# The Development of CLP's Pulverized Fuel Ash (PFA) in Hong Kong

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# Agenda

- CLP Overview
- Castle Peak Power Station (CPPS)
- CLP's PFA Studies
- PFA Applications and Advantages
- Coal Ash Production Process, Handling, Storage and QC Facilities
- Properties and Characteristics of CLP's Coal Ash
- Classified PFA Quality Control System
- CLP's PFA Production – Past and Future
- Conclusions

# CLP Overview


- Founded in HK in 1901
- Operate in five regions including Hong Kong, China, India, SE Asia, Taiwan and Australia.
- Serving 2.46 million customer accounts representing 80% of Hong Kong's population
- Operate three power stations in Hong Kong with total installed capacity of 6,908MW
- Manage nearly 14,700km of cable, and more than 14,000 substations.

| | |
|---|---|
| Supply area | Nuclear |
| Coal | Pumped storage |
| Natural gas | Control centre |
| Oil | 132kV substation |
| 400kV substation | 132kV circuit |
| 400kV circuit | 132kV Submarine cable |

4 * 677MW, 4 * 350MW
Castle Peak Power Station
Coal Fired

8 * 312.5MW
Black Point Power Station
Natural Gas

3 * 100MW
Penny's Bay Power Station
IDO

2 * 984MW * 70% +
Daya Bay Nuclear Power Station

1200MW * 50% +
Guangzhou Pumped Storage Power Station

+ CLP's right of Utilization

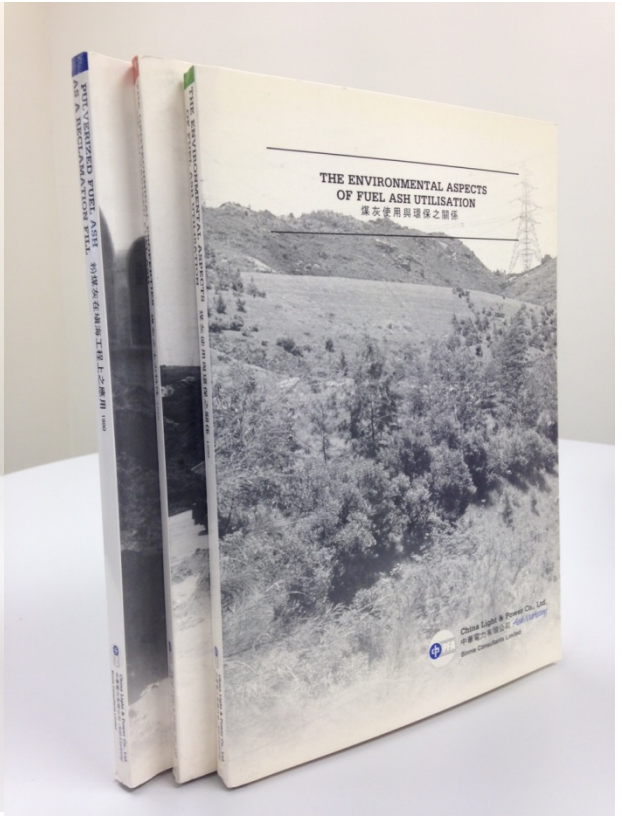
# Castle Peak Power Station (CPPS)

- A coal-fired power station
- Commissioned in: 1982 to 1990
- CPA: 4 x 350MW  CPB: 4 x 677MW
- Gross Installed capacity:  4,108MW
- Primary Fuel: Coal
  - >90%: Sub-bituminous coal (low calorific value LCV)
  - <10% Bituminous (high calorific value HCV)
- Major coal sources: Indonesia & Australia
- Annual Electricity Sent-out: 20,280 GWh in 2014
- Coal consumption: 9.75 MT (Physical) in 2014
- Ash production: 374kT in 2014

**CPPS is one of the major facilities for the supply of electricity and PFA for the Hong Kong economy**

# CLP's PFA Studies

From 1988 to 1998, CLP carried out a comprehensive research on the benefits of using PFA Concrete in Hong Kong


