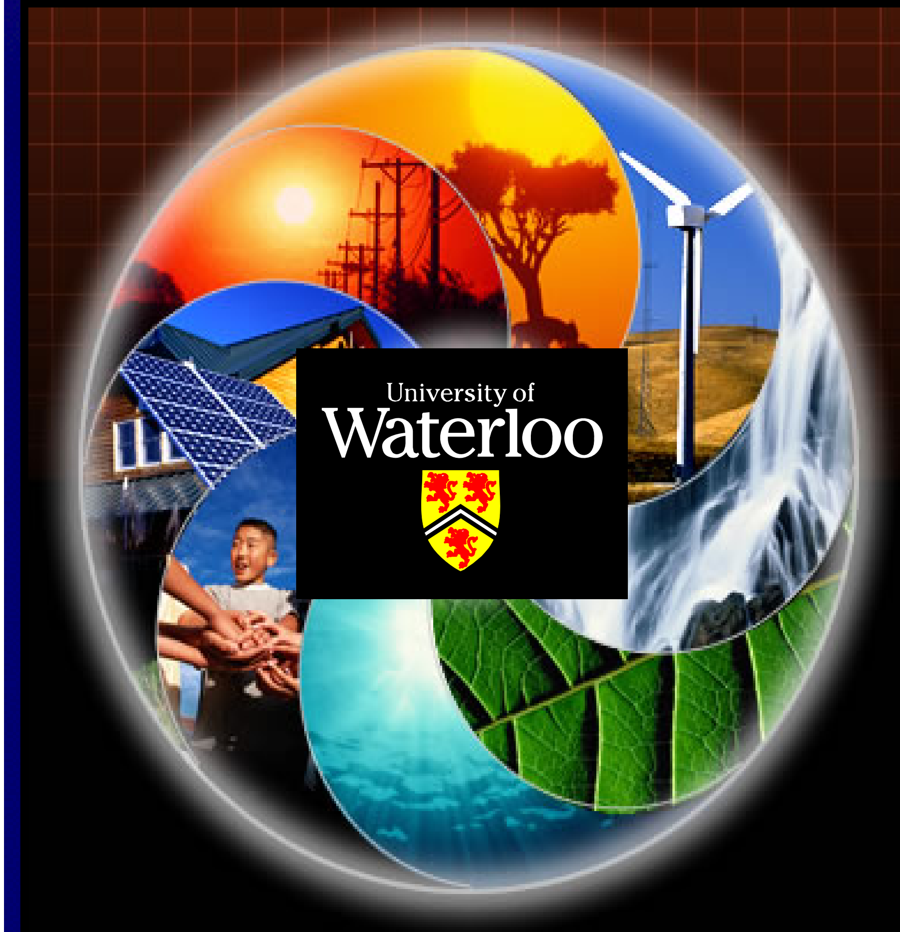
CO_2 Capture & Geological Storage in Ontario Workshop



Peter Douglas
Department of Chemical Engineering
University of Waterloo
Waterloo, Ontario

1-519-888-4601
pdouglas@cape.uwaterloo.ca
http://chemeng.uwaterloo.ca/faculty/douglas.html

R&D Mission Statement:

"Develop near-term CO_2 capture and mitigation strategies for Canada"

Presentation outline

- CO_2 mitigation group
  - Green Energy Research Institute (GERI) http://geri.uwaterloo.ca/
  - Ontario Research Chair in Public Policy for Energy Management
  - R&D areas
- some recent results
- summary and conclusions
- future work

GERI
GREEN ENERGY RESEARCH INSTITUTE

EXPERTISE
GREEN ENERGY SOURCES
STORAGE AND TRANSPORT
CONVERSION TECHNOLOGIES
GREEN ENERGY IMPACTS
OPTIMIZATION AND MANAGEMENT
GREEN ENERGY POLICY

GERI
Green Energy Sources
Storage and Transport
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What is Green Energy?

Green energy may be defined as the form and utilization of energy with no, minimal, or reduced negative environmental and societal impact, or simply as environmentally friendly energy use.

In the process of seeking official status as an institute at the University of Waterloo, the Green Energy Research Institute (GERI) develops and promotes green energy systems that strive for sustainable environmental, social and economic performance. The Centre accomplishes its mission through conducting original research to develop and promote technologies for diversified and localized energy systems, clean energy alternatives, sustainable development and energy security.

Green Energy Research at Waterloo

University of Waterloo is a leader in green energy research and innovation, especially in the areas of

- Green Energy Sources
- Storage and Transport
- Conversion Technologies
- Green Energy Impacts
- Optimization and Management
- Green Energy Policy

Ontario Research Chair in Public Policy for Sustainable Energy Management

"Integrating Excellence in Renewable and Clean Energy Technology with Sustainable Management Solutions for Ontario"

Like many jurisdictions, Ontario is at an energy-emergency crossroads. The solution lies in an integrated energy plan that provides a secure, reliable and high quality supply of energy in a manner that promotes economic growth, competitiveness and environmental performance. The Ontario Energy Conservation and Supply Task Force favored *"a diverse supply mix, and a balanced approach to filling the (demand-supply) gap"*. Renewable energy is a vital part of the future supply mix. The success of sustainable energy policy will require superior renewable energy technology and a sound strategy for integration in the energy supply system. Given the wide demand-supply gap, technologies and management strategies to improve the environmental performance of conventional energy sources are also vital. Electricity transformation will require a fundamental shift in the way in which the power industry is physically laid out and socially structured. The development of sustainable energy systems in Ontario will require an integrated understanding of energy technologies, policy options, risk and reliability, consumer and business interests, and environmental studies.

