VAIBHAV

Vaishwik Bharatiya Vaigyanik Summit

शोध मित्र

Acknowledging the Participation of

Prof. Sudip K Mazumder

in Panel Discussions held during 2nd - 31st Oct'20.

Prof K VijayRaghavan
PSA to GoI

Dr VK Saraswat
Member, Niti Aayog

VAIBHAV

Vaishwik Bharatiya Vaigyanik Summit

GLOBAL SUMMIT OF OVERSEAS AND RESIDENT INDIAN SCIENTISTS AND ACADEMICIANS - OCT 2020

शुद्धा हि बुद्धिः किल कामधेनुः ॥

VAIBHAV Summit Session Report

VERTICAL: **ENERGY**

Horizontal: Sustainable Mobility Technologies

Session: Sustainable Mobility Technologies

V10H2S1

Date: 03 October 2020; Time: 18:00 – 20:00 hrs (IST)

This report is based on actual deliberations in the session, the correctness of the technical content has been validated by the subject matter experts, i.e., moderator of the session and the respective Champion Institute.

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LIST OF ANNEXURES

1. GENERAL DETAILS

1.1 Session panellists

Table 1: List of session panellists

S.No.	Panellist Name	Role	Institute	Country of Residence
1.	S. A. Ilangovan	Moderator	Vikram Sarabhai Space Centre	India
2.	Kaushik Rajashekara	Panellist	University of Houston	United States of America
3.	Arumugam Manthiram	Panellist	University of Texas at Austin	United States of America
4.	N. Kalaiselvi	Panellist	CSIR–Central Electrochemical Research Institue (CECRI)	India
5.	Sudip K Mazumder	Panellist	University of Illinois at Chicago	United States of America
6.	Vijyamohanan K Pillai	Panellist	Indian Institute of Science, Education & Research, Tirupati	India
7.	Venkataraman Thangadurai	Panellist	University of Calgary	Canada
8.	Anji Reddy Munnangi	Panellist	Swansea University	United Kingdom
9.	Perumal Elumalai	Panellist	Pondicherry University	India
10.	Rangan Banerjee	Team Lead	Indian Institute of Technology Bombay	India
11.	N. Lakshminarasimhan	Coordinator	CSIR–Central Electrochemical Research Institue (CECRI)	India
12.	V. Ganesh	Co-coordinator	CSIR–Central Electrochemical Research Institue (CECRI)	India
13.	Ruchi Joshi	Organizing Team	VAIBHAV Summit	India

Total Number of Participants: ***226***

2. SESSION BRIEF

2.1 Sustainable Mobility Technologies (Planner)

The future of sustainable mobility is based on developments in alternative fuels, battery and fuel cell vehicles, hybrid electric vehicles, fueling and charging, grid powered by renewable and conventional energy sources. India's policy initiatives such as the Faster Adoption and Manufacturing of Hybrid & Electric vehicles in India are targeted towards self-reliant (*Aatmanirbhar Bharat*) and sustained e-mobility technologies in the future. As of now, the share of electric, hydrogen and bio-fueled vehicles is relatively low. Innovations in the supply infrastructures, reduction in vehicle costs and development of a manufacturing ecosystem require new ideas, technologies and enabling mechanisms. This panel discussion will try to identify strategies for India's pathways towards aiming the development of sustainable mobility technologies.

2.2 Opening remarks

Dr. N. Lakshminarasimhan, Coordinator, initiated the session by greeting all. He welcomed all the panellists and attendees and thanked all the organizers of VAIBHAV Summit. With a brief introduction about Vaibhav Summit, explained the vertical on Energy and the agenda of the session which is planned on the aspects associated with Sustainable Mobility Technologies, emphasis on reducing the carbon footprints, and usage of renewable energy resources in line with *Aatmanirbhar Bharat* objectives. Role of champion institutes organizing the session along with the session schedule of the energy vertical was touched upon.

Then, he introduced the session Moderator, Dr. S. A. Ilangovan and requested him to initiate the panel discussion. Subsequently, the Moderator provided an overview of the panel and introduced all the panellists of the session briefly and invited the distinguished Scientists to put forth their views on the topic.

2.3 Summary of the session

2.3.1 Technical Summary of presentations made by the panellists

Prof. Kaushik Rajashekara

SUMMARY:

Prof. Rajashekara explained the various advancements in transportation for the future of sustainable mobility and suggested the following best-preferred advancements for Indian conditions:

1. **Preferred for Indian conditions (rather than adapting all the other technologies also)**
   a. **Road** – Electric Vehicle, Electric Buses, Fuel Cell Buses, Connected Vehicles, Fast Chargers
   b. **Air** – Smaller electric/Hybrid Aircraft (10-12 Passengers)**,** VTOL Vehicles- only Air
   c. **Rail** – High-speed trains- 380 Km/Hr (currently in India is 180 Km/Hr max)

2. **Other** technologies being developed
   a. **Road** – Hybrid Vehicle, 48 V Vehicles, Fuel Cell Vehicles, Hybrid Buses, Autonomous Vehicles, V2G and G2V, Wireless Charging
   b. **Air** – More Electric Aircraft like Boeing 787**,** Hybrid Electric Aircrafts**,** Electric Aircrafts (2-4 Passengers)**,** Flying Cars- Land and Air**,** Flying cars with VTOL Capability
   c. **Rail** – High-speed trains- 600 Km/hr, Maglev, Hyperloop

For India, in spite of talent, technology, and advances in Space technology, there has been a lack of focus on the aircraft manufacturing sector. Hence, India could focus on civil aircraft manufacturing, particularly single aisle small aircrafts and urban air mobility vehicles (like VTOL vehicles). Also, focus has to be on high speed trains (about 400 km /hr), that will eliminate the need for bigger aircrafts.