- Field & Laboratory Studies for PFA Concrete:
  - Compressive Strength
  - Tensile & Flexural Strength
  - Deformation Behavior
  - Durability
  - Fresh & Early-Age Properties
  - Concrete Mix Design
- Geotechnical properties of PFA fills
- Site application of PFA as reclamation fill
- Environmental Aspects of PFA Utilization

**Research results indicated that use of PFA in concrete will impart improved workability, long-term strengths and durability to the finished product**

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# Applications and Advantages of PFA

CLP has been supplying PFA to Hong Kong construction industry since 1993

## Major PFA Applications

- Up to 35% cement replacement in concrete production
- Raw material for cement production, blending material for cement
- Construction of pile caps and substructures
- Production of other construction materials, e.g. mortar, grout

## Main Advantages:

- Low heat of hydration
- Reduce thermal cracking
- Improve workability
- Improve pumpability
- Good chemical resistance
- Cost saving

**Benefits of recycling of PFA are of threefold: Economic, Environmental & Technological**
**Significantly reduce land costs and support sustainable development**

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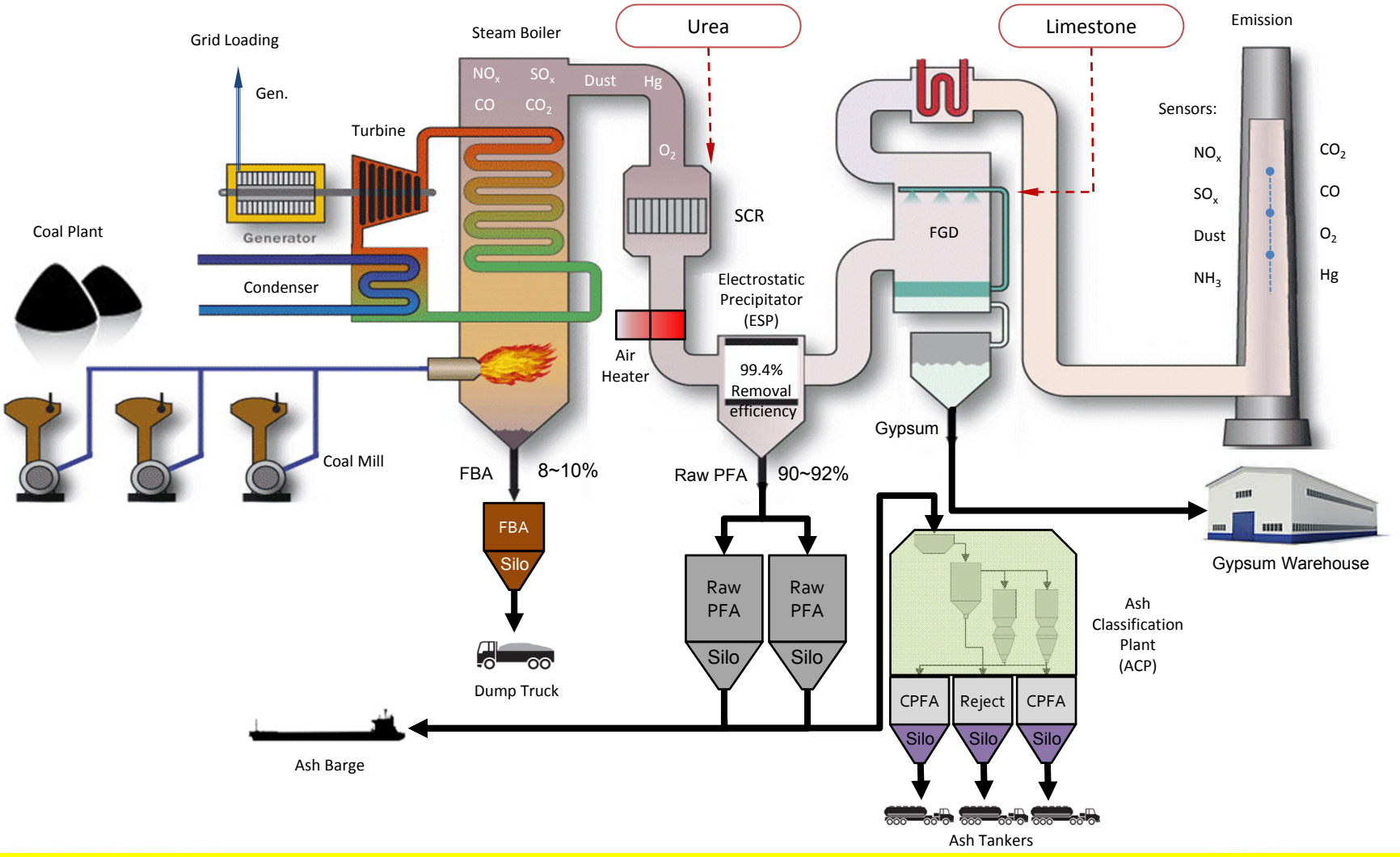
# Coal Ash Production Process




