对标：工业节能潜力评估
**Benchmarking:**
**Evaluating Energy Saving Potential in Industry**

**April 8, 2008**
**2008年4月8日**
**Beijing• P.R. China**
**中国•北京**

**Lynn Price, Christina Galitsky, Zhou Nan**
**Energy Analysis Department**
**Environmental Energy Technologies Division**
**Lawrence Berkeley National Laboratory**
美国劳伦斯伯克利国家实验室
环境能源技术处
能源分析室

LAWRENCE BERKELEY NATIONAL LABORATORY

---

# 议程
# Agenda

- 项目背景 Project background
- 国际对标经验 International experience with benchmarking
- 最佳水泥工具演示 Demonstration of BEST-Cement
- 反馈以及下一阶段计划 Feedback and next steps

## 项目背景
## Project Background

- 国家法改委要求能源研究所开发对标工具用以支持千家重点用能企业项目

  NDRC requested that the Energy Research Institute (ERI) develop benchmarking tools in support of the Top-1000 Energy Consuming Enterprise Program

- 美国劳伦斯伯克利国家实验室在能源基金会的资助下为能源研究所提供技术支持

  LBNL is providing technical assistance to ERI, funded by the Energy Foundation's China Sustainable Energy Program

- 可能的情况下，能源所和劳伦斯伯克利国家实验室将为千家企业开发对标工具

  ERI and LBNL will develop benchmarking tools for the Top-1000 industrial sectors, as possible

- 初期工具的开发集中在水泥和钢铁工业

  Initial tool development focusing on cement and steel industries

LAWRENCE BERKELEY NATIONAL LABORATORY

3

## 对标
## Benchmarking

- 对标是用于评估设备或企业绩效(资金、生产、能源)的一种普遍性方法

  Benchmarking is a common way to evaluate facility or company performance: financial, production, energy, etc.

- 全球已经开发了一定数量的工业节能项目的节能对标工具

  Energy efficiency benchmarking tools have been developed for use in a number of industrial energy efficiency programs around the world

- 节能对标的不同类型 Various types of energy efficiency benchmarking:

  — 与同行对比

     Peer to peer

  — 定期自我对比

     Self performance over time

  — 与国家或地区平均或最佳实践对比

     Self performance to national or regional average and best practice

  — 与国际最佳实践对比

     Self performance to international best practice

- 不同类型的优缺点 Advantages and disadvantages to all types

LAWRENCE BERKELEY NATIONAL LABORATORY

4

## 定期与同行和自我对比
## Peer to Peer and Self Performance Over Time

挪威工业能效网络
**Norway's Industrial Energy Efficiency Network (IEEN)**

- 支持政府节能目标的项目

  Program in support of government's energy-savings goal

- **IEEN**为企业提供技术和资金支持：

  IEEN provided technical and financial support for companies to:

  — 承担能源管理活动 Undertake energy management activities

  — 评估企业的节能潜力，包括对标活动　Assess their energy-efficiency potential, including undertaking benchmarking

