



加拿大的实践历程—全球首例燃煤电厂碳捕集利用与封存 工业化示范项目

Canada's Experience: The World's First Commercial Coal-Fired CCUS Project

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President, SaskPower CCS Initiatives

 **SaskPower**
Powering the future®

@SaskPowerCCS

Power
re future

加拿大萨省经济/环境

SASKATCHEWAN'S ECONOMY/ ENVIRONMENT



Growing both economically and demographically.

REGULATIONS in Canada

加拿大燃煤/燃气热电厂二氧化碳排放标准比较（2030达标）



COAL

- 加拿大燃煤热电厂二氧化碳排放标准为
- **420公斤/每兆瓦时**

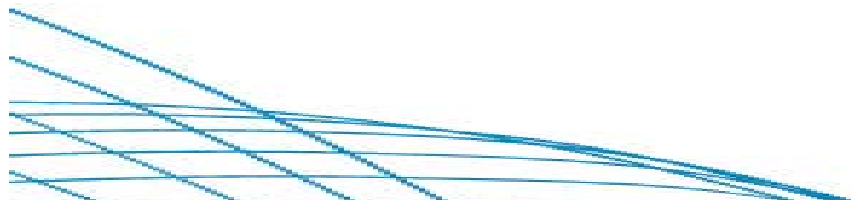
-420 KG / MWh-n



NATURAL GAS

- 加拿大燃气热电厂二氧化碳排放标准为
- **420公斤/每兆瓦时**

-420 KG / MWh-n



萨省政府批准实施全球首例工业化热电厂碳捕集利用与封存项目

Saskatchewan Government approved The World's First Commercial Coal-Fired CCUS Project

- **原预算12.4亿造价相当于全省人均\$1,200加元**
C\$1.24 Billion budget, equivalent to C\$1,200 per capita in a province with 1 Million people
- **联邦政府补贴近\$2.4亿, 企业负担: 10+亿。**
C\$240 Million subsidy from Federal Government, cost to SaskPower: C\$1.0+B.
- **省内国际能源署维本-米代尔油田封存与监测项目自2000年实施以来二氧化碳强化三次采油累计注入2700万吨以上**
The IEA Weyburn-Midale Project, which since 2000 has injected over 27 million tonnes of CO2 for EOR
- **全球最大规模经验证并受检测的碳捕集利用与封存/强化采油工业化运营** The world's largest verified and monitored commercial CCUS/EOR operation.

萨斯喀电力 - 技术创新的记录

SaskPower – Achievements

- 完成世界首例大规模近零排放燃煤热电厂工业化集成/示范

First in the world to have completed demonstrated commercial coal-fired power plant integrated with CO₂ post-combustion capture

- 创造了继续利用煤炭的经济可行符合环保要求的模式

Make a viable technical, environmental and economic case for the continued use of coal

- 强化了通过碳捕集用以强化采油结合封存的低排放发电的CCS 商业案例

Strengthen the CCS business case for low-emission electricity capturing carbon dioxide (CO₂) for enhanced oil recovery operations or storage in a deep saline formation; and

- 通过实践分享加拿大的知识与经验，扩大国际合作研发，降低成本，推动CCS发展

Contribute to international effort to advance CCS globally, by sharing Canadian knowledge and expertise while learning-from-doing, and continued R&D that drive down CCS costs.

