सीएचटी
ISO 9001:2015

उच्च प्रौद्योगिकी केन्द्र
(पेट्रोलियम एवं प्राकृतिक गैस मंत्रालय), भारत सरकार
Centre for High Technology
(Ministry of Petroleum & Natural Gas), Govt. of India

सीएचटी/एसएसी-87/ 2143
CHT/SAC-87/

26 दिसंबर 2019
26th December 2019

सेवा में/ To,

पेट्रोलियम और प्राकृतिक गैस मंत्रालय की हाइड्रोकार्बन पर वैज्ञानिक सलाहकार समिति के अध्यक्ष, सदस्यगण, स्थायी व विशेष आमंत्रित अतिथिगण।
(संलग्न सूची के अनुसार)
Chairman, Members, Permanent & Special Invitees of Scientific Advisory Committee (SAC) on Hydrocarbons of MoP&NG
(as per list attached)

विषय: पेट्रोलियम और प्राकृतिक गैस मंत्रालय की हाइड्रोकार्बन पर वैज्ञानिक सलाहकार समिति (SAC) की 87वीं बैठक का कार्यवृत्त

Sub: Minutes of 87th Meeting of the Scientific Advisory Committee (SAC) on Hydrocarbons of Ministry of Petroleum & Natural Gas

प्रिय महोदय/महोदया / Dear Sir/Madam,

आपकी सूचना एवं आवश्यक कार्यवाही हेतु दिनांक 13 दिसंबर, 2019 नई दिल्ली में सम्पन्न पेट्रोलियम और प्राकृतिक गैस मंत्रालय की हाइड्रोकार्बन पर वैज्ञानिक सलाहकार समिति की 87वीं बैठक के कार्यवृत्त की प्रतिलिपि संलग्न की जा रही है।

Enclosed please find a copy of the Minutes of 87th Meeting of the SAC on Hydrocarbons of Ministry of Petroleum & Natural Gas held on 13th December, 2019 in New Delhi for your kind information and necessary action.

सादर,
With kind regards,

भवदीय,
Yours sincerely,

(के.के.जैन)
कार्यकारी निदेशक
(K.K.Jain)
Executive Director

Copy for information to:

- **Secretary, P&NG**
- **Chairman IOCL**
- **CMD BPCL / HPCL / EIL**
- **MD MRPL / CPCL / NRL**

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Scientific Advisory Committee (SAC) on Hydrocarbons

1.	**Dr. Anil Kakodkar** Bhabha Atomic Research Centre, 7th Floor, Central Complex, Trombay, Mumbai – 400 085	Chairman
2.	**Dr. R. Kumar** Professor Emeritus, Department of Chemical Engineering, Indian Institute of Science, Bangalore, Bengaluru – 560 012	Member
3.	**Prof. J.B. Joshi** Professor Emeritus, Homi Bhabha National Institute, Anushakti Nagar, Mumbai – 400 094	Member
4.	**Dr. M.O. Garg** Head-Refining & Petchem R&D, RTG, Reliance R&D Centre, Reliance Corporate Park, Bldg.No. TC 30B, 2nd Floor, 'B' Wing, Thane-Belapur Road, Ghansoli, Mumbai – 400 701	Member
5.	**Prof. A.B. Pandit** Vice Chancellor, Institute of Chemical Technology, Nathalal Parekh Marg, Matunga (East), Mumbai – 400 019	Member
6.	**Dr. Shashi Kant** 58-Sundaramnagar Co-operative Hsg. Society, La Attic Villa, Near Vasna Jakat Naka, Vasna Road, Vadodara 390 007	Member
7.	**Prof. Shankar Narasimhan** Indian Institute of Technology Madras, Sardar Patel Road, Adyar, Chennai – 600 036	Member
8.	**Dr. R.K. Malhotra** Director General, Federation of Indian Petroleum Industry (FIPI), PHD House, 4/2, Sri Institutional Area, August Kranti Marg, New Delhi – 110 016	Member
9.	**Shri S.M. Vaidya** Director (Refineries) Indian Oil Corporation Ltd., SCOPE Complex, Core-2, Lodhi Road, New Delhi – 110 003	Member

10.	**Shri R. Ramachandran** Director (Refineries), Bharat Petroleum Corporation Ltd., Bharat Bhawan, 4&6 Currimbhoy Road, Ballard Estate, Mumbai – 400 001	Member
11.	**Shri V.S. Shenoy** Director (Refineries), Hindustan Petroleum Corporation Ltd., 17, Jamshedji Tata Road, Mumbai – 400 020	Member
12.	**Dr. S.S.V. Ramakumar** Director (R&D), Indian Oil Corporation Ltd., R&D Centre, Sector-13, Faridabad – 121 007	Member
13.	**Shri L.K. Vijh** Director (Technical), Engineers India Limited, EI Bhawan, 1, Bhikaiji Cama Place, New Delhi – 110 066	Member
14.	**Dr. Sanjeev Katti** Director General, ONGC Energy Centre, 8th Floor, Core-4, SCOPE Minar, Laxmi Nagar, New Delhi – 110 092	Member
15.	**Shri Manoj Jain** Director (BD), GAIL (India) Ltd., 16, Bhikaiji Cama Place, New Delhi - 110 066	Member
16.	**Shri Niranjan Kumar Singh** Secretary, Oil Industry Development Board, OIDB Bhawan, Sector – 73, NOIDA – 201 301	Member
17.	**Shri R.K. Ahuja** Executive Director, Petroleum Conservation Research Association, Sanrakshan Bhawan, 10, Bhikaiji Cama Place, New Delhi – 110 066	Member
18.	**Smt. Rashmi H. Urdhwareshe** Director, Automotive Research Association of India, S.No. 102, Vetal Hill, Off. Paud Road, Kothrud, Pune – 411 038	Member

