Task Force Committee Report

Flexibilisation of Thermal Power Plants

Progress under IGEF Sub-Group-1

27th October 2017

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Please find enclosed the Task Force Committee Report on Flexibilisation of Thermal Power Plants to adapt to fluctuating renewable energy generation for your kind perusal.

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Executive Summary

With the aim to ensure future security and reliability of power supply and stability of electricity grids while maximizing power from renewable energies, flexibilisation of existing coal-fired power plants is an important measure.

For enhancing the ,flexibilisation of existing coal-fired power plants, a Special Task Force under the Chairmanship of Director(Operations),NTPC was constituted under IGEF Sub-Group-1.

The work was divided into three parts, which were conducted in parallel:

A) Demonstration of technical and economic feasibility at two reference plants of NTPC.

B) Capacity building of coal fired power plants operators

C) Analysis of legal framework conditions

Studies for flexibilisation were conducted at NTPC Stations –Dadri (210 MW) and Simhadri (500MW). After detailed review by the Task force on the draft report, the Final Report was submitted by VGB on 27thSeptember 2017.

A team visited Germany in September 2016 for exposure to German experience on Flexibilisation.An Indian Delegation led by Secretary (Power), Sh.P.K.Pujari attended business roundtable at Germany in September 2016.Subsequently, and EEC organized a workshop on flexibilisation in December 2016.

EY (Ernst & Young) submitted a report on analysis of present framework conditions for flexible operation of coal-fired power plants. The report covers the existing regulatory framework and generic recommendation for adapted framework conditions to favour flexible operation of coal-fired power plants.

VGB recommended Technical measures for three scenarios, viz 50 % Load with no or minimal investment, 40% load with moderate investment and 25% load with high investment.

The Task Force recommends for implementation of Measures for 50 % in all stations including Central, IPPS and State Utilities.

Measures for 40% minimum load can be implemented in a phased manner, initially in all sub-critical units of Central, IPPs, and State Utilities, which are likely to be under part load operation due to their high Energy Costs. In addition, start-up optimization and install condition-monitoring equipment is also necessary for sustainance of flexible operation. The same can be implemented in other units at a later stage. Involvement of OEMs (BHEL, Siemens, and GE etc) is necessary for implementation of the measures.

The cost implication for measures (for 40 % minimum load, start-up optimisation and condition monitoring) will be USD 12,00,000 to 27,00,000 (INR 7.8 to 17.55 Crores) per unit. If it is to be implemented in NTPC Non Pithead stations, the cost per MW will be INR 2 lakhs to 4.6 Lakhs.

Measures for 25% load are not feasible as it is based on the availability of "good" quality coal. It requires further studies, and may be studied separately through JCoal, USAID or OEMs.

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I. Introduction

Flexible operation of existing coal-fired power plants was identified as a promising measure to assure proper balancing of fluctuating renewable energy power.

In May 2016 (New-Delhi) and September 2016 (Berlin) the Government of Germany, represented by Federal Ministry for Economic Affairs and Energy, and Government of India, represented by Ministry of Power conducted meetings within the Indo-German Energy Forum. Both governments affirmed aiming to assure future security and reliability of power supply and stabilize their electricity grids while maximizing the application of power from renewable energies.

II. Details of Initiatives:

- IGEF Sub-Group-1 meeting on fossil-fuelled power plants was held on 19th May'2016 subsequent to Ministerial level meeting. A Government interaction and Business Meeting was held on 20th May'2016 at German Embassy with participation of Indian and German companies and government representatives. Areas of potential cooperation, exchange of information and technology in the area of thermal and renewable energy were discussed
- The Sub-Group-1 under the Indo-German Energy Forum constituted a Special Task force on 19th May'2016 for enhancing flexibilisation of existing steam power plants.

- **Quote**

  Flexibilisation of coal fired plants to adopt to fluctuating renewable energy generation is a priority relevant energy issue for the work of this sub group. A task force shall be established with its first meeting the very next day of this subgroup meeting.