- **IEEN**开发了一套网络对标系统

  IEEN developed an internet-based benchmarking system

- 每年网上企业会员通过网络提供成果数据

  Every year industry network members provided performance data via the internet

LAWRENCE BERKELEY NATIONAL LABORATORY

5

---

## 定期与同行和自我对比
## Peer to Peer and Self Performance Over Time

- 参加的企业：铝业、面包店、啤酒厂、渔业、肉、乳制品、铸造业、纸业、木材制造业、洗衣店和干洗店 Participating industries: aluminium, bakeries, breweries, fishing, meat, dairy, grain-drying, fish meal, foundry, pulp and paper, timber and sawmill, laundries and dry cleaners
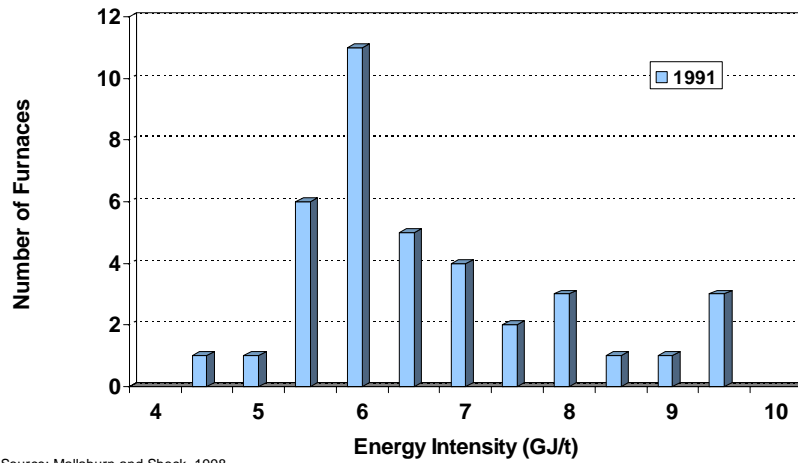
乳制品行业单耗 **Dairy industry specific energy consumption**
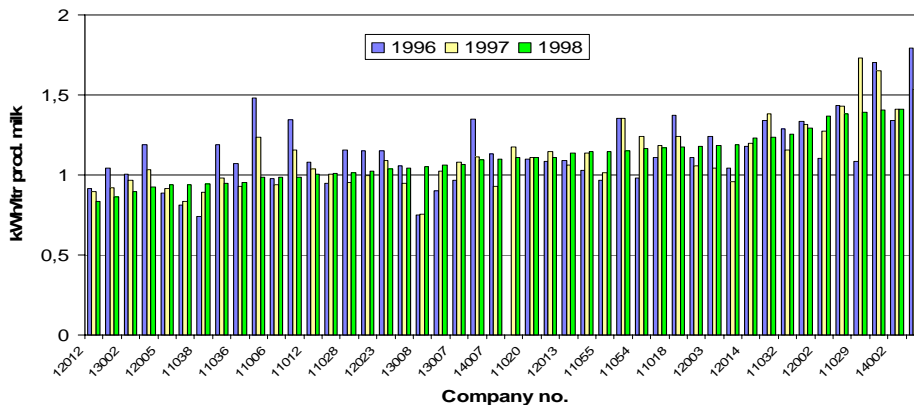


6

定期与同行和自我对比
**Peer to Peer and Self Performance Over Time**

**UK 最佳能效实践项目 UK Energy Efficiency Best Practice Programme**

对标Benchmarking – 玻璃制造熔炉Glassmaking Furnaces

Source: Mallaburn and Shock, 1998

LAWRENCE BERKELEY NATIONAL LABORATORY

7



定期同行业对比和自我对比
**Peer to Peer and Self Performance Over Time**

UK 最佳能效实践项目 UK Energy Efficiency Best Practice Programme
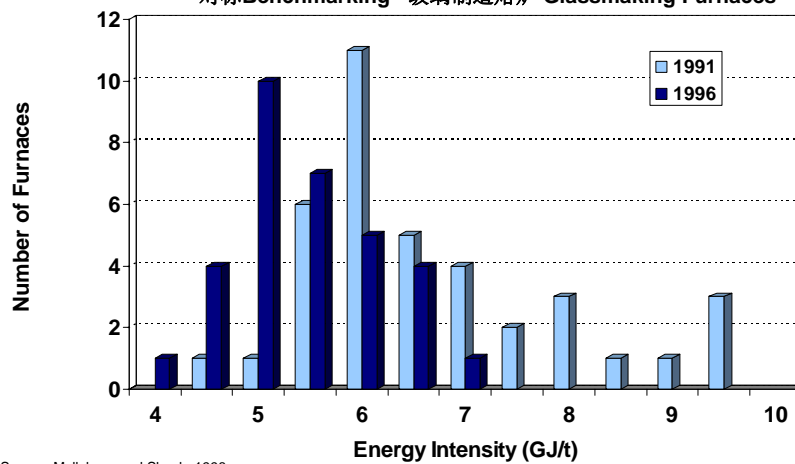
对标Benchmarking –玻璃制造熔炉 Glassmaking Furnaces

