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The Successful Evolution of CTX Technology in China

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www.cornerstonemag.net

Overview

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- Communicating Coal's Role
- China's Coal-Fueled Development
- The Evolution of CTX in China
  - Overview
  - ICTX
  - Case Study: Shenhua Group's DCTL project

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Communicating Coal's Role

Cornerstone

- Launched in 2013 by the World Coal Association (worldcoal.org)
- Constructive forum
- Published quarterly
- 6000 English copies
- 4000 Mandarin copies
- Website: cornerstonemag.net
- Offered free of charge

Shenhua Group at a Glance

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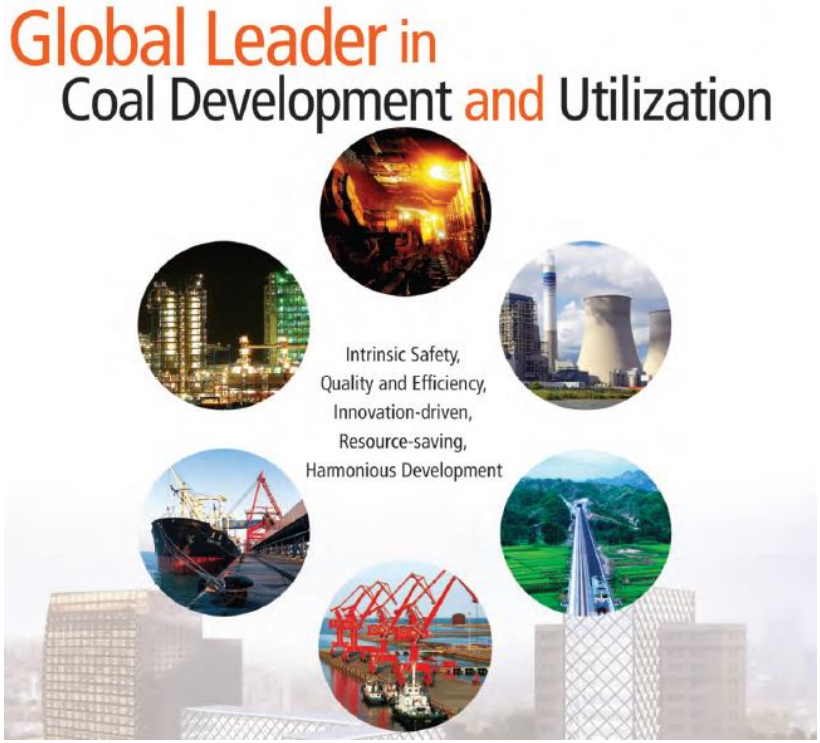
- Production
  - 2012 coal sales: 464.6 million t
- Transportation
  - Rail
  - Ports
- Conversion
  - Coal-to-liquids/chemicals
  - Electricity generation (207.9 billion kWh in 2012)