  Unquote

  ...From MOM of IGEF Sub-group meeting (19th May'2016)

- The Task Force was constituted with the following members:

  - Chairman: Director (Operations)/NTPC, Mr. K.K.Sharma,
  - Secretary: Mr. O.P.Maken, EEC

  Members
  - Mr. N. Nallarasan, POSOCO
  - Mr. T.Venkateswarlu, CEA
  - Dr. Claudia Weise, VGB
  - Dr. Oliver Then, VGB
  - Mr. Tobias Winter, IGEF-GIZ
  - Dr. Dariush Hourfar, Kraftwerksschule (KWS)
  - Mr. Anjan Kumar Sinha, NTPC (Co-opted)
  - Mr. Sanjeev Kumar Kassi, MoP then CEA
  - Mr. M. Yatheesh Babu, Bharat Heavy Electricals Ltd.

The Indian Excellence Enhancement Centre for the Power Sector (EEC), established under the Indo-German Energy Forum in 2011, coordinated the task force. It was decided to elaborate measures for enhancing the flexibility of existing coal fired power plants in India to be able to adapt to fluctuations of power generation by renewable energies.

The work was divided into three parts, which were conducted in parallel:

A) Demonstration of technical and economic feasibility

- Two reference plants: NTPC Dadri & Simhadri
- Assessment of the plant status quo.
- Techno-economic analysis of potential for flexibilisation of reference plants and general recommendations for thermal power sector of India.

B) Capacity building of coal fired power plants operators

- Study tour to Europe with seminars and visit of adapted power plants in 09/2016.
- Workshop "Adaptation of Thermal Power Plants to Fluctuating Renewable Energies" in 12/2016.

- Development of operator training concept for flexible operation of coal fired power plants.

C) Analysis of legal framework conditions

- Analysis of present framework conditions for flexible operation of coal fired power plants.
- Recommendations for adapted framework conditions to favour flexible operation of coal fired power plants.

III. Journey of the Task Force (Chronological Details)

A) Demonstration of technical and economic feasibility

- After a series of review meetings (on 4/11/2016, 28/11/2016, 28/12/2016, 6/02/2017) by Chairman,of the Task Force, the study of two of the reference plants of NTPC was finalized.
- Seven meetings of the Task Force with Germany through Videoconferencing were held.
  - 1st Meeting- 20th May,2016
  - 2nd meeting-13th June,2016
  - 3rd Meeting-9th Aug,2016
  - 4th Meeting-28th Nov,2016
  - 5th Meeting- 31st March,2017
  - 6th Meeting-30th May,2017
  - 7th Meeting-8th Sept,2017
- German Experts from VGB and CEO of EEC visited NTPC Plant at Dadri on 15th December'2016 to collect data and to plan for future course of action for study of the reference plants for flexiblisation.
- Experts from EEC and NTPC as well as from VGB and STEAG visited the two-selected model NTPC Stations at Dadri from 06.03.2017 to 08.03.2017 and Simhadri (from 08.03.2017 to 10.03.2017). The team had detailed discussions with the stations and collected data required for flexibilisation study.
- The VGB and STEAG experts and CEO of EEC had a meeting with Chairman Task Force on 8.03.2017, in which the requirements of the study was discussed.
- Subsequent data was sent to VGB as per requirement.
- For completion of the study of the model plants and fulfillment of further data requirement/queries a Video Conferencing was arranged in April'2017 with the

participation of senior level plant operators from Dadri and Simhadri participating at Delhi and VGB experts participating from Germany.

- The draft report was submitted by VGB in June 2017.
- A Video conferencing was organized, during which the Draft Report was deliberated upon in details, with the participation of members of the Task Force and representatives from the reference plants (Dadri and Simhadri) .VGB was requested to provide specific report on existing flexibilisation capabilities and specific measures for enhancing the flexibility of Coal plants along with cost benefit analysis and timelines of implementation of the measures. VGB was asked to make flexibility assessment w.r.t. Indian Coal.
- A revised report was submitted by VGB on 21st July, 2017.The revised report did not show the recommendations in form of a practical action plan.
- A review of the revised report was taken by JS(Thermal) on 8th August,2017 with the presence of the task force members.JS(Thermal) requested IGEF to submit specific recommendations and the different level of flexibilisation achievable with "no", 'moderate' and 'high' investments and the cost benefit analysis.
- This review meeting was followed up by The Task Force meeting through VC. The specific requirements was again clearly spelt out to VGB by the Chairman of the Task Force.
- The Final Report was submitted by VGB on 27th September 2017. This report includes an overview of recommended measures in order to achieve a minimum load of 50, 40 and 25 percent as well as to enhance the start-up procedure and the dynamic behaviour.The list of measures are attached in **Annexure-1**