More Aero focused institutions / Research centers have to be started. These institutes could be combined with Electrical & Mechanical Engineering Departments. Also, the Centers of Automotive Research could be converted to Centers for Automotive and Aeronautical Research. The future is more on electric and hybrid electric systems.

Prof. Arunmugam Manthiram

SUMMARY:

Prof. Manthiram focused on the six main control parameters for choosing a battery technology *viz.*, energy, power, cycle life, safety, environment, and cost. Further, he highlighted possible battery technologies, such as lithium-ion batteries, sodium-ion batteries, multivalent-ion batteries, metal-sulfur batteries, metal-air batteries, redox flow batteries, and all-solid-state batteries, and their challenges and prospects.

Projected some of the sustainable battery technology shares along with timeline for the future of India as:

- **Near Term (Now) –** Lithium-ion batteries with $LiFePO_4$ cathode and $Li_4Ti_5O_{12}$ anode (fast charge, temperature tolerance, abundant raw materials in India), and lithium-ion batteries with $LiFePO_4$ cathode and graphite anode (abundant raw materials).
- **Medium-term (~5 years or less)** – Lithium-ion batteries with no cobalt, sodium-ion batteries with no cobalt, lithium-sulfur batteries, redox flow batteries, and aqueous metal-air batteries.
- **Long term (> 5 years)** – Sodium-sulfur battery, all solid-state batteries (lithium- or sodium-based).

The battery area involves four segments for India to be self-reliant: new practically viable materials development, cell manufacturing, cell integration, and necessary infrastructure development. Considering the current situation, India needs to put more efforts on materials development and cell manufacturing to quickly become competitive. In addition, education of students on battery technologies at academic institutions and national laboratories needs to happen quickly to produce a well-trained workforce.

Dr. N. Kalaiselvi

SUMMARY:

Dr. Kalaiselvi explained on the different SUB-VERTICALS of Energy Theme of CSIR in the context of Sustainable Energy that involves Coal Energy (clean coal, gas, and gas hydrate), Petrol Energy (petroleum/ bio-waste to energy), Hydrogen Energy (including hydrogen economy), Energy Conversion and Related Devices, Energy Materials and Energy Storage, and Energy Management and Environment. CSIR–CECRI under the **T**echnologies **A**nd **P**roducts for **S**olar Energy **U**tilization through **N**etworks (TAPSUN) has successfully created the pilot plant for producing the 18650 Li-ion cells of about 100 cells per day. Augmentation of existing facility of 100 cells/day to 1000 cells/day (18650 type Cylindrical Cells) is one of the objectives of the upcoming CSIR Innovation Centre for Next Generation Energy Storage Solutions (ICeNGESS) at CSIR–CECRI, Chennai unit. Also, she mentioned that a 100 MW lithium-ion battery fabrication facility (ICeNGESS) through Mission mode program of CSIR is on-going with a funding support of Rs. 100 Crores to develop indigenous LIBs of both cylindrical and prismatic type.

Further, she discussed about the action plan related to the direct refurbishing of cathode materials from feedstock to provide second life to spent LIBs for extended cycle life applications. This involves and rather makes it mandate that collection booths for spent batteries are to be created to regulate the collection protocols, apart from processing of battery components from the dead/performance degraded Li-ion batteries using indigenous approach to separate out active materials, current collectors, etc., refurbishing of electrodes through customized strategies and fabrication of fresh Li-ion cells with refurbished electrode materials to ensure their second life in the new assembly.

Dr. Kalaiselvi explained the road map for Sustainable Energy / Energy Storage by CSIR-CECRI as:

- **Year 2020–'23 –** Large Scale Electrode Materials for lithium-ion batteries and supercapacitors, Pilot level production and Supply chain creation
- **Year 2023–'25 –** Device optimization, Public-Private Partnership, Scale up and Commercialization
- **Year 2030 –** Renewable EV Integration

Prof. Sudip K Mazumder

SUMMARY:

"*Fast DC Battery Charger for EVs*" was the main focus of Prof. Sudip Mazumder where facts such as tumbling EV battery prices (a drop of price by 19% every time the global supply doubles), reduction in the cost of EV with 200 miles range, and increase in projected sales of EV were presented. Further, Prof. Mazumder stressed that **India needs to catch up fast!** Only 6% of the automobiles sold in India by 2030 will be electric, according to new global EV outlook by research firm BloombergNEF and raised the question of India's EV dilemma as acquisition/ licensing or self-reliance.

After that, the key technical challenges between Electric Vehicle and Gasoline Vehicle were compared using parameters such as emission of gases, mile range, time to recharge/ refuel, cost per cent, etc. Also, levels of EV charging (i.e. AC Levels 1, 2, and 3 and DC Levels 1, 2, and 3) were discussed

and where currently, India's two- and three-wheeler AC Levels 1 and 2 battery charger market is and what India needs (i.e., DC Level 3 or higher fast charger) now for the four-wheeler market. Along with the charger levels, based on published data, current market share of DC (Level 3) Fast Charger (DCFC) in the United States of America, European Union and China was discussed.

