A Strategy to Reduce the CO_2 Footprint of SAGD Oil Sands Recovery

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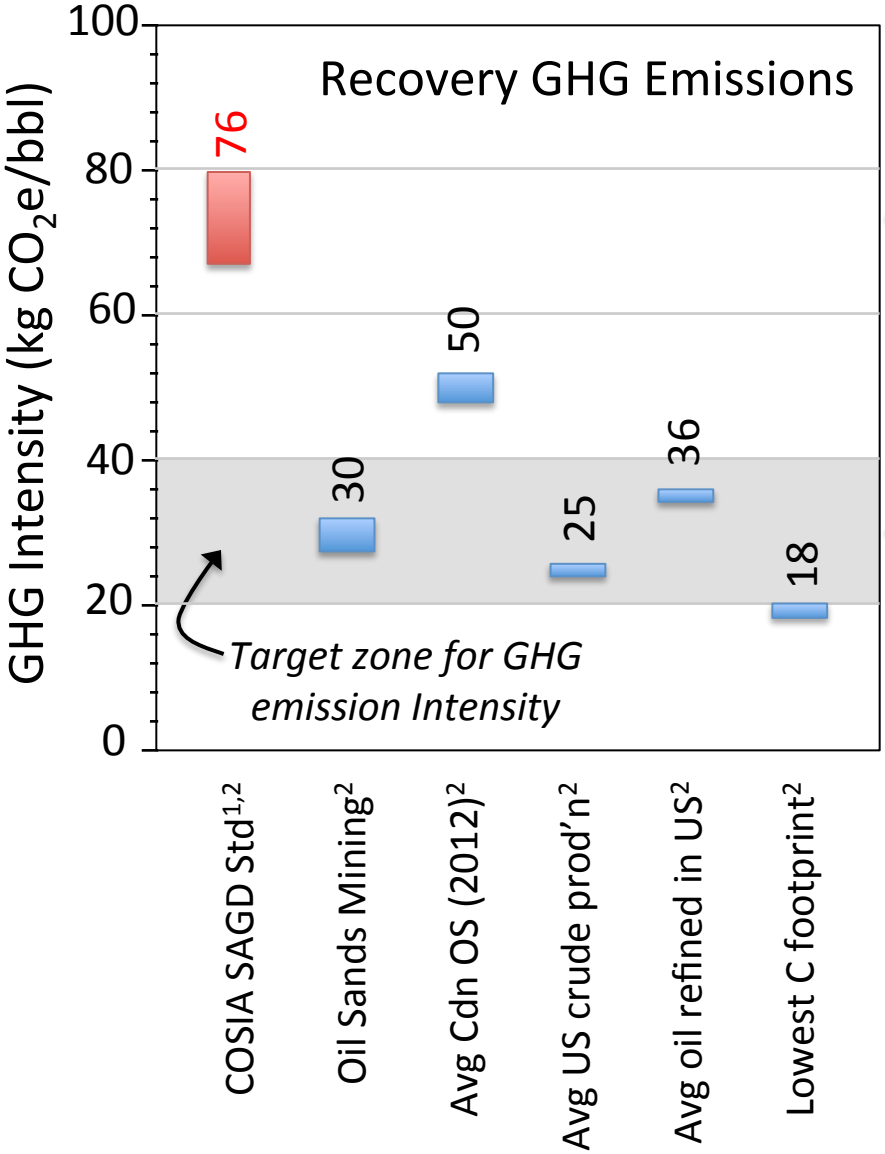
Steam Assisted Gravity Drainage (SAGD) is GHG Intense



Differential has undermined public support for :