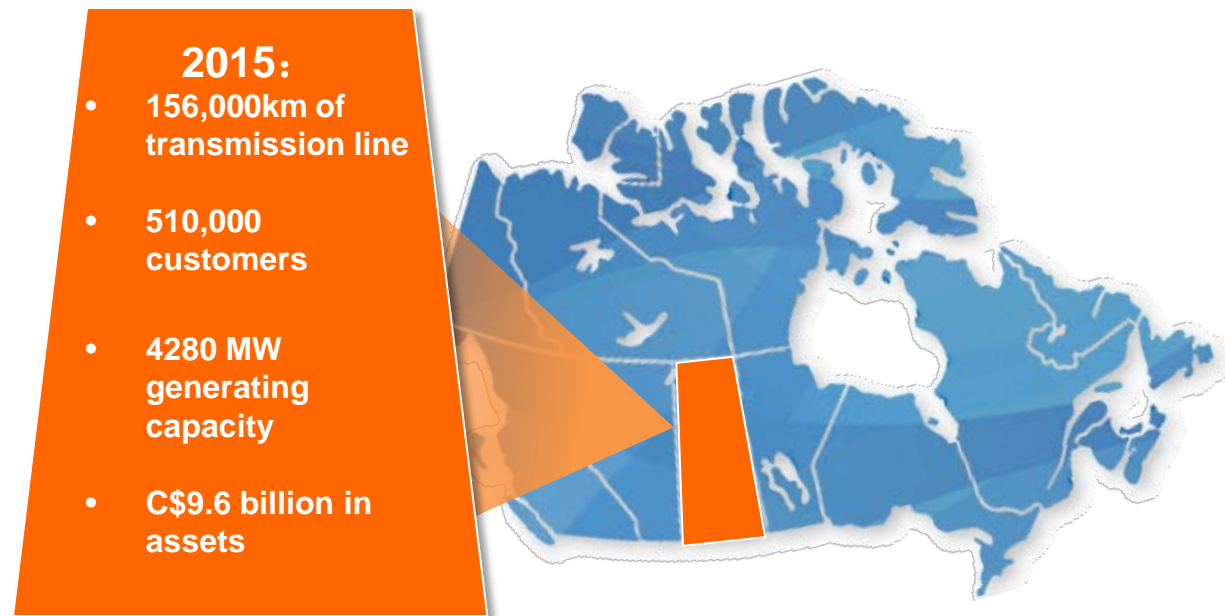
- 工业化示范悬浮颗粒，二氧化硫，硝和汞的脱除技术（加/美国家标准示范单位）

Demonstrated particulates, SO₂, NO_x and mercury removal technologies (Emission Control Research Facility) as well

萨斯喀电力——主导全省境内电力生产供应

SaskPower – Saskatchewan's Leading Energy Supplier

- 可支配装机容量：**4280兆瓦**。
- 发电量 (2012)：煤电 **52%**，天然气**22%**，水电**19%**，风电**3%**，输入电力 **3%**
- 用户：**51万**
- 电网规模：**156,000 km**
- 资产总值：**96亿 加元**



碳捕集， 利用与封存之必要性

The CCUS need

萨斯喀电力一直利用当地价格低廉, 资源丰富的煤炭支撑主要电力负荷

SaskPower has traditionally used a low-cost, abundant and locally available supply of coal to fuel a significant portion of our base load

煤炭支撑着世界40%的电力供应, 碳捕集, 利用与封存对全球减排可能产生重大影响

With coal supplying about 40% of the world's electricity, CCUS could hav major impact on global GHG emissions

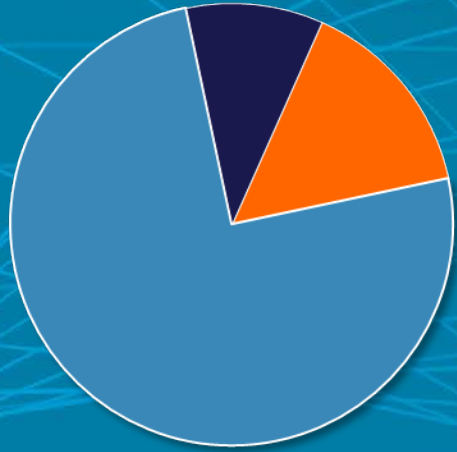
通过二氧化碳驱强化采油刺激石油生产, 增加政府的资源使用税

Stimulate petroleum production through EOR and increase government revenue from royalties