CHAIR OBJECTIVES

- Integrate and strengthen interdisciplinary research on the development of renewable energy technology and sustainable energy management strategies (policies)
- Train a new generation of professionals to facilitate the rapid integration of renewable energy technology within a diverse mix of energy options
- Engage in partnerships with communities and the private sector to facilitate knowledge transfer and integrated energy solutions

UW STRENGTHS

The University of Waterloo is in a unique position to establish an Ontario Research Chair in Public Policy for Sustainable Energy Management for several reasons:

→ UW is a North American leader in the development of solar (photovoltaics) and wind energy technology with extensive laboratory facilities and one of North America's largest power systems research groups

→ The ***Green Energy Research Institute (GERI)*** (http://geri.uwaterloo.ca/) is being established at UW as a focal point for interdisciplinary renewable and clean energy research activities of more than 25 researchers and four research groups

→ Waterloo has a well-established foundation of graduate programs in eight academic units across three faculties -- Engineering, Environmental Studies and Science and more than 19 graduate courses on planning aspects of energy systems

→ State-of-the-art research initiatives in power quality & distributions systems, risk and reliability of energy infrastructure, energy economics and policies, energy markets, CO_2 capture and sequestration, and power management planning and policy

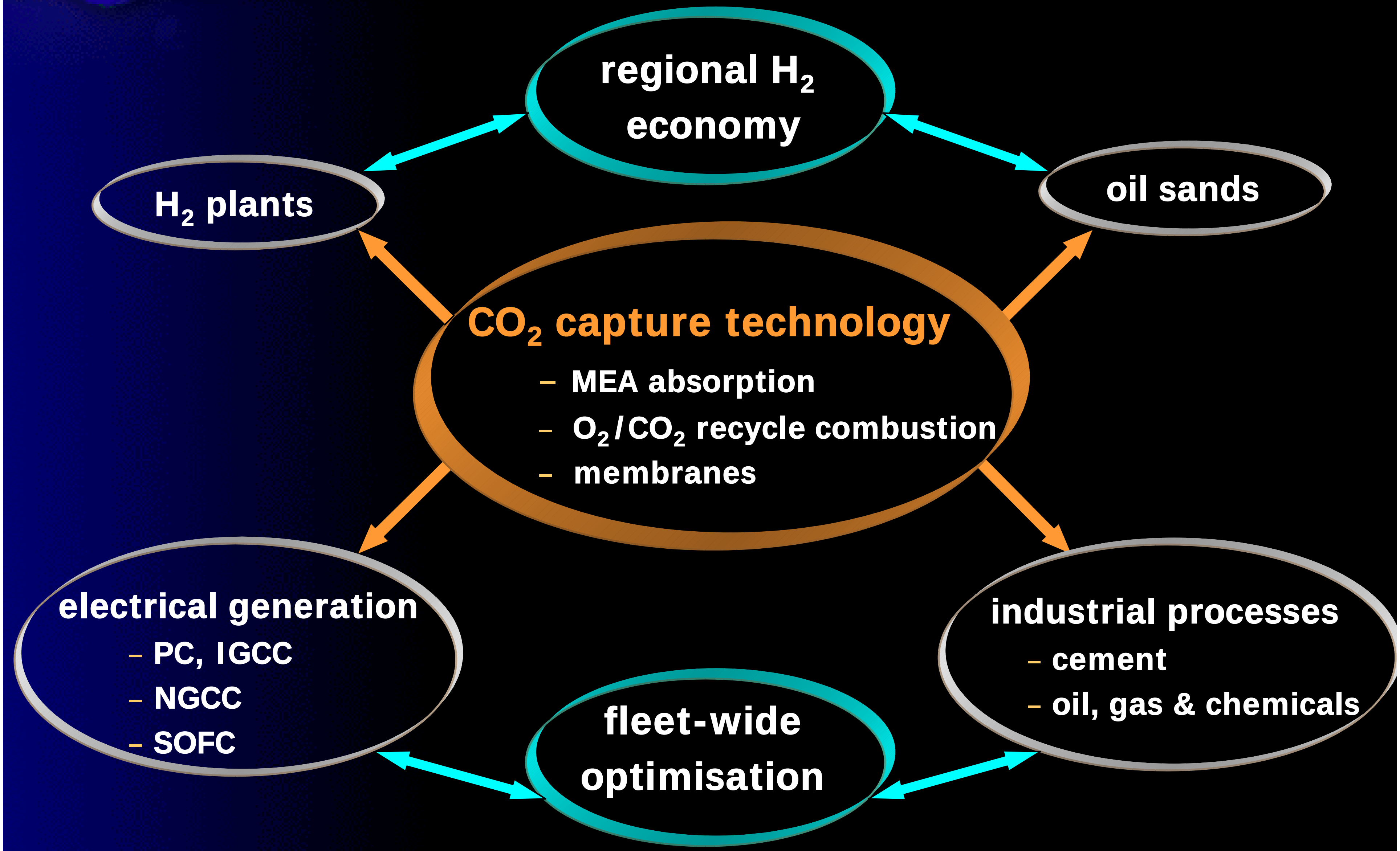
→ New research partnerships with the Municipality of Kincardine and various energy sectors in Kincardine provides opportunities for graduate student training, data sharing, knowledge transfer, establishment of "store front" green energy learning centre

→ Innovative community-based outreach (Residential Energy Efficiency Project) and demonstration projects (Solar Technology Education Project) promote awareness of energy efficiency and renewable energy