**CLP captures almost every bit of coal ash produced from electricity generation for recycling to minimize the impact to the environment**

# Ash Handling, Storage and QC Facilities

**Electrostatic Precipitators (ESP)**
- Collect PFA from flue gas

**On-site Laboratory**
- Quality control & monitoring

**ACC & FBA silos**
- Collect & store FBA
- Truck loading facilities

**Ash Classification Plant (ACP)**
- Separate fine PFA from coarse PFA
- Storage for both Classified PFA and Reject
- Ash Tankers loading facilities

**Raw PFA silos**
- Buffer storage for raw PFA

**Heavy Loading Berth**
- Load ash to barge

**CPPS has all sorts of facilities for handling, storage, control & monitoring of the quality of various kinds coal ash products**

# Type of CLP Coal Ash and Properties

- Coal Ash Content: 2~7% in coal using by CLP
- Composition: $SiO_2$, $Al_2O_3$, $Fe_2O_3$, CaO, MgO, $Na_2O$, $K_2O$, $TiO_2$, $Mn_3O_4$, $SO_3$, $P_2O_5$
- Collect different ash products at different locations:
  - Boiler furnace bottom: Furnace Bottom Ash (FBA)
  - Electrostatic Precipitator: Pulverized Fuel Ash (PFA)
  - Ash Classification Plant: Classified PFA (CPFA) and Reject PFA

| Major Composition | FBA | Raw PFA | Classified PFA |
|---|---|---|---|
| LOI | ~3% | ~1% | 0.5 ~ 2.5% |
| $SiO_2$ | ~50% | ~40% | 47 ~ 57% |
| $Al_2O_3$ | ~18% | ~20% | 17 ~ 25% |
| $Fe_2O_3$ | ~15% | ~15% | 10 ~ 15% |
| CaO | ~11% | ~14% | 8 ~ 15% |

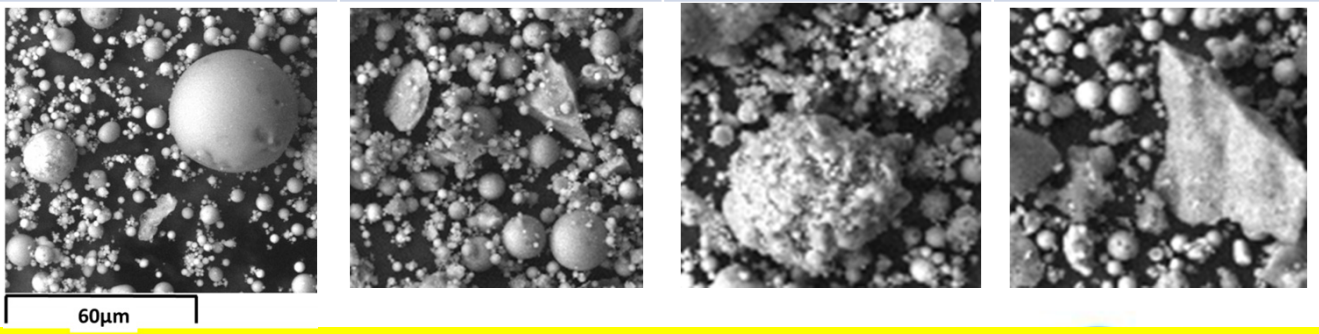
**Ash products have no significant variation in composition but size**