19.	**Dr. Anjan Ray** Director, CSIR – Indian Institute of Petroleum, P.O.IIP, Mohkampur, Dehradun – 248 005	Member
20.	**Dr. V.P. Joy** Director General, Director General of Hydrocarbons, OIDB Bhawan, Tower A, Sector 73, NOIDA – 201 301	Member
21.	**Shri Sunil Kumar** Joint Secretary (Refineries), Ministry of Petroleum & Natural Gas, Shastri Bhawan, New Delhi – 110 001	Permanent Invitee
22.	**Shri Sanjay Bhargava** Executive Director (R&D), Bharat Petroleum Corporation Ltd., Corporate R&D Centre, Plot No. 2 A, Udyog Kendra, Surajpur Industrial Area, Greater NOIDA – 201 306	Permanent Invitee
23.	**Shri S. Bharathan** Chief General Manager (R&D), HP Green R&D Centre, KIADB Industrial Area, Tarabahalli, Devanagundi, Hoskote, Bengaluru – 560 067	Permanent Invitee
24.	**Shri R. Srikanthan** Director (Technical), Chennai Petroleum Corporation Limited, Manali, Chennai – 600 068	Permanent Invitee
25.	**Ms. Vartika Shukla** Executive Director (T), R&D Centre, Engineers India Limited, Sector-16, Gurgaon – 122 001	Permanent Invitee
26.	**Shri D.V. Shastry** Executive Director (Training, R&D and Start-Up), GAIL Training Institute, Plot 24, Sector 16 A, NOIDA – 201 301	Permanent Invitee

26th December, 2019

Minutes of 87th Meeting of Scientific Advisory Committee (SAC) on Hydrocarbons of MoP&NG

1. The 87th Meeting of SAC was held on 13th Dec'19 at SCOPE Complex, Lodhi Road, New Delhi. The meeting was chaired by Dr Anil Kakodkar, Chairman, SAC.

   The list of participants is enclosed as **Annexure-I**.

2. Shri K.K. Jain, ED (CHT) welcomed the Chairman, JS (R), other esteemed members of the SAC and special invitees.

3. ED CHT gave the overview of the agenda as under;

   a. Discussion on RFS under 'Pradhan Mantri JI-VAN Yojana' (MOM separately issued)
   b. New R&D proposal of IOC R&D on hydrogen Fuel Cell bus for funding under HCF
   c. Review of on-going R&D projects: 11 Nos.
   d. Closure of completed R&D projects: 2 Nos.
   e. HCF Projects: 3 Ongoing

4. **Development & Demonstration of Fuel Cell buses based on Hydrogen produced from Multiple Pathways: IOCL/ KPIT / IISc**

   Hydrogen as fuel through application of fuel cell is fast emerging as the most efficient path for sustainable mobility solutions. The hydrogen as a carrier of energy has potential to address the issues of variability associated with solar power.

   Need of the program:

   1. The program is the first such programme in the country to provide end to end solution for producing hydrogen and using it in fuel cell based vehicles based on commercially viable indigenous stack technology.
   2. **Ensuring Energy Security:** Hydrogen produced through multiple pathways can address our energy and economic security. India, which has already missed the opportunity in the battery technology arena, can become global leader in hydrogen based fuel cell technology.
   3. **Alters geo-politics and geo-economics:** Hydrogen will lead to a reduction in import of crude oil and change our energy relationship with oil exporters in West Asia and global oil geopolitics as the fall in demand in oil would be significant, a scenario not envisaged till 2040's by oil companies globally. High oil prices impacts growth. Every dollar per barrel change in crude oil prices impacts the import bill by Rs 823 crores. India, by promoting hydrogen energy will gain tremendous economic benefit by

reducing crude imports and domestic companies will benefit from the hydrogen ecosystem.

4. **Overcoming dependence on China:** The transportation sector will gain tremendously from hydrogen as it will reduce oil demand, enable decarbonisation of our transportation systems and reduce pollution. Hydrogen also provides an alternative to dependence on Li-ion batteries (dominated by China) for Electric Vehicles.
5. **Rural development and agriculture**: Hydrogen production from Biomass will boost the agricultural ecosystem, thus increasing rural incomes.
6. **Addressing the Challenges with Batteries** – Range anxiety and high charging time associated with battery technology can be overcome by hydrogen based fuel cell technology, thereby making electric drive trains suitable for long distance applications.
7. **Reduce Environmental Emissions**: Hydrogen based fuel cell technology will be crucial in reducing CO_2, NOx & PM emissions vis-a-vis other conventional fuels / powertrains; thereby addressing the environmental issues grappling most Indian cities.

Broad Objectives

- A comprehensive pilot study to develop and demonstrate clean transportation solution through indigenized hydrogen fuel cell stack technology based on various indigenously designed hydrogen production pathways including bio-pathways / indigenously available resources reducing the cost of hydrogen.
- Understanding the performance and durability of fuel cell buses under Indian operating conditions.
- Establishing the know-how of developing, scaled up hydrogen production units and their operation for refueling the fuel cell buses.
- Developing an understanding of the complexities of hydrogen refueling station especially in terms of addressing the requirements of heavy duty fleet.
- Long term operation of the buses (for 1 year) for establishing the efficacy, efficiency and sustainability of the business model.
- Achieve the Total Cost of Ownership of fuel cell buses at par with Diesel buses.

Salient Features:

- 1st Make in India initiative in the country involving fuel supplier (IOCL), Technology developer (KPIT) and Academia (IISc.) targeting commercialization of heavy duty buses operating on hydrogen & fuel cells.
- 40 Kg/hr Hydrogen production envisaged through 4 sustainable pathways (10 kg/hr each) namely;
    a. Biomass Gasification
    b. Solar Electrolysis
    c. Biomethanation to hydrogen
    d. Natural Gas reforming
- Development of indigenous fuel cell stack technology 8- - 100 kW) – at globally competitive prices
- Cutting edge R&D on novel catalysts, gas diffusion layers and bi-polar plates with objective of using refinery hydrogen (impure but cheap) directly in the fuel cell stack, thereby lowering the operating cost of the buses.
- Comprehensive development and demonstration of 15 Hydrogen Fuel Cell based buses in India aimed towards achieving the commercial viability.
- On-site storage of hydrogen at 550 bars
- Hydrogen dispensing in the bus at 350 bar in Type III tanks
- Wide scale trials of the fuel cell buses for benchmarking performance & durability to reach commercialization and enhance public perception.
- A complete end to end program for establishing the Total Cost of Ownership (TCO) vis-a-vis other conventional power-trains and battery buses.

The program would enable the Oil & Gas companies to develop hydrogen retailing as a new core area (hydrogen as a new dimension for emerging e-mobility paradigm) with simultaneous reduction of carbon footprints. Upon successful development and validation of the technology, 1000 buses will be developed to operate in Delhi NCR region. IOCL, in collaboration with city gas distribution companies will expand the hydrogen infrastructure in the region to meet the refueling requirements at an affordable cost.

Project duration: 3 years which includes the R&D activities, setting up of infrastructure, development of Buses and undertaking the trials on 15 buses.

