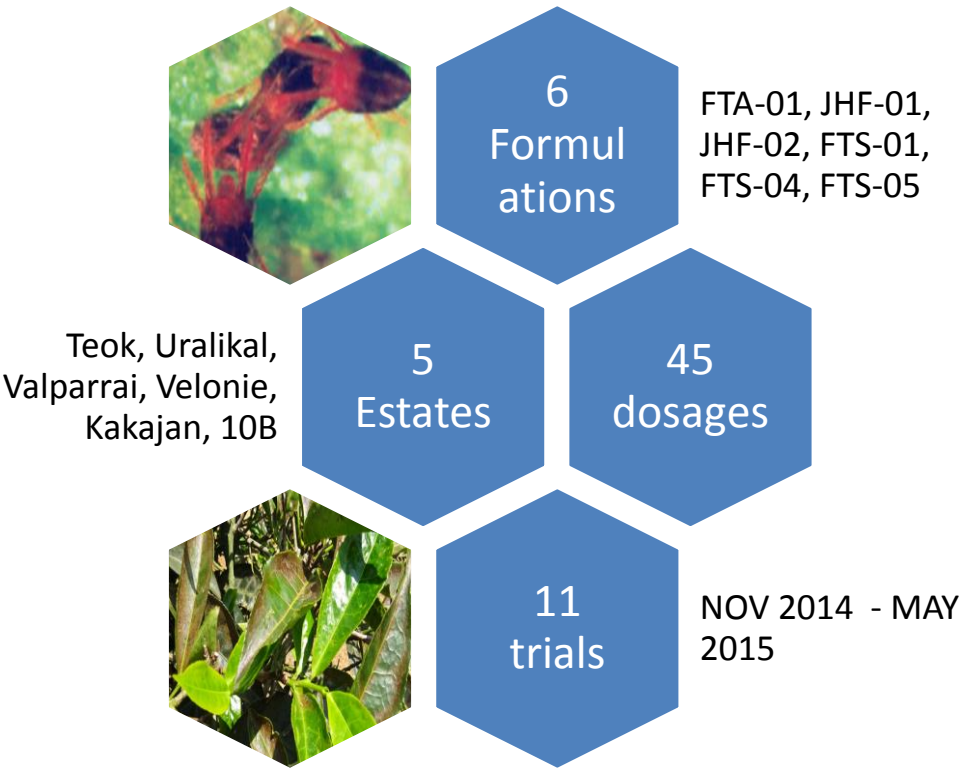
IC(FTS-01)

IC formulation , NA-01 @ 1700ml/ha has recorded about 50% reduction of red spider mite incidence in comparison with UTC at 7 days interval.

UTC



## Synopsis of trials for RSM



PLANTATION	FTS -01 highest bio-efficacy for RSM	Remarks
KDHP	72.2%	7 days after 2 <sup>nd</sup> Spray
TATA COFFEE (Annamalais)	85.5%	10 days after 3 <sup>rd</sup> spray
APPL	68.6%	10 days after 2 <sup>nd</sup> spray

Multi-locational trials demonstrate that NA – 01 displays a definite bio-pesticidal action on Red Spider Mites

# Green Crop-Care Formulations

Combination of - (i) cross plantations (with host plants for natural predators), (ii) using Naturals & once in a while (iii) therapeutic use of synthetics is recommended



Naturals



Cross -  
plantations



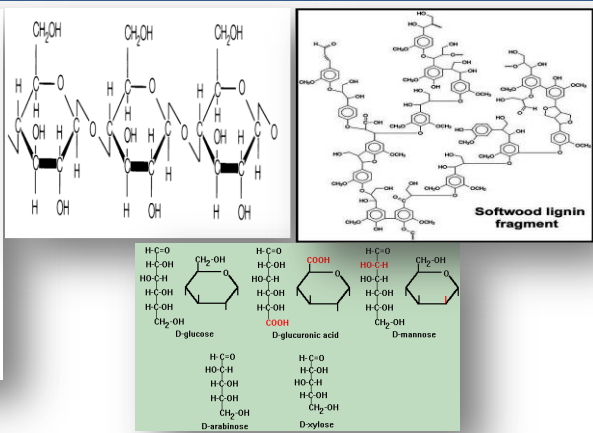
Therapeutic  
use of  
Synthetics

A fundamental shift to a total systems approach for crop protection is urgently needed to resolve escalating economic and environmental consequences of combating Agricultural pests