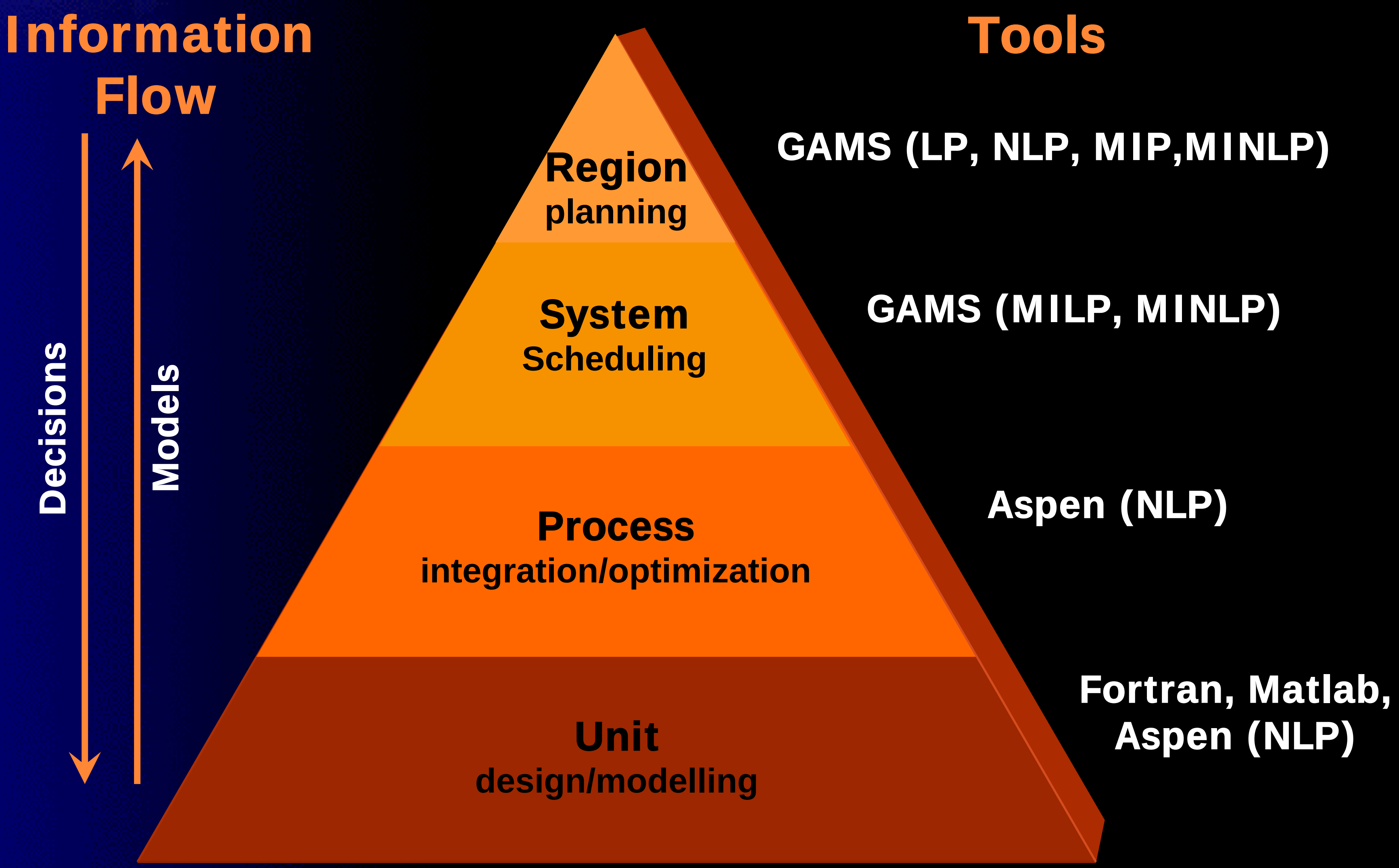
UW's Commitment ....

- *In addition to the Ontario Research Chair, the university will create two new junior faculty positions, one of these is a Tier 2 Canada **Research Chair** and the other created through university resources*
- *A new building will house the **Centre for Advanced Photovoltaic Devices and Systems** (initial funds in hand is $12 million) which is a key component of our sustainable energy program*

Overview of R&D areas



Overview of R&D areas cont'd



Overview of R&D areas.. cont'd

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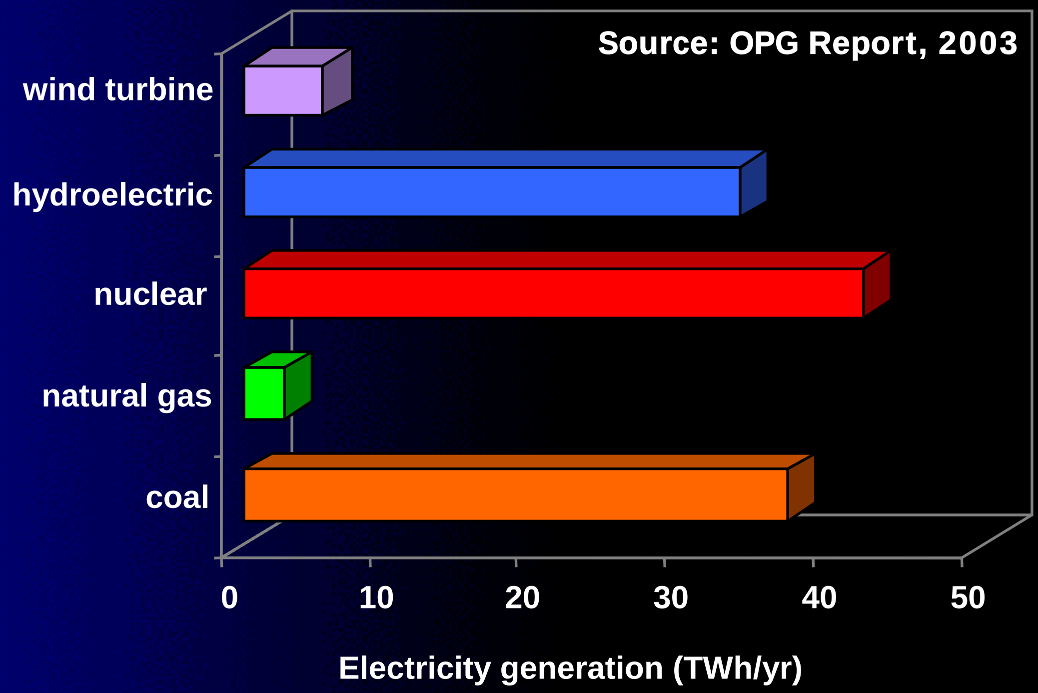
- **Unit level:**
  - fuel cells (SOFC: Solid Oxide Fuel Cells)
  - membranes for separating CO_2 from flue gases
- **Process level:**
  - techno-economic modelling CO_2 capture from flue gases:
    - pulverized coal (PC)
    - integrated gasification combined cycle (IGCC)
    - zero emission coal alliance (ZECA)
    - natural gas combined cycle (NGCC)
    - hydrogen plants
    - oil sands upgrading processes
    - oil refineries
    - cement plants

    - O_2/CO_2 recycle combustion
    - MEA absorption
    - membranes
  - sequestration of CO_2 in Ontario
  - optimal integration of MEA CO_2 capture process and existing power plant
- **Regional level:**
  - development of regional H_2 economy for Alberta oil sands region
  - optimal configuration of a fleet of power plants with CO_2 constraints