Budget:

The overall budget of the program is expected to ~ Rs. 296.66 crore out of which Rs.138.32 crore is being sought for funding i.e. 46.63% of the total budget.

Project Cost Breakup:

S. No.	Item	Amount (Rs. in crore)			
		Total cost	1st year	2nd year	3rd year
1.	Equipment*	176.10	88.55	58.28	29.26
2.	Manpower	84.40	26.32	28.19	29.89
3.	Consumables	33.50	17.08	6.89	9.54
4.	Contingencies/ Other Costs (IT tools required by IISc)	1.40	0.80	0.60	0.00
5.	Travel	1.26	0.40	0.42	0.44
6.	Consultancy	-	-	-	-
7.	Institutional Overhead charges	-	-	-	-
Total		**296.66**	**133.15**	**94.39**	**69.13**

Proposed Contribution from HCF:

S.No.	Item	Amount (Rs. in crores)			
		Total cost	1st year	2nd year	3rd year
1.	Equipment*	112.62	44.39	46.62	21.60
2.	Manpower	13.49	4.71	5.01	3.78
3.	Consumables	9.55	4.31	2.79	2.45
4.	Contingencies/ Other Costs (IT tools required by IISc)	1.40	0.80	0.60	0.00
5.	Travel	1.26	0.40	0.42	0.44
6.	Consultancy	-	-	-	-
7.	Institutional Overhead charges	-	-	-	-
Total		**138.32**	**54.61**	**55.44**	**28.27**

** Excluding Land cost for setting up the pilot plants, hydrogen dispensing units at IndianOil R&D*

CHT indicated that one of the pathways proposed to produce Solar H_2 through PEM, SOEC and Alkaline electrolysers are already approved in a separate project of IOC R&D at a cost of Rs 65 crore with contribution of Rs 25 crore from HCF. The same may be integrated with current proposal. IOC clarified that the fund requirement has been estimated considering the same.

SAC recommended the project in principle for funding from HCF.

OIDB indicated that the fund available in HCF is not adequate. After deliberation SAC recommended HCF contribution of first two years and the contribution for the third year may be reviewed based on the availability of fund in HCF and progress in the project.

5. Review of on-going R&D projects

5.1 Coal to Liquid (CTL) Technology: EIL/BPCL/Thermax

Objective: To develop technology for gasification of high ash Indian coal

MOU Date	Start Date	End Date	Extension
Mar 2009	July 2009	July 2013	June 2019

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20			2020-21
			BE	RBE	Expenditure	BE
CHT	#1483.95	*1220.95	95.00	180.00	-	60.00
EIL	924.00	799.85	-	-	-	-
BPCL	560.00	421.10	-	-	-	-
Thermax	332.00	301.50	-	-	-	-
Total	3300.00	2743.40	95.00	180.00	-	60.00

(EIL: Rs 923.95 lakh; BPCL: Rs 560 lakh) *(EIL: Rs 799.85 lakh; BPCL: Rs 421.1 lakh)

Status:

- CHT informed that the Expert Group under the chairmanship of Prof. R Kumar reviewed the project on 25th Oct'19.
- Probable causes of bed agglomeration & lower carbon conversion, choice of fluidization media, were discussed. The Expert group observed that Carbon conversion is still very low (40-50%) and advised EIL to set minimum targets for Carbon conversion and cold gas efficiency.
- EIL has proposed to complete remaining activities (including maintenance, pilot plant operation for data generation for CFD model and final report submission) by July'20 and indicated that all modifications and repair work shall be completed by end of Dec'19. Subsequently, continuous gasification operation shall be established upto 6 bar for at least 24 hrs.
- Prof. R. Kumar has advised that pressure limitations in present gasification operation to be explored by a select Group of EIL/Thermax/BPCL. The experimental outcomes shall be deliberated by the Expert Group and decision on further raising the pressure to be taken.
- EIL proposed following Cost Estimate for repair & modification work. The same was reviewed by the Expert Group and recommended.

Total Cost (Rs, lakh)	Contributions (Rs, lakh)		
	CHT	EIL	Thermax
276	118.125 (37.5%)	118.125 (37.5%)	39.75 (25%)

- SAC, in its 86th meeting, has approved re-appropriation of Rs 1.18 crore (CHT's contribution in total estimated expenditure of Rs 2.76 crore) from BPCL head to EIL.
- CHT expressed concern that no fund is released till date in FY 2019-20 against RBE of Rs 1.80 crore. EIL indicated that the same shall be availed by EIL during the remaining period of the F.Y. However, the above estimates are based on proportionate contribution by Thermax and the same is still being explored with Thermax.

After extensive deliberation, the following are the salient points of discussions;

- JS(R) expressed concern in delay in the project and advised to Fast-track the progress.
- SAC advised to establish operation at 6 bar and scale it up further as problems may go away at larger scale. Simplified model may be used to see whether current problems can be addressed. SAC also advised to use CFD model to study pressure effect in Gasifier operation and to aim for Gasifier operation at design pressure.
- SAC approved project extension upto July'20 as per plan submitted by EIL. SAC also advised EIL to submit way forward including midcourse correction, if any.
- Cost of production of drop in fuel through FT route to be evaluated by BPCL.
- The above points are to be deliberated by the Expert group.

5.2 Biomass Hydro-pyrolysis for production of fuel grade Hydrocarbons: HPCL/ CSIR-IIP

IIP: To develop catalyst & optimize operating conditions for a single step hydropyrolysis process in 100 g/h unit

HPCL: Demonstrate the process in 5 kg/h unit

Project started with MNRE since 2012.

- SAC, in its 84th meeting on 22nd Apr'19, advised to consider both MNRE & CHT funded projects together, as the scope of work pertaining to IIP is same.