Shenhua Group at a Glance

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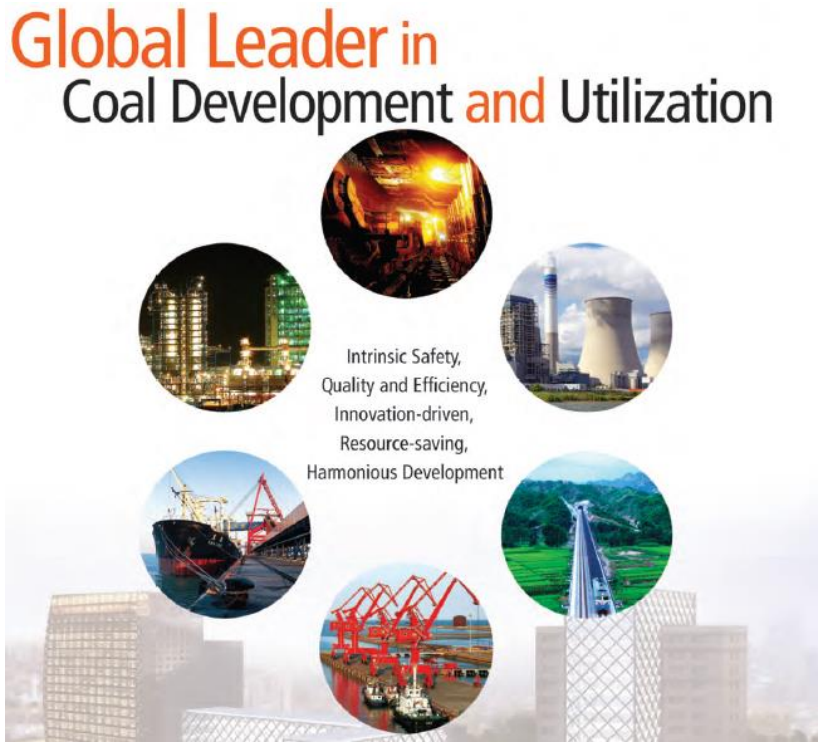
- 178 on 2013 Fortune Global 500 with operating revenue of $54 billion
- 2013 winner World Coal Association Leadership on Mining Safety (fatality per million tonnes of coal half of U.S. average)



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China’s Coal-Fueled Development

Dramatic Growth

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- 650+ million people lifted out of poverty
- Responsible for nearly all recent poverty alleviation
- 99% electrification
- “Growth at all costs”

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China’s energy situation

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- Largest energy producer and consumer
- Net oil exporter until the 1990s
- China is expected to become the largest oil importer in 2014
- Increasing LNG imports
- Generally moving toward market-based energy prices

China is largely fueled by coal

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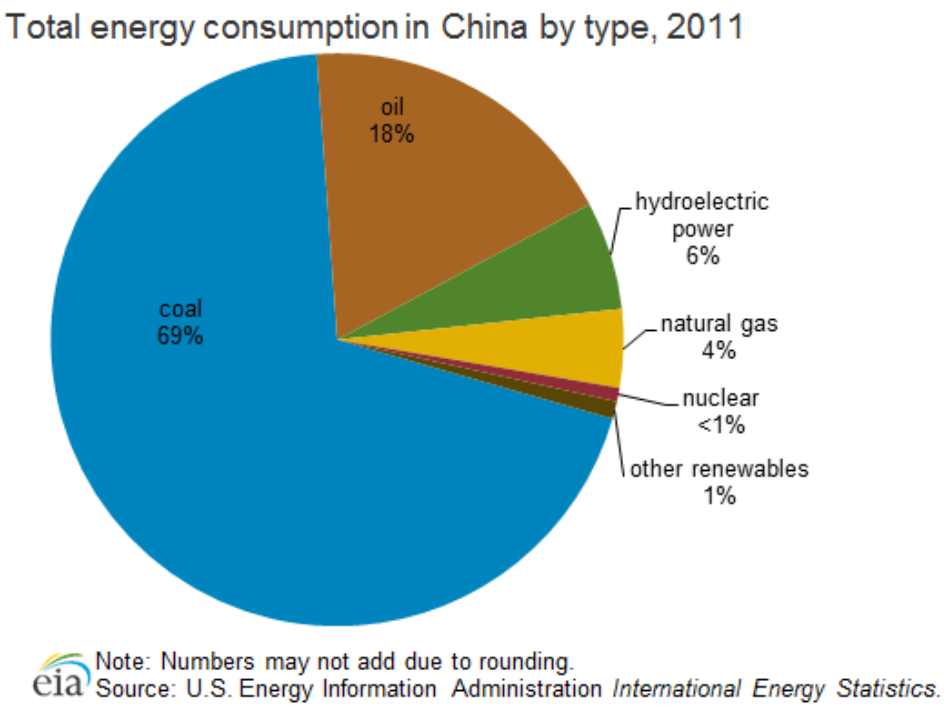
- 2011: 69% primary energy from coal
- EIA Estimates:
  - 2020: 65%
  - 2040: 55%
  - Even as percentage decreases, total consumption increases by 50%