- ❑ Oil sands development
- ❑ Pipelines needed for market access

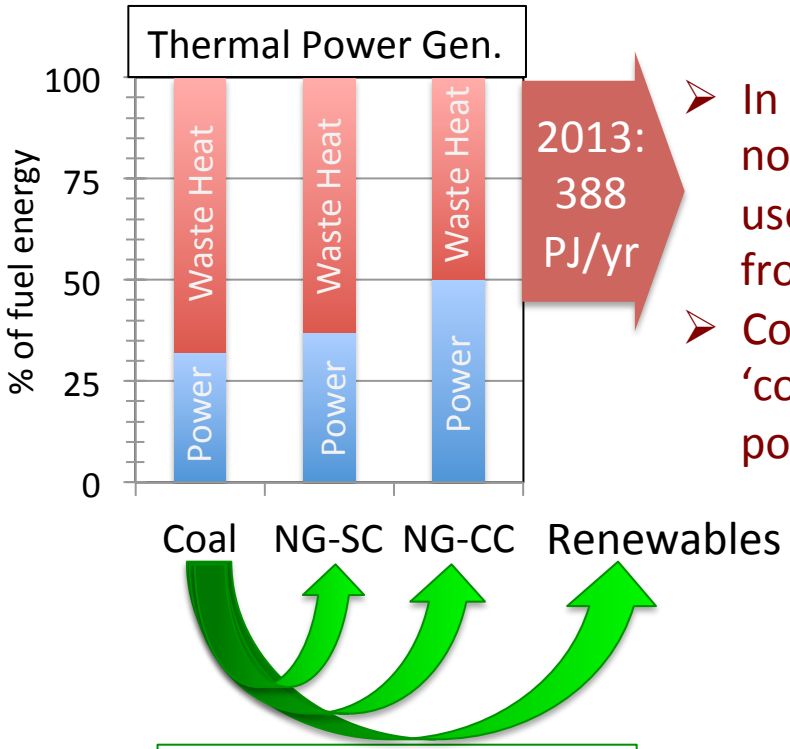
Cost-effective technologies are needed to reduce the CO_2 footprint of SAGD oil sands recovery;

1 COSIA Challenges 2014

2 IHS Energy. 2014. Comparing GHG intensity of the oil sands and the average US crude oil

Proposal:

SAGD 'Greens' the Alberta Grid (& Itself), Gaining Economic & Environmental Benefits



Default Strategy for Transforming the Alberta Grid

- In most jurisdictions, no industries could use the waste heat from power gen.;
- Considered to be the 'cost' of thermal power generation

Not in Alberta:

- ❑ SAGD heat demand:
  - 227 PJ/yr in 2013
  - 469 PJ/yr in 2020
- ❑ Plus heat demand for CSS, OS mining / upgrading

- SAGD could help & benefit -

The Time to Act is Now

- ✓ Carbon Price increases;
- ✓ 'Off-Coal' Policy (by 2030);
- ✓ 30% Renewable target (by 2030);
- ✓ Policies will be set within 6 months.