Total Cost of both Projects and contributions of all Agencies (Figures in Rs, lakh):

Participating/Funding Agencies	MNRE Project (IIP)		CHT Project (IIP / HPCL)		
	MNRE	CHT	CHT/OIDB	HPCL	Total
IIP	232.19	39.49	640	-	**911.68**
HPCL	-	-	800	966.9	**1766.90**

Total	232.19	39.49	1440	966.9	
	271.68		**2406.9**		**2678.58**

Total Expenditure by MNRE, CHT & HPCL in both Projects (Figures in Rs, lakh):

Participating/Funding Agency	MNRE	CHT/OIDB	HPCL	Total
IIP	232.19	531.81	-	764.00
HPCL	-	-	410.00	410.00
Total	**232.19**	**531.81**	**410.00**	**1174.00**

Status:

- Director, IIP mentioned that with Rice straw, having 15-20% ash, Bio-oil yield is very low at 11.6 wt % (with 85.5% oxygenate) against Global benchmark of 30% (with NIL oxygenates). He suggested to work on pine biomass (1% ash) as the same is available in plenty in the state of Uttarakhand and the experiments by IIP are showing good yield, which are comparable (48% against 50%) with N_2 (1 bar, 400^{0}C). Further improvement in yield up to 61% (1 bar, 500^{0}C) in the presence of H_2.
- IIP has developed two catalysts (Ru/bio-char, NiMo/Alumina) and their evaluation studies are in progress for removal of oxygenates for pine biomass and rice straw. IIP indicated that the Catalysts shall be finalized by Apr'20.
- Delay in analytical Equipment procurement at IIP (Mar'20 against May'19)
- Based on the above plan indicated by IIP, HPCL has prepared roadmap for project completion by Nov'22 (against original plan of Nov'19).

S. N.	Milestones as per MoU	Proposed completion date	Current Status
1	Preparation and characterization of catalysts	Apr 2020	Ongoing. Multiple catalyst systems prepared and characterized.
2	Catalyst screening using procured reactor setup	Apr 2020	In progress
3	Physico chemical characterization of reaction products, bio-oil generation etc	Apr 2020	In progress
4	Structure activity relationship and reaction mechanism studies	Apr 2020	In progress

5	Optimized reaction parameters for single step hydropyrolysis process	Apr 2020	Future Activity
6	Finalization of PFC of 5 kg/hr pilot plant and interaction with vendors for budgetary quote by HPCL	June 2020	Future Activity
7	Issuance of tender and purchase order	Oct 2020	Future Activity
8	Delivery of pilot plant	Dec 2021	Future Activity
9	Commissioning of pilot plant	Mar 2022	Future Activity
10	Data generation using scaled up catalyst	Sep 2022	Future Activity
11	Submission of the final report	Nov 2022	Future Activity

SAC advised that for confidence building pine wood can be tried. However, technology for Rice straw as feedstock also needs to be established.

SAC approved project extension till Nov'22.

5.3 Development of catalyst and process for Slurry phase Residue Hydro-cracking: IIP/ HPCL/ BPCL/ EIL

MOU Date	Start Date	End Date	Extension
June 2015	July 2015	July 2018	Dec 2019

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20		
			BE	RBE	Expenditure
CHT	#1366.00	*1325.83	29.00	40.17	--
HPCL	776.00	776.00	--	--	--
CSIR-IIP	93.00	93.00	--	--	--
Total	2235.00	2194.83	29.00	40.17	--

(CSIR-IIP: Rs 516 lakh, HPCL: Rs 850 lakh)

* (CSIR-IIP: Rs 475.83 lakh including interest of Rs 2.44 lakh, HPCL: Rs 850 lakh)

No fund is taken in FY 2019-20 against plan of Rs 40 lakh.

Status:

CHT informed that the Catalyst developed by HPCL, BPCL & IIP have been tried at HPCL pilot plant (1L reactor volume).

Feed: VR (>98% material 565+)

Operating Conditions: 430°C, 175 bar, 4 h Reaction Time and 5000 ppm catalyst.

Result:

Catalyst	HPCL	BPCL	IIP
Products	**Yield (%wt)**		
H_2S	5.19	3.44	3.98
C1-C2	4.34	3.09	3.28
LPG	8.83	2.57	3.23
Distillates (C5 – 370°C)	34.02	39.09	35.7
VGO (370°C – 565°C)	27.63	28.03	26.6
Unconverted Resid or Pitch	17.78	20.4	23.2
Coke	2.21	3.36	4.0
565°C+ Conversion	**79.9**	**76.3**	**73.3**

Hydrodynamics of slurry bed reactor, process simulation and modelling studies shall be carried out by EIL for the best catalyst based on the results of pilot plant studies carried out at HPCL. Based on their outcome, the decision on further scale up shall be taken (Reference: Record notes of Review meeting of R&D projects held on 25th June, 2019 under the chairmanship of Prof R Kumar.)

SAC advised EIL/IIP/BPCL/HPCL to deliberate on the results of catalysts and finalize action plan for remaining activities by mid Jan'20.

EIL reiterated that 6 months will be required to complete the kinetic modelling, hydrodynamic studies and process simulation & modelling of slurry phase reactor after receipt of data in totality on best catalyst generated in batch/semi-batch reactor and pilot plants.

SAC extended the project till July'20 considering catalyst finalization by Jan'20.

5.4 Renewable crude and liquid Hydrocarbon fuels from Algae: CPCL / ICGEB/ABAN

Objective: To demonstrate technical and economic feasibility of an integrated process for cultivation of microalgae and production of microalgal bio-crude, suitable for production of renewable fuels using existing refinery infrastructure.

The project was recommended by SAC under 2 phases (The current project is for Phase-1 only).

Phase-1: Cultivation of algal consortium in open pond and scale up studies in larger ponds (4000 m^2) to assess biomass productivity (with a target yield of 25 $g/m^2/day$) with GM algal strains to enhance the yield by 20-30%.

Phase-2: Process to handle 110 kg algal slurry / day

MOU Date	Start Date	End Date	Extension
Dec 2016	Mar 2017	Mar 2019	Aug 2020

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Fund released till date	2019-20			2020-21
			BE	RBE	Fund released	BE
CHT	#434.52	*385.77	35.72	29.00	12.71	32.45

(CPCL: Rs 386.34 lakh; ICGEB: Rs 48.18 lakh); * (CPCL: Rs 337.59 lakh; ICGEB: Rs 48.18 lakh)

Status:

- Algae harvesting in 4000 m^2 pond in progress (Sept'19 to Aug'20)

Month	Bio-mass productivity ($g/m^2/day$)	Bio-crude yield (wt. %)
Sep. 19	12	15
Oct. 19	12	15
Nov. 19	16	23

- Lab-scale: 32% increase with Nannochloropsis (NC) & 11% with Tetraselmis (TS)
- 100 Litre photo bioreactor: 100 % increase with Nannochloropsis (NC) & Tetraselmis (TS)

CPCL expressed that as advised by SAC, the possibility to carry out trials with GM algal strains in lab scale or in confined system has been explored. The same requires approval of Institutional Biosafety Committee (IBSC) comprising of following and to be registered with Department of Biotechnology (DBT).

a. Head of the organization or his designate (a suitable senior officer) as the Chairperson. The Chairperson should represent the organization and preferably have knowledge and experience in scientific research pertaining to rDNA technology and GMOs/LMOs.
b. Three or more scientists engaged in rDNA work or molecular biology with at least one outside expert in the relevant discipline.
c. A member with medical qualifications - Biosafety Officer (in case of work with pathogenic agents/large scale use).
d. A nominee of DBT

CPCL expressed its inability to perform trials with GM algal strains as they are mainly focussed on petroleum refining related research and lacking in the required expertise for the formation of IBSC.