Some recent results



70% of electricity in Ontario is produced by OPG

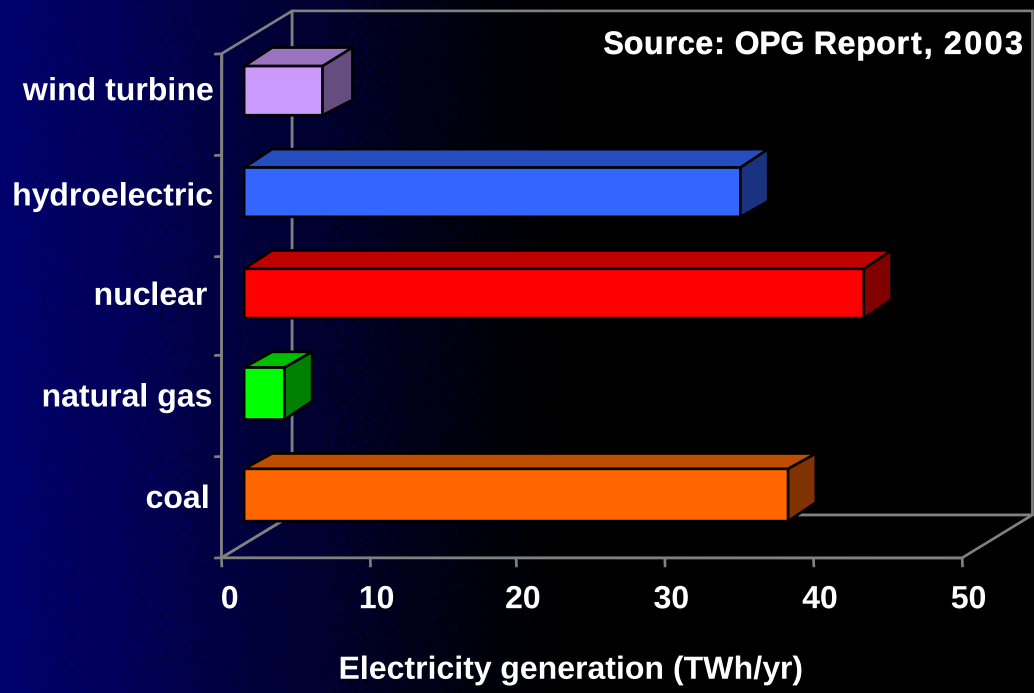
- *Nuclear - 44%*
- *Hydroelectric - 27%*
- *Fossil – 28.5%*
- *Wind turbine – 0.5%*

Electricity generation ≅ 120 TWh/yr

COE ≅ 2.35 ¢/KWh (calculated)

Question?

What is the best strategy for OPG to pursue to satisfy energy demand and reduce CO_2 emissions?



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OPG Fleet Superstructure

model all 74 OPG generating stations

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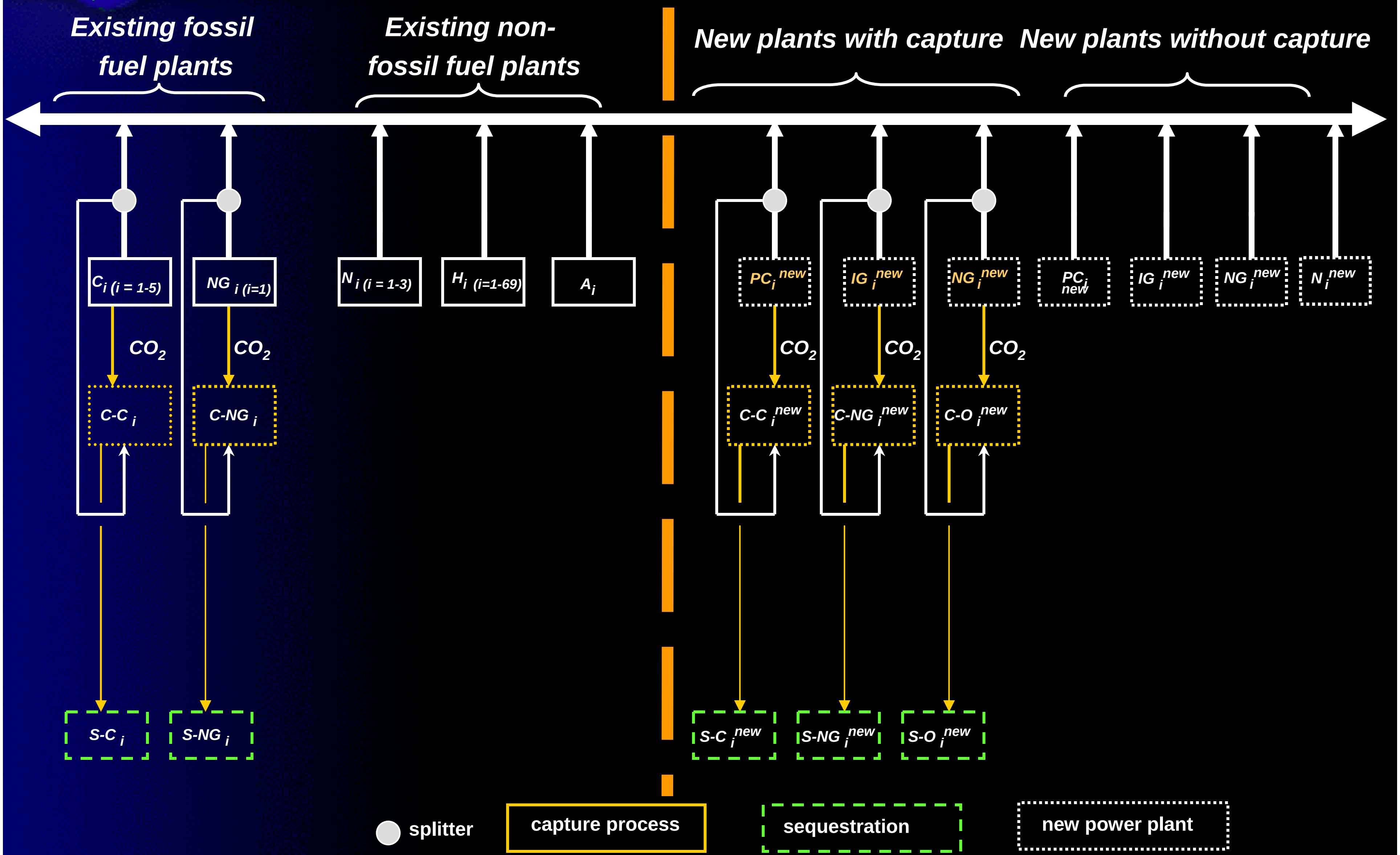
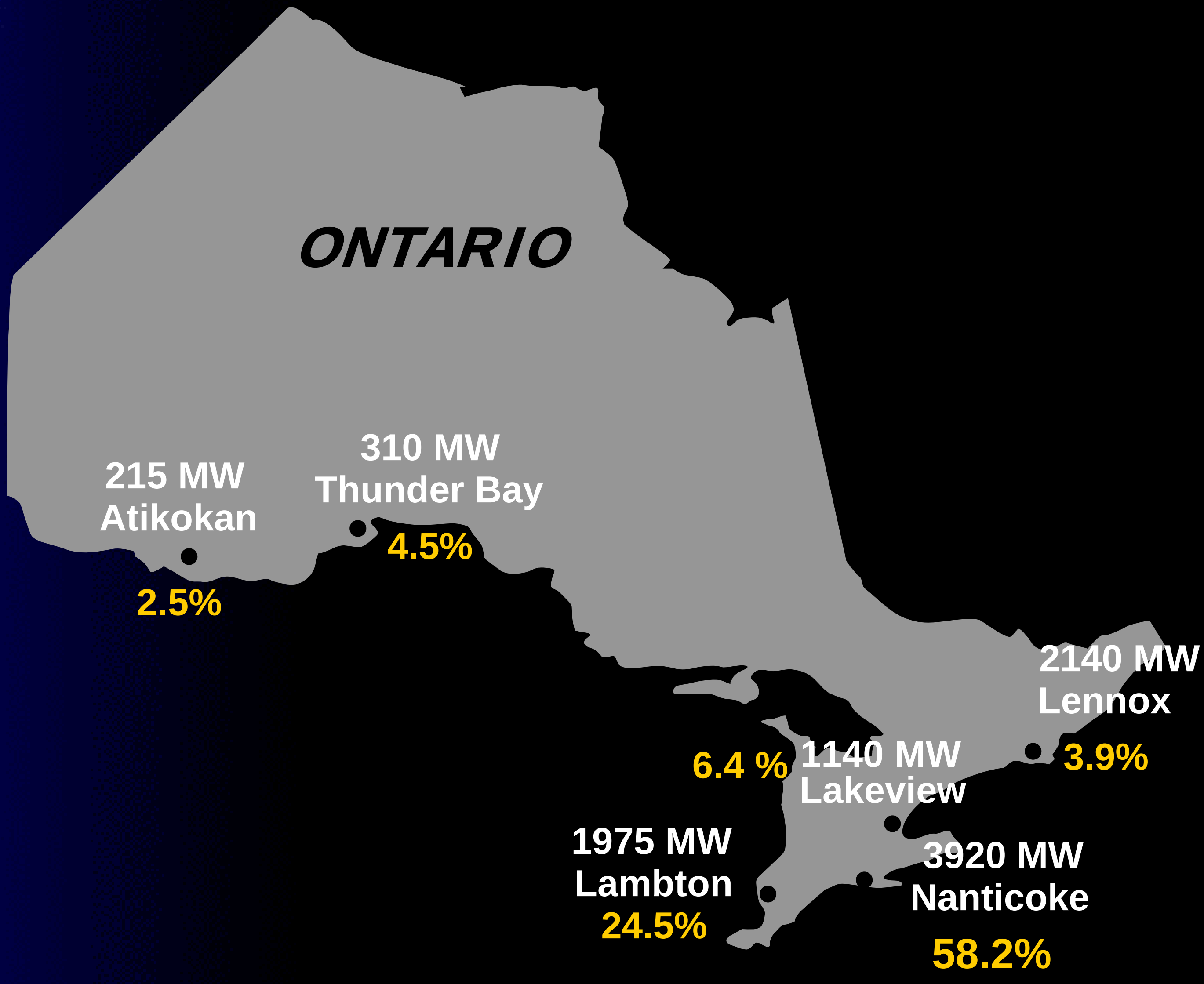