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China's CTX Industry

Coal is a raw material

Solar + Wind + Nuclear

H_2

Electricity to Process

Electricity to Grid

Biomass

Waste

Coal

New Coal-based Polygeneration

Fuels

Chemicals

Coal is a raw material

Solar + Wind + Nuclear

H_2

Electricity to Process

Electricity to Grid

Biomass

Waste

Coal

"The development of unconventional energy and renewable energy can change not only the coal-dominated energy mix, but also brings about multiple possibilities for coal conversion pathways …"

Fuels

Chemicals

CTX in China: Three Stages

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- Prior to 1980
  - Technology pioneered in South Africa by Sasol
  - China did not become involved in early ICTX development

CTX in China: Three Stages

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- 1980-2000
  - Rapid ramping up of CTX R&D
  - Playing catch-up
  - Most world focused on Cobalt F-T catalysts, China focused on Iron F-T catalysts
  - Shanxi Institute of Coal Chemistry developed a two stage process with two configurations & tested at pilot scale
    - Two fixed beds in series to improve efficiency
    - Modified F-T slurry reactor and fixed bed in series

CTX in China: Three Stages

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- Post-2000
  - China takes the place as the world leader of CTX development and deployment
  - Shenhua Group DCTX
  - ICTX
    - Shenhua Group
    - Yankuang Group
    - SXICC – Mass production of catalyst
    - SXICC, Yitai Group/Synfuels China
    - Sinopec GTL

ICTX in China

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- Fuels
  - Lower sulfur
  - Fewer aromatic hydrocarbons
  - Higher cetane number
  - High quality fuel produced
  - Used for blending
- Products
  - Wax, oil, etc.
  - Major R&D area

F-T is key to ICTX

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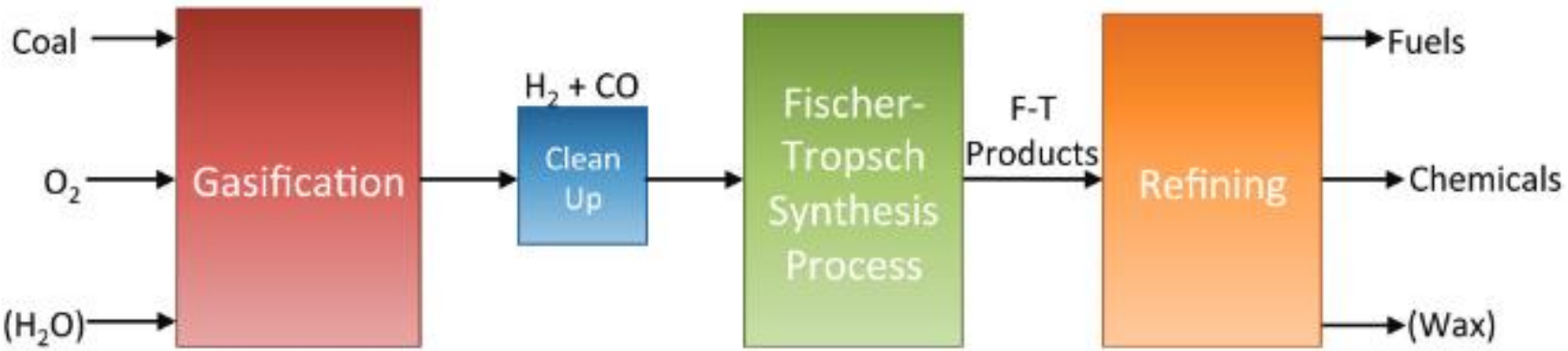

Volume 1, Issue 3 of Cornerstone includes a detailed technical discussion of ICTX

China's Experience in ICTX

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- Due to rapid growth, most operators have experience at several scales of development
- 2004: Pilot
  - Yanhuang 10-ktpa
- 2006-2009: Demonstrations
  - Shenhua, Yitai, Lu'an 160-180 ktpa demo Synfuels China ICTX Technology