# Characteristics of CLP's Classified PFA

| *Major Composition* | CLP's PFA (Typical range) | PFA Sample 1 (Local Supplier) | PFA Sample 2 (Imported, PRC) | PFA Sample 3 (Imported, PRC) |
|---|---|---|---|---|
| $SiO_2$ | 47% to 57% | ~60% | ~49% | ~52% |
| $Al_2O_3$ | 17% to 25% | ~23% | ~33% | ~33% |
| $Fe_2O_3$ | 10% to 15% | ~6% | ~6.5% | ~3.8% |
| MgO | 3.5% to 7.7% | ~2% | ~1% | ~1% |

| *Properties* | | CLP's PFA (Typical range) | PFA Sample 1 (Local Supplier) | PFA Sample 2 (Imported, PRC) | PFA Sample 3 (Imported, PRC) |
|---|---|---|---|---|---|
| Water Requirement | (≤95%) | 90 to 92% | 96% | 96% | 98% |
| Strength Factor | (≥0.80) | 0.89 to 1.00 | 0.90 | 0.88 | 0.83 |
| Initial Setting Time | (≥OPC) | 170 to 200min | 210min | 255min | 255min |
| Calcium Oxide | (≤20%) | 8% to 15% | 7.0% | 6.5% | 5.8% |
| Fineness (45μm sieve) | (≤12%) | 8% to 10% | 7.0% | 7.3% | 10.6% |

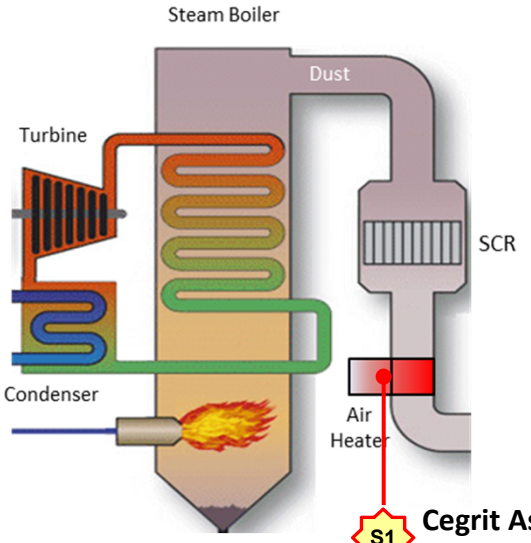
*Electron Microscope Images (x1000)*

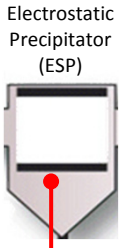


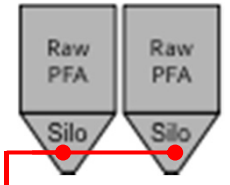

**PFA production process can largely affect the PFA properties, PFA originated from burning of coal without further processing could offer relatively low water requirement, short initial setting time & high strength**

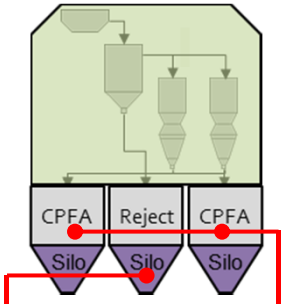
# Classified PFA QA & QC System

- Upstream : Coal ash properties as one of the coal selection / evaluation criteria
- Downstream : Frequent & regular testing of samples from various locations of the PFA production line




**S#** **Quality Control Points**

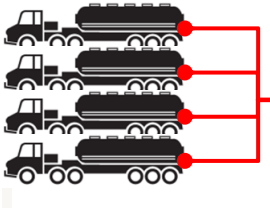
**S1** **Cegrit Ash Sample**
- LOI
- Freq.: Daily

**S2** **ESP Ash Sample**
- LOI, $SO_3$, CaO
- Freq.: Daily

**S3** **Raw Ash Sample**
- LOI
- Freq.: Ad hoc

**S4** **Reject Ash Sample**
- Fineness
- Freq.: 4/day

**S5** **CPFA (Silo) Sample**
- Fineness, LOI
- Freq.: 4/day



**S6** **CPFA (Tanker) Sample**

**Monitoring Parameters (BS 3892 Part 1 :1997 Requirements)**
- LOI, $SO_3$, $Cl^-$, CaO
- Fineness, Bulk Density, Particle Density, Specific Gravity
- Initial Setting Time, Strength Factor, Pozzolanic Activity
- Water Requirement, Moisture Content, Soundness