OPG Fossil Fuel Stations



Base Case – OPG fossil fuel plants (2002)

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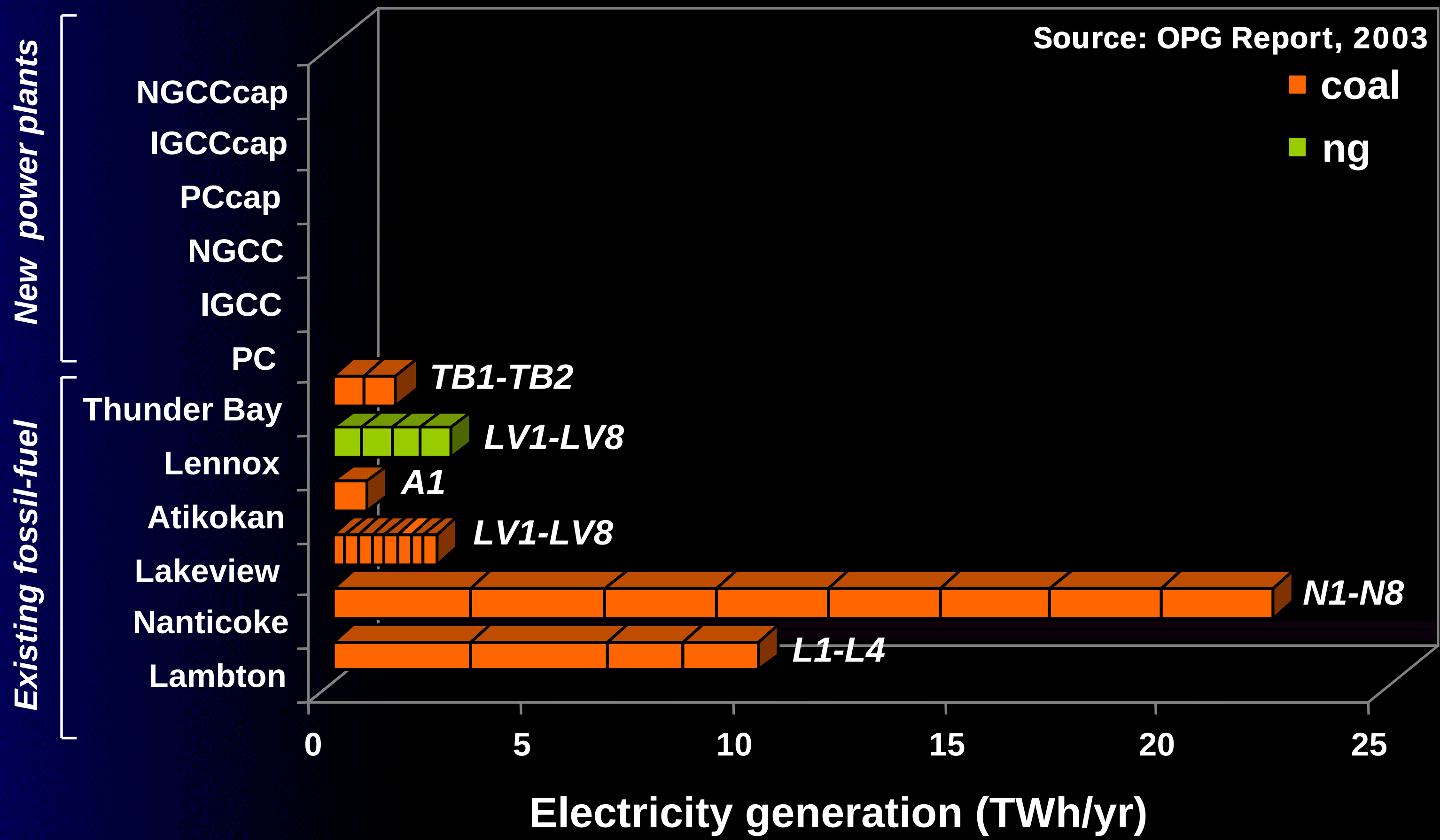