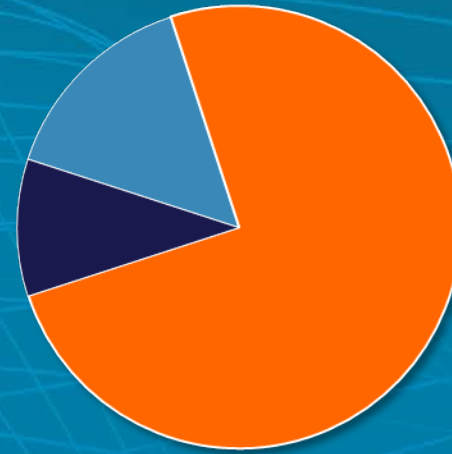
天然气发电与清洁煤电成本比较

COMPARING COSTS

Baseload Natural Gas
Cost of Electricity



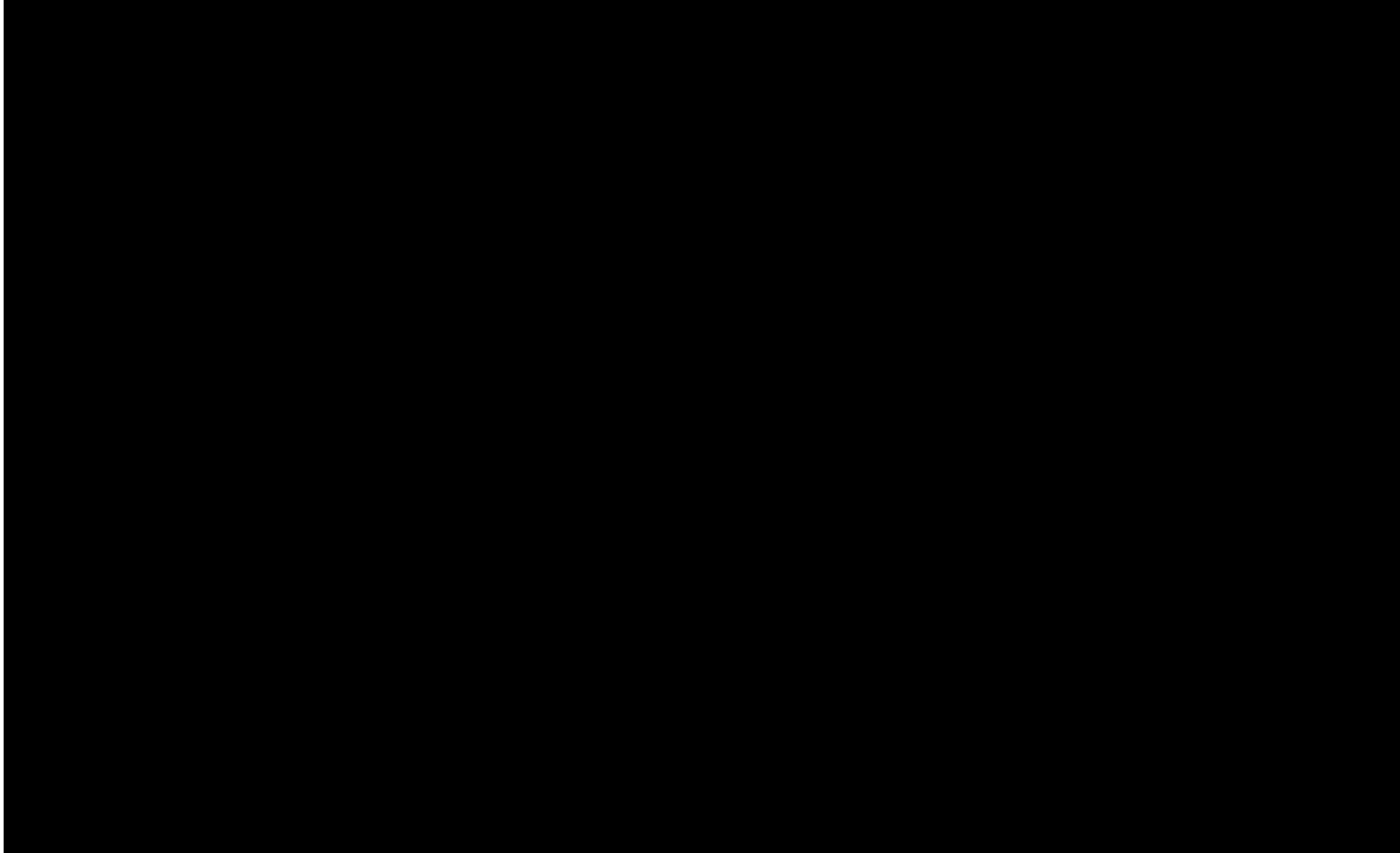
BD3 Carbon Capture
Cost of Electricity



- 资本投入 Capital Investment
- 燃料消耗 Fuel Expense
- 运营成本 O & M

2009-2010 年数据
Figures from 2009 - 2010

TIME LAPSE.