Source: Mallaburn and Shock, 1998

LAWRENCE BERKELEY NATIONAL LABORATORY

8

## 与平均和最佳实践对比
## Self Performance to Average and Best Practice

**欧洲委员会在自愿协议中的企业能效对标**
**European Commission**
**Energy Benchmarking at the Company Level Within**
**Industry Voluntary Agreements**

- 开发了一个自动的计算机系统，企业可以通过它与"最好的部门"进行能效对比
  Developed an automated computer system to allow companies to make a comparison with "the best of a branch" regarding the energy efficiency
- 行业：啤酒厂、乳制品、面包店 Sectors: breweries, dairies, bakeries

**具体的能耗Specific Energy Consumption – 啤酒厂的实例Brewery Example**
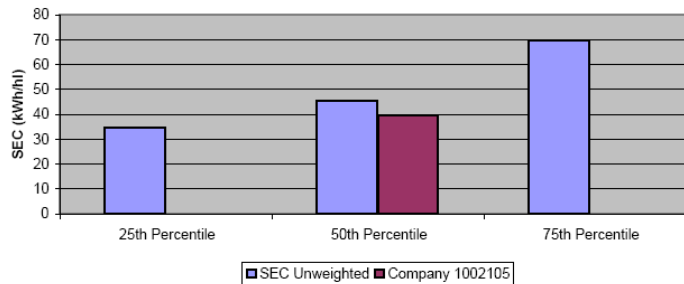


LAWRENCE BERKELEY NATIONAL LABORATORY

9

---

## 与国家平均和最佳实践对比
## Self Performance to National Average and Best Practice

**U.S. EPA Energy Star for Industry  美国EPA工业能源之星**
**Energy Performance Indicator (EPI) 能效指标**

- 将企业与美国平均和"高效"（即所有工厂中75％节能的）的工厂进行对标，美国所有工厂的能效
  Benchmarks the enterprise to the average and "efficient" plants in the U.S., where efficiency is defined as the 75th percentile of all plants
- 工厂经理输入工厂的运行数据，即得出一个能效等级 Plant managers input key plant operating data to receive an energy efficiency rating
- 为改进和监督进度设定目标
  Used to set goals for improvement and monitor progress
- 成为为企业授"能源之星"标识的依据
  Basis for awarding the ENERGY STAR label for a plant
- 已经提出了水泥、谷物磨制、汽车制造业的能效指标
  EPIs have been developed for the cement, corn milling, and automobile manufacturing industries
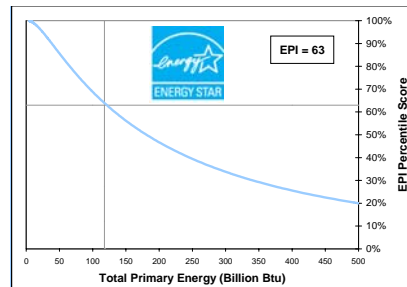


LAWRENCE BERKELEY NATIONAL LABORATORY

10

## 与国家平均和最佳实践对比
## Self Performance to International Best Practice

荷兰对标盟约
**Netherlands Benchmarking Covenants**

- 企业承诺至少到2012年成为世界能效领先者

  Industries pledge to be among the world's leaders in energy efficiency by 2012 at the latest

- 通过开展对SenterNovem监督项目的研究，评价本公司同"世界上最好水平"的距离

  Companies evaluate their distance from "best in the world" through studies that are overseen by SenterNovem

- 第三方专家确定能效国际最佳实践

  Expert 3rd party determines international best practice energy efficiency:

  — 荷兰之外的，企业规模和类型可比的地区（能效方面）。这个地区的平均水平就是对标的水平

  Top region (in terms of energy efficiency) outside The Netherlands that is comparable in terms of size and plants. Average of that region is the benchmark.