**Additional**
- MgO, TA, NASA
- Freq: 25% (one every 4 trucks)

**CLP controls and monitors the PFA quality throughout the entire supply chain i.e. from selection of coal to PFA delivery to ensure high quality products are delivered to customers**

# Laboratory Testing Equipment

## *Chemical property tests*

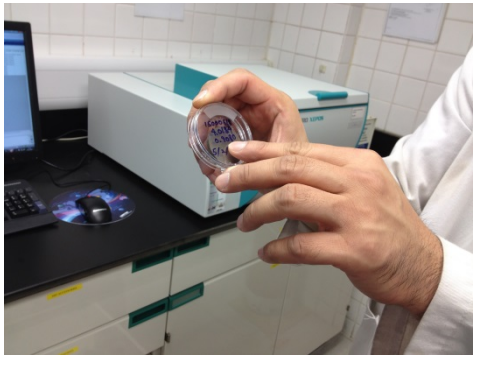
- Inductively Coupled Plasma Spectrometer (NASA)
- X-Ray Fluorescence Spectrometer (chemical composition)
- Sulphur Analyser
- TGA (LOI)
- Titration (Chloride ions)


**Inductively Coupled Plasma Mass Spectrometer (ICP-MS)**

## *Physical property tests*

- Compression Machine
- Flexural Machine
- Curing Tank, Mist Chamber, Mortar mixer
- Particle Size Analyser
- Setting time measurer
- Flow table (Water Requirement)
- Speed Sieve (Fineness)
- Oven (Moisture)
- Expansion Mold (Soundness)
- Vacuum density measurer

**Laser diffraction Particle Size Analyzer**




**X-Ray Fluorescence Spectrometer**

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# Test parameters for BS 3892:Part 1:1997

| | Parameters | Testing Method | HOKLAS |
|---|---|---|---|
| Physical Properties | Moisture | BS 3892:Part 1:1997 Annex C | √ |
| | Fineness | BS 3892:Part 1:1997 Annex D | √ |
| | Particle Density | BS 3892:Part 1:1997 Cl.7 | |
| | Water requirement | BS 3892:Part 1:1997 Annex E | √ |
| | Strength Factor | BS 3892:Part 1:1997 Annex F | |
| | Initial Setting Time | BS 3892:Part 1:1997 Cl.10 | |
| | Soundness | BS 3892:Part 1:1997 Cl.11 | √ |
| Chemical Properties | Sulphur Content | ASTM D 5016-95 | √ |
| | Loss on Ignition | BS 3892:Part 1:1997 Cl.12.2 | √ |
| | Chloride Content | BS EN 196-21:1992 Cl.4 | √ |
| | Calcium Oxide | In house Method SOP-A-11* | √ |

* Dissolution of the test portion is done in accordance with BS EN 196-2:1995 Cl.13. Analyses are measured by using ICP-OES