Prof. Mazumder stressed upon the importance of public-private partnership and key technologies required for self-reliance in terms of fast DC chargers as power electronics comprising wide-band gap semiconductor devices and modules, high-frequency magnetic materials and passive electronic components, advanced thermal and coordinated protection, and embedded microelectronics and cyber-physical systems.

Prof. Vijayamohanan K Pillai

SUMMARY:

Prof. Vijayamohanan Pillai provided a brief overview on "*CSIR-NMITLI Program on Polymer Electrolyte Membrane Fuel Cells*" and highlighted the joint role of CSIR and RIL in setting up India's first-ever test bed for 3-5 kW PEMFC system. The program was conducted to check the performance under real-life conditions and sustainability of developed products and technologies in terms of raw materials to the final product. The outcome of CSIR's efforts in PEMFC stack technology (such as bipolar plates, porous carbon paper, gasket, stack, membrane, HT-MEA, LT-MEA, and Prototype 1kW) was developed, benchmarked, built prototypes and the corresponding device development with few vendors.

In the end, Prof. Vijayamohanan remarked on the demonstration and validation of (i) LT-PEMFC System for Automotive Application (2016-18) with CSIR–NCL, CSIR–CECRI and KPIT (industrial partner) and (ii) 5 kW HT PEMFC-based Combined Cooling and Power System (2016-18) by CSIR–NCL, CSIR–CECRI, CSIR–NPL and Thermax (industrial partner) under NMITLI program. In his opinion, Mobility Mission requires urgent priority for not only manufacturing Li-ion batteries and developing charging platform but in Li-battery recycling capability also as India can become an international hub for this. Demonstration of Redox flow cells for large level energy storage and carbon-neutral hydrogen generation/storage technologies need to be targeted since strong expertise is available in this area with competent and well-reputed NRI researchers from US, EU and elsewhere.

Prof. Venkataraman Thangadurai

SUMMARY:

Prof. Thangadurai highlighted that India's Energy Deficiency is at 43% in terms of energy consumption *viz-a-viz* energy production in spite of being the third-largest energy consumer in the world after China and the USA in 2018. The current challenges with future solutions of rechargeable batteries, including current lithium ion and beyond lithium battery chemistry, was shared. Recent status of global EV market was presented based on the following facts:

- The current EV battery cells have a specific energy of 200-250 $Wh.kg^{-1}$, but an aggressive goal to reach 500 $Wh.kg^{-1}$ with a >10-year life and total mileage of ~150, 000 miles (US Battery 500 Consumption). EV battery packs of 125 US$ $kW.h^{-1}$ to be attained in 2022.
- Japan Consortium for Lithium-ion Battery Technology and Evaluation Center (Libtec) with Toyota Motor and Panasonic hopes to develop a solid-state battery that doubles the range of electric vehicles to 800 km (497 miles) by 2030 over the current 400 km (249 miles). For the time being, it is targeting a more modest range of 550 km (342 miles) by 2025.

Prof. Thangadurai has suggested that India should consider developing specific battery performance goals for targeted application and also develop network opportunity in energy storage in India in the near term. His further suggestion also focused on development of educational program that involves NRI around the world and India. He also advised to explore funding opportunity existing in various countries for collaborations and to enhance students' experience. In another area of clean energy, Prof. Thangadurai also drew the attention on the importance of solid oxide fuel cells that can produce clean electricity using a wide range of fuels including hydrogen, methanol, ethanol, biogas, coal and, applications in transport and stationary sectors.

Dr. Anji Reddy Munnangi

SUMMARY:

Dr. Anji Reddy covered the aspects of energy storage requirements for different battery modules. The energy storage capability of battery modules are not unique, based on adapted chemistries and technologies. Also, the nature of energy storage demanded by different applications is diverse and distinct. Hence, it is not always possible and safe to be dependent on single battery system. Storage battery characteristics required for different battery application modules are listed in the table below:

Table 2: Battery characteristics required for different applications.

	Electric Cars	Laptops and Mobiles	Solar Plants
Specific Energy	300 Wh/kg (300 miles)	150 - 300 Wh/kg	50 - 100 Wh/kg
Cost	100 – 150 $/kWh	No major issue	As low as possible
Battery temperature	-20C - +60C	+5C - +40C	-20C - +50C
Calendar life	10 years	2-3 years	15-20 years
Cycle life	3,000 – 7,000 cycles	500 – 1,000 cycles	10,000 – 15,000 cycles
Charge/ discharge rate	1 – 50 C	0.5 – 2 C	0.1 – 0.5 C

The need and possible electrochemical energy storage systems beyond Lithium-Ion Batteries such as Lithium-Air, Lithium-Sulphur, Lithium-Metal, Sodium ion, Fluoride ion, Chloride ion, Potassium ion, Magnesium ion, Aluminum, Zinc-Air with a road map up to 2040 were also proposed.