SAC considered the above and advised CPCL to complete the project without genetic modification of algae.

5.5 Synthetic Aviation Lubricants (SAL) - Phase 2: CSIR-IICT, HPCL & CEMILAC

Background & Objective:

- Project is an extension of Phase-1, wherein 2 synthetic lubricants (SVS 11 and SVS 21) developed.
- In the current project, 500 L each of both the lubricants (Base oil by IICT & Formulation by HPCL) were to be prepared for testing in TV-2 aero engine of MI-8 helicopter supplied by 3BRD. However, it was understood that TV-2 aero engine is going to be phased out and TV-3 aero engine shall be used in MI-17 helicopter. Therefore, it was decided to try these lubricants in TV-3 aero engine.
- Only SVS-11 has been found compatible while carrying out rubber seal compatibility study & tribology testing. Therefore, its testing in TV-3 aero engine & also in-flight tests (MI-17 helicopter) is to be done.

MOU Date	Start Date	End Date	Extension
Mar 2016	Apr 2016	Sept 2017	Mar 2020

Financial Progress (All figures in Rs, lakh):

Agency	Contribution		Expenditure till date	2019-20		2020-21
	Original	Revised*		BE	Expenditure	BE
#CHT	97.02	139.02	130.80	--	--	8.22
HPCL	118.00	169.10	87.10	--	--	--
CSIR-IICT	30.00	43.00	43.00	--	--	--
CEMILAC	5.00	7.16	--	--	--	--
Total	250.02	358.28	260.90	--	--	8.22

Only to IICT

Status of SVS-11:

- Elastomer compatibility test completed. Clearance from CEMILAC is awaited.
- In-flight test schedule finalization with Air HQ is in progress.
- HPCL to find other applications of the developed product as the development is nearing completion. The input from HPCL is awaited.
- Project is expected to be completed as per the revised schedule of Mar'20.

SAC noted the above.

5.6 Improving (Speedy) Leak Detection Time in Pipelines by Deployment of Real Time Ethernet Protocols: HPCL-VSPL/ ECIL

Objective:

- To reduce leak detection time in the pipelines from existing 15 to ~ 2-3 minutes with an accuracy of ± 200 meters compared to current range of ± 2 to 3 km.
- To reduce data acquisition time from existing 10-15 seconds to 10-20 milli seconds
- Demonstration at HPCL's VVSPL, wherein Electronic Systems Design & Manufacturing device and Firmware will be developed. ECIL will support in development of Electronics.

MOU Date	Start Date	End Date
Sept 2018	Nov 2018	Apr 2020

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20		
			BE	RBE	Expenditure
CHT	#55.20	20.74	34.46	34.46	-
HPCL	61.84	-	-	-	-
Total	117.04	20.74	34.46	34.46	-

CHT's contribution to HPCL

Status:

The System Architecture is completed. Field validation at two of the Successive stations shall be completed by end of Dec'19. The project is as per schedule.

SAC noted the above

5.7 Production of lower olefins (Ethylene and Propylene) from Syngas: IICT/BPCL

Objective:

Catalyst synthesis for direct conversion of syngas to lower olefins in a 4 CC reactor and establishment of proof of concept by CSIR-IICT.

BPCL shall join after proof of concept.

MOU Date	Start Date	End Date
Feb 2019	Mar 2019	Sept 2020

Financial Progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20			2020-21
			BE	RBE	Expenditure	BE
CHT	#84.044	41.80	30.00	8.20	-	34.04
CSIR-IICT	154.176	25.46	120.00	135.00	-	19.18
Total	238.22	67.26	150.00	143.20	-	53.22

CHT's contribution to CSIR-IICT

Status:

CHT informed that PO for HP Fixed bed reactor & automatic gas adsorption shall be placed by Dec'19 against May'19. There is a delay of 9 months in a project duration of 18 months. Accordingly, IICT has reduced its budget commitment from Rs 30 lakh to Rs 8 lakh. However, IICT is preparing and characterising the Catalyst (Fe with nano particle range) using existing facilities available at the institute.

SAC expressed concern in delay of the activities and advised CHT/ BPCL to follow up with IICT to expedite.

5.8 Development of Superior Absorbents for CO_2 Separation from Biogas: ICT-Mumbai/IOC

Objective:

- Batch experiments for CO_2 absorption and desorption separately to measure the efficiency of absorption and desorption: ICT
- Continuous experiments in a lab-scale, closed loop absorber-desorber setup to measure the CO_2 absorption efficiency and regeneration energy: ICT
- Experiments in a VLE setup to measure the CO_2 solubility and stirred cell to measure absorption rates and investigate absorption kinetics: ICT
- Continuous experiments in a pilot plant to investigate the performance and energy requirements: IOC R&D

MOU Date	Start Date	End Date
March 2019	March 2019	March 2022

Financial Progress (All figures in Rs, lakh)

Agency	Contribution	Expenditure till date	2019-20			2020-21
			BE	RBE	Expenditure	BE
CHT	#85.57	35.56	16.00	16.00	-	17.00
IOCL	87.97	-	-	-	-	-
Total	173.54	35.56	16.00	16.00	-	17.00

CHT's contribution to ICT-Mumbai

Status:

ICT has tried two solvents AMP (2-amino-2-methyl-1-propanol) and AHPD (2-amino-2-hydroxymethyl-1,3-propanediol) for CO_2 absorption. Their reactivity with CO_2 in aqueous solution is in the order of AMP > AHPD > MDEA.

Further, Both solvents are moderately reactive in organic solvent EG (ethylene glycol)/PrOH (1-propanol) and their reactivity is improved by 15% after water addition.

The Project is as per schedule.

SAC noted the above.

5.9 Stabilization and up gradation of biomass derived oils in a dual stage catalytic reactor: TERI/IOC

Objective:

Catalytic up gradation of bio oil vapors to aromatics and hydrocarbons for improving Oxygen content (<5%) and H:C ratio.