CO_2 Mitigation Options

- *Conservation*
- *Increasing power plant efficiency*
- *Increasing use of renewable energy*
- *Fuel balancing*
  - *reduce load on fossil plants and increase load on non-fossil plants when possible*
- *Fuel switching*
  - *switch to lower carbon intensive fuel, e.g. coal to natural gas or wind or nuclear*
- *Carbon capture and storage (CCS)*

Optimization Cases

- ***NG prices:***
  - ***$6/GJ, $7.80/GJ and $12/GJ***
- ***fleet-wide CO_2 reduction targets:***
  - ***3%, 6%, 20%, 40% and 60%***
- ***electricity demand:***
  - ***base case (2002) and 10% growth (1%/yr for 10 years)***

Effect of NG Price on COE and the best strategy
$6/GJ, $7.8/GJ and $12/GJ

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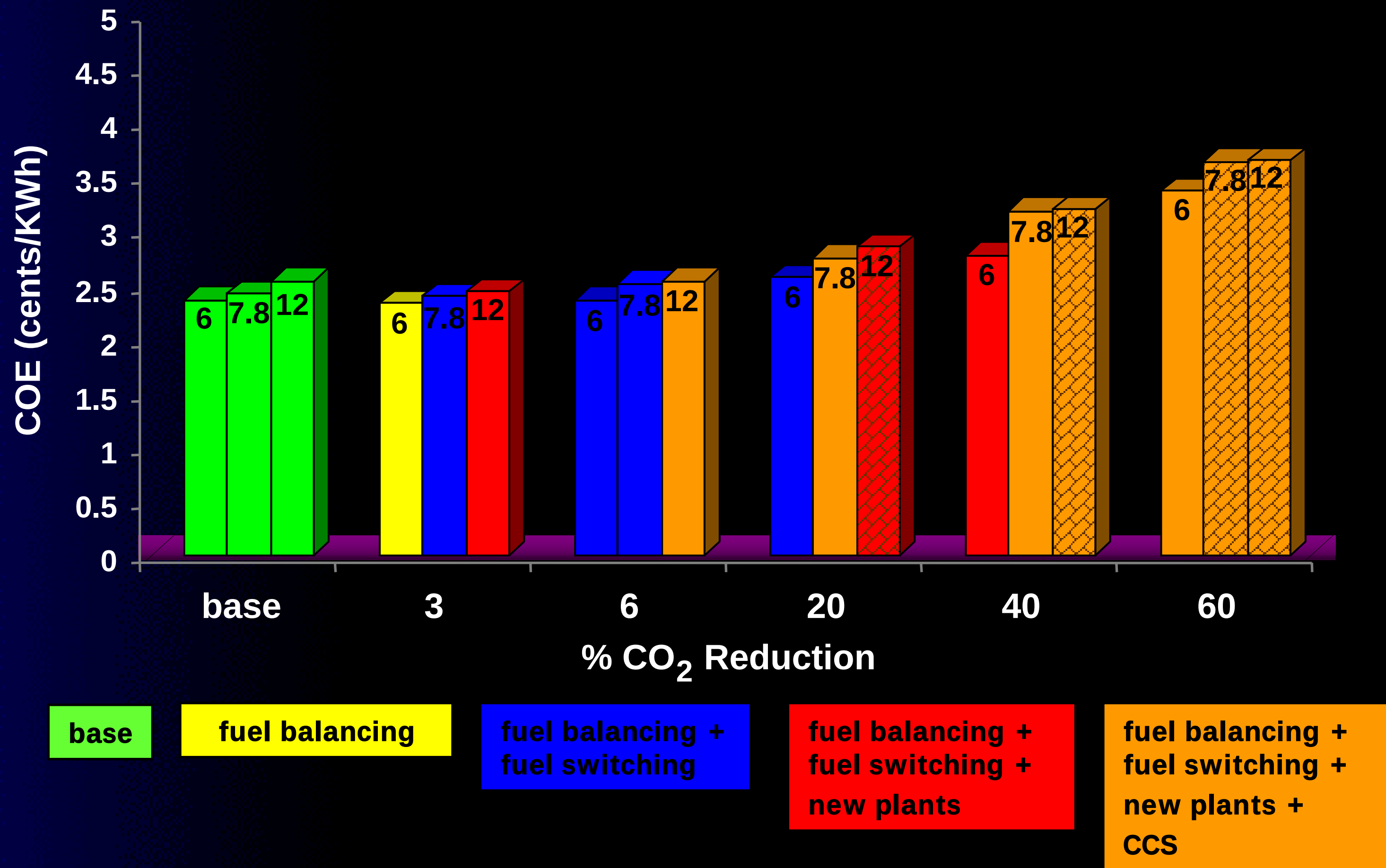
increasing NG price results in 'early' aggressive CO_2 mitigation strategy



Summary – 1

effect of NG price at base load

- *At low NG prices, $6/GJ:*
  - *< 40% CO_2 reduction*
    - *switching from coal to NG and NGCC is cost effective approach to CO_2 mitigation*
  - *at 60% CO_2 reduction*
    - *CCS (Nanticoke) and NGCC are recommended*
- *At medium NG prices, $7.8/GJ:*
  - *< 40% CO_2 reduction*
    - *switching from coal to NG and NGCC is cost effective approach to CO_2 mitigation*
  - *at 40% CO_2 reduction*
    - *CCS (Nanticoke) and IGCC plants are recommended*
    - *NGCC is not recommended*
  - *at 60% CO_2 reduction nuclear is recommended*
- *At high NG prices, $12/GJ:*
  - *at 6% CO_2 reduction CCS (Nanticoke)*
  - *> 20% CO_2 reduction*
    - *nuclear is recommended*
    - *NG is not recommended (no switching from coal or NGCC)*
  - *> 40% CO_2 reduction*
    - *CCS (Nanticoke & Lambton), IGCC, and nuclear plants are recommended*