Prof. Perumal Elumalai

SUMMARY:

Prof. Elumalai discussed the component of EV as electric motors, large battery, AC/ DC converter, electronics, regenerative braking system, EV fluids for cooling, etc. Reported the status of e-mobility in India which is around 1% of the total vehicle sales against the projected 50% vehicle by 2030. Features of Sustainable Fuel Cell Vehicles (FCV) such as superior efficiency, zero-emission, generation of its own energy, cost-effective for long-range transportation, and use of existing re-fueling station, etc. were discussed. Importance of hybrid devices was also highlighted. The use of hybrid device along with battery for EV will prolong the life of the battery as the momentary high power during acceleration and up-hill driving can be drawn from the hybrid device.

Prof. Elumalai also proposed the job opportunities in EV market and a few recommendations on the need for development of indigenous battery technologies with existing raw materials, international collaborations, start-ups in energy, and need to upgrade existing curriculum with importance for energy and environment.

A brief of energy research at Pondicherry University such as imparting training to human resources at Masters and Doctoral levels, substantial contribution on Lithium-ion battery and hybrid energy storage devices and, cathodes, anodes and solid electrolytes was also presented.

DISCUSSIONS & SUMMING UP:

There was a deliberation by the panellists on what India should target to envisage self-reliance in mobility technologies. The panel discussion was held for one hour based on the questions posted by the participants. Then, the Moderator, Dr. S. A. Ilangovan, summarized the discussion points. The session was concluded with a vote of thanks by Dr. V. Ganesh, Co-coordinator.

2.3.2 Extracts of Q&A

- Q 1: Is hybrid electric gas vehicle required in India?
- Response: Prof. Sudip K Mazumder was of a view that in Indian conditions, anything is better than gas; as a result, hybrid is welcomed provided the infrastructure for the same is best. India can start with EV, which will reduce pollution or can go with reusable battery, refurbishment. However, Prof. Kaushik Rajashekara had a contrary view that hybrid electric gas vehicle runs at a speed of approx. 360 km/h, which is not required in India as of now and electric vehicles needs to be focused.

- Q 2: What are the main challenges in electric vehicle charging?
- Response: (Prof. Kaushik Rajashekara): For Indian conditions, collaboration is a major challenge. China is developing fast chargers with Japan. India need to group with other companies and develop high power charger and small chargers. India is capable of building fast chargers, cost effectiveness is fundamental.

2.3.3 Challenges

- Challenges for India in manufacturing EV involve:
  - Material development (Cost, performance, durability, charging time)
  - Cell manufacturing (Cost, performance, reliability, charging time)
  - Battery integration and packaging (Cost, reliability, safety, maintenance)
  - Infrastructure for electric vehicles (Charging stations, battery replacement)
- Major challenge for slow growth of EV in India – Technology, Policy, Infrastructure, Investment. And key challenge as Public-Private Partnership
- The biggest global challenge – Climate change
- Safety, high-Cost, short cycle-life of rechargeable battery
- EV dream in India facing deferment because of challenges such as change in the fueling process, insufficient charging infrastructure, higher initial cost, limited travel distance per recharge, supply-side constraint, income demographics.
- Main obstacles in Sustainable Fuel Cell Vehicles (FCV) are cost of the vehicle, distribution infrastructure and hydrogen production.

2.3.4 Key take away and outcomes

Technical (if any)

- For India, Sodium–Sulfur batteries are preferred as sodium is available in plenty and sulfur can be produced easily. This can be a dream project for India.
- Focus on on-board fast charges in electric two- and three-wheelers
- Key Technologies needed for DCFC (Assuming a path of self-reliance) :
  - Wide bandgap semiconductor devices and modules
  - High-frequency magnetic materials and passive electronic components
  - Advanced thermal and coordinated protection
  - Embedded microelectronics and CPS
- For rechargeable battery, future can be :
  - Safety - Nonflammable solid-state electrolytes
  - High-Cost - Use of inexpensive materials like Fe, Ni, Mn
  - High Performance - High-capacity electrodes like Li, Si, S, O_2
- Developing indigenous battery technologies using raw materials available in India and encouraging basic research to technology development.
- Creation of spent battery collection booths, charge stations, solar powered charge stations, and cell manufacturing facilities using GOCO (Government Owned Company Operated) model
- Integration of fuel cell technologies

- Solving issues related to technologies of National Mobility Mission by using the expertise available with NRI researchers
- Founding universities and/or departments focusing on Aerospace & Aeronautics and Automobile & Aeronautics
- Identifying technologies and strategic collaboration based on India's need or ambitions
- New mechanisms of collaboration based on select technologies and strengthening the existing collaborative schemes
- Academia–Industry partnership for successful technologies

Policy related (if any)