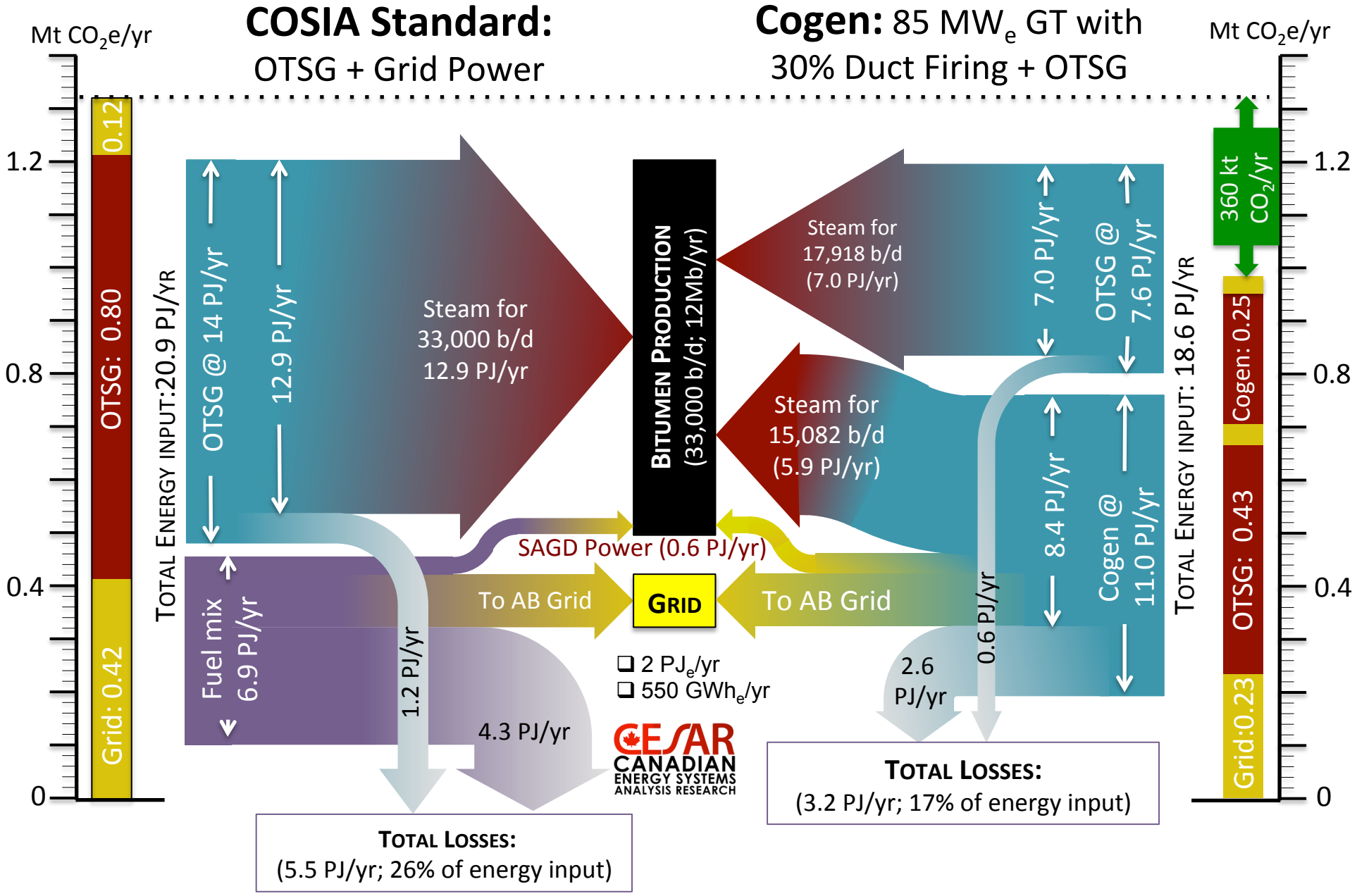
Cogeneration

- Already important in many OS facilities;
- Potential to dramatically increase deployment, especially on SAGD facilities:
- For a 'typical' 33,000 b/d facility:

# GE Frame 7 Gas Turbines	Duct Burning?	SAGD (33,000 bpd)		Contribution to 'Public' Grid		GHGs
		% Power	% Heat	GWh / yr	%	$ktCO_2/yr$
One	Yes	100%	~50%	Up to 590	~1%	-360
Two	Yes	100%	100%	Up to 1300	~2%	-800

- There is also potential to modulate SAGD heat & power output to provide low-cost backup for renewables while maintaining SAGD production.

Two Ways to Produce 33 kbbl SAGD/d + 550 GWh_e/yr to Grid



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CESAR CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH

Exploring the Potential in Alberta

Preliminary Scenario Models (2015-2030):