  - 荷兰之外可比企业的排序，排序最前的**10%**作为对标

    Ranking comparable plants outside The Netherlands and taking the top 10% as the benchmark

  - 世界运行最好的企业。对标水平定在小于**10%**的最佳企业

    Best operating plant worldwide. Benchmark is set at 10% below the best plant

---

## 与国家平均和最佳实践对比
## Self Performance to International Best Practice

对标和节能工具 （**BEST**）
**BEST: Benchmarking and Energy Savings Tool**

- **BEST**为每个设备提供了对标的核心，以表明在能效方面同国际最佳实践的距离

  BEST provides a benchmark score for each facility indicating its distance from international best practice in terms of energy

- 只比对能源情况，其他变量不变
- Compares only energy to best practices, keeping other variables the same.

  — 例如：最佳实践的水泥企业生产量同等，同样标号的水泥，使用同样的原材料，但使用高效技术。

  For example for cement , the best practice enterprise produces the same amount of cement, the same grades of cement and uses the same input raw materials but it (or they) uses the most efficient energy technologies to do so

- **BEST**制定提高能效计划和目标制定

  BEST allows for development of an efficiency improvement plan and target-setting

## 最佳实践对标工具
## Best Practice Benchmarking Tool

- 将企业能耗与中国和国际最佳实践进行对比
  Compares an enterprise's energy consumption to Chinese and international best practice

- 深入研究最不节能的环节
  Insights into which processes are most inefficient

- 仅将能耗与最佳实践对比，其他变量不变
  Only <u>energy</u> is compared to best practices, keeping other variables the same.
  - 例如：最佳实践的水泥企业生产量同等，同样标号的水泥，使用同样的原材料，但使用高效技术。
    For example for cement , the best practice enterprise produces the <u>same</u> amount of cement, the <u>same</u> grades of cement and uses the <u>same</u> input raw materials <u>but</u> it uses the most efficient energy technologies to do so

---

## Energy Intensity Index (EII)
## 能效指数

$$EII = 100 \cdot \frac{\sum_{i=1}^{n} P_i \cdot EI_i}{\sum_{i=1}^{n} P_i \cdot EI_{i,BP}} = 100 \cdot \frac{E_{tot}}{\sum_{i=1}^{n} P_i \cdot EI_{i,BP}}$$

EII      = energy intensity index 能效指数
n      = number of products to be aggregated累计产品数量
$EI_i$      = actual energy intensity for product I 产品I实际能耗
$EI_{i,BP}$      = best practice energy intensity for product i产品i最佳能耗
$P_i$      = production quantity for product i.产品i质量
$E_{tot}$      = total actual energy consumption for all products
         所有产品的实践总能耗

水泥行业实例：设定边界
**Cement Industry Example: Defining Boundaries**

准备添加剂
（石膏，粉煤灰等)
Preparing Additives
(gypsum, fly ash, etc.)