边界坝电站鸟瞰
BOUNDARY DAM



吸附塔
Absorber Towers



再生塔
CO₂ Stripper



硫再生塔
SO₂ Stripper



硫酸分部
Acid Plant



CO₂ 输出
Pipeline

边界坝电站#3机组减排效率

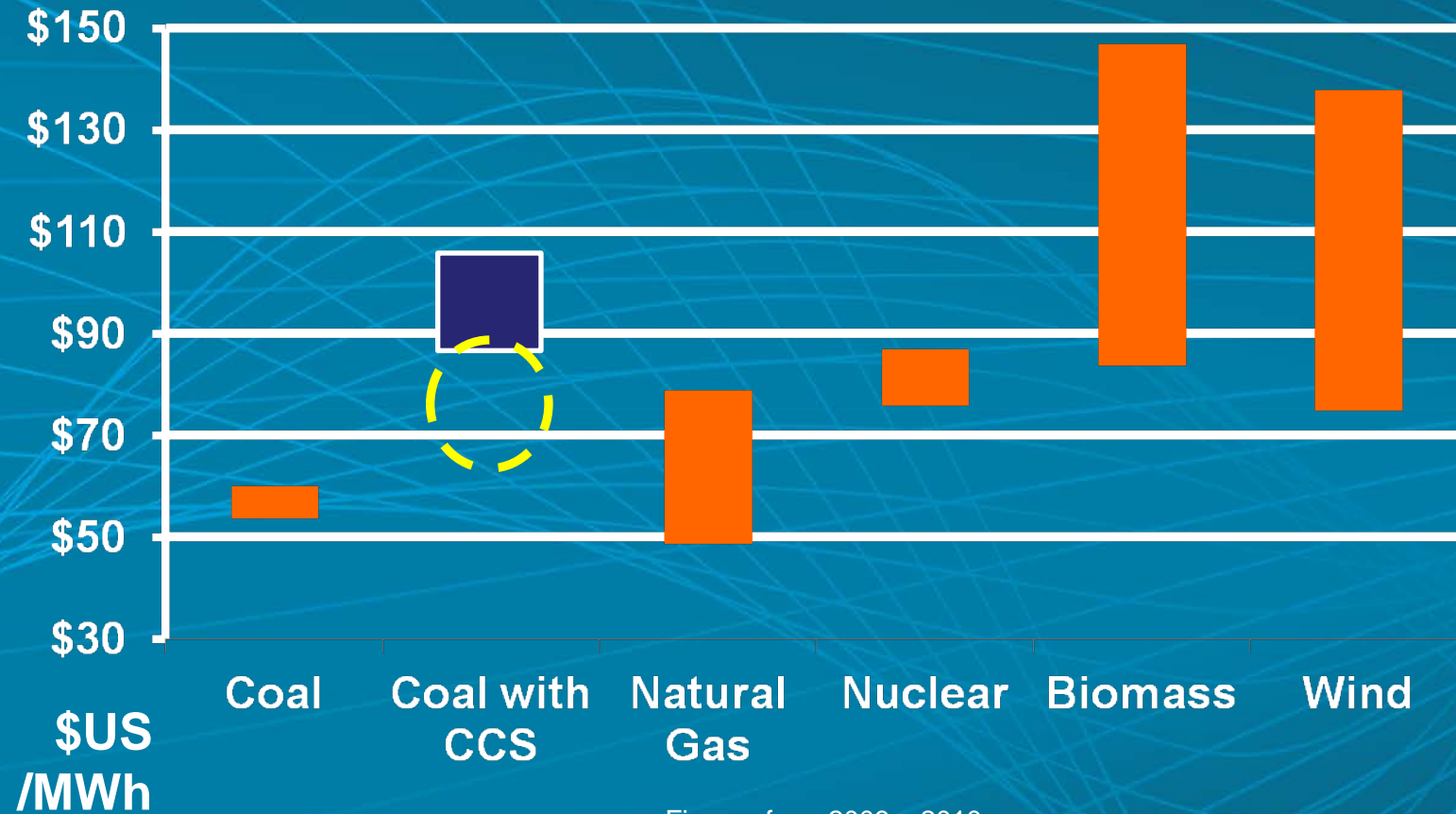
BOUNDARY DAM INTEGRATED CCS PROJECT OUTCOMES

Power to Grid	120 MW
Fly-ash	100% to Market
Sulphuric acid	100% to Market
CO₂ (Purity 99.99%)	90% to Market
Water Recovered for Cooling	34 M³ /hour (1/2)