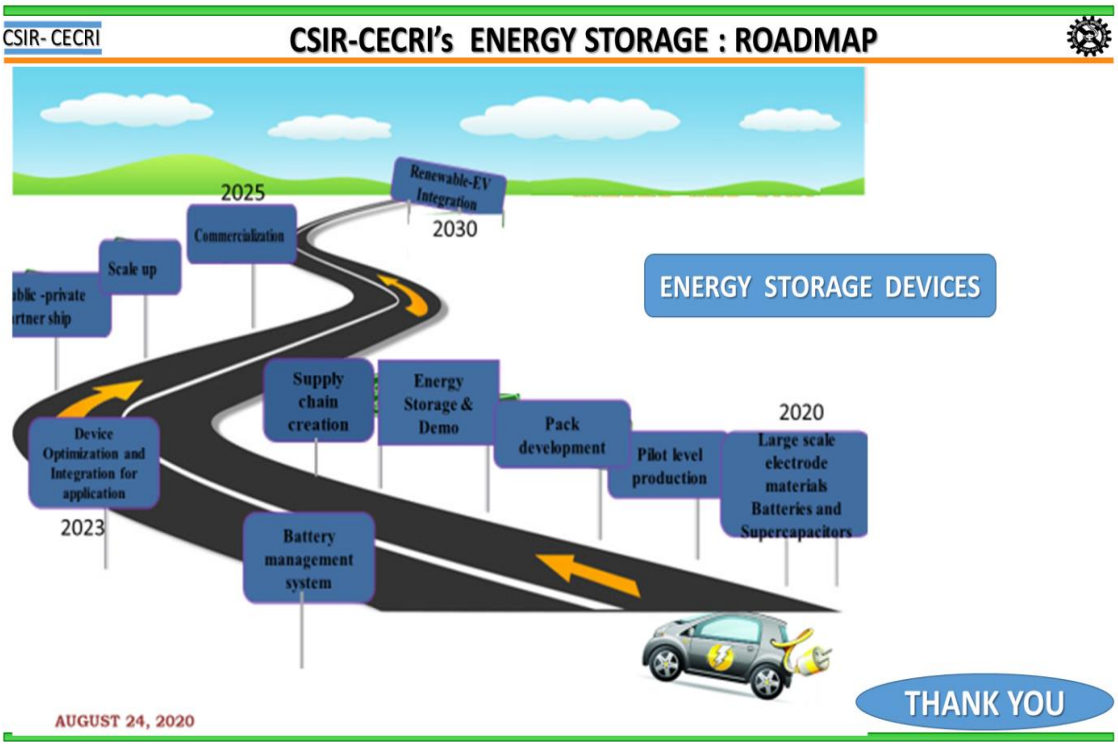
- More funding for international collaborative schemes
- Creating exchange programmes for students and researchers to visit abroad and get trained in advanced technologies
- Creation of battery cell manufacturing facilities using GOCO (Government Owned Company Operated) model

Others (if any)

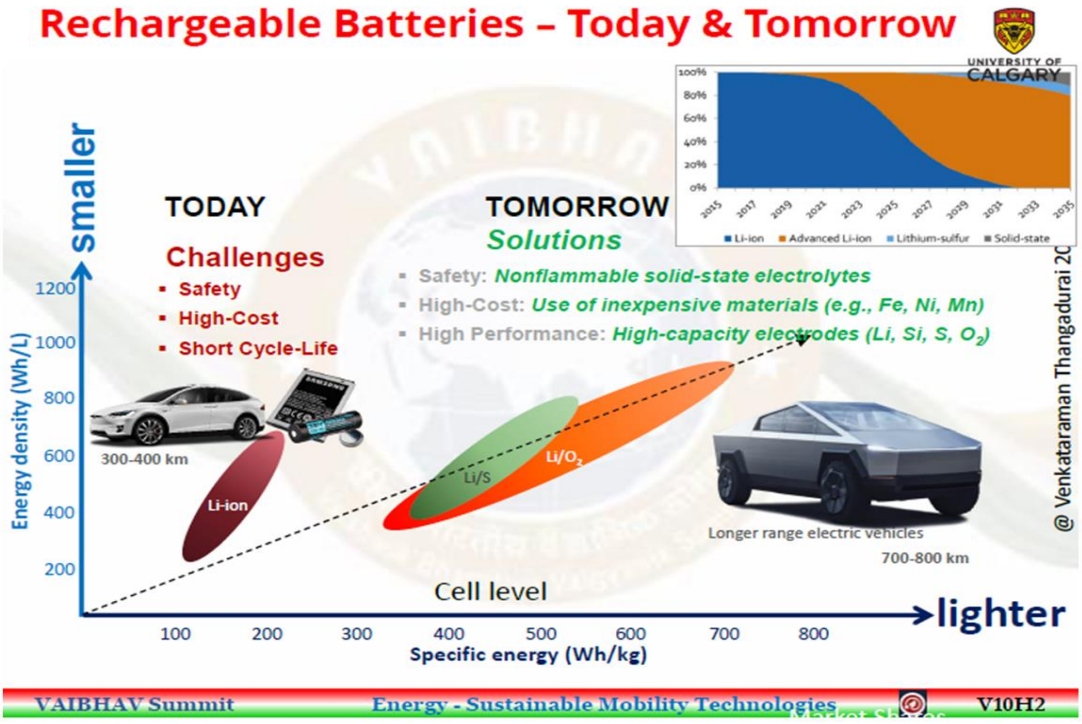
- Smaller electric/ Hybrid Aircrafts (10-12 Passengers) are preferable in India.
- Fast trains are preferred (with speed of approx. 400-600 Km/Hr) so that preference is given to railways over bigger aircrafts.
- Zero GHG emission technologies are necessity to tackle global challenge like climate change.
- Following Job opportunity can be generated in EV market
  - Batteries – Charging vs. changing
  - Charge stations – Conventional and Non-conventional, Home Charging Station Setup Service, Portable Charging Station, Solar charging station installation center
  - New design (car for 1 or 2 persons)
  - Electric car rental service, washing, service garage, spaying workshop
  - EV charging Station Management
  - Electrical workshop for electrical vehicle
  - Mobile Electric Cars Repair Services
  - Online shop for electric spare parts
- Training human resource in energy sectors
- Upgrading curriculum with more focus on energy and environment