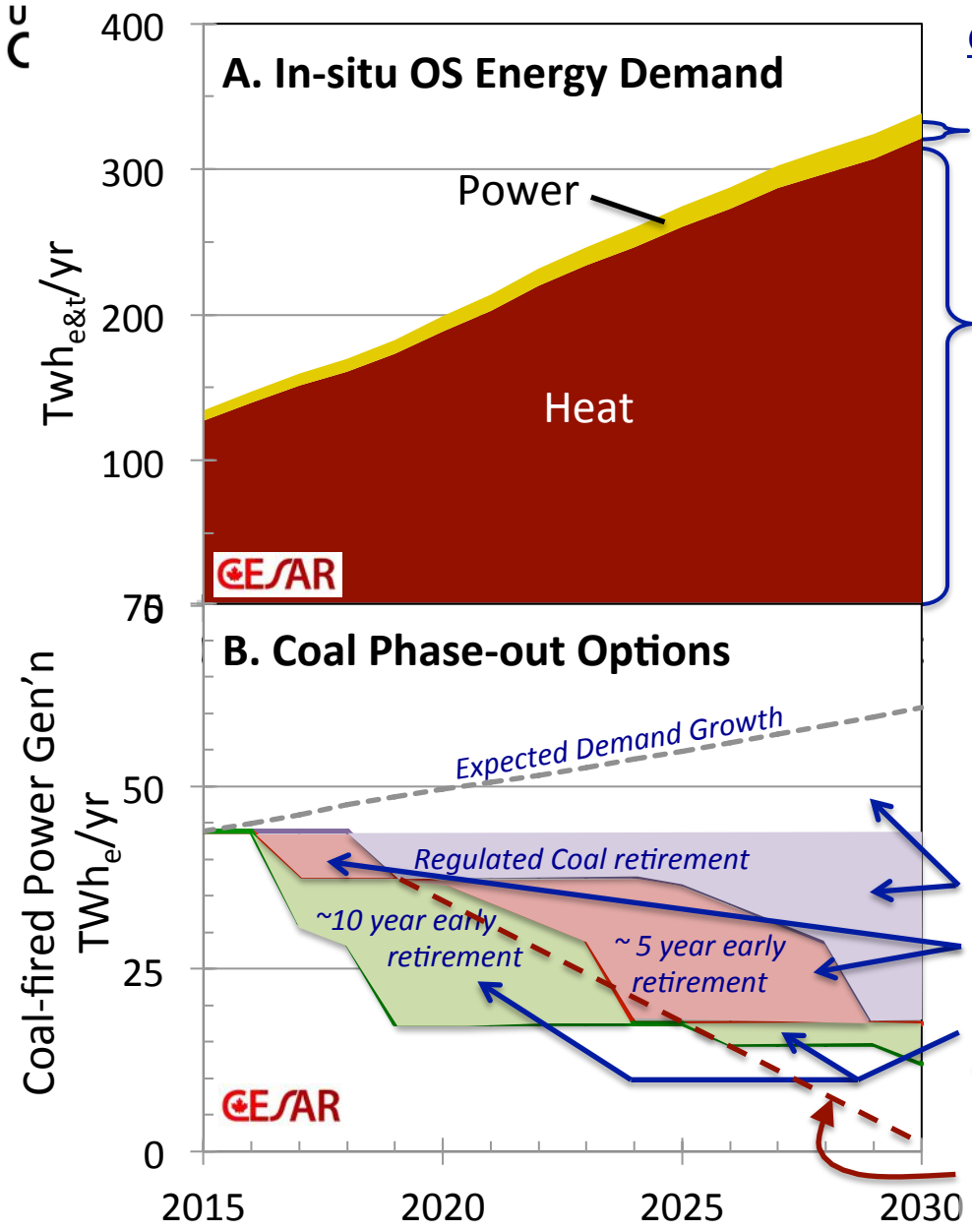
Assumptions:

- ❑ High Oil Sands Growth Future
- ❑ Cogen: One 85 MW Gas Turbine / 33kpbd SAGD with duct firing
- ❑ No major growth in renewables
- ❑ Five Scenarios:
  1. *Status Quo (continue with Coal)*
  2. *NG-CC to meet off-coal regulations*
  3. *SAGD-Cogen to meet off-coal regulations*
  4. *SAGD-Cogen exceeds off-coal regulations by 5 yrs*
  5. *SAGD-Cogen exceeds off-coal regulations by ~10 yrs*

SAGD operations not affected

The Next 15 Years in Alberta…

CANADIAN ENERGY SYSTEMS ANALYSIS RESEARCH



GHG Emissions*

kg CO_2/bbl

9.9

@grid avg 763 kg CO_2/MWe

66.4

76.3

*from COSIA Challenges 2014

GHG Savings

(Mt CO_2e)