Sanction Date	End Date	Extension
Sept'13	Sept'16	March 2020

Financial progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20		
			BE	RBE	Expenditure
CHT	44.07	37.90	6.17	6.17	-
MNRE	120.00	120.00	-	-	-
Total	164.07	157.90	6.17	6.17	-

Status:

CHT informed that Fixed Bed Catalytic Cracking Upgradation Unit has been delivered in Sept'19 against May'19 and their integration with existing pyrolyser and commissioning in progress. There is delay of 6 months from the plan. However, TERI has confirmed to cover up the time gap in subsequent activities.

TERI has already developed the catalysts for both the stages viz. Stage 1: Hydrotelcite based mixed metal for vapor phase aldol condensation and Stage 2: ZSM5 + Mesoporous catalyst (Al2O3/SiO2 based)

SAC noted the above.

5.10 Development of Fiber Optic Gas Sensors and System for Petroleum Industry: Chandigarh/BPCL

Objective:

To design & develop fibre optic gas sensors and system for gas composition analysis for mixture of gases for its application in Petroleum Industry.

SAC, in Sept'18 recommended the Project to be undertaken in 3 phases as under:

Phase-1: Proof of concept for CO & H_2S gases (12 months) at Project cost of Rs 75.83 lakh

Phase-2: Development of prototype & field testing along with BPCL (12 months)

Phase-3: Commercialization by identified manufacturing partner (shall be explored before taking up Phase-2)

BPCL shall join as commercial partner after proof of concept in Phase-1.

MOU Date	Start Date	End Date
Dec'19	Dec'19	Dec'20

Financial progress (All figures in Rs, lakh):

Agency	Contribution	Fund released till date	2019-20			2020-21
			BE	RBE	Fund released	BE
CHT	75.83	-	54.00	42.63	-	33.20

Status:

EC in its 27th meeting held on 9th July 2019 approved the proposal for Phase-1 at a cost of Rs 75.83 lakh with total contribution from CHT/OIDB.CHT mentioned that the MOA has been signed on 4th Dec'19.

SAC note the above.

5.11 Development of kinetic as well as 3D CFD Model for Gasifier: EIL / BPCL

Objective:

To develop an integrated model for complete fluidized bed coal gasification system using a combination of phenomenological models and state-of-the-art CFD modelling for

a. Credible scale-up of CTL technology

b. Enabling design of a demonstration unit and subsequently designing / offering commercial unit

c. Identifying problem areas in CTL technology development which shall help in overcoming problems in CTL pilot plant running.

MOU Date	Start Date	End Date
Sept 2019	Nov 2019	Feb 2022

Financial progress (All figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20			2020-21
			BE	RBE	Expenditure	BE
CHT	213.00	18.13	100.00	80.00	18.13	120.00
EIL	213.00	43.80	60.00	60.00	43.80	110.00

BPCL	213.00	-	80.00	80.00	-	100.00
Total	639.00	61.93	240.00	220.00	61.93	330.00

Status:

- Equipment procurement for developing population balance model in progress.
- Program developed for numerical solution of Population Balance Equations under Population Balance Modelling.
- NDAs with IITM and M/s ANSYS finalized by EIL.
- ANSYS Software new licenses purchased and installed. Procurement of hardware in progress.
- Literature on CFD modelling of Fluidized Bed Reactors (with & without gasification) being studied for identification of validation cases for gas – solid multiphase flow models within ANSYS CFD software.

SAC noted the above.

6. Closure of completed R&D projects

6.1 Development and Durability Testing of Ethanol-Diesel Blend Engine: ARAI, Pune

Objective:

- To evaluate the Emission and Power performance of engine using ethanol-diesel blend for BS-III & BS-IV emission norms
- To evaluate vehicle performance of ethanol blended diesel by comparing base diesel vehicle performance

MOU Date	Start Date	End Date	Extension
Sept 2017	Oct 2017	Mar 2018	May 2019
CHT Contribution (Rs, lakh)	**Fund released till date (Rs, lakh)**		
129.80	129.45		

Status:

Project has been completed. SAC, in 86th meeting, advised that ARAI may also incorporate data on CO_2 emission and thereafter the report may be circulated to members for comments. Draft report after incorporating CHT/ SAC observations was submitted on 18th Nov'19. CHT circulated the draft report to SAC members for their review and comments on 20th Nov'19.

Following are the salient outcomes of the project:

- As diesel & ethanol are immiscible, an additive/ binder (BERAID ED10), was indigenously prepared with the help of M/s Ackzonobel, Mumbai. Diesel – ethanol blends having varying ethanol percentage of 5, 7.7, 10, 12.5 and 15 were evaluated for its performance & emissions on the diesel engine.
- A blend of 7.7% Ethanol & 2% additive in Diesel was found to be suitable for power performance. The emissions were marginally higher than the commercial diesel fuel but less than the legislative limits. This optimum blend had minimal power drop of around 1% as compared to commercial diesel. As the blend was having similar CO and increased HC & NO_X emissions as compared to commercial diesel, the blend was modified for improving combustion efficiency by adding 1% of 2-EHN (Ethyl Hexyl Nitrate). Following changes were observed in emission using the modified blend as compared to diesel in both BS-III & BS-IV diesel engines:

Blend	CO	HC	NOx	PM	Smoke
BS III 7.7% E-Diesel Blend	17% ↓	15% ↑	2% ↓	11% ↓	43% ↓
BS IV 7.7% E-Diesel + modified additive	50% ↓	0%	11% ↑	8% ↓	30% ↓

- Increase in the NOx emissions is due to presence of oxygenated fuel i.e. Ethanol which makes the diesel further lean as compared to commercial diesel.
- As the ethanol percentage in the blend increases (from 5% to 15%), NOx emissions increase significantly by 22%. However, HC is more or less constant.
- Engine durability completed for 500 hrs. No deterioration and abnormality on engine components observed. Before and after endurance of 500 hrs, engine power and torque were found same.
- **Gradeability test:** The test vehicle passed 7^0 slope test.
- The CSFC of the blend is slightly lower (within 3%).
- The acceleration performance of the blend is slightly lower by 3.5% at the end of 1000 meters. So, for bus application even though the acceleration performance is less by 3.5% it would not hamper much as the vehicle qualifies for Gradeability test & this acceleration condition is hardly visible in field.
- **CO_2 Emission:** The CO_2 emission data primarily reveals about the combustion efficiency & the BSFC of the engine. Lesser the CO_2 emissions, better the engine BSFC.

The CO_2 Emissions have increased by 0.46% in BS-III in-use engine as the fuel system & combustion technology is less efficient.