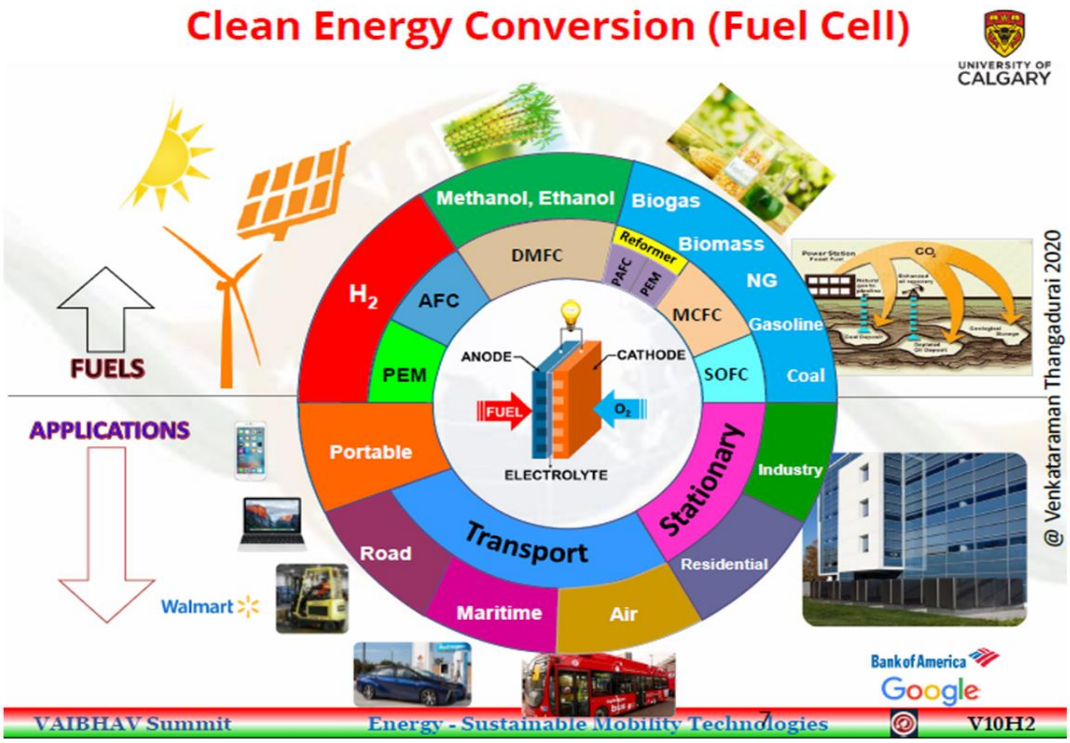
Annexures

Annexure I: Presentation of Dr. N. Kalaiselvi, CSIR–CECRI, India



Annexure II: Presentation of Prof. V. Thangadurai, University of Calgary, Canada



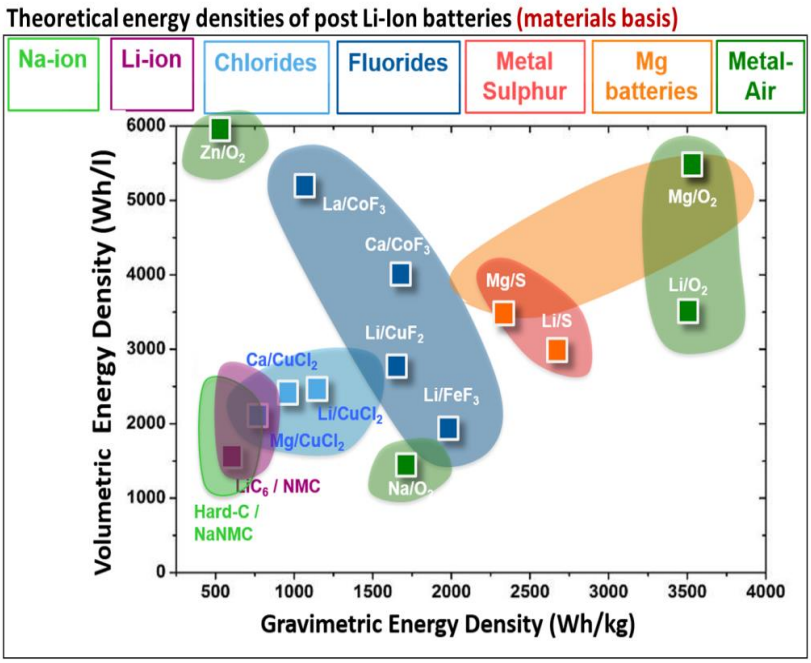


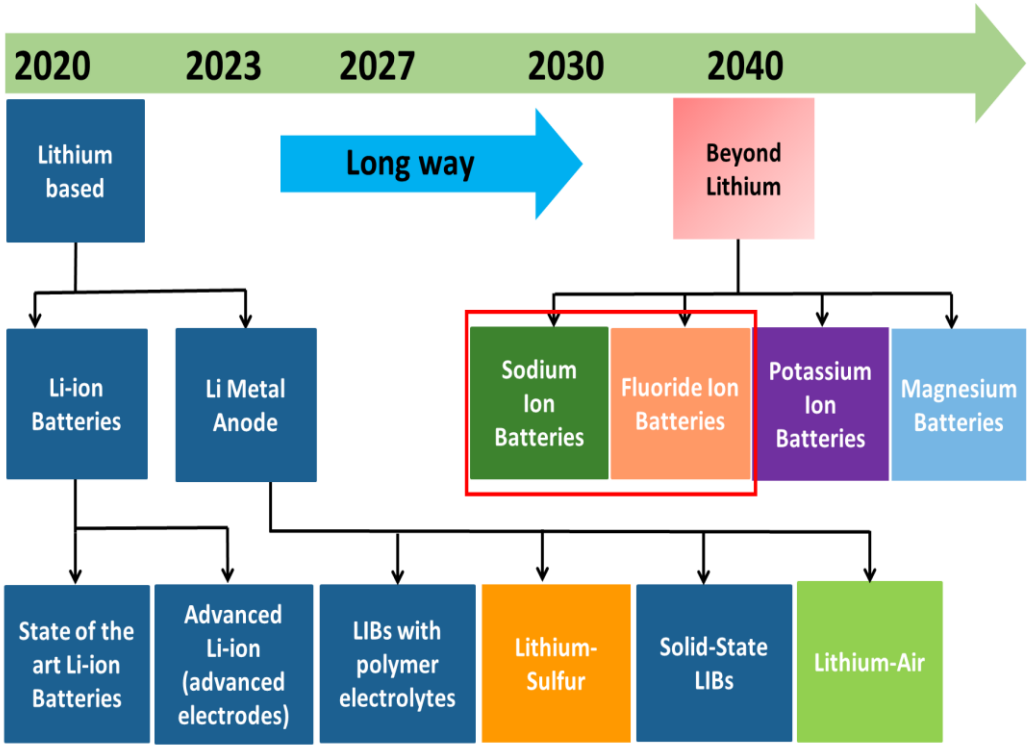
Annexure III: Presentation of Dr. Anji Reddy Munnangi, Swansea University, United Kingdom

Electrochemical energy storage systems beyond LIBs

Swansea University Prifysgol Abertawe

- Lithium-Ion Batteries
- Lithium-Air Batteries
- Lihium-Sulphur Batteries
- Lithium-Metal Fluorides
- Sodium-Ion Batteries
- Fluoride-Ion Batteries
- Chloride-Ion Batteries
- Potasium-Ion Batteries
- Magnesium Batteries
- Aluminum Batteries
- Zinc-Air Batteries





Annexure IV: Presentation of Prof. P. Elumalai, Pondicherry University, India

Job Opportunities in EV Market

- ✓ Batteries – Charging Vs. Changing
- ✓ Charge stations - Conventional & Non-conventional
- ✓ New designs (car for 1 or 2 persons)
- ➢ Electric car servicing garage. ...
- ➢ Electric car spaying workshop. ...
- ➢ EV Charging Station Management. ...
- ➢ Electrical work shop for electrical vehicle. ...
- ➢ Home Charging Station Setup Service. ...
- ➢ Charging Station Setup Training Service. ...
- ➢ Electric Car Rental Service.
- ➢ Electric Car Washing
- ➢ Mobile Electric Cars Repair Services
- ➢ Portable Charging Station
- ➢ Solar charging station installation centre
- ➢ Online shop for electric spare parts

Recommendations

- Develop indigenous Battery Technologies using Raw materials available in India
- Encourage basic research to Technology development
- Facilitate collaboration between the Institutions and with aboard intuitions
- Encourage start-ups in energy storage sectors