For Grid	*For SAGD*
133	53
0	+87
0	+87
133	227

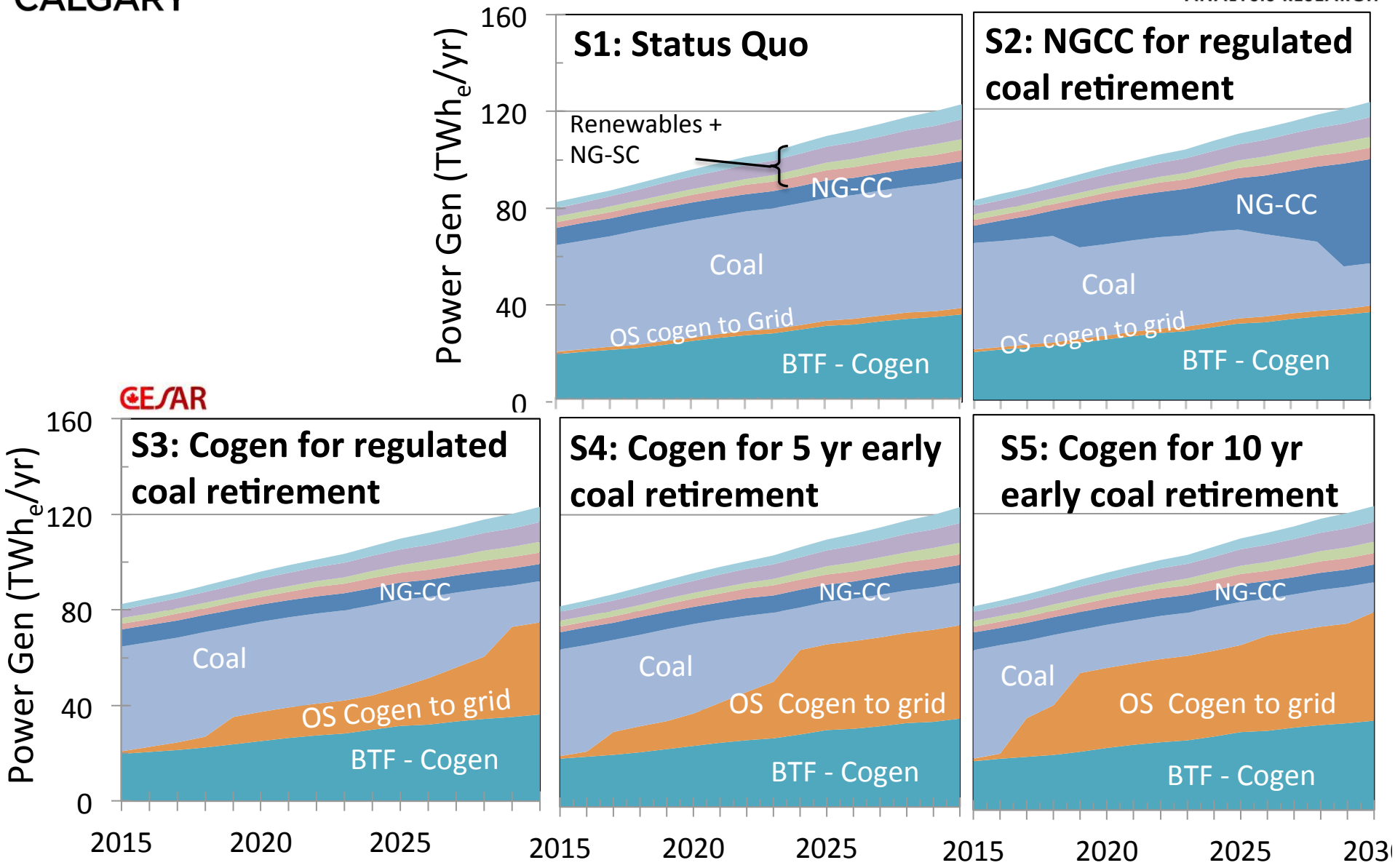
New off-coal target (not modeled here)