## Tata Group Co-development – Alternate cost effective materials

- ❖ Tata Steel processes 15,000 – 18,000 tons/day of iron ore for pelletization
- ❖ Present bentonite binder is 0.4 % w.r.t iron ore (required 40-60 Tons/day)
- ❖ Currently acceptable level of impurities is 2 to 2.1 % of Si & Al
- ❖ Na Bentonite consists of silica and alumia ( $\text{SiO}_2$  66.7%,  $\text{Al}_2\text{O}_3$  28.3%,  $\text{H}_2\text{O}$  5%)



Sr.No	Organic binder	Source	Backbone unit	Cost Kg/Rs.
1	Chitin	crabs, lobsters, shrimps and insects.	Glucosamine	200-300
2	Groundnut shell powder	Groundnut shell	Cellulose (35%), Hemicellulose (18%) Lignin	7-10
3	NaCMC	Wood constituents, Cotton fiber	Glucose	80-100
4	S-free Lignin	Wood constituents, paper & pulp industry	Coniferyl alcohol, Sinapyl alcohol, p-Coumaryl alcohol units	30-40
5	Gum Karaya	dried exudates of the sterculia urens tree (limited)	D-galactose, L-rhamnose, D-glucuronic acid and D-galacturonic acid	200-300

Alternate binder option are being explored to reduce impurities such as Na, Si, Al, S & P due to depleting ore quality

## Groundnut Shell Powder is a good substitute (in parts) for bentonite

Exp. No	Bentonite %	CMC %	GRN %	Lignin %	GCS Kg/pellet	DCS Kg/Pellet (>2.5Kg/pellet)	T °C	t min	CCS Kg/pellet	RI (>65%)	TDI (<28%)
A	0.4	0	0	0	1.67	6.93	1300	7	307.07	85.82	18.2
B	0.3	0.1	0	0	1.47	3.22	1300	7	291.43	83.58	19.2
C	0.3	0	0.1	0	1.86	5.41	1300	7	333.99	82.84	14
D	0.3	0	0	0.1	1.63	4.01	1300	7	297.52	82.84	14.8
E	0.2	0.2	0	0	0.61	2.66	1300	7	237.61	ND	ND
F	0.2	0	0.2	0	1.5	3.74	1300	7	310.22	87.31	15
G	0.2	0	0	0.2	1.54	3.37	1300	7	299.7	85.82	15.4
H	0.1	0.3	0	0	ND	ND	--	--	ND	ND	ND
I	0.1	0	0.3	0	1.52	2.68	1300	7	329.32	76.87	15.2
J	0.1	0	0	0.3	1.69	2.52	1300	7	324.27	79.11	21.6
K	0	0	0.2	0	1.55	2.84	1300	7	284.75	82.09	15.2
L	0.2	0.1	0	0.1	0.87	2.26	1300	7	279.27	86.57	8.8
M	0.2	0	0.1	0.1	1.63	3.58	1300	7	346.47	82.84	16.8



India cultivates about 7.74 million hectares and produces 7.61 million tonnes of groundnut pa (1.9 million tonnes pa of shell)

GRNS emerged as a path-breaking discovery because of naturally occurring in-built cellulose and lignin with minimal non-desirous elements

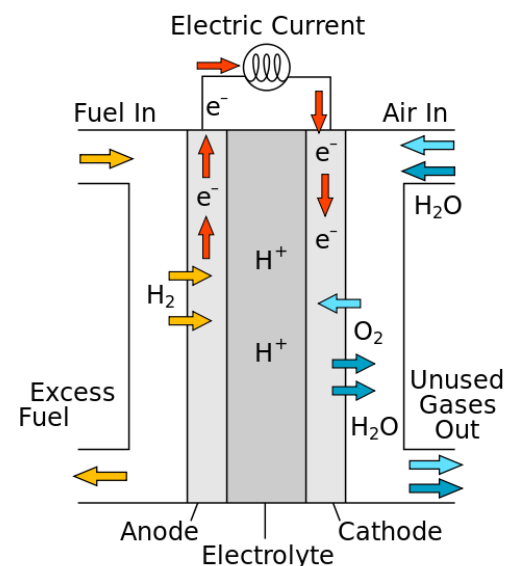
## Multi-functional materials – An innovative approach to develop cost efficient FC