B) Capacity building of coal fired power plants operators

- Indian Delegation has undertaken visit to Germany 18th to 25th September 2016. The delegation got exposure on how the plants in Germany are managing flexibilisation.
- The IGEF, in its tenth year of operation, with the aims of initiating strategic cooperation projects between German and Indian governments, institutions and the private sector held its 7th IGEF Meeting in Germany (Hamburg and Berlin) from 26th to 30th September 2016.
- Indian Delegation for 7th IGEF Meeting from 26th to 30th September 2016 was led by Secretary (Power), Sh.P.K.Pujari and accompanied by representatives from Ministry/related Public Sector Undertakings like NTPC, SECI, POSOCO and from various

Companies/Organizations like L&T, FICCI, EESL, TERI, GiZ, Amplus Solar, Welspun, EEC and IGEF Support Teams.

- During the Secretary, level meeting (7th IGEF Meeting) various issues related to Renewable energy integration and Flexibilisation were discussed.

- A special National Training Seminar on **"Adaption of Thermal Power Plants to Fluctuating Renewable Energies"** was held on 16thDecember, 2016, at New Delhi. This seminar was participated by MoP, NTPC, BHEL, DVC, TERI, NSPCL, NIWE. POSOCO, Siemens, NLC-India Limited, KSB Pumps, Crompton Greaves, Tata Power, JSW, CEA, HPGCL, Rajasthan, Gujarat, Haryana, WBPDCL, M.P., PWC, EEC, GIZ, IGEF, KFW and VGB.
- The Video conferencing was held on 31.03.2017 at IGEF office Delhi, with the participation of IGEF, CEA, POSOCO, BHEL, EEC and NTPC from India and VGB, KWS& STEAG from Germany. The details of development of operator training concept for flexible operation of coal-fired power plants were discussed.

- KWS submitted the draft of operator training concept for flexible operation of coal-fired power plants. During the 7th Task Force meeting through VC,Chairman, Task Force expressed that for "Training the trainers", German experts should come to India and impart the training at the selected Nodal hub. This will have better impact than sending people to Germany for the training.

C) Analysis of present legal framework conditions

- A report was submitted by EY (Ernst &Young) on analysis of present framework conditions for flexible operation of coal-fired power plants. The report covers the existing regulatory framework.
- The report also contains a generic recommendation for adapted framework conditions to favour flexible operation of coal-fired power plants. It does not contain a clear direction and implementable solutions.

Annexure-1

For enhancing the flexibilisation of Coal based Thermal plants, three aspects were covered, viz. lower minimum loads, Enhanced ramp rates and fast start-ups and shutdowns. The costs for achieving different levels of flexibilisation and the timelines for implementation of the measures were covered.

The subsequent compilation of measures provides an overview of recommended measures in order to achieve a minimum load of 50, 40 and 25 percent as well as to enhance the start-up procedure and the dynamic behavior.

A. Technical measures to reach minimum load of down to 50 percent load

The implementation of measures M1 to M4 is essential for flexible operation.

No	Measure	Flexibility impact and benefit	Cost range and timeline
M1	Re-assessment of O&M procedures with respect to water quality, maintenance of critical components, preservation of equipment and quality control for critical measurements	□ Strict compliance to O&M requirements is mandatory. □ Enhancements of maintenance strategy – special focus on critical equipment. □ Awareness and competency of power plant personnel is important to run the plant in cycling mode – training programs should be executed.	No hardware in-vestment needed, training and planning necessary □ 2 months (for O&M assess-ment) □ min. 12 months for training
M2	Optimization of automation and controls – main and underlying control loops	□ Pre-requisite for flexible operation – all important control loops must work smoothly at base-load conditions □ Smooth control of major power plant processes is a flexibility enabler. □ Ensuring a smooth and precise steam temperature control (root-cause analysis for the deviations of the re-heater steam temperatures). The optimization of the underlying control loops, i.e. coal sup-ply, drum level, pressure, temperature, air control is a basic requirement for stable operation of the power plant at nominal load and low load as well as load changes, and provision of control power. □ In terms of load reduction there might also be interlocks coming from logics. However, these interlocks are	Depending on the root cause, the investment might vary significantly – min. 100,000 U$ □ up to 6 months