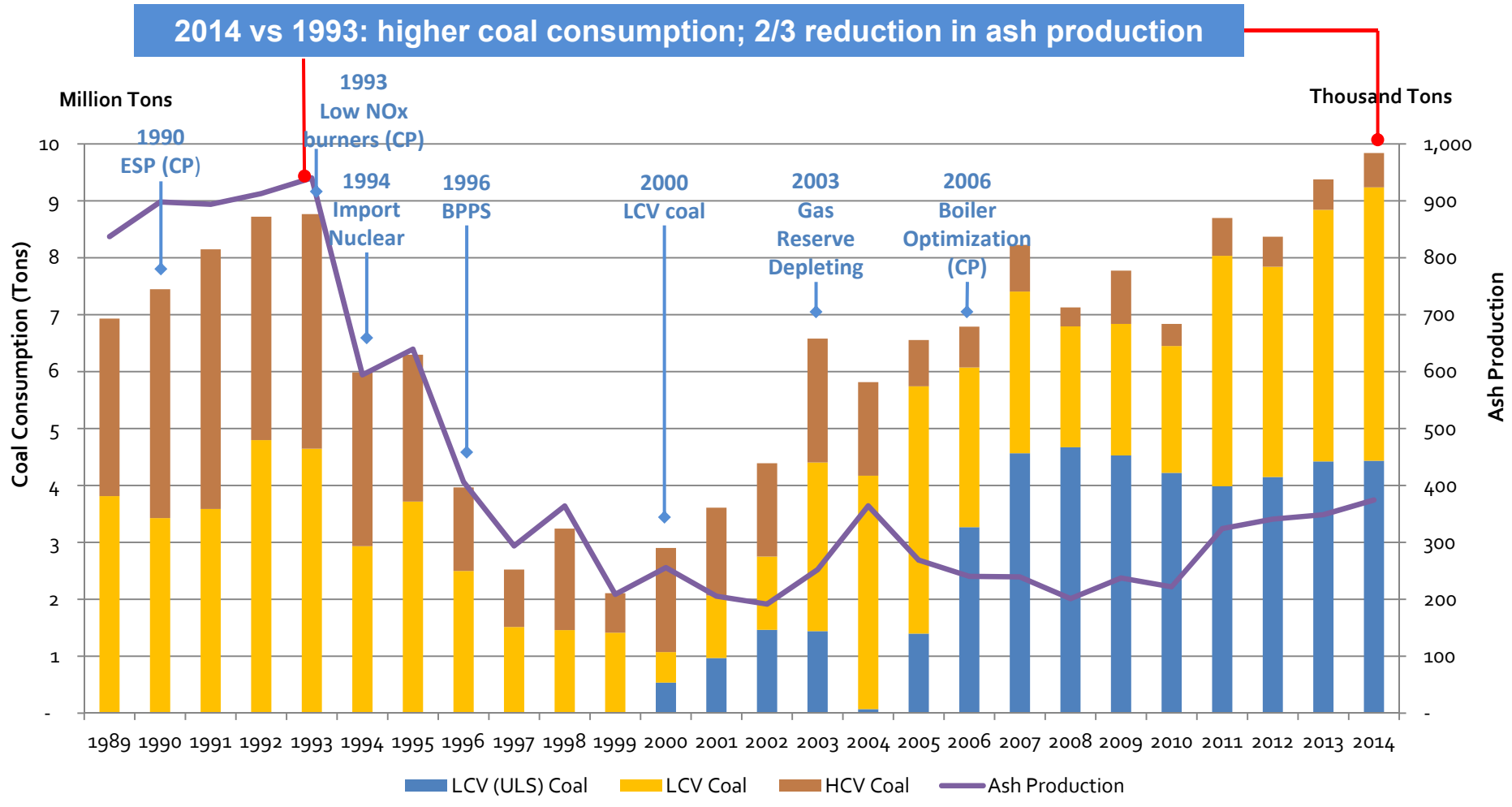
# Other relevant PFA's Test parameters

| Parameters | Testing Method | HOKLAS |
|---|---|---|
| Total Alkali Content | In house Method SOP-A-14* | √ |
| Potassium Oxide Content | In house Method SOP-A-14* | √ |
| Sodium Oxide Content | In house Method SOP-A-14* | √ |
| Nitric Acid Soluble Alkaline | In house Method SOP-A-12** | √ |
| Potassium Oxide Content | In house Method SOP-A-12** | √ |
| Sodium Oxide Content | In house Method SOP-A-12** | √ |
| Silica Content | ASTM D3682 | |
| Iron Content | ASTM D3682 | |
| Alumina Content | ASTM D3682 | |
| Insoluble Residue | EN 196-2:1994, Cl.9 | |

* Dissolution of the test portion is done in accordance with BS EN 196-21:1992 N.A.5.2. Analyses are measured by using ICP-OES
** Dissolution of the test portion is done in accordance with BS EN 196-21:1992 N.A.5.1. Analyses are measured by using ICP-OES