The Cogen Opportunity for SAGD Production

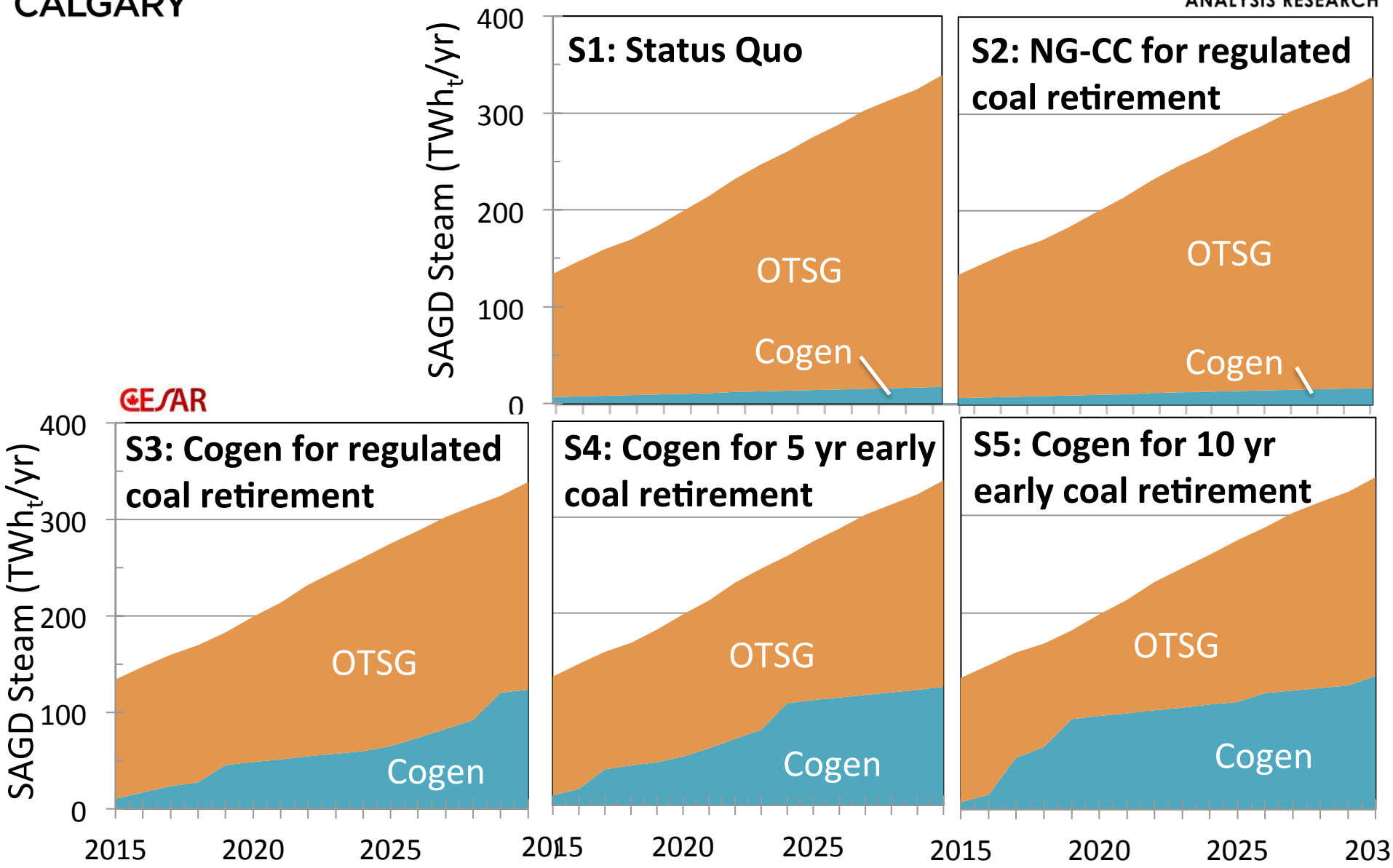
- ❑ Replace regulated coal retirements + new demand & get GHG benefits for both the AB Grid + SAGD.
- ❑ Go beyond regulation and claim the additional GHG benefits for SAGD.

Data from: COSIA Challenges 2014; CAPP Forecast 2014; AESO LTO2014; EDC associates