		usually relatively simple to identify and eliminate with test runs. □ In order to increase part load efficiency "single device" approaches (e.g. single FW pump, PA fan, etc. in operation) should be considered. However, this strategy requires a reliable implementation with respect to bump-less switchover to standby equipment in order to not force trips.	
M3	Evaluation of process limitations (in particular boiler and turbine) in co-operation with the OEM (BHEL and Siemens); documentation of limiting components, process conditions and design buffers	□ Evaluation includes a boiler calculation to assess the influences of low load operation and temperature- and pressure gradients on the boiler components and equipment. □ This inventory review is required to assess the plant status in de-tail and to derive a schedule for the test program and an action plan for measures. □ Transparency about the technical boundary conditions for flexible plant operation.	Depending on the OEM (whether or not bringing technical discussions into account) and availability of in-house expertise; no in-vestment needed in the first place □ 1 month
M4	Test runs to evaluate the plant flexibility potential	□ Transparency about the plant performance with respect to minimal load, start-up and cy-cling behavior with current set-	No hardware investment needed, planning and execution necessary
Note	Consider part and low operation in the design of the flue gas equipment	□ Cycling load operation has an impact on DeNOx- and DeSOx-systems. □ Flue gas treatment need to comply with environmental norms at all load conditions.	No hardware in-vestment needed, planning necessary

B. Technical measures to reach minimum load of up to 40 percent load

Measures M1 to M4 should be already implemented.

No	Measure	Flexibility impact and benefit	Cost range and timeline
M5	Reliable flame detection for each burner individually	□ As proper flame detection plays a major role in guaranteeing a reliable minimum load operation and in terms of avoiding trips during start-up, the current hardware needs to be considered for potential replacement. □ This measure is essential to ensure proper combustion control.	The costs for this measure is in the range of 300.000 to 600,000 US$ for each unit. 1 to 2 months
M6	Advanced frequency control / unit control (if frequency control is to be provided at 40% load)	□ Manual interventions should be reduced to a minimum. □ Enhances the dynamic behavior of the plant and positively contributes minimum load and cycling operation (to provide 5% frequency control power). □ The main options are condensate throttling and throttling of the ex-traction steam for the HP pre-heater (more information is included in chapter 7.3.2 and 7.4.2).	The costs for this measure is in the range of 300.000 to 600.000 US$ for each unit. 6 to 12 months

C. Technical measures to reach minimum load of up to 25 percent

Measures M1 to M6 should be already implemented. Based on the European experiences the VGB-team states that **load reductions up to 25 percent require a minimum coal quality**. A typical range for the volatile content – water and ash-free (waf) – of coals used in European plants is 35 to 40 per cent. Thus, especially in Simhadri, (manual) coal cleaning removing major impurities like stones could be considered to improve coal quality. However, in order to achieve very low loads up to 25 percent the use of washed coal would be necessary.

No	Measure	Flexibility impact and benefit	Cost range and timeline
M7	Stable two mill ope-ration	□ This mode of operation enables low minimum load operation up to 15 per cent. The operation of two mills should improve combustion stability since the resulting load for each mill increases to a nor-mal/stable range. □ Test runs, verification of accuracy of all relevant measurements and defined coal quality are pre-requisite.	The costs for this measure is in the range of 100.000 to 600,000 US$ for each unit. 6 to 12 months

		□ Comprehensive adaptation of the emergency shutdown system is likely to be required.	
M8	Online combustion management system	□ Efficient measure to optimize the combustion process, which plays an important role for low load and cycling operation as well as for start-up. □ Including an online pulverized coal (PC) and air distribution management system to measure the air/fuel ratio to the coal burners in each PC pipe to the coal burners in real time.	The costs for this measure is in the range of at least 600,000 US$ for each unit □ 6 to 12 months
M9	Online coal analysis	□ Transparency about coal quality is important to optimize the combustion control. □ A weighing and online analysis could be installed at the unloading area.	□ The costs for this measure is in the range of 300,000 to 600,000 US$ for each unit up to 6 months
M10	Re-commissioning of the steam coil air pre-heaters (for Dadri only)	□ Protects the regenerative air pre-heater by avoiding fly ash sticking and condensation of sulfuric acid.	□ The costs for this measure is in the range of 300,000 to 600,000 US$ for each unit. □ This measure is very much de-pending on the current condition of the steam coil air pre-heater.