### Advantages

- The most efficient way of converting energy - Fuel to Electricity
- Efficiencies: ~ 40 - 60% as standalone systems & up to 90% as part of a CHP system
- Zero emissions at point of use with clean fuels.
  - Emissions are a major driver. Indian cities are some of the most polluted globally
- Excellent NVH characteristics
  - Will become increasingly important when electricity is needed domestically or when used in urban or sub-urban areas
- Greater reliability, longer life and lower maintenance than ICE gen-sets

### Technology Challenges

- Cost : Gradually falling costs so new markets becoming commercially viable
  - Substantial grants & incentives to support development and to drive adoption
- Reliable Sub System, use of hydrogen problematic and alternative fuels expensive or difficult & form factor



## Multi-functional materials – A two-in-one catalyst for PEM Fuel cell

### Electrode catalyst

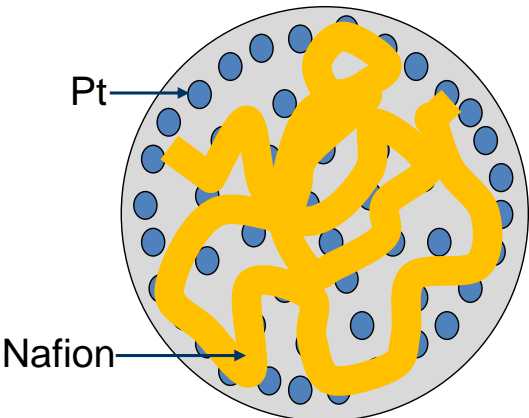
- Reduce Pt content
- Increase efficiency and durability
- Minimize CO poisoning
- Replace Nafion

### Objectives

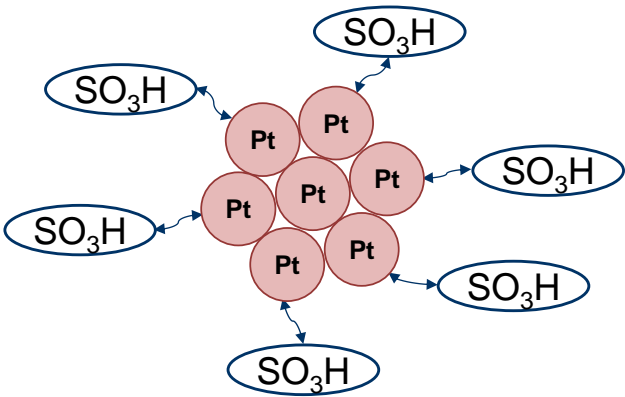
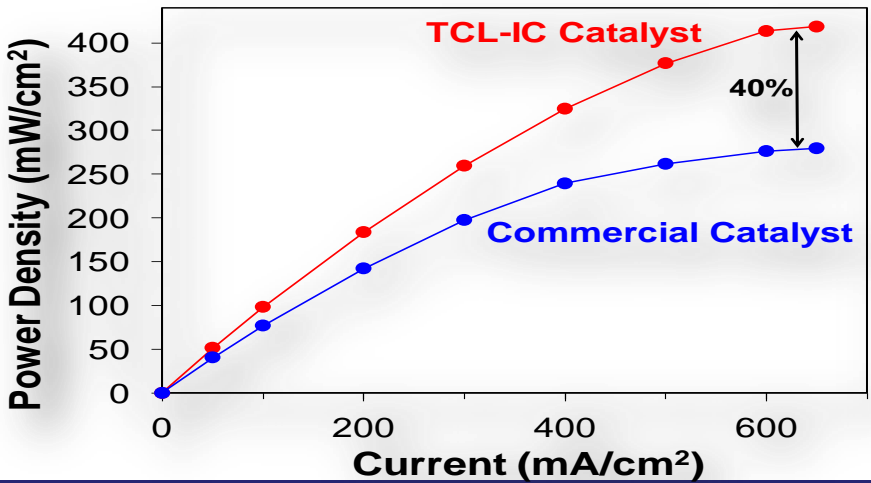
### Membrane

- Replace Nafion
- Increase efficiency and durability
- Cost reduction
- High temperature operation

Significant cost reduction of MEA and stack – viable for commercialization



Commercial Catalyst



TCL-IC Catalyst



## Significant cost reduction due to reduced catalyst (Pt) loading

Highly monodisperse Pt NPs coated with  $-\text{SO}_3\text{H}$  groups

Transparent mixed oxides containing  $-\text{SO}_3\text{H}$  groups

TCL-IC  
MEA

- $-\text{SO}_3\text{H}$  groups act as proton conductor
- Protects Pt NPs from agglomeration and deactivation
- Low or zero Nafion content as binder in electrode
- 25% reduction in Pt content compared to commercial catalysts
- Higher durability, efficiency and consistency than commercial Pt/C catalysts