Effect of NG Price on COE at 10 % growth

\$6 / GJ, \$7.8 / GJ and \$12 / GJ

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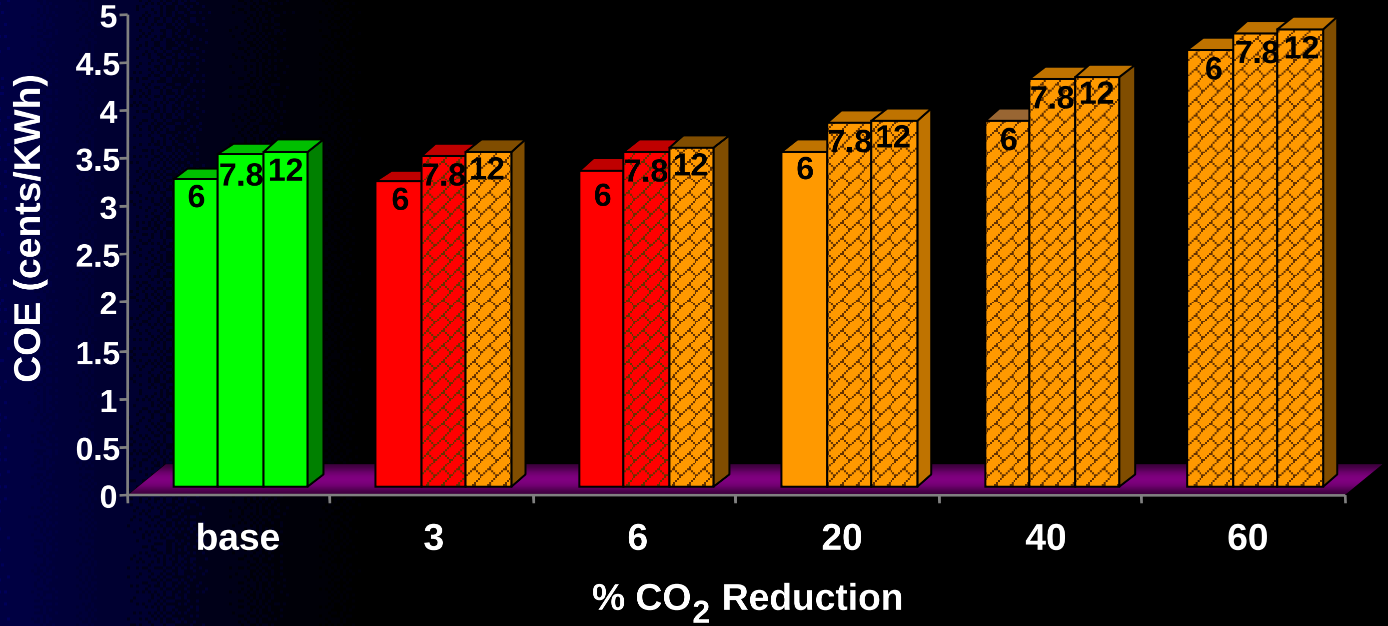
growth results in 'very early' aggressive CO_2 mitigation strategy



base

fuel balancing

fuel balancing + fuel switching

fuel balancing + fuel switching + new plants

fuel balancing + fuel switching + new plants + CCS

Summary – 2

effect of NG price at base load + 10% growth

- *At low NG prices ($6/GJ):*
  - *< 40% CO_2 reduction*
    - *switching from coal to NG is cost effective approach to CO_2 mitigation*
  - *> 40% CO_2 reduction*
    - *CCS (Nanticoke), NGCC and nuclear plants are recommended*
- *At medium NG prices, ($7.8/GJ):*
  - *NG switching, IGCC and nuclear are always recommended*
  - *> 40% CO_2 reduction*
    - *CCS (Nanticoke and Lambton) and NGCC is recommended*
- *At high NG prices, ($12/GJ):*
  - *IGCC, CCS and nuclear are always recommended*
  - *NG is not recommended*

Comparison of two cases

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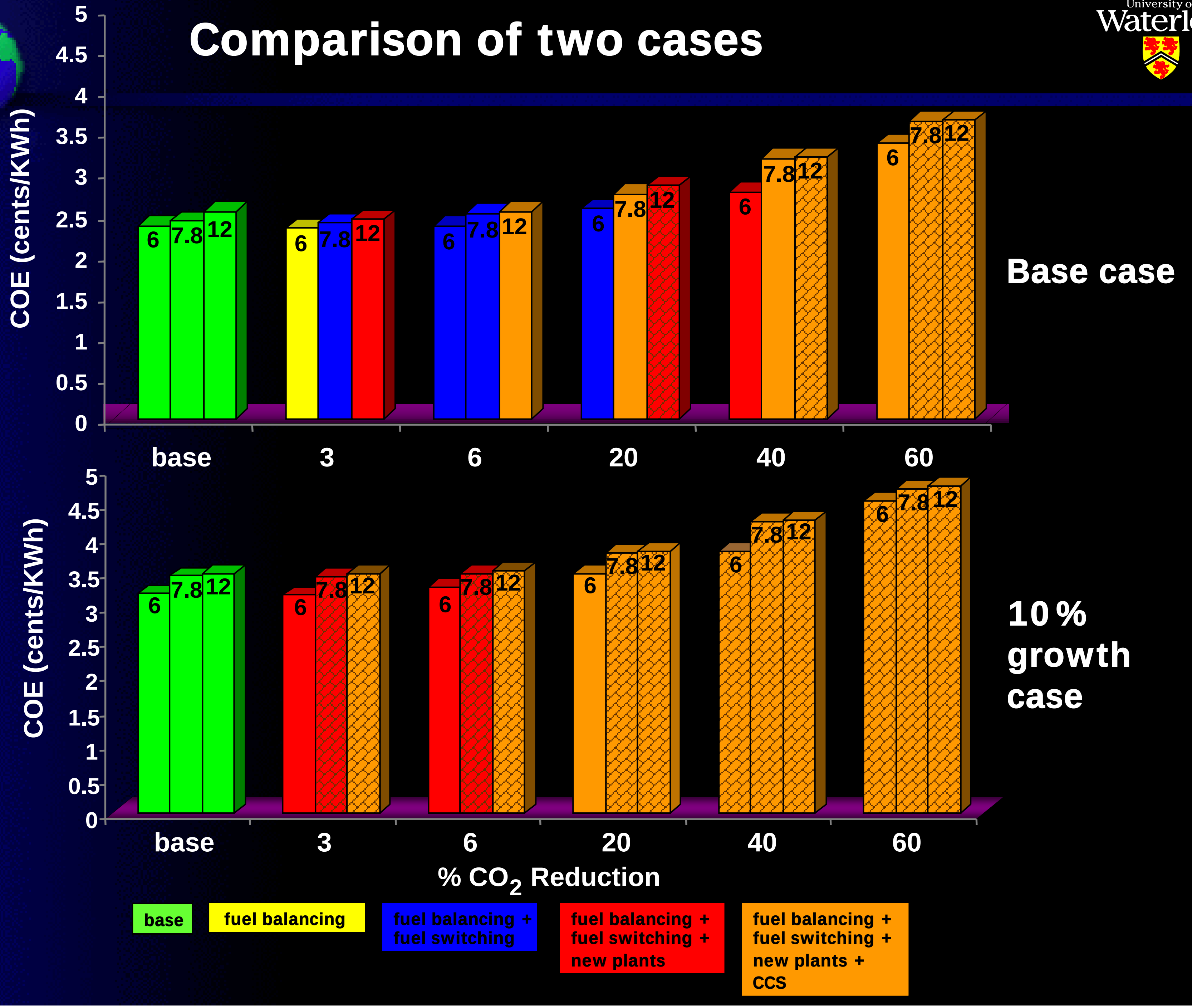