Power Generation

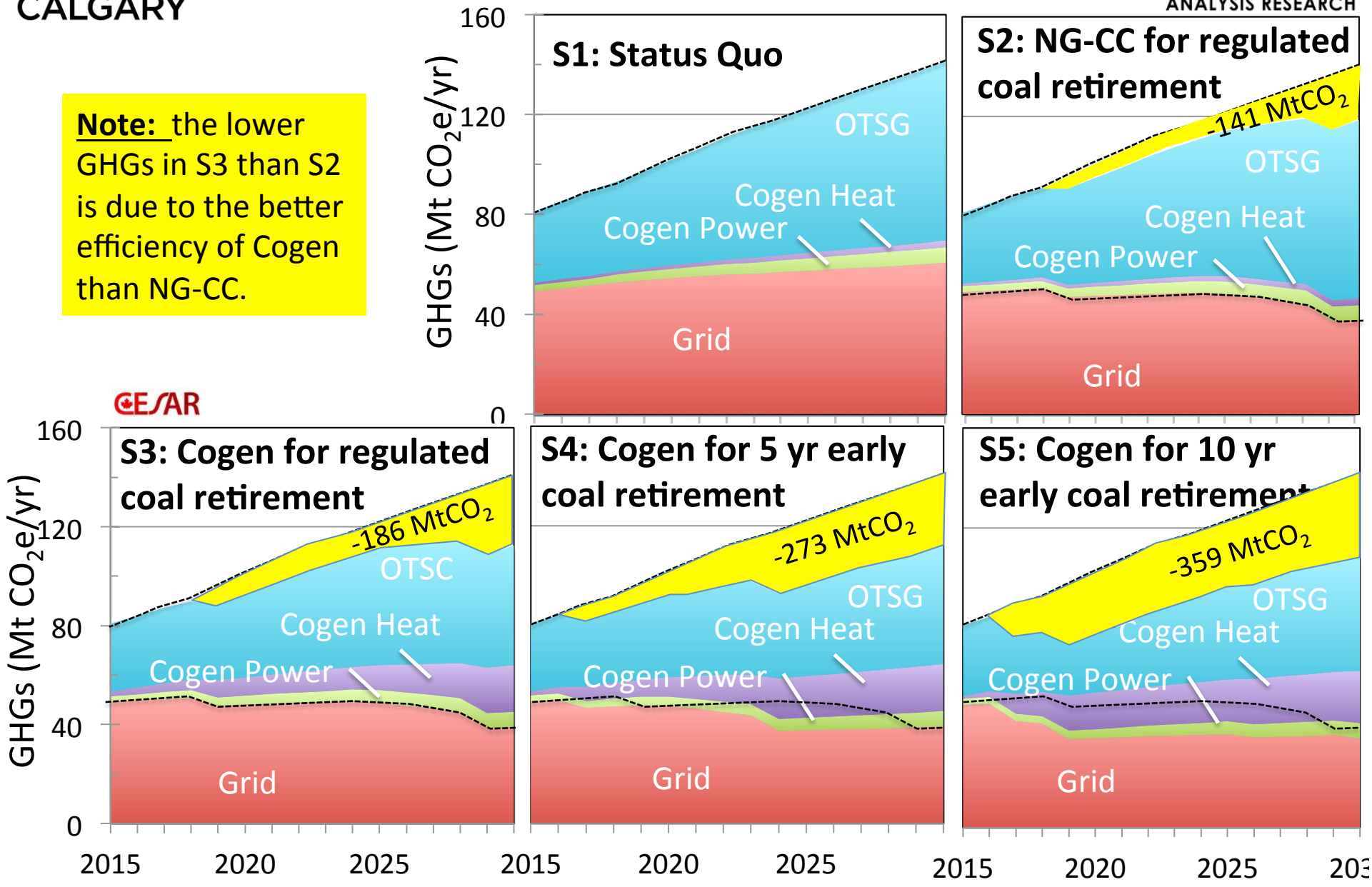


Source of Heat for SAGD Steam



GHG Emissions from Grid + SAGD

Note: the lower GHGs in S3 than S2 is due to the better efficiency of Cogen than NG-CC.