*准备添加剂*
*prepared additives*

原料开采& 矿材
Quarrying &
Mining Materials

*生料 raw materials*

准备燃料
Preparing Fuels

*燃料 fuels*

干燥
Drying Additives

*烘干添加剂*
*dried additives*

生料准备
**Raw Materials**
**Preparation**

*研磨生料Raw meal*

熟料烧成
**Clinker Making**

*熟料 clinker*

水泥粉磨
**Finish Grinding**

*水泥 cement*

运输 Transport

水泥业分析边界实例
*Example boundary of analysis for cement*
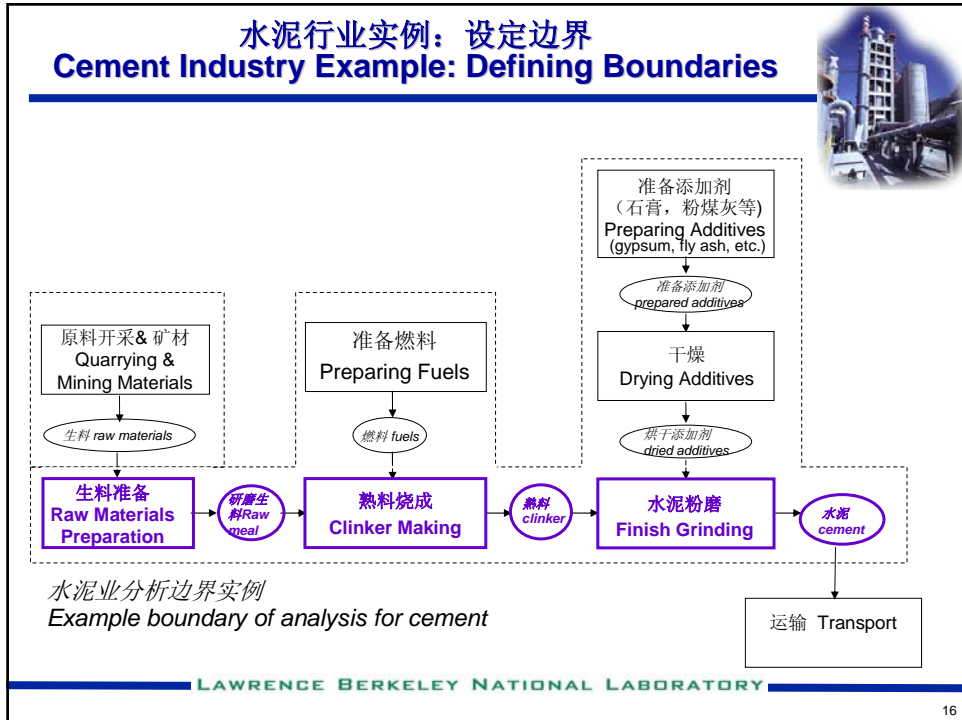
## 水泥行业实例：输入表格
## Cement Industry Example: Input Sheet

生产数据 Production Data
- 原材料的投入Raw materials input (t/year)
    - 石灰石Limestone
    - 添加剂种类Additives by type
- 窑型 Kiln Type
- 熟料产量 Clinker output (t/year)
- 水泥产量 Cement output by type (t/year)
- 水泥型号 Grades of cement
- 粉磨类型 Mill Types

## 水泥行业实例：输入表格
## Cement Industry Example: Input Sheet

能源数据 Energy Data
- 年燃料消耗（千克标煤/年或千瓦时/年）Fuel consumed per year (kgce/year or kWh/year)
    - 煤、焦炭、生物质（千克标煤/年） Coal, coke, biomass (kgce/year)
    - 电力（千瓦时/年）Electricity (kWh/year)
    - 其他 Other
- 工序用能 By process step
    - 原料准备（采矿，输送，预均化、配料和回收，破碎，粉磨，混合材制备，混合材烘干，燃料制备，均化）Raw material preparation (quarrying, conveying, prehomogenization, proportioning, reclaiming, crushing, grinding, additives preparation, additive drying, fuel preparation, homogenization)
    - 熟料烧成（预热器，分解炉，窑，冷却机） Clinker making (preheaters, precalciners, kiln, cooler)
    - 水泥粉磨 Finish grinding
    - 其他(运输、辅助、包装、非生产用能)
      Other (other conveying, auxiliaries, packaging, non-production energy use)
- 年燃料成本（元/千瓦时或元/千克标煤) Cost of fuel per year (yuan/kWh or yuan/kgce)

## 水泥行业实例：假设的对标
## Cement Industry Example: Hypothetical Benchmarking

**Distance from best practice**

| Energy Intensity Index (EII) | 137 |
|---|---|



BEST PRACTICE = 100
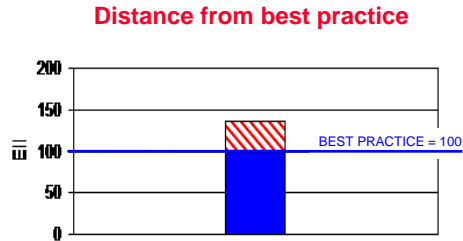
| Summary Data | Your Enterprise | Reference Enterprise | Potential for Efficiency | Potential Cost Reduction ($/year) |
|---|---|---|---|---|
| Electricity Consumption (kWh/year) | 18,741,000 | 13,905,108 | 4,835,892 | $270,810 |
| Fuel Consumption (kgce/year) | 13,950,000 | 10,110,922 | 3,839,078 | $268,735 |
| Final (site) Energy Consumption (kgce/year) | 16,253,269 | 11,819,859 | 4,433,410 | $539,545 |
| Primary Energy Consumption (kgce/year) | 21,501,701 | 15,713,996 | 5,787,705 | |
| Energy Intensity (kgce/tonne cement produced) | 172 | 126 | 46 | |