The CO_2 Emissions have reduced by 0.94% and 1.09% with the help of 7.7% E-Diesel & 7.7% E-Diesel +1% of 2-EHN blend respectively for BS-IV engine.

- **Difference between KSRTC & ARAI Study as sought by SAC:**

KSRTC had carried out trials on vehicle fleet while ARAI on engine as well as vehicle.

The fleet study done by KSRTC involves emission measurement done on portable 4-gas analysers i.e. PUC machines where the emissions are measured at end of tail pipe & at idle conditions. However, the mass emission benefit assessment as per the CMVR requirement was not carried out. On the contrary, ARAI has optimized the E-Diesel blend on engine test bed with test cycles as prescribed in CMVR and evaluated performance on vehicle for CSFC, Gradeability & acceleration.

KSRTC study includes the blend properties without any quantitative data, whereas ARAI study includes the test report of the Diesel-Ethanol blend as per IS 1460 – 2011.

- **Comments on Draft Report:** Only IOCL has given following comments on the draft report shared by CHT. ARAI responses are as under:

i. **The study is only a technical study and commercial viability of the above blend has not been seen. Techno commercial study needs to be carried out. The additive cost and cost of 2-EHN i.e. CETANE Improver needs to be looked into, these may make the blend as commercially unviable.**

a. The current project is of technical viability. However, the costing for the fuel blend is calculated based on the prices in Jan'19 in Pune & the additive cost is as declared by additive vendor.

Elements	Rate(Rs.) /ltr	Mix Ratio	Revised Rate(Rs.) /ltr
Diesel	74.25	89.30%	66.305
Ethanol	52.43	7.70%	4.03
Additive	100	3%	3
Total			73.335
Savings in fuel cost / ltr			**0.915**

b. Additionally, ARAI is discussing the scope to commercialize the blending process with BPCL. Primary thought is to implement the blend on a large fleet of vehicles so as to get the field response for the Diesel-Ethanol blend.

c. ARAI also approached ASTRU and ED-ASTRU assured ARAI to help this project for carrying out trials on large fleet.

ii. **The study also needs to be carried out on BS-VI grade HSD.**

The scope of the current project was to evaluate the blend on BS-III & BS-IV HSD fuelled engines. However, this can be further extended for BS-VI grade HSD fuel as a separate project.

iii. **Following parameters are not meeting the current specifications of HSD Moisture : 1435 ppm against spec of 200**

The specified value is applicable for automotive diesel fuel (High Speed Diesel Fuel) only. For ethanol blended diesel sample, moisture content is not specified in the Indian Standards.

To avoid phase separation & corrosion due to moisture, the additive contains corrosion inhibitor & blend stabilizer.

It is observed in one of the publications of American Society of Agricultural and Biological Engineers that the biodiesel blends with HSD show moisture content up to 1700 ppm at saturated conditions.

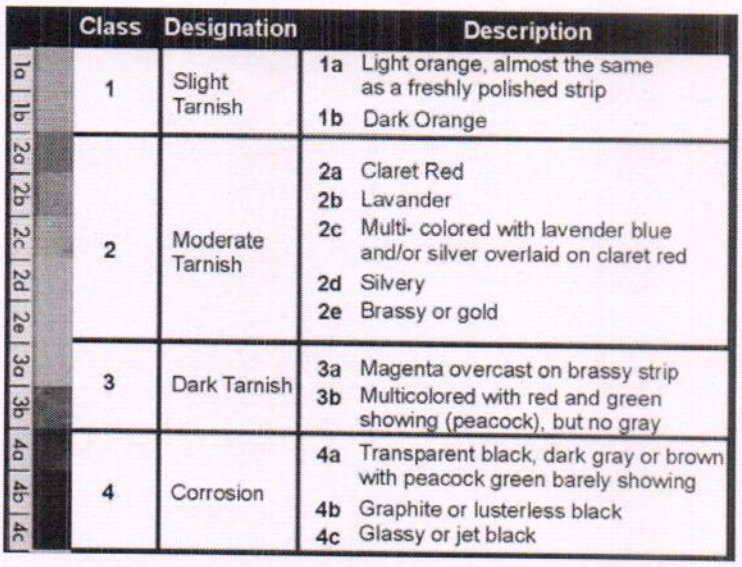
iv. **Cetane Index is 29 against spec of 46 minimum**

Cetane index calculations cannot account for Cetane improver additives and therefore do not measure total Cetane number for additized diesel fuels. Diesel engine operation is primarily related to the actual Cetane number, and the Cetane index is simply an estimation of the base (unadditized) Cetane number. Cetane number should equal or exceed Cetane index, depending on the amount of additive used.

v. **Copper strip corrosion is 1a slight tarnish against not worse than number 1 : Its effect on life of the engine not known/ studied**

The result 1a shows that the copper strip is almost the same as a freshly polished strip and the diesel-ethanol blend is not corrosive in nature. The engine has completed 500 hrs of durability with the 7.7% blended Diesel-Ethanol fuel and there was no failure of any fuel system part due to corrosion.

Moreover, the additive contains corrosion inhibitor called as Ethomeen 302V which prevents corrosion of metallic parts.



Class	Designation	Description
1	Slight Tarnish	1a Light orange, almost the same as a freshly polished strip 1b Dark Orange
2	Moderate Tarnish	2a Claret Red 2b Lavander 2c Multi- colored with lavender blue and/or silver overlaid on claret red 2d Silvery 2e Brassy or gold
3	Dark Tarnish	3a Magenta overcast on brassy strip 3b Multicolored with red and green showing (peacock), but no gray
4	Corrosion	4a Transparent black, dark gray or brown with peacock green barely showing 4b Graphite or lusterless black 4c Glassy or jet black

vi. Flash point reported is < 40°C, however specific value should have been reported

Ethanol, based on its flash point, is a Class-I liquid. In contrast, diesel fuel is a Class II liquid. E-diesel blends containing 10% or more ethanol have the flash point of ethanol, so they would also be classified as Class I liquids.

In our case, the E-Diesel blend is less than 10%. The specific value of flash point is awaited from our external test agency & the same will be reported once we receive it.

SAC deliberated on the outcome. On a query, ARAI indicated that they are exploring with BPCL for commercialization of this blend. While approving closure of the project, SAC advised CHT and ARAI to publicize the study.