Emission Change	Pre-CCS	Post-CCS	Reduction
CO₂ (000 t/a)	1139.7	112.7	90%
SO₂ (000 t/a)	7.12	0	100%
NOx (000 t/a)	2.41	1.05	56%
PM₁₀ (000 t/a)	.19	.015	92%
PM_{2.5} (000 t/a)	.065	.007	89%
Hg	Under Corporate Cap		



发电成本比较 GENERATION COSTS



Figures from 2009 – 2010

项目造价分割

BREAKING DOWN \$1.467B CAD

电厂改造

POWER PLANT
REFURBISHMENT



Turbine Flue Gas Ducting Boiler Asbestos

\$562M CND

新建捕集分厂

NEW CCS FACILITY



Compressor Absorbers Reclaimers Infrastructure

\$905M CND

副产品利用

SECURING OFF-TAKERS.



CO₂ 售予石油公司驱油
Sale of CO₂ to oil company for EOR.



硫酸售予化肥等行业
Sale of sulphuric acid, used primarily for industrial purposes, i.e. fertilizer.



烟灰 售予水泥企业
Sale of fly ash for concrete production.

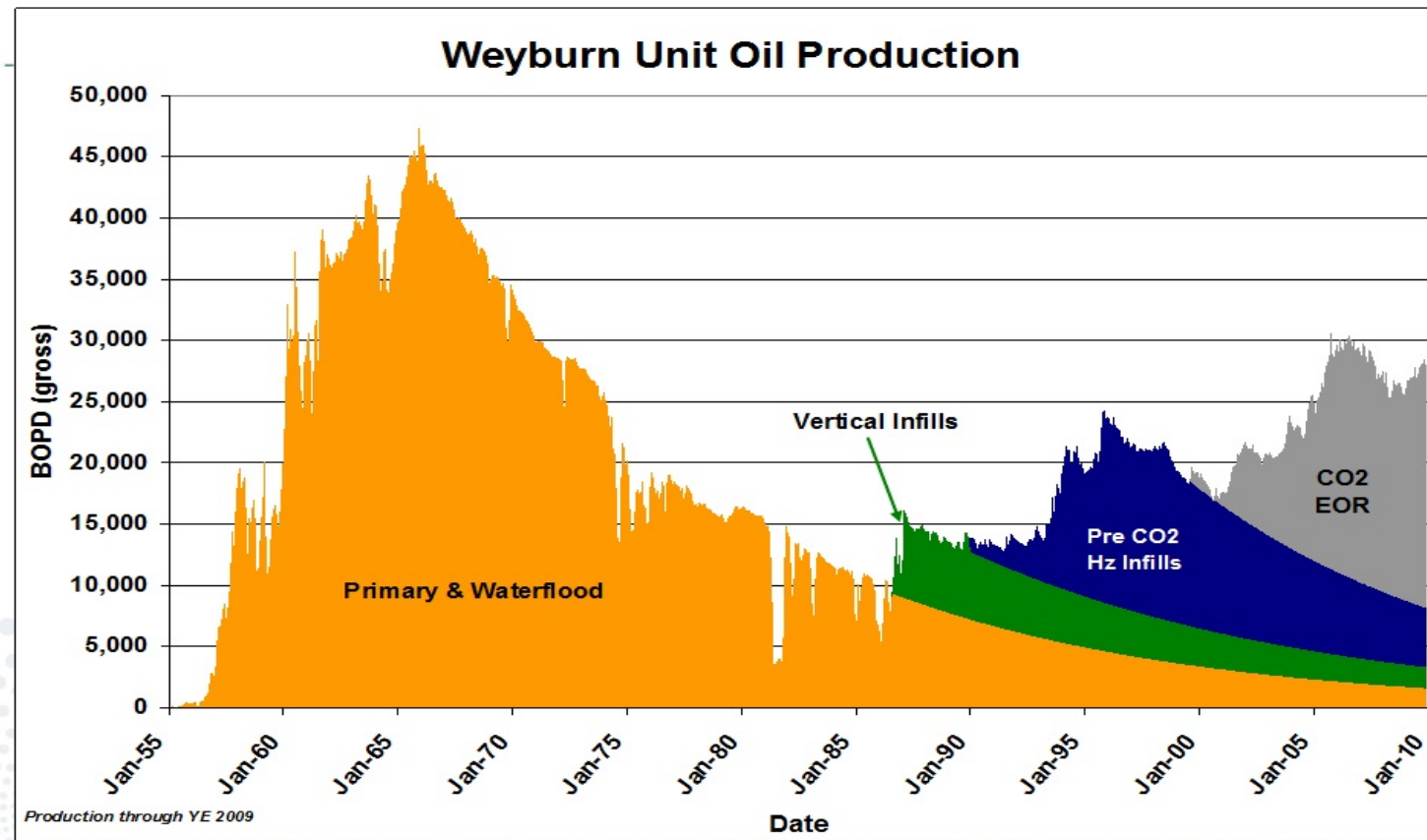
鼓励政策：二氧化碳驱强化采油资源使用税

Incentives: CO₂ EOR Royalties

- 投资回收前 Before Investment Payout
 仅缴纳毛收入的百分之一 1% of Gross Revenue
- 投资回收后 After Investment Payout
 - 收入的百分之20（毛收入---运营成本）
 - 20% of (Gross Revenue – Operating Cost)
- 结果：石油公司愿意购买更多二氧化碳，扩大二氧化碳驱强化采油规模
- Result: Oil Companies would like to take more CO₂ and expand EOR.