LAWRENCE BERKELEY NATIONAL LABORATORY

---

## 对标和节能工具 （BEST）
## BEST: Benchmarking and Energy Savings Tool

- 不仅提供对标的核心为目标的制定和能源管理提供进一步的能效菜单
  Provides not only benchmarking score BUT ALSO provides additional energy efficiency menu for target setting and energy management
  — 低成本和易评价的潜力
    Allows low-cost and easy evaluation of potential

- BEST制定提高能效计划和目标制定
  In this way, BEST allows for development of an efficiency improvement plan and target-setting

LAWRENCE BERKELEY NATIONAL LABORATORY

## 节能机会
## Energy Efficiency Opportunities

- 可实施的能效或减排措施清单
  Extensive menu of energy-efficiency or carbon emission reduction measures that could be implemented
  — 跨行业：电机系统、空压机、照明
    Cross-cutting: motor systems, compressed air, lighting
  — 同工艺相关：所有主要的工艺（窑炉升级，混磨）
    Process-related: all major process technologies (kiln upgrades, blending)
- 措施 Each measure
  — 产品单耗（熟料或水泥）
    Typical energy savings per ton product (clinker or cement)
  — 实施成本
    Cost of implementation
  — 投资回收期
    Typical payback period
- 一旦实施方案选定，BEST计算企业新的潜力
  Once options for implementation are selected, BEST calculates new, potential EII for plant

LAWRENCE BERKELEY NATIONAL LABORATORY

---

## 水泥行业能效措施初步清单
## Energy Efficiency Options for the Cement Industry

| Raw Materials Preparation | All Kilns |
|---|---|
| Wash Mills with Closed Circuit Classifier (Wet Process) | Improved refractories |
| Raw Meal Process Control (Dry process - Vertical Mill) | Energy management and process control systems |
| High-efficiency classifiers/separators (Dry process) | Adjustable speed drive for kiln fan |
| Use of Roller Mills (Dry Process) | **Rotary Kilns** |
| Efficient transport systems (Dry process) | Seal replacement |
| Raw Meal Blending (Homogenizing) Systems (Dry Process) | Grate cooler optimization |
| **Cement Grinding** | Optimize heat recovery in clinker cooler |
| Energy management and process control | Kiln combustion system improvements |
| Improved grinding mill (horozontal mill) | Low temperature heat recovery for power generation |
| Improved grinding media (ball mills) | High temperature heat recovery for power generation |
| High efficiency classifiers | Conversion to reciprocating grate cooler |
| **Product and Feedstock Changes** | Efficient kiln drives |
| Low alkali cement | Conversion of long dry kilns to preheater/precalciner kiln |
| Blended cements | Dry process upgrade to multi-stage preheater kiln |
| Use of waste-derived fuels | Upgrading of a preheater to a preheater/precalciner kiln |
| Limestone cement | Low pressure drop cyclones |
| Use of steel slag in kiln (CemStar®) | Indirect firing |
| **Motor Systems** | **Vertical Shaft Kilns (VSKs)** |
| High efficiency motors | Kiln combustion system improvements |
| Efficient fans with variable speed drives | Conversion to new suspension preheater/precalciner kiln |
| **Compressed Air Systems** | **Lighting Systems** |
| Reduce leaks | Replace mercury lights by metal halide or high pressure sodium lights |
| Maintenance of compressed air systems | Lighting controls |
| Heat recovery for water preheating | Replace magnetic ballasts with electronic ballasts |
| Reducing inlet air temperature | Replace metal halide HID with high-intensity fluorescent lights |
| Compressor controls | Replace T-12 by T-8 tubes |
| Sizing pipe diameter correctly | |