D. Activities related to start-up optimization

No	Measure	Flexibility impact and benefit	Cost range and timeline
M11	Check / potential replacement of start-up related temperature measurements (if already installed) in order to evaluate the thermal stress of thick-walled components	The temperature measurements are crucial to optimize the start-up and shut down procedure and to manage lifetime monitoring in a most efficient way. Alternatively, model-based methods can be applied which use the process temperature to evaluate the thermal stress.	Depending on extent of replacement; the costs are in the range of 100.000 to 300,000 US$ for each unit □ Standstill time depends on ex-tent of replacement □ The model-based approach is in a similar range. □ up to 4 months
M12	Optimization and automation of start-up sequence (see chapters 7.3.3 and 7.4.3)	By optimizing and automating the start-up sequence not only unnecessary waiting times can be avoided and faster gradients can be achieved but	The costs for this measure is in the range of 300.000 to 600,000 US$ for each unit.

		also oil consumption can be reduced to lower start-up costs.	at least 12 months (depending on the number of start-ups per year)
M13	FEM analysis to assess admissible temperature differences caused by material stress	Enhancing the start-up procedures and shortening start-up time by applying more ambitious temperature gradients / reducing the design buffer.	Depending on the availability of in-house expertise and according software (e.g. Ansys Work-bench) 2 to 3 months

E. To manage the consequences of cycling operation.

M14	Implementation of a condition monitoring system	The installation of such a system does not enhance the flexibility behavior of the plant itself but it is important to manage the consequences of cycling operation. Predictive Maintenance needs such systems ensuring an efficient life cycle management of the equipment.	The costs for this measure are in the range of 100.000 to 300,000 US$ for each unit. 3 to 4 months.

Roadmap for implementation of Flexibilisation measures:

A. **Minimum load of down to 50 percent load - is to be Implemented in all stations**

The Technical measures to reach minimum load of down to **50 percent load**, which require **no investment** or minimal investment is to be implemented immediately with following steps ahead:

(1) Optimization of automation and controls – main and underlying control loops; in particular spray water control.

(2) Test runs to evaluate the plant flexibility potential.

(3) Evaluation of process limitations (in particular boiler and turbine) in co-operation with the OEM and subsequently, documentation of limiting components, process conditions and design buffers.

(4) Re-assessment of O&M procedures with respect to water quality, maintenance of critical components, preservation of equipment and quality control for critical measurements – initiating training programs to address the background and motivation as well as O&M procedures for flexible operation.

NTPC stations are successfully operating its units at 55% Technical minimum, in line with IEGC amendment. By implementing the measures above (1 to 4), 50 % minimum load is achievable. **The same must to be implemented in all stations including ISGS Stations, IPPs and State Utilities.** A capability of 50 percent minimum load in All India basis will enable a flexibilisation band of 80,000+ MW (With the All India Coal Capacity of 193467 MW as on Sept'17).

These measures may be implemented by involving OEMs –BHEL, Siemens, and GE etc.

Timelines for Implementation: 2 Months. The implementation may be coordinated by CEA with assistance from NTPC.

B. The next level to reach minimum load of down to **40 percent load requires investments in the range of USD 6,00,000 to USD 12,00,000 (Rs 3.90 Crore to 7.80 Crore) for each unit.**

40 percent scenario including an optimization of the start-up procedure can be achieved with following steps:

(1) Implementation of reliable flame detection for each burner individually.

(2) Introduction of advanced unit control concepts such as model-based feedforward control potentially including condensate throttling and throttling of the extraction steam for the HP pre-heater – aiming at enhanced dynamic behaviour of the plant thereby positively contributing to minimum load and cycling operation.

(3) Operation with a reduced number of mills to ensure stable lower load operation.

(4) Check and potential replacement of start-up related temperature measurements (if already installed) in order to evaluate the thermal stress of thick-walled components. This allows more ambitious temperature gradients by reducing the design buffer and thereby resulting in more efficient start-up. A FEM-analysis would be beneficial for the reassessment of admissible temperature limitations.