Planned ICTX Plants

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Company	Location	Scale (10 ktpa)	Estimated Completion Date	Selected Technology
Shenhua Ningxia Coal Industry Group	Ningxia Province	400	2016	Iron-based catalyst, low-temperature Fischer-Tropsch (LTFT), slurry bubble column reactor (SBCR)
Shenhua Group	Inner Mongolia Xinjiang Province	100	Uncertain	
Yankkuana Group	Yulin Shaanxi Province	100	2015	
Yitai Group	Inner Mongolia Xin	180 (first project)	Uncertain	
Lu'an Group	Changzhi Shanxi Province	3 × 50	2015	

Potential Improvements

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- As CTX is scaled-up up there will be engineering problems – look to Sasol's model for problem solving
- Iron versus Cobalt catalysts
- Reduce water usage
- Water waste is at least 5% organics
- Increase scale and reduce costs for water treatment

- Iron catalysts less expensive initially
- More sulfur tolerant
- Longer preparation cycle
- Consume more water
- Shorter overall active life
- R&D on Cobalt catalysts is ramping up

What about the carbon footprint?

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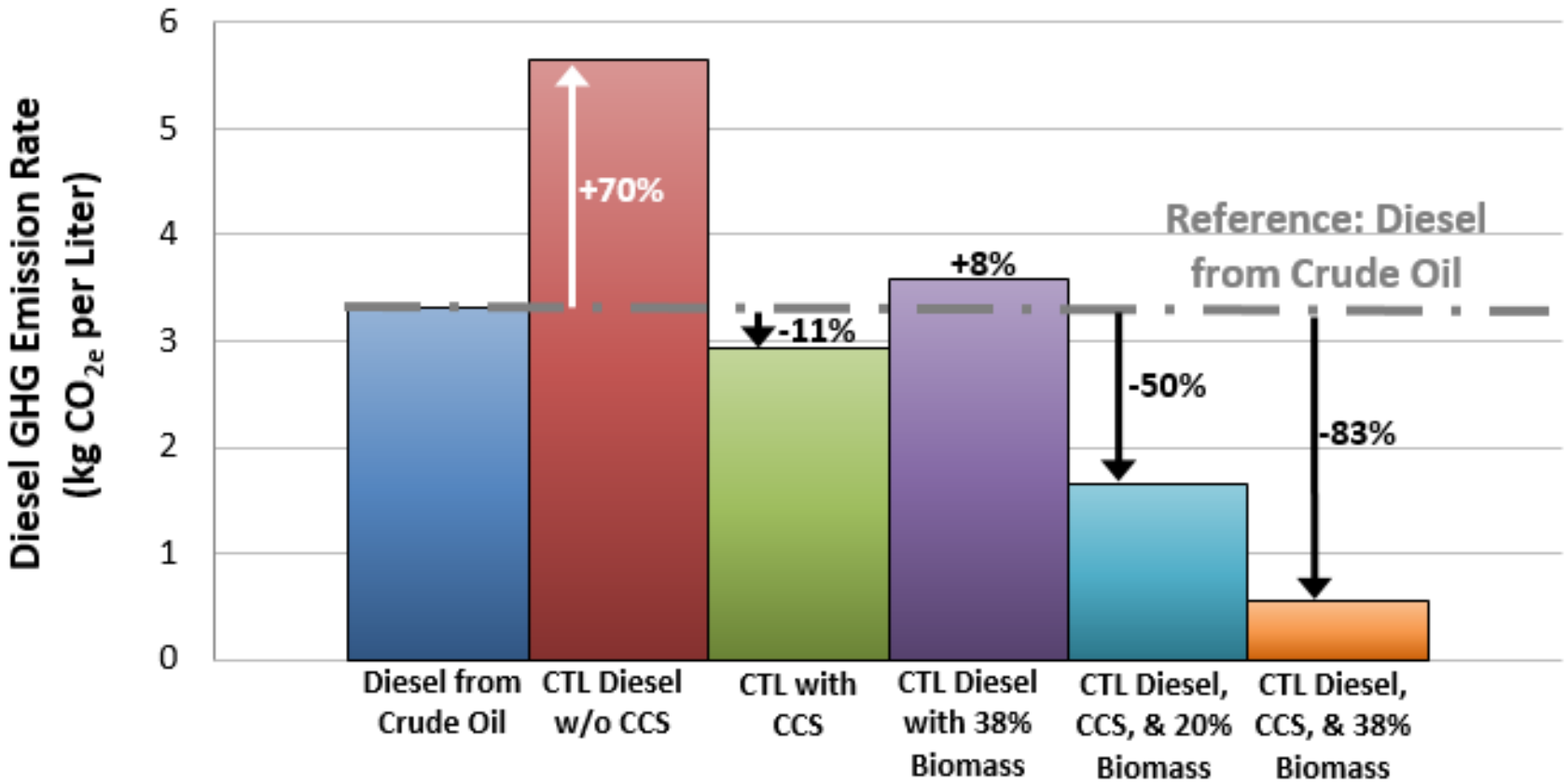