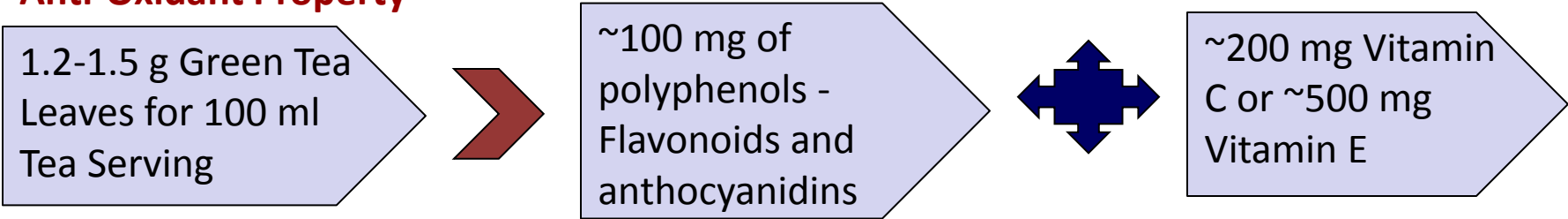
- $-\text{SO}_3\text{H}$  groups act as proton conductor
- Negligible methanol crossover
- Operates at both low ( $<80^\circ\text{C}$ ) and high ( $120^\circ\text{C}$ ) temperatures
- Complete replacement of Nafion
- Higher thermal stability, mechanical strength and proton conductivity, than commercial membranes

- Combined cost reduction due to improved performance, Pt content and Nafion would be  $\geq 30\%$