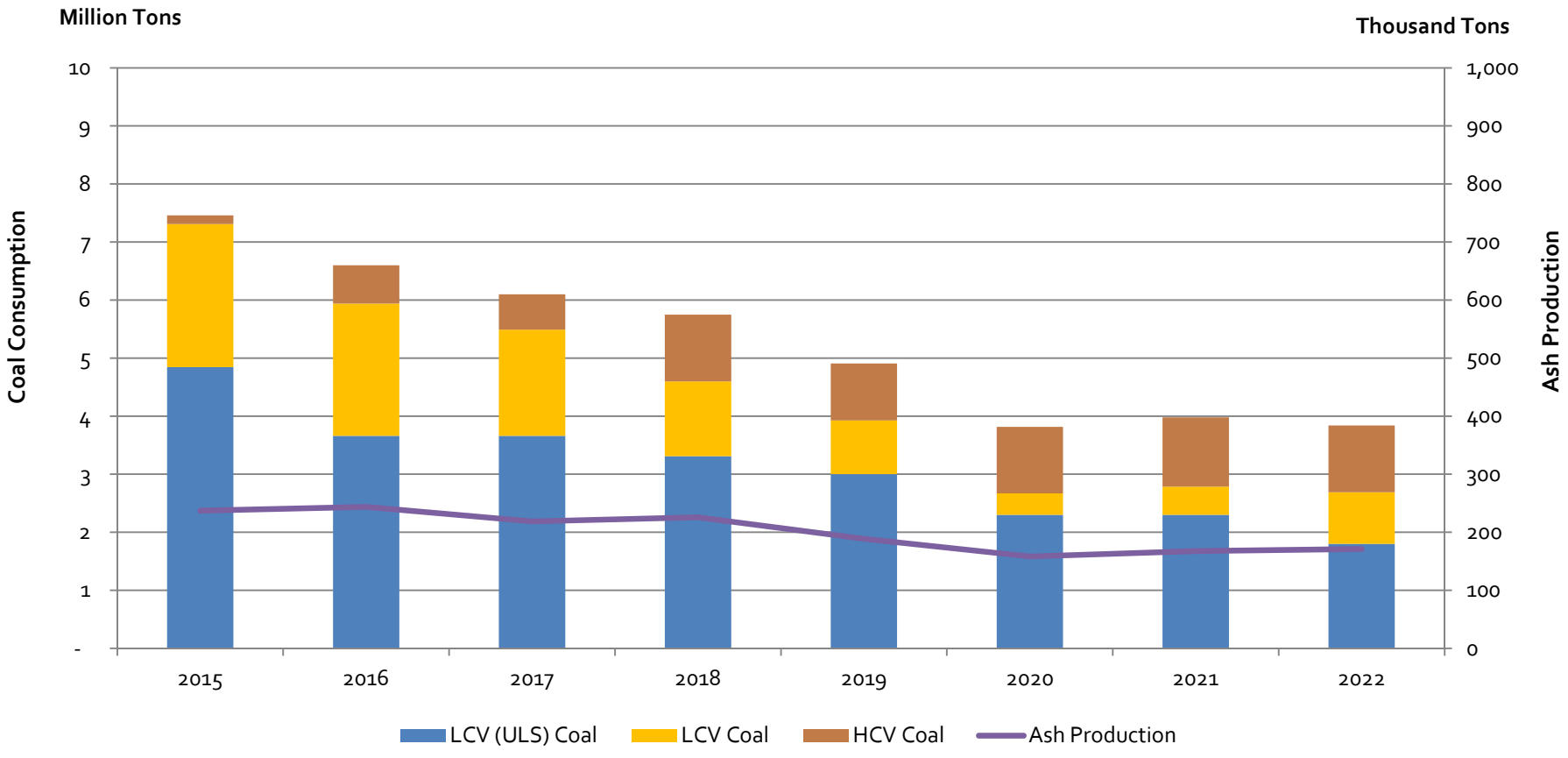
**CLP has put considerable resources on its PFA testing facilities and development of technical know-how to ensure efficient and accurate testing results are obtained and compliance with specification requirements**

# Historical Trend of CLP's PFA Production




**CLP started to use clean coal since 2000 to enable generating electricity at low costs, low emissions and low ash production to minimize impact to the environment**

# CLP's PFA Production Forecast




**35~40% year-on-year reduction in 2015 ash production, and moderately reduce in next 5 years.**
**In long run, more natural gas will be used for electricity generation and additional nuclear power will be imported, coal consumption and hence PFA production will be further reduced**