CTX in China Today

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- China's government is fast-tracking CTX plant permits and assisting with securing of capital
- In the last two years about 20 CTX plants have been built
- Increased CTX capacity by 45 million m^3/day
- Many of these are international collaborative ventures: Dow Chemical + Shenhua Group

Increasing energy diversity includes finding other non-petroleum sources of fuels and chemicals.

Why China is fast-tracking CTX

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- Reserves and infrastructure favor coal
- Energy security
- Coal producers are also coal-users
- Tremendous RD&D resources in the coal community
- Need low-sulfur transportation fuels

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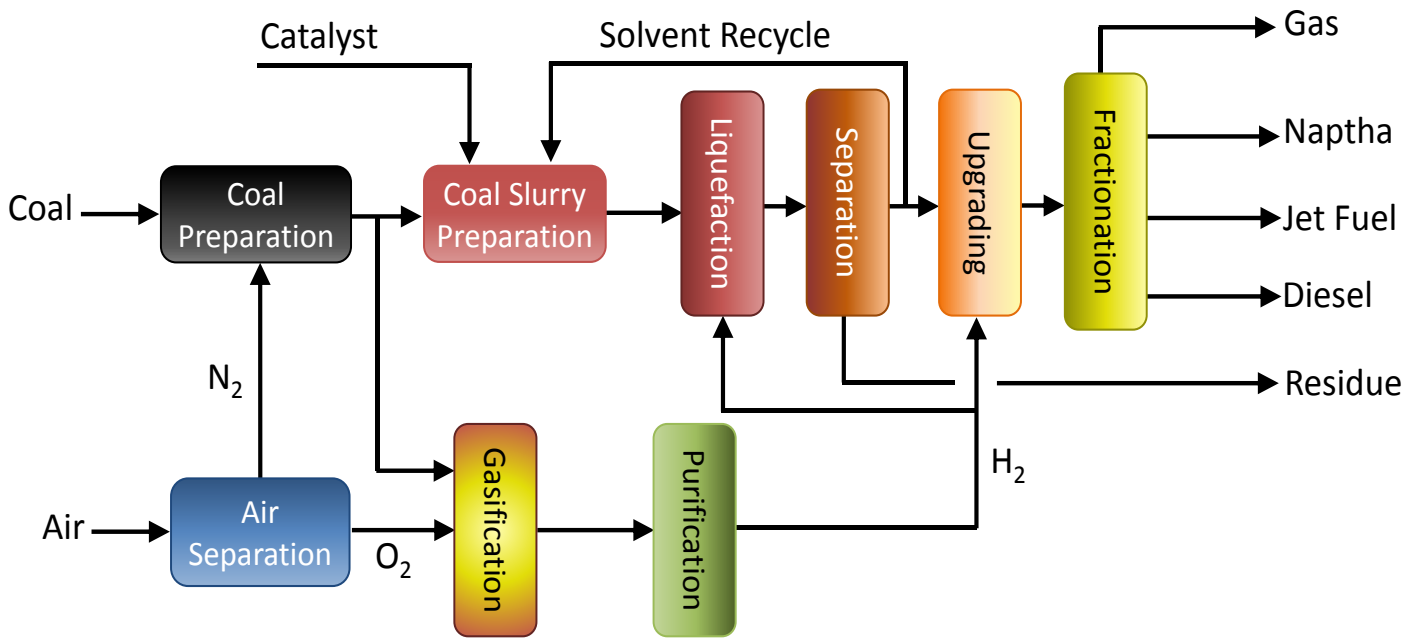
Shenhua Group's Direct Coal-to-Liquids