## Improving bioavailability & stability – More from Less

**Growing Consumer Awareness on Green Tea health benefits (anti-ageing & good for T2D)**

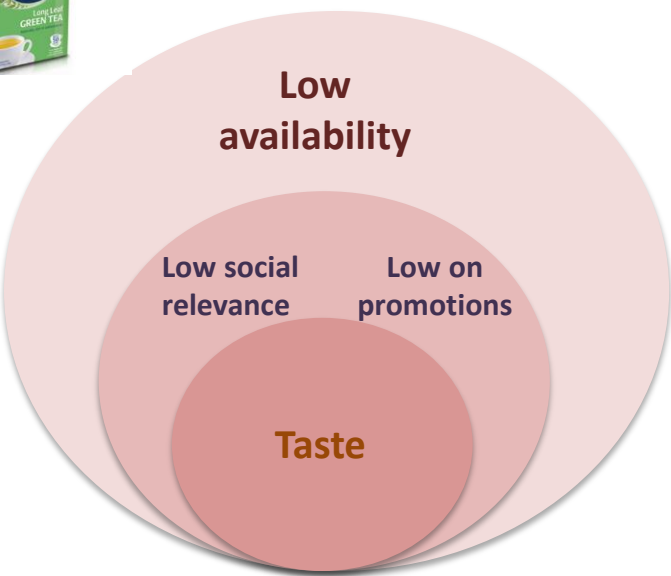
### Anti-Oxidant Property



### TRIGGERS

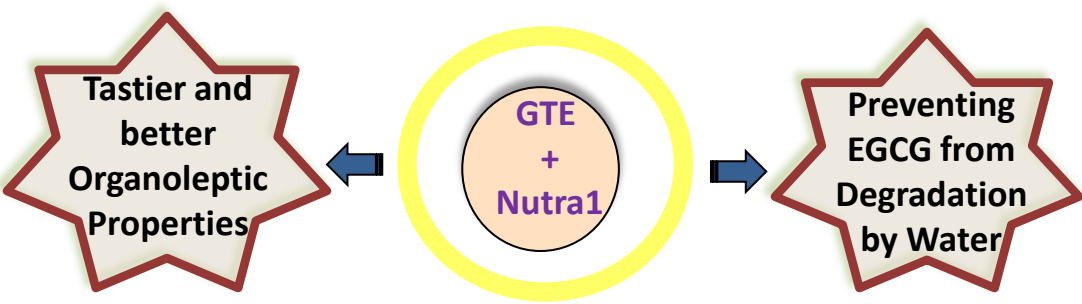
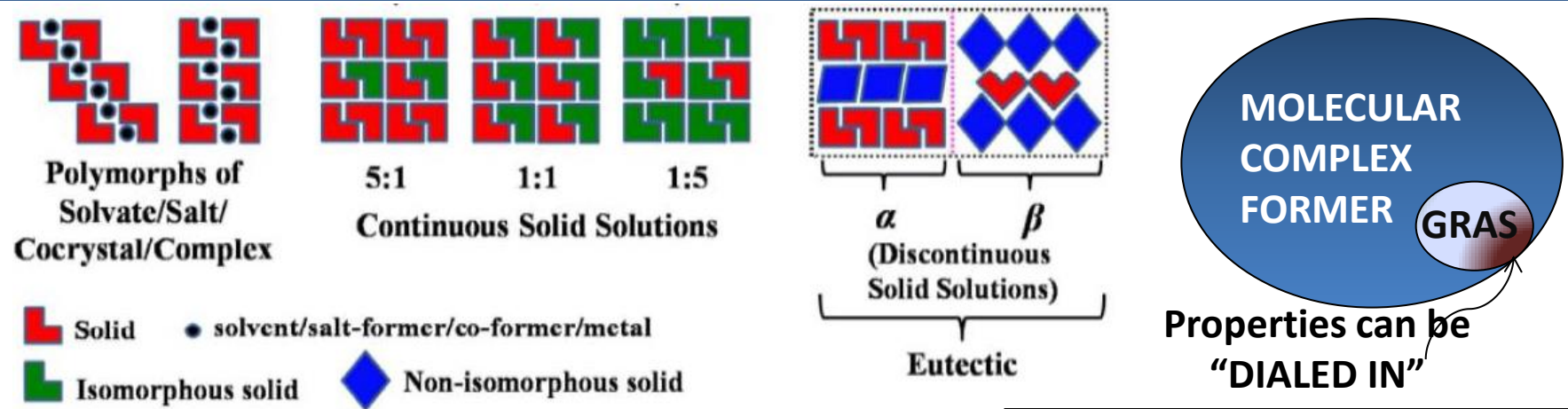


### BARRIERS

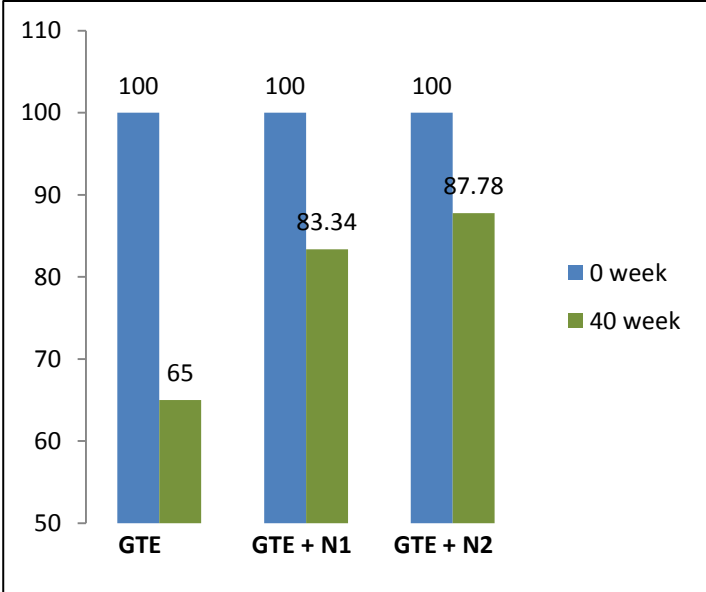


Green Tea Polyphenols are fastest growing in Tea Market at 8.3 % CAGR between 2013-2020

## Chemistry Inside – Less energy intensive process steps

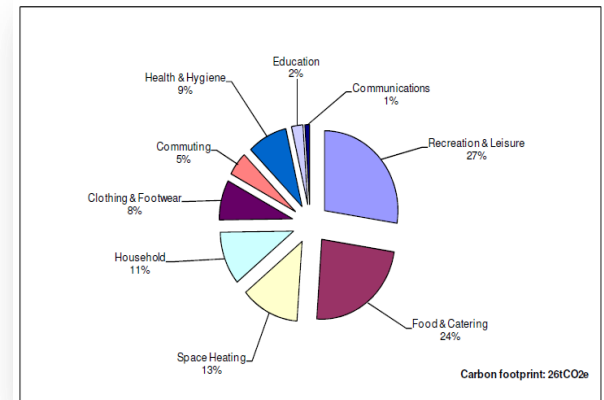


GTE- Nutra1 and GTE- Nutra2 are stable even after 40 weeks – high shelf life stability