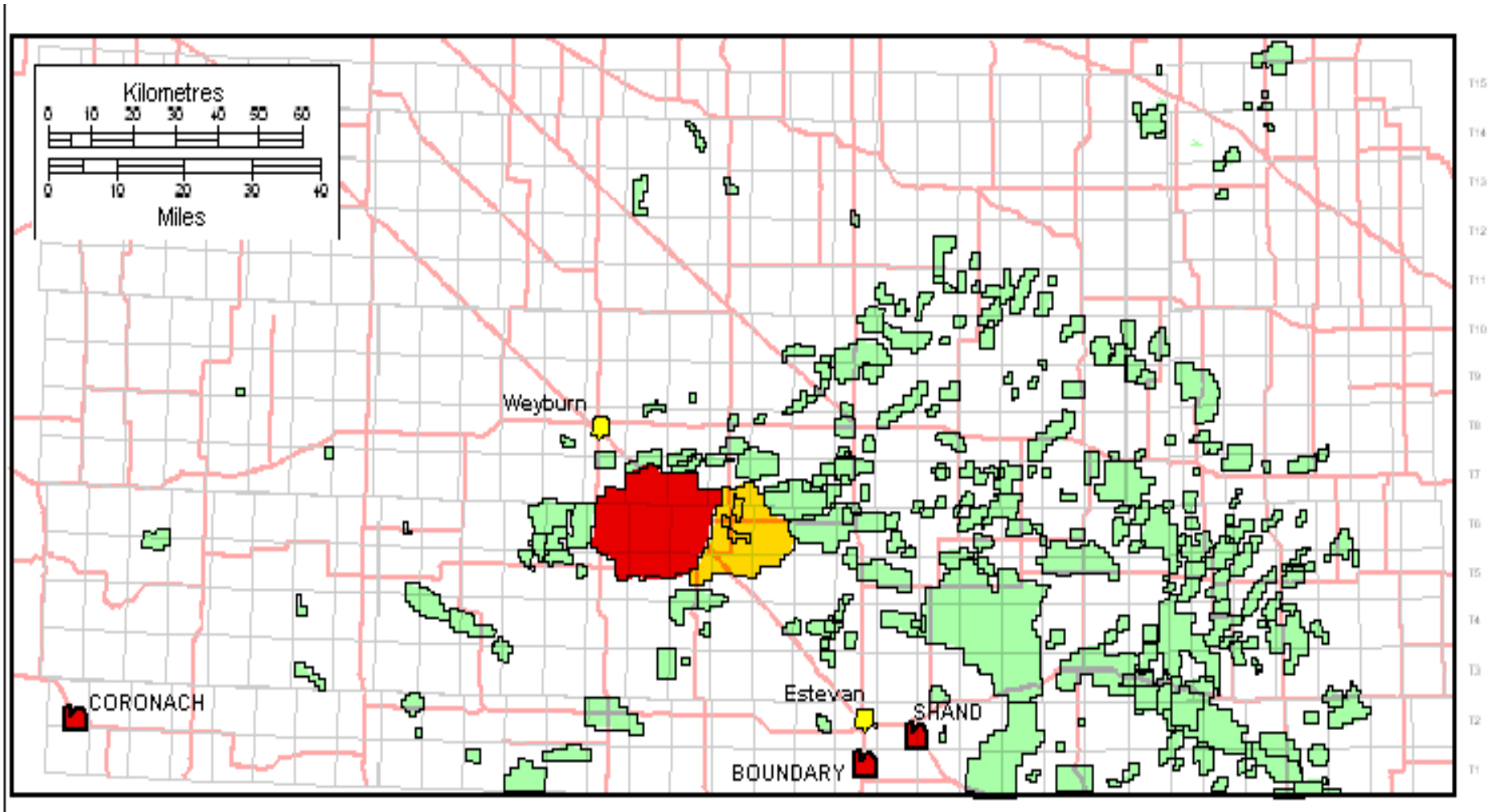
增采石油 ENHANCED OIL RECOVERY

- 日产量约4,500方， 二氧化碳驱增采量 占60%
- Up to 28,000 bbl/day: a 35-year high, 20,000 bbl/d are due to the CO₂ flood at Weyburn (韦本油田)
- 效率为1:3 performance for crude oil vs. CO₂: 1 :3



二氧化碳驱三次采油机遇

CO₂ EOR Opportunity



咸水层封存 STORAGE



深藏二氧化碳于地下**3.4公里**

Storing CO₂ 3.4 km underground in the Deadwood formation

管道输送, 距离现场**4公里**电厂区域内

Pipeline to site less than 4 km away

石油技术研究中心实施监测二氧化碳封存

PTRC will independently monitor the CO₂

萨斯喀电力碳捕集技术验证设施

SaskPower Carbon Capture Test Facility

27.6万千瓦善德火电站内

Located at SaskPower's 276-MW coal-fired Shand Power Station

为技术供应商提供中立的平台, 在商业运营的环境下验证并改进燃烧后捕集技术

Neutral platform for vendors to verify and improve post-combustion technologies in commercial setting

基本实验捕集能力为**120吨/日**

Primary test unit CO₂ capture capacity of 120 tonnes per day

将首先验证日立公司的胺捕集技术
Hitachi Ltd.'s proprietary amine technology will be the first tested



未来项目的基础

THE GROUNDWORK FOR FUTURE PROJECTS

- 10 余年研发 10+ years of CCS development
- 5年工程设计 5 years of detailed engineering design
- 2年建设经验 2 years of construction experience
- 未来项目可节省 Potential for saving for future projects:
 - 降低电耗20% cost reduction- electrical costs
 - 降低造价30% reduction- capital costs