DCTX Process

- Coal dissolved in solvent at elevated temperature and pressure
- Combined with H_2 and a catalyst



Direct CTX

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- Industrial scale production first realized by Germany in WWII
- Wartime development
  - Cost not optimized
  - Long term development not considered
- Some R&D
- Questionable equipment life and operation reliability (including solid/liquid separation) with slurries at high temperature and pressure
- Generally left behind in favor of ICTX

Technical hurdles to overcome

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- Mineral accumulation in reactor
- High-Temperature, High-Differential Pressure Relief Valves
- Coking
- Increasing equipment capacity
- Wastewater

Shenhua's DCTX Project

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- 2011: Shenhua constructs 1080 ktpa – more than a five fold increase in size
- 2013: More than two million tonnes of synfuels
- 30 times larger than any other DCTX projects

Shenhua DCTX main features

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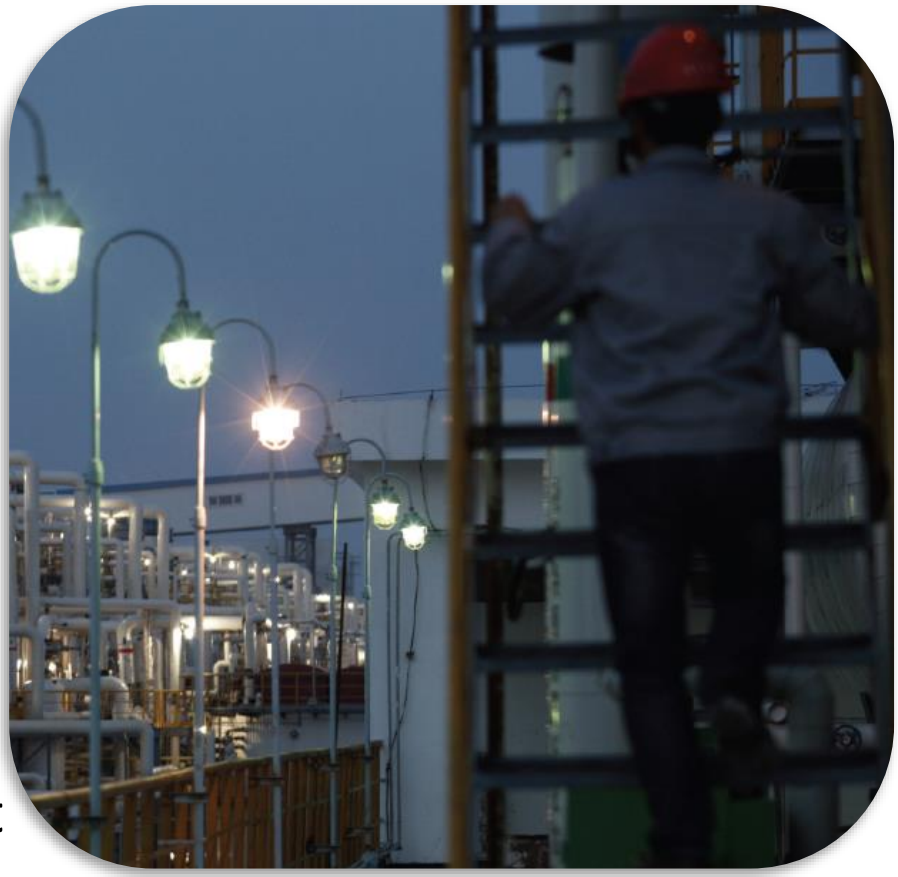
- Largest capacity of any single production line
- Superior synfuels yield
- Improved stability
- Process proven at bench, pilot, and demo-scale
- Major aspects of technology
  - High performance catalyst
  - Synfuels processing