LAWRENCE BERKELEY NATIONAL LABORATORY

## 钢铁行业的能效措施
## Energy Efficiency Options for the Iron and Steel Industry

| Overall Measures (measures apply to both integrated and secondary plants) | | |
|---|---|---|
| Preventative maintenance<br>Energy monitoring and management systems<br>Variable speed drives for flue gas control, pumps, and fans<br>Cogeneration | | |
| **Integrated Steel Making Measures** | **Secondary Steel Making Measures** | **Casting and Rolling (apply to integrated and secondary plants unless otherwise specified)** |
| *Iron Ore Preparation (Sintermaking)*<br>Sinter plant heat recovery<br>Use of waste fuels in the sinter plant<br>Reduction of air leakage<br>Increasing bed depth<br>Improved process control<br>*Coke Making*<br>Coal moisture control<br>Programmed heating<br>Variable speed drive on coke oven gas compressors<br>Coke dry quenching<br>*Iron Making - Blast Furnace*<br>Pulverized coal injection (medium and high levels)<br>Injection of natural gas<br>Top pressure recovery turbines (wet type)<br>Recovery of blast furnace gas<br>Hot blast stove automation<br>Recuperator on the hot blast stove<br>Improved blast furnace control<br>*Steel Making - Basic Oxygen Furnace*<br>BOF gas & sensible heat recovery (supressed combustion)<br>Variable speed drive on ventilation fans | *Electric Arc Furnace*<br>Improved process control (neural networks)<br>Flue gas monitoring and control<br>Transformer efficiency measures<br>Bottom stirring/gas injection<br>Foamy slag practices<br>Oxy-fuel burners/lancing<br>Post-combustion<br>Eccentric bottom tapping (EBT)<br>Direct current (DC) arc furnaces<br>Scrap preheating<br>Consteel process<br>Fuchs shaft furnace<br>Twin shell DC arc furnace | *Casting*<br>Adopt continuous casting<br>Efficient ladle preheating<br>Thin slab casting<br>*Rolling*<br>Hot charging<br>Recuperative burners in the reheating furnace<br>Controlling oxygen levels and variable speed drives on combustion air fans<br>Process control in the hot strip mill<br>Insulation of furnaces<br>Energy efficient drives in the hot rolling mill<br>Waste heat recovery from cooling water<br>Heat recovery on the annealing line (integrated only)<br>Automated monitoring & targeting system<br>Reduced steam use in the pickling line |

LAWRENCE BERKELEY NATIONAL LABORATORY

---

## 最佳水泥演示 BEST-Cement Demonstration



LAWRENCE BERKELEY NATIONAL LABORATORY

## 反馈和下一阶段计划
## Feedback and Next Steps

- 反馈 Feedback
- 下一阶段计划 Next Steps
    - —在两家水泥厂测试最佳水泥工具 Testing BEST-Cement with two cement plants
        - PG 水泥厂   PG Cement Plant
        - 六里河水泥厂  Liulihe Cement Plant
    - —修订并完成水最佳水泥工具Revise and Finalize BEST-Cement

## 反馈和下一阶段计划
## Feedback and Next Steps

— 最佳水泥工具培训 Training Course for BEST-Cement

| 地区 Region | 千家企业水泥厂数 Number of Top-1000 Cement Enterprises | 欧盟能效项目节能中心 EU-EEP Energy Conservation Center? |
|---|---|---|
| 江苏 Jiangsu Province | 8 | 有Yes |
| 山东 Shandong Province | 7 | 有Yes |
| 河北 Hebei Province | 4 | 有Yes |
| 山西 Shanxi Province | 2 | 无 No |
| 云南 Yunnan Province | 0 | 无 No |
| 上海 Shanghai | 0 | 有Yes |

— 钢铁对标工具开发 Development of Steel Benchmarking Tool

## For further information 联系信息

LBNL Industrial End Use Analysis Website:
http://industrial-energy.lbl.gov/

LBNL China Group Website:
http://china.lbl.gov

BEST Website:
http://industrial-energy.lbl.gov/node/100

Publications:
http://industrial-energy.lbl.gov/publications

- **Christina Galitsky (CGalitsky@lbl.gov)**
- **Lynn Price (LKPrice@lbl.gov)**
- **Zhou Nan (NZhou@lbl.gov)**

LAWRENCE BERKELEY NATIONAL LABORATORY