6.2 Parametric Study and Technology Development for Desalter Design: EIL & BPCL

Objective:

- To develop Skid-mounted proto-type model Desalter to carryout Parametric Study for various crudes for better understanding of intricacies in Desalter design & operational issues
- To develop indigenous Desalter technology

MOU Date	Start Date	End Date	Extension
Feb 2015	Mar 2015	Mar 2018	June 2019

Financial Progress (All figures in Rs, lakh):

Agency	Contribution		Expenditure till date
	Original	Revised	
CHT	853.0	#853.0	853.00
BPCL	348.1	469.31	426.42
EIL	250.0	352.72	286.86
Total	1451.1	1675.03	1566.28

#CHT's contribution to EIL

Status:

Project has been completed. EIL presented the project outcomes in last SAC meeting on 16th Aug'19. As advised by SAC, report was circulated to SAC members for their comments on 20th Nov'19. No comments have been received.

SAC approved closure of the project. SAC also advised that efforts should be made to commercialize the developed technology and emphasized need to be showcase in different platforms for its commercialization.

7. HCF projects

7.1 Scale-up studies and process development for Hydrogen Production by Catalytic Decomposition of Natural Gas: HPCL-R&D, CeNS and IIT Delhi

Objective and roles under the current project:

- HPCL & IITD developed a technology at lab scale in earlier project funded under HCF to produce H_2 & CNT.
- To produce H_2 & CNT at feed rate of 1 kg/hr. Subsequently, Basic engineering package shall be developed for Demonstration unit at HPCL (not in the scope).
- Role of IITD: H_2 & CNT production in 25 gm catalyst fluidized bed reactor (FBR) and to determine the hydrodynamic stability of catalyst in the FBR as well as the time required for optimum CNT deposition.
- Role of CeNS: Develop a protocol for CNT separation from deactivated catalyst. Regenerated catalyst shall be used again in the process. Further, CeNS shall find suitable applications of CNTs for techno-economic viability.
- Role of HPCL: Design and set up a pilot plant of 1 kg/h feed rate by using data from IITD & CeNS. The pilot plant's outcomes shall be used for the development of basic engineering package for a demonstration unit.

MOU Date	Start Date	End Date
Feb 2017	Mar 2017	Mar 2021

Financial Progress (Figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20			2020-21
			BE	RBE	Expenditure	BE
CHT	#1692.10	*110.43	360.00	31.00	4.85	218.50
HPCL	1253.60	596.20	150.00	100.00	43.00	150.00
Total	2945.70	706.63	510.00	131.00	47.85	368.50

(HPCL: 1489.80; IIT-D: 102.30; CeNS: 100.00); *(IIT-D: 69.91; CeNS: 40.52)

Status:

- IITD is developing catalyst for improving CNT yield. With 60% Ni 5%Cu 5% Zn on alumina catalyst, CNT yield was limited to 1-2 Kg CNT / Kg catalyst with CH_4 conversion of > 80%. After reducing metal content to 20% Ni 1.6% Cu 1.6%Zn on alumina, CNT yield was improved to 3.4 Kg CNT/Kg catalyst, However, in 3 h run time CH_4 conversion dropped from 75 to 10 vol%. The literature benchmark is 60-70 Kg CNT / Kg of Catalyst.
- CNT separation efficiency is 63% in 3 hrs. However, growth of CNT is very less and shorter length observed using regenerated catalyst. With the regenerated catalyst, the H_2 in off gas initially was observed at 50 Vol% for 1h and stabilized at 70 Vol%.
- SAC, in its 86th meeting, has advised HPCL to co-ordinate with IITD and CeNS to expedite the progress and also contact ARCI, Hyderabad and JNCASR for exploring CNT applications. HPCL had a meeting with ARCI and IICT regarding the issues in catalyst development. IICT's catalyst was evaluated at HPCL facility. It was found that the methane conversion is 80 vol% and CNT dia was >130 nm.
- HPCL had a meeting with CeNS on application development for spent catalyst without CNT separation. Oxygen evolution reaction (OER) and water purification applications are being explored.

SAC noted the above.

7.2 Creation of solar based Hydrogen production system and dispensing station for refuelling hydrogen fuel cell vehicles: IOCL

Financial Progress (Figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20			2020-21
			BE	RBE	Expenditure	BE
CHT	2500.00	-	-	-	-	2400.00

IOCL	4016.00	-	-	-	-	-
Total	6516.00	-	-	-	-	2400.00

Status:

GC, in its 37th meeting on 8th Aug 2019 has approved the project with HCF contribution of Rs 25 crore.

MOA is finalized and under signing.

SAC noted the above.

7.3 Setting up of Compact Reformer Unit for producing H-CNG and trials demonstration at Rajghat Bus Depot at Delhi: IOCL

Financial Progress (Figures in Rs, lakh):

Agency	Contribution	Expenditure till date	2019-20		
			BE	RBE	Expenditure
CHT	#920.00	-	18.39	9.20	-
IOCL	919.00	-	-	-	-
*TM, GoD	1500.00	-	-	-	-
Total	3339.00	-	18.39	9.20	-

#CHT's contribution to IOCL *Transport Ministry, Govt. of Delhi

- On Hon'ble Supreme Court advice, Transport Ministry, Govt. of Delhi has sanctioned grant of Rs 15 Crore through Environment Compensation Cess (ECC) for this project. IOC R&D requested balance of Rs 18.4 Crore from HCF.

Status:

- SAC, in its 84th meeting on 22nd Apr'19 and EC, in its 27th meeting on 9th Jul'19 recommended the Project.
- GC, in its 37th meeting on 8th Aug'19, approved that out of the additional funding of Rs 18.4 crore sought by IndianOil R&D, CHT shall fund 50% i.e. Rs 9.2 Crore from Hydrogen Corpus Fund and rest 50% to be borne by IndianOil along with its executing partner (M/s IGL).
- Subsequent to the commissioning of the said plant with the approved funding, Hon'ble Supreme Court may be approached for reimbursement of the total additional expenditure of Rs 18.4 Crore in addition to the initial grant of Rs 15 crore granted through Environment Compensation Cess (ECC).
- Post approval of Hon'ble Supreme Court, IndianOil shall return the fund released in the project from HCF to CHT/ OIDB.

- MOA is finalized and under signing.

SAC noted the above.

Annexure – I

List of Participants

87th meeting of SAC held on 13.12.2019 at SCOPE Complex, Lodhi Road, New Delhi

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List of Participants

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List of Participants

87th meeting of SAC held on 13.12.2019 at SCOPE Complex, Lodhi Road, New Delhi

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List of Participants

87th meeting of SAC held on 13.12.2019 at SCOPE Complex, Lodhi Road, New Delhi

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