Water

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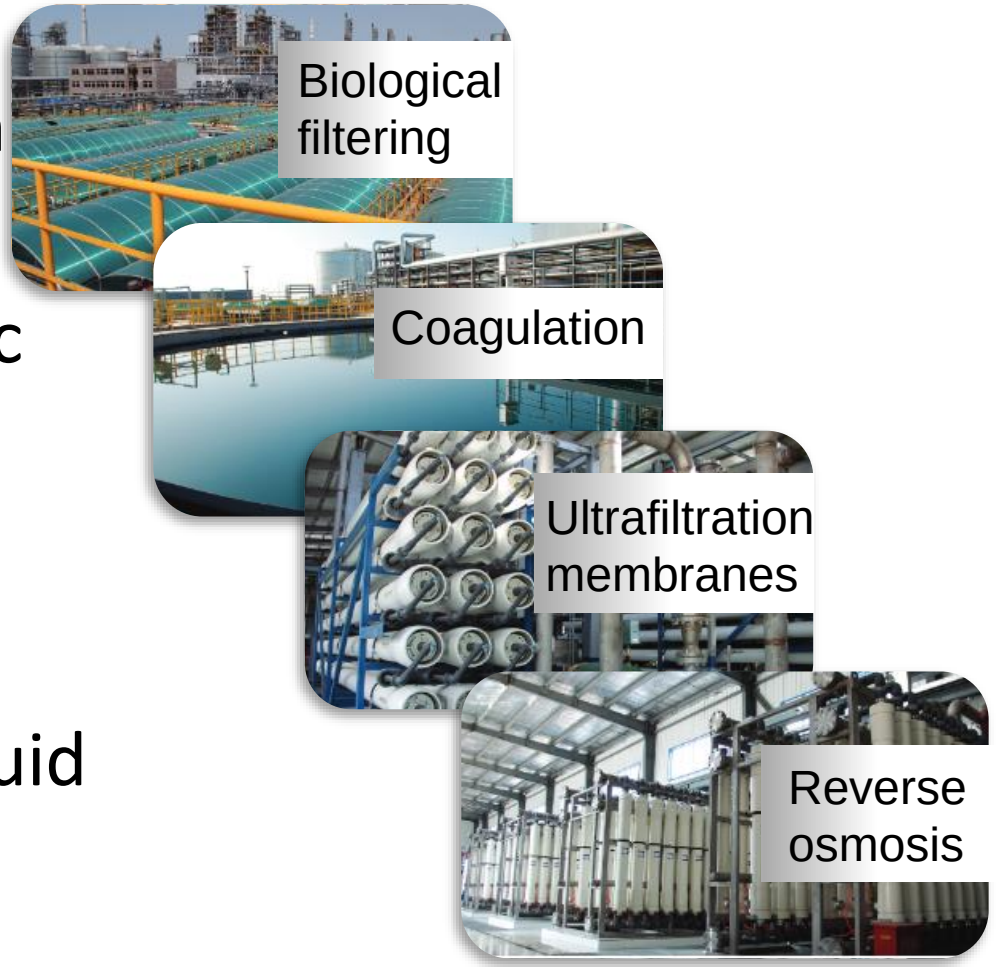
- Wastewater is high concentration
- Technology-specific treatment process
- RMB 890 million invested to date
- End goal is zero liquid discharge



Carbon capture

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- 100,000 tpa CCS
- Storage in saline aquifer
- Multi-stage monitoring
- Truck delivery of CO_2
- Cost at this scale is ~$44/tonne CO_2
  - Capital: $14
  - O&M: $30

Successful evolution of CTX

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Nation's 1st pilot ⇨ Customer's gas tanks in under a decade

WORLD COAL ASSOCIATION

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Thank you for your attention.

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