# Time is an important resource, there is a direct correlation of time with carbon emissions

- Carbon dioxide emissions (CO<sub>2</sub>), metric tons of CO<sub>2</sub> per capita is **1.6987 MT** for India (2011) or **4.65 Kg of CO<sub>2</sub>e per day** , while it is **9.66 MT** or **26.45 Kg of CO<sub>2</sub>e per day** for UK, and **17 MT** or **46.5 Kg of CO<sub>2</sub>e per day** for US
- Carbon footprint of an average UK household is **26 tCO<sub>2</sub>e**
- Combined carbon footprint is approximately 10 tons CO<sub>2</sub>e per household per year, that is about **32 Kgs of CO<sub>2</sub>e per day**
- Therefore, every day added leads to : **32 Kgs of CO<sub>2</sub>e** , apart from the emissions that would arise due to work (factory, laboratory & office space)
- **Therefore it is critical that shortest path to discovery be taken**





# Time is an important resource, that needs to be given adequate attention

Industry	Idea to Market	Reference
Automotive	3-4 years	<a href="#">PwC's Strategy&amp;</a>
Pharmaceuticals	10-15 years	<a href="#">Licensing Intelligence for Boehringer Ingelheim</a>
Biotech	Approx 16 Years	<a href="#">"Biotech Crop Development" by Monsanto</a>
Synthetic Biology	7.4 years	<a href="#">Lux research</a>
Chemical <ul style="list-style-type: none"> <li>➤ Product line extension</li> <li>➤ New product launch</li> </ul>	2-7 years 8-19 years	<a href="#">McKinsey</a>
Electronics	1-3 years	<a href="#">Book: Managing Projects in Research and Development</a>
IT Software	1-2 years	
FMCG average	15-22 months	<a href="#">BCG</a>

Time has to be factored while assessing the "green chemistry" aspects of a process.

E-factor = total waste (kg) / product (kg) \* weighted average of time spent.

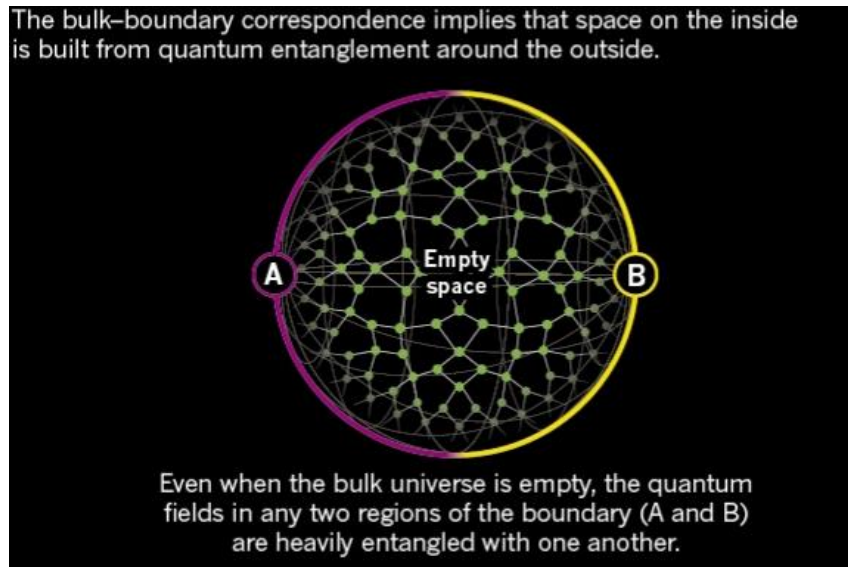
## Plausible Solutions :

- ❖ Teams should be given Multiple projects in parallel, with a good mix of Short, Mid & Long Term
- ❖ Shortest path to goal has to be given attention

## Key Message – Systems view of Life

Truly sustainable development is based on the recognition that we are an inseparable part of the web of life, of human and nonhuman communities, and that enhancing the dignity and sustainability of any one of them will enhance all the others.

– Fritjof Capra & Pier Luigi Luisi



***A thing is right when it enhances the stability and beauty of total ecosystem. It is wrong when it damages it. The sustainability of a larger system comes first . Everything else must fit itself within that frame.***

Quantum source of space and time - Nature Volume:527, Pages:290–293 , November 2015, doi:10.1038/527290a

## My Closing Message

***The best place to look for a helping hand...***

***...is at the end of your arm***



***Thank You***