WHERE WE ARE GOING
向何方

SaskPower
the future

AMINE CHEMICAL LAB





知识分享：全球知识联合体
CONSORTIUM

CCS国际合作中枢

- 在实践中学，直接参与转移扩散工业化示范知识经验，以实际项目(#4&5项目)为依托，优化创新第二代技术。
Optimize the innovative designs for the 2nd generation technology project , on basis of sharing the knowledge from the commercial project.
- 跨越地理与国际界限，吸收多元化创意，协力解决具体项目技术难题。
Break the barriers and silos, to facilitate the diverse approaches to innovative designs, to create synergy in solving real project challenges.
- 充分发挥技术创新的价值，降低知识分享大规模示范集成成果的门槛。
Maximize the value of innovations of the creative minds of members, while lowering the hurdle for access to the experiences, knowledge and data of the project.
- 与亚洲开发银行等国际组织合作推动大规模示范知识转移
To collaborate with Asian Development Bank and other organizations to promote transfer of knowledge & experiences from large-scaled demonstration

边界坝#4-#5机组未来决策

Decision on BD #4 and #5

- 代表二代技术的项目 Represents a Generation 2 undertaking
- 2016年决定 Required to make a decision by 2016
- 自筹资金 Needs to be fully funded by SaskPower
- 动工前需要可行性研究和工程筹备 Requires feasibility studies and pre-commitment engineering prior to making a decision to undertake
 - 边界坝#3 决策前评估费5千万加元 Spent \$50 million evaluating the BD#3 Go / No Go decision