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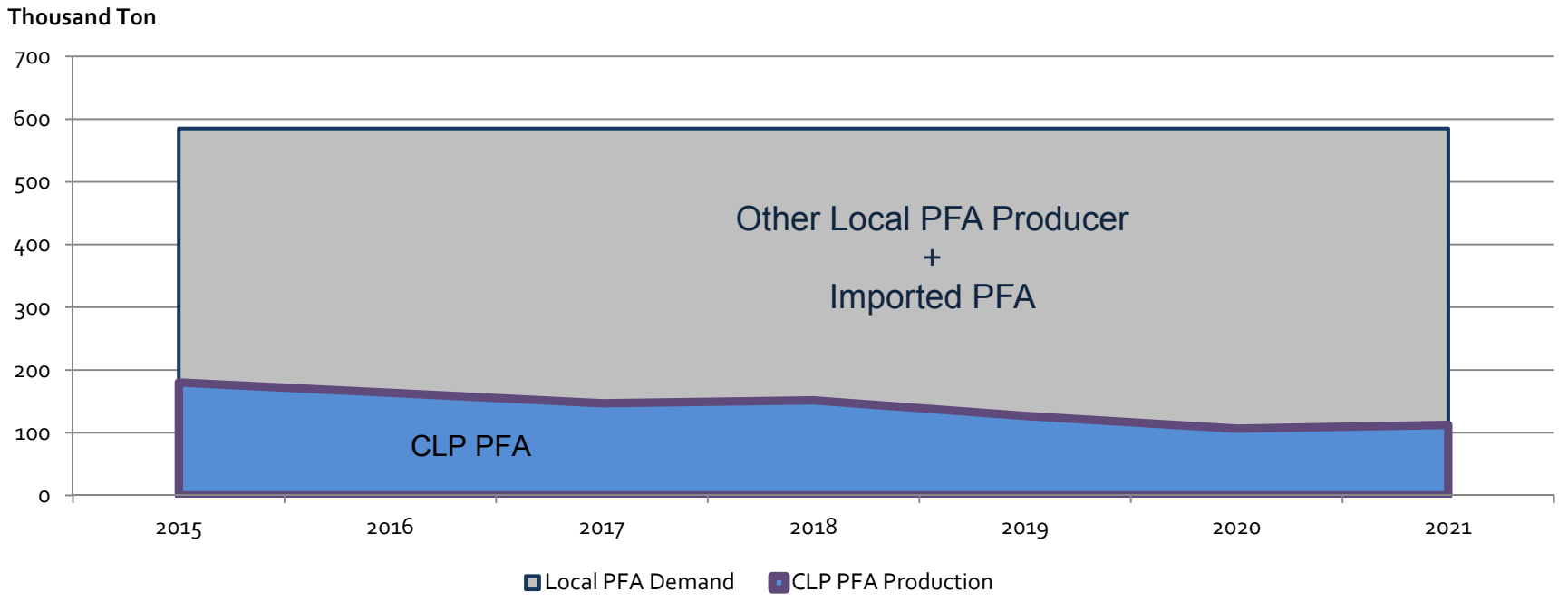
# 5-year PFA Demand & Production Outlook




- Several large projects and railway projects to be started in or after 2015, and hence high and stable concrete requirement is expected for next 5 years
- Estimated annual concrete requirement: approx. 6 to 7 million cubic metres
- Estimated annual PFA concrete requirement: approx. 4.8 million cubic metres
- Estimated annual PFA requirement: approx. 585kT

**Local PFA supply will be reduced moderately in the coming few years, increase reliance on PFA imported from Mainland China and other countries is expected**

# Conclusions

- CLP will keep on recycling as much coal ash as possible for economic, environmental, and technological reasons
- CLP will continue to support local construction industry with high quality PFA as long as Castle Peak Power Station is still in operation
- PFA supply from local producers will be diminished in the coming years and more PFA will be imported from China and other countries
- Quality of imported PFA varies and users should be careful in selection of PFA supplier(s) and throughout understanding of its production process is required.
- Implement necessary measures to uplift quality control and monitoring on PFA quality.

# Thank you

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