Additional cases

1. ***What if all coal fired generating stations are forced to shut down & replace with NG?***

2. ***What if Nanticoke and Lambton are allowed to stay open and all other coal fired generating stations are forced to shut down & replace with NG?***

Effect of NG Price on COE and the best strategy

$6/GJ, $7.8/GJ and $12/GJ

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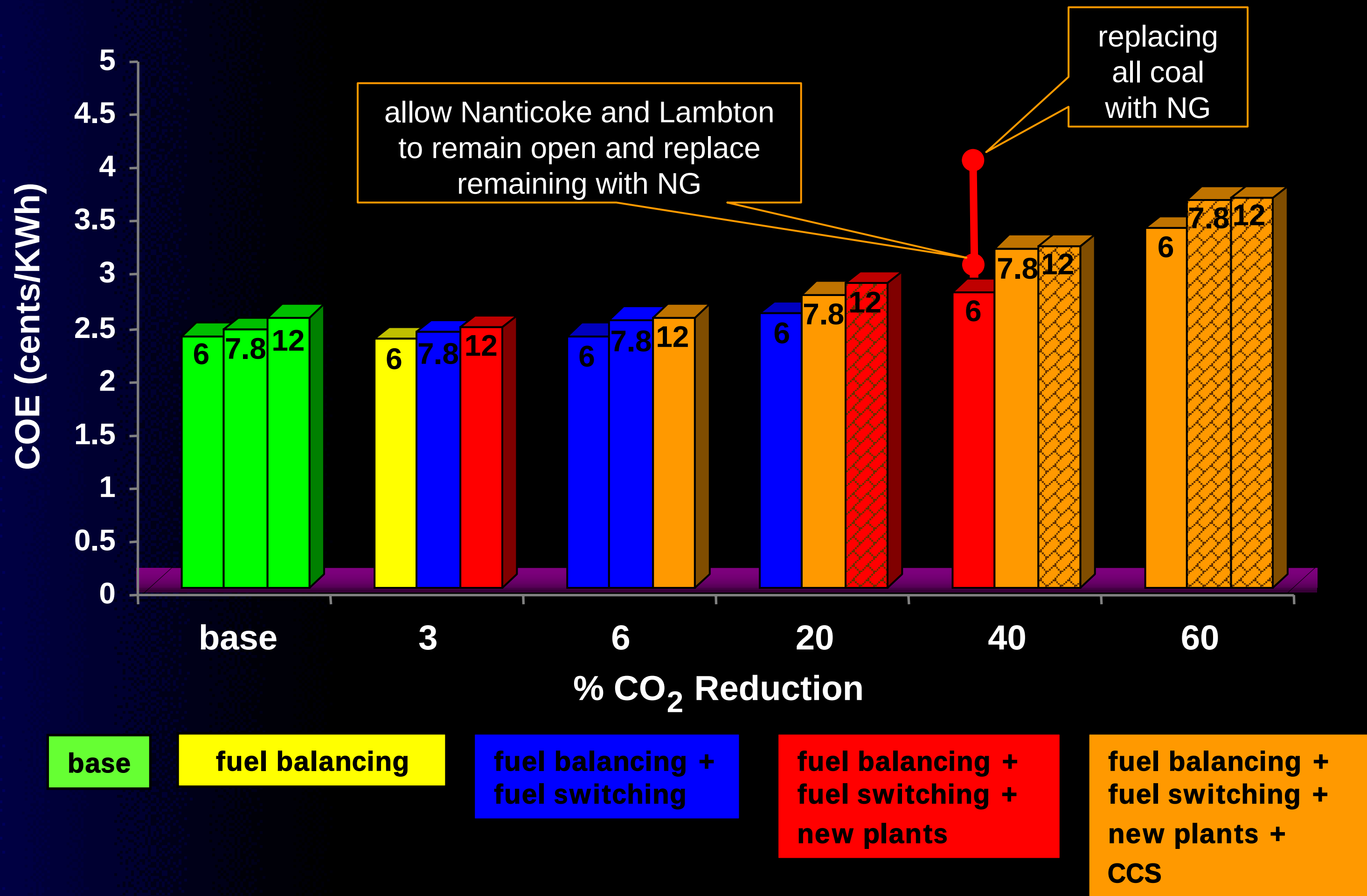
increasing NG price results in ‘early’ aggressive CO_2 mitigation strategy



Conclusions

- *No clear optimal strategy*
- *Depending on scenario, NG, NGCC, nuclear, CCS and IGCC are all recommended*
  - *NG price and expected growth rate have significant effect on best strategy*
- *More work on scenario development and cost estimates needs to be undertaken*

Future Work

- continue to develop regional planning model
  - scenarios
  - multi-period planning
  - stochastic models
  - load duration curve
  - multi-pollutant mitigation

- develop systems scheduling models with CO_2 constraints

- study other jurisdictions (Alberta)
  - electricity sector
  - oil sands
  - hydrogen plants
  - carbon storage

Acknowledgements

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  - Professor Eric Croiset, Ali Elkamel, Mike Fowler, Xianshe Feng
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- NSERC
- OPG (Blair Seckington)