- Trained human powers in energy sectors
- Upgrade curriculum with energy and environment

Energy Research @ Pondicherry University

PONDICHERRY UNIVERSITY

Department of Green Energy Technology

- Imparting trained human resources at Masters and Doctoral levels
- Substantial contributions on Lithium-ion battery and hybrid energy storage devices
- Cathodes, Anodes and Solid electrolyes

Annexure V: About the Panellists

Kaushik Rajashekara

Distinguished Professor Of Engineering
Electrical and Computer Engineering Department
Cullen College of Engineering
University of Houston, Texas, USA

Research Interests:

- *Power/energy Conversion, Transportation Electrification, Renewable Energy, Subsea Electrification, and Microgrid Systems*

Key Achievements:

- *More than 250 papers in international journals and conferences*
- *35 U.S. and 15 foreign patents and has written one book.*

Awards/Honors:

- *Member of the US National Academy of Engineering in 2012*
- *Fellow of the National Academy of Inventors in 2015*
- *Fellow of Indian National Academy of Engineering in 2013*
- *Distinguished Alumnus of Indian Institute of Science*

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Arumugam Manthiram

Cockrell Family Regents Chair in Engineering
Director, Texas Materials Institute
Director, Materials Science and Engineering Program
University of Texas at Austin, USA

- **Areas of expertise, research interests**
  Energy conversion and storage: Batteries and fuel cells
  Development of new materials and new battery chemistries
  Materials chemistry: synthesis, characterization, properties

- **Key achievements**
  810 journal articles with 69,000 citations and an h-index of 130
  Web of Science Highly Cited Researcher in 2017, 2018, 2019