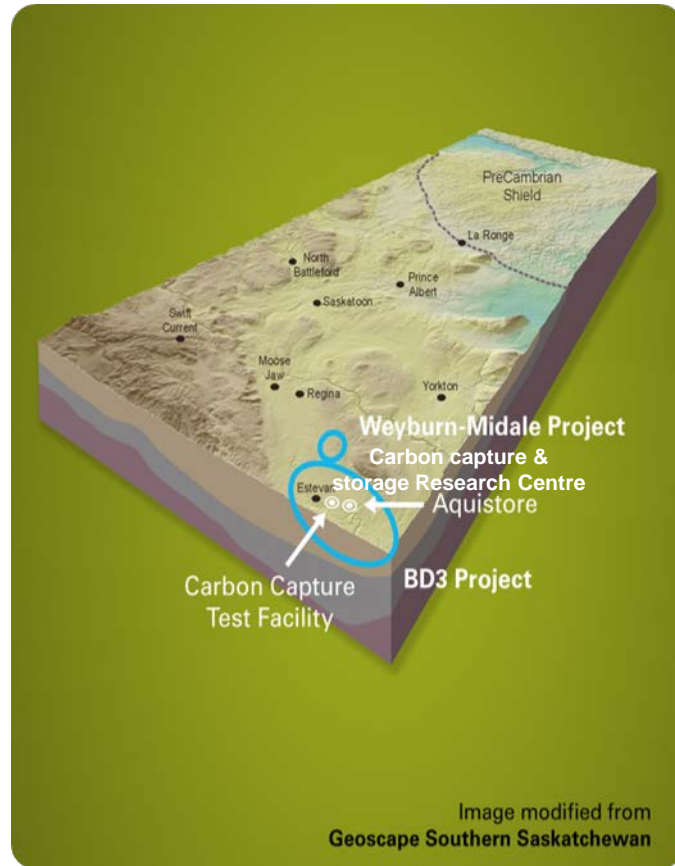




GLOBAL UNIVERSITY NETWORK

加拿大萨斯喀彻温省：碳捕集利用与封存技术创新的中心

Saskatchewan: A Centre of CCUS Innovation



萨斯喀电力 碳捕集与封存综合工业示范项目
Integrated Carbon Capture & Sequestration
Demonstration Project

萨斯喀电力碳捕集技术验证设施

Saskatchewan Carbon Capture Test Facility

咸水层CO₂深度封存工业示范项目 (3400米)
Aquistore –Deep Saline CO₂ Storage Demonstration (3,400m)

韦本-米代尔国际能源署CO₂ 监测与封存工业示范项目
IEA Weyburn-Midale CO₂ Monitoring & Storage Project

重油藏CO₂ 驱油与封存先导示范项目
CO₂ EOR / Sequestration piloting in Heavy Oil Reserves
(SRC/Husky Energy)

加拿大与中国共同领导二氧化碳地质封存国际标准制定
Standard Council of Canada and China co-lead developing ISO
standards for CCS (TC 256)

加拿大石油技术研究中心

Petroleum Technology Research Centre (PTRC)

萨斯省研究院

Saskatchewan Research Council (SRC)

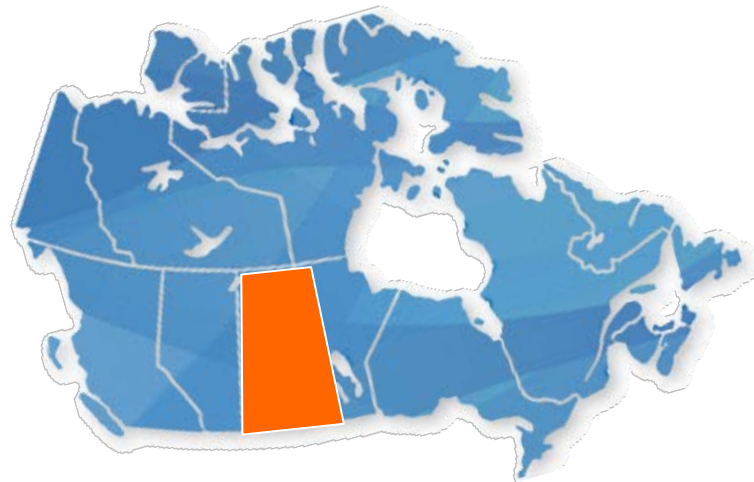
里贾纳大学—加拿大能源与环境首席科学家

University of Regina-Canada Research Chair-Energy
& Environment

加拿大欢迎你 Welcome!

“国际能源署温室气体研究计划” 第三届燃烧后捕集大会
(9月8-11日, 加拿大里贾纳市)

*IEAGHG 3rd Post-Combustion Capture Conference
(PCCC3) & 2015 SaskPower CCS Symposium
(September 8-12 , Regina, Canada)*





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Thank You!

于泽伟 高级顾问
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