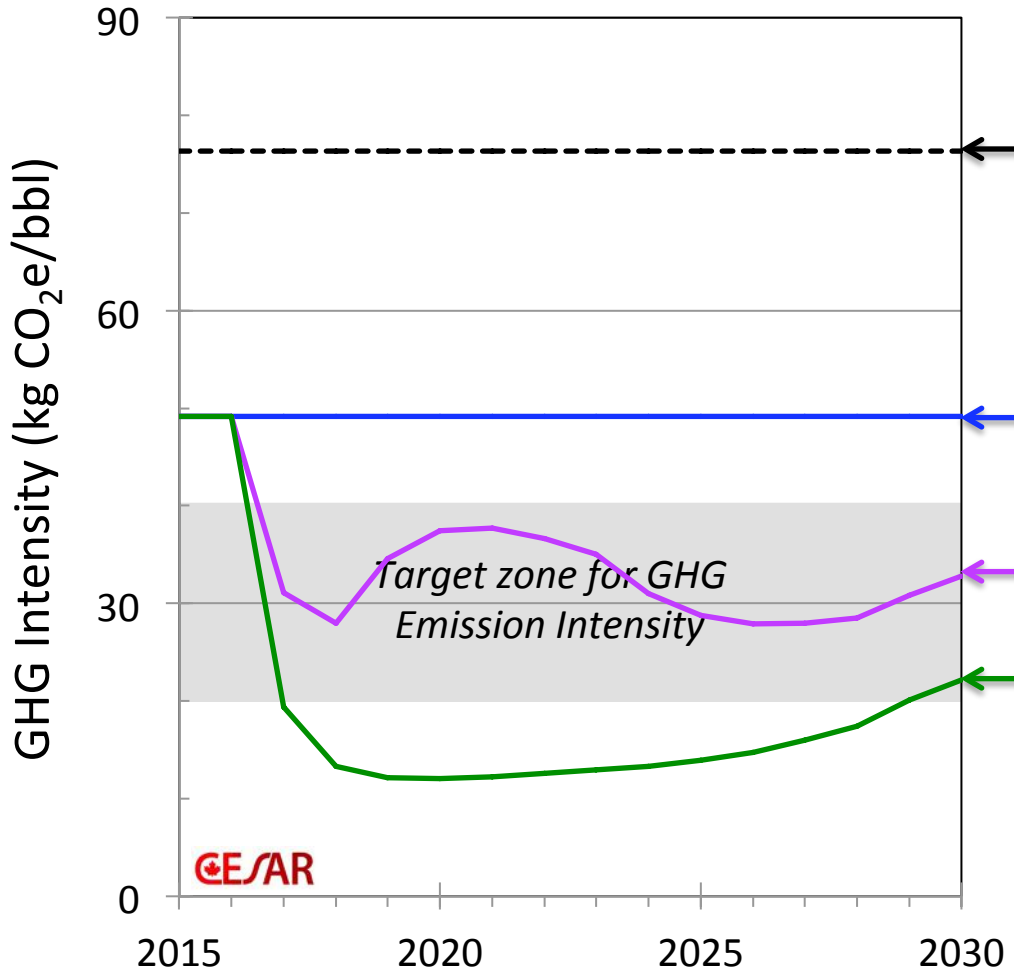


Overview of GHG Scenarios (2016 to 2030):

Scenario Change	Cumulative GHG Benefit (Mt CO_2e)		
	TOTAL	GRID	SAGD
Coal Dom. Grid to **NGCC** to meet regulations, no change in SAGD (S1 →S2)	141	141	0
Coal Dom. Grid + SAGD (COSIA) to **Cogen** to meet regulations (S1 →S3)	186	133	53
More SAGD Cogen to retire coal plants ~5 yrs early (S3→ S4)	87 87	68 [0]*	19 [87]*
More SAGD Cogen to retire coal plants ~10 yrs early (S4→ S5)	87 87	68 [0]*	19 [87]*
TOTAL BENEFIT of Cogen Alternatives (S1→S3→S4→S5)	**359** **359**	**269** **[133]***	**90** **[227]***

** Assumes that GHG benefits of initiatives which go beyond regulations (e.g. early coal retirement) can be assigned by proponents to areas of their choice (i.e. SAGD)*

GHG Intensity for SAGD Bitumen from Cogen Heat



NOTE

COSIA Std SAGD [76]

S1 (Status Quo), S2 (NGCC) & S3 (Cogen A) [49]

S4 (Cogen B) [wtd avg. 33]

S5 (Cogen C) [wtd avg. 22]

Conclusions

By deploying cogeneration (with duct burning) at SAGD facilities between 2017 and 2030, Alberta could simultaneously:

- *Reduce reliance on coal-fired power, with associated air quality / health benefits;*
- *Consume less natural gas (reduce price risk);*
- *Eliminate **359 Mt GHG emissions** (133 Mt from Power generation; 227 Mt from SAGD operations);*
- *Produce SAGD bitumen with a GHG footprint equivalent to / better than conventional crudes;*
- *Create a second source of income from SAGD facilities;*
- *…with little or no increase in either the cost of power or bitumen recovery.*

Next Steps

- *New Context:*
  - *Low Oil Sands Growth Future*
  - *Complete decommission of coal power by 2030*
  - *Up to 30% Renewable Power by 2030*
  - *Assume Retrofit of SAGD with 1 or 2 GT per 33,000 bpd facility*
- *Compare Cogen energy efficiency and GHG intensities during 'normal' operation & when 'modulated' to provide backup for renewables*
  - *Compare various water treatment and power generation technologies to optimize SAGD production, grid power supply and backup capacity for renewables*
- *Looking for an industry partner to develop site specific CAPEX & OPEX estimates to evaluate project economics and CO_2 avoidance costs.*