  Provided training to 265 students and postdoctoral fellows
  Graduated 62 Ph.D. students and 26 M.S. students
  51 students and postdocs are faculty around the world

  Discovered polyanion cathodes for lithium-ion batteries in 1980s
  Developed cobalt-free layered cathodes for lithium-ion batteries
  Co-founded three start-up companies in the battery area

  Delivered **2019 Nobel Prize Lecture** on behalf of **Prof. Goodenough**

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N. Kalaiselvi

Director
CSIR–Central Electrochemical Research Institute (CECRI)
Karaikudi, Tamil Nadu
India

Research Interests:

- ❑ Electrochemical power systems
- ❑ Lithium and beyond lithium batteries
- ❑ Supercapacitors
- ❑ Waste-to-wealth driven electrodes and electrolytes for energy storage and electrocatalytic applications

Achievements:

- ➢ Raman Research Fellowship, 2009
- ➢ INSA Visiting fellowship, 1999
- ➢ Brain Pool Fellowship of Korea, 2003
- ➢ Marqui's Who is Who in Science and Engineering in Asia, 2006
- ➢ Top 100 Scientists of the year, 2007
- ➢ International Scientist of the year, 2007

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Sudip K Mazumder

Professor, Univ. Scholar, Distinguished Researcher,
Univ. of Illinois
President, NextWatt LLC
Director, Laboratory for Energy and Switching-Electronics Systems

Research Interests:

- ❑ Switching-sequence and switching-transition based control of power-electronics systems and networks
- ❑ Power electronics for renewable energy, micro/smart grids, energy storage
- ❑ Wide-bandgap (GaN/SiC) power electronics
- ❑ Optically-triggered power semiconductor devices

Key Achievements:

- ❖ *Fellow, IEEE*
- ❖ *Distinguished Lecturer ('16-'19), IEEE Power Electronics Society*
- ❖ *Editor-in-Chief at Large, IEEE Transactions on Power Electronics*

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Vijayamohanan K Pillai

Professor
Chair, Department of Chemistry
Dean, R&D
Indian Institute of Science, Education & Research
Tirupati, India.

Research Interests:

- ❑ Energy conversion and storage systems
- ❑ Redox flow batteries and supercapacitors
- ❑ Fuel cells
- ❑ 2D layered materials for energy conversion
- ❑ Modified electrodes for sensing and catalytic applications

Key Achievements:

- ❖ JC Bose Fellow
- ❖ PEM Fuel cell technology developed with Reliance Industries Ltd.
- ❖ MRSI-ICSC Super Concuctivity and Materials Science Annual Prize, 2016
- ❖ MRSI Medal, 1996

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Venkataraman Thangadurai

Professor
Associate Head, Department of Chemistry
Associate Director, Calgary Advanced Energy Storage and Conversion Research (CAESR)
University of Calgary
Canada

- ***Research Interests***

Novel materials for next-generation clean and sustainable electrical energy conversion and storage devices, including solid oxide fuel cells and all-solid-state batteries, as well as gas sensors.

- ***Key Achievements***

Fellow | Royal Society of Chemistry (RSC), UK | IAAM Sweden | FECS (US)
Parex Innovation Fellows, University of Calgary, Calgary, Canada.
Keith Laidler Award, Canadian Society of Chemistry (CSC), Canada
Outstanding Invention of 2013, University of Maryland, USA
Alexander von Humboldt (AvH), University of Kiel, Germany.

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Anji Reddy Munnangi

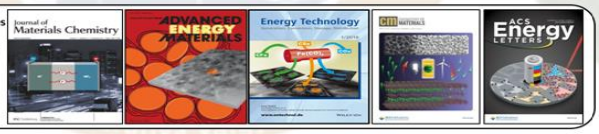
Senior Lecturer in Energy in Storage
College of Engineering
Swansea University
UK

Research Interests:

- Electrochemical Energy Storage and Conversion Systems, Non-aqueous Batteries, Solid-State Batteries, Solid Electrolytes, Interfaces and Interphases, Inorganic Polymers, Transition Metal Intercalation.
- New electrode and electrolyte materials for Fluoride-Ion, Lithium-Ion, Sodium-Ion, Lithium-Sulphur and Solid-State Batteries
- Design, synthesis, characterization and structure-property correlation of materials for various battery systems

Key Achievements:

53 journal articles
2 US patents
3 book chapters
5 cover pages
35 invited talks
22 h-index
1800 citations



Articles features in cover pages

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Perumal Elumalai

Professor
Head, Department of Green Energy Technology
Pondicherry University
Puducherry, India

Research Interests:

- Li-ion, Na-ion, Metal-Air and Metal-Sulphur batteries, Supercapacitors and Fuel cell catalysis

Key Achievements:

- Published more than 80 peer-review papers with h-index 26
- Holds 6 patents on Battery and Hybrid device
- Published a book on Lithium-ion battery for e-vehicles
- Made substantial contributions on anode materials and hybrid supercapacitors
- Cover articles in ***NJC*** and ***ChemElectroChem.***

- *Awards/Honors:*
  - JSPS Fellow
  - Young Ceramist Award by Japan Ceramic Society
  - Member of DST-MECSP Energy Storage Consortium
  - Received Best Teacher Award from PU consecutive 5 times

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