Initially, these measures can be implemented in non-pit head stations or the stations, which are likely to be under flexible operation because of its high Energy Charges. For Pithead stations, this may be implemented at a later stage. Based on the study, the sub critical unit should be considered for implementation. The cost of implementing these measures for NTPC's Non-pithead stations(Cap-11410 MW,30 Units) will be USD 180,00,000 to 36,00,000 (INR 117 to 234 Crores).The cost per MW will be INR 1 to 2 Lakhs approximately.

This should also be implemented in other similar ISGS, IPPs and state utilities. For state Utilities, the cost per MW will be higher due to smaller unit size.

The implementation of the above measures requires the involvement of OEMs – BHEL, Siemens, and GE etc. to address the issues of safety and long-term equipment health. Further OEMs involvement are also required for implementation of measures in super critical units.

Timelines for Implementation at each unit: 6 to 12 Months. The implementation may be coordinated by CEA and assisted by BHEL where OEM involvement is required.

C. As per VGB recommendations, the **minimum load of down to 25 percent is possible only with good quality of coal** (volatile content – water and ash-free (waf) – of coals used in European plants is 35 to 40 per cent). For Indian coal, there will be additional cost

for coal washing. This may not be practical on a large scale in the present scenario. Moreover, investment of USD 24, 00,000 (Rs. 15.60 Crores) will be required for each unit.

Timelines for Implementation: 6 to 12 Months

These measures are not feasible for the Indian Scenario, as the same has been based on the assumption of good quality coal that is not practical for Indian condition. Further studies involving more consultants through JCoal, USAID and OEMs may be considered before implementation.

D. Implementation of recommendations for start-up optimization will incur an expense of USD 5.00.000 to USD 12.00.000 (Rs. 3.25 Crore to 7.80 Crore) for each unit.

Flexibilisation of coal stations will require frequent starts/stops. Start-up optimization will be required to be implemented along with measures for 40% minimum load,

Timelines for Implementation: 4 Months. To be coordinated by CEA and BHEL.

E. To manage the consequences of cycling operation it would be necessary to install condition-monitoring equipment as recommended by VGB. The cost implications would be USD 1, 00,000 to USD 3, 00,000 (Rs 0.65 Crore to Rs 1.95 Crore) for each Unit.

Timelines for Implementation: 4 Months. To be coordinated by CEA and BHEL.

F. For Capacity Building ,KWS has suggested for **"Training the Trainers"** .The Task Force recommends that **Trainers from Germany should organise the same in India in a "hub Institution"** like NTPC's Power Management Institute or NPTI(National Power Training Institute. Simulator Training must include modules on Flexible operation.

Timeline: 6-12 Months. To be coordinated by CEA.

G. Ernst and Young has not provided a clear and implementable market / compensatory framework to favour flexible operation of coal-fired power plants. For implementation of the measures of flexibilisation, a compensation mechanism needs to be in place to accommodate the additional CAPEX and OPEX for enhancing Flexibilisation. **The Task Force recommends that Consultants through JCoal and USAID be engaged to conduct separate studies on Compensation mechanism.**

Timeline: 6-12 Months. To be coordinated by CEA and POSOCO

The Task Force concludes that:

- Measures for 50 % is to be implemented in all stations including Central, IPPs and State Utilities.CEA to coordinate with assistance from NTPC.
- Measures for 40% minimum load should be implemented in a phased manner, initially in all sub-critical units of Central, IPPs, and State Utilities, which are likely to be under part load operation due to their high Energy Costs. In addition, start-up optimization and installation of condition-monitoring equipment is also necessary for sustainance of flexible operation. The same can be implemented in other units at a later stage, coordinated by CEA and assisted by BHEL.
- The cost implication for measures (B),(D) & (E) will be USD 12,00,000 to 27,00,000 (INR 7.8 to 17.55 Crores) per unit. If it is to be implemented in NTPC Non Pithead stations, the cost per MW will be INR 2 lakhs to 4.6 Lakhs.
- Trainers from Germany should organise the "Training for Trainers" in India in a "hub Institution".CEA to coordinate the implementation.
- Separate studies on Compensation mechanism through consultants is required to be conducted. To be coordinated by CEA and POSOCO.